

# PREVIEW



## NEWS AND COMMENTARY

New AEM data released  
Historic gravity and gradiometry  
data now publicly available  
Seismic data and minerals  
exploration – call for AEGC  
workshop  
Data visualisation – finding  
common ground

## FEATURES

Aftershock monitoring -rapid  
deployment in SW WA  
How geophysics ruined music



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## FRONT COVER



Members of the Queensland Branch of the ASEG, including the ASEG President-elect (Emma Brand, third from left), getting in some target practice at a recent branch meeting. See ASEG Branch News in this issue for more information.

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# Sub 22

## From imaging structures to predicting processes

Our Deep Earth Imaging Future Science Platform presents Sub 22, an interdisciplinary subsurface conference.

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- A platform to contribute, discuss and learn about the interdependence between the science pillars imaging, conceptualisation and prediction for the exploration, characterisation and management of energy, mineral and water resources.
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28–30 November 2022

The National Wine Centre of Australia, Adelaide

[research.csiro.au/dei/sub22](https://research.csiro.au/dei/sub22)





## Editor's desk



Lisa Worrall

This issue of *Preview* features an article by Tim Dean on the contribution of geophysics, or more specifically a geophysicist, to the development of modern music – an eye-opening and thoroughly entertaining read!

Also, in a mini-feature, Ruth Murdie and her colleagues describe the rapid deployment of seismic equipment to monitor aftershocks during Western Australia's COVID lock-out. It was all West Australian hands to the pump!

The pandemic did not slow the acquisition and delivery of AEM data

by the Geological Survey of Western Australia and Geoscience Australia (*Geophysics in the surveys*). An astonishing 90% of Western Australia is now covered with contiguous airborne electromagnetic surveys at 20 km line spacing or better, and 100% coverage is expected by the end of 2022.

The Geological Survey of South Australia may have struggled to put people in the field over the last couple of years, but they have not let the grass grow under their feet – 65 historic gravity surveys have been added to their online database (see also *Geophysics in the surveys*). The continuous flow of data from government agencies presents its own problems – nice problems to have, mind you – and Terry Harvey seeks to address one of these problems by looking for common ground in data visualisation strategies (*Mineral geophysics*).

In other news and commentary, David Denham (*Canberra observed*) takes a look at the Federal Government's

push to commercialise the results from university research. He also notes, somewhat ruefully, that the Geoscience Australia building is up for sale – again. Marina Pervukhina (*Education matters*) interviews Michele Spencer from the Geological Survey of Western Australia. Mike Hatch (*Environmental geophysics*) delivers the second episode of Niels Christensen's adventures. Mick Micenko (*Seismic window*) shares some of his fan mail that calls, in part, for an AEGC workshop on the use of seismic data by mineral explorers - it is pretty clear that, in the view of this reader at least, such a workshop could be sub-titled "Tips and traps for the unwary"! Tim Keeping (*Data trends*) has a crack at spatially classifying petrophysical data, and Ian James (*Webwaves*) alerts us to the appearance of the *Exploration geophysics* digital library on the ASEG website.

Enjoy!

Lisa Worrall  
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## President's piece



Kate Brand

Dear Members and readers,

I am writing this - what will be my last President's piece in *Preview* - with just three weeks left in my presidential term. We are certainly in a unique time, just as it seemed like the world was starting to slowly recover from the pandemic, a historic flood event undoubtedly affected some Members in New South Wales and southern Queensland - my thoughts go out to you all. And then there is the recent and devastating war in Ukraine - this must be an immensely difficult time for anyone with family/loved ones in Ukraine. You may be familiar with (or a regular user of) the quality geophysical instruments produced by Lemi LLC who are based in Lviv, Ukraine. A GoFundMe has been set up to provide them with direct humanitarian support - visit <https://gofund.me/3f0f47f1> if you would like to donate. The sanctions imposed on Russia, including the banning of Russian oil imports by the US and many other countries, and the withdrawal from Russian projects by multiple major energy companies, has led to a surge in oil prices. These prices were already rising as countries began to recover from the pandemic - from US\$65 a barrel to over US\$130 in just a few months - and they are now the highest they have been since 2014. The resultant supply shortages are having huge impacts around the world, including in Australia.

Moving away from major global events, in the December 2021 issue of *Preview* I alluded to the development of an ASEG Strategic Action Plan. A summary of this plan has been released to the ASEG membership. If you have renewed your membership for 2022 you can access it by logging onto the ASEG website (login at the top right-hand corner of the webpage at [www.aseg.org.au](http://www.aseg.org.au)) and then navigating to the "Documents" tab of the Secure Member Area. We would love to have your feedback on the plan. If something

takes your interest, please don't hesitate to reach out and get involved.

To further support these new initiatives, we have been working hard to build up our volunteer base. To help ensure our volunteers feel valued, we are in the early stages of developing a volunteer recognition programme. As a first step we are excited to be releasing our 2021 Volunteer Almanac at the AGM. You may (like me) be astounded to hear that the Almanac lists over 160 of our Members who are all ASEG volunteers (for reference, we had 864 Members at the end of 2021 - so at least 18.5% of our membership volunteer in some capacity!). There's always room for more, so please reach out if you would like to help. In particular, I am very keen to increase our support for our international membership, and if you would like to volunteer to join/chair the (currently inactive) ASEG International Committee, I would love to hear from you.

To highlight just one of the many exciting initiatives (mind you, they aren't all exciting - some are just plain necessary - such as streamlining workflows and improving record management) from the Strategic Action Plan, progress is being made on planning an inaugural geophysics field camp. The camp, to be held in September 2022, is a pilot project and will be run by the ASEG and NExUS. The camp aims to help address the diminishing geophysical education opportunities that are a consequence of the removal of many geophysics subjects and degrees from universities across Australia. It is planned to hold the camp over a one-week period. Students, early career geoscientists, or anyone looking to improve their applied geophysics skills can apply to attend (places will be limited). Attendees will learn to acquire a variety of different geophysical datasets, which they will process and model and, importantly, interpret. Hopefully this camp will become a key event ingrained in the annual ASEG calendar.

As I've discussed in previous *President's pieces*, the Federal Executive acknowledges the importance of supporting geophysicists through the energy transition (the gradual progression toward a net-zero future), so we are delighted with the launch of a new webinar series designed to educate Members on topics ranging from CCUS, geothermal, hydrogen and, importantly, the role of geophysicists in this transition. We also will highlight the

pivotal role that the oil and gas industry will continue to play for years to come as the world navigates the transition. Dr Andrew Long has recently taken on the newly developed position on the Professional Development Committee of "Energy transition lead", and he has been busy behind the scenes establishing a webinar series on "Geophysics for energy transition". We are also in the early planning stages for a workshop on the same topic, currently earmarked for September 2022 - more news to come on this.

In other news, the ASEG Research Foundation will spend the next few weeks sorting through submissions to grant geophysics scholarships - I'm sure some tough decisions will have to be made - thank you to the committee that does this. In addition, applications for the Richard Lane scholarship close on April 29.

We are just weeks away from the AGM and the feeling of handing over the presidency to Emma Brand is bittersweet. I am excited to support Emma as the ASEG's next leader, and am certain that she and the Federal Executive will work together brilliantly. On the other hand, I am sad that my term is coming to an end. I am incredibly grateful to have had the opportunity to be ASEG President and I'm excited to be continuing to work with the Federal Executive in my new roles as Immediate Past President and Chair of the Professional Development committee. Your next *Preview President's piece* will come from Emma who will have the honour of introducing our new Federal Executive members and the President-Elect for 2022.

Now I've definitely taken up more space than I was allocated, so I won't go into more details on the brilliant work that our other ASEG committees have been doing, but rest assured they have all been busy and I am very much looking forward to updating you all at the looming ASEG Annual General Meeting on 7 April (you can attend virtually or in-person in Brisbane).

On that note, I would like to take this opportunity to thank the departing members of the Federal Executive, and of the Branch committees (check the Branch news section for updates on that). A very special thank you to Dr Ted Tyne, who will be stepping down as Chair of the Publications Committee and Federal Executive member after joining the Federal Executive in 2018

as President-Elect. He was President in 2019, the pinnacle of his long-standing contributions to the Society (he received an ASEG Service Certificate in 2000!). As President, Ted expertly led the Society through the 2<sup>nd</sup> Australasian Exploration Geoscience Conference. During this time he strengthened relationships with the South African Geophysical Association (SAGA) and the Society of Exploration Geophysicists (SEG). Ted also served as Co-Chair of the Publications Committee with Danny Burns, and they negotiated new publishing contracts for *Exploration Geophysics* and *Preview*, which led to considerable cost savings and substantially increased international exposure to ASEG publications. In 2021 Ted served his final year on the Executive

as Publications Chair. We will miss Ted's friendly face on the Federal Executive, his business aptitude, his thoughtful contributions and his extensive knowledge of the ASEG and its history. I'm delighted that Ted will remain on the Publications Committee and continue his involvement with the Research Foundation and History committees.

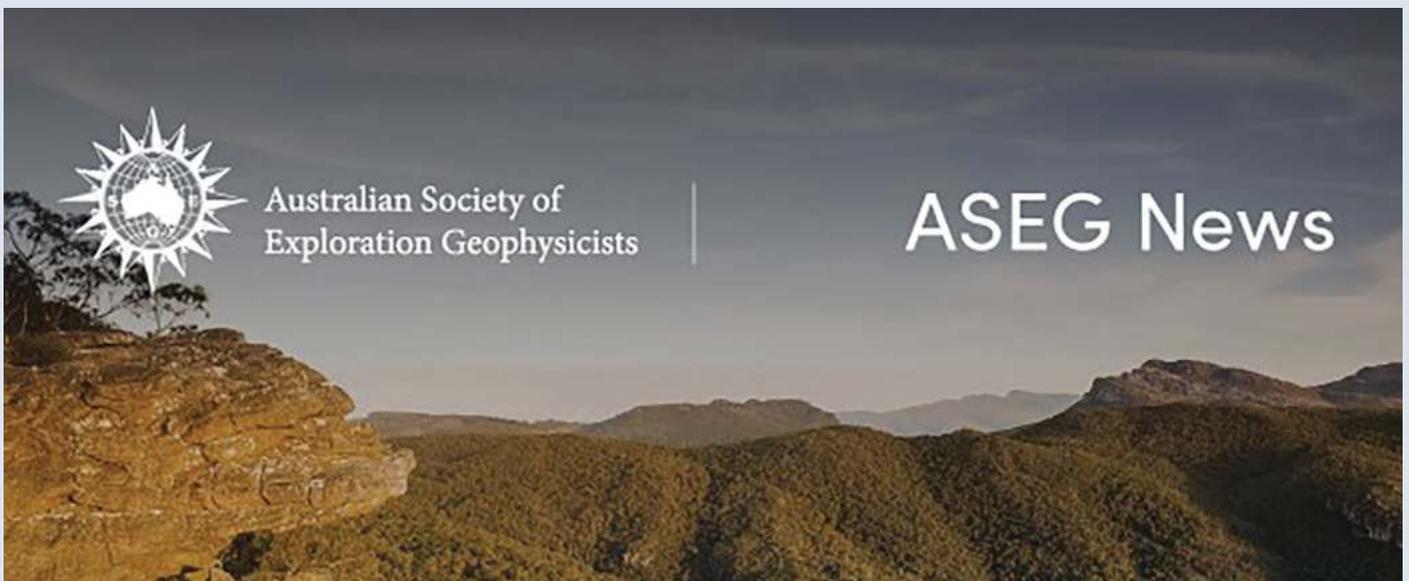
Dr Kate Selway will also be stepping down from the Federal Executive after serving as Education Committee Chair for the last year. Kate has been very busy during that time, and amongst her achievements she has produced an excellent overview of the state of play of geophysics education (*Preview 213*), rebuilt the Education Committee (from

zero to now five members), and led the Committee through the development of school outreach programmes and the aforementioned geophysics field camp. Again, I'm glad to inform you that Kate will continue on the Education Committee.

Last but not least, I would like to thank you all for supporting me as your President for 2021/22, and for making this last year so enjoyable (albeit busy!). I hope to see you at an ASEG event in-person or online in the near future.

Bye for now,

Kate Brand  
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## Members spotlighted in the ASEG newsletter

The first Member spotlighted in an ASEG newsletter dates back to May 2018. Over 40 geophysicists /geologists (list below) have now shared their experiences, views and interesting stories. You can find them at <https://www.aseg.org.au/publications/newsletters>. If you would like to subscribe to the ASEG Newsletter, nominate someone else for the Member spotlight or leave any suggestions, please email us at [communications@aseg.org.au](mailto:communications@aseg.org.au).

### List of Members spotlighted

#### 2018

Marina Costelloe  
Ted Tyne  
Roger Henderson  
Stephanie Kovach  
Mark Lackie  
Danny Burns  
Glen McFadzean  
Jenni Clifford

Rusty Camille  
Tim Dohey  
Chris Wijns  
Matthew Zengerer  
Megan Nightingale  
James Alderman  
Philip Heath  
Suzanne Haydon  
Mike Hatch  
Andrew Fitzpatrick

Kate Robertson  
Aurore Joly  
Yvette Poudjom Djomani  
Ian James  
Mark Duffett  
Steph Hawkins  
Andrew Thompson  
Doug Roberts  
Millicent Crowe

Emma Brand  
Peter Gunn  
Regis Neroni  
Tim Dean  
Sandra Occhipinti  
Stanislav Glubokovskikh  
Henk van Paridon  
Gregory Street

#### 2019

Teagan Blaikie  
Janelle Simpson  
Kate Selway

#### 2020

Shane Evans  
David Annetts

#### 2021

Phill Wynne  
Leslie Atkinson  
David Pratt

#### 2022

Nicholas Josephs  
Bhavik Harish Lodhia



## 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. This brief reports on the monthly meetings that were held in February and March 2022. If there is anything you wish to know more about, please contact Leslie at [fedsec@aseg.org.au](mailto:fedsec@aseg.org.au).

### Finances

The Society's financial position at the end of February 2022 was:

Year to date income: \$90 478

Year to date expenditure: \$36 722

Net assets: \$1 158 067

### Membership

As of 2 March 2022, the Society had 723 financial Members, compared to 639 at this time in 2021. It is wonderful to see the Society membership increasing once again. The ASEG currently has five Corporate Members, including two Corporate Plus Members. A huge thanks to all our Corporate Members for your continued support into 2022. Don't forget to have a look for our Corporate Members on the contents page of *Preview* and to support them as much as you can. Our state branches have additional local sponsors. These

sponsors are acknowledged at all branch meetings and at the beginning of all webinars.

### ASEG AGM 2022

The upcoming AGM will be held on Thursday 7 April 2022 at XXXX Brewery in Milton, Brisbane at 17.00 AEST for a 17.30 start. The AGM will also be available to attend via Zoom from 17.30 AEST. We will welcome in the new Federal President for 2022, Emma Brand. Our guest speaker at the AGM, Dr Taku Ide, will be giving a presentation entitled "The role of the Oil and Gas Industry towards a Net Zero Future". Please register for the online event prior to the event at <https://us02web.zoom.us/meeting/register/tZAtde-gpzsue9Zyv6QogISQ5TQqbyAVmnm1> and keep an eye out for further details on social media and in the newsletter. Please also register to attend the AGM in person <https://www.eventbrite.com.au/e/aseg-agm-and-talk-role-of-the-oil-and-gas-industry-towards-net-zero-tickets-304470859537>. It would be great to see you all there in person, or via Zoom.

### Positions vacant

There are vacancies for the position of Chair of our International Affairs and Education Committees. Our other

standing committee chairs would also welcome any 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](mailto: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 [in](#) [facebook](#) [t](#) for all the latest news and events.

### Online events

Even as face-to-face meetings and events return, the ASEG will continue with the webinar series with some interesting talks lined up for 2022. The webinars are coordinated and run at both state and federal level. The sessions are all recorded and available for viewing at the [ASEG website](#) or on our [YouTube Channel](#). The number of face-to-face meetings will also increase, so keep a look out for notifications from your state branches to see what is coming and get out there and reconnect with your colleagues.

*Leslie Atkinson*  
ASEG Secretary  
[fedsec@aseg.org.au](mailto:fedsec@aseg.org.au)

## Welcome to new Members

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

First name	Last name	Organisation	State	Country	Membership type
Cristina	Angheluta	DMIRS	WA	Australia	Active
Matthew	Auld	RMIT	Vic	Australia	Student
Noele	Carvalho	University of Queensland	Qld	Australia	Student
Reece	Cunnold		WA	Australia	Active
Ehsan	Farahbakhsh	University of Sydney	NSW	Australia	Active
Craig	O'Neill	GHD	NSW	Australia	Active

## ASEG Technical Standards Committee: JORC update

Two issues facing the committee are converging. Firstly, that the Joint Ore Reserves Committee (JORC) code should encourage the review of geophysical data by competent geophysical persons and secondly, that the Government Geoscience Information Committee (GGIC) refers authors to the ASEG for geophysics reporting questions. Kim Frankcombe pointed out that this situation creates an opportunity for the ASEG to develop best practice reporting guidelines.

Kim also pointed out that geochemists are already producing a set of guidelines for reporting on geochemical data. If the ASEG were to follow suit, that would address the poor JORC reporting standards for geophysical data – both for ASX and Government reports. The guidelines would need to be broad enough so that they are not constrictive, and clear enough so that they can be easily followed. If we are successful the various agencies could point clients to the ASEG website for the appropriate template.

A sub-committee of the ASEG Technical Standards Committee will be established to draft prototype reporting guidelines to accompany the official JORC code update. We would welcome any opinion or ideas on this or any other matter. Please email the Committee at [technical-standards@aseg.org.au](mailto:technical-standards@aseg.org.au).

*Tim Keeping*  
ASEG Technical Standards Committee Chair  
[technical-standards@aseg.org.au](mailto:technical-standards@aseg.org.au)

## ASEG Young Professionals Network: Update

Apologies for the lack of recent news flow. With rising oil prices, let's just say it has been a busy start to the year! Hope this also means that more YPs are gainfully employed!

In some news from the WA Branch, your new YP representative on the local committee is JJ Leong from Terra Resources. JJ replaces Carolina Pimental who ably carried the torch for many years - and we thank her for her many contributions. JJ is planning a local mentoring event so stay tuned for more information on that.

Now for some great news for the YPs. Thanks to our thoughtful FedEx committee (shout out to Yvette Poudjom

Djomani in particular) we have been allocated a sizeable budget for YP events to be held this year around the nation. Initial thoughts were to support networking events for YPs, but it is really in your hands. So, pester your local YP representative, or just organize it yourself. And don't forget to get in touch for more info or support.

Finally, I am still planning to launch a remote mentoring scheme this year, specifically targeting YPs who are based outside of major population centres or based overseas. It is important to make it clear that such a scheme is not meant to replace any existing local schemes or collaborations with other societies. It

is just an attempt to help any ASEG YPs who have thus far fallen between the cracks of those excellent initiatives.

Thank you to the mentor volunteers who responded already to my email on this, reaffirming their support, and also to new volunteer mentors. You are all in the database and I will most likely be in touch with a mentee for you during the year. The next step is to put the call out to the remote mentees and then attempt some form of reasonable pairing with a mentor.

*Jarrod Dunne*  
ASEG Young Professionals Network Federal Chair  
[ypadmin@aseg.org.au](mailto:ypadmin@aseg.org.au)

## First call for nominations for the 2023 ASEG Honours and Awards



To be presented in conjunction with AEGC 2023:  
13 – 18 March 2023, Brisbane, Queensland.



Award categories requiring nominations from ASEG members prior to the conference include:

- Outstanding contributions to the geophysical profession
- Outstanding contributions and service to the ASEG
- Recognition of innovative technological developments
- Promotion of geophysics to the wider community
- Significant achievements by younger ASEG Members

Lists of previous awardees, award criteria and nomination guidelines can be found on the ASEG website at <https://aseg.org.au/about-aseg/honours-awards>

For further information, preliminary expressions of potential nominations, and submission of nominations, please contact:

*Andrew Mutton*  
ASEG Honours and Awards Committee Chair  
[awards@aseg.org.au](mailto:awards@aseg.org.au)

## ASEG branch news

### Queensland

On 15 February, the Queensland Branch started the year by throwing increasingly large axes at targets. Despite what geologists might think, this wasn't a geophysical targeting exercise, but our first social event of the year at Maniax in Newstead. Ten seasoned ASEG Members competed for the honour of greatest axe thrower, with our very own treasurer **Roger Cant** taking out the top prize.

Recent weather caused our usual meeting spot, the XXXX Brewery, to be flooded, but it promises to be back up and running come April. The Queensland Committee extends our support to any Members affected by recent flooding events and hope everyone managed to stay safe and well.

Technical talks are lining up for the next few months. The Queensland Branch will be hosting the Federal ASEG AGM at XXXX Brewery on Tuesday 7 April, details appear elsewhere in this issue of *Preview*. Following this meeting, on Tuesday 26 April, we'll be welcoming **Mark Covington** from Geoimage for a technical talk about Space and Satellites. We welcome any expressions of interest to present a technical talk later in the year.

James Alderman  
[qldpresident@aseg.org.au](mailto:qldpresident@aseg.org.au)

### South Australia and Northern Territory

With a quiet start to the year the SA-NT Branch is slowly picking up with **Steve Begg** from the Australian School of Petroleum and Energy Resources at Adelaide University giving a talk on "Would you know a good decision if you saw one?" at the Hotel Richmond on April 29. We have our annual Fall Fling networking night with the YPP, PESA and SPE at the Havelock Hotel on 5 May, which is always a great night to catch up with colleagues and friends. We'll be partnering with the Adelaide University Geological Society (AUGS) again for our usual Student Networking Night at the Belgium Beer Café, which always has a good turnout with the last few details currently being finalised.

As usual, we couldn't host any of our fantastic events without the valued support of our sponsors. The SA-NT



Axe throwers from the Queensland Branch



Jamin Crystal of Anglo American celebrating a 7 point "broken heart shot"

Branch is currently sponsored by **Beach Energy, Borehole Wireline, Oz Minerals, Vintage Energy, Minotaur Exploration, the SA Department for Energy and Mining, Zonge, Santos and Heathgate.**

We look forward to seeing as many of you as possible at the SA-NT ASEG events during the year and if you're interested in joining the local Branch Committee, please feel free to contact myself or any other of the local committee members.

Ben Kay

[sa-ntpresident@aseg.org.au](mailto:sa-ntpresident@aseg.org.au)

## Tasmania

Dr **John Bishop** of Spa\*ark Energy and founder of Mitre Geophysics will be addressing a joint meeting of the ASEG Tasmania Branch and the Geological Society of Australia Tasmania Division on Thursday 28 April in the Geology Lecture Theatre at the University of Tasmania. The topic is "Getting warmer: the search for geothermal resources in Tasmania". This promises to be a fascinating overview of exploration spanning many geophysical methods and participants as well as years, and in the process revealing tantalising features of otherwise completely concealed eastern Tasmanian geology, not to mention highly novel geothermal prospects.

As well as in-person, this presentation will also be broadcast as a webinar: the first of a new monthly ASEG series curated by **Andrew Long** on the role of geophysics in the energy transition, as featured elsewhere in this issue of *Preview* and ASEG social media. The Tasmania Branch is pleased to assist in kicking off this opportunity to highlight how critical geophysics will be in providing the expanded level and diversity of resources needed to support a global transition to clean energy.

John's talk will be preceded at 17:15 by a long overdue Annual General Meeting, with new blood on the committee eagerly anticipated. The venue will be confirmed in direct communication to Tasmania Branch members, but is likely to be either the CODES Conference Room or Geology Lecture Theatre.

Mark Duffett

[taspresident@aseg.org.au](mailto:taspresident@aseg.org.au)

## Victoria

The Victorian Branch has had a typically routine start to 2022 - no action in

January, a little hype by February, and then demoralisation by March. Couple this with the untimely departure of our Branch Secretary, the indefinite postponement of the annual Summer Social and we have the makings of another challenging year for members. I sound awfully happy about the state of our society, don't I?

After demolishing my branch-funded private liquor cabinet at home, I came to the sobering realisation that our declining loyal member base would probably like to see/hear something tangible from the Branch before the bunny rabbit hops around delivering chocolate eggs. I write this branch news edition while seated on a late-night train ride home after our first Technical night meeting of the year. As I struggle to recollect the proceedings on this particular night (excessive drinking does this to you, you know?), I am overwhelmed with sinister-like thoughts about the fact that I was re-elected earlier this evening to continue in my role as Branch *El Presidente* for foreseeable future.

So, this happened. The Victorian Branch held its first AGM in five years, much to the bewilderment of some members that only showed up for the free drinks. All standing committee members stood for re-election, with the exception of our Secretary - **Nathan Gardiner** - who has decided to vacate the position

citing irreconcilable differences with our Treasurer (just kidding!). Anyway, our nominations went unopposed, and our run for office was confirmed by a landslide show of hands in favour of Jarrod and me retaining our villainous positions. Thank you to members for your unwavering support. I can't even begin to convey the emotions I am feeling at the thought that my private liquor cabinet will continue to be restocked unchecked.

Following the AGM, Victorian Members had the pleasure of hearing Dr **Laurent Ailleres** (Monash University) give a sermon on the topic of "Loop - an interoperable, integrative, probabilistic 3D geological modelling platform" at The Kelvin Club. Laurent currently leads the Loop initiative - a strange parallel world where users and developers come together to build 3D geological models at frightening pace. Despite our eyes being 7 cm apart and enabling us to see in stereoscopic vision, I still find it difficult to conceptualise subsurface geology in three dimensions (excessive drinking does this to you 😊). Loop apparently has the ability to generate sophisticated 3D geological models from 2D maps, structural data recorded on a map or from drillhole data and helps users visualise their 3D geometrical interpretations rapidly. I wonder what fascinating models Loop could produce if I trained it on Google Earth images of landscapes. Hmmm...



Laurent Ailleres presenting to the Victorian Branch at the Kelvin Club



## ASEG news

Despite summer being officially over, I am pleased to announce that the annual ASEG-PESA-SPE inter-society >(insert season here)< social event will be held on Wednesday 30 March this year at The Common Man, South Wharf. Please look out for email notifications regarding this not-to-be-missed event. Ciao.

*Thong Huynh*  
[vicpresident@aseg.org.au](mailto:vicpresident@aseg.org.au)

### Western Australia

What do you call a bunch of retired geophysicists sitting around on a summer afternoon recounting stories from their glory days?

That was the conundrum facing the WA ASEG team who were tasked with the job of recording the histories of older geophysicists for the History Committee. Led by **Kim Frankcombe**, the group decided to take a different approach to other states. We would record the histories in video format rather than written formats, and - just to make it more fun for everyone involved - we would combine the recording of several histories into the one big event. The name coined for this event was: "ASEG Legends BBQ"

Current young (and not-so-young) geophysicists were engaged as volunteers to interview the Legends using a questionnaire cheat-sheet as a starting point, and letting the conversations run from there. The interviews were arranged in groups of four, with the small groups set up in order to "amiably challenge claims that seem implausible and fish that grow too big - the older we get, the better we were".

The inaugural Legends BBQ was held in Perth on January 29. **Greg Steemson**, a legend himself, offered to host the event at his property in the Perth hills along with his wife **Barbara**. It was a scorching hot afternoon with the sea breeze nowhere in sight, but the participants arrived full of enthusiasm. The event kicked off, catching up with old friends over an ice-cold drink. For some of the participants it had been many years, even decades, since they had seen some of their geophysical peers, and the chance to catch up was taken up with much appreciation.

After renewing acquaintances, we got down to the task at hand. Participants

(Legends and interviewers) broke into small groups and found quiet, secluded (shady) parts of the property to conduct the interviews. The interviews were recorded using smartphones and custom-made tripods (thanks again to Kim). The legends recounted stories from their careers and recorded insights for the archives. Some amazing anecdotes were revealed, from times when the industry was very different. Our local branch archivist **Ian James** was kept busy with huge data files coming in from phones at regular intervals.

As the afternoon cooled off, we shared a meal together and continued the reminiscing. Despite the weather, and looming threat of COVID, the event was very well attended and rated as hugely successful by those who participated.

Thanks to our generous hosts **Greg** and **Barbara Steemson**, also to the organisers **Anne Tomlinson**, **Bill Peters**, **Ian James**, **Tom Hoskin** and **Kim Frankcombe**. Appreciation also to our interviewers - they are the legends of tomorrow, who will one day be recounting their own stories to a new generation.

There is still a lot more work to do on editing and archiving material from the event. However for a bite-size 'trailer' of the history videos please see the ASEG website at the following address: <https://www.aseg.org.au/history/history-members>

This will be the first of many "Legends" events. As well as being a great multi-generational social occasion, it is playing a role in preserving the rich history of ASEG. The next batch of legends will be tapped on the shoulder and we will once again be looking for younger geophysicists to play the role of interviewers. We hope you can take the time to enjoy watching some of the interviews from our well-known geophysicists over the coming months.

*Darren Hunt*  
[wapresident@aseg.org.au](mailto:wapresident@aseg.org.au)

### Australian Capital Territory

The ACT Branch will hold its Annual General Meeting in early April, and **Mark Dransfield** has been invited to give a technical presentation on the state of the art in gravity gradiometry.

We also have **Audrey Addison** from Google Research (US) lined up for

our next talk/meeting in early May - sometime after the school holidays - stay tuned for details!

*Anandaroop Ray*  
[actpresident@aseg.org.au](mailto:actpresident@aseg.org.au)

### New South Wales

If 2021 saw the ASEG NSW Branch ending the year strongly, 2022 has started on an extremely wet note! At the time of writing, there has been unprecedented flooding across the Sydney Basin - with bridges disappearing, major roads becoming rivers, and tunnels becoming water slides. Let's hope the Sydney sun returns soon!

The ASEG NSW Branch had its first event of 2022 in February, which was the AGM and Technical talk. The ever-charismatic **Mike Smith** hosted the AGM portion of the evening, which saw all members of the NSW Committee being voted in unanimously, with a slight reshuffle and a new face. The ASEG NSW 2022 Committee is comprised of: **Steph Kovach** as President, **Bhavik Lodhia** as Secretary, **Ben Patterson** as Treasurer, **Josh Valencic** as Social Media Officer, **Stuart Clark** as Technical Officer, and **Jim Austin** as a general committee member. **Roger Henderson** and **Mike Smith** will be on hand as always to offer their wisdom.

In the technical section of the meeting, Jim Austin (CSIRO) presented a talk entitled "Geophysical vectors for iron oxide copper-gold (IOCG) exploration: Cloncurry METAL project". Jim explained how many Cloncurry-type IOCG deposits typically do not have gravity anomalies, while other deposits do not have magnetic anomalies, and some have neither. To combat this lack of anomalies, novel geophysics-based approaches were outlined that can be used for IOCG exploration. These geophysical based approaches involved combining geophysics and petrophysics, and integrating anisotropy of magnetic susceptibility (AMS) data with quantitative mineralogy to translate metasomatic processes into geophysical parameters. This enabled mapping of structural controls and prediction of ore body geometries.

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to



Scenes from the WA Branch's ASEG Legends BBQ



2022 ASEG NSW committee (left to right): Bhavik Lodhia – Secretary, Steph Kovach – President, Ben Patterson – Treasurer, Jim Austin – committee member, and presenter of the Tech talk at the February meeting.

be in town at the time. Most talks are livestreamed on Zoom and uploaded to ASEG's YouTube page later, so you also have the option to join us online. Meetings are generally held on the third Wednesday of each month from 17:30 at Club York. News, meetings notices, addresses and relevant contact details can be found at the NSW Branch website. All are welcome.

*Stephanie Kovach and Jim Austin*  
[nswpresident@aseg.org.au](mailto:nswpresident@aseg.org.au)

## ASEG national calendar

Date	Branch	Event	Presenter	Time	Venue
30 Mar	Vic	ASEG-PESA-SPE Summer social		1730	The Common Man, South Wharf, Melbourne
31 Mar	National	Tech talk	Heather Handley & Iain Stewart	1800	Virtual
07 Apr	National	ASEG AGM	Taku Ide	1730	Virtual /XXXX Brewery, Milton, Brisbane
26 Apr	Qld	Tech talk	Mark Covington	1700	XXXX Brewery, Milton, Brisbane
Apr	ACT	AGM	Mark Dransfield	TBA	TBA
28 Apr	Tas	AGM	John Bishop	1715	Geology Lecture Theatre, University of Tasmania, Hobart
29 Apr	SA-NT	Tech talk	Steve Begg	1800	Hotel Richmond, Adelaide
05 May	SA-NT	YPP, PESA and SPE Fall Fling	Various	TBA	Havelock Hotel, Adelaide
10 May	National	Tech talk	Tom Rayment	1900	Virtual
May	ACT	Tech talk	Audrey Addison	TBA	TBA
July	SA-NT	Student Networking night	TBA	TBA	Belgian Beer Cafe, Adelaide

## Vale: William Francis Budd (1938 – 2022)



Bill Budd

All of geoscience suffered a loss on January 23 with the death of William "Bill" Budd. He was the face of Antarctic glaciology for half a century.

Bill was born on October 16, 1938, in the decayed mining town of Mount Hope, between Hillston and Cobar, NSW. He studied at Sydney University, graduating with a Bachelor of Science in Applied Mathematics, and continued to earn a Diploma of Education to qualify as a high school mathematics teacher. After only one year of teaching, he joined the Australian Antarctic Division in 1960 as glaciologist for the wintering expedition at Wilkes Station.

In early 1961, he sailed from Melbourne on the ship to Wilkes, at that time a joint Australian-USA station. He spent much of the year making meteorological and glaciological observations, and helping with geophysical measurements as well. These were a continuation of studies

initiated by American scientists during the International Geophysical Year (1957-58), and included several months of measurements east of Wilkes over Law Dome, a local icecap 200km in diameter, separated from the main icecap by the Totten and Vanderford glaciers.

Returning to Melbourne in early 1962, Bill started writing up the results of this work under guidance from Fritz Loewe and Uwe Radok. As a Jew, Dr Loewe had fled Germany to England in 1934, where he worked at the Scott Polar Research Institute in Cambridge. From Cambridge, Loewe was recruited in 1937 to start a department of meteorology at the University of Melbourne. He was an experienced glaciologist as well as a meteorologist, having wintered on the Greenland icecap in 1930-31, losing all his toes to frostbite.

Uwe Radok was a younger German, who was one of the refugees brought on the

Dunera from England to Australia in 1940. He ended up in the Department of Meteorology in Melbourne, and became Reader in charge of the department when Dr Loewe retired in 1966.

Bill wrote the 1961 Law Dome data into the thesis which earned him a Master of Science from Melbourne University, and in 1964 headed south again, this time to Mawson Station, which he used as a base to study the Amery Ice Shelf east of Mawson. Over the following years he translated his two years of physical observations, supplemented by further field work by other workers on both Law Dome and the Amery Ice Shelf, into mathematical theories, and put them into a PhD thesis with the title *The Dynamics of Ice Masses*. He received his doctorate in 1969, and the same year became the leader of the Antarctic Division's Glaciology Section, which hired a young geophysicist named Les Denham in 1969 to continue Bill's 1961 work on Law Dome during 1970.

Over the following decade the Glaciology Section, located within the University's Meteorology Department, expanded from two or three people to a team of fifteen or more. Bill introduced and led studies of ice sheet mass budget, ice rheology, ice sheet thermodynamics, iceberg distribution and drift, surging glaciers, drifting snow, sea ice-climate interactions and much more. He initiated Australian ice core drilling (initially for study of ice dynamics and later for palaeo-climate research), radio echo sounding of ice thickness and satellite remote sensing of ice. He started Australian ice core drilling, radio echo sounding of ice thickness, and remote sensing of ice from satellites. These programmes, which Bill initiated more than 50 years ago, still form the core of Australian glaciological research.

In the mid-1970s, Bill added general-circulation models for climate and climate/ice-sheet response to his repertoire. In 1979, the University of Melbourne established a new chair of Meteorology, and Bill resigned from the Antarctic Division to become the first Professor of Meteorology, while retaining his strong links with the Antarctic Division programme.

Bill's research through the 1980s included modelling of ice sheet changes through ice ages, simulations of the response



of the present Antarctic Ice Sheet to climate change, and general circulation modeling of future warming. His models of the interaction of ice sheets and climate have been extensively used in international assessments of climate change and Antarctica's response to future global warming.

The Antarctic Cooperative Research Centre in Hobart (Tasmania) was established in 1992, and Bill moved from Melbourne to Hobart as the Professor of Meteorology, Leader of the Polar Atmosphere Programme and to continue his active collaboration with the Antarctic Division glaciology group which also transferred to Hobart. He continued his work on ice-sheet and sea-ice modeling and ice/ocean/atmosphere coupled modelling.

Bill Budd was active internationally. He helped start the International Antarctic Glaciological Project (IAGP) in 1968; he was a Vice-President of the Scientific Committee on Antarctic Research from 1988 to 1992, and made considerable input, often as an office bearer, to organisations as diverse as the World Climate Research Programme, the International Glaciological Society, the International Commission on Snow and Ice, the International Association of Meteorology and Atmospheric Physics and many others.

Bill was awarded the Polar Medal in 1969, the Edgeworth David Medal (of the Royal Society of NSW) in 1971, the Royal Society of Victoria's Research Medal in 1977, was elected a Fellow of

the Australian Academy of Science in 1993, and in 1996 received the Seligman Crystal, the highest award of the International Glaciological Society.

He retired from formal employment around 2005, but remained active as Emeritus Professor.

Bill was my boss during my employment by the Antarctic Division (July 1969 to January 1972) but I did not see very much of him: in 1970, he was in Melbourne and I was in Antarctica, and in 1971 he was in Seattle most of the year, while I was in Australia. He did introduce me to Fritz Loewe and Uwe Radok, for which I am very grateful.

*Les Denham*  
[denhamles@gmail.com](mailto:denhamles@gmail.com)

## Henderson byte: The first radiometric surveys for uranium in Australia

The occurrence of uranium in Australia has been known since the 1890s. Uranium was produced as a bi-product of radium mining in South Australia at Radium Hill from 1906, and Mount Painter from 1911 (radium being used for medical purposes). From the 1930s, Radium Hill was operated as an underground mine.

According to Thyer (1979), following the conclusion of the Aerial Geological and Geophysical Survey of Northern Australia (AGGSNA) in 1941, the then remaining geophysical staff were transferred to what became known as The Mineral Resources Survey (MRS) led by H G Raggatt, the Geological Advisor to the Commonwealth. Several surveys were carried out by the MRS (see Thyer, 1979) from 1941 until 1946, when the federal government created the Bureau of Mineral Resources, Geology and Geophysics. In 1944, the British and Australian Governments requested that a search for uranium deposits commence, and officers from the MRS carried out surveys in the Mount Painter and Radium Hill areas of South Australia, the only areas where uranium had previously been mined (Dickinson, 1954).

The surveys at Mount Painter were conducted by R F Thyer in August-September, 1944 using a Geiger-Mueller ratemeter built in the Physics Department of Adelaide University. Surveys at Radium Hill were conducted by J M Rayner and C H Zelman using a G-M ratemeter and counter mounted on a truck (the first mobile survey). Surveys continued at both areas through 1945 (Thyer, 1979).

In 1948 tax concessions were offered by the Commonwealth for successful discoveries, which encouraged individual prospectors to participate.

In 1950, the geophysical branch of the South Australian Dept. of Mines conducted radiometric logging of diamond drill cores and a scintillometer survey of the underground workings at Radium Hill.

During the early establishment of the BMR, newly built scintillometers from Canada and the United States were included with airborne magnetometer surveys from 1952 on, with the first being at Rum Jungle in the Northern Territory in August, 1952 and Radium Hill in November, 1952.

While radiometric surveys can detect uranium directly, other geophysical methods also have important applications to uranium exploration situations. Gravity, magnetic, electromagnetic, and induced-polarisation surveys, conducted on regional and local scales, can be shown to be useful over a wide variety of uranium deposits.

### References

Dickinson, S.B., 1954. S.A. Dept. of Mines Report for 1953.  
Thyer, R.F., 1979. *ASEG Bulletin*, **10** (4), 244-251.

*Roger Henderson*  
[rogah@tpg.com.au](mailto:rogah@tpg.com.au)

## Geoscience Australia: News

Welcome to Geoscience Australia's programme update for April. While plans are very much afoot for large scale acquisition throughout Australia over this year, torrential rains, ongoing COVID restrictions and redeployment of survey aircraft for emergency evacuation works, means that we have only just started to ramp up. Working with our State and Territory partners, we have three very large programmes kicking off under the Federal Government's Exploring for the Future initiative, including airborne EM along the NT – WA – SA borders (through the 'Western Resources Corridor'), the SA-NSW borders (through the 'Eastern Resources Corridor') and across the eastern coast of Tasmania (see Figure 1 and the tables following this section).

As reported by the Geological Survey of Western Australia in this issue of *Preview*, we were pleased to jointly release located data and inversion products for the 17 600 line-km Murchison airborne EM (AEM) package last month. This data will shortly be supplemented by acquisition across remaining parts of Western Australia between May and August 2022. Upcoming data releases include the Geological Survey of Queensland's Canobie airborne gravity gradiometry survey and the Northern Territory Geological Survey's 55 000 km<sup>2</sup> ground gravity survey near Tennant Creek.

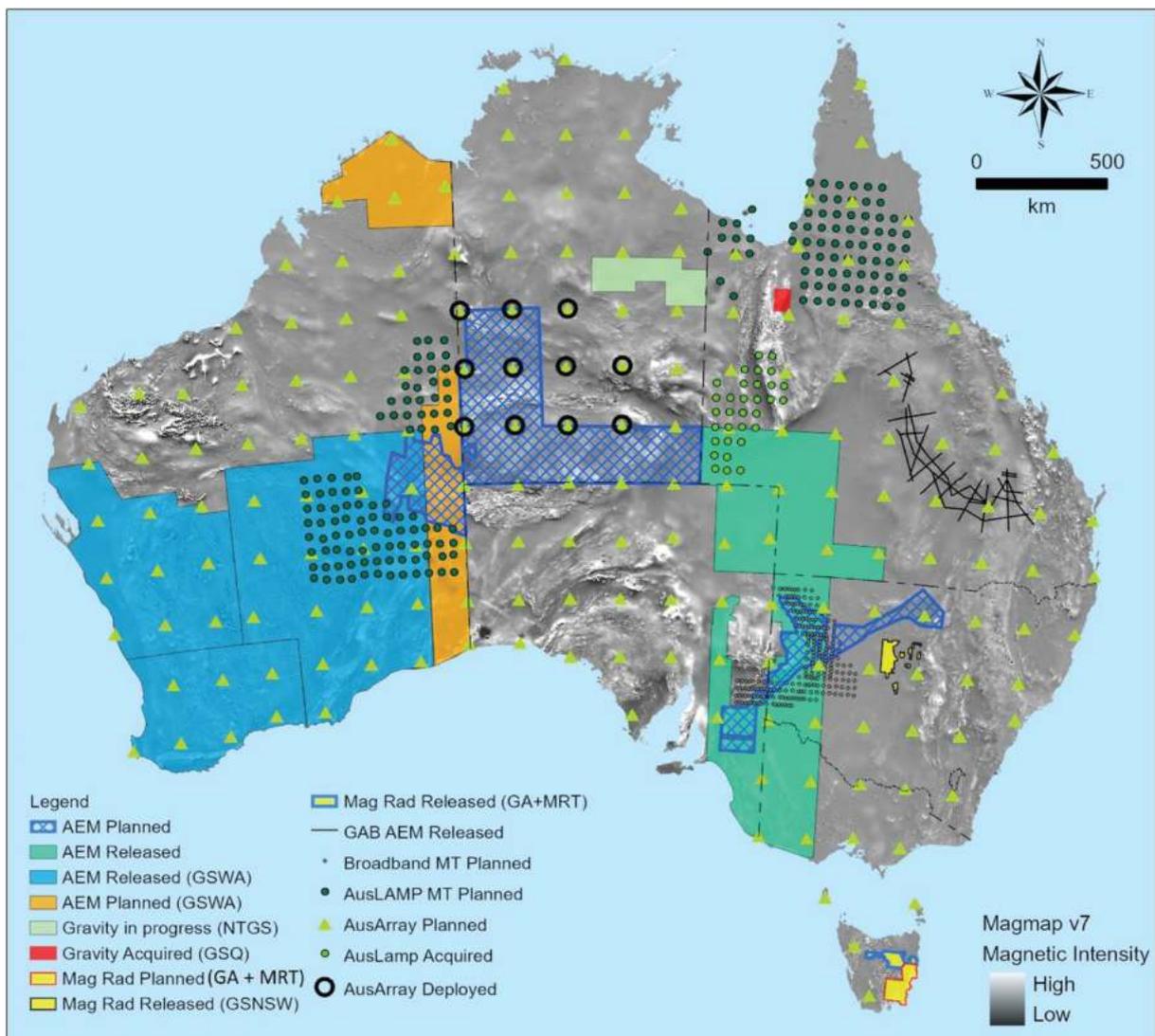
### Release of 2017 – 2019 airborne gravity and gradiometry datasets

You may have noticed a series of airborne gravity and gradiometry

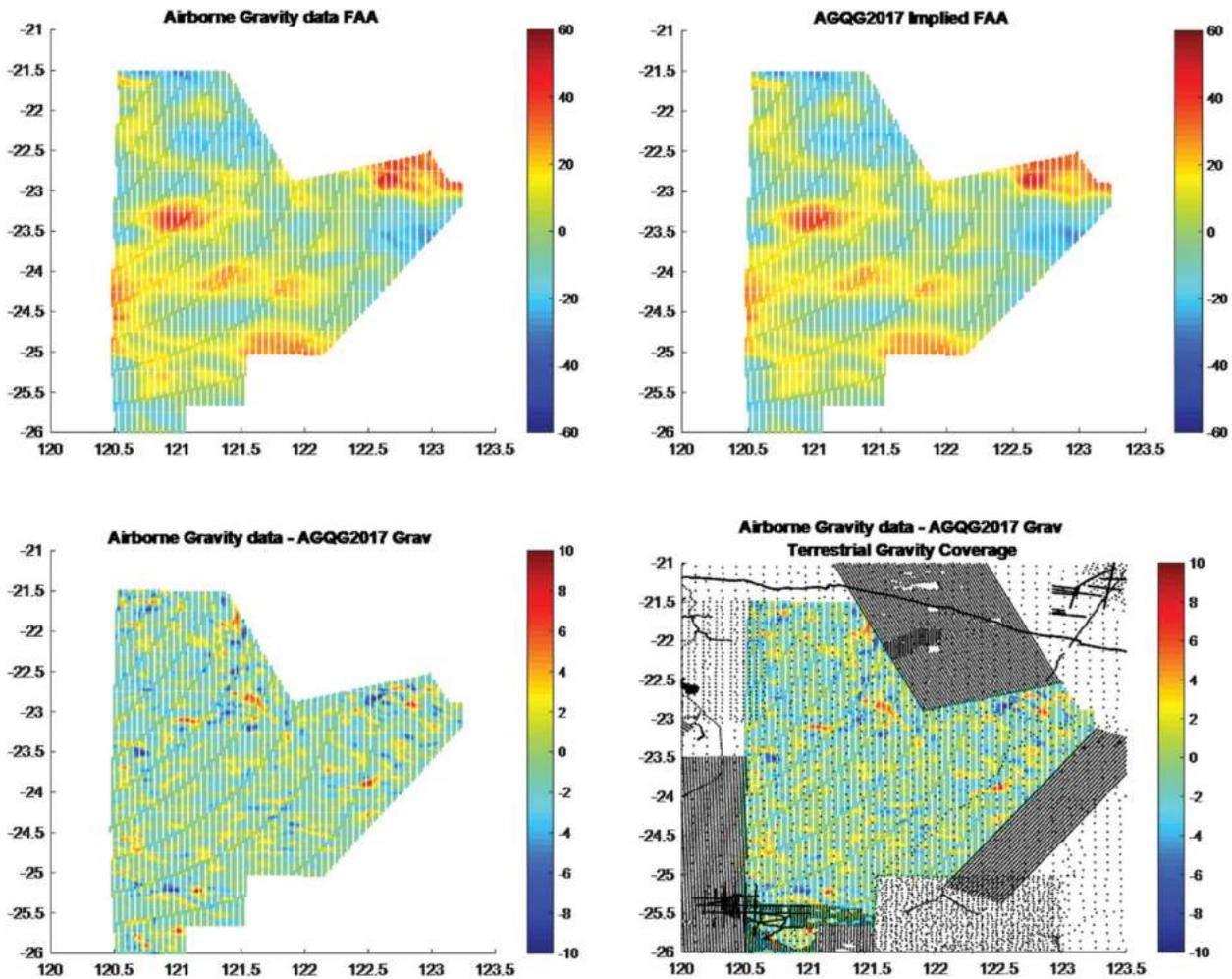
datasets listed in the tables following this section that have been in the "to-be-released" state for some time now. Our dear colleague Richard Lane was working on their release up until his death early last year.

We are very pleased to say that having spent much of last year designing technical standards for airborne gravity and gradiometry acquisition, together with quality control flow streams, Geoscience Australia is close to releasing the datasets through our electronic catalogue and (eventually) through the geophysical portal (GADDS).

One of the key issues was demonstrating the equivalence to ground data with a simple and replicable process on a survey by survey basis. The process



**Figure 1.** 2021–2022 geophysical surveys – in progress, planned or for release by Geoscience Australia as part of the Exploring for the Future (EFTF) programme and in collaboration with State and Territory agencies. Projects that are substantially or wholly funded by state government agencies are identified by the bracketed contributors. Background image of national TMI compilation, Geoscience Australia, 2019 (see <http://pid.geoscience.gov.au/dataset/ga/144725>).



**Figure 2.** Top: The point located 100 second 1D and 5000 m 2D filtered free air gravity anomaly data (scale in mGal) – left, and the AGQG2017 implied gravity anomaly upward continued/interpolated to the location of the point located data (scale in mGal) - right. Bottom: The difference between the point located 100 second 1D and 2750 m 2D filtered free air gravity anomaly data and the AGQG2017 implied gravity anomaly upward continued/interpolated to the location of the point located data. (scale in mGal) – left, and the same but with existing terrestrial gravity data coverage overlaid as black marks - right.

applied for gravimetry is summarised by Dr Jack McCubbine, InSAR Team Leader, National Geodesy Section, Geoscience Australia, as thus:

*We have compared filtered (generally to a 2.5 km resolution) free air airborne gravity anomaly data to the gravity anomaly implied by the AGQG2017 geoid model. This check verifies that the airborne derived gravity data match existing (ground) data within the limitations of the existing data coverage. The AGQG2017 geoid model is effectively a 2 km grid of the Earth's gravity potential and it can be transformed into a gravity anomaly map with some mathematical operations. Importantly, the AGQG2017 "implied gravity anomaly" corresponds to one that is external to all gravitating masses – akin to the airborne gravimetry measurements which are made*

*well above the topography. AGQG2017 was calculated using an optimised combination of EGM2008, and terrestrial gravity data, from a 2016 release of the Australian National Gravity Database. A topographic reconstruction technique is also applied to model short wavelength topographic effects using a standard rock density of 2670 kg/m<sup>3</sup> (Featherstone et al., 2018). The accuracy of the model largely is limited by the terrestrial gravity spacing and the assumed rock density to compensate for short wavelength topographic effects where the gravity data spacing is sparse.*

In the example presented in Figures 2a and 2b, AGQG2017 implied gravity anomaly data has been upward continued to the same height as the airborne gravity. The difference is remarkably small, particularly

considering that the ground data was acquired on 11 km spacing compared to airborne gravity acquired on 2 km line spacing (and after a 2500 m spatial filter applied). The standard deviation of the differences is approximately 1.8 mGals.

**Reference**

Featherstone, W.E., McCubbine, J.C., Brown, N.J., Claessens, S.J., Filmer, M.S. and J.F. Kirby, 2018. The first Australian gravimetric quasigeoid model with location-specific uncertainty estimates. *Journal of Geodesy* 92(2): 149-168. <https://doi.org/10.1007/s00190-017-1053-7>

Mike Barlow  
Geoscience Australia  
[Mike.Barlow@ga.gov.au](mailto:Mike.Barlow@ga.gov.au)



## 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 29 March 2022).

Further information about these surveys is available from Mike Barlow [Mike.Barlow@ga.gov.au](mailto:Mike.Barlow@ga.gov.au) (02) 6249 9275 or Ron Hackney [Ron.Hackney@ga.gov.au](mailto:Ron.Hackney@ga.gov.au) (02) 6249 5861).

**Table 1.** Airborne magnetic and radiometric surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Line spacing Terrain clearance Line direction	Area (km <sup>2</sup> )	End flying	Final data to GA	Locality diagram (Preview)	GADDS release
Eastern Tasmania	MRT	GA	MAGSPEC	Mar 2022	53 000	200 m	11 600	Jun 2022	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 (km <sup>2</sup> )	End survey	Final data to GA	Locality diagram (Preview)	GADDS release
Canobie	GSQ	GA	Xcalibur Multiphysics	Nov 2021	~5000	1–2 km	5300	Dec 2021	Mar 2022	See Figure 1 in previous section (GA news)	Expected Apr 2022
Brunette Downs Ground Gravity	NTGS	GA	Atlas Geophysics	Oct 2021	~ 12 000	2 x 2 km grid	55 000	TBA	TBA	TBA	TBA
Melbourne, Eastern Victoria, South Australia	AusScope GSV DEL WP	GA	Sander Geophysics	TBA	137 000	0.5–5 km	146 000	TBA	TBA	See Figure 1 in previous section (GA news)	TBA
Kidson Sub-basin	GSWA	GA	Xcalibur Multiphysics	14 Jul 2017	72 933	2500 m	155 000	3 May 2018	15 Oct 2018	See Figure 1 in previous section (GA news)	Set for release Apr 2022
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 Apr 2022
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 Apr 2022
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 Apr 2022
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 Apr 2022
SE Lachlan	GSNSW/GSV	GA	Atlas Geophysics	May 2019	303.5 km with 762 stations	3 regional traverses	Traverses	Jun 2019	Jul 2019		Set for incorporation into the national database in 2022

TBA, to be advised



**Table 3.** Airborne electromagnetic surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km <sup>2</sup> )	End flying	Final data to GA	Locality diagram (Preview)	GADDs release
Western Resources Corridor	GA/GSWA	GA	Xcalibur Multiphysics	Mar 2022	~ 38 000	20 km	760 000	TBA	TBA	See Figure 1 in previous section (GA News)	TBA
Musgraves	GA	GA	Xcalibur Multiphysics	Mar 2022	~ 22 000	1 – 5 km	~ 100 000	TBA	TBA	See Figure 1 in previous section (GA News)	TBA
Upper Darling River	GA	GA	SkyTEM	Feb 2022	25 000	.25 – 5 km		TBA	TBA	See Figure 1 in previous section (GA News)	TBA
DCD	GA	GA	SkyTEM	Feb 2022	14 500	1 – 10 km		TBA	TBA	See Figure 1 in previous section (GA News)	TBA
Eastern Resources Corridor	GA	GA	Xcalibur Multiphysics	Apr 2021	32 000	20 km	640 000	Jul 2021	Oct 2021	See Figure 1 in previous section	Oct 2021 <a href="http://pid.geoscience.gov.au/dataset/ga/145744">http://pid.geoscience.gov.au/dataset/ga/145744</a>
Mundi	GSNSW	GA	NRG	Mar 2021	1900	2.5	~ 5000	Apr 2021	Dec 2021	See Figure 1 in previous section (GA News)	Oct 2021 <a href="https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/145897">https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/145897</a> or <a href="https://www.regional.nsw.gov.au/meg/geoscience/minexcrc/mundi">https://www.regional.nsw.gov.au/meg/geoscience/minexcrc/mundi</a>
AusAEM20	GSWA	GA	Xcalibur Multiphysics & SkyTEM	Aug 2020	62 000	20 km	1 240 000	Nov 21	Dec 2021	See Figure 1 in previous section (GA News)	Mar 2022 see <a href="http://pid.geoscience.gov.au/dataset/ga/146345">http://pid.geoscience.gov.au/dataset/ga/146345</a>

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 32 stations deployed in 2021	50 km	Long period MT	The survey covers areas of NT and Qld. Data package: <a href="http://pid.geoscience.gov.au/dataset/ga/134997">http://pid.geoscience.gov.au/dataset/ga/134997</a> Model: <a href="http://pid.geoscience.gov.au/dataset/ga/145233">http://pid.geoscience.gov.au/dataset/ga/145233</a> News article: <a href="http://www.ga.gov.au/news-events/news/latest-news/exploring-for-the-future-takes-a-deeper-look-at-northern-australia">http://www.ga.gov.au/news-events/news/latest-news/exploring-for-the-future-takes-a-deeper-look-at-northern-australia</a> Acquisition of 32 new sites in SW Qld completed mid-2021, data to be released late 2022 together with additional data planned to be acquired under Exploring for the Future during 2022.
AusLAMP NSW	GSNSW/GA	NSW	AusLAMP NSW	~300 stations deployed 2016-21	50 km	Long period MT	Covering the state of NSW. Acquisition is essentially complete with fewer than 10 sites remaining to be acquired or reacquired. Phase 1 data release: <a href="http://pid.geoscience.gov.au/dataset/ga/132148">http://pid.geoscience.gov.au/dataset/ga/132148</a> .
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.
Spencer Gulf	GA/GSSA/UofA/AuScope	SA	Offshore marine MT	12 stations completed	10 km	BBMT	This is a pilot project for marine MT acquisition. <a href="https://www.auscope.org.au/news-features/auslamp-marine-01">https://www.auscope.org.au/news-features/auslamp-marine-01</a> Preliminary results were presented at the Australasian Exploration Geoscience Conference in Sep 2021.

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
Officer Basin	GA	SA	Shallow legacy data	~2000	Varies	Varies	3-6 sec	2D shallow legacy data, explosive, vibroseis	GA commissioned reprocessing of selected legacy 2D seismic data in the Officer Basin, South Australia, as part of the Exploring for the Future programme. The objective is to produce a modern, industry-standard 2D land seismic reflection dataset to assist industry to better target areas likely to contain the next major oil, gas and mineral deposits. Reprocessing by Velseis is complete and data have been QC'ed. Release of the Velseis direct processed data package is planned for Nov 2021. A Velseis direct processed data package is available on request to <a href="mailto:clientservices@ga.gov.au">clientservices@ga.gov.au</a> .
Officer Basin	GA	SA	L137 Officer Basin	550	40 m	240 m	20 sec	2D deep crustal seismic explosive reflection seismic	GA commissioned reprocessing of 2D legacy deep crustal seismic data in the Officer Basin, South Australia, as part of the Exploring for the Future programme. The objective is to produce a modern, industry-standard 2D land seismic reflection dataset to assist industry to better target areas likely to contain the next major oil, gas and mineral deposits. Reprocessing by Velseis is complete and data have been QC'ed. A GA website data package (images, segy and metadata) is available from <a href="http://pid.geoscience.gov.au/dataset/ga/74944">http://pid.geoscience.gov.au/dataset/ga/74944</a> . A Velseis direct processed data package is available on request to <a href="mailto:clientservices@ga.gov.au">clientservices@ga.gov.au</a>
Pedirka Basin	GA	SA	Shallow legacy data	~2000	Varies	Varies	3-6 sec	2D shallow legacy data, explosive, vibroseis	GA commissioned reprocessing of selected legacy 2D seismic data in the Pedirka Basin, South Australia, as part of the Exploring for the Future programme. The objective is to produce a modern industry standard 2D land seismic reflection dataset to assist industry to better target areas likely to contain the next major oil, gas and mineral deposits. Reprocessing of these data by Geofizika started in May 2021 and is planned to be complete by the end of Nov 2021. Final deliverables in QC/QA stage and due for completion by the end of Jan 2022.
Central Darling Basin	Coal Innovation NSW (CINSW)	NSW	Central Darling seismic survey	~208	10 m	10 m	6-16 sec	2D high resolution and deep crustal seismic	GA and CINSW signed an MoU to acquire and process 2D high resolution and deep crustal seismic data in the Central Darling Basin. New seismic data will be acquired, processed and interpreted to assist in proving up a geological resource in NSW for the safe and permanent storage of CO <sub>2</sub> . The new seismic data obtained will provide greater certainty in planning for future drilling. Data acquisition was completed in May 2021. CINSW contracted Velseis to process the data and the GA seismic team is QCing the processing of this dataset. Processing of these data started in Jul 2021 and is due for completion by the end of 2021.
2019 Camooweal 2D Seismic Survey Archiving Project	GSQ	Qld	Camooweal seismic survey	~300	30 m	10 m	20 s	2D deep crustal seismic	Under a MOU with GSQ, GA is preparing a Data Processing Package for the 300 line km 2019 Camooweal 2D Seismic Survey. This data package will support an interpretation project being undertaken by GSQ to produce new precompetitive geoscience information to assist industry in better targeting areas likely to contain significant gas and sedimentary-hosted mineral deposits.



**Table 6.** Passive seismic surveys

Location	Client	State	Survey name	Total number of stations deployed	Spacing	Technique	Comments
Australia	GA	Various	AusArray	About 180 temporal seismic stations	~200 km spacing	Broad-band ~18 months of observations	The survey will cover all of Australia to establish continental-scale model of lithospheric structure and serve as a background framework for more dense (~50 km) movable seismic arrays. Deployment of this national array commenced with an initial 11 seismic stations deployed in the NT and will progress to other States and Territories depending on the pace of land clearance process and the status of COVID-19 travel restrictions.
Northern Australia	GA	Qld/NT	AusArray	About 265 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 data release of the transportable array was in 2020, with further data and model releases expected by Dec 2022. See: <a href="http://www.ga.gov.au/efft/minerals/nawa/ausarray">http://www.ga.gov.au/efft/minerals/nawa/ausarray</a> Various applications of AusArray data are described in the following Exploring for the Future extended abstracts: <ul style="list-style-type: none"> <li>· AusArray overview: <a href="http://pid.geoscience.gov.au/dataset/ga/135284">http://pid.geoscience.gov.au/dataset/ga/135284</a></li> <li>· Body wave tomography: <a href="http://pid.geoscience.gov.au/dataset/ga/134501">http://pid.geoscience.gov.au/dataset/ga/134501</a></li> <li>· Ambient noise tomography (including an updated, higher resolution model for the Tennant Creek to Mount Isa region): <a href="http://pid.geoscience.gov.au/dataset/ga/135130">http://pid.geoscience.gov.au/dataset/ga/135130</a></li> <li>· Northern Australia Moho: <a href="http://pid.geoscience.gov.au/dataset/ga/135179">http://pid.geoscience.gov.au/dataset/ga/135179</a></li> </ul>
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 backbone 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 <a href="http://www.iris.edu">http://www.iris.edu</a>

## Richard Lane Scholarship 2022



Richard Lane (1962-2021)

An ASEG Scholarship has been established to support geophysics Honours and Masters students and to commemorate the life and work of ASEG Gold Medal recipient Richard Lane. The scholarship is open to all BSc (Hons) and MSc geophysics students at an Australian University and consists of a grant of \$5 000 to the best ranked student for the current year. Ranking will be based on a 200 word discussion, overview of a geophysics project and on an academic transcript. For 2022 we acknowledge and thank Jayson Meyers and Resource Potentials Pty Ltd for the initial concept and donation.

All Honours (BSc) and Masters (MSc) students with focus predominantly in exploration geophysics are invited to apply. The closing date is 29 April 2022 and application details and form are at [www.aseg.org.au/foundation/richard\\_lane](http://www.aseg.org.au/foundation/richard_lane)

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



# Geological Survey of South Australia: SA Geodata gravity module data update completed

The process of updating the gravity module in the SA Government database SA Geodata, as flagged in the last issue of *Preview* (216), is now complete. 56 surveys were added to the database and they will soon be visible online. This work, which is described in the summary report that follows, was largely carried out on a voluntary basis by Sara Mobasher. Sara is now about to commence studying for a PhD at Adelaide University.

## Project objective and action items

The project had the following simple objective:

Update the geophysical section (gravity module) on DEM-GSSA Database (SA Geodata).

To achieve this objective the following action items were addressed:

1. Segregating the gravity survey data folders; identifying which gravity surveys were already available on the database, and which surveys were missing.
2. Ensuring that the missing gravity survey data files comply with the standard format set by DEM for uploading data to the database.
3. Verifying that survey data new to database was acquired at an export quality level (or not).

## Background

Gravity surveys carried out in South Australia fall in MGA Zones 52, 53 and 54. Exploration companies are allotted tenement numbers for their exploration area. The same piece of land may have different tenement numbers over a period of time, as the tenement numbers are revised every time they are re-issued.

Tenement holders are obliged to share all newly-acquired geophysical data with the SA Government as part of their annual reporting. The file format is usually an Excel sheet in comma-delimited (\*.csv) format, but this format may vary from company to company, and some even share the files in a notepad format. The excel sheet usually comprises key information, for example acquired gravity stations' locations, observed gravity values, gravity correction values, zone etc.

The format of excel sheets laid out by DEM-GSSA for data uploading to the database includes nine columns. It includes point number (*i.e.*, station number and line number) or station number only, Longitude and Latitude in decimal degrees, MGA zone, height according to the Australian Height Datum, height according to Australia-wide gravimetric quasigeoid model (AUSGeoid09), height according to Geocentric datum of Australia 2020 (GDA 2020), observed gravity in mgals or  $\mu\text{ms}^{-2}$  and a grid flag (effectively an indication of the quality of data).

In order to ensure that the data being uploaded complies with the DEM-GSSA standards, the subsequent methodology was adopted.

## Methodology

At the start of the project, an ArcMap "project" was initiated, displaying gravity stations along with the tenement boundaries. The gravity survey data folders to be uploaded on the database were then reviewed, one by one. The surveys that were already in CSV file format with the minimum required information were converted into shapefiles and dropped into ArcMap to cross-check whether they were already on the database, or needed to be uploaded. If the gravity survey needed to be uploaded, it was kept in a separate folder to prepare and upload to the database in the last stage of the project. This step was performed for about 200 Excel sheets.

After the data folders were sorted, the data files were formatted according to the DEM-GSSA standards. The DEM-GSSA standard comprises nine columns:

Column 1: The station number or point number. The DEM-GSSA database will give an error if it receives a file with more than nine digits in a point number.

Columns 2 and 3: This comprises of Longitude and Latitude. Some of the raw files had challenging Longitude and Latitude values, which were resolved depending on their format: 1. If the Latitude and Longitude values were in degrees, minutes and seconds (the desired format is in decimal degrees), they were converted using an in-house

DEM-GSSA decimal degree conversion excel sheet.  
2. If the given Longitude values were corrupted, Northing and Easting values were used to calculate new decimal degree values.

Column 4: Adding the correct zone. The zone column was missing in a small number of files and was added in the formatted files. This information was extracted from the contractor's report.

Column 5: Elevation AHD. Almost all raw files had this information, although it was missing in one file and was calculated by using the AUSGeoid09 batch processing tool, which can transform between Ellipsoidal and AHD heights.

Column 6: Elevation AUSGeoid09. This height was calculated using the AUSGeoid09 batch processing tool. A CSV file comprising of Latitude (positive value), Longitude, type of height (AHD), height, model without any header was required. The output generated has an AUSGeoid09 height.

For example:

Latitude	Longitude	Type of height	Height	Model
23.567	132.5467	AHD	67	AUS geoid09

Column 7: Elevation GDA2020. This height was calculated using the AUSGeoid2020 batch processing tool. A CSV file with Latitude (positive value), Longitude, type of height (AHD) and height was required. The output generated has a GDA2020 height. Please note that GDA2020 heights are not currently used for Bouguer Gravity calculations but are added to the database for completeness and potential future-proofing.

For example, an input file might look like:

Latitude	Longitude	Type of height	Height
23.567	132.5467	AHD	67

Column 8: Observed gravity. All raw files, with the exception of one file, had the observed gravity column in mgals. Where only Bouguer Gravity was given, observed gravity can be back calculated to meet the requirements (using an

News

in-house DEM gravity conversion sheet, available upon request).

Column 9: Grid flag: This flag allows GSSA geophysicists to quickly identify points suitable for use in generating statewide-grid products. The observed gravity value of the “new to database file” is compared with already existing data in ArcMap. If the new database file gravity values are in sync with existing gravity values that suggests the data will be suitable for use in future state grid products.

Populating the database

The data was uploaded to the database by following the steps below:

- Step 1: Search the database with the given tenement number, or the year in which survey was performed, or the surveyor’s name.
- Step 2: From the queried results, search if a similar survey exists (or not)? Sometimes survey entries were created, but no stations were uploaded.
- Step 3: Fill in the existing survey, or create a new survey if it does not exist.

Step 4: To create a new survey, complete the following mandatory fields:

- Survey name as per the contractor’s report
- Start and end date of survey
- Client name and surveyor’s name
- Number of base stations
- Gravity meter name, serial numbers and accuracy
- Base station names and gravity values
- GPS processing service (usually it is AUSPOS)
- The column numbers for the uploaded elements
- Type of position data (GDA94 or other)
- Verification of datum
- Processing technique for gravity GPS data (e.g., Post processed or RTK)
- Select if it is export quality

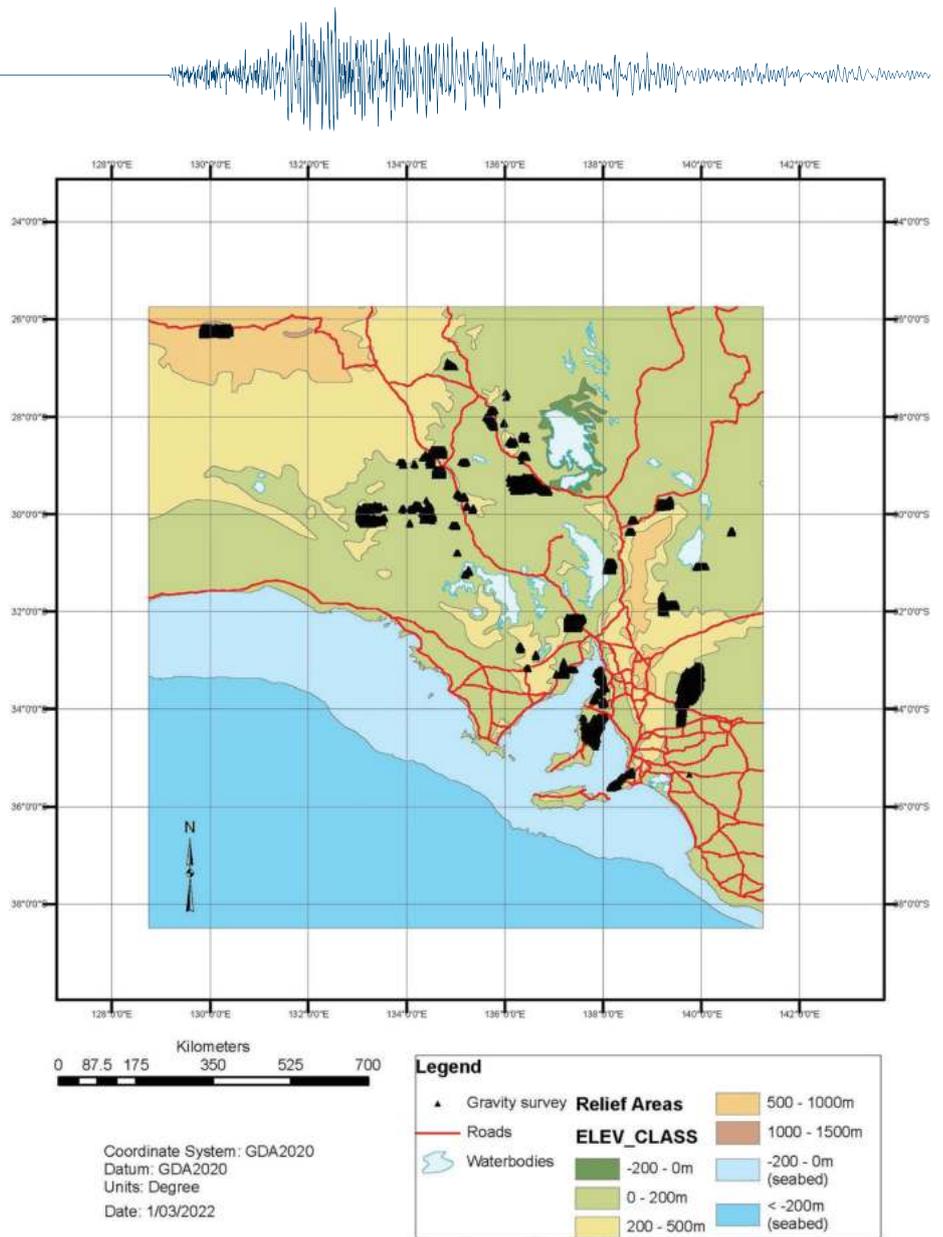


Figure 1: Location of the gravity surveys recently added to the SA gravity module

- Toggle on if the data is confidential (all data uploaded as part of this project were in the public domain)

If there were any errors in the file (e.g., a repeated point or values outside pre-set limits), the data base generated an error message. Otherwise, it uploaded the file.

Results

In total 56 surveys were added to the database, comprising 66 410 individual gravity observations. The distribution of the surveys is shown

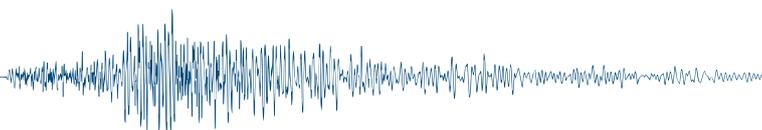
in Figure 1. GSSA geophysicists are now working to make these data visible online and available for public consumption. As always, if assistance is required accessing geophysical data from SARIG, please contact [resources.customerservices@sa.gov.au](mailto:resources.customerservices@sa.gov.au).

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 Geological Survey of South Australia

**Table 1:** A list of gravity surveys that were uploaded to the database

Survey number	Survey Code	Survey name	no. of gravity readings
1162	2007A29	Algebuckina (EL3226)	571
1291	2009A2	Morgan	774
1447	2002A43	Wandearah (2002)	1429
1463	2014A7	Cootanoorina	617
1464	2010A12	Mullaquana 2010	3821
1466	2015A01	Oodnadatta (2015)	364
1467	2015A02	White Horse Phar Lap	377
1470	2015A03	Coppertop Hill Gravity Survey	843
1475	2011A13	Bute 2011	610
1476	2013A05	Bute 2	232
1479	2011A14	Pound Creek	3493
1484	2012A04	Kokatha	918
1487	2011A17	Port Broughton	410
1489	2010A14	Scott Hill	1218
1491	2012A06	Bulgunnia 2012	2548
1495	2008A54	Wandearah Project	1155
1500	2010A15	Jungle Dam 2	298
1501	2010A16	Jungle Dam 3	1236
1504	2014A10	Barney Bore	994
1510	2013A07	Commonwealth Hill 2013 Grav	2312
1512	2015A06	Sherlock	119
1519	2014A11	Fleurieu Peninsula	295
1528	2010A17	Yorke Peninsula 2010	1736
1532	2012A12	Bourne And Doone	1066
1535	2011A19	Cooper Pedy Projects	707
1538	2002A48	Cedric Bore (2002)	721
1541	2009A27	Hicks Hill	444
1542	2009A28	Parachilna 2009	411
1543	2013A13	William Creek Gravity Survey	433
1544	2012A15	Marree Gravity Survey	1416
1545	2013A14	2013 Yorke Peninsula Gravity Surveys	561
1548	2013A15	William Creek Old Umbum	1069
1549	2012A16	Commonwealth Hill (Ibis)	2257
1550	2012A17	Commonwealth Hill II	5014
1551	2012A18	Marla	115
1552	2012A19	Marla II	11
1553	2013A16	Lake Anthony - Mt Christie	1673
1554	2015A08	Gawler Craton Project Gravity Survey	208
1555	2011A20	Cooper Pedy Projects Additional Points	134
1556	2014A12	Cootanoorina Part 2	559
1557	2014A13	Commonwealth Hill JV	2014
1558	2014A14	Margaret Dam	192
1559	2013A17	Yorke Peninsula Gravity Surveys	1915
1560	2014A15	Billa Kalina	1638
1561	2013A18	Cooper Pedy Gravity Survey	853
1562	2014A16	Gawler Project	1204
1563	2010A18	Lake Millyera	654
1564	2017A3	Hesso	3313
1565	2005A49	Benagerie Gravity Survey	162
1566	2003A35	Kimba Gap	750
1567	2010A19	Onesteel Mawson Gravity Survey	7869
1568	2009A29	Norwood Gravity Survey	317
1569	2012A20	Deering Hills	1777
1570	2011A21	Death Adder Gravity Survey	583
		(total)	66410



## Geological Survey of Western Australia: AusAEM–WA 90% complete with Murchison SkyTEM block release

Data from the AusAEM–WA Murchison SkyTEM block were released on 3 March 2022, bringing Western Australia to 90% coverage with contiguous airborne electromagnetic surveys at 20 km line spacing or better (Figure 1).

We expect full coverage by the end of the calendar year 2022, when surveys of the remaining areas in the east and northeast of the State, fully funded under the Western Australian Government’s Exploration Incentive Scheme, are completed as part of Geoscience Australia’s latest tranche of AusAEM work (see *Preview 216*, February 2022).

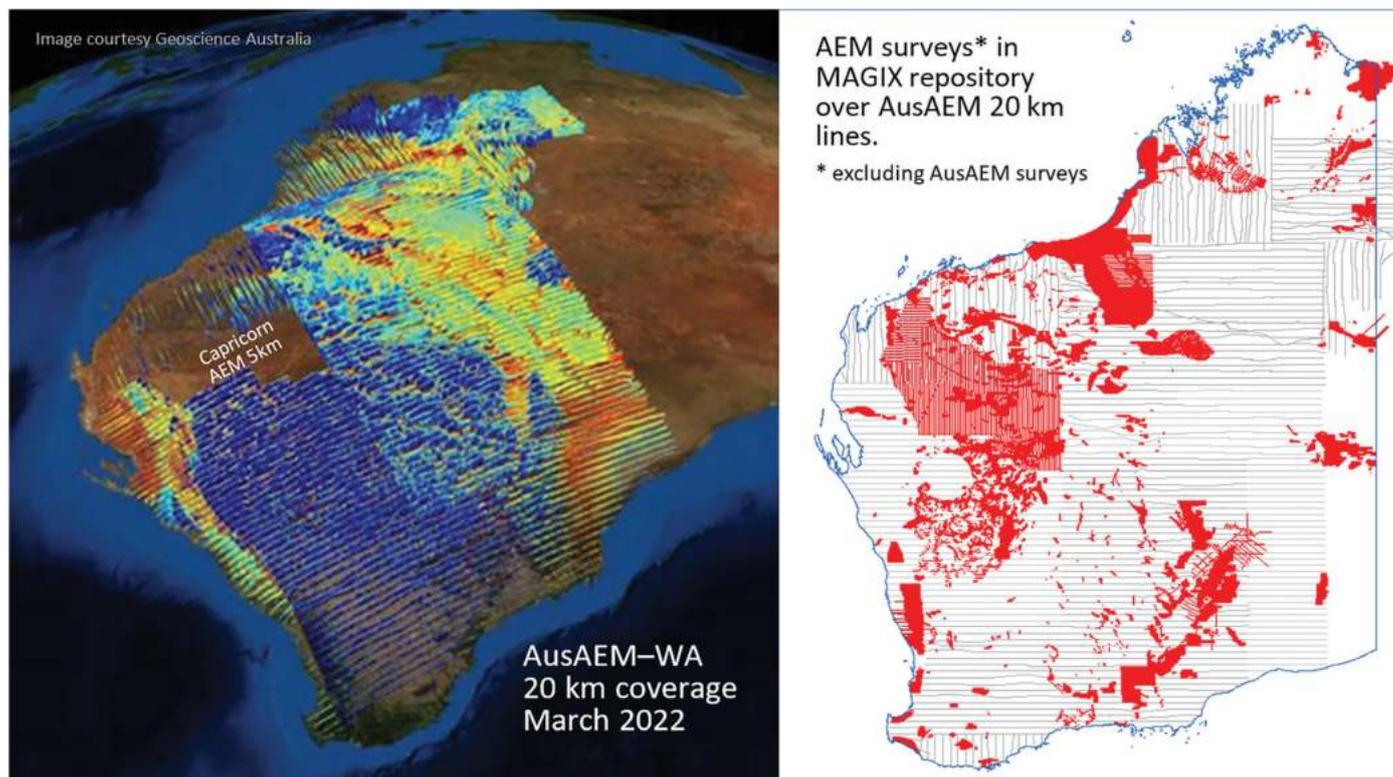
The uniform coverage of the AusAEM 20 km data in Western Australia provides conductivity context for the almost 1.3 million line-km of AEM data from more than 700 targeted surveys registered in the Geological Survey of Western Australia’s (GSWA) MAGIX data repository (Figure 1, right). This coverage can also be used to inform the design of new exploration-scale surveys. And who knows what serendipitous discoveries may be contained in the 125 000 line km of AusAEM data so far acquired in Western Australia?

Data from the AusAEM programme in Western Australia, from other Western

Australian government-funded regional surveys, and from open-file company surveys, can be downloaded from the MAGIX platform (<https://magix.dmirswa.gov.au>), and from GeoVIEW.WA — GSWA’s interactive mapping, data discovery, and data delivery platform. All AusAEM data are available from Geoscience Australia’s eCat delivery system.

For more information, contact [geophysics@dmirswa.gov.au](mailto:geophysics@dmirswa.gov.au).

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**Figure 1.** (Left) Stacked ‘AEM inversion curtains’ from AusAEM surveys in Western Australia (courtesy Geoscience Australia); (right) outlines of AEM surveys from private company and government agency surveys in the MAGIX data repository shown over the AusAEM 20 km survey lines.

## Canberra observed



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### The big push to commercialise the results from university research

First it was the Prime Minister, who 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."*

Then it was Stuart Roberts (Acting Minister for Education and Youth) who in December 2021 ordered the Australian Research Council to allocate 70% of all Linkage Grants to be aligned with future economic development (commercialisation).

This was followed in February 2022 by a University Research Commercialisation and Package and Action Plan. This document has one of the highest ratios of irrelevant pictures to information that I have ever seen (<https://www.dese.gov.au/university-research-commercialisation-package/resources/university-research-commercialisation-action-plan>).

However, if you scroll past the pictures, it is well worth the read. It argues that although "Australia produces world-leading foundational research, we currently underperform in achieving commercialisation outcomes.

*This limits the economic impact of our universities and shrinks the return on investment from publicly funded research.*

*Too often, research that could be used to benefit our economy and communities is not taken through to innovations which*

*can create new products and services, create jobs and lift productivity in businesses."*

I would have thought that the size of the Australian economy is a crucial factor, but this is not counted as significant.

The bottom line is that \$2.276B of new Australian Government funding over 11 years will be devoted to commercialisation of research. This is a good step forward.

Science & Technology Australia (STA) wasted no time in taking advantage of the government's new commitment. Its President, Mark Hutchinson, gave a very persuasive talk in early March at the National Press Club, using his Centre of Excellence in Nanoscale BioPhotonics (CNBP) as an example of what can be achieved. He claimed that he was able to leverage an initial investment of \$23M into creating 16 start-ups with a combined market capitalisation of \$519M over a seven-year period. Using CCNBP as an example, he argued that if just five percent of the innovators backed by the new scheme are successful on the scale of CNBP, then the new fund would have paid for itself.

I get the feeling that the drive and energy of Mark Hutchinson is quite exceptional, and his talents are not spread as widely as we would like throughout the science and technology sector.

*"Science & Technology Australia (STA) is Australia's peak body in science and technology. It represents more than 80 000 scientists and technologists.*

*Its mission is to advance the public good and social and community welfare, and strengthen civil society, through education, outreach and programs.*

*It aims to advance the impact of science and technology to help solve some of humanity's greatest challenges, including saving and improving lives."*

The emphasis on making profits from research has never been emphasised so strongly.

The public good and community welfare research should not be undertaken to make a profit. Human curiosity and our search for new knowledge cannot

easily be valued in dollar terms, but we know that these factors make massive contributions to our social wellbeing.

In the context of the percentage of GDP Australia spends on research (1.79%), the additional \$200M per year is small. To catch up with the OECD average investment (2.31%) we would have to increase our investment by about 0.52 percent of GDP or a rather large \$7B per year. Not a good look – we should be doing better.

### Geoscience Australia building up for sale again

The Geoscience Australia building was funded by the Commonwealth government and completed in December 1997, with Geoscience Australia occupying the building in January 1998.

It has been put on the market by German investment manager Real I.S., which bought it for \$234M in late 2006. This will be the third time it has been sold, and it is expected to fetch \$360M or more when it goes on sale to an international market in April.

It has a net annual income of \$26M and is 100 per cent leased to Geoscience Australia.

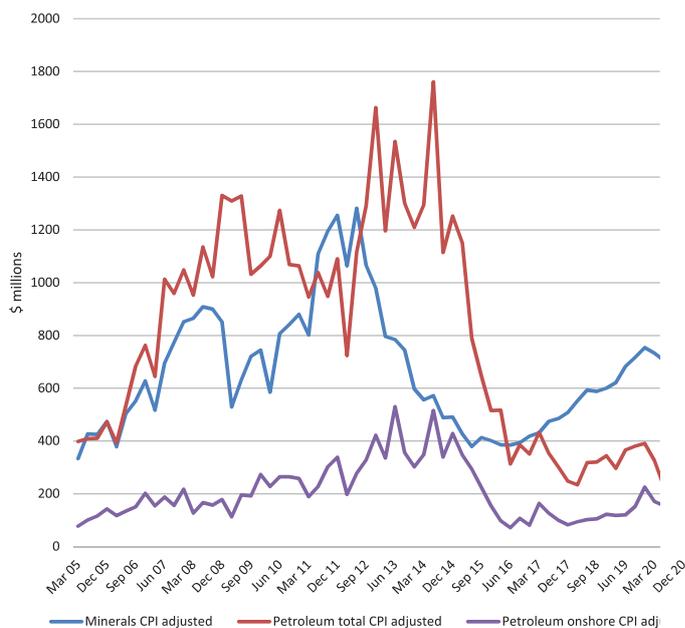
What a stuff up. The government sold a building housing a national institution with unique laboratories to international investors soon after it was completed. It is inviting international interests to buy it again.

We have already sold a major port and major shares in our electricity network to overseas entities.

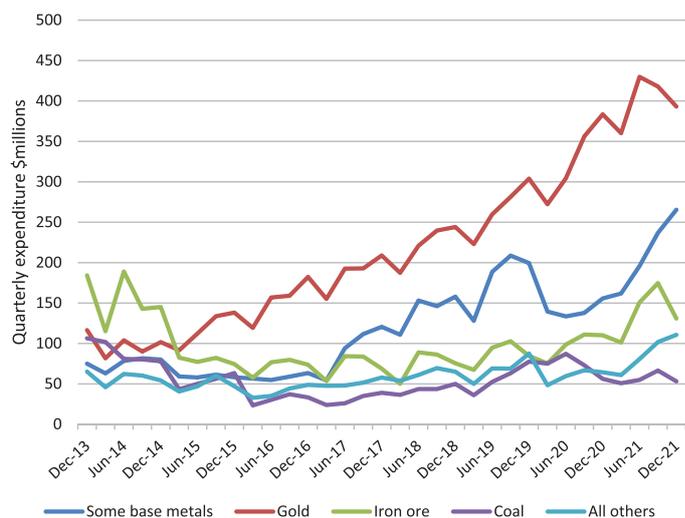
What's next? Sell the War Memorial or the National Library?

### Mineral exploration investment powers ahead

Although the December Quarter numbers fell, the steady upward trend in the investment for mineral exploration since 2016 continued throughout 2021 (<https://www.abs.gov.au/statistics/industry/mining/mineral-and-petroleum-exploration-australia/dec-2021>). The decline in the December quarter applied to the three main commodities, coal, gold, and iron ore. Figure 1 shows the



**Figure 1.** Quarterly investment in mineral and petroleum exploration 2005-2021.



**Figure 2.** Breakdown of quarterly investment of the main commodities, unsurprisingly gold is the dominant mineral. The numbers have been seasonally adjusted by the ABS (<https://www.abs.gov.au/statistics/industry/mining/mineral-and-petroleum-exploration-australia/dec-2021>).

results for the period 2005 through 2021. The future looks good for minerals.

The investment in offshore exploration has not recovered, but the war in Europe has yet to make an impact. The graph represents the original data from the 2005 - 13 and seasonally adjusted by the Australian Bureau of Statistics (ABS) from 2013 (<https://www.abs.gov.au/statistics/industry/mining/mineral-and-petroleum-exploration-australia/dec-2021>).

Figure 2 shows which sectors attracted the most investment, and gold once again dominated the numbers once again.

### Petroleum exploration in the doldrums

The petroleum exploration expenditure is still in the doldrums because of the paucity of any significant offshore investment. This might change because of the situation in eastern Europe, but the cost of offshore exploration has increased substantially as the easy to reach areas are explored. The good news is that the onshore exploration has continued to increase, mainly because of the search for natural gas.

As we go to press the cost of 98 unleaded petrol has risen in one month from \$2.00/l to \$2.30 /l and the inflationary impact will be significant.

## The ASEG in social media

Have you liked/retweeted/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](mailto:Communications@aseg.org.au) for suggestions for our social media channels.

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

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## Education matters



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### We have to start early if we are to persuade students to consider a career in the resources industry

In this issue of *Preview* we continue our series of interviews with industry and government agency leaders in the field of earth sciences. Michele Spencer from the Geological Survey of Western Australia shares her insights into state government department expectations of a university education.



Michele Spencer

MP: Michele, may I ask you to introduce yourself to our readers?

MS: I currently work for the Geological Survey of Western Australia. I am Director of Mineral and Energy Resources and have been there for almost three years. Prior to that I worked in the resources sector as a mine and exploration geologist at various levels across various commodities. I also spent several years working in Vietnam for a nickel exploration and mining company.

MP: That was really interesting and different environment, Vietnam, right?

MS: Yes. The expat lifestyle is great and the cultural experience for my kids was

life changing. Geologically, the role was really interesting also... and you know the food is pretty amazing!

MP: It would be interesting to know what brought you to geoscience?

MS: Initially, I wanted to be a primary school teacher. I had done a little bit of work experience in an early childcare facility and I really enjoyed it. In the first year of my education degree I chose an earth science subject. I loved it and swapped degrees the following year to a Bachelor of Science majoring in geology. My university offered a cooperative education component where you could go and work in your chosen field for a year. I chose to do that after second year, and I travelled from Brisbane where I was studying at Queensland University of Technology, to Kambalda in Western Australia. It was a bit of a culture shock, but I felt like I'd found my people. I completed my degree at the School of Mines in Kalgoorlie and went on to do my honours degree in structural geology after that.

*“At GSWA we are focused on geology and data and so to come to GSWA in a technical capacity you need to have those degrees”*

MP: It looks like you really like Western Australia.

MS: Yeah, I definitely do. I have been in Western Australia since the late 1990s. Except for those years that I spent in Vietnam, of course.

MP: In the current rapidly changing energy landscape, what does the West Australian Government's Department of Mines Industry Regulations and Safety expect from tertiary education? How do companies see their “fresh blood”, their new recruits?

MS: We still expect that the universities will produce forward thinking generalists and specialists. Universities are pretty good at transforming to stay relevant and evolve with emerging technologies and trends. An example would be data science... years ago it wasn't a degree, but now value creation from data is massive and on the rise. Data, as you can imagine, is particularly important to the Geological Survey of Western Australia.

We've seen a lot in the news lately about the reliance of universities on foreign

student intake. The supply impacts of COVID-19 through border closures has taught us an important lesson in diversification, but perhaps too late, as the impact of funding loss to the universities has seen the closing of many departments. I know that the resources sector is particularly concerned by the downsizing or closure over the past few years of earth science departments across Australian universities, which actually started before COVID-19. This will have a really important flow-on effect for years to come for the resources industry and, therefore, the resource reliant renewable energy sector.

I think it's important not to sacrifice one degree for another to fill the gaps and skills for renewable energy. Although obviously eventually some degrees may become redundant. I think that's still a very long way off.

MP: What has changed in the recruitment process in the last twenty years? In the last ten years?

MS: The internet has significantly changed how jobs are advertised and how applicants search for a new job. There's a much broader reach now, with job seekers and organisations advertising roles using social media such as Facebook and LinkedIn or targeted job search platforms such as Work180, Seek and Indeed. These platforms, particularly LinkedIn, also enable organisations to head-hunt for ideal candidates based on certain skill sets.

The use of technology in the interview/application process has also increased, and it's now the new norm. For example, it's common for job-seekers to record snippets of themselves answering questions, and submitting these with job applications, especially to the bigger companies. Personally, I don't like this lack of human touch.

Overall, organisations have evolved to incorporate workplace culture and non-remuneration benefits like flexible work hours and child care facilities in the office. Also, more and more now people work at home, and companies offer this as an option to attract candidates competitively in the market and to be the employer of choice. It is definitely an employee's market at the moment.

Recruiting to include diversity and inclusion has also increased. For



example, twenty years ago there was significantly less of a spotlight on women in leadership. I don't really agree with quotas as I don't think using discrimination to fight discrimination makes sense, and you could end up in a situation where it is perceived that you haven't found the best person for the role but, to fill a quota, you've found the best women for the role. No one wants that, not the business nor the women. I think that quotas definitely had a place initially in impelling the change. It's clear that women do make great leaders and by highlighting diversity and the positive impact it can have on a business, acceptance becomes unconscious and ultimately that's how change becomes normalised, almost by osmosis. It's not forced or resented, it's just natural and progressive.

MP: I believe that we are just at the beginning of this transition. And I know a lot of women that make great leaders.

*“Digitalisation will accelerate the clean energy transition”*

MS: I agree, and marketing the great things that women are doing also really helps keep the momentum going. An example is a study by McKinsey & Company, of more than 1000 companies in 15 countries that has shown that organisations with gender diverse executive teams and boards outperform on profitability compared with those that don't. It is results like these that ultimately drive the change and once we normalise it, it isn't something that we aspire to anymore, it just becomes something that we do. Great leaders already know the importance of diversity, they don't need convincing.

MP: Yes, exactly. And that's what I am also trying to do. Women working in earth science, in science in general, are already doing excellent work, but also have to be connected, have to grow networks, and increase visibility...

MS: Agreed, mentoring is also really important and groups like WIMWA (Women In Mining WA) do an amazing job of promoting women.

MP: Should we expect evolution or revolution in Tertiary education to ensure a smooth and efficient transition to clean energy?

MS: It's a clean energy transition and it's already upon us, and so I think it's definitely an evolution and not a revolution. There's not a requirement to completely transform within Tertiary education, and as mentioned before the universities are really good at keeping up and even driving innovation. A lot of the roles within the oil and gas sector overlap with low carbon industries in terms of skills, but all sectors will need to evolve to ensure that the industry grows and develops to produce a sustainable, accessible and inexpensive energy supply. I think if anything, “on the job” training and technical education are both required, because outside of Europe there's not much knowledge or experience, especially for things like wind farms.

In terms of university education there are already new degrees in energy systems, climate change, climate change policy and, renewable energy engineering. There's a definite skills shortage at present as the renewable energy sector competes with other sectors, including oil and gas, during the transition.

*“The impetus for clean energy has been from societal pressure on world leaders, through people communicating globally via the internet and social media”*

At GSWA we are focused on geology and data and so to come to GSWA in a technical capacity you need to have those degrees. However, we are looking across the state more broadly, and considering how we can contribute to the clean energy transition. There is an obvious fit in terms of providing data on WA's critical mineral resources, or on options for geological abatement of greenhouse gases using carbon capture and storage and mineral carbonation. At the moment GSWA can get this work done using our existing diverse skill set.

MP: Do you already feel that it's difficult to find specialists in a particular field because there are not enough graduates?

MS: The resources sector moves in cycles, and during boom times it is hard for organisations to attract specialists. I think this could be exacerbated in the future by the downsizing and closing of university earth sciences departments. In simplistic terms, when the mining industry was booming masses of geologists were

being produced, because everyone wanted to work in mining. However, this has really changed with the push for renewable energy and net zero. Along the way mining became synonymous with environmental vandalism. It seems more difficult to get students interested in studying geology, as they associate geology with mining, which has a poor reputation environmentally. However, the mining and petroleum industry is critical to a successful renewable sector. Critical minerals are required to build renewable energy infrastructure, and oil and gas will still be needed during the transition. These are really important messages that we need to get out to students, and the younger they learn this the better. The resources sector must improve the way it markets itself.

In Vietnam, researchers conducted a study to determine how to increase the number of students enrolling in their universities. Initially they spoke to students in their last year of high school, to try to get them interested in going to university. They were unsuccessful, because by then the students had already decided, or it was decided for them, that they were going to work in their parents' or family business. They found that in order to get students thinking that studying at university was an option for them, they had to start this messaging very early... in the early years of primary school. I think we can apply this learning here. To get students to consider a career in the resources industry, we have to start early. There are organisations like AusEarthEd that promote STEM in schools, but we have to ensure our messaging is targeted to let the kids know how important the resources sector is to things like climate change.

MP: Yes, we need energy-critical minerals to ensure the clean energy transition in Australia and the world.

MS: The mining and resources companies now work really hard to ensure environmental excellence. Their social license to operate depends on it, but they live on this earth too. Mining has to overcome a legacy of environmental damage by unknowing, and probably at times unscrupulous operators. But mining today is very different to mining 50 years ago in this country.

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

MS: I think that digitalisation will accelerate the clean energy transition. We've seen innovation in artificial Intelligence, block chain technology, Internet-of-Things, and crowd-sourcing – consider for example how rapidly the COVID-19 vaccine was developed using international data sharing. I think an enormous amount of collaboration is required to achieve net zero globally.

It will require the use of high-performance computing, algorithms, modelling (for example optimising wind farms), and digital twin technology (where our real life environment is virtualised). Organisations could plan, optimise, operationalise and manage their clean energy asset within a virtual world.

*“Specific education might include degrees in computer science and engineering, data science, information processing but more broadly might include dual degrees like marketing and information technology to communicate how digitalisation will benefit the community”*

The impetus for clean energy has been from societal pressure on world leaders, through people communicating globally via the internet and social media. People have more power than ever before to instigate change and this is more evident now that it has ever been. This is why marketing and messaging needs to be targeted, specific and honest, to counteract the disinformation and “fake news”.

So, specific education might include degrees in computer science and engineering, data science, information processing, but more broadly might include dual degrees like marketing and information technology to communicate how digitalisation will benefit the community.

MP: That's great. I haven't thought about this in this way. So, what do you do at the GSWA to ensure digitisation of your work and digitalisation of the sector?

MS: We are focussed on our data. The role of GSWA has typically been to collect data sets and produce tools that mitigate exploration risks for the state. But during COVID we couldn't travel

and do field trips to collect the data. Instead we analysed and synthesised our data and this produced some pretty amazing results. We delivered 100 new interpretive datasets, consisting of over 1000 new layers across all areas of geoscience in key regions of the state. These have been published online and will accelerate our understanding of the state's geology and mineral prospectivity. They are available for download from our website.

MP: At CSIRO, we are using your datasets and believe that you are doing a great job. And the dataset systems are much more convenient than they were before.

MS: Yes, and to answer your question, our Geoscience Data Transformation Strategy is well underway. This strategy will ensure we digitalise and transform the way we collect, use and deliver our data. We successfully secured \$10.6M in state government funding to fast track the delivery of this strategy over the next four years.

MP: I am looking forward to seeing what's coming out of this project. My next question is about hydrogen. What kind of specialists are required to pursue the hydrogen economy in Australia?

MS: There is potential for both manufactured and natural hydrogen in Australia. In the 19<sup>th</sup> century the world was manufacturing gas (town gas) by burning coal, but large natural gas reserves were later discovered, which were cleaner and cheaper and so we explored for those instead.

*“Western Australia also has the potential for natural hydrogen and the GSWA and CSIRO are already doing research in this area”*

Hydrogen could be a case of history repeating. Global economies are already manufacturing hydrogen from hydrocarbons and water but it's expensive, utilises a lot of natural resources and has the potential to cause land use conflict as the renewable infrastructure required to make “green” hydrogen in particular can take up a lot of land i.e. solar farms.

Countries like Mali have shown, though, that natural hydrogen as a source of electricity has enormous potential. This project has been in the experimental

stage for years but more recently Hydroma (the hydrogen company) has been supplying electricity to the local village and plans to export the natural hydrogen.

To enable a natural hydrogen industry, mining and/or petroleum laws will need to be amended to include hydrogen. South Australia has already done this and recently granted exploration licences for hydrogen in the State. Western Australia also has the potential for natural hydrogen and the GSWA and CSIRO are already doing research in this area.

The specialist skills required will depend on the “type” of hydrogen - natural or manufactured. A host of specialists will be required, including geologists, probably specifically hydrogen specialists, because the technical and scientific knowledge of natural hydrogen systems is still quite limited.

Historically, resources sector geologists have been either “oil-and-gas” or “minerals” geologists, but exploration for natural hydrogen might require all these skills as it can be associated with hydrocarbons in sedimentary basins and also with crystalline basement terranes.

Other specialists will include industrial chemists, various engineers (wellsite, processing plant, pipeline, electrical...), geophysicists and environmental scientists. The transition to renewable energy is a really interesting space but it will take patience, international collaboration and massive investment to develop. We need to consider things like the best use of the land, accessibility to infrastructure, expense to the consumer, sustainability and, of course, regulation. I'm curious to see what happens with the large direct-air carbon capture and storage facilities. How much CO<sub>2</sub> can we safely remove from the air in perpetuity? How will this be regulated globally?

The issue of land usage conflict is something that I deal with in my role daily at the Geological Survey. We are looking at the compatibility of emerging industries with other land use. The new industries need an equal opportunity to develop for the benefit of Western Australians, but we do need to ensure we don't develop one industry to the detriment of another.

MP: Can you share an example of what the Geological Survey of Western Australia is doing in this field to ensure



the hydrogen economy in Western Australia and Australia in general?

*“The transition to renewable energy is a really interesting space but it will take patience, international collaboration, and massive investment to develop”*

MS: While GSWA’s primary role is to provide objective and authoritative geoscientific data, information and services to support access to extraction of the State’s natural resources, GSWA also provides advice and supports the

State’s evidence-based decisions for creating a strong economy. For example, the Western Australian Minister for Mines and Petroleum has an approvals role with respect to grants of land tenure under the State’s land administration legislation, which is required to facilitate non-mining activities and projects, such as manufacturing of hydrogen and other renewable energy infrastructure. GSWA’s role is to consider the impact of such land tenure applications on access to State’s resources and involves geoscience mapping and prospectivity analysis. Part of this role is also fostering early engagement, and looking for opportunities for cooperation and

coexistence between different parties and land uses. So in essence we are aiming to facilitate a multi land use approach while ensuring access to the State’s natural resources is not unnecessarily sterilised. For the benefit of the WA community, we believe that all industries, existing and emerging should be committed to working together. This of course has flow-on effect on the rest of the country, both in terms of economic activity and associated benefits, as well as technological advances and innovation.

MP: Thank you so much for sharing your deep and thought-provoking insights, Michele. Much appreciated.

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## Energy transition webinars: Call for contributors

As geoscientists we are deeply relevant to the global transition to a low-carbon energy system that is based on renewable energies and improved energy efficiency. Recent global events highlight the fact that pragmatic “transition” is going to be critical, but there are many opportunities ahead.

We are soliciting contributing speakers and subject matter experts who can provide webinars to ASEG Members and affiliates on the many elements of this “Energy Transition” revolution. In the manner of previous ASEG webinars, content will be archived for public access and should be non-commercial.

We are open to ‘everything’: geothermal, mining for critical metals and minerals, geotechnical preparations for wind and solar, CCS/CCUS, economic perspectives as well as geoscience, ESG and legislative, and so on.

If you can offer some content or suggest someone who can, please contact Andrew at [Andrew.Long@pgs.com](mailto:Andrew.Long@pgs.com) Our ambition is to begin with a monthly webinar event, and gradually expand the scope of the ASEG activities in this new arena.

## South African Geophysical Association's 17<sup>th</sup> Biennial Conference & Exhibition



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## Environmental geophysics



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Welcome readers to this issue's column on geophysics applied to the environment. In this issue I am continuing the series that was started in the last *Preview* issue: reminiscences by Niels Christensen on his career, centred around Aarhus University, that he called "Seven Scenes". I especially enjoyed Niels' short "Adventures

Excerpt" that he included at the end of his piece here; for me pretty much every field excursion I have ever gone has some "war story" aspect to it (*i.e.* something that just didn't go right), even to the most benign of locations and simplest of surveys. I guess that is what almost always makes this work an adventure. Over to Niels...

## Pivotal moments: Seven scenes from a geophysics adventure



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### Scene 2

*... in which the transient electromagnetic method makes its entry in Denmark, and "buried valleys" becomes a household term.*

#### In the forest

For the umpteenth time I get up and walk to the car, a Toyota Hiace, the most recent acquisition of the Department for field use. I get into the van, start the engine, drive a bit back and forth until it is 1 m closer to the transmitter loop. I stop the engine, get out, measure the distance between the wire and the car and make a note about it. Then I walk to the receiver box of the transient instrument and for the umpteenth-plus-one time I push the button that starts a new measuring sequence. Sometimes the thought strikes me that if someone has been watching

my activities for some time, it will look rather mysterious. Fortunately, I never meet anyone; I have deliberately chosen a very calm and quiet place in the forest around Fløjstrup, about 10 km south of Aarhus, as far away as possible from power lines, buried cables, electric fences and other man-made installations that might disturb the measurements. Here I can experiment with what it takes to disturb the recordings: How close to the transmitter wire can I park the car? Can the car be inside the transmitter loop? How far can I move the receiver coil from the centre of the transmitter loop before it has an effect? How sloppy can I be in laying out the square  $40 \times 40$  m<sup>2</sup> transmitter loop. Etc., etc. ... Does the transmitter display show the correct current value, and is the metre linear? There is an endless list of issues to be tested when you get a new instrument, and by and large I spend every day for two weeks in the forest. Not bad, really. I like the place.

So - we succeeded! We did manage to get a transient instrument!

Every year since I came back from Berkeley in 1987, I made applications to the National Research Council for money to buy a transient instrument to explore its possibilities and limitations in relation to hydrogeological investigations, but in vain. As a newly appointed Associate Professor I didn't have the clout to carry a project of that magnitude, at least that is what they seemed to think. However, in 1991, our Department joined a group from the Technical University of Denmark

(DTU) and we were funded on a project on Deep Aquifers. The group was led by Professor Arne Villumsen who did not have problems with professional weight. In the project there was money for the acquisition of an instrument, and after careful investigations I chose the Geonics Protem 47 instrument, which at that time was able to measure at earlier delay times than other instruments on the market and thereby potentially provide the best resolution of near-surface layers. In the autumn of 1990 I went to Canada to take a closer look, and in 1991 we bought it.

After the necessary initial exercises in the forest, we began to make rather small series of measurements in the areas around Aarhus, but fairly soon we got involved in major mapping campaigns with the Water Authorities of Aarhus and Aarhus County which was responsible for administering natural resources: raw materials like gravel and clays and water. Through the first campaigns, we realised that we had found precisely the data type that made it possible to map the buried valley structures in Eastern Jutland that completely controlled the hydrogeology. During and after the latest glaciation, the buried valleys were eroded out in heavy Tertiary clays and then filled with a variety of Quaternary materials, and presently they were completely obscured by the Quaternary landscape at the surface. In these buried valleys thick sand formations were found which constituted the best aquifers.

The transient method permitted us to map the depth to the bottom of

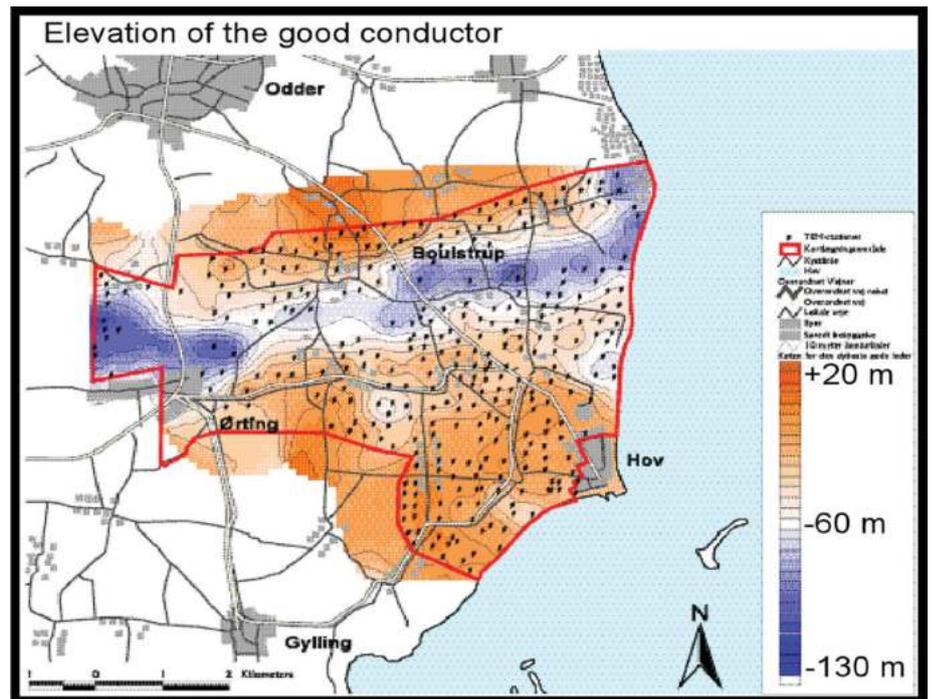
the valleys and the well-conducting Tertiary clays, to hitherto unachievable depths and accuracy, and to a large degree also discern between the sand and clays formations within the valleys. The geophysical contribution to hydrogeological investigations had just taken a leap forward, and we had substantially improved the knowledge base necessary to implement a sustainable abstraction practice in the densely populated area of Aarhus. Furthermore, our activities contributed to a better understanding of the formation processes behind the structure of the present geology.

### A leap forward

An important aspect of the success was the much-improved productivity: two people could make 16 - 20 soundings per day. We soon learned that you had to stay 150 - 250 m away from cables above or below ground and from closed electrical fences to avoid cultural coupling to man-made good conductors. Soundings were placed with an average distance between them of ~200 m, meaning that a couple of square kilometres could be covered in one day. With a reasonable effort, it was now possible to cover large areas with a dense mesh of soundings and thereby provide reliable information about the subsurface.

The first investigation that unequivocally demonstrated the potential of the method and showed the way for future investigations was the mapping of the Beder valley, south of Aarhus. [Figure 1](#) shows the depth to the bottom of the buried valley and for all of the people involved in these early activities, it has acquired an iconic status.

During the same period we conducted a major investigation on the island of Rømø in the North Sea, close to the west coast of Jutland. We made two transects across the island that clearly showed the depth to the saltwater, information of major importance in relation to a sustainable administration of the limited fresh-water supply of the island. Within a very short time, word got around, and the transient method was applied to many and varied hydrogeophysical issues



**Figure 1.** One of the first maps of the elevation to the top of the conductive unit that correlates with the depth of the palaeo-valley - produced from a dense set of TEM soundings in the Beder Valley, south of Aarhus.

in many different geological locations in Denmark, and an almost explosive growth in its application followed. A new geophysical era in Denmark had begun.

### Excerpts from The Strange Adventures of a Geophysicist

Some of the most memorable field days with the Protem 47 instrument in which I have been involved took place on the island of Amager, just south of Copenhagen. The Øresund Bridge (Yes, that one! The one from the TV series: The Bridge!) and the connecting new train tracks were in the planning phase. Together with people from the company Rambøll we carried the instruments across a low-lying, inundated part of the island being very careful to keep our socks dry and not step into the deeper holes. The most debilitating conditions for electromagnetic measurements is water - water and electrical current simply don't go together well - but we did succeed in making some soundings. We had to find the few tussocks sticking out of the water that were big enough and forming the right pattern so that we

could place the receiver box on one, the transmitter on another, and the receiver coil on a third one. Sometimes, in the absence of properly placed tussocks, we would hang the receiver coil in the branches of a small bush. All the wires went from one unit into the water to appear out of the water at the other box! The data were just perfect! And we did find the depth to the salt water in the limestone under the island which was the purpose of the efforts.

During the same investigations, we tried to make soundings in a football stadium, but that was not a good idea. The many wires for the light towers buried around the green field completely drowned out the data in cultural coupling. And we made soundings in a cemetery, where the - fortunately few - visitors gave us curious looks while we rolled the wires out and in again along the footpaths between the graves and did our best to be invisible. This is where your gothic fantasies can come alive, but as far as I know, we did not manage to wake the dead ...

To be continued...



## Minerals geophysics



Terry Harvey  
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### Common ground

After we've done all the geophysical data processing, generated presentations

of the results and completed the interpretations, we may need to make these available to our co-workers, particularly those in other earth science disciplines. Where this sharing is done within the same organisation there's a good chance that everyone will have the same software. But what about when the data presentations and interpretations are to be accessed by a wider audience? Commonality is a lot less likely.

Fortunately, astute software developers have foreseen this need and have made the viewing portions of their geophysical processing and presentation software packages available at no cost. Of course, appropriate software modules need to be purchased for advanced functions such as data processing, inversions, etc. But, for viewing the data

processing products, presentations and interpretations, it's free.

As an example, Mira Geoscience have developed just such a package. In response to my request to provide "a piece setting out the advantages of software such as *Geoscience Analyst* as a widely (and freely) available platform for geoscience data sharing, with the added bonus of (purchasable) processing options", they have provided the description that follows.

In the interests of better informing *Preview* readership, I encourage other software developers who offer geophysical processing and presentation packages with a free viewing component, to make contact with a view to publishing similar write-ups in future *Preview Mineral geophysics* columns.

## Geoscience ANALYST



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Geoscience ANALYST is a free standalone platform for visualising, integrating, and exploring multi-disciplinary geoscientific data in 3D. Its intuitive and modern user interface (Figure 1) is geared toward rapid understanding of complex data. The viewer allows users to import, visualise, annotate, save, and distribute a multitude of different data types and models, for free. Geoscience ANALYST imports a wide variety of industry-standard file formats allowing users to compile 3D scenes composed of multi-disciplinary data, interpretations, and models. Import methods range from 'drag and drop' to an ODBC connection for drillhole databases. Exploration projects can comprise a range of data types including drillholes, 3D geological models, airborne and ground

geophysical surveys, 2D and 3D seismic SEG-Y, 2D and 3D grids, images, and embedded documents. It is also routinely used on underground and open pit mine sites for compilation of numerous data types including mine geometry, support, stress models, ground deformation, seismicity, and hazards. Geoscience ANALYST is in use by many thousands of geoscientists and engineers in the minerals industry.

Project spaces are saved in a geoscience-customised HDF5 format (.geoh5) that can be opened and examined with any HDF5 viewer. The 'Hierarchical Data Format version 5' (HDF5) is an open-source file format that supports large, complex, heterogeneous data. An open-source Python API called *geoh5py* reads and writes to the *geoh5* workspace format. In addition to everyday operational use by geoscientists and

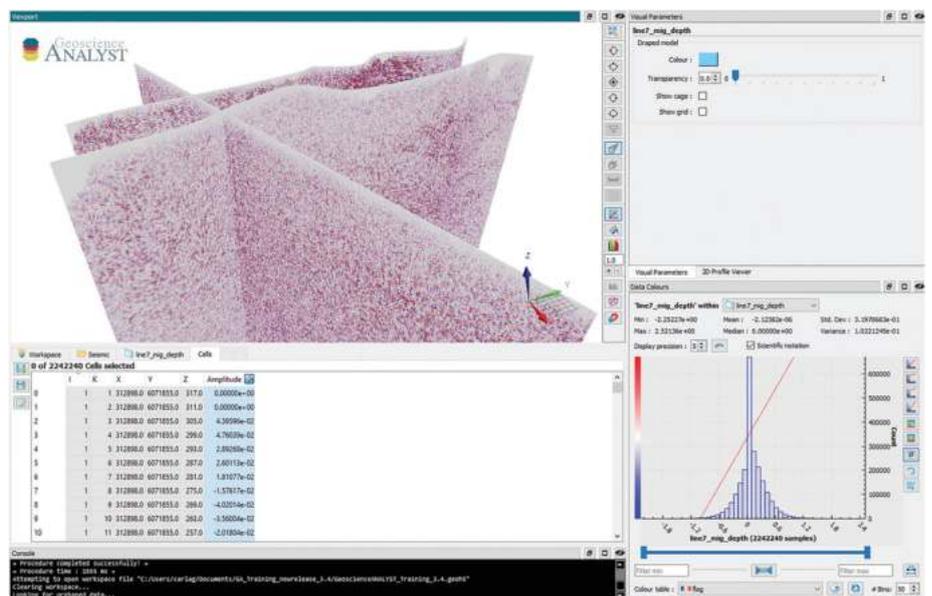
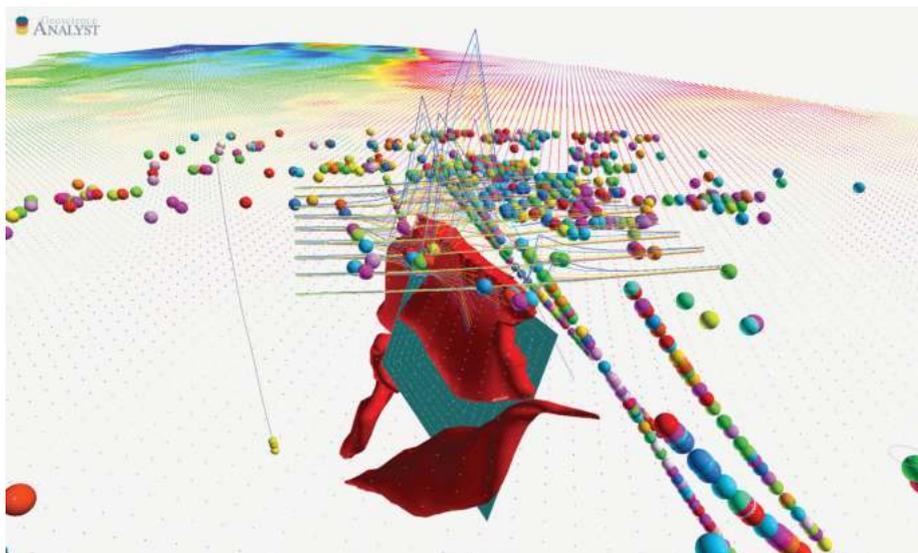


Figure 1. Free 3D visualisation and communication software for integrated, multi-disciplinary data and models. Available from [www.geoscienceanalyst.com](http://www.geoscienceanalyst.com).



**Figure 2.** Pro offers low-cost tools for interpretation, targeting, drillhole design, and geophysical inversion.

engineers, the flexibility of the API provides the perfect environment for R&D projects where 3D visualisation is required. The open format geoh5 workspace file and geoh5py API provide a connection to the Python ecosystem, supporting interoperability with public and open-source repositories for modelling, inversion, and machine learning. Researchers don't have to reinvent visualisation platforms and practitioners have a streamlined path to make use of research results or to develop their own tools (in addition to the open format geoh5 workspace, a multi-user on-premise or cloud-hosted data management system can also be deployed.)

Beyond the free viewer, Geoscience ANALYST Pro provides a very low-cost

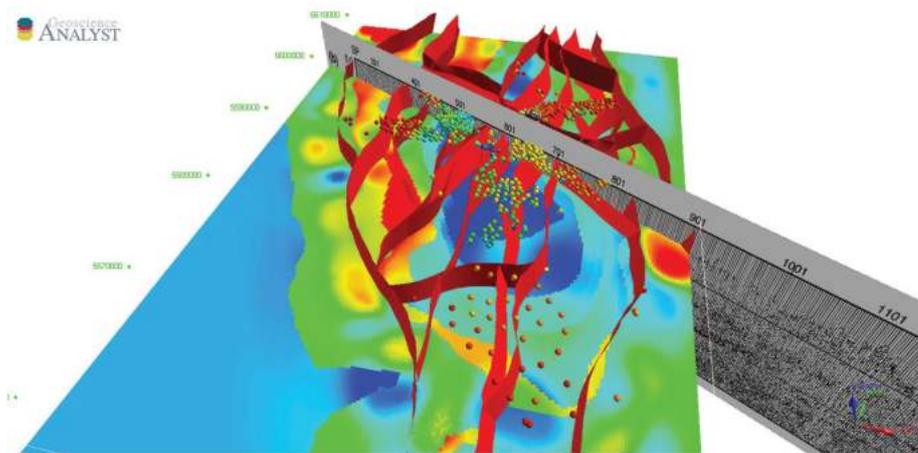
solution for tools beyond 3D compilation and visualisation, such as object creation, digitisation, data transfer, scripting and editing, unsupervised machine learning, and export (Figure 2). Other Geoscience ANALYST Pro features include geophysical survey design, 2D gridding and filtering, drillhole design, a live link to EMIT's Maxwell for electromagnetic data interpretation, a live link to IMDEX's ioGAS for geochemical analysis, and potential-field forward modelling and unconstrained inversion. A live connection to the geoh5py Python API and JSON-format UI designer allows users to seamlessly leverage their Python capabilities within the Geoscience ANALYST user interface.

Geoscience ANALYST Pro Geophysics comprises an additional set of tools

focused on delivering software and methods that make the use of advanced geophysics a day-to-day, practical reality for industry (Figure 3). This includes on-premise or cloud-hosted geologically-constrained geophysical modelling and inversion across all methods. The development of features within 'Pro Geophysics' is guided by a consortium of industry sponsors currently including major mining companies such as Anglo American, Barrick, BHP, Boliden, Cameco, Glencore, LKAB, Newcrest, Rio Tinto, Teck, and Vale—in addition to numerous mid-tiers, juniors, geological surveys, and universities. Geoscience ANALYST Pro Geophysics currently provides formal interfaces to VP Geophysics Suite, UBC-GIF, and SimPEG codes, thereby supporting a multitude of forward modelling and inversion styles that include potential fields, DC resistivity and induced polarisation, and electromagnetic data. The combination gives one the ultimate flexibility in selecting the inversion or forward modelling style for the data type and geological problem at hand. The various forward modelling and inversion options allow you to test your existing geological model against geophysical data for geological model evaluation and validation.

Geoscience ANALYST can be downloaded by anyone here: <https://mirageoscience.com/mining-industry-software/geoscience-analyst>. Find out more through Mira Geoscience's website or through their YouTube channel where you will find over 50 how-to and tutorial videos.

**Kristofer Davis** is a Scientific Programmer at Mira Geoscience who completed his PhD in Geophysics at the Colorado School of Mines. As a Post-Doctoral Researcher at UBC he worked on several advanced problems in geophysical inversion, focusing, amongst other research areas, on development of software workflows to support constrained geophysical inversion. His industry and academic background provide the ideal experience to continue development of VP Suite products, GIFtools, and other geophysical tools and workflows. Kristofer is based in Vancouver.



**Figure 3.** Pro Geophysics offers advanced, geologically-constrained geophysical modelling and inversion across all methods.



## Seismic window



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### Minerals industry fan mail

One of my regular correspondents wrote to me a few months ago (actually he wrote to my colleague Terry Harvey - Associate Editor for Minerals geophysics and copied me) regarding our recent articles on seismic for minerals exploration.

John Hughes has some ideas for the mineral exploration geologists and geophysicists to consider before they hurl themselves into the seismic domain. Our exchange is reproduced below:



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Hi Terry (and Mick)

Your article on hard rock seismic in the latest Preview, along with Mick's forays into the topic in Issues 210 and 213 will hopefully generate some interest in what could very well be a much more valuable tool in mineral exploration than hitherto accepted (or realised!).

Unfortunately, especially here in Oz, the oil/gas industry appears to have lost its way in its appreciation of what seismic data can achieve. Perhaps that is due

to the pre-occupation of average (and I really mean average) interpretation geophysicists simply wanting "railway lines" that they can easily map so that the majority of informative (and often very relevant) information is processed (or "washed" out of the data)? Thus, I sincerely trust the "mineral guys" (or should that be "persons"? ) won't take a leaf out of the "average" oil/gas guys playbook and instead apply some critical thinking to the issues at hand.

Some issues that come to mind:

- The seismic wave is more than a simple reflected wave
- There are refractions, surface waves, even multiples, etc - the pre-occupation with removing these in processing (or acquisition) as opposed to using them to "invert" the whole data set to a model of the subsurface, means that we are not using all the data available to us.
- Many oil/gas interpreters these days completely ignore the shallow section and simply map the "railway lines" produced for them by compliant processing geophysicists. This is even though the signals that they are mapping have travelled through (and generally been distorted by) the variable geology between the surface and the target horizon. Recently, in a review of an area, I noted that a well had been drilled into a very significant sink-hole (the rig nearly sunk into it and caused a doubling of the drilling budget!). This location was on a seismic line that actually showed a problem in the shallow section at the well location and had it been properly investigated, would have highlighted the risk.
- I'm of the view that there is actually huge (and I mean huge!) potential in reprocessing already acquired onshore seismic data (especially more recently recorded nodal data) but this time using the very significant amount of additional data conventional seismic processing has "thrown away" (using routines such as first break suppression and FK filtering). This would involve integrating other types of waves in the data such as refracted waves and surface waves into the solution.
- The above point may give the "minerals guys" a 'stepping stone to evaluating the usefulness of seismic data without the quantum leap" (and budget!) of acquiring a new seismic data set.

Anyway, as you mentioned Terry, a "new mind-set" is definitely needed but not just in the interpretation area - it goes back to fully utilising all the data acquired and, in Alistair Brown's words (which was actually applied to processed 3D data!) "LET THE DATA SPEAK."

I sincerely hope that your and Mick's articles on hard rock seismic will generate more discussion and perhaps change the mind-set of at least some ASEG Members!

Thanks for writing about the topic.

Cheers

John

John then followed up with a second letter after he'd done some research. He found there had been a great deal of work done in the last ten years and suggested a workshop on the topic

My concern is about the younger crop of interpreters who, partly due to the great rotation, don't have sufficient guidance to understand what good seismic data really is. Anyway, that possibly a discussion for another day!

Having Googled the topic since first bringing it up, I note that there was quite a lot of activity in the early part of the (20)10s (quite a few papers dated 2012) and that Curtin's hard rock seismic involvement was as part of the DETCRC, which ran from 2010 but wound up in 2018. The DETCRC (Deep Exploration Technologies CRC) website is still running and I found a summary of their objectives and proposed outcomes.

I note their focus was on 3D reflection seismic which, to my mind, was probably a mistake ("trying to run before they could walk"). There was probably a lot of other work using refracted waves and surface waves as well as reflected waves on 2D seismic that should have been carried out before pushing the concept of 3D reflection seismic for hard rock exploration (note the word exploration, and not development/mining which, to me, would make more sense).

I suspect the cost of 3D reflection seismic was too much for most mineral explorers to seriously consider.

Terry, do you have any mineral industry comment on what DETCRC project 3.1 actually achieved?

I'd be a bit concerned about making a workshop or special session (if it were to



proceed) on the topic too commercial by involving a contractor in the organisation. Note, other than HiSeis there is another contractor - Ultramag - that is very active in running boutique seismic data sets for mineral explorers.

My thoughts on a workshop/special session would be to invite a keynote speaker on the topic and build a series of presentations (mainly by invitation - not leaving it open), hopefully outlining case histories, from minerals company geophysicists, that would outline not only successes but also the limitations and even failures of using seismic for hard rock exploration.

I realise that it is becoming more and more difficult for even oil industry geophysicists to share data and ideas and accept that it may be more difficult for minerals geophysicists (possibly due to the way mineral leases are licensed?).

However, breakthroughs are generally only achieved when data/ideas are shared and different ideas are canvassed and respected. Innovation can only occur when individuals/groups question the current way of doing things. Alas, in these days of political correctness, this is often frowned upon in most organisations!!??

Anyway, I thought I'd make a start this coming week by contacting Richard Hillis who I note led the DETCRC up to the time it was wound up in 2018. I also note Geoscience Australia was (and will still be) very much involved so I would not be surprised if Richard refers me to a particular person there.

If either of you have any additional or alternative suggestions (e.g. on summary of the workshop format) please don't hesitate to let me know.

Cheers

John

So here is the challenge for any seismologists in the minerals industry:

- Don't take shortcuts like the petroleum geos but work the data to come up with solutions to your specific problems

And

- Share your ideas with the wider industry with a workshop (attached to next year's AEGC)

Update: I had lunch with John and he has followed up with Richard Hillis and asked about the outcomes of the DETCRC. Apparently there is a final report but it is only available to sponsors and not the general public/industry.

## Henderson byte: Henri Becquerel

Another famous scientist whose name is used as an SI unit is Antoine Henri Becquerel (1852 – 1908). The Becquerel, with the symbol Bq, defines the *activity* of radioactivity where one Becquerel is equivalent to one atomic disintegration per second. As this is a very small unit, a more practical unit is the Curie (Ci) in cgs units.  $1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$ .

Radioactivity in nature has enabled geophysicists to develop a number of applications. The direct detection of uranium and other common emitters of gamma rays, such as potassium and thorium, contribute to the mapping of geology, especially with airborne detectors. Radioactivity is also important in oil and gas exploration with bore-hole logs using a radioactive source to estimate porosity, etc. Radioactivity is used in engineering geophysics to map faults, groundwater contamination and the extent of industrial waste. Radiocarbon dating, which we rely on to determine geological ages, makes use of the half-life of radioactive decay.

In January 1896, Becquerel heard of Roentgen's discovery of x-rays, and thought that the phosphorescent uranium salts he had been studying might absorb sunlight and reemit it as x-rays. After some tests with photographic plates shielded from the sun that on developing, showed clear outlines of objects, he concluded that the uranium salts were emitting radiation without sunlight. In May 1896 he announced that the element uranium was indeed what was emitting the radiation. In 1899 Becquerel showed that unlike x-rays, which are neutral, his rays could be deflected by electric or magnetic fields.

(See more at: <https://www.aps.org/publications/apsnews/200803/physics/history.cfm>).

In 1901, when Becquerel left a piece of radium in his vest pocket, he noticed that he had been burnt by it. This discovery led to the development of radiotherapy, which is now used to treat cancer. He was awarded the Nobel Prize for Physics in 1903, jointly with Pierre and Marie Curie for their studies of Becquerel radiation.

Becquerel came from a family of scientists. His grandfather, Antoine César Becquerel, had discovered piezoelectricity and his father, Alexandre-Edmond Becquerel, had invented the phosphoroscope, a device that measures how long a phosphorescent material continues to glow after removing the source of light.

Becquerel died in August 1908, at the age of 55, in Le Croisic, France. His name is remembered in craters on the Moon and on Mars and a mineral called Becquerelite.

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## Data trends



Tim Keeping

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fruitful, although some oddities remain. These oddities mostly disappeared when samples were spatially joined to magnetic geological domains of similar age to the stratigraphy (see Figure 1).

Spatially the Wandearah Formation separated easily. The spatial groupings corresponded with two recognised sub-domains, which plotted with overlapping but surprisingly distinctive magnetic susceptibility profiles. Samples from the Moonta Subdomain (cyan) were almost exclusively highly ferromagnetic, whereas samples from the Gawler Craton (magenta) were dominated by lower paramagnetic values, although there were a similar number of ferromagnetic rocks (see also Figure 1).

The Gawler Range Volcanics (GRV) stratigraphy is a bit too complicated for

spatial clustering, and it was not possible to discriminate where Wallaroo Group and GRV domains pop up inside neighbouring domains (top right Figure 1). The unnamed samples (green) are clearly high density and high ferromagnetism compared to those in the Gawler Range Volcanics Domain (magenta), and the famous Hiltaba Suite (yellow) sits somewhere in between (bottom panel Figure 1). The Wallaroo Group (black) and the Donington Suite (cyan) straddle the whole range and could be treated as one unit for potential field modelling purposes, showing individual ranges are not always necessary.

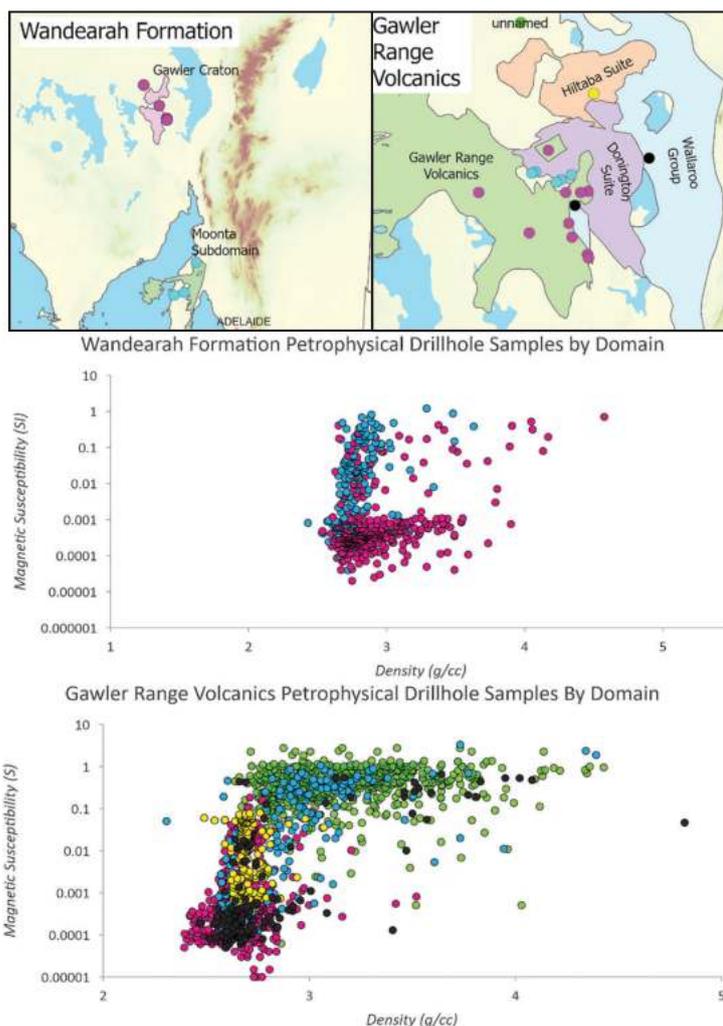
Keep an eye out for GSSA's report on this analysis, as hopefully it will be of value in better constraining tenement scale geophysical and geological models.

### Spatial classification of petrophysical data

At the Geological Survey of South Australia we have been working on a report on drillhole petrophysical data from the Gawler Craton, which includes measurements from Olympic Dam kindly provided by BHP. For the curious, the theoretical average rock in South Australia has density of 2.79 g/cm<sup>3</sup> and geometric mean susceptibility of 0.001 SI, teetering between unaltered and Fe-enriched paramagnetic minerals. But, as we are all aware, these values do not reflect random sampling, but the custom of targeting "bullseyes" in magnetic and gravity data.

The density histograms sorted by stratigraphy generally have normal distributions with low variation. Any other distribution would indicate alteration, mineralisation or a need to further split the stratigraphic logs. Magnetic susceptibility histogram distributions are typically wider with large variance and long skew tails or multiple peaks. Less definitive signs than density, but still worth a second look.

Lithology and mineralisation logs would obviously achieve more precise categorisation of petrographic samples, but this information is often not digitised in a format that is as easy to sort as one stratigraphic name. Machine learning style clustering of the sample data fails as stratigraphic properties crossover, and are not easily separated. Spatial clustering seemed like a silly idea but proved



**Figure 1.** Drillhole locations of petrophysics samples from Wandearah Formation (top left) and Gawler Range Volcanics (top right). Colours in the scatter plots (middle and bottom) represent geological domains coincident with samples. The colours used in the scatter plots do not correspond with the colours used in the location diagrams.



# Webwaves



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As with any legacy dataset, there are some eccentricities. Figure 1 shows the *Exploration Geophysics* digital library for the years 1992 - 1995. At this time, *Exploration Geophysics* was published in four issues per volume. Where these extended over multiple issues they have been placed in the location of the lowest numbered issue, leaving a blank afterwards. For example in 1995, Vol 26, No2/3 presented the conference papers from the 11<sup>th</sup> ASEG Geophysical Conference and Exhibition and has been placed in the issue 2 column, leaving a gap for issue 3.

(Volumes 1 - 35) have been reproduced as they were. The oldest vintage of *Exploration Geophysics* originate from scanned copies, while the newer volumes are digital versions. All volumes have been concatenated with the cover material, the ancillary material, then the journal articles. As with the CD copies, this means that there may be some pages out of order, with the ancillary material containing content from before and after the published papers.

This library has been compiled through considerable personal effort and any mistakes therein are entirely my own. Please email [webmaster@aseg.org.au](mailto:webmaster@aseg.org.au) if you spot any problems.

The historical *Exploration Geophysics* files that came from a set of CDs

## Exploration Geophysics on the ASEG website

In *Webwaves* in December 2020, I mentioned the *Preview Digital Library* (<https://www.aseg.org.au/publications/preview-digital-library>). This library makes all back issues of *Preview* available on one easy to navigate page on the ASEG website. Today I am happy to announce that, after many hours of effort, all back issues of *Exploration Geophysics* and *The ASEG Bulletin* are now also available on the website, via the following Members only webpage (<https://www.aseg.org.au/publications/publications-members-only>).

Alongside manual cataloguing, command line utilities in Ubuntu were used to prepare the documents for the website. These included the PDF Toolkit (pdftk) and ghostscript (gs). The following operations were required, run using batch scripts wherever possible:

- Collecting historic files from archives, CDs, CSIRO Publishing and Taylor & Francis
- Removing the first page of articles downloaded from Taylor & Francis containing article statistics and information
- Cleaning data, removing duplicates and checking data integrity
- Renaming PDFs to ensure that articles are concatenated in the correct order
- Concatenating PDFs into a single file per volume/issue
- Extracting the front page from each PDF and converting it into a jpg file for display on the website
- Uploading all files
- Creating the digital library



Figure 1. *Exploration Geophysics* digital bookshelf.



## Rapid deployment for earthquake aftershock monitoring in southwest Western Australia – the Arthur River swarm 2022

Ruth Murdie<sup>1</sup>, Huaiyu Yuan<sup>2</sup>, Meghan S Miller<sup>3</sup>, Robert Pickle<sup>3</sup>, Michelle Salmon<sup>3</sup> and Justin Whitney<sup>4</sup>

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On 5 January 2022, the residents in Western Australia's Southern Wheatbelt were in for a shock – quite literally. They experienced a magnitude 4.0 earthquake. Reports from the area tell of cracks in masonry and pictures falling off the walls. Although the State's southwest is known as the southwest seismic zone, (Doyle, 1971), one of the most seismically active regions in Australia (Leonard, 2008, Dentith and Featherstone 2003), this event came as a surprise to many and there was more in store for this normally quiet community. Aftershocks continued to register on the Earthquakes@GA website at a rate of several per day.

The initial measurements by Geoscience Australia estimated this event to have occurred close to the community of Arthur River at a depth of approximately 7 km. However, these measurements relied on data from stations located mainly to the north of the event with the nearest being located at Narrogin—approximately 50 km away. The depths of earthquakes in the southwest seismic zone have always been uncertain, as although large surface-wave phases observed in the seismic signal demonstrate the earthquake sources are very shallow, the low density of the earthquake monitoring network makes it challenging to resolve the earthquake depth with any accuracy.

This earthquake alerted the South West Australia seismic Network (SWAN) team (ARC linkage grant LP180101118) consisting of scientists from Australian National University (ANU), Geoscience Australia (GA), Macquarie University, Geological Survey of Western Australia (GSWA) and the Western Australian Department of Fire and Emergency Services (DFES) (Murdie *et al.*, 2020) who are in their second year of monitoring the earthquakes of southwest Western Australia. The current SWAN deployment has three stations within 60 km of the epicentre, but additional closer instruments would be critical to characterise the ongoing earthquake sequence. With Western Australia's border still closed, and GA's aftershock monitoring instruments still deployed following the  $M_w$  5.9 22 September 2021 Woods Point earthquake in the Victorian Highlands (Ninis *et al.*, 2021; Quigley and La Greca, 2021), the question was put to the Western Australian contingent of SWAN “could we get seismometers on the ground to monitor any aftershocks?” The enhanced understanding gained from recording the seismicity of Western Australia thanks to the deployment of monitoring equipment following the Lake Muir earthquakes of 2018 demonstrates the importance of such initiatives (Clark *et al.*, 2020).

Up until now, however, Western Australia has had no rapid deployment capabilities. But as luck would have it, Dr. Huaiyu Yuan of Macquarie University, who is based out of the Centre

for Exploration Targeting at the University of Western Australia, was recently equipped with a new set of Smartsolo IGU-BD3c-5 seismometers sitting under his desk and would be perfect for this purpose. This looked like a good opportunity to test them out. DFES were also interested in what could be done in such an event. GSWA and Dr. Yuan used the DFES regional network to gain contacts in the Arthur River area as first points where seismometers could be deployed.

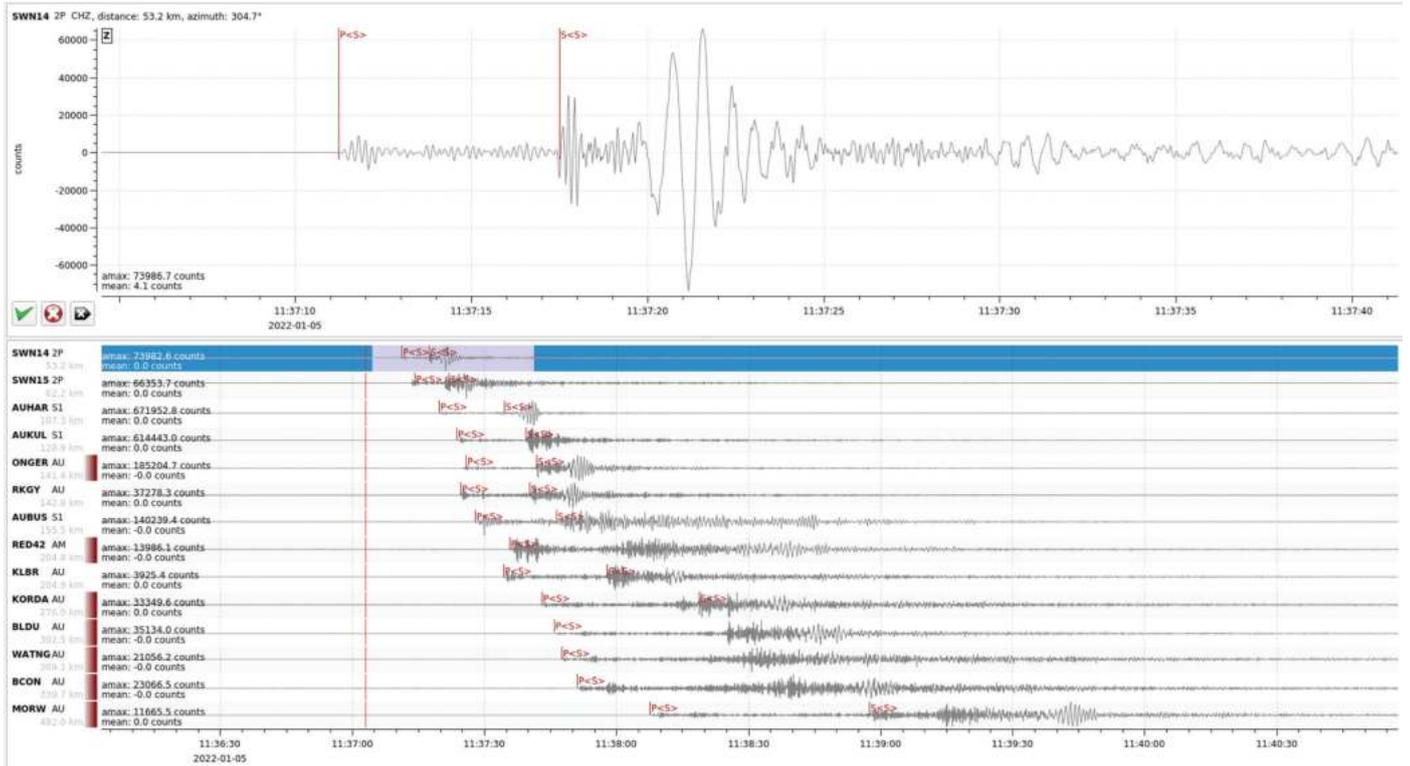
Five days after the initial shock, on 10 January, six additional seismometers were installed in the immediate area of the swarm to bolster the pre-existing SWAN network (Figure 1). Retired seismologists from the Seismologists Association of Australia also deployed an instrument in the area.

These instruments were initially left for three weeks. During this time, the largest event in the sequence so far - an ML 4.8 - occurred on 24 January and was felt across southwest Australia including Perth, Albany and Margaret River (Figure 2). This event was again followed by many aftershocks over the next two weeks; so many that the local community became quite used to them. Data was collected on 1 February. A local farmer reckoned the swarm was over as he hadn't felt any events for a couple of days, but as the team were driving away from the area that evening, a third main shock of ML 4.3 occurred. The swarm was not over yet!

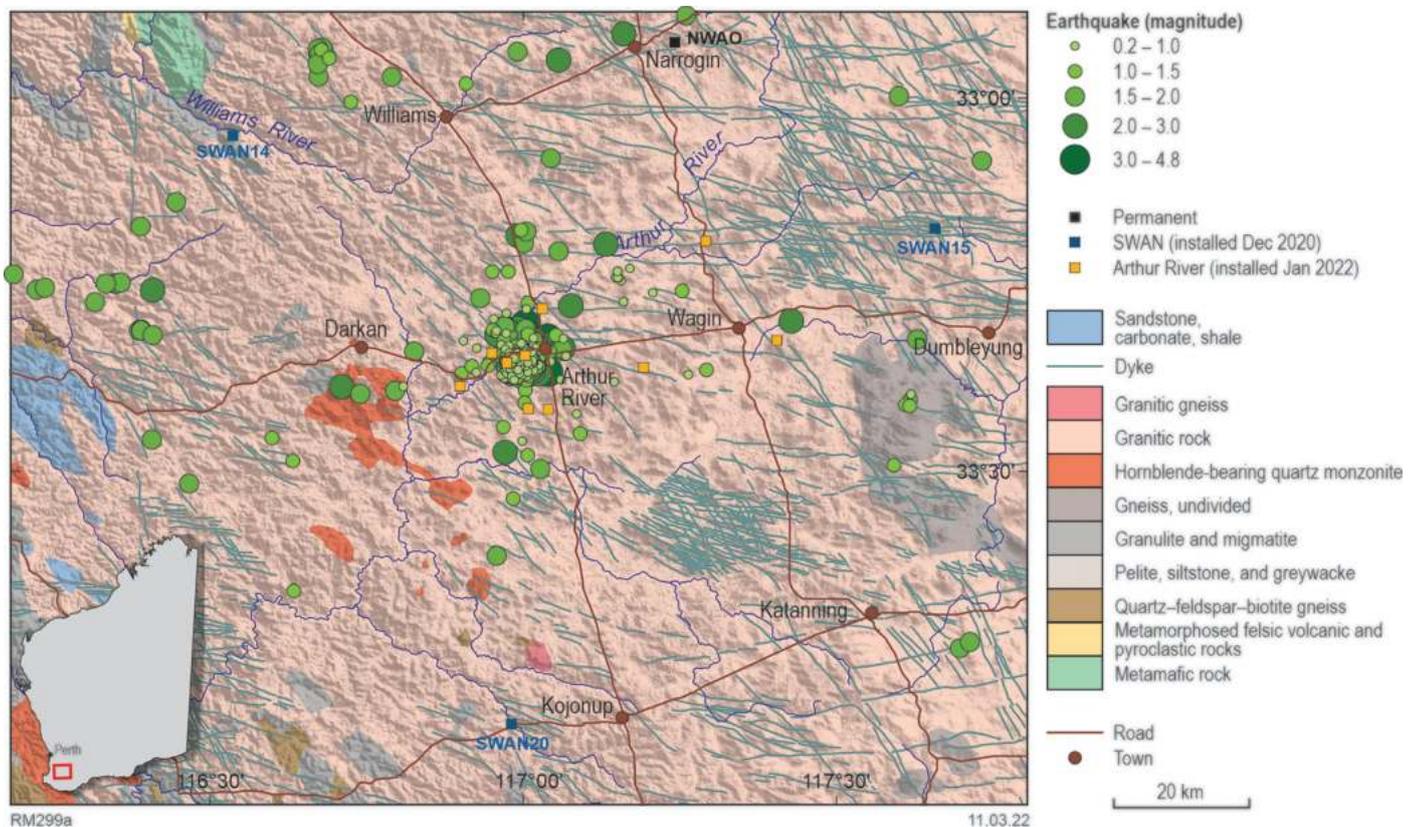
Data was passed to ANU and was run through a machine-learning detection algorithm which has been trained to identify the phase arrivals of very small earthquakes with high precision. The initial earthquake locations from the period between the first main shock to the start of swarm deployment included two SWAN sites plus the Australian National Seismograph Network (ANSN; managed by GA) and the Seismometers in Schools (managed by the ANU) stations. Unfortunately, the SWAN instruments situated just south of the swarm had failed to record anything during this initial period. Based on the available instruments, the events were estimated to have occurred just



**Figure 1.** A typical installation includes a seismometer (front) and an accelerometer (back) to accurately record seismic vibrations caused by the Arthur River earthquake swarm.



**Figure 2.** Waveforms from the ML4.0 on 5 January 2022 as recorded on the ANSN stations and two SWAN stations. The enlargement shows the P and the S-wave picks as picked by the machine learning algorithm.



**Figure 3.** Locations of the earthquakes in the Arthur River area from 5 January to 1 February 2022.



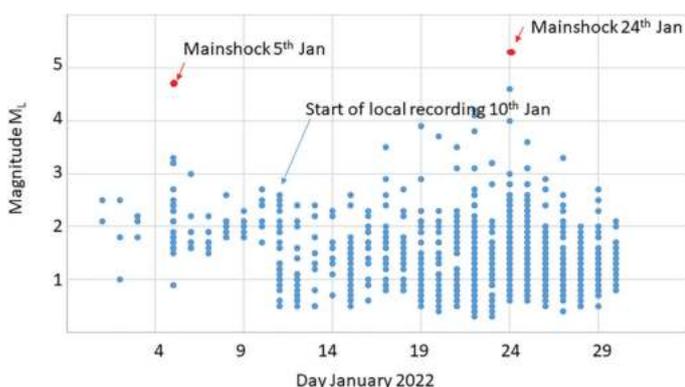
## Feature

north of the small community at Arthur River. However, the repair of the faulty monitoring equipment and the installation of the rapidly deployed instruments, the data collected between 10 January and 1 February enabled the SWAN team to determine that the centre of the swarm was further south than previously estimated, and actually to the west of Arthur River (Figure 3). This shift likely reflects the increase in location precision brought about by the addition of the new temporary sensors deployed. Aside from shifting many epicentres southward, the higher-precision locations shifted initial depth estimates from 15–20 km to 0–5 km and reduced hypocentre uncertainty in all orientations by a factor of two or more. The updated epicentral locations are also now more consistent with the highest shaking intensities reported through GA's felt report system (Allen *et al.*, 2019).

In the first three weeks of the local deployment, Geoscience Australia recorded 94 events using only the ANSN. When the rapid deployment data were analysed, over 950 earthquakes were identified with magnitudes down to  $-0.3$  in a tight cluster just west of Arthur River (Figure 4). The objective now is to identify fault locations, and see if we can use these new earthquakes to improve our understanding of the local stress field and the seismic hazard of the area.

At the time of writing, the swarm is continuing with another half dozen events being recorded on the ANSN per week. Data from the second download is now being analysed and will include waveforms from all SWAN stations, the rapid deployment stations and an additional two stations that have since been deployed by retired seismologists that have been sending real-time data to a private server.

Although there were many aspects of the rapid deployment that were less than optimal, this project showed the importance of quickly deploying monitoring stations after sizable earthquakes. It also and brought greater collaboration between all parties and will be the basis of building a regular capacity within WA for a rapid deployment capability without scientists having to fly across the country.



**Figure 4.** A time-magnitude plot of the Arthur River swarm events showing the how number of events increased, particularly in the lower magnitude ranges, once the local monitoring network was installed. Note these are preliminary magnitudes have been generated by the machine learning algorithm and are slightly different from those reported by Geoscience Australia.

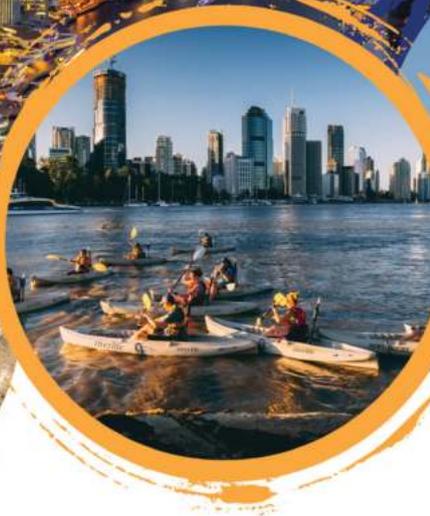
Strong ground motions recorded by the aftershock network, together with the SWAN sites, will contribute towards an improved understanding of earthquake impacts to buildings and infrastructure in southwest Western Australia (e.g., Wehner *et al.*, 2020) and will be used to guide future revisions of the National Seismic Hazard Assessment (e.g., Allen *et al.*, 2020). Outcomes from the SWAN project are intended to be used by DFES and GA to raise community awareness of earthquake hazards and risks in the southwest WA region.

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## How geophysics ruined music



Tim Dean and Tim Brice  
tim.dean@angloamerican.com  
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### Introduction

The USS Missouri (Figure 1) was the last battleship to serve with the US Navy. Entering service in 1944, she was finally decommissioned in 1992. Her service included hosting the signing of the Japanese surrender at the end of WW2 in 1945, as well as bombarding Iraqi positions during the first Gulf War in 1991. For those of us of a certain vintage, the Missouri may be more familiar as the setting of the video clip for Cher's 1989 hit *If I could turn back time*. The US Navy agreed to the use of the Missouri in a bid to boost recruitment, but were reportedly unhappy with the outfit Cher wore (the video was only shown on MTV after 9 pm). Although the influence of the video clip itself is debatable, the song did reach number one in Australia.

Cher's musical career began as a duo with her husband Sonny Bono (Figure 2), their song *I got you babe* reaching number one in 1965. As well as continued success in music, Sonny and Cher went on to have a successful television career during the 1970s (*The Sonny & Cher Comedy Hour* was the 7<sup>th</sup> most popular show on US television in 1973/74). Following her divorce from Sonny in 1975 (Sonny went on to be the mayor of Palm Springs and a Republican member of Congress before dying after hitting a tree while skiing in 1998; his 4<sup>th</sup> wife, Mary, went on to be elected in his Congressional seat seven times before being defeated in 2012), Cher went on to act on both the stage and screen (winning the Academy Award for Best Actress for *Moonstruck* in 1987). Cher also continued to release music, with mixed success during the 1980s and 1990s.

In stark contrast, geophysicist Andy Hildebrand earned a doctorate in electrical engineering before joining Exxon in 1976 (Cher's only release of the year, *Long Distance Love Affair*, failed to chart). In 1980 he left Exxon and co-founded Cyberan



Figure 1. A photo of the USS Missouri taken in the 1980s.



Figure 2. A photo of Sonny and Cher taken during the 1960s.

*Geophysical Corporation* and then *Landmark* in 1982 where he served as head of software development. In 1989 Andy's career changed rather unexpectedly when he left geophysics to spend a year studying music composition. During this period he invented a way to seamlessly loop samples using a synthesizer. This work led him to found *Antares Audio Technology* which in-turn, developed *Auto-Tune*, which pitch corrects vocal tracks in real-time<sup>1</sup>.

1998 marks the year in which these two seemingly divergent careers cataclysmically collided and, as the title suggests, led to geophysics ruining music. The catastrophe itself was a song called *Believe* and was Cher's first US number one in 33 years (a record for the longest gap between number-one singles<sup>2</sup>). It also reached number one in 23 countries, becoming the most successful single of her career. Those of us unfortunate at the time to be relying on the radio for our entertainment (Napster, the first popular music file-sharing site was not founded until 1999) were continuously tormented by the weirdly electronically distorted sound of her voice accompanied by a euro-disco beat. This vocal crime (later dubbed the *Cher effect*) was achieved using the Auto-Tune feature invented by Andy Hildebrand turned up to 11 (I will give him the benefit of the doubt when it comes to foreseeing the future pain that his invention would cause).

Although the use of Auto-Tune to the extent of Cher's "smash hit" remains relatively unusual, it has become ubiquitous in the recording industry to correct any off-key notes. Interestingly, the producers of Cher's hit refused to disclose how the sound had been achieved, although this was more to protect their methodology from competition rather than to prevent further pain to the listening public.

The next artist to really embrace the full potential of Auto-Tune was an American rapper with the perhaps appropriate name of 'T-Pain', short for "Tallahassee Pain" after his feelings about his home town (we are guessing he wasn't a big fan); not to be confused with the band *T'Pau* who had a number one hit

<sup>1</sup>Even back in 1999 (the year when he was awarded the Enterprise Award from the SEG) Auto-Tune was estimated to be employed on 90% of all commercial music.

<sup>2</sup><https://www.rollingstone.com/music/music-news/artists-who-went-years-between-hits-721938/>

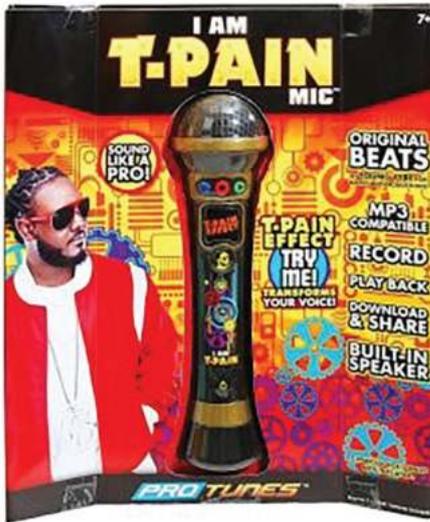


Figure 3. The “I am T-Pain” microphone (not to be confused with “I am in pain”).

in 1987 with *China in your hand* (rather bizarrely, a song about the book *Frankenstein*). Readers, like ourselves, who seemed to have somehow missed this rich period of musical history, will be perhaps surprised to learn that T-Pain had a number one album in 2007<sup>3</sup> that sold over 800 000 copies in the US and has received two Grammy Awards<sup>4</sup>

T-Pain used Auto-Tune to create a sound that was so distinctive it became eponymous and led to the launch of the “I am T-Pain microphone” (Figure 3), perhaps the world’s most ubiquitous geophysical instrument (pun intended). Despite being listed at number seven on the “worst Christmas toys” list in 2001 with the claim “your kid can get the illusion that he can sing, even if he sounds like a cat held over a bathtub when he belts out the national anthem”<sup>5</sup> (number one was the long since forgotten “Moxie Teenz” doll), the microphone was surprisingly successful although has since been rendered obsolete by the release of similar mobile phone apps<sup>6</sup>.

### The Auto-Tune algorithm

To geophysicists the correction of pitch seems relatively straightforward. Pitch is just frequency, so we just need to measure the frequency using the FFT and then increase/decrease it as appropriate. As described in the Auto-Tune patent (US 5973252, Figure 4), however, such a simplistic method is unsuitable as (a) better estimations of the pitch are obtained using longer windows but then applying a single-value pitch correction to a large time window is undesirable and (b) the use of windows, and in particular their overlaps introduces distortions. An alternate, time domain method involves dividing a waveform into single periods and then expanding/contracting the waveform within the window so that the pitch (the period) is corrected. Although effective, this method similarly results in “unnatural sounds” due to distortion of the amplitude spectrum. An example of the

<sup>3</sup><https://www.billboard.com/music/t-pain/chart-history/top-album-sales>

<sup>4</sup><https://www.grammy.com/grammys/artists/t-pain/6998>

<sup>5</sup><https://www.csmonitor.com/Business/2011/1206/Seven-worst-Christmas-toys-for-kids/I-am-T-Pain-Mic>

<sup>6</sup><https://www.rollingstone.com/music/music-news/i-am-t-pain-Auto-Tune-and-recording-app-comes-to-iphone-104445/>



United States Patent [19] Patent Number: 5,973,252  
Hildebrand [45] Date of Patent: Oct. 26, 1999

[54] PITCH DETECTION AND INTONATION CORRECTION APPARATUS AND METHOD  
[75] Inventor: Harold A. Hildebrand, Auburn, Calif.  
[73] Assignee: Auburn Audio Technologies, Inc., Auburn, Calif.[21] Appl. No.: 09/172,978  
[22] Filed: Oct. 14, 1998

Primary Examiner—Jeffrey W. Donalds  
Attorney, Agent, or Firm—Gary L. Bush, Esq.; Mayer, Day, Caldwell & Keeton, L.L.P.  
[57] ABSTRACT  
A device and method is disclosed to correct intonation errors and generate vibrato in solo instruments and vocal performances in real time. The device determines the pitch of a musical note produced by voice or instrument and shifts the pitch of that note to produce a very high-quality, high fidelity output. The device includes a pitch detector that automatically recognizes the pitch of musical notes quickly. The detected pitch is then used as an input to a pitch corrector that converts the pitch of the input to an output with a desired pitch. The corrected musical note is then in tune with the pitch standard. The device and method employ a microprocessor that samples the signal from a musical instrument or voice at regular intervals using an analog-to-digital converter and then utilizes data derived from an auto-correlation function of the waveform to continuously determine the period of the waveform. The period of the waveform is then compared to a desired period or periods (such as found in a scale). The ratio of the waveform period and the desired period is computed to re-sample the waveform. This ratio is smoothed over time to remove instantaneous output pitch changes. The ratio is used to re-sample the input waveform. The resulting output waveform is processed through a digital-to-analog converter and output through audio interfaces.

Related U.S. Application Data  
[60] Provisional application No. 60/063,319, Oct. 27, 1997.  
[51] Int. Cl.: G10H 7/00  
[52] U.S. Cl.: 84/603; 84/610; 84/645  
[58] Field of Search: 84/603–605, 619; 84/645, 657

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38 Claims, 9 Drawing Sheets

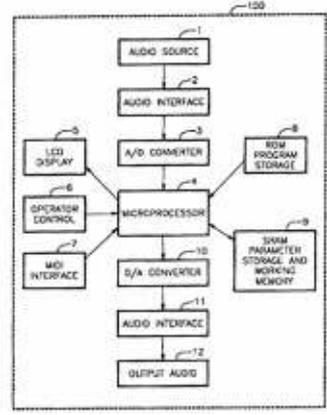


Figure 4. The first page of the Auto-Tune patent granted to Andy Hildebrand in 1999.

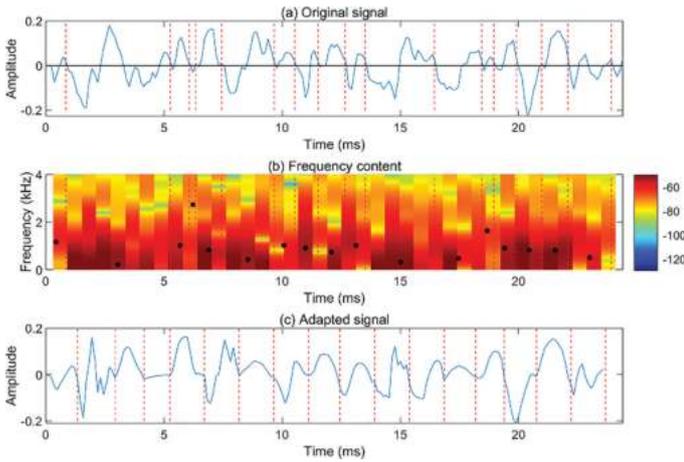
process is shown in Figure 5. Figure 5a shows the original signal with each period indicated by the red lines. Figure 5b is a display familiar to geophysicists, a spectrogram, in the calculation of the spectrogram the time windows are equal in size whereas the sampling of the frequency of each period (the black points), is affected by the window size. Figure 5c shows the signal after the periods have been equalised (i.e. the pitch is now the same), note how some of the higher frequency detail in the segments that have been shortened has been removed.

A similar approach can be used to change the tempo of music, but to avoid changing the pitch of the sound the original signal is windowed and then the windows summed together with overlaps sufficient to increase the tempo. Another issue with these types of methods is that they do not work in real-time, the data must be recorded and then processed. What was required, therefore, was a system capable of calculating and correcting pitch in real-time, which is what Andy Hildebrand created.

The Auto-Tune algorithm is based on the autocorrelation. Hildebrand noted that for a periodic signal, such as the sine wave in Figure 6a, the autocorrelation at lags equal to multiples of the period (in this case 1 s) is equal to the autocorrelation at t=0.



Feature



**Figure 5.** (a) An original audio signal with the boundary of each period indicated by the red lines. (b) A spectrogram of the same signal with time windows equal in size. (c) The signal after the length of each period has been equalised.

Additionally, the autocorrelation value at any lag value approaches the value at  $t=0$  only if the lag is a multiple of the period.

The autocorrelation can therefore be used to track for the periodicity (pitch) of signals but computing the autocorrelation is compute intensive. Mathematically, the auto-correlation of a signal with a finite length  $L$  at lag  $n$  is given by sum of the piecewise multiplication of the original signal and the signal after being shifted by  $n$  samples

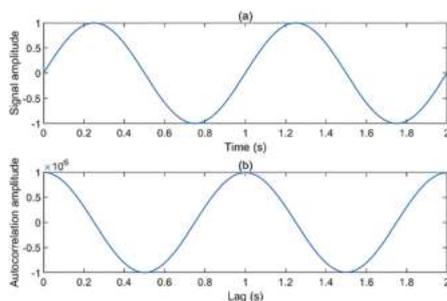
$$\Phi_L(n) = \sum_{j=0}^L x_j x_{j-n} \quad (1)$$

The peak of the autocorrelation ( $n=0$ ) is the energy of the signal which is the sum of the sample amplitudes  $x_j$  squared. In this case we limit ourselves to calculating the peak autocorrelation value over two periods  $L$  of the data

$$E_i(L) = \sum_{j=0}^{2L} x_j^2 \quad (2)$$

As we move along the signal lags we only need to take the value for the previous window  $E_{i-1}(L)$  subtract the first value from the current window  $-x_{2L}^2$  and add the next value outside the current window  $x_i^2$ .

$$E_i(L) = E_{i-1}(L) - x_{2L}^2 + x_i^2 \quad (3)$$



**Figure 6.** (a) A sine wave with a period equal to 1 s. (b) The autocorrelation of the sine wave, note how the amplitude of the autocorrelation at a lag of 0 s is equal to that at multiples of the period (1 s, 2 s, ...).

Rather than calculate this autocorrelation at other lags and then identify the pitch, the assumption is made that the pitch has not changed, to confirm this we just need to calculate the autocorrelation value at a lag equal to the period  $L$

$$H_i(L) = \sum_{j=0}^L x_j x_{j-L} \quad (4)$$

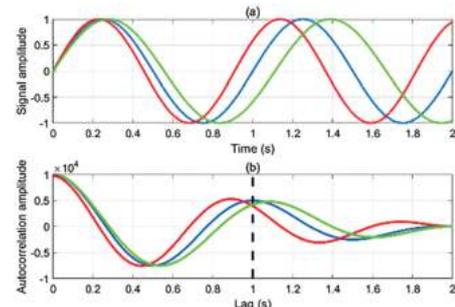
The value at the next sample is then simply involves taking the previous value  $H_{i-1}(L)$  subtracting the value from the start of the previous window  $x_{i-L}x_{i-2L}$  and adding the value from the end of the new window  $x_i x_{i-L}$ .

$$H_i(L) = H_{i-1}(L) - x_{i-L}x_{i-2L} + x_i x_{i-L} \quad (5)$$

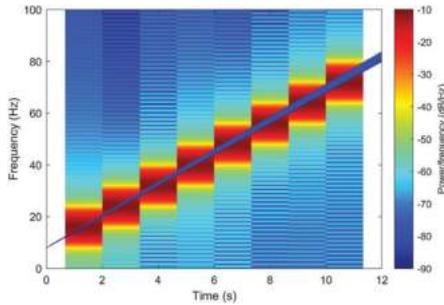
If we only calculate the autocorrelation over a range of lags equal to twice the period then the autocorrelation value at a lag value equal to the period will be half that at the zero lag. This is illustrated in Figure 7a which shows three waves with periods equal to 0.9 (red line), 1 (blue line) and 1.1 (green line) seconds. Figure 7b shows the autocorrelations of these three waves, note how at a lag of 1 s the autocorrelation of the blue wave is exactly half the zero lag value whilst the values of the other two waves are lower. If this condition is met then the frequency has not changed.

In his patent Hildebrand describes two methods for applying his algorithm, the first is referred to as “detection mode”. In this mode the autocorrelation is calculated at 109 lag values ranging from 0.36 to 19.9 ms (50.1 to 2,756 Hz) and the peak value of the autocorrelation across the lags used to determine the frequency. For example, in Figure 7 the peak of the first lobe of the autocorrelation of the red curve occurs at a lag of ~0.91 s which is the period of the data. The other mode “correction” requires the pitch to be continuously tracked, to reduce the computational effort required the range of  $L$  values is shifted so that it is constrained by the previous pitch. Figure 8 shows how this technique can be applied to calculate the instantaneous frequency of a vibroseis sweep overlain on a conventional spectrogram, the jitter at the end of the trace is due to issues with the sampling interval.

Correction mode can be used to either “snap” the detected frequency to the closest note or to match the frequency with an input signal. This mode works by checking the ratio between the zero-autocorrelation value and the value at a lag equal to the period of the previous sample, if the ratio differs significantly from a threshold value then the correction is initiated. The correction works by calculating the autocorrelation at a larger range of lag values to identify the new frequency. Rather than use the new frequency



**Figure 7.** (a) Three sine waves with periods of 0.9 s (red), 1 s (blue) and 1.1 s (green). (b) Shows the autocorrelations of the three signals.



**Figure 8.** Output of the instantaneous frequency calculated for a synthetic linear 9-80 Hz vibroseis sweep using the Auto-Tune algorithm overlain on a spectrogram of the same sweep.

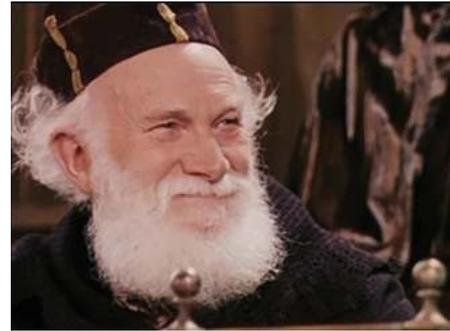
directly as an indication of the pitch a value is found by interpolating the values near the turning point.

Aside from its commercial use the ubiquity of Auto-Tune now extends to Karaoke as well. Although the reader is not, at this stage, likely to be speculating on the author's enthusiasm for Auto-Tune, in the case of Karaoke it could be considered, literally, to be a lifesaver. The *My Way* killings were a series of at least 12 murders over 10 years that arose from discordant renditions of Frank Sinatra's 1969 "hit" (although very popular, it only reached number 27) in the Philippines, where it has since been removed from many Karaoke machines. In 2008 eight people were shot dead in Thailand in a Karaoke dispute that featured multiple consecutive renditions of John Denver's 1971 number two hit *Take me home, country roads*. Hopefully the use of Auto-Tune for Karaoke machines will reduce such incidents in the future.

Perhaps the title of this paper is a misnomer, perhaps Auto-Tune is in-fact the greatest contribution that geophysics has made to the arts. Why shouldn't we use signal processing techniques to tweak a performance and produce singers with perfect intonation? Its critics argue that these digital tools are responsible for making many musical artists sound mediocre, bland, and like a copy of everyone else using the same tools. They remove the uniqueness of vocal performances by turning glissandos, the natural slide between notes, into multiple successive notes (the Cher effect) and make a singer with a powerful and wide vibrato sound like a human synthesizer. Singing with perfect intonation does not always make a great performance; just because it is "technically perfect", it is not necessarily better. Good singers can hit a note perfectly but will often go slightly flat or sharp to achieve specific resonances and harmonic overtones in their voice and add flavour to a part of a song (interestingly Hildebrand's patent claims the opposite and says that "When voices or instruments are out of tune, the emotional qualities of the performance are lost").

To be fair, it should be stated that there are many people who favour its use. It has been argued that Auto-Tune opens up new possibilities in music as many musicians (such as T-Pain) use it as a unique tool to augment their performances. Indeed, in the 1970s, when synthesisers and other forms of electronic music came along, many artists resisted them as they did not see that you could use those tools in a new way instead of just replacing the instruments that came before.

Perhaps, however, the debate over the merits of Auto-Tune are moot and in-fact geophysics has contributed to the arts in fields other than music. Although nothing immediately sprang to mind, we did think it worthy of some further research...



**Figure 9.** Nigel Anstey appearing in the film *Harry Potter and the Philosopher's Stone*.

## Geophysics in the arts

Details of the contributions of geophysics and geophysicists to the arts are somewhat hard to come by, even with all the advantages of internet film databases. Turning to geophysicists first, Nigel Anstey (Figure 9), recipient of multiple awards from the SEG and EAGE, appeared in *Harry Potter and the Philosopher's Stone* (he is the grandfather of the actor Tom Felton who played Draco Malfoy).

Films that feature geophysics at their core are limited. Known examples include *Tremors* (1990) where a seismologist tracks large worms that burst out of the ground to devour people. *Tremors* was a success but despite one of the stars, Kevin Bacon (who else?), stating that it only made "a fifth of what the charts (accountants) at Universal said it would" a further five sequels, and one prequel were made (including the dramatically titled *Tremors: A Cold Day in Hell*).

In *The Core*, a geophysicist discovers that the earth's inner core has stopped rotating leading to a deterioration of the earth's magnetic field. After saving the day, the hero geophysicist, to his credit, turns down the opportunity to join NASA to educate the next generation "NASA could use a few good men, you know" replying that "Yeah. Unfortunately, so could my freshmen geophysics students." For those contemplating watching this movie, the reviews<sup>7</sup> are not encouraging (e.g. "big, dumb, explosion movie", "Is it bad? Oh yes"). Sidney Perkowitz, a professor of physics at Emory University in the US attributed the movie's failure to the fact that "people understood the science was so out to lunch"<sup>8</sup>

In the 2009 movie, *2012*, a geophysical team warns of an impending catastrophe due to radiation from solar storms heating the earth's crust. Despite being poorly reviewed by critics "Wears out its welcome at a ridiculous two hours and 40 minutes, throwing out every cliché in the disaster movie handbook" the film was commercially successful and despite the geophysicist not being the lead character (instead being a "struggling writer" played by John Cusack) at least he survives.

Unfortunately, geophysics can often be portrayed negatively, in the 2019 *Godzilla: King of the Monsters* it mentions that the monsters that go on to ravish the earth were awakened by seismic surveys ("They returned because of us. It was our atomic testing that awoke Godzilla. Other creatures like the MUTOs from strip mining and seismic surveys"); and in 2017's *Kong: Skull*

<sup>7</sup><https://www.rottentomatoes.com/m/core>

<sup>8</sup><https://www.theguardian.com/film/2010/feb/21/hollywood-films-obey-laws-science>



Feature



**Figure 10.** Stills taken from the 2019 movie "Godzilla: King of the Monsters" showing the use of "seismic explosives".

Island the dropping of "seismic explosives" being used to map the sub surface of the island (Figure 10, "The seismic response is incredible") enrages King Kong.

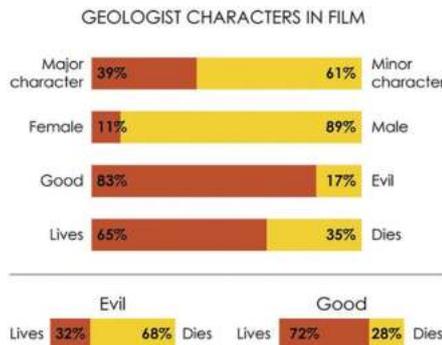
Taking things to the extreme, in the 2013 Danish film *Skytten* (The Shooter) a "hot-headed" geophysicist is so enraged by the potential damage from drilling in the Arctic that he takes a journalist, and later the city of Copenhagen, hostage, threatening that unless the drilling stops he will start killing people.

The involvement of geophysics in literature is even more sparse, although the prolific author (he has sold over 160 million copies of over 40 books) Ken Follett's book *The Hammer of Eden* concerns a group of eco-terrorists who use a stolen seismic vibrator to set off a series of earthquakes.

For those prepared to widen their viewing to movies involving geologists, an excellent place to start is a 2015 article that lists appropriate movies<sup>9</sup> including *Swamp Women* (1956) and *The Age of Stupid* (2009). For those not prepared to sit through them all, the authors include a summary of the major attributes of the geologist characters (Figure 11). Interestingly 83% of geologists are portrayed as "good" and of the evil ones 68% die (compared to just 28% of the good ones).

Conclusion

The success of Auto-Tune cannot be denied, its near omnipresence in modern music provides proof of its appeal. Its artistic value, however, continues to be debated, with Time



**Figure 11.** Summary of the characteristics of geologist characters in films.

Magazine including it in their list of 50 of the world's worst inventions<sup>10</sup> along with Agent Orange, DDT, asbestos (if you can claim that a mineral was invented), and Crocs. Unfortunately, the contribution of geophysics to other areas of the arts is minimal, and not even consistently positive, leaving Auto-Tune as by far the most influential. Given the rapid advances in seismic data processing made in recent years, perhaps there will be another opportunity for geophysics to make a positive contribution to music...

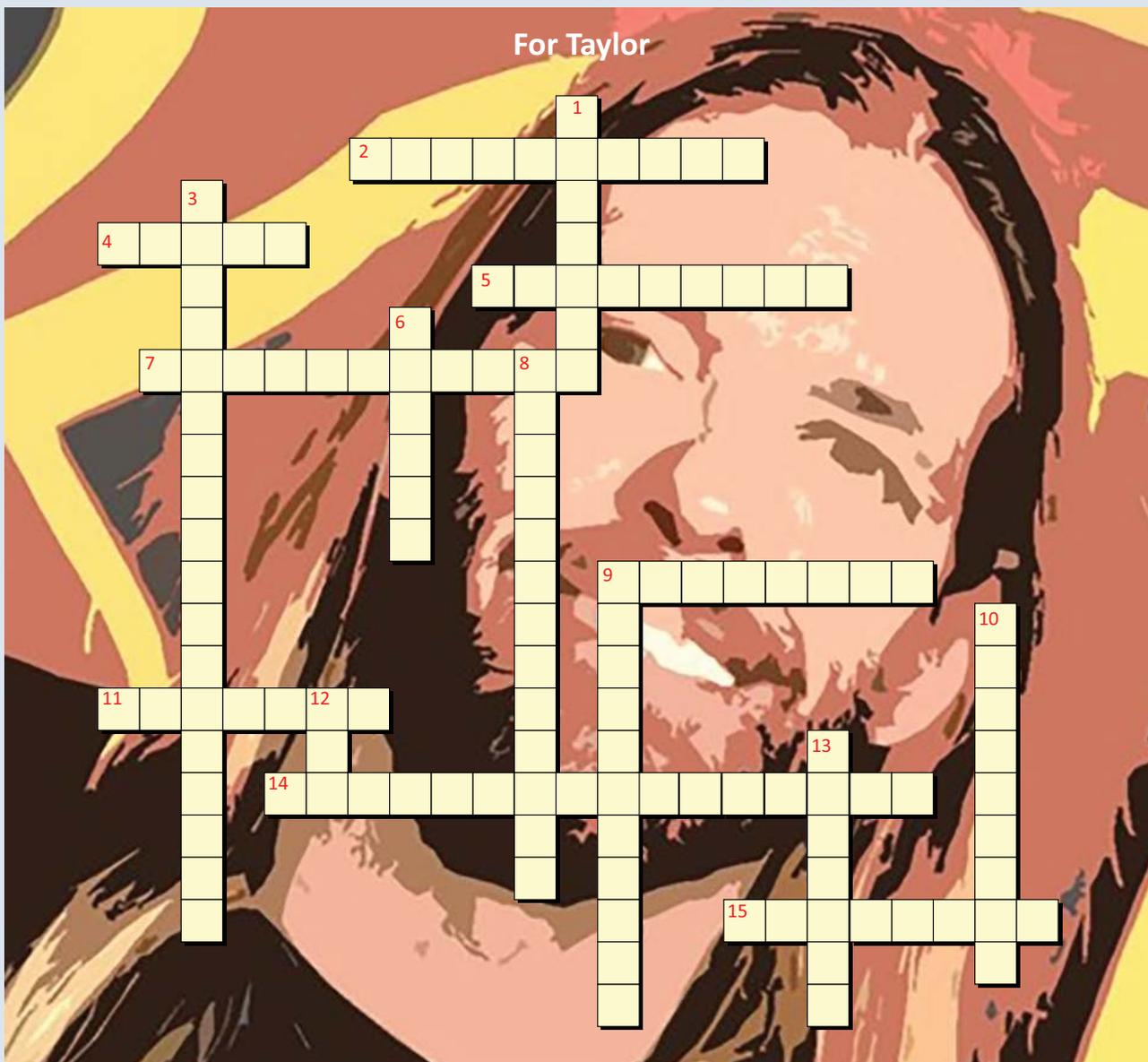
**Tim Dean** is a Specialist Project Geoscientist for Anglo American. Prior to joining Anglo American he was a Specialist Geophysicist at BHP and a Research Fellow within the Department of Exploration Geophysics at Curtin University. This followed an extensive career at Schlumberger/WesternGeco/Western Geophysical in a variety of roles including marine and land field operations, software development, and research located in Saudi Arabia, England, Norway and Australia. Following his final position within Schlumberger as Principal Research Geophysicist at the Schlumberger Fibre-Optic Technology Centre Tim joined HawkEye Technology (a division of Sony) as a Project Advisor for the introduction of goal-line technology into the UEFA Champions League. He also conducted research into the use of sensors within sports as diverse as cricket, AFL, and volleyball. Tim has an Honours degree in geophysics from Curtin University and a PhD in physics from the University of New South Wales. His research interests include land acquisition, particularly vibroseis sources, land data processing, and distributed fibre-optic sensing.

**Tim Brice** has a BSc in geological sciences from Leeds University an MSc in Petroleum Geophysics from Imperial College, London, and until recently was Chief Geophysicist (acquisition) for Shearwater Geoservices. He began his seismic career with Horizon exploration in 1989 as a field geophysicist and then worked for Schlumberger/WesternGeco where he held multiple positions until moving to Shearwater in 2018. He has been mainly involved with acquisition geophysics and seismic survey design and has published numerous papers and taught courses in these fields. Areas of work have included Australia, Europe, North America, The Middle East and Far East. He retired from the seismic industry at the end of 2021 so this is probably his final technical paper.

<sup>10</sup><http://content.time.com/time/specials/packages/completelist/0,29569,1991915,00.html>

<sup>9</sup><https://www.earthmagazine.org/article/rock-stars-geologists-silver-screen/>

Preview crossword #19



Across	Down
2 "He got monkey finger, he shoot coca-cola."	1 "Just put me in a wheelchair, get me on a plane."
4 "Nothing really matters, anyone can see."	3 "Pay your surgeon very well to break the spell of ageing."
5 "Can you tell a green field, from a cold steel rail?"	6 "Out here in the fields, I fight for my meals."
7 "Come down and waste away with me."	8 "No more will my green sea go turn a deeper blue."
9 "Every step that I take is another mistake to you."	9 "Your head is humming and it won't go, in case you don't know."
11 "Show me, show me, show me how you do that trick."	10 "Are we demented or am I disturbed? The space that's in between insane and insecure."
14 "I torch my soul to show the world that I am pure deep inside my heart."	12 "When you're sure you've had enough of this life, well hang on."
15 "She dreams in colour, she dreams in red."	13 "Sunburn with freezer burn, choking on the ashes of her enemy."

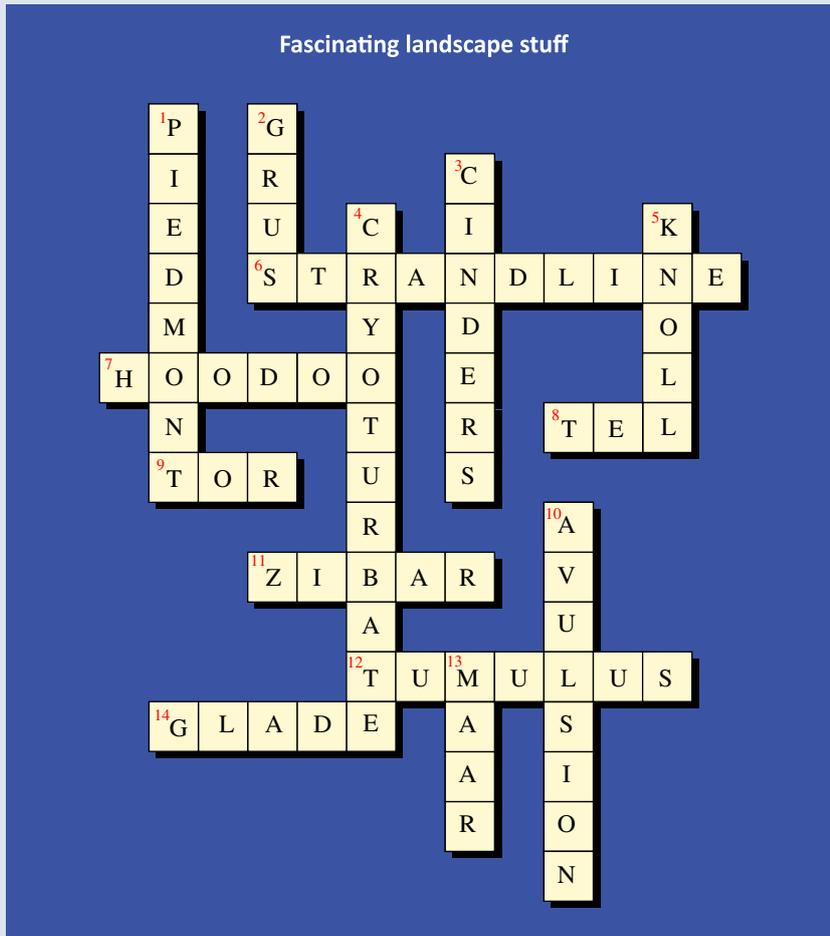
Play to win!!

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

Good luck!



Preview crossword #18 solution



Business directory



**Tensor Research**  
Geophysical Software Research and Services

**Kerryn Parfrey** BSc, MGeoscience  
Manager Geophysical Software

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

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**Richard Almond**  
Director

Tel: +61 (2) 6241 2407  
E-mail: ralmond@geoss.com.au  
Web: www.geoss.com.au

18 Bungaree Crescent,  
Ngunawal, ACT 2913,  
Australia



Australian Society of  
Exploration Geophysicists



**Join our diverse network  
of geoscientists from over  
40 countries, foster your  
professional network and receive  
a wide range of member benefits.**

#### **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**

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# 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](mailto:secretary@aseg.org.au) Website: [www.aseg.org.au](http://www.aseg.org.au)

## Application for Active & Associate Membership 2022

### INSTRUCTIONS FOR APPLICANTS

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

#### Section 1. Personal identification

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

#### Section 2. Choice of Membership grade (Active or Associate)

- Active Please complete all sections
- Associate Please complete all sections
- 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 subsidised 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			
Secunder			

**Section 5. Membership of other societies**

Australian:

 Aus IMM Grade \_\_\_\_\_  AIG Grade \_\_\_\_\_  GSA Grade \_\_\_\_\_  PESA Grade \_\_\_\_\_

International:

 AAPG Grade \_\_\_\_\_  EAGE Grade \_\_\_\_\_  SEG Grade \_\_\_\_\_  SPE Grade \_\_\_\_\_ Others \_\_\_\_\_**Section 6. ASEG Member record**

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

 Yes  No

Please complete this section for the ASEG Membership database.

**Employment area:** Industry  Contract/ Service 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. Membership grades and rates**

- |  |  |
|--|--|
| <input type="checkbox"/> Active/Associate (Australia) - \$182.00             | <input type="checkbox"/> Active/Associate 5 Year Membership (Australia) - \$910.00             |
| <input type="checkbox"/> Active/Associate (Group IV Countries) - \$165.50    | <input type="checkbox"/> Active/Associate 5 Year Membership (Group IV Countries) - \$827.50    |
| <input type="checkbox"/> Active/Associate (Group III Countries) - \$49.70    | <input type="checkbox"/> Active/Associate 5 Year Membership (Group III Countries) - \$248.50   |
| <input type="checkbox"/> Active/Associate (Group I & II Countries) - \$18.20 | <input type="checkbox"/> Active/Associate 5 Year Membership (Group I & II Countries) - \$91.00 |
| <input type="checkbox"/> Associate-Graduate (Australia) - \$91.00            |  |

**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 will not use the Member list for any purpose other than advertising and for 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**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: \_\_\_\_\_



**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 of 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 Member 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 may 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.



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Email: [secretary@aseg.org.au](mailto:secretary@aseg.org.au) Website: [www.aseg.org.au](http://www.aseg.org.au)

## Application for Student Membership 2022

### INSTRUCTIONS FOR APPLICANTS

- 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.
- Student Membership must be renewed annually.  
The duration of a Student Membership is limited to five years.
- Fill out the application form, ensuring that your supervisor signs Section 2.
- Submit your application to the Secretariat at the address shown on the top of this page, retaining a copy for your own records.

#### Section 1. Personal details

Surname		Date of Birth
Given Names		Mr / Mrs / Miss / Ms / Other (list)
Address		
Country	State	Post Code
E-mail		
E-mail (non-University alternative)		
Mobile	Phone (W)	Phone (H)

#### Section 2. Student declaration

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

#### Section 3 Membership grades and rates

- |   |      |
|---|------|
| <input type="checkbox"/> Student (Australia & Group IV Countries) | FREE |
| <input type="checkbox"/> Student (Group III Countries)            | FREE |
| <input type="checkbox"/> 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:

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

Yes  No

#### Section 5 Declaration

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

Signature: \_\_\_\_\_ Date: \_\_\_\_\_



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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 Member 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.
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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 geophysicist, 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 may 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.



Month	Year	Event	Location	Country
<b>April 2022</b>				
5–6		Annual Geoscience Exploration Seminar (AGES) <a href="https://resourcingtheterritory.nt.gov.au/news-and-events/ages">https://resourcingtheterritory.nt.gov.au/news-and-events/ages</a>	Alice Springs	Australia
11–14		International Geological and Geophysical Conference and Exhibition <a href="https://eage.eventsair.com/saint-petersburg-2022/">https://eage.eventsair.com/saint-petersburg-2022/</a>	St Petersburg	Russia
<b>May 2022</b>				
9–13		8th Mines & Wines Conference 2022 <a href="https://www.aig.org.au/events/8th-mines-wines-conference-2022/">https://www.aig.org.au/events/8th-mines-wines-conference-2022/</a>	Orange	Australia
23–27		EGU General Assembly 2022 <a href="https://www.egu22.eu">https://www.egu22.eu</a>	Vienna	Austria
<b>June 2022</b>				
5–9		83rd EAGE Annual Conference & Exhibition <a href="https://eage.eventsair.com/eageannual2022/">https://eage.eventsair.com/eageannual2022/</a>	Madrid	Spain
12–17		19th International Conference on Ground Penetrating Radar <a href="https://learn.mines.edu/gpr2022/">https://learn.mines.edu/gpr2022/</a>	Denver	USA
13–15		Prospectors and Developers Convention (PDAC) Face-to-face <a href="https://www.pdac.ca/convention">https://www.pdac.ca/convention</a>	Toronto	Canada
28–29		Prospectors and Developers Convention (PDAC) Online <a href="https://www.pdac.ca/convention">https://www.pdac.ca/convention</a>		Virtual
<b>July 2022</b>				
6–7		AAPG - Structural Geology and Our Future - The Role of Tectonic Geoscience in Energy Transition, Focusing on the Asia-Pacific Region <a href="https://www.aapg.org/global/asiapacific/events/workshop/articleid/60687/structural-geology-and-our-future-the-role-of-tectonic-geoscience-in-energy-transition-focusing-on-the-asia-pacific-region">https://www.aapg.org/global/asiapacific/events/workshop/articleid/60687/structural-geology-and-our-future-the-role-of-tectonic-geoscience-in-energy-transition-focusing-on-the-asia-pacific-region</a>	Sydney	Australia
<b>August 2022</b>				
1–3		Diggers and Dealers <a href="https://www.diggersdealers.com.au/">https://www.diggersdealers.com.au/</a>	Kalgoorlie	Australia
15–19		12th International Kimberlite Conference <a href="https://12ikc.ca/">https://12ikc.ca/</a>	Yellowknife	Canada
28 Aug–02 Sept		International Meeting for Applied Geoscience & Energy (SEG   AAPG IMAGE 2022) <a href="https://imageevent.org/2022/Save-the-Date">https://imageevent.org/2022/Save-the-Date</a>	Houston	USA
<b>September 2022</b>				
18–22		Near Surface Geoscience Conference & Exhibition 2022	Belgrade	Serbia/Virtual
27–29		AIG Symposium: Structural Geology and Resources 2022 <a href="https://www.aig.org.au/events/aig-symposium-structural-geology-and-resources-2022/">https://www.aig.org.au/events/aig-symposium-structural-geology-and-resources-2022/</a>	Kalgoorlie	Australia
26–30		Australian and New Zealand Geomorphology Group Conference <a href="https://www.anzgg.org/conferences">https://www.anzgg.org/conferences</a>	Alice Springs	Australia
<b>October 2022</b>				
24		Asia Pacific Meeting on Near Surface Geoscience & Engineering <a href="https://eage.eventsair.com/5th-asia-pacific-meeting-on-near-surface-geoscience-engineering/abstract-submission">https://eage.eventsair.com/5th-asia-pacific-meeting-on-near-surface-geoscience-engineering/abstract-submission</a>	Taipei	Taiwan
<b>November 2022</b>				
28		SAGA 2022 <a href="https://m.facebook.com/events/sun-city-conference-centre/saga-2022-17th-biennial-conference-exhibition/1846354198894057/">https://m.facebook.com/events/sun-city-conference-centre/saga-2022-17th-biennial-conference-exhibition/1846354198894057/</a>	Sun City	South Africa
28–30		Sub 22 <a href="https://research.csiro.au/dei/sub22/">https://research.csiro.au/dei/sub22/</a>	Adelaide	Australia
<b>March 2023</b>				
13–18		Australasian Exploration Geoscience Conference (AEGC 2023)	Brisbane	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

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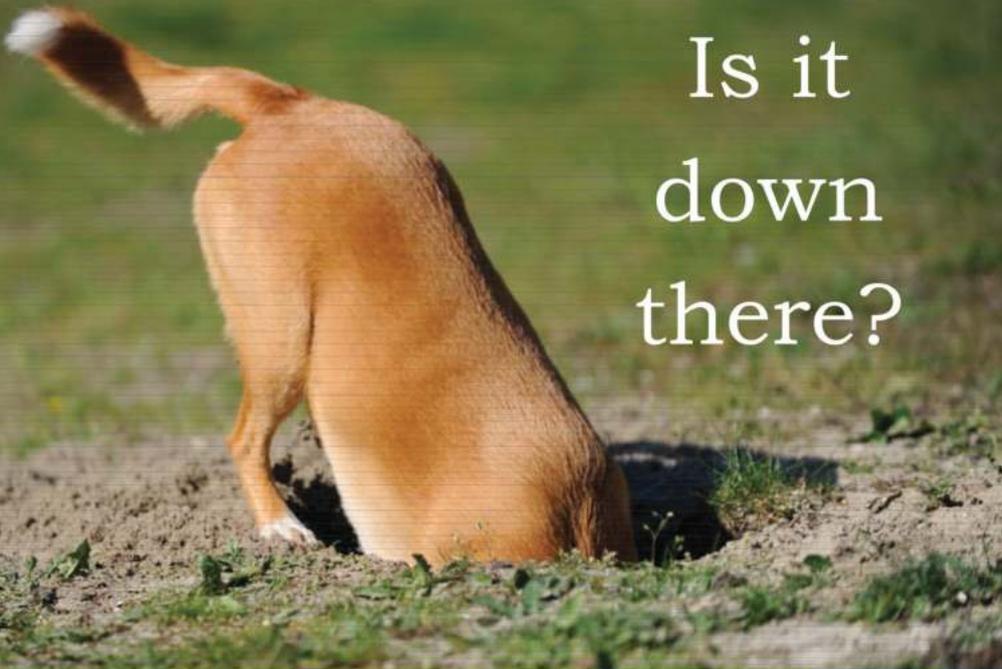
Single copies of *Preview* can be purchased from the Publisher.

All proposed contributions should be submitted to the Editor by email at [previeweditor@aseg.org.au](mailto:previeweditor@aseg.org.au)

For style considerations, please refer to the For Authors section of the *Preview* website at: <https://www.tandfonline.com/toc/txp20/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 13 May 2022.

For the advertising copy deadline please contact the Publisher on [advertising@taylorandfrancis.com.au](mailto:advertising@taylorandfrancis.com.au)

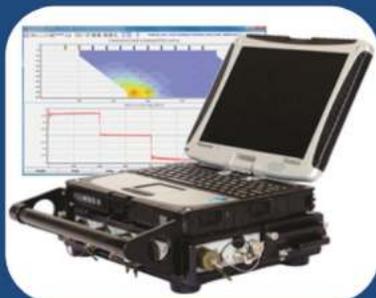


Is it  
down  
there?

# EMIT

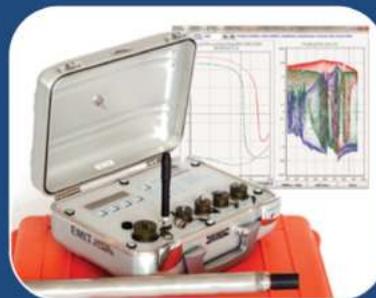
[www.electromag.com.au](http://www.electromag.com.au)

Over  
**25 YEARS**  
of helping you  
find out



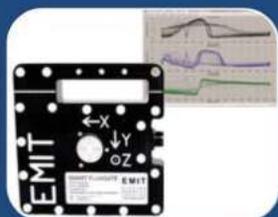
### SMARTem24

Rugged and reliable PC-based, 16 channel, 24-bit electrical geophysics receiver system with time-series recording, powerful noise rejection, GPS sync and an optional separate Transmitter Controller. Works seamlessly with a wide range of transmitter systems and most sensors for EM and IP. The SMARTem24 application plots decays, profiles, maps and pseudo-sections providing powerful QC capabilities. Hot-swappable batteries, touch-screen, solid-state HDD and water/dust protection make this an instrument for serious electrical geophysics. Compatible with EMIT's Transmitter Multiplexer and other tools for increasing productivity.



### DigiAtlantis

3-component digital borehole fluxgate magnetometer system in a 33mm tool for EM and MMR with simultaneous acquisition of all components, time-series recording and powerful noise rejection. Compatible with a wide range of transmitter systems and EMIT's Transmitter Multiplexer for increasing productivity. Samples the whole waveform providing on and off-time data. Magnetometer DC signals are recorded to give 3-component and total-field geomagnetic data. Orientation data gives hole inclination and azimuth in real-time without additional surveys. Designed to be used with industry-standard winches with 2-core and 4-core cable.



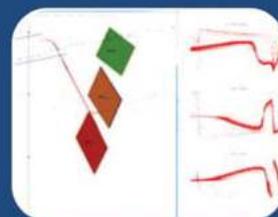
### SMART Fluxgate

Rugged, low noise, calibrated, 3-component fluxgate magnetometer with recording of geomagnetic fields, digital tilt measurement and auto-nulling.



### SMARTx4

Intelligent and safe 3.6 kW transmitter for EM surveys using standard generators. Clean 40A square wave output, inbuilt GPS sync and current waveform recording.



### Maxwell

Industry standard software for QC, processing, display, forward modelling and inversion of airborne, ground and borehole TEM, FEM and MMR data. Training workshops available.

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