Australian Society of Exploration Geophysicists

AUGUST 2023 • ISSUE 225
ABN 71 000 876 040 ISSN 1443-2471

PREVIEW

NEWS AND COMMENTARY

FEATURE

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FRONT COVER

Preview is freely available online at
https://www.tandfonline.com/toc/texp20/current

ISSN: 1443-2471 eISSN: 1836-084X

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AEM2023

3-7 September 2023
Fitzroy Island, QLD, Australia

8th International Airborne Electromagnetics Workshop

The AEM23 Workshop is an in-person event between the **3-7 September 2023** and will consist of:

- 4-day technical program featuring speakers from academia, government, and industry, with keynotes delivered by leading experts in their respective streams (4-7 Sept).
- International case studies covering geotechnical, mining, energy, groundwater, and environmental applications.
- Advances in airborne electromagnetic systems, modelling, and interpretation.
- Ample social and networking opportunities (3-6 Sept), including gala dinner.
- Downtime and tours available of the unspoilt tropical paradise of rainforest and beaches within the calm sheltered waters of the Great Barrier Reef.
- Opportunities to bring accompanying guests and families.

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Register now at:
aem2023.org.au

Email: aemconference@theassociationspecialists.com.au

Editor's desk

This issue of *Preview* features the AEM 2023 Workshop handbook, including all of the short abstracts. This means that those of you who aren't lucky enough to get to Fitzroy Island for the workshop will be able to get a taste of what is on offer – which is the latest developments in airborne electromagnetic technologies and their application. I was tempted to select a few abstracts as "best of" but at this stage I don't think I should be playing favourites!

In other news and commentary, in this issue of *Preview* David Denham (*Canberra observed*) takes a close look at the Australian Government's new Critical Minerals Strategy. Marina Pervukhina (*Education matters*) interviews Dr Ian Mackinnon, Professor at the Centre for Clean Energy Technologies and Practices at the Queensland University of Technology. Ian has quite a lot to say about improving our education system. His views resonate with me, particularly his views on the need for scientists to be trained to communicate and write well – I am thinking of adopting his mantra "concise and precise" as my own!

Mike Hatch (*Environmental geophysics*) explores inversion for difference – a topic that will no doubt be discussed at the swim-up bar on Fitzroy. Terry Harvey invites Andrew Carpenter from Expert Geophysics to describe the development of the MobileMT system – which considerably advances airborne magneto-tellurics (MT) surveying. Mick Micenko (*Seismic window*) brings us the latest from the APPEA and EAGE conferences. Tim Keeping (*Data trends*), spurred on by Kim Frankcombe, considers sustainable file assessment, and Ian James (*Webwaves*) briefs us on the re-design of the ASEG website – with the launch anticipated before the end of the year.

Enjoy!

Lisa Worrall
Preview Editor
previeweditor@aseg.org.au

The view from Foxy's Bar on Fitzroy Island – which will no doubt be the site of many fruitful discussions about life, the universe… and AEM.

Free subscription to *Preview* online

Non-members of the ASEG can now subscribe to *Preview* online via the ASEG website. Subscription is free. Just go to https://www.aseg.org.au/publications/PVCurrent to sign up. You will receive an email alert as soon a new issue of *Preview* becomes available. Stay informed and keep up-to-date by subscribing now!!

NB: ASEG Members don't need to subscribe as they automatically receive an email alert whenever a new issue of Preview *is published.*

President's piece

Eric Battig

This edition of *Preview* comes at an exciting period for the ASEG as after a period of absence we reinstate our presence at international events, host diverse and high-profile local events and continue to realise benefits from the recent Brisbane conference.

In early June we were fortunate to have had nine volunteers respond to the call to represent the Society at the EAGE in Vienna, and I am very grateful to all for your time and efforts. Across the board feedback was positive, and planning is already underway to deliver an improved volunteer and visitor experience next year.

It's extremely satisfying to see that CAGE is back for 2023. This one-week field camp, to be held in Septemeber in Forrestania, Western Australia, will once again provide an opportunity for the 25 successful applicants to learn about common geophysical techniques from industry leaders. Field and theoretical training will cover topics from survey design right through to interpretation, and we thank the camp's sponsors for generously covering all attendance costs and the SMEs for their enthusiasm and willingness in volunteering their time.

September will also play host to the 8th International Airborne Electromagnetics Workshop (or AEM2023), held at the beautiful Fitzroy Island in Queensland. The four-day technical programme will showcase content on AEM systems, modelling and interpretation, applied to mining and non-mining sectors.

Now in it's third year, the MAG (Modern Applications of Geophysics) one-day symposium will once again provide an opportunity for geoscientists to hear from a wide range of case studies spanning the minerals industry value chain. This year the event will coincide with a lab-info open day at CSIRO, and organisers are expecting well in excess of 150 delegates.

In a first for the ASEG, a total of 310 extended abstracts from the 2021 and 2023 AEGC conferences have been published online under a Creative Commons license. The Publications Committee have recognised this as the emerging license of choice for scientific publications, retaining copyright with, and strong protections for, our authors. The Committee are continuing to analyse future publication models for *Preview* and *Exploration Geophysics*, emphasising quality and aiming to improve the impacts of these publications for our readers, authors and the Society. We will need more volunteers to help with the transition and I encourage anyone curious about the direction or wanting to help out to please contact Steve Hearn (publications@aseg.org.au).

To finish up, I am pleased to report that in response to the delay of the next bi-annual AEGC to 2025, we are making good progress toward an off-year ASEG event. We anticipate this will feature not-to-miss workshops and short-courses across a variety of geophysical techniques, presented by world leaders in their disciplines. We will also be bringing you an exciting new-look social programme – more details to follow soon. We will need a great deal more volunteers to come forward to make this event a reality, and I am hoping you have just misplaced my email address (president@aseg.org.au)!

As always, please reach out with any thoughts, comments or feedback.

Eric Battig
ASEG President
president@aseg.org.au

ASEG Members holding the fort at the EAGE.

Executive brief

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

The new FedEx members had their third meeting on 15 June 2023. General updates on finance, membership, events, and communications are as follow.

Finances

The financial report presented in the June meeting covered the reporting as of 31 May 2023. The May 2023 operating income was $1721, which mainly related to membership fees totalling. The May 2023 operating expenses were $27 700, which included the monthly management fee of $8986, meeting expenses of $4716 and publications expenses of $8534. YTD profit for the Society is $46 618.

	May 2023	YTD
Total income	$1712	$173 254
Total expense	$27 700	$126 635
Net profit	($25 988)	$46 618
Net assets		$1 004 593

Membership

As of 12 June 2023, the ASEG has 786 Members. We welcomed five new Members in May. Our Corporate Plus Members are **Velseis** and **Total Seismic**. Corporate Members are **HiSeis**, **Transparent Earth**, **Santos**, **Southern Geoscience**, **DUG Technology**, **Planetary Geophysics** and **SkyTEM**. It is great to see that there is 4% increase in membership from last year in June. Welcome to all our new Members and thanks to all our renewed Members, Corporate Members, and local sponsors of our local branches for their continued support in 2023.

Events

I attended the June WA Branch Tech talk session, and it was wonderful to see a great crowd. I had a lovely evening with an excellent presentation, good food and lots of networking. I would really encourage you all to take the opportunity to attend local state branch events and conferences for networking and professional development. All upcoming events are listed in the newsletter and the ASEG website. Please keep an eye on the notifications regarding events in local state branches via emails. There are also some excellent webinars coming up and links to the past webinars are available in the ASEG website on our YouTube channel https://www.youtube.com/@ASEGVideos/videos. CAGE 2023 dates are 24 September to 1 October and venues are Forrestania, WA and Hyden for the field and theory components respectively.

Communications

There are many avenues to stay connected with ASEG including *Preview* magazine, the ASEG website, our wonderful newsletter and various social media such as LinkedIn, Twitter and Facebook. There have been continuously increasing Facebook and LinkedIn views in the recent months. Top posts have been the ASEG WA Branch event alert on 1 June on Facebook, and the *Preview* Issue -April 2023 on LinkedIn. Most page views for the ASEG website came from Western Australia. Please consider using social media to promote ASEG events and publications.

Please contact Asmita at fedsec@aseg.org.au for more information about any of the above.

Asmita Mahanta
ASEG Secretary
fedsec@aseg.org.au

Welcome to new Members

The ASEG extends a warm welcome to 14 new Members approved by the Federal Executive at its June and July 2023 meetings (see table).

First name	Last name	Organisation	State	Country	Membership type
Christopher	Allen	University of Tasmania	Tas	Australia	Student
Ali Reza	Almasi	University of Western Australia	WA	Australia	Student
Leandro	Aque	Curtin University	WA	Australia	Student
David	Baker	University of Adelaide	SA	Australia	Student
Liam	Brunton	University of New South Wales	NSW	Australia	Student
Ismail	Kazeera	Arabian Gulf Oil Company	Benghazi	Libyan Arab Jamahiriya	Associate
Ayshia	Mortimer	Curtin University	WA	Australia	Student
Samuel	Newman	University of New South Wales	NSW	Australia	Student
Amajuoritse	Okoroh	SIMEC Mining	Qld	Australia	Active
Audrey	Quealy	Monash University	Vic	Australia	Associate
Rasoul	Ranjbarkarami	University of Queensland	Qld	Australia	Student
Nafees	Ullah	BGP	Charsadda	Pakistan	Associate
Vitaly	Vidavskiy	Avalio	WA	Australia	Associate
Nick	White	University of Melbourne	Vic	Australia	Associate

ASEG Young Professionals Network: Where to from here?

The Young Professionals Network (YPN) is primarily a database of two groups of ASEG Members. Obviously, as the name suggests, we have a list of those who identify as young professionals, or at least did when they signed up to the mailing list. The second group consists of "not so young" professionals who, at some point, volunteered to mentor YPs.

With this in mind, the idea of a remote mentoring scheme was broached in this column. And that was the end of it…well almost. The first announcement resulted in a couple of offers from willing mentors and that was about it. Until about one month ago, when I decided to push ahead and email the ASEG YPN with an open invitation to nominate for remote mentoring.

The idea was simple: if you've fallen through the cracks of state-based mentoring initiatives, then you can ask to be paired with a suitable mentor, using videoconferencing, phone, email, or whatever works for you, to achieve virtually the same career support as you would from an in-person mentoring scheme. A small committee of senior geophysicists would oversee the pairing process, from a database of around 80 volunteers.

So far, the response has been completely underwhelming. In fact, I've only received one nomination to date. Other YPN emails over the past few years seem to receive a similar level of engagement. Which is totally fine, but begs the question: what should the longer-term purpose of the ASEG YPN be? Or put bluntly, why should I continue sending emails to 100 people when only one person replies?

When the ASEG YPN was established, we set out to focus on networking, training and mentoring. Acting through conference committees and some state branches, we've hosted many networking and mentoring events (often well attended, as regularly documented in this column). I feel we've dropped the ball on training - although the pandemic certainly hasn't helped (I think all would agree that we see very few public training opportunities outside of conference workshops these days).

I'm keen to understand what the lack of interest in remote mentoring means. Have the states already succeeded in allocating mentors to all YPs who would like one? Or are there very few YPs who are based outside of major Australian capital cities? Is mentoring valued less than networking? Have most of our YP mailing list become "not so young professionals" or have they unsubscribed? Is it worth pushing ahead with new YP initiatives and, if so, which ones?

I'd send out a survey to figure out what is going on - but for the fact that it wouldn't receive a statistically significant response. So, may I suggest that if you feel strongly about anything you read here, then please write back, either through *ypadmin@aseg.org.au* or as a letter to *Preview*. Where do you think the focus of the YPN should be, from this point on?

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

Henderson Byte: Equatorial plasma bubbles and volcanoes

Equatorial plasma bubbles (EPB) are an ionospheric phenomenon occurring near the Earth's geomagnetic equator at nighttime.

The plasma bubbles form after sunset when the sun's rays no longer ionise the ionosphere and particularly in the F region (150 to 800 km above the surface). The ions then recombine, forming a lower density layer than its surroundings, which rises by convection making the bubble. The bubbles have dimensions of tens to hundreds of kilometres and are turbulent with irregular edges.

What effect do they have? They are known to degrade the performance of GPS satellites by delaying the transmission of radio waves which carry the GPS signals. This is especially of concern with precise GPS positioning such as used for autonomous vehicles in mining and agriculture and for self-driving cars.

Different times of the year and locations have differing frequencies of occurrence. In Northern Australia, the most common times are February to April and August to October, when a plasma bubble is expected every night.

It has been thought that bubbles can also be formed by volcanic activity and proven correlation may just have been found following the huge eruption of the volcano in Tonga in January 2022. (*New Scientist*, 27 May 2023, p.10). There was degradation of GPS signals at the time and in this case up to thousands of kilometres away from the equator including as far south as Townsville, Queensland. A team of space scientists led by RMIT University's Brett Carter not only mapped the extent of the bubble over Australia, but also calculated its influence on navigation systems. (*ABC Science*, 31 May 2023).

The disturbance by the volcano may have been augmented by the geomagnetic storm which occurred at that time. Magnetic field fluctuations can also be associated with EPBs.

Of course, future such events related to volcanic action will not be able to be forecast until the prediction of volcanoes is perfected.

Roger Henderson
rogah@tpg.com.au

ASEG Research Foundation: Richard Lane Scholarship winner 2023

Claire Mortimore

The winner of the third annual Richard Lane Scholarship is **Claire Mortimore** from the School of Earth Science, University of Western Australia. Claire is undertaking an Honours degree in geophysics and has been awarded $5000. Claire's supervisor is Professor Mike Dentith.

The ASEG Richard Lane 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 and consists of a grant of $5000 to the best ranked student in the current year. Ranking is based on a 200-word discussion, overview of a geophysics project and academic transcript. We acknowledge and thank Jayson Meyers and Resource Potentials Pty Ltd for the concept and donations.

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

Why Claire is studying geophysics (200-word discussion)

I was first exposed to mineral exploration geophysics in my undergraduate years when I took a keen interest in geological mapping and geological interpretation of geophysical data. I appreciate the versatility of geophysics and see it as a science that can adapt well to a variety of subspecialties including environmental science, agriculture, and archaeology. I have personally applied near surface geophysics in archaeological contexts and in groundwater mapping and these field investigations were particularly fascinating and highlights of my junior career thus far.

Geophysics has allowed me to integrate multidisciplinary datasets and interpret them in a broader geological context to solve complex problems. Studying under Mike Dentith at UWA, and later working under Barry Bourne at Terra Petrophysics, I learnt about petrophysics in a mineral exploration context, which I consider to be the key to linking conflicting geological and geophysical datasets. My background in petrophysics has allowed me to develop a thorough understanding of the foundations of geophysics. As a geoscientist and laboratory manager at Terra Petrophysics, I have had the chance to participate in geophysical fieldwork using techniques such as Loupe TEM and GPR. Most recently, I acquired Loupe data over my research prospect in South Australia. The latest magnetic and conductivity physical property measurements over the south Eyre Peninsula were taken in the 1950s. This warranted the collection of more recent petrophysical data from the available AC and outcrop, especially given Mike Dentith's more recent petrophysics in the Eyre Peninsula over Uley, which showed dissimilar results to the historical values. Therefore, I believe it would be valuable to conduct reinvestigation with modern instrumentation over the Koppio prospect in South Australia which would involve additional travel and field expenses. The funding from this scholarship would support my research project in this way.

Claire's Honours project

Geophysical exploration for graphite mineralisation on the eastern Eyre Peninsula, South Australia.

This research project concerns processing and interpretation of new geophysical data from the Koppio and adjacent Kookaburra Gully graphite prospects and seeks to understand geological controls on graphite mineralisation and to assess how best to use geophysical data when exploring for graphite resources in this geological environment.

This involves working with newly acquired and existing geophysical data from the prospects. This includes recently acquired ground and airborne Time-domain EM (TEM) collected by Lincoln Minerals in collaboration with Terra Resources, and Geological Survey of South Australia (GSSA) funded aeromagnetic data. Historical geophysical surveys completed in the 1950s and 1980s include frequency-domain EM and self-potential (S.P) surveys and are also available.

The overarching goal is to determine a workflow for geophysical exploration of graphite in the high-grade terrains of the eastern Eyre Peninsula. A set of subsidiary objectives are listed below and contribute to the achievement of the overarching goal.

- Using the GSSA regional magnetic data; complete a geological interpretation over the Koppio/ Kookaburra Gully and Uley areas to identify possible district-scale structural controls on graphite mineralisation. Compare and contrast regional TMI at Koppio/ Kookaburra Gully to Uley. Are the controls on graphite mineralisation similar?
- Interpretation of detailed airborne EM (AEM) and magnetic data from Koppio to determine prospect-scale controls on mineralisation.
- Compare TEM and AEM. Is the cost of AEM warranted? Is EM, overall, a reliable indicator for graphite exploration across the eastern Eyre Peninsula?
- Compare the modern geophysical data with the legacy datasets. Frequency domain EM is rarely used today, instead Time-domain EM (TEM) is the industry standard electromagnetic survey method. TEM is generally; more efficient and simpler to operate, has a greater depth penetration, higher signal: noise ratio and is more cost effective than frequency domain EM. Similarly, SP data is slow to acquire, and often ambiguous in interpretation and has been consequently replaced by more modern geophysical survey methods. The question becomes, how much more effective are the modern geophysical exploration techniques than the outdated techniques? Does the new data (TEM) alter the existing interpretation of the Koppio graphite deposit?
- Petrophysical measurements: Collect magnetic susceptibility and inductive conductivity physical property measurements on mineralised and non-mineralised samples at Koppio. These data will be used for calibration of geophysical interpretations.

Doug Roberts
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research-foundation@aseg.org.au

Australian Society of Exploration Geophysicists
50th Anniversary Special Publication

MEASURING TERRESTRIAL MAGNETISM

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

People, Planes, Places and Events
1100s – 1949

W.D. (Doug) Morrison

This Special Publication is co-sponsored by
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MEASURING TERRESTRIAL MAGNETISM

the evolution of the AIRBORNE MAGNETOMETER and the first anti-submarine and aeromagnetic survey operations – People, Planes, Places and Events 1100s –1949

W. D. (Doug) Morrison

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

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

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

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

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

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

ISBN 978-0-6450691-0-5 (paperback)
https://www.aseg.org.au/publications/book-shop

ASEG branch news

South Australia and Northern Territory

On Wednesday 24 May the SA-NT Branch co-hosted the SEG Honorary lecturer **Prof Roman Pevzner** for a lunch time lecture titled "Surface and Borehole Seismic Monitoring of CO_2 Geological Storage". This event was closely followed by the Fall Fling on 25 May, co-hosted by ASEG, SPE, PESA and YPP. Both were well attended events and provided some excellent networking opportunities.

Dr Mike Hatch spoke on the "Application of shallow electromagnetics surveys (Loupe EM) to support management of environmental water to floodplains on the River Murray in SA" on the evening of June 15. This was a well-received talk and provided some interesting insight into the environmental applications of the Loupe system.

Keep your eyes peeled for the imminent posting of invites for both the 2023 ASEG Wine Tasting event and the 2023 Melbourne Cup, which will once again be held at Adelaide Oval. And lastly, we couldn't host any of our fantastic events without the valued support of our sponsors. The SA-NT Branch is currently sponsored by **Beach Energy**, **Borehole Wireline**, **Oz Minerals**, **Vintage Energy**, **Minotaur Exploration**, the **Department for Energy and Mining**, **Zonge**, **Santos and Heathgate**.

Paul Soeffky
sa-ntpresident@aseg.org.au

Mike Hatch presenting to the SA_NT Branch on June 15.

Tasmania

The Tasmanian Branch of the ASEG will hold its Annual General Meeting at 17:30 on Wednesday 23 August 2023 in.the CODES Conference Room at the School of Earth Sciences, University of Tasmania Sandy Bay. Drinks and nibbles will be available beforehand. Following voting formalities and a brief presentation from erstwhile Branch President **Mark Duffett** on "Expanding the scope of public geophysics", Members, guests and friends will adjourn to a suitable nearby establishment for dinner and to toast the new committee members.

Meeting notices, details about venues and relevant contact details can be found on the Tasmanian Branch page on the ASEG website. As always, we encourage Members to keep an eye on the seminar/webinar programme at the University of Tasmania / CODES, which routinely includes presentations of a geophysical and computational nature as well as on a broad range of earth sciences topics.

Mark Duffett
taspresident@aseg.org.au

Victoria

How often would you say you look through your wallet or purse? Do you know what's in it currently? I mean, I carry my wallet on me whenever I leave home to go to work, to take the kids to swimming or footy training, to go grocery shopping, down to my local or to go visit family and friends. As with most people, my wallet holds my driver's licence, my Medicare card, various bank cards, a MYKI card and several membership cards to various organisations e.g., health insurance membership card etc. Today, I decided to look through it and saw a faded Bunnings receipt from way back when and exactly $25 in hard cash – a crisp $20 note and a mangled $5 note. I have a name for my wallet – Scott – Scott no friends, because it goes everywhere with me, but I have no practical use for it. No offence to anyone named 'Scott' reading this although I don't think there would be any 'Scotts' scrolling through this column because literary intelligence probably isn't your thing 😊

You see, that $25 has been in my wallet since around ANZAC day. I recall paying

for a take-away meal with cash around that time because the fast-food shop I visited offered a 10% discount when paying with cash. The fact that that $25 has been sitting in my wallet for a quarter of the year was no real shock. We live in a contactless, frictionless, cashless world – all in the name of convenience. As a society, we have given up on cash, with the unfortunate flipside being we all tend to spend more when we pay with a card…appended to a digital wallet… on a smart phone. I love using my credit card, and I assume most people that have one do too, because it postpones the unpleasantness of actually paying for things until the bill arrives. I'll be the first to admit, I am guilty of confusing how easy it is to pay for something with how easily I can afford it simply because I am able to swipe, tap or dip my smart phone or my smart watch. This illusion of affordability can be particularly distressing on a monthly basis.

Fatemeh Amirpoorsaeed presenting to the Victoria Branch members.

At our popular technical meeting nights, the Victoria Branch's entertainment charges can be swiftly drained like money is going out of fashion. Point in case - we hosted two (2) technical meeting nights in May in as many weeks. The first was reported in the June edition of *Preview*. The second branch gathering on 24 May saw PhD candidate **Ms Fatemeh Amirpoorsaeed** present a brief overview of her dissertation, "The impact of craton margin geometry on deformation at the edges of the North Australian Craton". A little more about habitual spending habits shortly. Craton margins have been studied, using geophysical imaging methods, to exhibit wedge-shaped geometries, which can be inward or outward dipping. Fatemeh's investigation makes use of geophysical interpretation and analogue modelling techniques to better understand the potential for mineral systems development at the craton margins, which suggests a crucial role in controlling the distribution and concentration of minerals at the crustal-level. Turns out craton margins with inward dipping geometries exhibiting associated structural deformation tends to be associated with potentially greater economic fertility. Go figure. Fatemeh has since taken up a role as an exploration geoscientist at Rio Tinto Exploration. We wish her all the best with her latest endeavours.

Now, at back-to-back events in May, Victoria members thoroughly enjoyed membership benefits that have been generously provided by the ASEG. I am completely in favour of supporting a forum for members to gather and exchange geoscience ideas over a tipple or two. Know this - the ASEG is meticulously economical when it comes to authorising branch expenditures such that a litany of paperwork for any cash outflow becomes so troublesome that it discourages committee members from ever bothering to ask for permission to spend ASEG funds in the first place. True story. I have found the only way around this is to spend the money first then plead with the ASEG for forgiveness in the form of a payment requisition (not to be taken as advice). It usually works a treat every time. Unfortunately, this is where I foundered recently with respect to the two events in May. As is the case after every technical meeting, I often settle the evening's expenses using my personal credit card. The confusion of how easy it is to pay for something with how easily I can afford it rears its ugly head. Not once but twice this May. Because I am not a very organised individual, a month went by before I realised I had forgotten to submit a timely cost reimbursement for ASEG expenses occurred on my personal credit card. I was in the hole for a substantial amount…arrrgh! The convenience of living in a cashless society can have its faults. I had 'paid' for something weeks earlier not because I could afford it but because I had the option (and assured safety) of actually paying for it later. I've considered consigning Scotty to the 'abandonment' basket where it will join the likes of once enjoyable things such as my old Tamagotchi, DVDs and an 80Gb music iPod.

I am aware other state branches often(?) ask their members to pay for their own drinks at events. It's an interesting idea but isn't a new idea and has been suggested to me on more than one occasion by the ASEG. I am mindful of our already falling member numbers and lack of financial sponsorship. It's already difficult getting members to attend our events by offering free drinks let alone asking them to attend one and remain sober. A rock and a hard place if you ask me, but a compromise will need to be made soon. It probably won't change the way how our events are being paid for (any suggestions?). If anything, asking members to pay a small cash amount up front at each catered event will just mean more random cash notes ending up in my wallet for lengthy periods of time.

Thong Huynh
vicpresident@aseg.org.au

Western Australia

The ASEG WA Branch took part in the Trinity College Careers Expo on 13 June 2023. The Expo aimed to promote careers in geophysics to high school and tertiary students

Cameron Thompson manning ASEG's booth at the Trinity & Mercedes Career Expo 2023.

A sample rock from the collection displayed at the ASEG booth, which attracted much interest from young Expo visitors.

and parents. The careers event is one of a kind in WA, bringing together parents, teachers, and students to learn about potential career paths for the industry's future leaders. Proudly wearing his Resource Potential uniform, **Cameron Thompson** (ASEG WA Branch committee member) shared his passion for geophysics and demonstrated to students how exploration works. During this event, students were given brochures, a brief description of rock samples, and an overview of various geophysical instruments. If you or your school would like us to participate in your next career event, please get in touch by contacting wapresident@aseg.org.au

The guest presenter at the ASEG WA Branch Tech night on 1 June was **Michelle Thomas**, the global practice lead of geophysics at BHP. Michelle is responsible for geophysics technical excellence and capability at BHP. Her focus is on connecting the physical properties of the Earth to critical business decisions across BHPs global value chain today and into the future.

During her talk Michelle discussed the minerals geophysicists' role in achieving the United Nations General Assembly's 17 Sustainable Development Goals (SDGs), which are focused on the dimensions of people, prosperity, and the planet. She also reviewed the Geophysical Sustainability Atlas published in the *Leading Edge* by Capello *et al.*, 2021, and the UNESCO Geoscience in Action report it subsequently inspired.

The guest presenter at the ASEG WA Branch Tech night on 22 June was **Brian Evans**, who graduated as an electrical engineer from Liverpool in 1970. He worked for GEC Automation as a control design engineer and then went to work for Geoservice, Paris as a mud logger. He worked as an instrument engineer for GSI and finally as a geophysical consultant in London. In 1976, he migrated to Perth, eventually to become CEO of Australasia's only offshore geophysical consultancy. He spent six years as a Senior Geophysicist with Woodside and Shell Australia before returning to school for an MSc and PhD in geophysics at Curtin. During that time, he helped establish the Geophysics Department at Curtin and was later Head of the Department of Petroleum Engineering. He retired from Curtin in 2019 and is a John Curtin Distinguished Emeritus Professor, Chair of the Emeritus Professor's Forum, and an H_2/He exploration consultant.

Brian is author of the best-selling SEG book *Seismic Data Acquisition in Exploration*. He also wrote the texts *A Simple Guide to Technology and Analytics* and *Tales of a Travelling Geophysicist*. He is presently writing a new book *A Simple Guide to Quantum Technology*.

Michelle Thomas addressing the audience at the beginning of her well-attended and inspiring talk.

Brian Evans engaging with the audience during his presentation.

During his talk Brian discussed the current demand for hydrogen and helium. The drilling of a natural hydrogen trap in Mali in 2010, and its commercial production in 2017, saw many in the exploration and mining industry sit up and take notice. Serious exploration for both gases has been rare. However, the presence of both H_2 and He in Amadeus Basin wells, the current drilling for H_2 on Kangaroo Island, and activities by DMIRS in northern WA have brought it further under the spotlight. Like any hydrocarbon resource, H_2 needs a kitchen, a migration pathway, a reservoir, and a seal. The greatest problem H_2 has is that it needs a totally impervious seal, and conventional seals are simply inadequate (the Mali seal is a dolerite dyke!).

Brian showed a model for locating H_2 in the Officer Basin, which has undergone thrusting and rotation. He used open-file seismic, gravity and magnetic data to show that the Officer has "beautiful structures". Its basement can produce hydrogen, which travels up natural fractures with groundwater, passing into the Townsend quartzite only to be trapped by salt uplift beneath diapirs. Salt is the best trap there is, but there another problem - the Officer Basin is a long, long way from anywhere, and the H_2 will be deep, deep down. It is an exploration challenge!

The ASEG WA Branch is pleased to welcome DELFT INVERSION as a new sponsor for 2023.

Thank you to Delft Inversion for supporting the ASEG WA Branch as it continues to serve our members and community. More sponsors would be very welcome so if you or your company would like to sponsor us, please get in touch by contacting wapresident@aseg.org.au

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

Australian Capital Territory

I attended the World Mining Congress 2023 in Brisbane in July. It was nice to get away from the cold in Canberra for a few days, and I was impressed by the wide range of topics, from geoscience and discovery, to critical mineral, to environmental sustainability, and more…

On 24 May, the ACT Branch hosted a talk by **Sebastian Wong**, titled "Continental-scale multilayered chronostratigraphic interpretation of airborne electromagnetics". Seb showed an innovative workflow developed to interpret AEM data to characterise cover and the depth to basement, and some amazing results. The talk generated a number of questions and discussions.

The Australian Government's Exploring for the Future programme, led by Geoscience Australia, will be holding an online public showcase between 15 and 17 August 2023 (2023 Showcase | Exploring for the Future | Geoscience Australia). The showcase programme is packed with presentations from keynote speakers—including an expert panel discussion—new data releases, geological insights, technical workshops, open Q&A sessions where stakeholders can directly engage with our scientists and more.

Lastly, I would like to thank the immediate past ACT Branch President **Phillip Wynne** for his ongoing support.

Wenping Jiang
actpresident@aseg.org.au

***Wenping Jiang** and **Marcus Haynes** at the Geoscience Australia booth at the World Mining Congress.*

New South Wales

In May, **Dr Stuart Clark,** Associate Professor at The University of New South Wales (UNSW), presented a talk entitled "Engaging Students in Geophysics with interactive notebooks and team-based learning".

Dr Clark highlighted the potential of modern educational tools to augment classroom teaching, particularly in geophysics. He uses interactive notebooks, enabling students to explore geophysical principles interactively by adjusting various parameters. Dr Clark shared examples from his teaching practices, demonstrating the effectiveness of these digital tools in helping students gain practical skills in geophysics. He further discussed his pedagogical framework, emphasising the importance of team-based learning for enhancing student engagement and comprehension. This talk provided a fresh perspective on deploying advanced online tools in the classroom and offered insights into innovative teaching strategies for complex subjects like geophysics.

The session was not just a lecture, but an interactive exchange that delved deep into the potential of modern educational tools like Colab notebooks and various interactive platforms, such as InteDashboard. Dr Clark brought a fresh perspective, proving how these digital resources can simplify complex geophysical principles and boost student engagement. Stuart's session was enlightening, helping us understand the potential of these digital tools for enhanced teaching and learning outcomes in geophysics.

In June, **Dr Bhavik Lodhia** a Research Scientist at CSIRO, presented a talk entitled "The El Dorado of UK shale gas". Dr Lodhia gave a detailed account of the rise and fall of the onshore UK shale gas industry. In 2013, reports by the British Geological Survey and Department of Energy and Climate Change (DECC) estimated that the UK held over 2000 TCF of onshore shale gas reserves, sparking optimism for the UK to transition from a net energy importer to an exporter. However, these expectations soon faltered due to a series of missteps.

Dr Lodhia presented his recently published shale gas resource estimation for Northwest England. He compared it with the original estimates from a decade ago, highlighting the overestimations of reserves and underestimations of

Dr Clark discussing interactive team-based learning.

Audience participating in the interactive exercise through InteDashboard platform.

Dr Lodhia comparing the difference between the US and the UK shales.

geological complexities that contributed to the decline. He also touched upon the varying gas content in shale formations across different regions, contrasting the UK's experiences with the successes in the US.

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

Harikrishnan Nalinakumar and Jim Austin
nswsecretary@aseg.org.au

Queensland

The highlight of the ASEG Queensland winter season occurred on 25 May with the annual ASEG winter ball quiz night. Once again, the Edward Room at the Stock Exchange hotel played host to the annual battle of wits as six tables vied for intellectual bragging rights and the customary bloated prize pool. Early betting focused on the 'Redcliffe Dolphins' whose combined life experience (cruelly estimated by one attendee at 400 years, for a team of four), as well as the adjacent inspiring signage, intimidated the other participants. Unfortunately, this was not to be their night…

Master quiz master **Henk van Paridon** led the participants through four challenging rounds based on geography, numberwang (?…), either/or, and 'the crown' with an intermediate musical round to give his voice a break. The customary side challenge this year was 'mystery milk' with participants charged with identifying 12 different flavours of flavoured milk, cunningly disguised with food colouring. It turned out that local ASEG members do not lack for talent in the lactose-game, with all but one team successfully identifying all the samples.

Members of the 'Redcliffe Dolphins' (and Kyle) at the ASEG Queensland quiz night.

Members deep in thought at the annual ASEG Queensland winter ball quiz night.

By the end of the evening the winners were crowned, securing bragging rights until next year with the losers left to drown their sorrows/point the finger at their team-mates/call Rudi Guiliani to file a lawsuit about scoring-related fraud…

Thanks again to Henk for organising a great night, and we look forward to next year.

The next local event was a technical presentation by **Roman Pevzner** (Curtin University), the SEG's 2023 South & East Asia Honorary Lecturer, on "Surface and borehole seismic monitoring of CO_2 geological storage" on 29 June. Despite the lack of milk on offer, a large audience

Winners of the annual quiz.

*Roman is congratulated on his presentation by ever-joyful Queensland President **Nick Josephs**.*

enjoyed a summary of Roman's many years of research in the field (with a dash of his famous dry humour thrown in).

Queensland events that will be reported on in the next issue of *Preview* include Brisbane Brews on 14 July, this month at Future Magic Brewing, and a technical talk by Randall Taylor on exploration in Timor Leste on 20 July. Beyond that ASEG Queensland will be going back to school, albeit 'Beer School' at BrewDog in the valley. As always, we are happy to welcome interstate visitors and shy local members, particularly those who are prepared to share their work in a jovial and supportive environment.

Tim Dean
qldsecretary@aseg.org.au

*Attendees of the recent technical night, including a vibrantly clad **Shaun Strong**.*

ASEG national calendar

Date	Branch	Event	Presenter	Time	Venue
ASEG Branches hold face-to face meetings and webinars. Registration for webinars is open to Members and non-members alike, and corporate partners and sponsors of state branches are acknowledged before each session. Recorded webinars are uploaded to the ASEG's website (https://www.aseg.org.au/aseg-videos), as well as to the ASEG's YouTube channel (https://bit.ly/2ZNgIaZ). Please monitor the Events page on the ASEG website for the latest information about events.					
10 Aug	WA	Tech night	TBA	17:30	The Shoe Bar and Café 376-420 Wellington St., Perth
16 Aug	NSW	Technical meeting	TBA	17:30	Club York, York St., Sydney
23 Aug	Tas	AGM	Mark Duffett	17:30	CODES Conference Room, School of Earth Sciences, University of Tasmania, Sandy Bay
20 Sep	NSW	Technical meeting	TBA	17:30	Club York, York St., Sydney
24 Sep–Oct	National	CAGE 2023	Various	09:00	Forrestania, WA
15 Nov	WA	MAG23	Various	08:00	Fraser's Kings Park, Perth

Geoscience Australia: News

Recent highlights of Geoscience Australia's geophysical projects, as conducted as part of the Australian Government's Exploration for the Future, and in collaboration with our state and territory survey partners, are summarised below. Details of all current and recently completed projects and survey locations can be found in Figure 1 and the tables that follow this section.

Australian Fundamental Gravity Network refurbishment.

Geoscience Australia (GA) and the Geological Survey of Queensland (GSQ) recently collaborated on an update and refresh of the Australian Fundamental Gravity Network (AFGN) in northern Queensland. The AFGN provides a datum for all gravity surveys conducted in Australia to be tied to a consistent level for broad scale geoscientific investigations. This survey was funded through the Queensland Resource Industry Development Plan, to further the use of geophysics in support of resource exploration.

The survey was conducted during the first three weeks of May 2023, and resulted in the establishment of a dozen new benchmarks. The condition of 33 existing benchmarks was investigated, with 18 confirmed as destroyed and 15 found to be in an acceptable condition to be re-occupied. All benchmarks were measured using GA's MircoG A10 Absolute Gravimeter, with locations for new benchmarks chosen for their future utility to GSQ for survey planning.

The collected information will be added to Geoscience Australia's AFGN webpage by the end of July. Information will include the location, condition, gravity value, and images used to help locate the new benchmarks.

For further information on the AFGN, please contact Phillip Wynne, Geophysicist - Geophysical Acquisition and Processing, at Phillip.Wynne@ga.gov.au

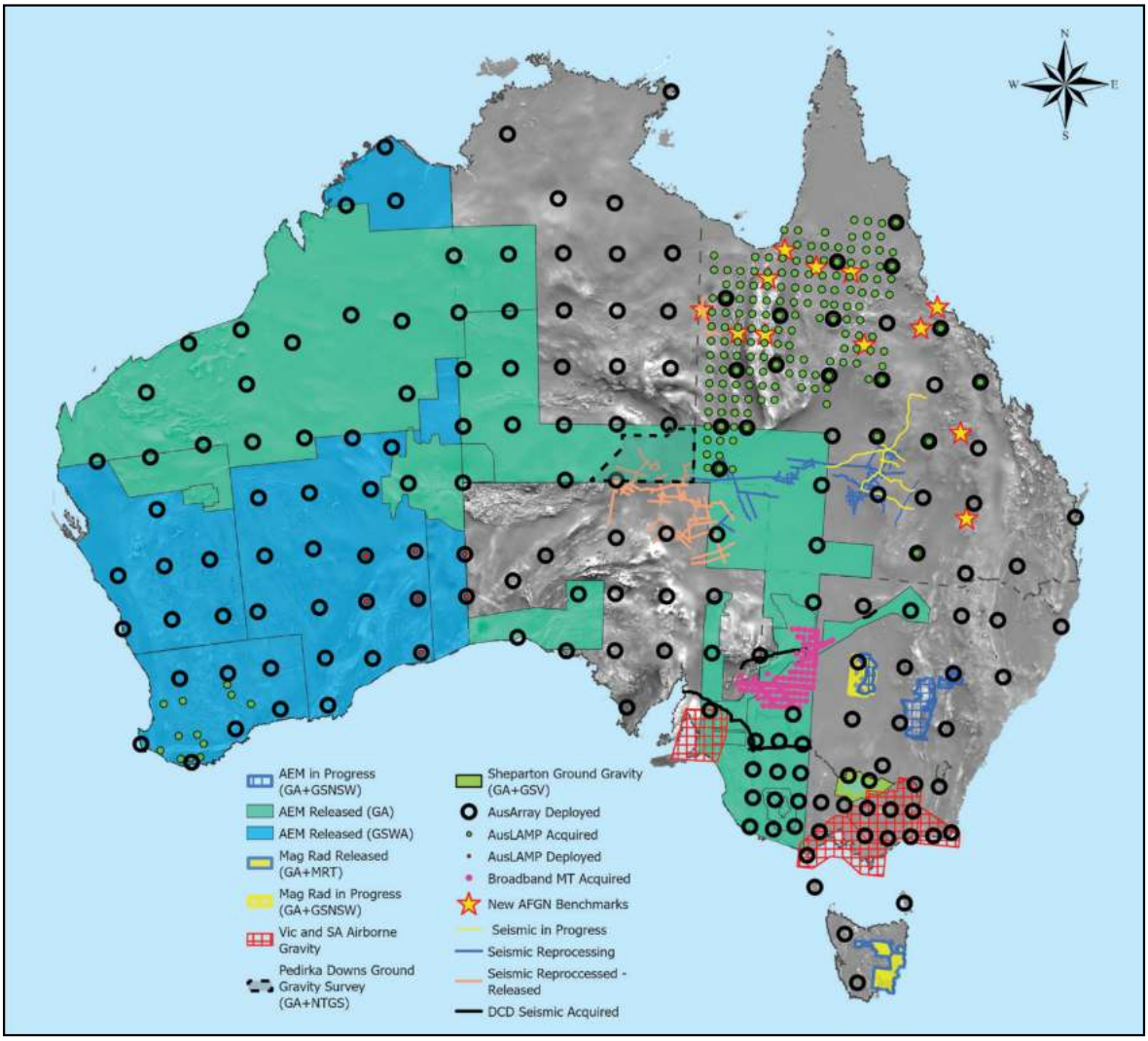

Figure 1. *2021-2023 geophysical surveys – in progress, released or for release by Geoscience Australia as part of Exploring for the Future and in collaboration with state and territory agencies. Projects that are partially or wholly funded by state government agencies are identified by the bracketed contributors. GA = Geoscience Australia, GSNSW = Geological Survey of New South Wales, GSWA = Geological Survey of Western Australia NTGS = Northern Territory Geological Survey, MRT = Minerals Resources Tasmania, GSV = Geological Survey of Victoria, AusLAMP = The Australian Lithospheric Architecture Magnetotelluric Project, MT = Magnetotelluric, AFGN = Australian Fundamental Gravity Network, DCSD = Darling-Curnamona-Delamerian Project. Background image of national magnetics compilation (first vertical derivative of the reduced to pole magnetics), Geoscience Australia, 2019 (see http://pid.geoscience.gov.au/dataset/ga/144725). Magnetic instensity after Poudjom Djomani 2019.*

Figure 2. *Map of survey area. The route taken is indicated by the yellow lines, with the red marks new benchmark locations.*

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

Geoscience Australia (GA), in collaboration with the Geological Survey of NSW, have recently completed the acquisition of over 15 000 line km of airborne electromagnetic (AEM) data over four blocks within the Cobar- Yathong areas of NSW. These data have been acquired to help increase New South Wales' resilience to drought and provide geoscientific information on critical minerals, which will drive investment and help meet the surging global demand. Notably, data was acquired over the Warrumbungle Caldera in the Warrumbungle National Park with the aim of locating groundwater to support the national park in times of drought.

Additionally, acquisition of the Yathong region airborne magnetic and radiometric (AMR) survey is currently underway and will be completed by the end of spring. Acquisition is along east–west lines spaced 200 m apart and north–south lines spaced 2 km apart, and this survey is being acquired to expand knowledge of the geology and potential deep groundwater resources in the area.

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

NTGS Pedirka ground gravity survey

Geoscience Australia (GA), in collaboration with the Northern Territory Geological Survey (NTGS), has recently begun acquiring ground gravity in the southeast corner of the NT adjacent to the Queensland and South Australian borders. The survey is helicopter assisted and is acquiring gravity data on a 4 x 4 km grid over an area of 61 370 km^2, with infill in selected areas at 2 km spacing. A minimum of 11 400 gravity stations are to be acquired. This survey forms part of the NTGS's Resourcing the Territory Initiative, which aims to support resource exploration in the NT. Current gravity coverage in the Pedirka survey area is of an age and density unsuitable for the goals of this project.

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

Geodetic gravimetry data portal

As part of the AuScope Geodetic Gravity Project, Geoscience Australia (GA) have released a new portal to ensure gravity data from the joint GA and Australian National University project is FAIR (Findable, Accessible, Interoperable and Reusable). The data provided through this portal allows academia (predominately geodesists and geophysicists) to improve their understanding of temporal deformation of the Earth's surface and mass-density changes beneath. The portal helps users access and visualise

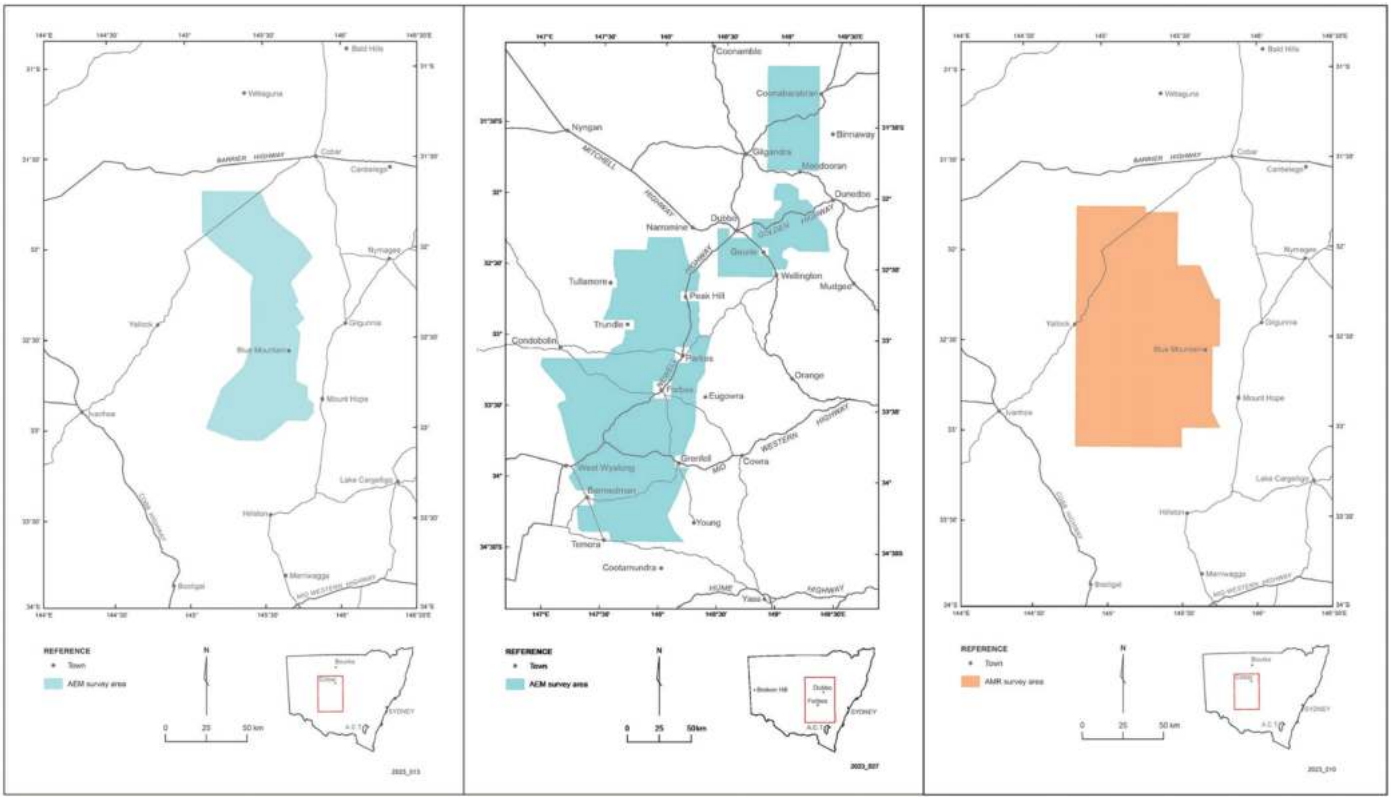

Figure 3. *Location of the Yathong (left) and Forbes-Dubbo (centre) AEM surveys, and the Yathong Airborne Magnetic and Radiometric Survey (right).*

Figure 4. *Geodetic gravimetry data coverage.*

the data (see Figure 4), enabling self-service and can be found here: https://geodeticgravity.ga.gov.au/.

For further information on the Geodetic Gravimetry Data Portal, please contact Jack McCubbine, Geodetic Gravity Team Leader - National Geodesy Section at jack.mccubbine@ga.gov.au

Curnamona Cube Extension magnetotelluric survey

As part of Exploring for the Future, Geoscience Australia undertook the Curnamona Cube Extension Magnetotelluric (MT) survey in western New South Wales and eastern South Australia during February and March 2023. The survey complements the University of Adelaide/AuScope Curnamona Cube MT survey by extending the coverage from the Curnamona Province into the Delamerian Orogen (Figure 5).

Geoscience Australia contracted out the data acquisition and processing. Audio and broadband MT data was acquired at 99 sites on an approximately 12.5-25 km grid with denser sites across known geological structures and along seismic lines acquired by Geoscience Australia in 2022 (L213 Darling-Curnamona-Delamerian 2D Seismic Survey, eCat #147423). Instruments were set up to record five channels (three magnetic and two electric fields) for a minimum of 24 hours with a target bandwidth of 0.0001–1000 s. Processed data shows

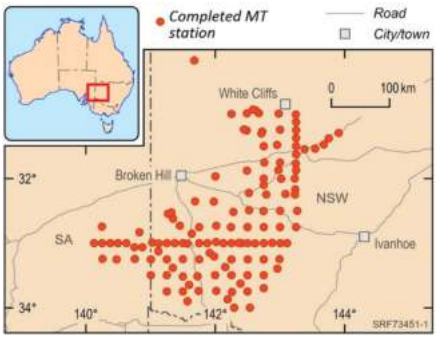

Figure 5. *Curnamona Cube Extension MT project area.*

good quality at most of the survey sites; a few sites are affected by environmental and cultural noise. The acquired data will be used to derive resistivity models and to enhance the understanding of the geodynamics and mineral potential in the Curnamona Province and Delamerian Orogen.

The released survey data contains a field logistics report, processed data in EDI format containing spectra, and site locations in shape file and .txt format. It is available from https://doi.org/10.26186/147904. A 3D electrical conductivity model based on this data will be released in August 2023.

Time-series data in ASCII format is available on request from clientservices@ga.gov.au, quoting eCat #147904.

Adam Bailey
Geoscience Australia
Adam.Bailey@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 12 July 2023)

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

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Line spacing Terrain clearance Line direction	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Eastern Tasmania	MRT	GA	MAGSPEC	Mar 2022	57 000	200 m	11 600	Jun 2022	Sep 2022	See Figure 1 in previous section (GA news)	Dec 2022 - http://pid.geoscience.gov.au/dataset/ga/147455

TBA, to be advised.

Table 2. Ground and airborne gravity surveys

Survey name	Client	Project management	Contractor	Start survey	Line km/ no. of stations	Line spacing/ station spacing	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Canobie	GSQ	GA	Xcalibur Multiphysics	Nov 2021	~5000	1–2 km	5300	Dec 2021	Mar 2022	See Figure 1 in previous section (GA news)	Released by GSQ and GA, Apr 2022 https://dx.doi.org/10.26186/146760
Brunette Downs Ground Gravity	NTGS	GA	Atlas Geophysics	Oct 2021	~ 12 000	2 x 2 km grid	55 000	Apr 2022	May 2022	See Figure 1 in previous section (GA news)	Released by NTGS and GA in Jun 2022 https://dx.doi.org/10.26186/146941
Melbourne, Eastern Victoria, South Australia	AusScope GSV DEL WP	GA	Sander Geophysics	TBA	137 000	0.5–5 km	146 000	Expected Jun 2023	~ Oct 2023	See Figure 1 in previous section (GA news)	Late 2023
Kidson Sub-basin	GSWA	GA	Xcalibur Multiphysics	14 Jul 2017	72 933	2500 m	155 000	3 May 2018	15 Oct 2018	See Figure 1 in previous section (GA news)	Dec 2022 http://pid.geoscience.gov.au/dataset/ga/147481
Little Sandy Desert W and E Blocks	GSWA	GA	Sander Geophysics	W Block: 27 Apr 2018 E Block: 18 Jul 2018	52 090	2500 m	129 400	W Block: 3 Jun 2018 E Block: 2 Sep 2018	Received by Jul 2019	195: Aug 2018 p. 17	Oct 2022 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/147066
Kimberley Basin	GSWA	GA	Sander Geophysics	4 Jun 2018	61 960	2500 m	153 400	15 Jul 2018	Received by Jul 2019	195: Aug 2018 p. 17	Oct 2022 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/147066
Warburton-Great Victoria Desert	GSWA	GA	Sander Geophysics	Warb: 14 Jul 2018 GVD: 22 Jul 2018	62 500	2500 m	153 300	Warb: 31 Jul 2018 GVD: 3 Oct 2018	Received by Jul 2019	195: Aug 2018 p. 17	Oct 2022 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/147066
Pilbara	GSWA	GA	Sander Geophysics	23 Apr 2019	69 019	2500 m	170 041	18 Jun 2019	Final data received Aug 2019	See Figure 1 in previous section (GA news)	Nov 2022 https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/147265
SE Lachlan	GSNSW/ GSV	GA	Atlas Geophysics	May 2019	303.5 km with 762 stations	3 regional traverses	Traverses	Jun 2019	Jul 2019	See Figure 1 in previous section (GA news)	Set for incorporation into the national database in 2023

TBA, to be advised

Table 3. Airborne electromagnetic surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Western Resources Corridor	GA/ GSWA	GA	Xcalibur Multiphysics	May 2022	~ 38 000	20 km	760 000	Oct 2022	Dec 2022	See Figure 1 in previous section (GA news)	Mar 2023 https://dx.doi.org/10.26186/147688
Musgraves	GA	GA	Xcalibur Multiphysics	Jun 2022	~ 22 000	1 – 5 km	~ 100 000	Aug 2022	Dec 2022	See Figure 1 in previous section (GA news)	Mar 2023 https://dx.doi.org/10.26186/147688
Upper Darling River	GA	GA	SkyTEM	Mar 2022	25 000	.25 – 5 km	14 509 line km	Jun 2022	Oct 2022	See Figure 1 in previous section (GA news)	Oct 2022 http://pid.geoscience.gov.au/dataset/ga/147267
Darling-Curnamona-Delamerian	GA	GA	SkyTEM	Jun 2022	14 500	1 – 10 km	25 000 line km	Oct 2022	Dec 2022	See Figure 1 in previous section (GA news)	Feb 2023 https://dx.doi.org/10.26186/147585
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 (GA news)	Oct 2021 http://pid.geoscience.gov.au/dataset/ga/145744
AusAEM20	GSWA	GA	Xcalibur & SkyTEM	Aug 2020	62 000	20 km	1 240 000	Nov 2021	Dec 2021		Released Mar 2022 - http://pid.geoscience.gov.au/dataset/ga/146345

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/ WA	Exploring for the Future – AusLAMP	500 stations deployed 2016-23	50 km	Long period MT	The survey covers areas of NT, Qld and WA. Data acquired 2016-19 and related model released 2020. Data package: http://pid.geoscience.gov.au/dataset/ga/134997 Model: http://pid.geoscience.gov.au/dataset/ga/145233 News article: http://www.ga.gov.au/news-events/news/latest-news/exploring-for-the-future-takes-a-deeper-look-at-northern-australia Data acquired 2020-22 and related model will be released late-2023.
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: http://pid.geoscience.gov.au/dataset/ga/132148.
Curnamona Province-Delamerian Orogen	GA/GSNSW/ GSSA/ University of Adelaide	NSW/ SA	Exploring for the Future - Curnamona Cube Extension	~100 stations deployed 2023	25-12.5 km	Audio and broadband MT	This survey will extend the University of Adelaide-AuScope Curnamona Cube MT survey from the Curnamona Province into the Delamerian Orogen. Data was released in May 2023, https://doi.org/10.26186/147904.

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
Darling – Curnamona – Delamerian deep crustal reflection survey	GA	SA, NSW, VIC	Darling – Curnamona – Delamerian deep crustal reflection survey	~1275	10	10/40	20	2D Deep Crustal/ high resolution vibroseis seismic survey.	This survey will create an image of important crustal boundaries including the structure of the Delamerian margin, which runs through NSW, SA and Vic, separating older rocks of the Gawler Craton and Curnamona Province from younger rocks of the Lachlan Fold Belt (Tasmanides). Acquisition commenced in Jun 2022 and concluded in Aug. Raw data for this survey are available on request from clientservices@ga.gov.au Quote eCat# 147423. Data are currently being processed.

(*Continued*)

Table 5. Seismic reflection surveys (*Continued*)

Location	Client	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
Central Australian basins	GA	Qld/ SA	Shallow legacy data	~1257	Varies	Varies	3-20 sec	2D shallow & deep legacy data, explosive, vibroseis	GA commissioned reprocessing of selected legacy 2D seismic data in Qld and SA, as part of Exploring for the Future, Australia's Future Energy Resources Project. The objective is to produce a modern industry standard 2D land seismic reflection dataset to assist in imaging the subsurface. Reprocessing of these data is underway.
Adavale Basin	GA	Qld	Deep and shallow legacy data		Varies	Varies	3-20 sec	2D shallow & deep legacy data, explosive, vibroseis	GA commissioned reprocessing of selected legacy 2D seismic data in the Adavale Basin, Queensland Australia, Data driven Discoveries Initiative. The objective is to produce a modern industry standard 2D land seismic reflection dataset to assist in imaging the subsurface. Reprocessing of the legacy data is complete and the data package will be released in the second half of 2023.

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 covers all of Australia to establish a continental-scale model of lithospheric structure and serve as a background framework for more dense (~50 km) movable seismic arrays. Deployment of this national array was completed in June 2023. Data will be acquired over 12-18 months.
Northern Australia	GA	Qld/NT	AusArray	About 265 broad-band seismic stations	50 km	Broad-band 1-2 years observations	The survey covers the area between Tanami, Tennant Creek, Uluru and the WA border. The first public data release of the transportable array was in 2020. See: http://www.ga.gov.au/eftf/minerals/nawa/ausarray Various applications of AusArray data are described in the following Exploring for the Future extended abstracts: · AusArray overview: http://pid.geoscience.gov.au/dataset/ga/135284 · Body wave tomography: http://pid.geoscience.gov.au/dataset/ga/134501 · Ambient noise tomography (including an updated, higher resolution model for the Tennant Creek to Mount Isa region): http://pid.geoscience.gov.au/dataset/ga/135130 · Northern Australia Moho: http://pid.geoscience.gov.au/dataset/ga/135179
Australia	GA	Various	AusArray, semi-permanent	12 high-sensitivity broad-band seismic stations	~1000 km	Broad-band 4 years observations	Semi-permanent seismic stations provide a back-bone for movable deployments and complement the Australian National Seismological Network (ANSN) operated by GA, ensuring continuity of seismic data for lithospheric imaging and quality control. Associated data can be accessed through http://www.iris.edu
AusARRAY Victoria Collaborative	Project	GA/GSV	Victoria	~ 20 temporary seismic stations	~100 km	Broad-band ~12-18 months of observations	Data acquired from the movable array sites will add to the scientific understanding of the Earth's lithosphere on the national and regional scale. Phase 1 of the deployment (~100 km) was undertaken in Mar 2023.

Table 7. Survey technical requirements

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

Geological Survey of South Australia: Overview of the receipt and processing of company mineral geophysical data by the South Australian Department of Energy and Mines

Mineral geophysical data are regularly acquired by mineral exploration companies throughout South Australia, and the South Australian Mining Act 1971 (revised in 2021) defines the material that must be provided to the South Australian Government as part of tenement reporting. Despite some changes to the wording in the 2021 revision, the rules for geophysical data reporting are much the same.

Division 6 of the Act (section 15AI) includes a list of definitions of "designated material." This includes, but is not limited to: records of surveys, geological samples, logs, and prescribed material. "Prescribed material" is any document, instrument, report, information, samples or other material created under the Act or provided to a designated person under this Act, or otherwise obtained by a designated person under the Act. Geophysical data fit into this category.

Section 15AL talks about the release of material, and is summarised as "… the Minister or the Director may, in such manner as the Minister or the Director thinks fit, release any prescribed material." Specifics of the release of data are contained in a separate document, the Mining Regulations 2020 (part 5, section 17).

In summary, any designated material provided to the Director under this part must not be released … "until (a) the expiry of the period of 5 years from the date on which the designated material was so provided to the Director; or (b) the expiry, cancellation or forfeiture of the tenement to which the designated material relates; or (c) the surrender, relinquishment or reduction (in whole or in part) of the tenement to which the designated material relates (being, in a case involving a part of a tenement, the designated material that relates to that part); or (d) the designated material has been made publicly available; or (e) a holder of the tenement consents to the release of the designated material, whichever occurs first."

Part 5 of the Act outlines the requirements of Exploration Licence holders, and section 30AAA details the specific requirements around expenditure. In summary, the tenement holder must provide statements outlining their exploration operations, and must be accompanied by such information or evidence required by the Minister (4)(a), and under subsection 6: "…and any information or evidence required under subsection (4)(a), must, if the Minister so requires, be verified by an independent person with qualifications, and in a manner, specified by the Minister."

This is reiterated under Part 12 (miscellaneous) of the Act, Section 90. "A tenement holder must, at the request of the Minister, provide a report verifying any information or material provided to the Minister or the Director under this Act. A report … and any information or material required under this section, must, if the Minister so requires, be verified by an independent person with qualifications, and in a manner, specified by the Minister."

The geophysicists at the Geological Survey of South Australia – a business unit within DEM – act as the independent persons with qualifications, who review all mineral geophysical data (DEM also employs qualified persons to review drillhole data, logs, and other prescribed material).

From a practical point of view, Exploration Licence holders submit reports and data to the DEM company reporting officer. This officer undertakes an initial review of the data. If any mineral geophysics data have been provided, the officer and a data manager check if there are both data and reports related to the claimed expenditure and work done, before forwarding to the geophysical data coordinator. The geophysical data coordinator reviews the material in more depth and if necessary, requests further information from the company reporting officer.

Once everything is in order, the geophysical data coordinator assigns the material to a processing geophysicist, who will examine the data in detail. The processing geophysicist will also prepare the data for future release online, creating a data package for each survey containing the original data and reports, as well as processed located data in a variety of formats, grids and shapefiles.

The data package is then forwarded to a checking geophysicist who undertakes a final review. If everything is in order it is forwarded to a data administrator who checks the confidentiality status and then moves the package to a Single Point Of Truth (SPOT). From here, public domain packages are moved onto the cloud, metadata created on Geonet, and the geophysical data becomes available on SARIG. The GSSA typically release new surveys in batches every few months.

DEM currently has online data submission via email and Kiteworks, but is progressing to online data submission via a new DEM database (MERS). We envisage this will streamline our processes, and ultimately ensure data is available quicker.

The GSSA also create value-added products; a suite of statewide images in the form of ER Mapper grids. These are the statewide magnetics, gravity and radiometrics grids. New public domain surveys are compiled and merged into seamless products that are available for free download on SARIG.

For any assistance with SARIG, please don't hesitate to contact our customer services team: dem.customerservices@sa.gov.au

Ngaityalya (Kaurna, thank you)

Philip Heath
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Geological Survey of New South Wales: Geophysics blitz

The geophysics team at the Geological Survey of NSW have had a busy first half of 2023. A swathe of new data acquisition spanning five different techniques and covering nearly 20% of the state, alongside the continued update and release of nation-leading, high-resolution geophysical merges has kept our hands full.

Geophysical surveys acquired in 2023 include:

- Yathong AEM (April, 6030 km^2)
- Forbes-Dubbo AEM (May – June, 21 460 km^2)
- Norther Extension AEM (June, 3240 km^2)
- Yathong AMR (May – August, 11 400 km^2)
- Cobar-Yathong Seismic (April – June, 500 line km)

These surveys are the tip of a much larger iceberg, with 27 904 km^2 of acquisition also performed between 2019-2022 (Figure 1). And the fun doesn't stop now.

106 608 km^2 of acquisition is planned for the near future, including extensive Airborne Gravity over the New England region and the release of the statewide Airborne Gravity survey conducted by the Department of Customer Service.

The motivation behind such a strong push for geophysical acquisition is multi-faceted. Provision of pre-competitive data to support the exploration industry is very important, however these surveys also provide excellent datasets for geological study of the respective regions, as well as helping to search for potential groundwater in drought-ravaged areas of the state. The data for all surveys performed by GSNSW are made open-file and distributed through our online portal MinView. To access these data, simply scan the following QR code.

In addition to contributing a wealth of new geophysical data, GSNSW is dedicated to providing the highest quality geophysical datasets in the country by merging the best available data into regional products. With statewide merges now at 25 m grid cell size, and a large-scale regional merge of the highly prospective Central NSW down to 10 m grid cell size, the resolution of the data has never been better.

The drive to revitalise the statewide geophysics merges in NSW began with exhaustive metadata production and QA/QC of all airborne geophysical

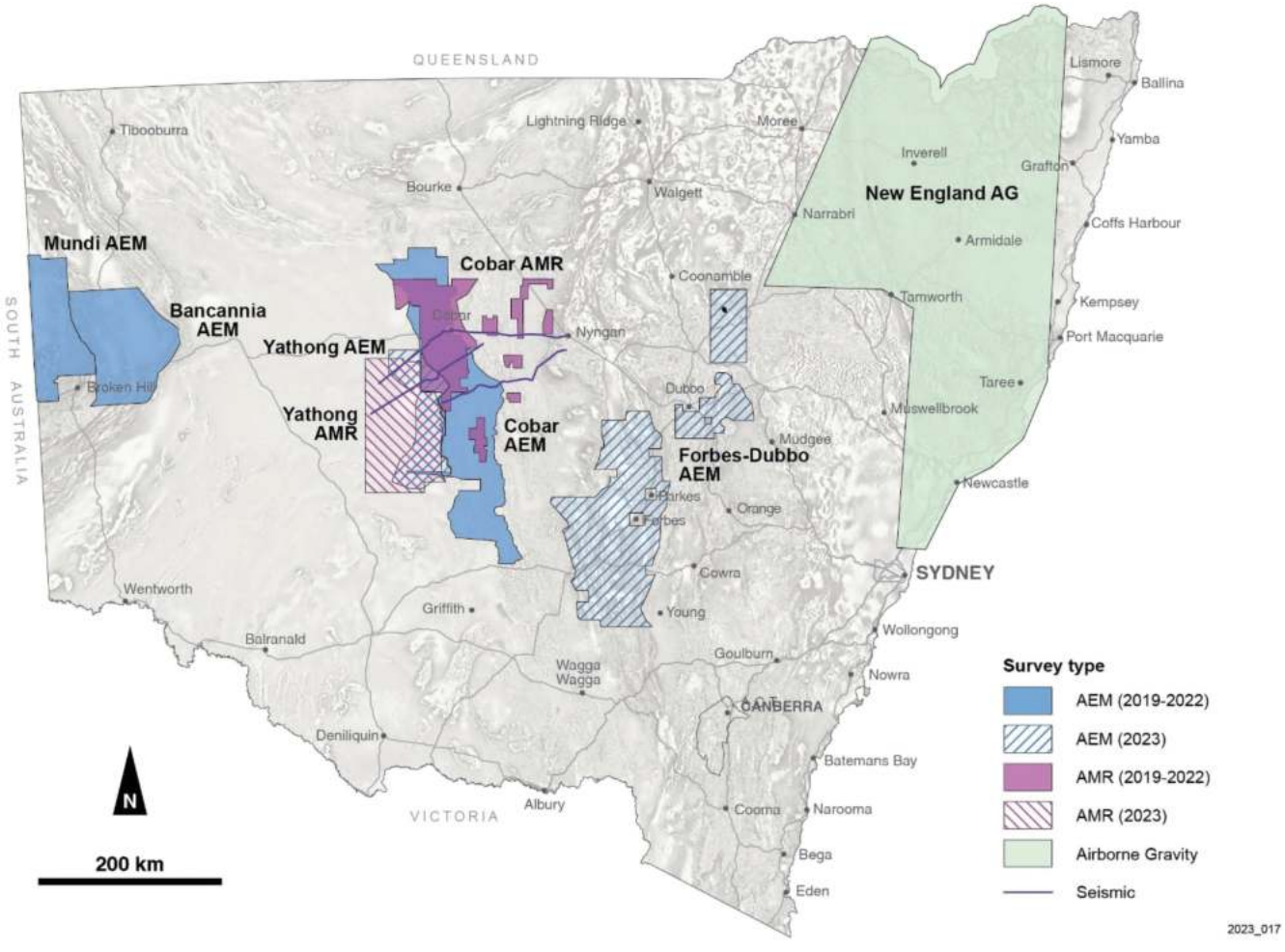

Figure 1. *Map of recently completed and upcoming geophysical acquisition in NSW.*

data within the state, with more than 800 surveys dating back to the 1950s. Particular emphasis was placed on stringent documentation of procedures, and this process has been presented at several conferences by Dr Sam Matthews:

https://www.youtube.com/watch?v=dwEQkiYeWXc

Several large milestones have been accomplished during the push to increase the quality of the statewide geophysical merges in NSW, including:

- Incorporating high-resolution company data into the magnetic merge (2020 – present)
- Reducing grid cell size from 50 m to 25 m for the magnetic merge (2020 – present)
- Incorporating high-resolution company data into the radiometric merge (2022 – present)
- Reducing grid cell size from 100 m to 50 m for the radiometric merge (2022)
- Reducing grid cell size from 50 m to 25 m for the radiometric merge (2023).

This year sees the release of the latest addition to GSNSW's geophysical repertoire - the Central NSW ultra-high resolution merge package. This dataset spans twelve 1:250K geological map sheets, from Cobar in the northwest to Goulburn in the south east. Within these bounds, the geophysical merges for magnetics, radiometrics, and DEM are all produced at a grid cell resolution of 10 m, which is made possible by the wealth of ultra-high resolution company data in the area.

Figure 2 provides a visual demonstration of the geophysical surveys flown at 50 m or less line spacing in the area, which provided the impetus to increase the overall resolution in order to make the most out of the high-quality data. The imagery for these and all of the statewide merges can be viewed and downloaded from the following link:

https://shorturl.at/qRVX9

For any queries related to the geophysical acquisition or merge products in NSW, please contact:

geophysics.products@regional.nsw.gov.au

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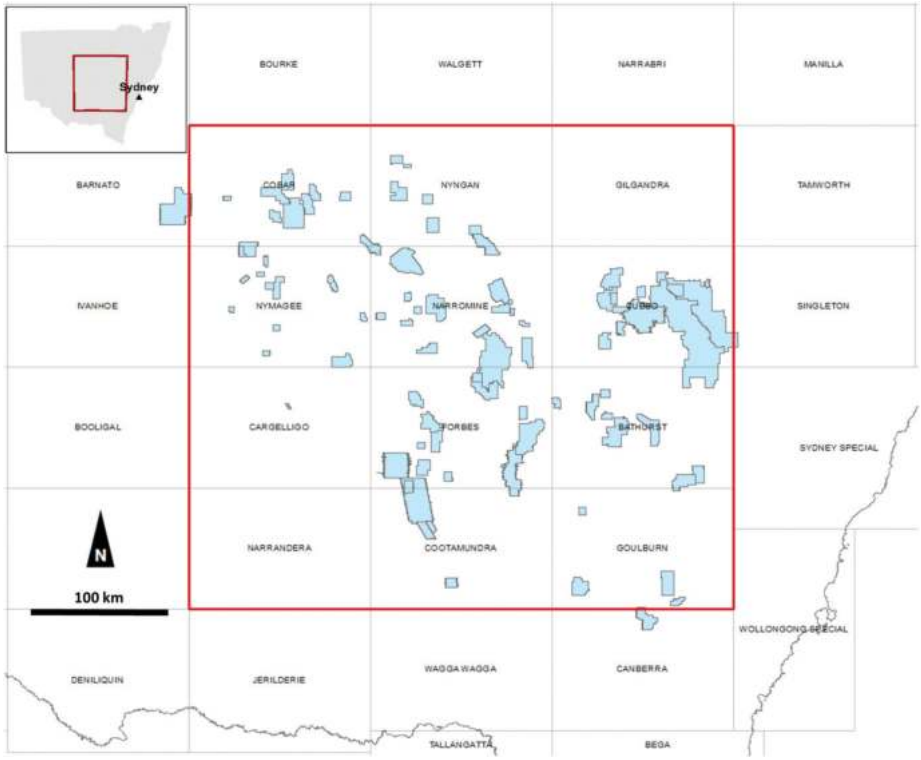

Figure 2. *Map displaying the area of the Central NSW ultra-high-resolution merge (red). Blue polygons represent surveys flown at 50 m line spacing which contribute to far higher resolution than is possible to display in the statewide merge products.*

Canberra observed

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The Australian Government's Critical Minerals Strategy, 2023–2030.

In July 2023 Madeleine King, the Federal Government's Minister for Resources, launched the Australian Government's Critical Minerals Strategy, 2023–2030.

Background

Copper, iron and nickel are always going to be in demand, but with need to increase electrification globally, a whole range of new minerals will be required

If you look at: https://www.ga.gov.au/scientific-topics/minerals/critical-minerals, you will see the twenty-six critical minerals identified by Geoscience Australia in July 2023.

Figure 1 shows some of the minerals needed to build batteries and four of the key critical minerals and Figure 2 shows where the mineral deposits and operating mines are situated – there's a lot of them.

Back to the strategy….

The framework

According to the Minister:

"Australia's critical minerals sector is well placed to seize the opportunities of the clean energy transition thanks to Australia's:

- rich geological reserves
- expertise at extracting minerals
- track record as a reliable producer and exporter of energy and resources."

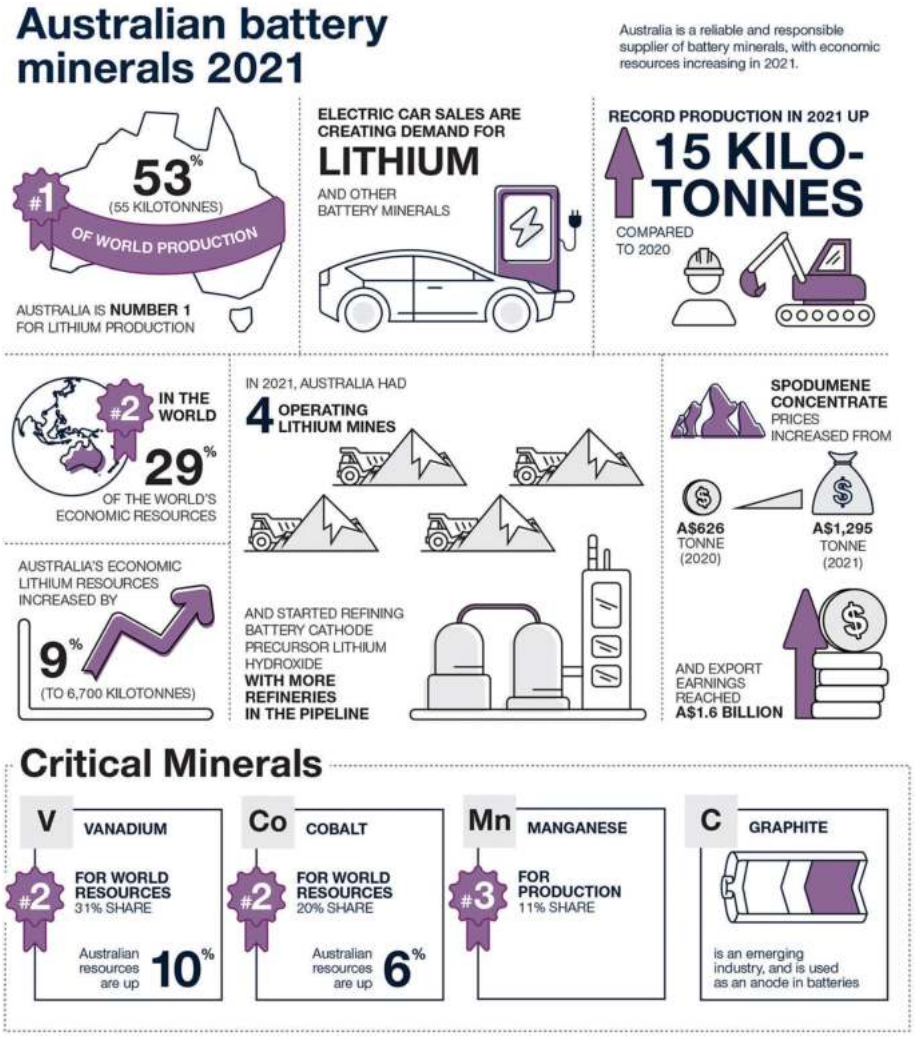

Figure 1. *Australian battery minerals 2021, and some critical minerals identified by Geoscience Australia (https://www.ga.gov.au/scientific-topics/minerals/critical-minerals.*

The vision

"By 2030 Australia:

- has grown the geostrategic and economic benefits of its critical minerals sector
- is a globally significant producer of raw and processed critical minerals
- supports diverse, resilient and sustainable supply chains."

Objectives

"create diverse, resilient and sustainable supply chains through strong and secure international partnerships

- build sovereign capability in critical minerals processing
- use our critical minerals to help become a renewable energy superpower
- extract more value onshore from our resources, creating jobs and economic opportunity"

You can read the whole report at https://www.industry.gov.au/publications/critical-minerals-strategy-2023-2030

Actions

Some of the words in the Vision and the Objectives may read like the script from *Utopia*, but when you investigate further you find that Geoscience Australia has a $225 million budget for the Exploring for the Future programme. This provides precompetitive geoscience data and information to encourage investment in new resource projects.

To date, the programme has stimulated new investment in Australia, with

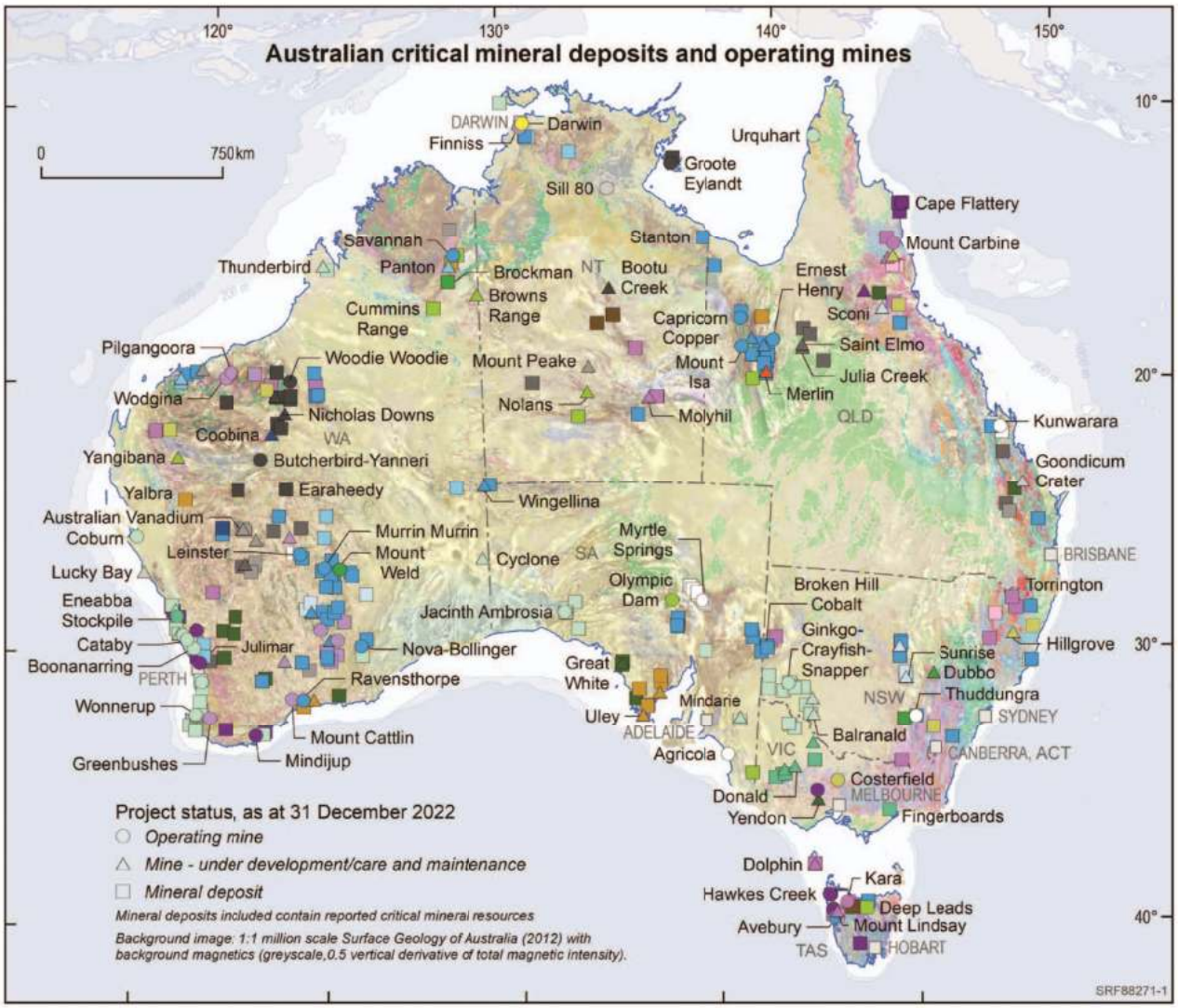

Figure 2. *Locations of critical mineral deposits and operating mines, from Geoscience Australia(https://www.ga.gov.au/scientific-topics/minerals/critical-minerals).*

the uptake of 419 new exploration tenements by 49 companies.

In addition, the $100 million Critical Minerals Development programme has provided nineteen grants to help early and mid-stage critical minerals projects to overcome technical and market barriers to production. These projects will produce minerals such as lithium, cobalt, graphite, high-purity alumina (HPA), tungsten, tantalum, battery precursor chemicals and vanadium.

Finally, there will be funding available from the $6 billion National Reconstruction Fund.

The future looks good!

Correction In the last paragraph of the *Canberra observed* column in *PV* 224, on page 24, all of the "millions" should be replaced by "billions".

Education matters

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Improving our education system

Our special guest in this issue is Dr Ian Mackinnon, Professor at the Centre for Clean Energy Technologies and Practices at the Queensland University of Technology. He is answering my questions about educational needs in the field of geoscience.

Ian Mackinnon

MP: Ian, before we start talking about education, can you tell us a bit more about your background?

IM: I commenced my undergraduate science degree (physics, chemistry, pure maths and applied maths) at James Cook University in the days when a scholarship was required to pay for the privilege – that is, before Whitlam-era free education. I scraped through first year but found chemistry relatively easy (my high school chemistry teacher – Mr Bonamini - has to be credited with that!) and, in second year, I decided to start on a full geology programme as well the other sciences. As you would probably know, nature's chemistry is much more intriguing and informative – particularly, as I learned later, when interpreting human-derived solid-state chemistry, now often seen as part of materials science.

So, it was not long before I became quite keen on mineralogy and what we might learn about geological processes from an understanding of crystal structures and physical properties. I completed full majors in both chemistry and geology but did not finish off the second degree because my Honour's year covered both with a geochemistry/crystallography focus mapping the megacrysts of Arthur's Peak. Uni holidays during those studies were spent on fieldwork in North Queensland with local exploration companies and earning just enough to cover the next year's car repair costs.

Geophysics is crucial to our understanding of planet Earth and was a torchbearer for the explosion of geological knowledge during the 50s and 60s that continues today

My Honour's project set me up for a more detailed PhD study on the crystal chemistry of pyroxene and amphibole megacrysts from Arthur's Peak – the assumption being that we could estimate the formation conditions of megacrysts by interpreting cation site occupancies in these minerals. Among the many knowledgeable and accessible academics at JCU at the time, both Les Power and Chris Cuff strongly encouraged this multi-disciplinary foray – unusual in Australia in those days –into exploring the combined tools of chemistry and geology. This first of my many cross- or multi-disciplinary studies required single crystal diffraction tools (neutron and X-ray) only available then at Lucas Heights (ANSTO). The plus with this arrangement were many lessons in the physics of diffraction as well as in practical data collection and analysis from the great onsite physics and computing staff. At the time, it also helped that I'd taken second year probability and statistics as part of that unfinished second degree; a useful background for thesis work and in later life.

Because of my interest in crystallography, it was natural to be caught up in the excitement of the first "atomic images" of minerals using high resolution transmission electron microscopy (HRTEM). Consequently, I decamped to Arizona State University (ASU) where – as it happened – quite a contingent of Aussies had established themselves at the Centre for Solid State Sciences.

ASU is still one of the leading centres for HRTEM and development of many other electron beam techniques. This focus attracted researchers from many backgrounds – mineralogy, meteoritics, crystallography, solid state physics and chemistry, metallurgy, thermodynamics, geochronology/geochemistry, economic geology, air pollution etc. etc. To be in an environment where the intersection of not only scientific disciplines but also of rapidly evolving technologies, were being pursued by outstanding researchers, was exceptional. This nexus – delivering outcomes from knowing the science while having an eye on emerging technologies – continues to be part of my professional activities today.

The focus of my latter years in the USA – at NASA Johnson Space Centre and the University of New Mexico (Dept of Geology) – became the use of HRTEM and Analytical EM to understand extraterrestrial minerals in meteorites and interplanetary dust particles. Sometimes this meant stripping down a TEM to modify and improve elemental analyses or developing new sample preparation techniques to benefit interpretation. So, very hands-on with instrumentation and with targeting "next generation" tools or equipment.

My mineralogical instincts became finely tuned as these extraterrestrial materials – at least those considered part of early Solar System formation – include layer silicates, or clays. Imaging these very fine-grained, beam sensitive minerals required a bit of dexterity with the instruments of the day. This led to analyses of other aluminosilicates such as zeolites and mixed layer clays common in catalytic conversion of hydrocarbons and in conventional reservoir formations. From my own educational perspective, mixing with meteoritics and Solar System researchers meant exposure to a wide range of disciplines – from astrophysics and planetary systems to geochronology, atmospheric physics, cosmochemistry and remote sensing. I enjoyed learning to speak the language(s) of different disciplines to try to understand what their paradigms were in order to see if there was a way to collaborate to solve specific problems. After all, we were chasing common objectives.

On returning to Queensland, I elected to translate that background knowledge into something that was useful for

Australia. So, I continued my interest in techniques to assess the clay minerals of Australia (our continent's surface, or regolith, is dominated by clays) as well as building characterisation facilities at The University of Queensland (UQ) that many other researchers could use; along the lines of the centre David Cockayne established two decades earlier at the University of Sydney. The vision was to provide a multi-user materials characterisation facility that all researchers at UQ could use; rather than lock up an expensive piece of equipment for just one special professor or one or two fortunate research students.

…the basic skills that postgraduates should gain, the primary and critical skill is a capacity for critical thinking without prejudice.

This approach has been successfully operating at the Centre for Microscopy and Microanalysis at UQ for about thirty years now, and I was able to improve and further refine the model when given the opportunity at the Queensland University of Technology (QUT). In the latter case, a wider range of analytical tools (*e.g.* for genomics, proteomics, histology, mass spectroscopy, electrochemistry, mechanical and physical properties) were included in the service model. The added benefit was that curious researchers from different disciplines could learn about, and gain access to, tools that may not typically be used in their field. So, fertilisation of new ideas – innovation even – is stimulated and delivered. In Australia, we are very fortunate to have similar styles of characterisation facilities at all capital cities and some regional centres; this makes for excellent performance in many STEM fields.

This approach to sharing expensive, or multi-disciplinary, research facilities is now not new – many of the NCRIS-style initiatives in earth sciences and environmental sciences (*e.g.,* AuScope, RV Investigator, ACCESS-NRI, ALA, NCI, TERN) – perform this function and are perhaps underappreciated by many in our communities.

MP: Ian, from your point of view, what changes can be made to further improve the education system in Australia in general, and in earth science in particular?

IM: Here I will only talk about Research and Development (R&D) because firstly, that is my primary experience and secondly, because R&D or RD&D, when done properly, is another form of targeted education.

To me, one of the things that we've not done very well in Australia for the past two or three generations, is that we've now trained researchers to be very much about "me", about themselves and their HI value or only about the group dynamics that they're working in. So, today's researcher might dig a deeper and deeper funnel of enquiry into their specific discipline; in some cases, this is beneficial – but few are trained to take the opportunity to look a little further afield – to look outside the hole that's been dug. Often this is driven by the current day obsession with bibliometrics which, for some reason, seems to be associated with prestige.

Most researchers intuitively know that a single digit performance parameter is rarely a good indicator of quality or of contribution to the stock of knowledge. Even in crystallography – a quite precise science – we use more than one parameter (*e.g.,* GoF, R, R_w, NObs) to assess the quality of data collection and analysis for a simplified average model of a crystal structure (nowadays, data collection can take about 10 seconds; compared to two reactor cycles – about eight weeks – in my student days at ANSTO). So, why do we, particularly in Australia, persist with quite specific terms (*e.g.,* h-index, FWCI) over very limited periods of time – to measure "research performance", or to determine promotion and progress, or to award grants?

Why is this important? Well, because we live in an increasingly complex world. All areas of STEM are expanding exponentially; not surprising since our global human population has been doing so since the turn of the 20th Century. These exponential changes mean we have a greater need for scientists, engineers, professionals to understand complexity itself and the complex world in which we and other species – plant, animal and the three other kingdoms – live. High school biology students learn about the "web of life" as context for how ecosystems succeed or fail. Today there are layers and layers of complex ecosystems – including that of research communities. We need to learn how these systems – be they natural, built or virtual – work productively and sustainably together for our future planet.

So, to go back to education in the broadest sense of the word, we should aim to train a proportion of our future research cohort to become what we used to term "model-T" professionals. The term is meant to describe persons with a strong disciplinary skillset moderated by an understanding, or perhaps an equally deep knowledge, of other disciplines (often closely associated within a broad field such as "geoscience", "engineering", "medicine", "manufacturing", "mathematics" or "energy").

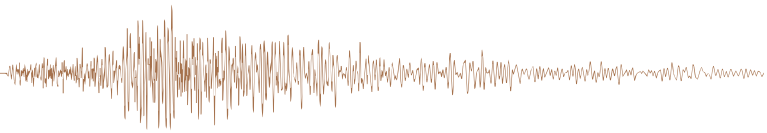
Which now brings me back to geology and those broad, interdisciplinary areas called geochemistry and geophysics – all of which are encompassed in one way or another by earth (and planetary) sciences. Training in earth sciences is a wonderful way to appreciate the truly unique location that we inhabit in our universe and, more importantly, to gain the skills for interdisciplinary research if that is a career interest.

…wouldn't it be great if one day we had a Prime Minister with a PhD in [insert STEM field]?

Geophysics is crucial to our understanding of planet Earth and was a torchbearer for the explosion of geological knowledge during the 50s and 60s that continues today. The International Geophysical Year (IGY) in 1957 was a stimulus for international collaboration to better understand our planet. The IGY precipitated many global practices we take for granted today such as use of satellites and geodesy, remote sensing, plate tectonics, stratospheric and ionospheric phenomena; and led to key legacy institutions. For example, the IGY led to establishment of the World Data Centre, the Antarctic Treaty and many other international initiatives over the past 60 plus years.

Better understanding of our planet set the stage for solar system exploration of all our planets, their moons and other bodies such as asteroids and comets. Many say that the book by Rachel Carson, "*Silent Spring*", started the environmental movement in the 1950s. What cemented a global awareness of planet Earth was the colour photo taken by William Anders called "*Earthrise*" as he orbited the Moon during the 1968 Apollo 8 mission. A photo that still resonates. For me, that's really what inspired many people to think about the fragility of our planet and our unique place in the universe.

Finally, one more matter for education in general. Good science requires excellent



communication and that includes writing. I notice that many of younger generations are not highly skilled in writing their *lingua franca* let alone English, even if it is their native language. Science and many other research areas now use English as the primary means of communication. Yet, we do not train our scientists in the finer attributes of writing in a language that is both facile and effective in communicating nuances of the field. My excellent high school English teacher used to drum two words into us: "concise and precise". This remains good advice.

…the focus for universities must be on … critical thinking, validation/verification of facts and assessment of methodologies all embedded within a broad perspective of history and culture.

MP: What do you think industry and government organisations expect from graduates? How do they see their new team members or recruits?

IM: Well, I can't really speak for recruitment from undergraduate education because I've not been involved in that part of higher education. I've only been involved in education at postgraduate level. So, in terms of the basic skills that postgraduates should gain, the primary and critical skill is a capacity for critical thinking without prejudice. For me, that is the core reason to do a higher degree, particularly a PhD. To show that you can think about and explain a problem, to identify what might be a possible solution, to then prosecute a means proving or disproving that possible solution and finally, to explain the learnings to others (*i.e.*, to educate).

I think if postgraduates go through that process successfully, then finding a job in any market is quite viable. In my view, we don't train people to do a PhD in order to become a clone of the supervisor or to view working in a university as "…the only option"; because that fundamental training in critical and rational thinking as well as in communication is very valuable. These skills are needed in all walks of life.

In an earlier role, I would often pose a rhetorical question to higher degree students: "wouldn't it be great if one day we had a Prime Minister with a PhD in [*insert STEM field*] ?" Sometimes, I'd say "geophysics" or "mathematics" or "climate science". Perhaps our debates in parliament on climate change over the past two decades would have employed fewer grandiose epithets and more reasoned discussion if persons with better content, or sector knowledge were present.

So, it would benefit our country if people in roles of importance better understood science, engineering, social science and technology. Wouldn't it be great if at least 10% of our parliamentarians had a background in the natural sciences? Most politicians are skilled professionals, and skilled in the art of politics. However, this does not always mean they have content know-how that draws on an intuitive understanding of geophysics, or of climate science or other key disciplines in our complex world. Many politicians in our government circles will seek advice from such professionals, but sometimes the advice is only as good as the question you ask. What I'm getting at is that people with sector knowledge can have very valuable input as practitioners in governance processes, whether at federal, state or regional/local levels. More "model-T" type professionals in our leaders of the future – we do have some today – would perhaps better prepare our communities for the challenges ahead.

MP: What must we change in the education system to provide the necessary specialists for the energy transition?

IM: In general, I consider that our Australian university system requires substantial change. To elaborate on all the reasons and the extent of change would take another day of conversation. However, to be concise, may I suggest one example: changes to university curricula are much too slow to address the exponential rate of change in knowledge, or to compete with the way new knowledge is now readily accessible to many. So, the focus for universities must be on those skills mentioned earlier – critical thinking, validation/verification of facts and assessment of methodologies all embedded within a broad perspective of history and culture. But this shift – to encompass rapidly transforming fields – needs to occur at a rapid pace at all levels of our higher education sector.

Additionally, we have failed to effectively demonstrate to our political cohort the long-term social and economic benefits of Australian R&D to our country. A nascent understanding of this may have entered the consciousness during the COVID 19 crisis; our epidemiologists, immunologists and virologists were at the forefront of scientific and practical knowledge on the topic – because the R&D community was prepared, coherent, and innovative. We should similarly prepare our R&D communities in earth sciences, environmental science, climate science and clean energy, as well as in the allied health and social sciences, for the future ahead.

We have also tended to cauterise our technology-related fields including the trades best served with on-the-job apprenticeships or training. This omission over the past decade or so has become evident in the energy sector – particularly in Australia – as we transition to a more diverse and less centralised approach to energy generation and use. Some states in Australia are addressing this gap in skills training in key regional locations, but there is much more to be done.

Hydrogen, particularly what's known as "green hydrogen", is important because it will help meet challenges in those industries with hard-to-abate greenhouse gas emissions

In both the technical skills and the professions, the energy transition will still require electricians and plumbers as well as electrical, mechanical, civil and process engineers, and many scientists. The training will be slightly different but related to this energy transition. In other words, the learning will be about new technologies, new systems and the safety and procedures required for a just and sustainable energy transition. I might add, this is nothing new – the curriculum for a geology degree or a power engineering degree granted in 1965 would be quite different to that of today – so, our educators are used to, and required to, adapt to changing community standards. My concern is about the pace of adaptation now required.

MP: What kind of specialist do we need to develop a hydrogen economy?

IM: I see hydrogen and the hydrogen economy as part of the overall clean energy story. Hydrogen, particularly what's known as "green hydrogen", is important because it will help meet

challenges in those industries with hard-to-abate greenhouse gas emissions due to dependence on fossil fuels. These challenges are being met – both here and overseas – but the innovations still need to be implemented at scale. For Australia, there is significant opportunity to re-imagine our industrial sectors by building upon our mining, farming, pastoral and transport industries to deliver value-added, and more integrated "green" products to our own consumers as well as to the rest of the world. By this I mean we add to our core industrial sectors with a wide range of sustainable products. These products could readily include "green" fuels, steel, ammonia, critical minerals, concrete, aluminium, building materials, cars, trucks, buses, data centres and all kit for renewable energy generation including for hydro and pumped hydro power.

Flexible learners and flexible learning environments with systems and equipment to gain practical hands-on skills and know-how are the key ingredients for success in the innovation value chain.

So, to answer your question, the type of specialist will, as noted above, still have the same general moniker – "electrical engineer", "sparky", "mining engineer", "chemist", "plumber", "environmental scientist", or "actuary" – but with different training and qualifications that reflect the know-how of this new energy economy. Some of these skills can be learnt "on-the-job" as industries transition and others via micro-credentials or through courses offered by professional associations.

Flexible learners and flexible learning environments with systems and equipment to gain practical hands-on skills and know-how are the key ingredients for success in the innovation value chain. That's why I've spent a reasonable part of my professional life planning, facilitating and establishing pilot plants for different processes (zeolite manufacture, water treatment, battery manufacture, green hydrogen production) as well as building analytical centres in order to help our communities appreciate the benefits of these environments.

Environmental geophysics

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Inversion for difference

Welcome readers to this issue's column on geophysics applied to the environment. For this issue, I was inspired by a conversation that I had recently with Tim Munday, from CSIRO. He told me about some interesting developments in the data inversion space. He was referring specifically to "inversion for difference".

Most of us take "raw" data sets, *i.e.,* some form of voltage data recorded from various ground sensors, and use various pieces of computer code that invert these data into something that we hope reflects the "real" distribution in the ground of conductivities, or seismic velocities, or whatever information our ground sensors are designed to collect. We then use other information (drill data or geological info, *etc*.) and our imaged inversions to "fill in the dots" between sparse data to help us interpret the bigger picture.

However, especially in the environmental/engineering space, we may be collecting data that is intended to quantify a localised change in the property that we are measuring. For instance, over the last few years I have been involved in a project collecting electromagnetic induction (EM) data over floodplains on the River Murray in South Australia. The aim of this project is to quantify changes in salinity levels on these highly salinised floodplains when they are either naturally or artificially flooded. Like my Riverland surveys, more and more surveys are run to collect a baseline data set and then subsequent data snapshots are collected, hoping to see change as environmental conditions change.

My (apparently primitive) approach to visualising the change is to invert each "snapshot" dataset separately, and then to manually highlight areas in each inversion generation that appear to have changed. I have considered calculating conductivity residuals on the data sets but, with noise and natural variability, this has seemed to me to be unlikely to work. So maybe I need to be inverting for "change" rather than for "best image".

In most of the papers that I have read in preparing this column (see references below), this is the simplest version of the "independent inversion" approach, since each time step is inverted independently of every other. It is possible (and more sophisticated) to run a "normal" inversion on the first data set and then invert for either "conductivity differences" or "ratios". Again though, each step is inverted independently and any noise or other external factor affecting a given data set will affect the final result.

So far, we have more or less covered what I have at least contemplated for my big, multiple generation data sets. According to the literature, the better approach is to run "time constrained" inversions. In these approaches, the cost function used to "regularise" the inversion include a weighting term that is used to minimise the difference between data snapshots (see *e.g.* Equations 6 and 7 in Dimech *et al.* (2022)). Dimech *et al.* (2022) and others then tell us that there are two different approaches to using this new regularisation scheme. The slightly simpler (and apparently less effective) approach is "cascade" inversion. The initial data set (the baseline data) is run using normal inversion controls. Each subsequent data snapshot is inverted using the previous inversion results as starting models, and the constraint equation described in Equation 7 (Dimech *et al.* 2022). The more sophisticated methodology is the "simultaneous" approach where all data sets are inverted simultaneously using the regularisation terms described above. This way, all of the data sets are constrained exactly the same way and the results have to really "fit together".

An interesting paper to look at in this space, at least for me as it focuses on ground EM data and inversion, is Xiao *et al.* (2022). In this paper the authors first show results on a synthetic data set, and then on a real data set, using the simultaneous inversion approach to invert time-lapse transient electromagnetic (TEM) data collected over a geothermal project in Iceland. They show the results by plotting each inversion separately, and then calculating resistivity ratios from each of the inversion snapshots. Their approach appears to be quite robust, as, for example, the number of data points used between inversions was different (and at slightly different locations). The ratio plots for the simultaneous inversions are big improvements over the ones prepared using the independent inversion approach.

I don't usually dabble in the seismic space, but in the process of researching this article I found an interesting book chapter by Lin *et al.* (2022) on time lapse inversion applied to seismic waveform inversion. In this work the authors, once again, firstly show how the method works on synthetic data, and then provide a case study based on reservoir monitoring in Texas. So far as I can tell, they used the cascade approach (initial model, and then inverting for differences) but replace the "normal" data misfit term in the regularisation terms so that their inversion minimises not only true data change between two snapshots, but also include a term that minimises the simulated/modelled data between the two snapshots. They call this "double differencing". Ultimately, the two inversions are differenced to plot an inversion residual. They show the results of a number of inversion variations and, to no one's surprise, the inversion version with the most sophisticated processing produces the best result - pretty convincingly.

As an aside, the Dimech *et al.* (2022) paper discusses how a measured resistivity may vary significantly depending on the temperature of the data medium (*i.e.* the ground in most cases). They state, based on other studies, that "resistivity decreases by a factor of close to 2% for an increase of 1° C in the medium". They argue that this should be accounted for when comparing data collected at different times of the year (even for diurnal variation). In my work I have always assumed that temperature variation didn't affect my ground data much, especially below about 1 m depth, and really only affected deeper surveys like MT, where the crust and mantle temperatures are (significantly) different at different locations. I'm going to have to look into this further.

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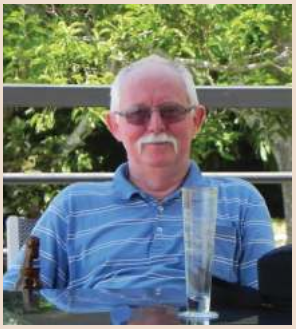
Minerals geophysics



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Aspects of innovation II

In this issue of *Preview,* we have another in the series by geophysical contractors and consultants who are innovators in their field. Andrew Carpenter from Expert Geophysics describes aspects of the development of the MobileMT system, an advance in airborne magneto-tellurics (MT) surveying. As a proponent of MT for use in a wide range of resistivity environments, and a past user of the technique in ground surveys, continued development of an airborne version is definitely of interest. I invite you to read Andrew's contribution below.

And, as I wrote in the last issue of *Preview*, if you or your organisation have a story of innovation in mineral exploration geophysics you'd like to tell, please get in touch. We'd love to hear it.

Expert Geophysics driving ground-breaking new developments in airborne AFMAG technology

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MobileMT in the Patterson Ranges.

Australia is an ancient continent, and much of its undiscovered mineral wealth is masked by a thick cover of weathered rock, regolith, sediment, and soil, posing formidable exploration challenges. Mineral explorers lack the technological tools to discover new resources buried beneath the cover. Expert Geophysics, a Canadian company with offices in Toronto, Perth, and Johannesburg, is leading the development of the latest Airborne EM technologies capable of penetrating Australia's deep and highly conductive cover.

Historically, airborne electromagnetic induction methods (AEM) with controlled primary field sources have been given attention by many specialists. Frequency-domain systems (FDEM), which use a harmonic magnetic field source, were under constant development and active use during the last century. After many decades of service, the frequency-domain method remains limited in its depth of investigation despite being sensitive to a broader range of resistivities. Time-domain systems (TDEM) excited by a step pulse have replaced frequency-domain systems for most exploration applications due to a greater depth of investigation. Many improvements to airborne time-domain systems were achieved during the last 20 years. However, several limitations persist that restrict the use of the time-domain AEM principle, including:

- The depth of investigation only sometimes meets exploration requirements, especially in conductive environments and areas with conductive overburden.
- The measured signal and depth of investigation are highly dependent on the transmitter height, tilt, and geometry.
- This dependence creates difficulties and restrictions for surveys in rugged terrain.

- There are challenges in getting a measurable response in relatively resistive terrain (commonly higher than 1000 ohm-m) and subtle resistivity contrasts.
- There are parasitic IP and SPM effects on measured induction under specific near-surface conditions.

Methods that exploit natural electromagnetic fields (magneto telluric and magneto variational, AFMAG) can overcome the limitations of airborne systems with controlled primary field sources. A comparative estimation of the depth of investigation of different airborne electromagnetic principles is presented in Figure 1.

The first period of theoretical development and practical usage of AFMAG (audio-frequency magnetic technique) as an inductive electromagnetic method exploited audio-frequency natural magnetic fields. One of the main reasons for the development was the potential to provide significant depth information without exploiting technically limited primary field, controlled sources. McPhar Geophysics Limited commercially used the airborne AFMAG system in the 1960s and early 1970s. The company then shifted their commercial focus to radiometry, and thus the development of electromagnetic methods was terminated.

The Dicon/Q-Trac airborne EM system introduced in 1997 by Barringer Geosystems Inc (USA) based on natural source AMT/MT was listed under the testing/R&D status. The Dicon system, in its test configuration, measured orthogonal components of the E and H fields.

High-Sense Geophysics (Canada) further developed an AFMAG system in 1998 with Petr Kuzmin. The first field test, in 1999, was successful and promising. The development was terminated after consolidation with Fugro.

Other airborne AFMAG prototypes in 2001 and 2002 developed by Geotech Ltd. played the role of transitional and non-commercial designs. The AirMt system with three orthogonal inductive receiver coils was announced as being at an R&D stage and was not commercially available. The AirMt system measured the rotational invariant part of the in-phase and quadrature transfer functions in the frequency domain for three magnetic geometrical components from the airborne receiver and three magnetic geometrical components at a stationary reference base station.

The tipper-type, magnetovariational airborne platform ZTEM became the next generation of AFMAG technology and the first commercial airborne 'AFMAG' system more than 40 years after the original AFMAG. The ZTEM system is based on measuring the induced signal's vertical magnetic component, primarily caused by lateral resistivity variations in the subsurface geology. ZTEM outputs are the tipper components as the transfer function of a vertical magnetic field; Tipper measurements (Hz/Hx or Hz/Hy) are dimensionless, cannot resolve layered geology, and tipper responses are considerably diminished for compact 3D bodies compared to 2D geological strikes. Since the tilt of the flying coil is unstable during a survey, ZTEM uses attitude sensors to correct the source of the error. Still, the error correction quality is affected by unknown differences in the horizontal components between the audio-magnetic field magnitudes at the reference and in-flight positions.

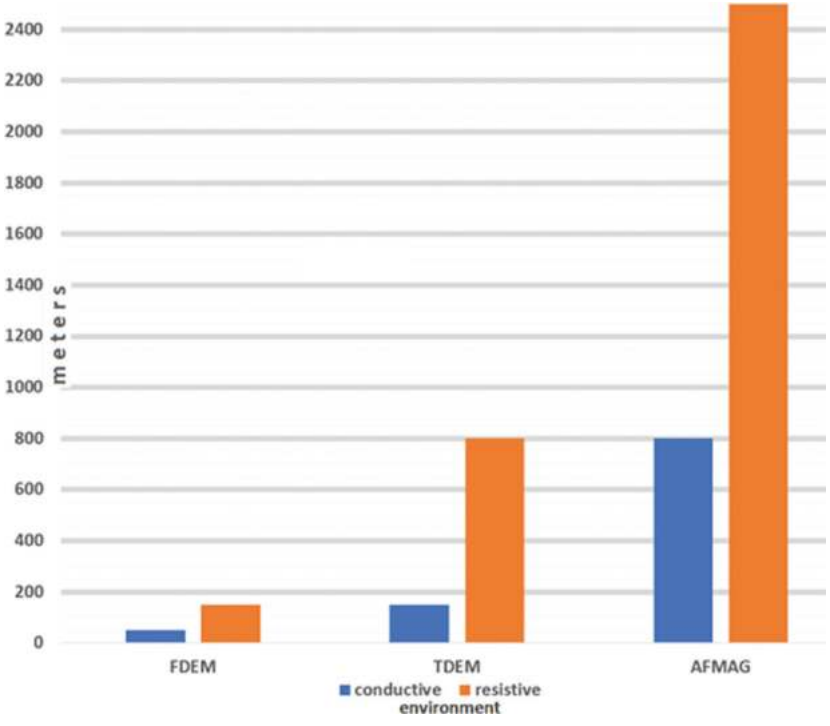

Figure 1. *Approximate depth of investigation estimation of different airborne electromagnetic principles.*

All the systems from the AFMAG family suffer from bias effects of the recorded data, arising from weak natural signals. These distortions cannot be corrected by signal filtering, and, as a result, significant systematic errors and false anomalies occur. This technical problem has been solved with the development of the MobileMT technology.

The MobileMT system, introduced in 2018, was developed by Expert Geophysics Limited to continue the evolution of the airborne electromagnetic natural fields technology 12 years after the introduction of ZTEM and 60 years after the first commercial AFMAG system.

MobileMT in Western Australia.

MobileMT employs an airborne receiver which comprises three orthogonal induction coils to take measurements of alternating magnetic fields, and a ground electric base station, which measures reference and signal electric fields in two perpendicular directions with four pairs of electrodes. The E-field base station includes the 'reference' orthogonal pair of grounded lines, utilised to eliminate local noise, and correct for data bias distortions. In the MobileMT technology, the E-field data is used to reference the primary natural electromagnetic field variations to facilitate the separation of the time-variance from the space-variance of the measured fields.

The signal-to-noise ratio for the electrical field measurements is considered much higher than the signal-to-noise ratio for the magnetic field, which is one of the advantages of the MobileMT system. The electric component of MobileMT is one of the features that distinguish it from its predecessors.

The technical solutions realised in the airborne MobileMT technology provided exploration capabilities that overcome the limitations of other AEM systems based on different principles, including those using controlled primary field sources.

The specific technical advancements that enable exploration advantages include:

- Measurement of magnetic field variations with three orthogonal coils (total field). This provides sensitivity to any direction of geoelectrical boundary, from horizontal to vertical.
- Measurements are obtained over three decades of frequency, from 19 Hz to 26 kHz. This allows imaging of near-surface structures and those at > 1 km depth, depending on the conductance of the geologic environment.
- The frequency range is divided into 30 windows that provide high in-depth resolution and a good opportunity for data selection, depending on cultural noise sources, natural EM field signal, and exploration goals.
- The high sampling rate of the airborne data and the base station data result in bias-free and denoised data.

The main advantages of the natural field method, in general, include:

- The depth of investigation consistently exceeds the capabilities of systems with controlled sources.
- The method is sensitive to conductors and resistivity differences in the range of thousands and tens of thousands of ohm-m, which is challenging for existing time-domain systems. At the other end, for time-domain systems, the response from superconductors (hundreds and thousands of Siemens) is not visible in the off-time channels of the dB/dt stream. For the natural field EM principle, it is not a limitation.
- There is no critical dependence on the terrain clearance of the system. This allows for less aggressive flying in rugged terrain conditions, improving the overall safety of data acquisition.

IP and SPM parasitic effects are inherent to impulse time-domain systems that badly influence the inductive response. These effects are not formed and do not distort the secondary electromagnetic field data for methods using natural fields.

An excellent example of the advantages of MobileMT technology was acquired at Coda Minerals Elizabeth Creek project, located in the Olympic Dam district, which is a belt of Cu-enriched basement of the Gawler Craton, South Australia. The district's Mesoproterozoic and older crystalline basement is overlain by a thick succession of Neoproterozoic, Cambrian, and younger sedimentary basin rocks known as the Stuart Shelf. The copper-cobalt deposits (fine-grained sulphides) are hosted by flat-lying, undeformed Late Proterozoic sedimentary rocks deposited on the Stuart Shelf. These platform sediments are known as the 'Cover Sequence,' they unconformably overlie the complexly deformed and metamorphosed igneous rocks of the Archaean basement. The Emmie Bluff prospect in the north of the Elizabeth Creek project is an underground target with a top of mineralisation at around 400 m depth from the surface.

Historically, several active source airborne EM surveys have been flown in South Australia, including VLF (very low frequency) and frequency domain and time domain surveys. Due to the presence of highly conductive cover, the success of these methods to aid in the location of ore deposits has been limited. The Gawler Province is an area approximately the size of France, with very little fresh rock outcrop. As such, understanding the subsurface relies on information from drill holes and non-invasive geophysical methods. Despite the conductive cover/regolith, which limited the success of other airborne EM technologies, the MobileMT data successfully mapped the strata-bound zones with related mineralisation at depth.

Figure 2 shows the resistivity section derived from 1D inversions with the

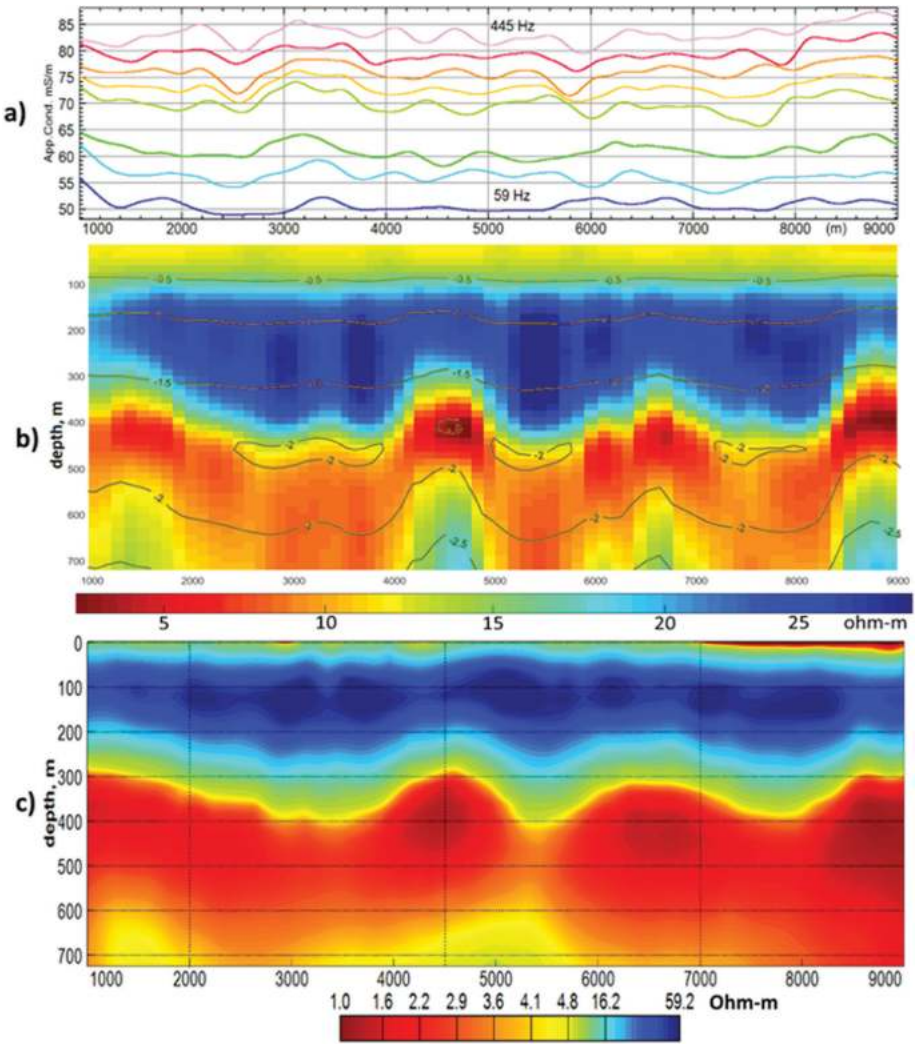

Figure 2. *MobileMT apparent conductivity profiles (a); resistivity section from the 1D model with contours of the data inversion logarithm of sensitivity (b); resistivity section from the 2D model (c) along a survey line from the Emmie Bluff prospect over a known mineralisation.*

logarithm of the inversion sensitivity contour lines for the DOI reference. Corresponding resistivity-sounding curves from the measurement stations along the line are also shown. The resistivity section resulting from 2D inversions of the data along the same line is shown in the final figure. The 1D and 2D inversion results are consistent; just absolute values of resistivity derived from the 2D model should be closer to reality for non-layered conductors.

Ground magnetotelluric data was acquired between 0.001 and 250 Hz with a site spacing of approximately 500 m. Twelve frequencies were involved in the MobileMT data inversion between 27 and 445 Hz. The depth range of the sections is limited by the MobileMT depth of investigation estimated for the survey area. The results of inverting the ground magnetotelluric data vs the MobileMT data are provided in Figure 3. This field example demonstrates exploration capabilities of the airborne MobileMT technology in a highly conductive environment with decent depth of investigation. Direct comparison of the airborne EM with ground MT resistivity shows a good match between the two resistivity-depth images.

Expert Geophysics is a company primarily driven by R&D; there are more technicians and engineers on staff than there are geoscientists. The engineering team led by Petr Kuzmin continues to pioneer the latest in AFMAG technologies, with improvements to the MobileMT technology rolling out regularly. Andrei Bagrianski, the company's President and Alexander Prikhodko, the company's Chief Geophysicist, work closely with clients to find new technological solutions to today's geophysical exploration problems. An exciting new development driven by the industry's need for new technology includes the TargetEM system, a new patent pending airborne time-domain electromagnetics system, which combines the latest achievements in electronics and sophisticated signal processing techniques to extend the capabilities of current airborne time-domain systems into the future. The system is designed to provide VLF, AFMAG, and time-domain EM data, all acquired simultaneously on a single platform. The technological leap forward offered by the TargetEM is only just being realised, with several software and processing vendors currently working towards taking advantage of the capabilities of this new exploration tool.

TargetEM 26 now flying in Australia.

As technological advancements continue and improvements are made to the hardware and software involved in the MobileMT technology, it is anticipated to become an increasingly reliable and versatile tool for the mining and resource industry. Advancements to the 1D modelling used to invert the apparent conductivity data and retrieve the resistivity depth distribution are ongoing to improve the agreement between the theory and the real-world implementation. In addition, 2D inversion codes, such as MARE2DEM, and 3D inversions, compatible with MobileMT data, can provide more accurate resistivity models in specific circumstances. With the advent of the TargetEM, which sees the merging of the very best of time domain, VLF and AFMAG technology, the future looks bright for Airborne EM surveying globally and in Australia specifically as the ability to acquire data across a broader range of resistivities and explore deeper from the air than ever before offers new and much needed technical capability to Australian mineral explorers.

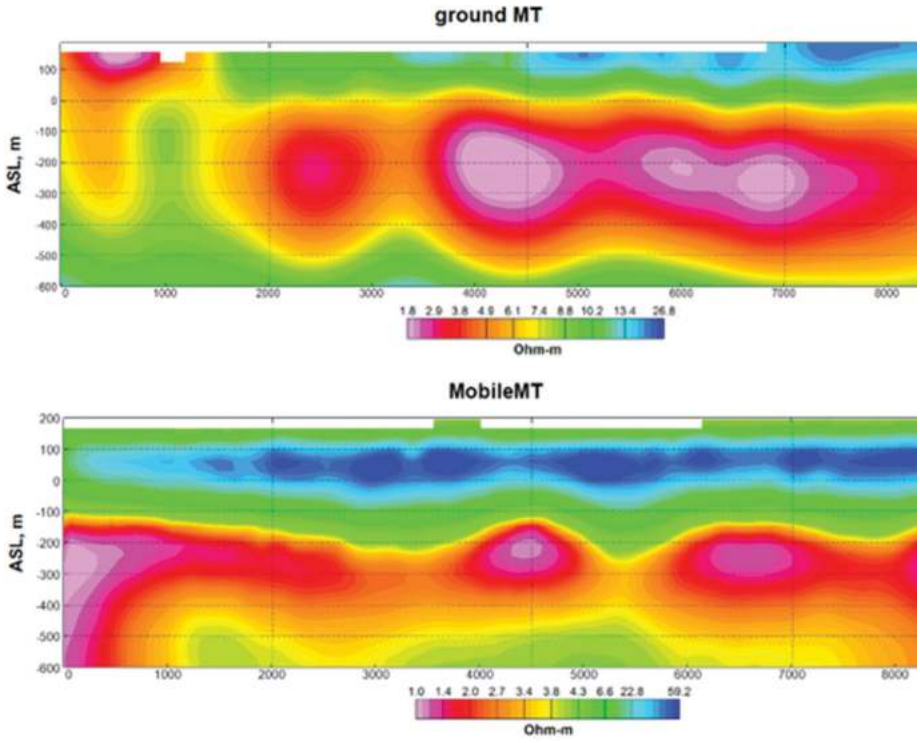

Figure 3. *Resistivity sections over the same line derived and inverted from MobileMT and from ground MT data provided by CODA Minerals. Emmie Bluff block.*

Seismic window

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Conference highlights and trends

I recently attended the APPEA (Adelaide) and EAGE (Vienna) conferences and it is quite obvious that the direction of exploration has changed significantly in the last year. The transition to nett zero has taken off with all the talk about renewable energy and the role of gas as a transition fuel. Nobody mentions oil at all anymore. I feel like a blacksmith standing by my forge watching all the cars drive past. At least I'm familiar with all the new buzz words such as "net zero", "carbon capture and sequestration (CCS)" and "hydrogen".

On another tack, a new product that will have a big impact on us all is Artificial Intelligence. This is not the AI I have used for defining faults in seismic data, but rather it is software that can write articles for *Preview*. So, for a little bit of fun, I tried the AI software that had somehow wormed its way into my computer using only the list of buzzwords above as input. Three seconds later I had a 250-word article. No more racking my brain for ideas for me, just think of a topic and somewhere a full-blown *Preview* article is created in less than a minute and sent to the Editor. See what you think – the AI article below seems to make sense to me.

> "The transition to a net-zero decarbonised economy has become an urgent priority in addressing climate change, and Carbon Capture and Storage (CCS) coupled with hydrogen production plays a crucial role in this endeavour. CCS technology involves capturing carbon dioxide (CO_2) emissions from industrial processes and power generation, transporting it, and then securely storing it underground. This process prevents CO_2 from being released into the atmosphere, effectively reducing greenhouse gas emissions.
>
> Hydrogen, as a clean and versatile energy carrier, has gained significant attention in the drive towards decarbonisation. It can be produced through electrolysis, utilizing renewable energy sources, or through reforming fossil fuels with CCS. The latter method, known as blue hydrogen, allows for capturing and storing CO_2 emissions, thereby enabling the production of low-carbon hydrogen.
>
> By integrating CCS with hydrogen production, the energy sector can effectively decarbonise various industries, such as transportation, power generation, and manufacturing. Hydrogen can be utilised in fuel cells for zero-emission vehicles, blended with natural gas in existing gas pipelines, or used as a feedstock for industrial processes like ammonia production.
>
> The CCS-hydrogen transition offers a unique opportunity to rapidly reduce emissions while maintaining energy security and supporting economic growth. However, successful implementation requires substantial investments in infrastructure, research, and development. Governments, industries, and research institutions must collaborate to accelerate the deployment of CCS and hydrogen technologies, establish supportive policies and regulations, and foster innovation.
>
> In conclusion, the combination of CCS and hydrogen technologies presents a promising pathway towards achieving a net-zero carbon economy. This transition holds the potential to significantly reduce emissions from various sectors and enable the long-term sustainability of our planet."

Nodes

I mentioned ocean floor nodes in an article earlier this year but what about onshore? In the EAGE Exhibition Hall I was impressed by the latest node technology being showcased by STRYDE (www.strydefurther.com). At only 129 mm high and 35 mm diameter (Figure 1) these are the world's smallest nodes. In that small package there is a battery and memory for

Figure 1. *This 150 g node contains a battery, memory, GPS and a sensor and can continuously record seismic data for 28 days.*

28 days continuous recording (or 45 days if they are told to turn off at night) plus a GPS receiver and a sensor. That's a lot to pack into a 150 g package. Charging is by induction and takes four hours, and data is also harvested wirelessly so there are no plugs or ports.

These nodes have been tested in urban and rural areas with snow, deserts, jungle, and rocky terrains and I expect we will see more of them in future seismic surveys.

Boulders

Another trend in seismic interpretation software is the move away from traditional picking and mapping with vendors now concentrating on reservoir modelling and simulation. No doubt this is because engineers tend to have easier access to exploration funds. But a number of software companies have implemented a boulder detection module. This works best in the shallow section and is used to identify possible boulders which may be troublesome when installing the foundations for wind turbines.

Well, that's my take on the conferences and exhibitions – now it's back to the forge for me.

Data trends

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

Sustainable files assessment

Kim Frankcombe pointed me towards the seven factors the US Library of Congress use to assess if a file format is sustainable, and therefore suitable for them to store.

https://www.loc.gov/preservation/digital/formats/index.html

Their seven pillars of sustainability are:

- Disclosure – how accessible is the file and can you make one? Of note from the site, "What is most significant is not approval by a recognized standards body, but the existence of complete documentation".
- Transparency – can it be opened with basic tools such as a text-only editor (note to self – are there generic binary editors with a GUI that let me easily play around with data types until it looks right?)
- Self-documentation – a basis of information to use or display the data correctly (starting points, datums, formatting, etc).
- External dependencies – hardware and software requirements
- Patents – as we have found, "open" licenses change with ownership. We cannot fault companies for running a business, but need to understand what people will do with the data when said company is no longer around.
- Technical protection mechanisms – if a certain program stops, does encryption/compression also stop access?

For an example we looked for the mother of the ER Mapper grid file – the BIL (Band Interleaved by Line), see Table 1. US Congress list this as one of their sustainable formats, which is often accompanied by ASCII text files allowing transparency.

Table 2 describes the results of a basic analysis using the US Congress format to assess our beloved grid file. We intend to apply this to our other file types to construct a reference, which will likely be published on our website for others.

Table 1. Earth Resource Mapping Raster (ERS) grid file: Identification and description

Full name	Earth Resource Mapping Raster (ERS) Image Encoding
Description	Earth Resource Mapping Raster (ERS) is a discovery wrapper for Band Interleaved by Line (BIL) Image Encoding. Data is stored in a binary file with no extension line by line as per the BIL encoding format. Additional information needed to interpret the image data is provided in the accompanying .ERS text file of the same name, such as the numbers of rows, columns, and bands, and relate the image to geospatial locations. Additional information may be contained in a header within the BIL raw image data file.
	Relationship to other formats
Contains	BIL, Band Interleaved by Line (BIP) image ERS,
Equivalent to	ERS, Earth Resource Mapping Raster ASCII data

Table 2. Analysis of the sustainability of the Earth Resource Mapping raster (ERS) grid file format

Disclosure	The uncompressed raster data encoding is described by the BIL format and requires no formal specification. Usage data is described in the ERS text file.
Documentation	The technical description for ERS data are described in www.aseg.org.au or Scribd. Data is readable by following BIL such as Understanding Rasters by Joseph Collins-Unruh and BIL, BIP and BSQ raster files from ESRI online documentation.
Adoption	ERS is effectively an information wrapper for the common BIL raster image encoding for remote sensor data. File reading and writing are supported by many commercial programs such as ENVI, ER Mapper, Intrepid, Geosoft and other geophysical programs. File reading and writing is also available in Open Source software such as QGIS and SAGE. ESRI products read but do not write. See BIL_enc for information on imagery distributed in BIL encoded format.
Licensing and patents	None.
Transparency	The raw data has a simple form and image dimensions, and the number of spectral bands are supplied in the ERS text file.
Self-documentation	A companion ASCII header file contains a wide range of data regarding image capture instrumentation, date, and other data for identifying, displaying, and georeferencing the image.
External dependencies	Accompanying header files may be compatible only with certain software applications. It is relatively straightforward to program a language to read and write the binary and ASCII text files.
Technical protection considerations	No capabilities for encryption or other technical protection mechanism inherent in the format or in its use have been found by the compilers of this analysis.

Webwaves

Ian James
ASEG Webmaster
webmaster@aseg.org.au

Figure 1. *Website access by country (January - July 2023).*

The 2023 ASEG website redesign

In today's digital age, a well-designed and user-friendly website is crucial so that the ASEG can effectively engage with its Members and the wider geoscientific community. Last year we recognised the need to revamp our website, http://www.aseg.org.au/, with a focus on addressing various usability challenges and providing an enhanced online experience.

Views of the ASEG website continues to increase, so now is a good time to refresh the platform and optimise on the increasing exposure. Figure 1 shows the number of website users by country for January to July 2023. While activities including the CAGE field camp have driven high numbers of viewers, *Preview*, events and technical content continue to be the most viewed pages. *Preview* continues to be the most viewed content on the ASEG website.

Some of the top issues being addressed in the website redesign are outlined below.

Improving login and access:

> To combat login and access issues, the redesign is incorporating a fully integrated and refreshed database using Membes, a robust membership management platform. Membes streamlines the login process, allowing members to access their accounts without being diverted out of the website for authentication. Additionally, the signup and renewal process will be upgraded, removing a common pain point on the website.

Easier access to popular pages:

> The redesigned website makes it easier to access popular pages, such as *Preview, Exploration Geophysics* and events. Links to these pages will be prominently featured in a secondary menu at the top of the homepage.

Improved volunteer experience:

> Volunteers play a vital role in the success of the ASEG. Recognising this, the website redesign includes the integration of event creation and registration. By implementing a user-friendly event management system, volunteers can easily create and manage events, track registrations, and communicate with participants through the website. This integration will not only streamline operations but also enhance the overall experience for volunteers, which we hope will lead to increased participation. Additionally, by integrating with the ASEG Member database, participation at ASEG events can be tracked.

Simplifying and refreshing the website:

> Advancements in web design and user expectations have necessitated a redesign of website features to a simplified and intuitive user interface, ensuring easy navigation and improved readability. A responsive web design philosophy has been used to ensure users are able to access content equally well, regardless of the screen size and resolution of their device.

Feedback welcome:

> Whilst we look forward to a refresh and enhanced version, the current website has served its purpose for the last seven years. However, the redesign of http://www.aseg.org.au/ will mark a step forward in enhancing user experience and promoting the online presence of the Society, with the new website aiming to be up before we open membership renewals for 2024. Feedback on any issues with the current website or input into content on the new website is always highly appreciated and should be sent to webmaster@aseg.org.au.

Figure 2. *Mock-up of the updated ASEG menu with direct link to Preview on the homepage.*

WORKSHOP HANDBOOK

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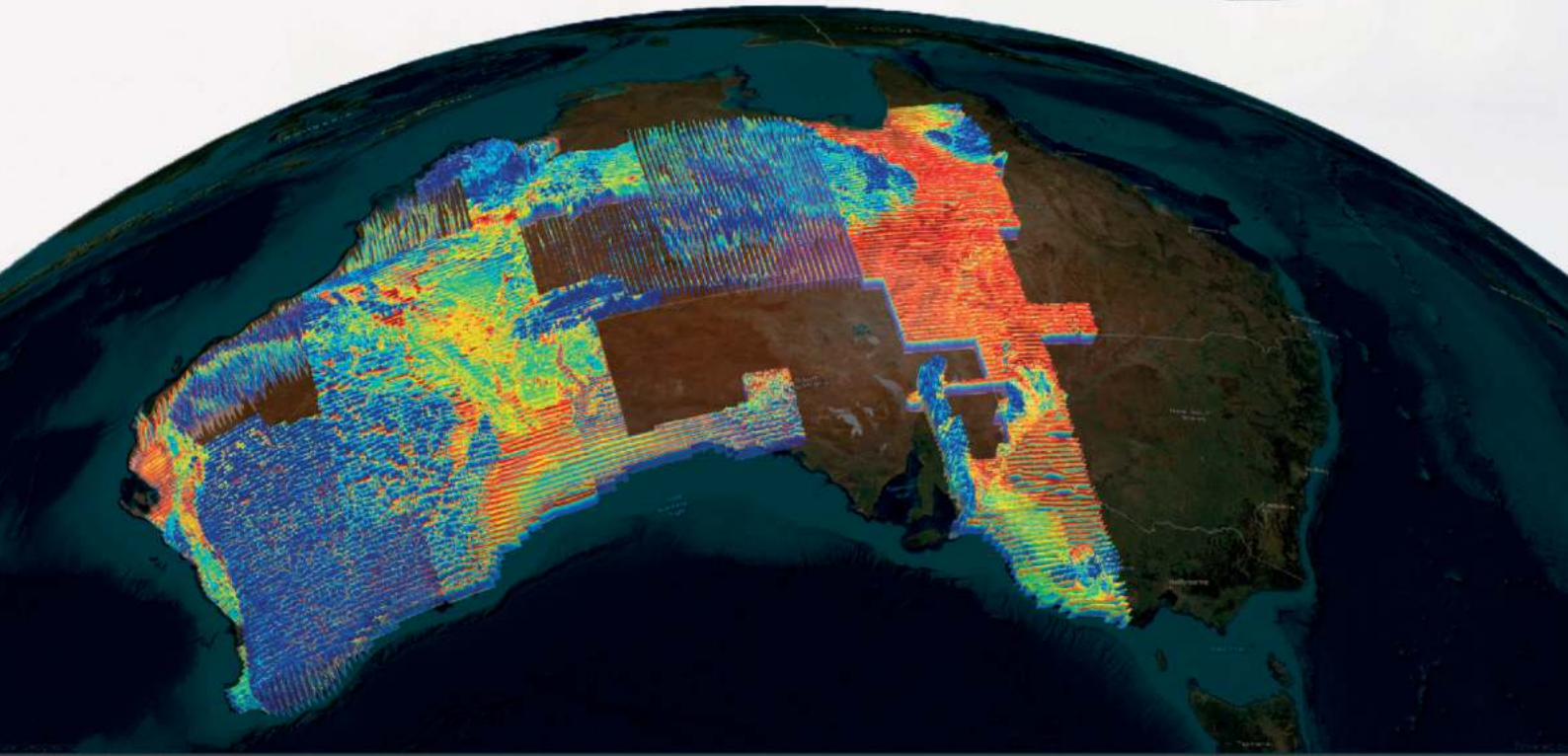

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Welcome to AEM 2023

On behalf of the AEM 2023 Organising Committee it is a pleasure to welcome you to the 8th International Airborne Electromagnetics Workshop. The event, being held between Sunday the 3rd and Thursday the 7th of September 2023, will be at the Fitzroy Island Resort in tropical north Queensland, Australia. The workshop, now held every five years, has established itself as the foremost international event concerning airborne electromagnetic technologies and their application.

I would also like to take this opportunity to acknowledge the Guggandji people as the Traditional Owners of the land on which we will be meeting and pay my respect to their Elders past and present.

We have a full programme with over 60 presentations planned by participants from ten countries. The subjects vary from acquisition, system development and improvements, semi-airborne systems, case studies for groundwater, volcanology and minerals applications, open-source data and software and AI to name just a few. It's great to see work from such widely varying perspectives and backgrounds being shared at this workshop, which is part of a series held only every five years.

Our invited speakers come from across the globe and will cover a variety of topics. They include Andrew Green, Magdel Combrinck, Lindsey Heagy, Katherine McKenna, Bradley Moggridge, Andi Pfaffhuber and Bernhard Siemon.

I'd also like to acknowledge and sincerely thank our sponsors, without whom we wouldn't have had the opportunity to run this event. Our confirmed sponsors include Xcalibur Multiphysics, Geotech Ltd., Skytem Australia, Geoscience Australia, NRG Australia, and CGG Electromagnetics.

Hosts for the event are the Australian Society of Exploration Geophysics (ASEG) and CSIRO, and on behalf of the Organising Committee I'd like to express our appreciation of their support for this event, helping bring together researchers, practitioners, and industry professionals to foster collaboration across disciplines and help drive innovation in this field.

Lastly, a special thanks to the authors for their valuable contributions. The research and insights shared during the workshop will undoubtedly serve as a valuable resource for many years to come, aiding future advancements and discoveries in airborne electromagnetic technologies.

Once again, a warm welcome, and I hope that the workshop proves to be an enjoyable and memorable experience for all participants.

Andrew Fitzpatrick
Chair AEM 2023 Organising Committee
Andrew.Fitzpatrick@igo.com.au

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MONDAY 4 SEPTEMBER				
START	**FINISH**		**SPEAKER**	**SESSION**
9:00	9:10	Welcome to participants and opening comments	Andrew Fitzpatrick	
9:10	9:30	Welcome to country		
9:30	9:50	Design of BIPTEM: an airborne B field IP and TEM system	James Macnae	AEM systems
9:50	10:10	Helitem2: System updates for broadband AEM data	Darren Burrows	AEM systems
10:10	10:30	New helicopter-borne TEM system HoriZOND for effective exploration	Alexey Trusov	AEM systems
10:30	11:00	MORNING TEA		
11:00	11:20	The development of the TEMPEST AEM system	Andy Green	KEYNOTE
11:20	11:40	The last five years of Tempest system development	Teo B Hage	AEM systems
11:40	12:00	TEMPEST electromagnetic transmitters with multiple loops and multistep waveforms	Andrew Sunderland	AEM systems
12:00	12:20	TEMPEST data system bandwidth comparisons	Nirocca ND Devkurran	AEM systems
12:20	13:20	LUNCH		
13:20	13:40	AEM base frequency and depth of investigation	Magdel Combrinck	KEYNOTE
13:40	14:00	Estimating noise in AEM data	Aaron Davis	AEM data processing
14:00	14:20	Noise considerations for TEMPEST data	Peter Wolfgram	AEM data processing
14:20	14:40	Supervised stacking to improve the signal-to-noise ratio of AEM data	Pierre-Alexandre Reninger	AEM data processing
14:40	15:00	Analysis of the self-interference model and compensation methods in airborne electromagnetics	Evgeny Karshakov	AEM data processing
15:00	15:30	AFTERNOON TEA		
15:30	15:50	Reconciling the previously incompatible through the continental scale AusAEM survey	Yusen Ley-Cooper	Regional data acquisition and interpretation
15:50	16:10	Australian continental-scale multilayered chronostratigraphic interpretation of airborne electromagnetics	Sebastian C.T. Wong	Regional data acquisition and interpretation
16:10	16:30	Free AEM data over NSW, Australia	Astrid Carlton	Regional data acquisition and interpretation
16:30		END		

Note: This programme is provisional and may change

TUESDAY 5 SEPTEMBER				
START	**FINISH**		**SPEAKER**	**SESSION**
9:00	9:20	Lessons learned from a decade of AIP modelling	Andrea Viezzoli	AEM data processing
9:20	9:40	A forward model study to investigate 25, 12.5 and 6.25 Hz AEM system responses to IP and SPM effects in the regolith	Rodney Paterson	AEM data processing
9:40	10:00	Joint inversions of AEM modelling AIP effects: Helicopter-borne, Ground IP and Fixed-Wing systems	Francesco Dauti	AEM data processing
10:00	10:20	Modelling induced polarisation effects in frequency-domain data	Dmitry Khliustov	AEM data processing
10:20	10:50	MORNING TEA		
10:50	11:10	Use of airborne electromagnetics for mineral exploration and mining	Katherine McKenna	KEYNOTE
11:10	11:30	Some comparisons of AEM systems for specific mineral exploration problems	Michael Whitford	Mineral system studies
11:30	11:50	Going the extra mile - Julimar, a case study from Western Australia	Camilla Sorensen	Mineral system studies
11:50	12:10	An airborne heterodyne sulphide exploration test at Kempfield	James Macnae	Mineral system studies
12:10	12:30	The Valen Prospect: It's SPM,… No it's not,…Yes it is!.. No wait….	Tim Munday	Mineral system studies
12:30	13:30	LUNCH		
13:30	13:50	Enhanced weathering and oxidation modelling in coals by integration of ATEM results with standard coal geoscience data at Peak Downs Mine, Queensland, Australia	Geoffrey Peters	Geological settings and mineral systems
13:50	14:10	Investigating volcanic systems via multi-scale electromagnetic imaging	Paul A Bedrosian	Geological settings and mineral systems
14:10	14:30	AEM imagery down to one kilometre depth: New constraints for geological and hydrogeological modeling in volcanic contexts	Anne Raingeard	Geological settings and mineral systems
14:30	14:50	ZTEM airborne natural field EM-Magnetics and mineral targeting results over the Berg Porphyry Copper Project, near Houston, British Columbia.	Jean M Legault	Geological settings and mineral systems
14:50	15:10	Passive and active airborne electromagnetics – separate and combined technical solutions and applicability		Geological settings and mineral systems
15:10	15:40	AFTERNOON TEA		
15:40	16:00	Geotechnical ground investigations with a small airborne TEM prototype system	Andi Pfaffhuber	KEYNOTE
16:00	16:20	Developing a fully airborne drone TEM system	Nicklas S. Nyboe	UAV
16:20	16:40	An early time semi-airborne loop source TEM system	Esben Auken	UAV
16:40	17:00	Combined ground-UAV TDEM survey over gold prospect in Baikal-Patom Highlands (eastern Russia) with detection of AIP effect	Vladislav Kaminski	UAV
17:00		END		

Note: This programme is provisional and may change

Richard Lane Scholarship 2024

Richard Lane (1962-2021)

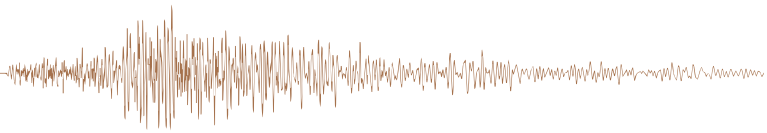
An ASEG Scholarship has been established to support geophysics Honours and Masters students and to commemorate the life and work of ASEG Gold Medal recipient Richard Lane. The scholarship is open to all BSc (Hons) and MSc geophysics students at an Australian University and consists of a grant of $5000 to the best ranked student for the current year. Ranking will be based on a 200 word discussion, overview of a geophysics project and on an academic transcript. For 2024 we acknowledge and thank Jayson Meyers and Resource Potentials Pty Ltd for the initial concept and ongoing donation.

All Honours (BSc) and Masters (MSc) students with focus predominantly in exploration geophysics are invited to apply. The closing date will be in April 2024 and the application details and form are at www.aseg.org.au/foundation/richard_lane

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

WEDNESDAY 6 SEPTEMBER				
START	FINISH		SPEAKER	SESSION
9:00	9:20	MORNING FREE		
9:20	9:40			
9:40	10:00			
10:00	10:20			
10:20	10:50			
10:50	11:10			
11:10	11:30			
11:30	11:50			
11:50	12:10			
12:10	12:30			
12:30	13:30	LUNCH		
13:30	13:50	BGR helicopter-borne frequency-domain EM – past, present, future	Bernhard Siemon	KEYNOTE
13:50	14:10	AEM survey of the Neretva Delta (Croatia): a case study for hydrogeology	John Moilanen	Hydrology/hydrogeology
14:10	14:30	AEM-derived watersheds in crystalline domain under volcanic cover	Damien Ciolczyk	Hydrology/hydrogeology
14:30	14:50	Quantifying salinity in the layered coastal aquifers underlying and adjacent to Delaware Bay USA using AEM-derived resistivity	Lyndsay Ball	Hydrology/hydrogeology
14:50	15:10	Using regional airborne electromagnetic conductivity data to characterise surface water groundwater interaction in the Cooper Creek floodplain in arid central eastern Australia	Neil J Symington	Hydrology/hydrogeology
15:10	15:40	AFTERNOON TEA		
15:40	16:00	An AEM experience in Northern Italy. Innovative and multidisciplinary approach for a modern groundwater and land management	Matteo Gisolo	Hydrology/hydrogeology
16:00	16:20	Integration of airborne transient electromagnetic models with ground geophysics and borehole data for groundwater mapping in Hawkes Bay region, New Zealand	Richard Kellett	Hydrology/hydrogeology
16:20	16:40	System-scale airborne electromagnetic surveys in the lower Mississippi River Valley support multidisciplinary applications	Burke Minsley	Hydrology/hydrogeology
16:40	17:00	California's Statewide AEM Surveys: Project implementation and next steps	Katherine Dlubac	Hydrology/hydrogeology
17:00		END		

Note: This programme is provisional and may change



THURSDAY 7 SEPTEMBER				
START	**FINISH**		**SPEAKER**	**SESSION**
9:00	9:20	Indigenous knowledge and methodologies to inform science and data capture	Bradley Moggridge	KEYNOTE
9:20	9:40	Round Table discussion on approaches to indigenous engagement/involvement with Airborne EM acquisition & application		
9:40	10:00	POSTER SESSION		
10:00	10:30	MORNING TEA		
10:30	11:00	Deep learning for the inversion of Airborne EM data	Eldad Haber	ML&AI: Joint inversion
11:00	11:20	Automated data processing of a large-scale airborne time-domain electromagnetic survey by a deep learning expert system	Muhammad Rizwan Asif	ML&AI: Joint inversion
11:20	11:40	Finding geology structures in depth sections from airborne geophysics: Automatic workflows	Simge Ayfer	ML&AI: Joint inversion
11:40	12:00	Airborne magnetics as structural guide in the 3D inversion of Airborne EM data	Carsten Scholl	ML&AI: Joint inversion
12:00	12:20	Thoughts on layered inversions	Andrew King	ML&AI: Joint inversion
12:20	13:20	LUNCH		
13:20	13:40	Advances in open-source software for 3D electromagnetics using SimPEG	Lindsey J Heagy	KEYNOTE
13:40	14:00	Closing the gap between galvanic and inductive methods: EEMverter, a new 1D/2D/3D inversion tool for electric and electromagnetic data with focus on Induced Polarisation	Gianluca Fiandaca	Open source codes
14:00	14:20	HiQGA: Open source deterministic and probabilistic AEM inversion	Anandaroop Ray	Open source codes
14:20	14:40	Toward Open Science: Introducing the Geophysical Survey (GS) Data Standard and GSPy Toolbox	Stephanie R James	Open source codes
14:40	15:00	EEMstudio: an open-source freeware QGIS plugin for processing, modelling and inversion of electric and electromagnetic data	Nicole Anna Lidia Sullivan	Open source codes
15:00	15:30	AFTERNOON TEA		
15:30	15:45	Paper awards		
15:45	16:05	Next Venue - 9th International Workshop		
16:05	16:25	Closing Remarks		
16:25		END OF WORKSHOP		

Note: This programme is provisional and may change

POSTERS	
Title	**Author**
Using airborne electromagnetics to improve depth to bedrock estimates in Wisconsin	Burke Minsley
Adaptive correction for airborne electromagnetic measurements	Evgeny Karshakov
Airborne electromagnetics: dealing with the aircraft speed	Evgeny Karshakov
Targeting epithermal Au-Ag using helicopter TDEM, magnetic, and radiometric data at Lawyers Project, North-Central BC, Canada.	Jean M Legault
Beyond conductive targets: Characterising lithium-prospective lacustrine evaporite mineral systems of North America's Basin and Range Province with regional-scale AEM	Lyndsay Ball
Airborne electromagnetic imaging for critical-minerals resource assessment	Paul Bedrosian
An overview of SkyTEM surveys in New Zealand: data acquisition, community engagement, and results from Northland	Maiwenn Herpe
Automated integration of AEM data, VES and borehole logs	Stefano Galli

AEM 2023: Invited speakers

Dr Magdel Combrinck

EM Data Processing Manager, NRG

Magdel studied exploration geophysics at the University of Pretoria, South Africa, culminating in a PhD on the modelling of Time Domain Electromagnetic data. She has been involved on contract basis in groundwater exploration, mineral exploration and engineering geophysics since 1996. She lectured at University of Pretoria for four years and has spent another four and a half years with Geotech Airborne Ltd. In 2010 she moved to Canada and partnered in launching Tau Geophysical Consultants Inc., based in Calgary. She started working with NRG in 2015, participating in the development and launch of the Xcite helicopter EM system. Currently she is acting as EM data processing manager for NRG, and still enjoys unravelling the mysteries of Time Domain EM.

Presentation title: *Perspectives on AEM processing for geophysical exploration in Canada and worldwide*

Dr Andy Green

OTBC Pty Ltd

Andy Green has been involved with airborne and space-borne geophysics and remote sensing for longer than he cares to remember. He started research with CSIRO where he was eventually Deputy Chief, CSIRO Division of Exploration Geoscience (1991-1992) and Director CRC for Australian Mineral Exploration Technologies (1992-1996). His research has involved the development of a wide range of remote sensing, signal processing, potential field and electromagnetic geophysical methods for mineral exploration. His current research is in mineral spectroscopy. He is excited and privileged to be able to be a small part of the development of HyLogging technology.

Presentation title: *The development of the TEMPEST AEM system.*

Dr Lindsey J Heagy

University of British Columbia

Lindsey is an Assistant Professor in the Department of Earth, Ocean and Atmospheric Sciences and Director of the Geophysical Inversion Facility at UBC. She completed her BSc in geophysics at the University of Alberta in 2012 and her PhD at UBC in 2018. Prior to her current position, she was a Postdoctoral researcher in the Statistics Department at UC Berkeley. Her research combines computational methods in numerical simulations, inversions, and machine learning for using geophysical data to characterize the subsurface. Primary applications of interest include mineral exploration, carbon sequestration, groundwater, and environmental studies. She is a co-founder of the SimPEG and GeoSci.xyz projects which develop open source software and educational resources for geophysics. In 2019, she was awarded the Gerald W. Hohmann Outstanding Young Scientist for advances in simulation and inversion of electromagnetic data and promotion of an open source culture for collaborative, inclusive and reproducible research.

Presentation title: *Advances in open-source software for 3D electromagnetics using SimPEG.*

Katherine McKenna

BHP

Katherine is principal geophysicist at BHP in Perth, with over 30 years of experience in mineral exploration, oil and gas exploration and applied geophysics. She started her career in mineral exploration in Australia and New Zealand and then moved into airborne and ground geophysical acquisition, processing and interpretation for mineral exploration companies, governments and

oil and gas explorers. She has worked throughout Asia, Africa, Europe and Middle East. Katherine's experience is in the use and integration of geophysical methods to enhance and improve geological knowledge under cover. In her present role at BHP, she is responsible for the use of geophysics for the Australasia metal exploration and generative groups. In 2021, she was awarded the ASEG 50th Anniversary Special Award for exceptional and highly distinguished contributions to the ASEG, the profession and the broader community by a Member, resulting in wide recognition across the geoscience community. Katherine holds a MBA from Curtin University, a BSc in geology and geophysics from Macquarie University and a BA in Classical Languages and Ancient History from University of New England.

Presentation title: *Use of airborne electromagnetics for mineral exploration and mining.*

Bradley Moggridge

Centre for Applied Water Science

Associate Professor Bradley Moggridge is a proud Murri from the Kamilaroi Nation living on Ngunnawal Land and is a researcher in indigenous water science (with qualifications in hydrogeology and environmental science) and is in the final stages of his PhD candidature at the University of Canberra. Until 2021 he was the Indigenous Liaison Officer for the Threatened Species Recovery Hub under the National Environmental Science Program. Associate Professor Moggridge is a Board member with the NSW EPA and Biodiversity Council and a member of the Wentworth Group of Concerned Scientists, a Governor of WWF Australia and President of the Australian Freshwater Science Society. He is a Fellow of the Peter Cullen Trust and Alumni of the International Water Centre.

Associate Professor Moggridge has won several awards, has presented widely, published in his area and is on many committees – from local to international adding to his 25 years in water and environmental science, cultural science, regulation, water planning and management, including policy development, legislative reviews, applied research and project management. He hopes to encourage future generations to pursue interests in STEM, promote his ancestors' knowledge of water and mentor emerging Indigenous scientists

Presentation title: *Indigenous knowledge and methodologies to inform science and data capture*

Dr Andi Pfaffhuber

EMerald Geomodelling

Dr Andi Pfaffhuber is the CEO of Oslo-based EMerald Geomodelling and the visionary behind airborne geoscanning. Before founding EMerald in 2019, he spent 12 years at the Norwegian Geotechnical Insititute (NGI). He introduced airborne geophysics to NGI in 2007, initially for resource exploration and later for the unique application in geotechnical projects. Andi Pfaffhuber established the NGI Geosurveys section in 2012 to develop, adapt and implement geophysical, remote sensing and GIS methods in NGI's advanced geotechnical projects. Ten years of research in the field of geotechnical geophysics led then to the strategic technology spin-off from NGI to EMerald. Andi holds a PhD in applied geophysics from Bremen University (2006) and an MSc in applied geoscience from Technical University Berlin (2001). His field of expertise spans from research, innovation, project management, business development and scientific consulting primarily with a focus on the infrastructure industry.

Presentation title: *Geotechnical ground investigations with a small airborne TEM prototype system.*

Dr Bernhard Siemon

Bundesanstalt für Geowissenschaften und Rohstoffe

Bernhard Siemon received a diploma in physics (1986) and a PhD (1991) from the University of Göttingen, Germany. After working for several private consulting and government research institutes, he returned to the German Federal Institute for Geosciences and Natural Resources (BGR) in 2001, where he is now head of the airborne geophysics unit. His research interests include the inversion of electromagnetic data and the application of airborne geophysical data in groundwater, mining and near surface problems. He is a member of DGG and EAGE.

Presentation title: *BGR helicopter-borne frequency-domain EM – past, present, future.*

AEM 2023: Short abstracts*

Automated data processing of a large-scale airborne time-domain electromagnetic survey by a deep learning expert system

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The new generation of airborne electromagnetic (AEM) surveys yield large data sets of thousands of line km. Parts of these data are often contaminated by noise from various sources, *e.g.*, fences, power lines, which corrupts the data to a degree that it can no longer be used. The problem intensifies in urban areas where the risk of data corruption is highest due to dense infrastructure. The inversion of corrupted data risks interpreting spurious subsurface features and flawed geological interpretations. Therefore, in many cases, the corrupted data is identified and culled prior to inversion. This process of culling corrupted data is generally a manual task requiring specialists to examine the data in detail, which is an extremely complex and time-consuming process.

Recently, we proposed a deep learning expert system to automate the complex AEM data processing workflows. The proposed method uses a deep convolutional auto-encoder to identify corrupted data and was trained such that it generalises to diverse geological conditions and various survey areas. In this study, we investigate the generalisation capabilities of our deep learning method on a large AEM survey area in Northland, New Zealand. Our approach takes ~ 600 s to process 3984 line-km of data and displays strong spatial correlation for the data identified as corrupted. The inversion results show very few potential anomalies in the model space which are being inspected by a manual operator. In general, the proposed approach is generalisable and displays high-quality data processing within short amounts of time, which requires minimal further quality inspection

An early time semi-airborne loop source TEM system

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We present a new semi-airborne transient electromagnetic (TEM) system, dTEM, for subsurface imaging. The dTEM system is designed for both imaging of groundwater and mineral resources. The system uses a large ground loop for transmitting energy into the ground. It's a dual moment system with peak current up to 30 A for high moment and 1-2 A for low moment. The fast LM turn off time is around 8 µs from the beginning of the turn-off ramp. The receiver coil is a high frequency, low noise, open air coil carried by the drone as a slung load. The high accuracy synchronisation between the transmitter and the receiver is achieved by GPS, within less than 50 nanoseconds. The drone is equipped with two lasers for determination of the attitude and real-time image processing has been developed to measure and control the movement of the receiver coil with the drone in the airspace. Data from all sensors are continuously streamed to the ground station. The system can be used for mapping of deep targets. However, as the current waveform and system bandwidth is well defined also more shallow layered targets can be mapped. The latter makes it possible to use the system to map shallow ground water aquifers in terrains inaccessible for traditional ground-based TEM systems.

Finding geology structures in depth sections from airborne geophysics: Automatic workflows

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The explosion in new airborne electro-magnetic surveys is creating the need for less cutting of corners, better honouring of the known physics in the algorithms, and proper use of all the system monitors. The importance of a "good" starting model in a deterministic, iterative, non-linear inversion, such as that provided by the 2.5D Moksha code, has been recognised for many years. This study touch bases on two project scale examples that were collected by the same aircraft. Clearly in the context of an emerging continent wide AEM campaign to acquire prospective surveys, the implications for these developments are critical, in that these tools can also manage complete surveys, no matter what line length are involved. This concentration of predicting geology structures in depth sections has demonstrated the ability to identify possible exploration targets and map steeply dipping and folded geology in a deformed terrain. Equally important, is the creation of workflows and visualisation toolkits to help interpreters, no matter what scale, or which aspect of geology or rock properties they wish to interrogate. The *laissez faire* situation of accepting sub-optimal methods for estimating potential field gradients has plagued, and held back, the successful use of potential field geophysics for too many years now. Almost all interpretation methods are based upon estimating these gradients.

Beyond conductive targets: Characterising lithium-prospective lacustrine evaporite mineral systems of North America's Basin and Range Province with regional-scale AEM

Lyndsay Ball, Paul Bedrosian and Chloe Gustafson

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The Basin and Range province of North America hosts substantial lacustrine evaporite mineral systems prospective for lithium, a critical mineral currently listed for mineral resource assessment by the U.S. Geological Survey. Airborne electromagnetic (AEM) surveys are being conducted to support these assessments by identifying shallow clays and brines, as well as through improving the shallow subsurface geologic

*Presentations are listed alphabetically by first author.

framework of the regional fluid flow system. In 2022-23, three focus areas with proven lithium resources or considered highly prospective for lithium are being surveyed. Results from this effort can help to improve our understanding of the geologic conditions and geophysical signatures associated with known resource regions and benefit future lithium resource assessments by identifying regions with similar geophysical and geologic characteristics.

Quantifying salinity in the layered coastal aquifers underlying and adjacent to Delaware Bay USA using AEM-derived resistivity

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Airborne electromagnetic (AEM) methods are particularly well suited to coastal aquifer salinity studies, yet the quantitative translation from bulk resistivity to fluid salinity carries uncertainty that can impact mapped salinity distributions and interpretations of the freshwater-saline interface and hydrostratigraphic layers. A recent AEM survey of the region near the Delaware Bay, USA highlights several challenges common to coastal hydrogeologic settings that may influence both qualitative and quantitative interpretation. We use a Bayesian inversion to estimate geophysical parameter uncertainty, and results are integrated with hydrogeologic measurements to develop quantitative interpretations of salinity across the freshwater-saline interface in stacked aquifers.

Investigating volcanic systems via multi-scale electromagnetic imaging

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Electromagnetic imaging provides a wealth of information about the structure, composition, and processes within volcanic systems. While deep-sensing techniques such as magnetotellurics (MT) focus on the magmatic system, airborne electromagnetics (AEM) is capable of mapping active hydrothermal cells and their alteration products, faults, lava flows, water-saturated zones, and perched aquifers. All these components are important to improving volcanic hazard assessments and understanding magmatic and hydrothermal processes at work beneath active volcanoes.

We present two recent AEM studies at Yellowstone and Kīlauea volcanoes. At Yellowstone, AEM studies map conduits that connect heat and deep thermal fluids to surface thermal features. We further identify a distinct electrical signature over hydrothermal domes which sheds light on their formation and potential for hydrothermal explosions. At Kīlauea, AEM models image the structural backbone of this complex volcano, including elevated conductivity over the summit lava lake, along faults accommodating collapse of the volcano's south flank, and along both the flanking rift zones that have sourced lavas from fissure eruptions over the past two centuries. Work at both volcanoes is ongoing of merging AEM and MT data sets to image these systems from the base of the crust to the surface.

Airborne electromagnetic imaging for critical-minerals resource assessment

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Mineral resource assessments are fundamentally grounded in data – specifically data that differentiate regions prospective for a resource from those that are not. The Earth Mapping Resources Initiative is collecting baseline geophysical data over targeted areas of the United States to support upcoming critical mineral assessments. Approximately 30 000 line-km per year of airborne electromagnetic (AEM) data are being collected as part of this effort. In the first year, surveys in Nevada, Alabama and Alaska will be carried out to inform national-scale graphite and lithium assessments. AEM surveying for graphite is one of the few cases where geophysics can directly map the resource of interest; we describe AEM surveys to be flown over two of the primary graphite resources in the nation. We also describe a regional survey focused on lithium brines and clays, where AEM models will be used to constrain deposit genesis models and to narrow the currently vast region considered prospective for lithium. We highlight aspects of the survey design and show preliminary results for those surveys that have already begun flying.

Helitem2 – System updates for broadband AEM data

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In the last five years, advances in receiver suspension and receiver construction have made airborne electromagnetic low-base frequency operation possible and greatly improved the ability to explore in conductive environments. We discuss the changes made to the Xcalibur Helitem2, helicopter time domain EM, system to enable low base frequency operation - first at 15 / 12.5 Hz, and then at 7.5 / 6.25 Hz.

The transmitter has also been redesigned to now use a square input waveform at 50% duty cycle, with a rapid turn-off. At low base frequencies this results in a long, high powered transmitter pulse that still creates high frequency signal.

Various data examples will be shown to illustrate the practical advantages of the system updates. This includes an example from Nevada where various Helitem2 system configurations were flown over a line of ground TDEM data at different heights, as well as a Nickel exploration project.

Free AEM data over NSW, Australia

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The Geological Survey of New South Wales (GSNSW) in the Department of Regional NSW, Mining Exploration & Geoscience, has an online application, called MinView, which allows

users to view and download geoscientific data, including airborne electromagnetic (AEM) survey data and inversion sections. Much of the AEM data are from surveys acquired in collaboration with Geoscience Australia and other NSW state government departments. Other surveys were acquired by exploration companies. Exploration companies are required to submit geophysical data to the government. After five years the data can be made publicly available.

Data is free to download, and its use is covered by CC-BY copyright, which gives the users the right to use distribute, adapt, remix or build upon so long as attribution is given to the author. This abstract provides the reader with instructions on how to access AEM data on MinView.

AEM-derived watersheds in crystalline domain under volcanic cover

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In the Chaîne des Puys (CdP, France), volcanic edifices and their emissions cover the weathered conductive low-permeable basement and fill the palaeo-valleys, hiding the groundwater flows. The 3D delineation of such buried watersheds can be achieved studying variations of conductivity related to primary geological contrasts as well as secondary weathering-induced contrasts.

We used AEM data to delineate the geometry of the undercover volcanism-basement interface in the northern part of the CdP and derived watersheds. Despite the highly resistive volcanic cover, our processing allowed structural imaging up to a depth of investigation of 330 m on average. The processing and inversion of AEM data highlights the interface between a strongly resistant volcanic cover (~104-105 Ωm) and a decametric conductive weathered horizon at the top of the basement (30-300 Ω.m).

We picked the weathered horizon of the basement on several resistivity profiles, to build an elevation model of its top. The newly derived watersheds noticeably differ from the ones proposed in literature.

AEM base frequency and depth of investigation

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Recent advances in time domain airborne electromagnetic (AEM) data acquisition include lower noise levels and subsequently the use of 12.5 Hz and even 6.25 Hz base frequencies instead of the dominant 25 Hz. The main advantages associated with lower base frequencies are increased depth of investigation (DOI) and improved conductor discrimination and detection in the high conductance range. A study was undertaken to quantify these improvements for the Xcite system that resulted from implementing a new suspension system.

A synthetic model study was done, evaluating the effect of base frequency and noise levels (utilising noise samples collected at high altitude) on a variety of conductance models. The results were displayed in different formats to illustrate the combined effects of conductance, base frequency and noise levels on DOI. There is no simple formula or correlation to quantify DOI as a function of all relevant parameters and visual analysis of model and inversion results for relevant conductance models is recommended to determine the best acquisition parameters for a survey.

The results highlighted the importance of noise levels compared to base frequency to achieve larger depths of investigation and the value of lower base frequencies when exploring for conductive targets in a relatively conductive host environment.

Perspectives on AEM processing for geophysical exploration in Canada and worldwide

Magdel Combrinck

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Acquiring and processing AEM data in different regions of the world require different approaches and procedures to deliver the best data. Four case histories are discussed to illustrate the effect of jungles, mountains, electrical and magnetic storms on AEM and ancillary data. Lesson learned as well as current approaches to deal with challenges in this region are presented. There is no "one-size-fits-all" processing workflow and critical evaluation of data an survey conditions are required to deliver the best data.

An AEM experience in Northern Italy. Innovative and multidisciplinary approach for a modern groundwater and land management

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Climate changes are strongly affecting water supply all around the world and Northern Italy does not make exception to this. In addition, pollutant contamination due to human, both industrial and farming, activities is increasingly spreading in the high Po Plain region and its lateral valleys. Hence, in 2021 an AEM survey has been conducted, aiming at the identification of unknown water reservoirs, on an area of about 200 km^2 located West of the Garda Lake. A time-domain transient EM system (SkyTEM) has been used to perform airborne measurements.

To address the complex depositional environments typical of the subalpine region, the resulting geophysical data, joint with lithological data collected from wells in the last decades, have been interpreted through a cognitive approach. Where neither electromagnetic nor lithological data were available, a number of ground TDEM tests has been performed to cover the lack of knowledge. The 3D geological model has been constructed manually as a voxel model with lithofacies attributes supplemented by several bounding surfaces. Two different modelling methods have been combined, namely smooth and sharp, allowing to get the geological complexity.

Starting from the geological model and based on an *ad hoc* piezometric campaign, carried out in the meanwhile on the same area, two 3D FEM flow models has been developed, namely a steady-state one and a transient one. These achievements have allowed us to understand complex operational situations and to manage them with robust awareness. In the light of these promising results, we have decided to extend the investigation on a wider area, covering further 1700 km^2. The whole activity will provide a detailed database, from which impressive multidisciplinary applications can be inferred. Amongst them, priority will be given in settling drought effects, assessing groundwater vulnerability and evaluating geotechnical phenomena, such as saturated loose sand liquefaction.

Joint inversions of AEM modelling AIP effects: Helicopter-borne, ground ip and fixed-wing systems

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It is nowadays widely accepted that Induced Polarisation (IP) effects can affect Airborne Electromagnetic (AEM) measurements. Modelling the AEM data with a dispersive-resistivity allow to properly retrieve the halfspace parameters avoiding high inversion misfits and wrong structures. Even if the Airborne IP (AIP) modelling it is a known and controlled practice, there are still some open questions regarding the complexities of this modelling approach. Most of this lie into the AIP sensitivity to geological targets, others in its capability in integrate with the ground IP and other more about the parametrical management during the inversion process. To contribute on the AEM-IP modelling field of research, with this work we performed two joint inversions on real data modelling AIP effects. For the first experiment we jointly inverted AEM-IP fixed-wing data with helicopter-borne data. For the other experiment, we jointly modelled ground DCIP and helicopter-borne AEM data, modelling AIP parameters. With these experiments we retrieved that inductive airborne IP can contribute, in term of sensitivity, to the ground IP modelling procedure and that fixed-wing airborne data have a good sensitivity to chargeable geological targets as well as helicopter-borne platforms. More in general, it has been seen that inductive IP contains complementary information for modelling IP effects.

Estimating noise in AEM data

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In this paper, I discuss a method to obtain reliable noise estimates for airborne electromagnetic (AEM) surveys based on the reversible-jump Markov chain Monte Carlo method. In addition to estimating electrical conductivity and thickness using 1D layered-earth models, the method provides estimates of the additive error required to make all measurements of a repeat line agree. The noise estimates can also be obtained from a single line where repeat line information is unavailable. The resulting additive noise estimates then can be used in a general deterministic inversion. Analysis of inversions shows that model regularisation has little effect at depths where the data is informative. This improves the reliability of the inverted models, since it is the noise-adjusted data which is informing the model.

TEMPEST data system bandwidth comparisons

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The TEMPEST fixed wing TDEM system continually undergoes evolutionary advancements, pushing the technical boundaries for meeting industry needs of improved accuracy and reliability. Higher speed data acquisition rates (increased bandwidth) have been one of the developments for improving resolution and imaging products that would benefit hydro geological exploration and reservoir characterisation. Multiple sampling rate data will be acquired over a known (geologically mapped) setting and an assessment will be made against drill hole information, in order to understand the response as a function of varying bandwidth.

California's statewide AEM surveys: Project implementation and next steps

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Passage of the Sustainable Groundwater Management ACT (SGMA) in California has resulted in the need for improving the understanding of groundwater aquifers to support groundwater managers in developing and implementing groundwater management plans and actions. The California Department of Water Resources (DWR) has supported this effort by implementing the statewide AEM Survey Project, where data are collected in a reconnaissance grid across California's priority basins. Raw, processed, inverted, and interpreted AEM data as well as digitised lithology and e-logs are made publicly available and novel tools have been developed to support data accessibility.

With the Statewide AEM Surveys nearing completion, DWR is undertaking an effort to utilise the Statewide AEM Survey dataset along with other existing data (surface geophysics, lithology logs, e-logs, geologic cross sections) to provide an improved understanding of basin characteristics. To support this task, new tools are being developed that will analyse all data available to produce refined, texture and hydrogeologic models. Results will be archived in DWR's California groundwater publication and basin reports and models will be available to visualise through new and innovative 3D, GIS-based tools.

To support this effort, DWR will also be conducting pilot studies that will include the collection of additional data with the goal of filling data gaps and addressing specific SGMA implementation questions. The first pilot study will be conducted on the eastern side of the San Joaquin Valley in

California's Central Valley and will include the collection of infill AEM data, as well as other ground-based geophysical surveys.

Closing the gap between galvanic and inductive methods: EEMverter, a new 1D/2D/3D inversion tool for electric and electromagnetic data with focus on induced polarisation

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The interest on Induced Polarisation (IP) in AEM data (AIP) has significantly increased in recent years, both within the research community and in the industry. However, the inversion of AIP data is particularly ill-posed, especially when spectral modelling, such as Cole-Cole modelling, is used. Furthermore, the comparison of AIP and galvanic ground IP inversion models is hindered by the fact that the IP effect is usually modelled differently in the inductive and galvanic computations.

In this study we present a new inversion software, EEMverter, which has been developed to model IP in electric and electromagnetic (EM) data within the same inversion framework. In particular, three specific goals have been identified within EEMverter's development: i) to allow multiple inversion cycles that mix, sequentially or simultaneously, 1D, 2D and 3D forward modelling, for diminishing the inversion burden; ii) to allow the joint inversion of AIP, ground EM-IP and ground galvanic IP data; iii) to allow time-lapse inversions of AIP, EM and galvanic IP data.

EEMverter has been tested on several AEM and AIP surveys, also in conjunction with ground EM and ground galvanic IP data in joint inversion. In this study, the inversion of the VTEM AIP survey over the Valen Cu-Ni deposit is presented, highlighting the improvements in model resolution when compared to standard inversion approaches.

Automated integration of AEM data, VES and borehole logs

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Airborne electromagnetic (AEM) surveys are widely used for hydrogeological applications. The areas targeted for AEM campaigns may present a great deal of ancillary information (*e.g.* resistivity logs, lithology, etc.) and integrating it with AEM data is fundamental. Yet, using this information either as *a-priori* or *a-posteriori* may bring out conflict between different datasets, preventing reconciliation everywhere. For instance, some borehole drillings may have been logged inaccurately, AEM data may present bias, or data may have been acquired at different times, with variations occurring in between.

In this study we present a way to integrate AEM data and other types of resistivity data (boreholes electrical logging and vertical electrical soundings, in this case), through an inversion scheme that identify automatically conflicting data without preventing the general convergence of the process. To do so, we make use of a generalisation of the minimum support norm, the asymmetric generalised minimum support (AGMS) norm, for defining the data misfit in the objective function of an iterative reweighted least squared (IRLS) gauss-newton inversion. The AGMS norm in the data misfit puts a cap on the weight of non-fitting data points, allowing for the inversion to focus on the data points that can be fitted. Outliers are identified after the AGMS inversion and excluded, in order to complete the inversion process with a classic L2 misfit.

The development of the TEMPEST AEM system

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TEMPEST's origins lie in the difficulty half-sine AEM systems had in mapping the Australia's dryland salinity. This resulted in the development of the SALTMAP system, a collaboration between World Geoscience Corp and CSIRO. This was a 500 Hz square wave system with excellent high frequency response, full-waveform digital acquisition, processing, calibration and bird positioning. With the advent of the CRC for Australian Mineral Exploration Technologies (CRCAMET) and an industry push for an Australian system with deeper penetration, the SALTMAP System was taken to a lower base frequency (25 Hz) and higher power while retaining as much higher frequency response as possible. The previously implemented signal processing and calibration was retained enabling a reliable conversion to Step Response for ease of interpretation.

The development history of TEMPEST is a result of collaboration between company, university and government research. Funding came from a diverse range of sources, government grants, collaborative industry funds and WGC. However, like most other fixed-wing systems, it was caught up in the consolidation and subsequent decadal changes in ownership that started after TEMPEST first became operational. But the consolidation was good for TEMPEST. At the end of 2000 it was operating on a platform that had limited power and an airframe that constrained the bird to a shape that made coil motion noise difficult to reduce. The merger with Geoterrex brought new aircraft, better coil suspension and extensive operational experience that took TEMPEST to another level of operational efficiency.

Deep learning for the inversion of Airborne EM data

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In the recent decade Deep Learning have revolutionised fields such as computer vision and image understanding. However, its use for the solution of inverse problems have been limited. In this work we examine the use of deep learning for the processing and inversion of airborne EM data. Preliminary results show that by incorporating deep learning it is possible to eliminate many of the artefacts that are commonly observed in airborne inversion allowing us to obtain much more reliable inversions that fit not only the data, but also our *a-priori* information.

The last five years of Tempest system development

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Over the last five years, TEMPEST development efforts have centred around extending bandwidth, improving system geometry measurements, improving the signal processing and making the system more robust, integrating additional instruments on the platform, modernising hardware and building additional TEMPEST systems.

Pioneered by Geoscience Australia's AUSAEM project, global demand for regional and country scale Airborne EM has increased significantly. The data is being used for a broad range of applications, with geophysical mapping to improve the understanding of geology at regional scale and mapping the thickness and character of the regolith remaining popular use of the data. However, increasingly TEMPEST data is being used for groundwater resource assessment, evaluation of the effectiveness of in-fill EM in particular areas, and by some innovative companies and individuals, to aid in the search for critical minerals.

Advances in open-source software for 3D electromagnetics using SimPEG

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Open-source software is increasingly being adopted by the geophysics community. Their emergence has greatly reduced the time required for students and researchers to be able to implement and explore new ideas, and having new developments implemented in an open-source project facilitates technology transfer and collaboration between research and commercial organisations. SimPEG is an open-source project for geophysical simulations and inversions. In this abstract, we provide an overview of the capabilities and recent advancements in SimPEG that are relevant to the airborne electromagnetics community

An overview of SkyTEM surveys in New Zealand: data acquisition, community engagement, and results from Northland

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While the demand for groundwater has increased throughout New Zealand, there are still significant knowledge gaps in the understanding of most regional aquifer systems. To address those knowledge gaps, close to 30 000 line-km of airborne TEM data have been collected in New Zealand for groundwater characterisation over the past five years. GNS is currently involved in five regional projects (Hawke's Bay, Greater Wellington, Northland, Tairāwhiti (Gisborne) and Southland), working closely with local water managers and communities. The data interpretation and hydrogeological models resulting from those surveys will greatly improve the understanding of NZ's regional aquifers and inform opportunities for economic diversification in increasingly resource pressured environments. Extensive communication is undertaken in each region prior to the survey, ensuring engagement and interest of the general public. In Northland, the Te Hiku Water Study project is the result of an integrated, community-led water management and economic development plan. The project proposal was initially developed by the community and involved a significant level of community engagement. The team members' advocacy for the project in the community has been a valuable element of building local buy-in to the project. We are looking into expanding the use of SkyTEM to other regions of New Zealand, primarily to help inform water management, but also to subsequently contribute information to researchers in other disciplines (*e.g.*, fault mapping, coastal depositional processes, geological mapping etc.).

Toward Open Science: Introducing the Geophysical Survey (GS) data standard and GSPy Toolbox

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The diverse field of geophysics comprises many data formats and archival conventions, often separated by specialty (*e.g.*, electromagnetic, seismic, potential fields). Airborne geophysical methods exemplify this complexity, with critical auxiliary information on survey and system parameters, required to fully utilise and understand the data, often detailed separately throughout dense reports. An open, portable, self-describing data standard is needed to increase the interoperability, comprehensibility, and long-term archival of geophysical data. Here, we propose a new Geophysical Survey (GS) data standard that uses the NetCDF file format, in conjunction with extensions to the established Climate and Forecasts (CF) metadata convention. We have also developed an accompanying open-source Python package, GSPy, to provide methods for producing and interacting with GS-standardised files. We utilize the advantages of the NetCDF format to attach metadata directly to the data, and organise distinct, but related, datasets into groups within a hierarchical structure while leveraging the binary format to produce smaller file sizes. A root survey group contains global metadata about the geophysical survey, and all data groups are located within the survey. To simplify operations, data are categorised based on geometry as either tabular (unstructured) or raster (structured) datasets. Community development and adoption of a NetCDF-based data standard can greatly improve how these complex geophysical datasets are shared and utilised, increasing the accessibility and impact of geophysical surveys.

Combined ground-UAV TDEM survey over a gold prospect in Baikal-Patom Highlands (eastern Russia) with detection of AIP effect

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The study is describing a combined ground-UAV TDEM survey, carried out over one of the gold prospects in Eastern Russia. A drone-mounted receiver was used to measure TDEM response from ground, excited by a transient field powered line transmitter. Effect of Airborne Induced Polarisation was detected in the data, so the collected data were further inverted using a Cole-Cole model approximation in order to extract the four physical parameters, which were then mapped and interpreted in an attempt to delineate mineral exploration targets.

Airborne electromagnetics: Dealing with the aircraft speed

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It is no secret that the solution of Maxwell's equations depends on the coordinate system. But in current studies, the dependence of the solution on both the speed of the transmitter and the speed of the receiver is usually not discussed.

In this article, I present an analysis of such an effect on the readings of an alternating magnetic field receiver and on the secondary field. I have found that the effect of the receiver's motion is critical. I have proposed a compensation method now implemented in some systems, after which the measurements of a moving receiver can be considered as signals of an equivalent stationary receiver at the current position.

It is also shown that the field distortions proportional to the aircraft speed are related to the flight altitude and the electrical conductivity of the medium. I analysed data from the EQUATOR airborne electromagnetic system obtained over the sea surface. It is shown that the influence of speed is much less than the influence of restrictions on the environment model, which are imposed during the inversion of airborne electromagnetic data.

Analysis of the self-interference model and compensation methods in airborne electromagnetics

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We compare various compensation methods for the EQUATOR system and for several modifications of the airborne electromagnetic system EM4H: with a transmitter loop attached to the fuselage of Mi-8 helicopter, with a loop attached to the fuselage of An-3 aircraft, and with a loop towed by Eurocopter AS350B3. We consider two ways of the transmitter signals interference modelling: in the form of a stationary systematic component of the measurements and in the form of a stationary field vector rigidly connected to the transmitter. To implement the second approach, the EM4H and the EQUATOR use two additional dipoles to determine the relative location of the transmitter and the receiver. At high altitude, in the absence of a response from the ground, the following statistical parameters of the signals remaining after interference compensation were analysed: the standard deviation and the difference between the minimum and the maximum values.

Integration of airborne transient electromagnetic models with ground geophysics and borehole data for groundwater mapping in Hawkes Bay region, New Zealand

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As part of the Hawke's Bay 3D Aquifer Mapping Project (3DAMP), airborne electromagnetic data have been collected over several basins. The project was a three-year initiative (2019 – 22) jointly funded by the Provincial Growth Fund (Kānoa Regional Economic Development & Investment Unit), Hawke's Bay Regional Council (HBRC) and GNS Science (GNS). The object of the study is to improve the hydrogeological model of the area using a resistivity model that extends to 300 m depth. The model was generated from an airborne TEM (SkyTEM) survey that covered the region at a line spacing of 170 - 250 m. A total of 7780 line-km was flown in a period of four weeks. Supporting data includes ground-based geophysical surveys (TEM, resistivity, and seismic reflection lines), and detailed geological data from a set of research boreholes. A total of 6800 boreholes exists in the catchments but the majority are less than 30 m deep. A set of 30 deeper boreholes across the area with more detailed geological information provide valuable control on the SkyTEM processing and modelling. The integration of a 3D model developed from the inversion of the SkyTEM data and ground geophysics data, displays the geometry of the fluvial systems (gravel), marine incursions (silt and clay), and complex faulting that affects the deposition of the sedimentary units. Work is ongoing to develop models of aquifer potential based on hydrogeological facies that will improve the understanding of the groundwater system.

Modelling induced polarisation effects in frequency-domain data

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Induced polarisation (IP) effects may have significant impact on airborne electromagnetic (AEM) data. They lead to dependence

of apparent resistivity on the frequency of the signal. The classic approach to modelling IP consists in deriving analytical models of frequency dependent resistivity of each layer of the model. However, the number of parameters for such models grows fast with the number of layers. Hence the problem of numerical inversion becomes intractable due to high dimensionality and ill conditioning.

This work suggests an approach to overcoming this problem. We show that the effects of IP are concentrated in relatively small number of layers and propose a simple algorithm for finding them. The results of inverting real data showing strong IP are presented.

Thoughts on layered inversions

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The earth is composed of layers of rock of different lithology, with sharp boundaries between them, so surely it is better to use layered AEM models than smooth models? However, this idealised cartoon model is complicated by the fact that most electrical conductance is through pore water of varying salinity rather than through the rock matrix, and by factors, such as weathering gradients, which will induce gradients in physical properties. This paper discussed experiences with trying to use layered, rather than smooth, inversions of AEM data.

Targeting epithermal Au-Ag using helicopter TDEM, magnetic, and radiometric data at Lawyers Project, North-Central BC, Canada.

Jean M Legault and Karl Kwan

Geotech Ltd., Aurora, ON, Canada

In September 2018, Geotech Ltd. completed a VTEM helicopter time-domain electromagnetic, magnetic and radiometric survey on behalf of Benchmark Metals Inc. over the Lawyers property, in northcentral BC. The magnetic results reveal a strong spatial relationship between sharp magnetic lineaments and the known mineralisation. Radiometric results show that mineralisation is characterised by hydrothermal alteration resulting in potassium enrichment, manifested as K/Th highs. The VTEM electromagnetic results identified local EM anomalies representing both discrete and structural conductors. However, none of the EM anomalies making up conductive zones coincide with the known epithermal mineralisation, instead all the known Au-Ag deposits and occurrences are located in zones of high apparent resistivity.

Subsequent analysis of the VTEM data analysed using AIIP mapping revealed that all the known Au-Ag mineralised zones coincide with moderate to high Cole-Cole time constant (TAU) anomalies, consistent with relatively coarse-grained polarisable material, such as disseminated sulphides or hydrothermally altered clays.

The previous targeting approach focused on individual analyses of magnetic, structural, radiometric, EM resistivity and AIIP results, then arriving at a targeting model, based on geologically and geophysically based considerations. A new approach for targeting uses a semi-automated, machine-learning (ML) assisted approach that includes: Structural Complexities (SC), Self-Organizing Map (SOM) classifications, and Supervised Deep Neural Network (SDNN) targeting of the geophysical data. The new targeting approach has further reduced the number of priority targets from previous five (5) to three (3), which includes most of the known epithermal Au-Ag occurrences, as well as two areas for follow-up.

ZTEM Airborne Natural Field EM-Magnetics and mineral targeting results over the Berg Porphyry Copper Project, near Houston, British Columbia.

Jean M Legault and Karl Kwan

Geotech Ltd., Aurora, ON, Canada

A ZTEM natural field helicopter EM and magnetic survey was flown over the Berg copper-molybdenum-silver project in the Huckleberry district, near Houston in central British Columbia, Canada. Mineralisation at Berg surrounds a quartz monzonite intrusion. Analyses of the airborne geophysical responses, using 2D-3D inversions, show combined well-defined ring-like resistivity low surrounding a resistive core and similar annular magnetic high and low signatures over the known and suspected porphyry deposits, similar to those previously found in ZTEM surveys over other porphyry deposits in the Western Cordillera. A mineral targeting approach is implemented that uses a semi-automated, machine-learning (ML) assisted method that includes: Structural Complexities (SC), Self-Organizing Map (SOM) classifications, and Supervised Deep Neural Network (SDNN) targeting of the geophysical data. The new targeting approach has identified both the Berg and Bergette porphyry copper occurrences, as well as two others our areas for follow-up that also host known mineral showings.

Reconciling the previously incompatible through the continental scale AusAEM survey

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Geoscience Australia (GA) has acquired hundreds of thousands of line-km of airborne electromagnetic (AEM) data over the years to better understand the Australian subsurface. A more recent planned approach of acquisition has been the AusAEM programme. This systematic effort has delivered extensive detailed conductivity-depth-models over large swaths of land. This effort will deliver a continental-scale, long lasting geophysical dataset. Simultaneously, GA's in-house processing and inversion codes enable the seamless integration of conductivity models from both helicopter and fixed wing systems, compatibility of X and Z component data from the same survey, as well as the reconciliation of historical and recent datasets. Of particular note, is the reprocessing of data using the magnitude of the measured magnetic field in the plane of the inline flight direction. It deals with many transmitter-receiver geometry problems and leads to glitch-free subsurface images. GA's efforts in advancing the modelling and inversion codes have verified the presence of geological units at deeper depths in stratigraphic sequences than we were able to resolve pre-2016. The concerted development of a strategic acquisition programme together with modelling and inversion codes have allowed us to stitch together a nearly continent-wide dataset

Design of BIPTEM: an airborne B field IP and TEM system

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The BIPTEM project was funded by several companies and developed a 1 MA m^2 transmitter which was tested with a concentric loop B field inductive magnetometer in 2017. A report on the system was presented at AEM18. With the rotation sensing and inertial navigation technology available at that time, motion noise corrections to the collected data did not perform well enough to justify further substantial investment and the project was mothballed. Following improvements in fibre-optic technology, and the announced future commercial availability of breakthrough quantum rotation sensors, Newmont funded research to improve the BIPTEM system and test its ability to map IP targets.

Many experiments and flight tests were conducted, and extensive software developments were undertaken to bring the system to full operation. Parallel modelling and ground experiments showed that the optimum system for IP effect detection has a large Tx and a horizontal component Rx (separated by about 300 m in the Slingram geometry

An airborne heterodyne sulphide exploration test at Kempfield

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We continue to investigate an ancillary method to Induced Polarisation for sulphide exploration, using analysis to measure heterodyne effects in time-domain Airborne Electromagnetic data. We investigate how a parameter named mixabiity can characterise these effects in terms of frequency content and composition, finding that with sufficiently low noise levels, heterodyne effects could theoretically be observable in time-domain AEM data.

Analysing existing AEM survey data, we earlier found no spatial correlation between known sulphide distribution and mixability. We postulated that this is because potential heterodyne effects due to sulphides were being masked by two different limitations of the survey dataset we used; firstly, variable transmitter waveform asymmetry; and secondly, the decreasing signal levels from the fixed a ground-loop transmitter resulting in increasing relative noise levels away from the transmitter. We therefore conducted a airborne Slingram EM/IP survey with the BIPTEM system to address the identified limitations of existing test data.

We present results from an airborne test at Kempfield, the test site for definitive ground tests of the heterodyne method for sulphide detection. The small mixability anomalies detected in the airborne data were not consistent with either drilled sulphides or mapped IP anomalies.

Use of airborne electromagnetics for mineral exploration and mining

Katherine McKenna

BHP – Metals Exploration

The use of airborne electromagnetics (AEM) in mineral exploration and mining has expanded over time. Initially with an objective of targeting, it is now also used for mapping, water delineation, structural identification, environmental monitoring, and the list is growing. It has been proven, AEM has had success in identifying mineral deposits under cover, but the challenges come as we try to explore deeper. There is a need to achieve better resolution at shallower and deeper depths, to continue with the creation of better and more meaningful inversions, to incorporate petrophysical and geological data and adapt to the changing expectations of exploration and mining. Examples of how AEM is used in mineral exploration and mining show the development to date, the challenges of the interpretation and the way the results can be communicated to geological, geo-technical or environmental teams.

System-scale airborne electromagnetic surveys in the lower Mississippi River Valley support multidisciplinary applications

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The lower Mississippi River Valley spans over 200 000 km^2 in parts of seven states, encompassing areas of critical groundwater supplies, natural hazards, infrastructure, and low-lying coastal regions. From 2018 – 22, the U.S. Geological Survey acquired over 82 000 line-km of airborne electromagnetic, radiometric, and magnetic data over this region to provide comprehensive and systematic information about subsurface geologic and hydrologic properties that support multiple scientific and societal interests. Most of the data were acquired on a regional grid of west-east flight lines separated by 3 – 6 km; however, several high-resolution inset grids with line spacing as close as 200 m were acquired in targeted areas of interest. Approximately 8000 line-km were acquired along streams and rivers to characterise the potential for surface water-groundwater connection, and another 6000 line-km were acquired along the Mississippi and Arkansas River levees to characterise this critical infrastructure. Here, we present a summary of the data along with several examples of how they are being used to inform regional groundwater model development, inferences of groundwater salinity, identification of faults in the New Madrid seismic zone, and levee infrastructure.

Using airborne electromagnetics to improve depth to bedrock estimates in Wisconsin

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Depth to bedrock is often an important factor in hydrologic systems because hydraulic properties of bedrock and overlying sediments are typically appreciably different. For example, the thickness of glacial sediments overlying bedrock in Wisconsin controls the routing of groundwater in surficial aquifers and its connection with surface water bodies such as lakes and wetlands. In fractured bedrock environments, shallow bedrock can be vulnerable to degraded water quality when contaminants at the surface infiltrate quickly through permeable formations. Here, airborne electromagnetic surveys were acquired in three different parts of Wisconsin, totalling more than 5700 flight line-km, to improve understanding of depth to bedrock, the lithologic composition of overlying sediments, and as input structure for groundwater model development.

AEM survey of the Neretva Delta (Croatia): a case study for hydrogeology

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Groundwater salinisation is a serious problem affecting numerous areas of the world, and Neretva's delta in Croatia is one of them. Airborne electromagnetics is already widely used to feed data-driven decision and management processes with accurate (hydro) geomodels and, by doing so, to mitigate the detrimental effects of salinisation.

In this perspective, in 2021, an airborne electromagnetic survey was flown over about 100 km^2. The overall goal of the survey was to better understand the hydrogeology of the plain leading to a more quantitative assessment of the saltwater intrusion and possible preferential paths.

Here, we present the results of data processing and inversion. We built a (pseudo-)3D resistivity model based on 1D forward approximation. And we compare it against ground-based electrical measurements. According to the available boreholes, freshwater is related to a relatively resistive unit.

Indigenous knowledge and methodologies to inform science and data capture

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Indigenous knowledge and methodologies are a missing component in science in Australia. On this dry, flat and ancient continent Traditional Knowledge has been passed on from generation to generation for millennia (over 65 000 years). This is a profound reliance of knowledge of water, species and country, has been critical to ensure the survival of indigenous peoples in a dry landscape, through the role of traditional knowledge in finding and protecting cultural landscapes. Indigenous knowledge and methodologies can provide new (but old) evidence that is culturally appropriate, and which generates a cultural safe space with indigenous researchers and communities leading. The aim is to present protocols and principles to shift the research paradigm away from indigenous peoples being the researched under non-indigenous research methodologies to becoming the researchers. This allows the indigenous scientist to derive the terms, questions and priorities of what is being researched, how the community is engaged, and how the research is delivered.

The Valen Prospect: It's SPM,… No it's not,…Yes it is!.. No wait….

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The choice of systems and interpretation approaches for the exploration for critical mineral systems under a complex and varying regolith cover using airborne electromagnetics, can be informed by forward modelling methods. However, the direct assessment of systems and modelling algorithms using data acquired under real survey conditions can be equally informative. For example, it provides an opportunity to assess the effects of real geological variability and noise, arising in a true survey configuration for different systems, and the artefacts that may result from the use of different inversion codes. Here we discuss the application of 1, 2 and 3D inversion approaches to resolving the geometry and complexity of the geology in an area on the South Australian side of the Musgrave province and consider modelled responses from coincident lines of fixed wing (SPECTREM-Plus and TEMPEST – High Moment), and heliborne (VTEM and SkyTEM) time domain EM systems over a known (from ground EM and drilling) deep, steeply dipping, conductor - the Valen Prospect.

All inversion methods and AEM systems contributed to our understanding of geological variability and structural complexity, although all generate smoothed versions of geological reality. Results from the 1D inversions appear to map geological variability and complexity in the near surface (regolith character?) in greater detail compared to those from the 2 and 3D inversions, even though the geology is recognisably 3D in character. The Valen Prospect characterised as a distinct, small, and narrow late time anomaly, is modelled in 1D, albeit deeper than drilling and ground EM suggests. While the 2 and 3D models have good global data fits, in some instances they failed to fit measured data at late time, consequently overlooking Valen. It was suggested that problems with fitting the anomaly at late times may be the result of regolith-related superparamagnetism (SPM) in the near surface which often beset AEM data sets in Australian settings. However, decay-rate analysis of the Valen anomaly suggests a deep conductor response for the SkyTEM, SPECTREM and TEMPEST systems. The decay rate of the corresponding VTEM anomaly suggests an SPM response. However, the shape of the VTEM decay also suggests the presence of deeper conductive material.

Developing a fully airborne drone TEM system

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Aiming at improving the efficiency and versatility of the time-domain electromagnetic method for geotechnical and environmental applications, we are developing a fully airborne small-scale drone TEM system. In this paper we will outline the main reasonings and design choices leading to the present system implementation. The development of the complete airborne drone TEM system has involved the development of numerous system parts, which all present their own challenges and optimisations both as individual elements and when working together. In fact, our development of the airborne drone TEM system has essentially progressed in two parallel branches, where one branch has constituted drone and frame developments, while the other has constituted transmitter and receiver developments. Practical field tests of the various transmitter and receiver prototypes have typically been performed as minor surveys at various test locations using a scaled-down SkyTEM frame towed by a helicopter. We will present former and present capabilities of the system, primarily exemplified through descriptions of these prototype test surveys.

Geotechnical ground investigations with a small airborne TEM prototype system

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In this paper we show how time domain electromagnetic data from a small airborne prototype system was successfully used for geotechnical ground investigations at a road construction site in Central Norway. The measured data were processed and inverted with time efficient semi-automatic processing tools. Subsequently, the resistivity models recovered by AEM data inversion were automatically interpreted with machine learning based algorithms that were trained with geotechnical drilling data. Both the thickness of a sediment layer overlaying bedrock and the type of sediment was estimated. The measured data and the inverted resistivity models are compared to those from a regular SkyTEM304 system, which was utilised earlier at the same site. Also, the sediment depth and sediment type estimated from the two AEM datasets were compared, proving the feasibility of such a small airborne TEM system for geotechnical ground of the shallow subsurface.

A forward model study to investigate 25, 12.5 and 6.25 Hz AEM system responses to IP and SPM effects in the regolith

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2.5D forward modelling has been completed on a series of synthetic electrical property models to evaluate and compare the responses of the 25 Hz Tempest, 25 Hz VTEMplus and 12.5 and 6.25 Hz HeliTEM2 systems to a large tabular conductor buried between 30 and 430 m below 30 m of conductive cover with and without chargeable IP properties. The response to a surface SPM layer above the conductive cover or at surface in the resistive host is also modelled and compared. The properties chosen to populate the model are representative of environments encountered in recently inverted surveys for these systems.

The model results show that as the waveform turnoff sharpens and the system frequency decreases the sensitivity to shallow near surface IP effects increases dramatically and suggests that in this environment common in Australia and other deeply weathered regions in Africa, the benefits of using these systems to detect deeper and more subtle conductors are not being realised.

A selection of the model results was inverted using the Moksha 2.5D inductive only and the joint inductive and IP inversion methods to determine if these complex models are accurately recovered.

The results indicate that it is very difficult or nearly impossible to recover the original geoelectric section when IP dominates the inductive signal in this way.

Passive and active airborne electromagnetics – separate and combined technical solutions and applicability

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Airborne electromagnetic methods are divided, by primary field sources, into 'active' (with controlled primary field sources) and 'passive' (without the ability to control the primary field). Each has pros and cons related to the depth of investigation, bandwidths, sensitivity, resolution, terrain clearance requirements, and parasitic effects. Expert Geophysics Limited has developed AEM systems utilising active and passive principles, separate and combined. The MobileMT system is an entirely passive system using a remote reference technique. The system provides low-noise broadband data extracted from natural field audio frequency (AFMAG) and a very-low-frequency (VLF) power spectra. In addition to the passive field data, but with limited broadband, the TargetEM system measures time-domain data with an active and focused source of the primary transmitting field. The combined (active and passive) airborne electromagnetic system records broadband streaming data used to extract AFMAG, VLF, and time-domain components. The natural field data, even in a limited frequency range, is valuable in filling the gaps when the time-domain method is limited – at mapping highly resistive geological terrains, in detecting superconductors, during surveys in rugged relief conditions, and at parasitic effects appearance. In this paper, we present the combined "active-passive" system.

AEM imagery down to one kilometre depth: New constraints for geological and hydrogeological modeling in volcanic contexts

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We present the integration of airborne magnetic data and five different airborne electromagnetics data sets spanning

from 3000 NIA up to 1 000 000 NIA magnetic moments (three different AEM systems were used) in La Réunion volcanic island. Subsequently, a 3D geological model of the first km beneath the Plaine des Fougères was built, in order to constrain 3D hydrogeological modelling. This approach allowed for the correlation of different datasets, providing a comprehensive image of the subsurface and enabling a greater hydrogeological understanding. It was used to position the route of a deep-water drainage gallery and has great potential for applications in other areas.

HiQGA: Open source deterministic and probabilistic AEM inversion

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The High Quality Geophysical Analysis (HiQGA) package is a framework for geophysical forward modelling, Bayesian inference, and deterministic imaging. A primary focus of the code is production inversion of airborne electromagnetic (AEM) data from a variety of acquisition systems. Adding custom AEM systems is simple using a modern computational idea known as multiple dispatch. For probabilistic spatial inference from geophysical data, only a misfit function needs to be supplied to the inference engine. For deterministic inversion, a linearisation of the forward operator (i.e., Jacobian) is also required. For fixed wing geometry nuisances, probabilistic inversion is carried out using Hierarchical Bayesian inference, and deterministic inversion for these nuisances is done using BFGS optimisation. The code is natively parallel, and inversions from a full day of production AEM acquisition can be inverted on thousands of CPUs within a few hours. This allows for quick assessment of the quality of the acquisition and provides geological interpreters preliminary subsurface conductivity images and associated uncertainties. These images are used to create subsurface models for a range of applications from natural resource exploration to its management and conservation.

Supervised stacking to improve the signal-to-noise ratio of AEM data

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AEM method has proven to provide useful information on the subsurface for many applications. However, measured decays are affected by many noises, limiting its effectiveness and which may prevent to acquire usable data, especially in resistive environments. Stacking techniques are applied in an attempt to improve the signal-to-noise ratio. However, stacking all decays falling within a stack interval can be ineffective, given the nature of noises that can affect the data from decay to decay. To a lesser extent, arbitrarily increasing the stack size may also be ineffective, especially in an anthropised environment. Stacking is generally done without any real control on the data taken into account.

This paper introduces a supervised stacking method that stacks decays falling within a stack interval considering different combinations and estimates the signal-to-noise ratio of the resulting decays. The estimation of the signal-to-noise ratio is performed using the singular value decomposition filtering which has proven to be effective in identifying and removing noise affecting an AEM dataset.

The supervised stacking method is applied on the raw data. It has been tested on two AEM datasets, acquired in Reunion and Auvergne (France), where EM noise is high, and resistivity can easily exceed 1000 Ωm in some places. The results show that the presented method improves the signal-to-noise ratio and can reduce sferics and certain noises from man-made installations. It provides less noisy decays for post-processing and offers new possibilities for processing AEM data

Airborne magnetics as structural guide in the 3D inversion of Airborne EM data

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Airborne Magnetics and Electromagnetics surveys are widely used in mineral resource exploration. Beyond the sensitivity of both to certain mineral deposits, magnetics serves as a useful proxy for geological structure.

We extend our previous work on cross-gradient, structurally-guided 3D EM inversions to use two-dimensional gradients derived from pre-processed magnetic grids as a structural guide in inversions of AEM data sets.

We compare 3D resistivity inversion results obtained with this structural guiding approach to those without, for AEM data recorded in a survey in New Brunswick, Canada.

This structurally-guided 3D inversion method using magnetics data is generic and can be applied to inversion of other geophysics data such as ground electromagnetics, etc.

BGR helicopter-borne frequency-domain EM – past, present, future

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Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, LOWER SAXONY, Germany

The German Federal Institute for Geosciences and Natural Resources (BGR) has been conducting airborne geophysical surveys worldwide for more than four decades. Most of these airborne surveys applied frequency-domain heli-copter-borne electromagnetics (HEM) in combination with magnetic and radiometric measurements.

HEM surveys served and still serve as acquisition of baseline data for a number of applications in mineral, groundwater and soil exploration. After starting with anomaly detection in mineral exploration surveys, the focus was set to groundwater surveys during the following decades. Spatial mapping of freshwater resources, seawater intrusion, submarine fresh-water outflows, and buried valleys are some typical applications. Recently, environmental issues have gained more and more importance. Therefore, BGR conducted most of the current surveys in Germany. These provided not only resistivity distributions, but also estimated

parameters such as groundwater chloride content in coastal and salt dome areas, groundwater iron content in former lignite mining areas, and peat volumes of mires. These applications combined local data (*e.g* boreholes) or external models as well as airborne geophysical data to derive spatial estimates, which then served as baseline date for advanced (hydro-) geological modelling.

The HydroGeosITe for AEM mapping: characterisation through joint inversion of AEM, ground EM and DCIP data

Alessandro Signora[1], Stefano Galli[1], Matteo Gisolo[2], Gianluca Fiandaca[1] and Ilaria Menga[1]

1. Univ. of Milan, Dep. of Earth Sciences A. Desio, The EEM Team for Hydro & eXploration, Milano, Italy
2. A2A Ciclo Idrico S.p.a., Brescia, Italy

The HydroGeosITe project aims at the establishment of the first Italian calibration and reference site for airborne electromagnetic (AEM), ground EM and electric geophysical methods within the largest AEM campaign carried out in Italy for groundwater mapping and management.

The geophysical characterisation of the HydroGeosITe combines AEM, ground EM and galvanic direct current and induced polarisation (DCIP) surveys, for the retrieval of a unique 3D distribution of conduction and polarisation electrical properties, able to describe all geophysical data.

This is achieved through a joint inversion of all inductive and galvanic data in terms of dispersive resistivity, with data misfit comparable to the independent inversions and significantly improved resolution.

The HydroGeosITe will serve as calibration site for future AEM campaigns, as well as for ground-based EM and galvanic surveys. Furthermore, borehole drillings down to several hundreds of meters are being carried out, with lithological description and geophysical logging, for establishing a reference in the interpretations of the resistivity models retrieved by the AEM campaign.

Going the extra mile - Julimar, a case study from Western Australia

Camilla Søerensen[1], Timothy Munday[2] and Toke Søltoft[1]

1. Seequent, Aarhus, NA, Denmark
2. CSIRO, Kensington, WA, Australia

The Julimar Complex, which is located in Western Australia, hosts the recently discovered Gonneville deposit which contains massive sulphide mineralisation (Pd, Pt, Ni, Cu and Co). The deposit was discovered by using a moving loop EM survey and follow up geophysics including AEM confirmed the find.

In this study we use a SkyTEM AEM line, which was acquired as part of the AUS-AEM initiative, which crosses the Gonneville deposit. The objective is to extract as much information from that data as possible to demonstrate that AEM can be used for general geological mapping in addition to anomaly detection. By using several inversion methods and analysing the results we get an understanding of the most believable model. In addition to a deterministic full non-linear inversion of the data, we also use a stochastic reverse jump Monte Carlo Markov Chain inversion on the SkyTEM data.

The results from both algorithms are comparable and correlate well with the known geological information published by Chalice mining, based on drill holes and other geophysical surveys.

Using Airborne EM for exploring for minerals under cover could provide a lot more information about the subsurface than just mapping highly conductivity sulphide mineralisation zones.

EEMstudio: an open-source freeware QGIS plugin for processing, modelling and inversion of electric and electromagnetic data

Nicole Anna Lidia Sullivan[1], Andrea Viezzoli[2] and Gianluca Fiandaca[1]

1. Università degli Studi di Milano, Milano, ITALY, Italy
2. EMergo srl, Pisa, Italy

The typical workflow in electric and electromagnetic methods includes the acquisition of the data, processing of the received signal and inversion to achieve a model of the electrical properties of the ground. The data processing is a crucial step that defines the outcome of the resulting model. The electromagnetic method, in fact, as well as the induced polarisation in galvanic acquisitions, is particularly susceptible to the systematic noise caused by anthropogenic infrastructures. Therefore, it is mandatory to remove the noisy data in order to retrieve reliable models. The standard method for this task is the visual culling of the data that are most affected by noise and interferences (the so-called outliers), through software with graphical user interfaces designed with this specific aim.

EEMstudio is a QGIS plugin that allows to visualise electric and electromagnetic data, to select and remove outliers, as well as modelling data and launch inversions though the modelling and inversion kernel EEMverter, keeping always a link to the map during the process.

EEMstudio is composed by a docked widget in QGIS where the soundings are plotted, a main window for data processing, equipped with ad hoc plots to visualise the data, and other windows for launching forward modelling on synthetic data as well as inversions, having all the useful tools in a minimum space. Furthermore, EEMstudio is distributed as a freeware and open-source tool, accessible to anyone and editable to suit new necessities, under the EUPL 1.2 free software licence.

TEMPEST electromagnetic transmitters with multiple loops and multistep waveforms

Andrew Sunderland[1] and Eric Steele[2]

1. University of Western Australia, Crawley, WA, Australia
2. Xcalibur Multiphysics, Jandakot, Western Australia, Australia

The vertical resolution of airborne electromagnetic systems is limited by the earliest time window and how fast the transmitter current can transition. Presented is how transmitter loop geometry and different transmitter waveforms could decrease the transmitter ramp time by up to a factor of eight.

Using regional airborne electromagnetic conductivity data to characterise surface water groundwater interaction in the Cooper Creek floodplain in arid central eastern Australia

Neil J Symington, Tim Evans, Nadege Rollet, Larysa Halas, John Vizy, Sarah Buckerfield, Anandaroop Ray, Yusen Ley-Cooper and Ross C Brodie

Geoscience Australia, Symonston, ACT, Australia

Airborne electromagnetic (AEM) data has been acquired at 20 km flight line spacing across much of the Australian continent, and electrical conductivity models generated by inverting these data are freely available. Despite the wide line spacing of these data, they are suitable for imaging the shallow subsurface and can greatly assist in understanding groundwater systems.

AEM data acquired using a fixed-wing towed system over the Cooper Creek floodplain, an ephemeral, anabranching river system in arid eastern central Australia, were inverted using deterministic and probabilistic methods. We integrate the AEM conductivity data with a range of surface and subsurface data to characterise the hydrogeology of the region and infer groundwater salinity from the shallow alluvial aquifer across an area of more than 14 000 km^2. The conductivity data reveal several examples of focused recharge through a river channel forming a freshwater lens within the more regional shallow saline groundwater system.

This work demonstrates that regional scale AEM conductivity data can be a valuable tool for understanding groundwater processes at various scales, with implications for water resource management. This work is particularly important in the Australian context, where high quality borehole data is typically sparse, but high quality geophysical and satellite data are often available.

New helicopter-borne TEM system HoriZOND for effective exploration

Alexey Trusov and Oleg Kontarovich

Aerogeophysica, Moscow, RU, Russia

Airborne electromagnetic (AEM) methods have been widely used for mineral exploration and environmental and geotechnical applications because of their efficiency in covering vast survey areas without ground access. Over a few decades, various airborne EM systems have been developed. As a result of many years of R&D, a newest time-domain EM helicopter system named HoriZOND was developed. The first tests were conducted in 2019.

Lessons learned from a decade of AIP modelling

Andrea Viezzoli

Emergo srl, Cascina, ITALY, Italy

Work carried out from AEM 13 till now shows that IP effects in AEM data need to be modelled. Doing so augments the overall impact of an AEM survey on a variety of levels, whether the physical proxy for the mapping is conductivity or chargeability. Modelling IP effects in AEM data will soon become the industry standard**.**

Adaptive correction for airborne electromagnetic measurements

Andrey Volkovitsky and Evgeny Karshakov

V.A. Trapeznikov Institute of Control Sciences, Russian Academy of Sciences, Moscow, MOSCOW, Russia

We present results of development and practical implementation of the adaptive correction method and algorithm. They ensure high accuracy and stability of the airborne low-frequency inductive electromagnetic measurements. We describe the theoretical foundations of the method and the basic schemes of the algorithm, and consistently consider the stages of computational transformations. We provide several examples of experimentally obtained data proving the effectiveness of the method. The main result achieved is the possibility of functioning of the airborne electromagnetic system without calibration during the entire flight.

Some comparisons of AEM systems for specific mineral exploration problems

Michael Whitford and Andrew Fitzpatrick

IGO Ltd, South Perth, WA, Australia

Simple comparisons of airborne EM systems are limited, and those that are available have finite relevance of ~ 5-10 years due to ongoing improvements in current systems and new systems being offered. The comparisons are hindered by the myriad of system design features, but moreover each comparison must have a purpose, as no system is "the best", but there are many systems "suitable" to answer exploration questions. Several comparisons are presented here, where systems are compared for a specific application using mostly coincidentally acquired field data.

Noise considerations for TEMPEST data

Peter Wolfgram, Teo Hage and Eric Steele

Xcalibur, Perth, WA, Australia

The noise characteristic of an AEM system is crucial not only for designing the signal processing strategy but more importantly for interpreting the data in terms of an earth model. *Ad hoc* estimates of noise are often all that is available to the user of an AEM data set, leaving noise as the "elephant in the room". We present a rigorous approach to estimating noise from first principles. We illustrate how such estimates may be obtained from high-altitude calibration data and then be applied to processing and interpretation of TEMPEST data.

Australian continental-scale multilayered chronostratigraphic interpretation of airborne electromagnetics

Sebastian C.T. Wong[1], Ian C. Roach[1], Karen A. Connors[2], Juliana F.M. Vilhena[2], Liam Pitt[1], Malcolm G. Nicoll[1], Jackie A. Hope[1], Marie-Aude Bonnardot[1], Ross C. Brodie[1] and Alan Yusen Ley-Cooper[1]

1. Geoscience Australia, Canberra, ACT, Australia
2. University of Queensland, Brisbane, QLD, Australia

A key issue for explorers in Australia is the abundant sedimentary and regolith cover obscuring access to

underlying potentially prospective rocks. Multilayered chronostratigraphic interpretation of regional broad line-spaced (~20 km) airborne electromagnetic (AEM) conductivity sections have led to breakthroughs in Australia's near-surface geoscience. A dedicated/systematic workflow has been developed to characterise the thickness of cover and the depth to basement rocks, by delineating contact geometries, and by capturing stratigraphic units, their ages and relationships. Results provide a fundamental geological framework, currently covering 27% of the Australian continent, or approximately 2 085 000 km^2. Delivery as precompetitive data in various non-proprietary formats and on various platforms ensures that these interpretations represent an enduring and meaningful contribution to academia, government and industry. The outputs support resource exploration, hazard mapping, environmental management, and uncertainty attribution. This work encourages exploration investment, can reduce exploration risks and costs, helps expand search area whilst aiding target identification, and allows users to make well-informed decisions. Presented herein are some key findings from interpretations in potentially prospective, yet in some cases, underexplored regions from around Australia.

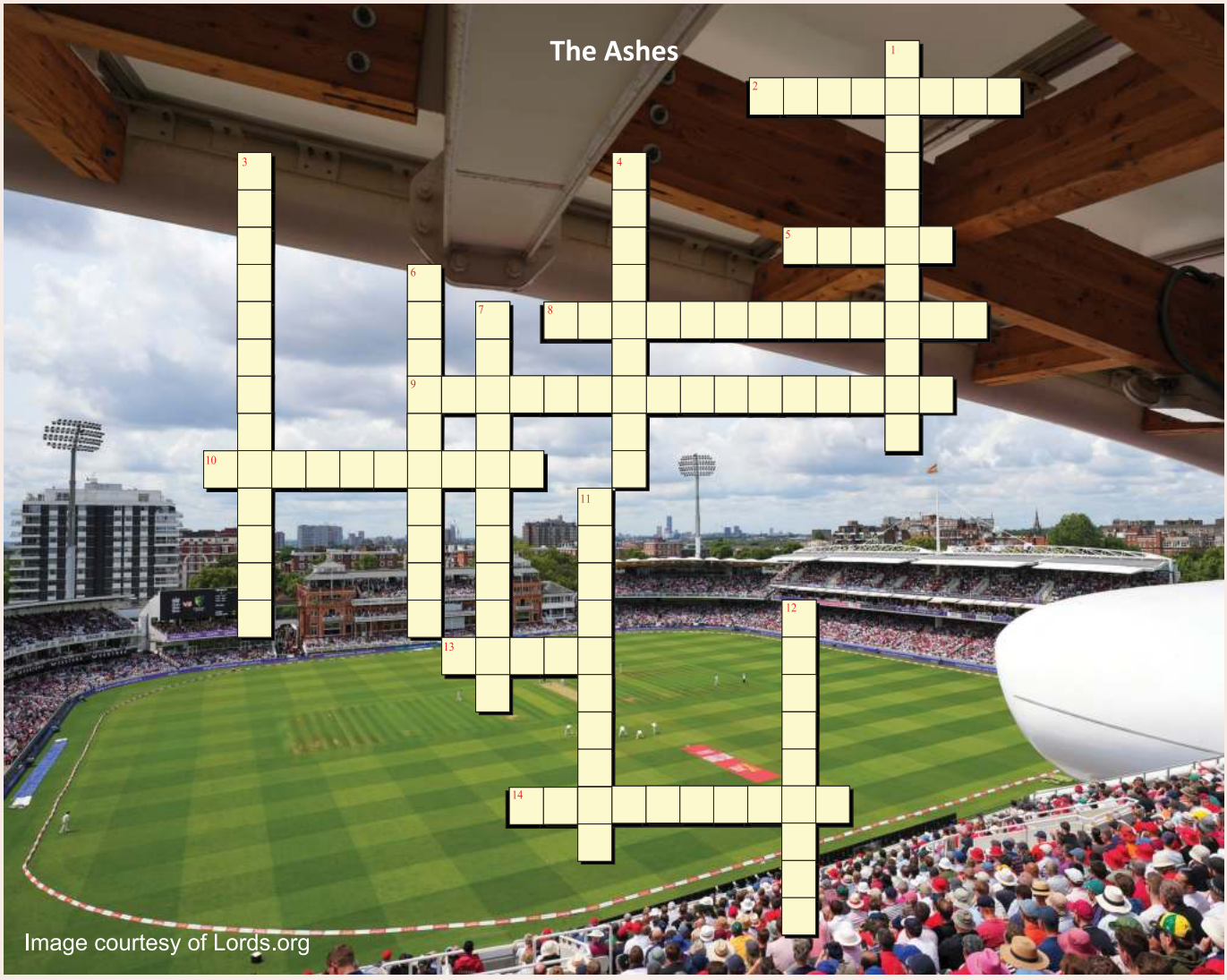
Enhanced weathering and oxidation modelling in coals by integration of ATEM results with standard coal geoscience data at Peak Downs Mine, Queensland, Australia

Amanda Zawada, Jonathan Lowe and Geoffrey Peters

BHP, Brisbane, QLD, Australia

Geological processes of alteration such as oxidation and weathering lead to coal quality degradation. In the context of coal mining, this is significant because engineers must optimise mine plan designs with respect to waste rock and marketable coal. Airborne Transient Electromagnetic Methods (ATEM) can be useful in demarcating a coal seam's Limit of Oxidation (LOX) and add confidence to the related thickness of a weathered zone. This study demonstrates an attempt at using state of the art, high resolution ATEM data acquired over the Peak Downs Mine to improve upon the positioning of LOX 'lines', which can be notoriously difficult to model acutely where the coal seams are sub-parallel to the base of weathering estimate. The interpretation techniques applied throughout this study focus on using ATEM results visualised as X and Z component data profiles, compared to laterally constrained conductivity-depth inversions and borehole data. Such studies may enable geoscientists to better inform mine planning and development decisions.

Preview crossword #27



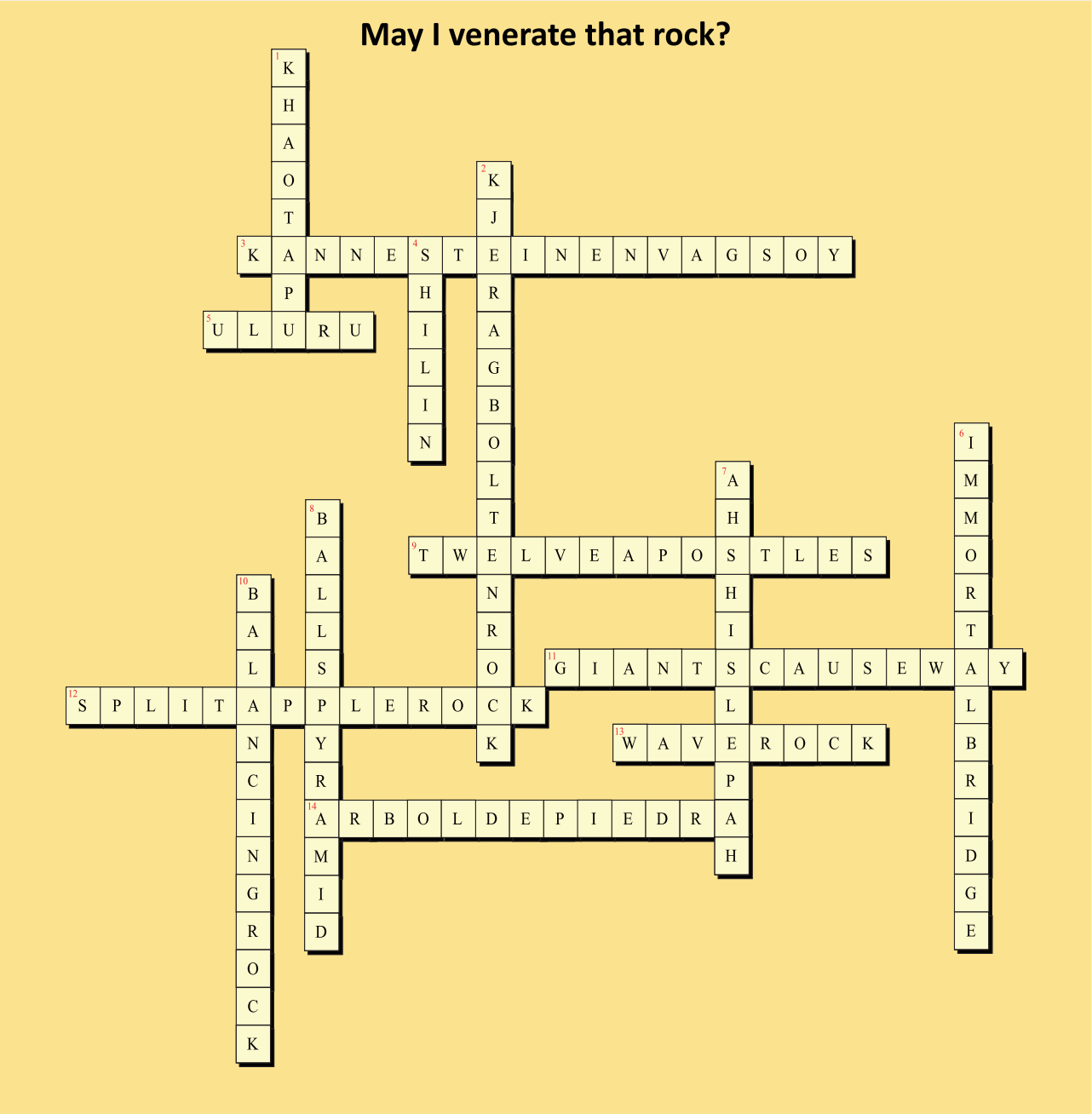
Across	Down
2. This infamous series will be remembered for England's tactics in combating the phenomenal batting skills of the Australians, where English bowlers would bowl at the batsman's body	**1.** As of 2023, Women's Ashes leading run-scorer and Ashes leading wicket taker [6,5]
5. The number of Ashes series whitewashes in history, all completed by Australia	**3.** Clubbed the fastest ever Ashes century [4,9]
8. Only the second set of brothers in Ashes history to make hundreds in the same innings [5,8]	**4.** Batsman with the highest score in an Ashes innings [3,6]
9. It's been 30yrs since that very first Ashes ball, leaving Mike Gatting, and the world, in complete disbelief [4,of the,7]	**6.** Most Ashes runs and centuries by any batsmen [3,7]
10. Most Ashes wickets ever by any bowler [5,5]	**7.** Australia had lost five of the previous six Ashes series but carved out a stunning 4-0 triumph in England under Captain Grumpy [5,6]
13. The ground on which a young 21 year old Don Bradman finished the day on 309 not out	**11.** This English bowler took a marathon 19-wickets in an Ashes test match, a feat likely to remain unchallenged…forever [5,5]
14. The last batsman to score hundreds in each innings of an Ashes Test [5,5]	**12.** Most career catches in Ashes history by a non-wicketkeeper [3,6]

Play to win!!

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

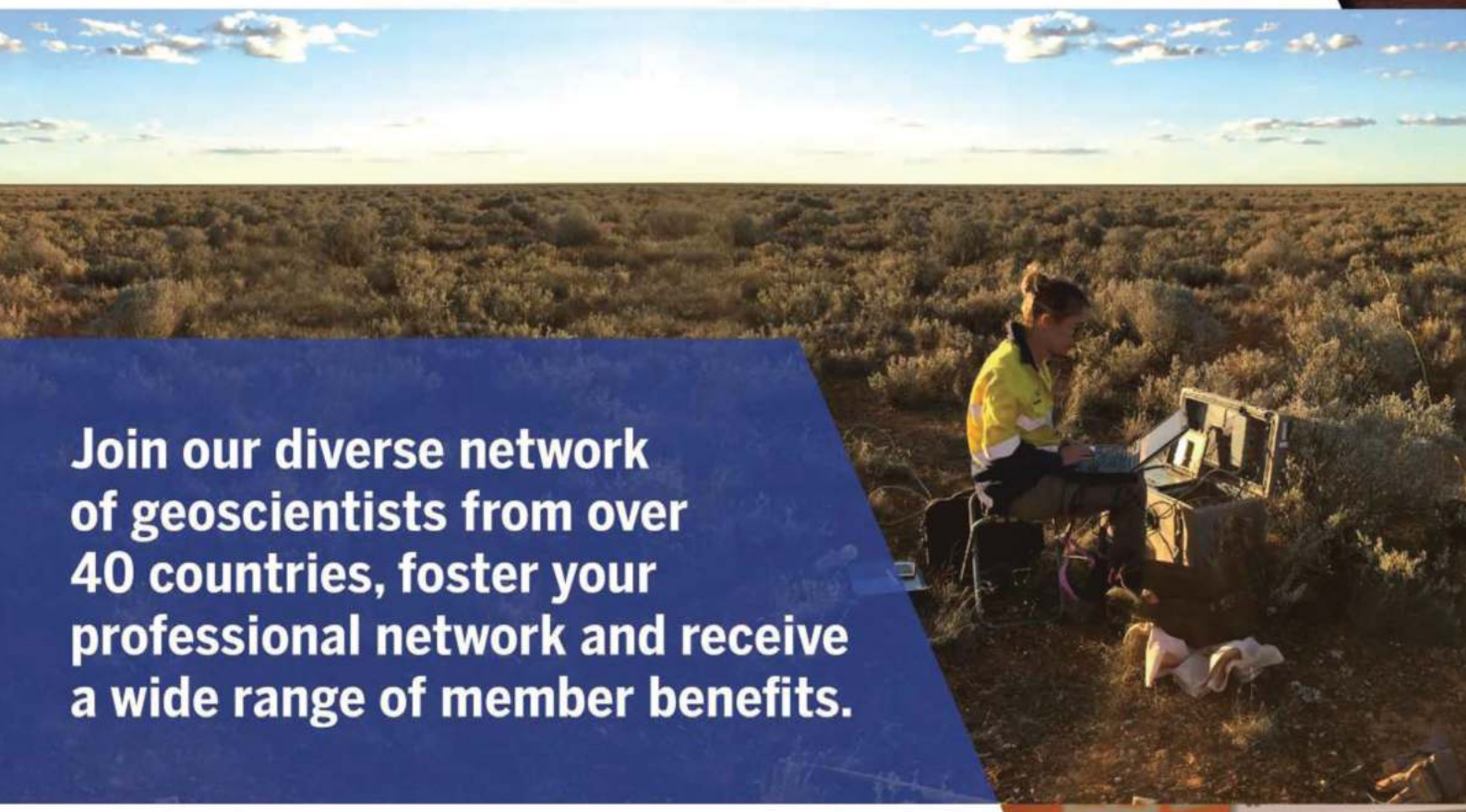
Good luck!

Preview crossword #26 solution



Business directory

Australian Society of
Exploration Geophysicists



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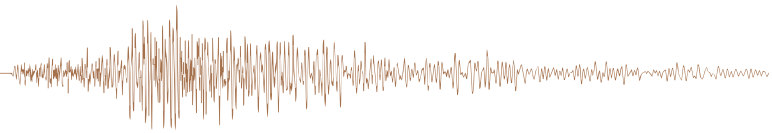

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

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Application for Active & Associate Membership 2023

INSTRUCTIONS FOR APPLICANTS

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

Section 1. Personal Identification

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

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

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

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

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

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

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

Section 3. Academic and Professional Qualifications

Month/Year (From – To)	Organisation/Institution	Position/Degree (incl. Major)	Professional Record Only: Years of Independent Work

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

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

Section 5. Membership of Other Societies

Australian:
❑ Aus IMM Grade _____ ❑ AIG Grade _____ ❑ GSA Grade _____ ❑ PESA Grade _____
International:
❑ AAPG Grade _____ ❑ EAGE Grade _____ ❑ SEG Grade _____ ❑ SPE Grade _____

❑ Others _____

Section 6. ASEG Member Record

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

❑ **Yes** ❑ **No**

Please complete this section for the ASEG membership database.

Employment area:
❑ Industry ❑ Contract/ Service 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

❑ Active/Associate (Australia) - $193.00 (incl GST)	❑ Active/Associate 5 Year Membership (Australia) - $965.00 (incl GST)
❑ Active/Associate (Group IV Countries) - $175.50	❑ Active/Associate 5 Year Membership (Group IV Countries) - $877.50
❑ Active/Associate (Group III Countries) - $52.70	❑ Active/Associate 5 Year Membership (Group III Countries) - $263.50
❑ Active/Associate (Group I & II Countries) - $19.30	❑ Active/Associate 5 Year Membership (Group I & II Countries) - $96.50
❑ Associate-Graduate (Australia) - $97.00 (incl GST)	

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**

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

ASEG members can elect to have hardcopy Preview delivered to their nominated address (offer does not apply to Student members).

I would like to receive hardcopy Preview as part of my ASEG membership.

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

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Application for Student Membership 2023

INSTRUCTIONS FOR APPLICANTS

1. Student Membership is available to anyone who is a full-time student in good standing at a recognised university working towards a degree in geophysics or a related field.

   Eligibility for Student Membership shall terminate at the close of the calendar year in which the Student Member ceases their graduate or undergraduate studies.

   Student Membership must be renewed annually.

   The duration of a Student Membership is limited to five years.

2. Fill out the application form, ensuring that you provide contact details for your supervisor or coordinator

3. 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 Email

Section 3 Membership Grades and Rates

❑	Student (Australia & Group IV Countries)	FREE
❑	Student (Group III Countries)	FREE
❑	Student (Group I & II Countries)	FREE

Section 4 Preview & Exploration Geophysics

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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 5 Declaration

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Signature: _____ Date: _____

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

August	**2023**		
27 Aug–02 Sep	International Meeting for Applied Geoscience & Energy (IMAGE) https://www.imageevent.org/	Houston	USA
September	**2023**		
3–7	Near Surface Geoscience Conference & Exhibition 2023 https://eagensg.org/	Edinburgh	UK
4–8	8th International Airborne Electromagnetics Workshop (AEM 2023) aemconference@theassociationspecialists.com.au	Fitzroy Island	Australia
12–13	EAGE Conference on the Future of Energy - Role of Geoscience in the Energy Transition https://eage.eventsair.com/eage-conference-on-the-future-of-energy---role-of-geoscience-in-the-energy-transition	Kuala Lumpur	Malaysia
October	**2023**		
16–19	18th International Congress of the Brazilian Geophysical Society & Expogef https://sbgf.org.br/congresso/	Rio de Janeiro	Brazil
17–20	Seventh International Conference on Engineering Geophysics (ICEG)	Abu Dhabi	UAE
25–27	Offshore Technology Conference (OTC) https://otcbrasil.org/	Rio de Janiero	Brazil
29 Oct–3 Nov	Mexican Geophysical Union (UGM) Annual Meeting: RAUGM2023 https://www.raugm.org.mx/?lang=en	Puerto Vallarta	Mexico
November	**2023**		
3–5	14th Biennial International Conference (SPG 2023) https://spgindia.org/spg2023/index.php	Kochi	India
7–8	EAGE/Aqua Foundation Second Indian Near Surface Geophysics Conference & Exhibition https://www.nearsurfacegeophysics.in/	New Delhi	India
15	Modern Applications of Geophysics: Mineral Case Studies (MAG23)	Perth	Australia
December	**2023**		
5–7	Latin America URTeC https://urtec.org/latinamerica/2023/	Buenos Aires	Argentina
February	**2024**		
28 Feb–02 Mar	Offshore Technology Conference Asia (OTC Asia) https://2024.otcasia.org/	Kuala Lumpur	Malaysia
May	**2024**		
13–15	6th Asia Pacific Meeting on Near Surface Geoscience and Engineering https://eage.eventsair.com/6th-asia-pacific-meeting-on-near-surface-geoscience-and-engineering/	Tsukuba	Japan
June	**2024**		
10–14	85th EAGE Annual Conference & Exhibition	Oslo	Norway
August	**2024**		
25–31	International Meeting for Applied Geoscience & Energy (IMAGE) https://www.imageevent.org/	Houston	USA
August	**2025**		
24–29	International Meeting for Applied Geoscience & Energy (IMAGE)	Houston	USA

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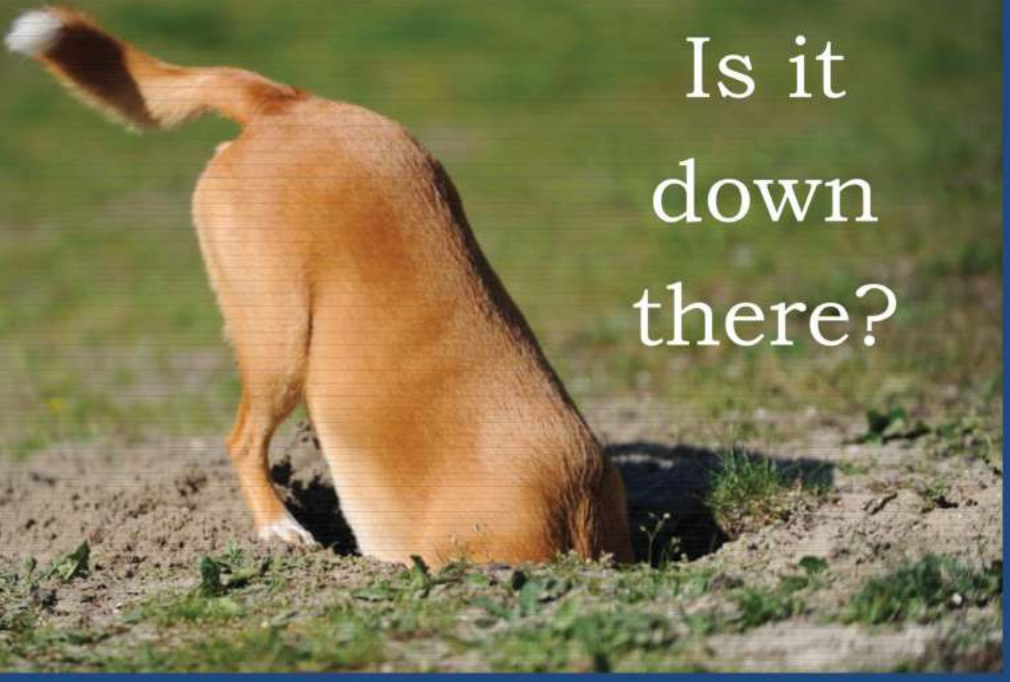
Preview is published bimonthly in February, April, June, August, October and December. The deadline for submission of material to the Editor is usually the second Friday of the month prior to the month of issue. The deadline for the October issue is 8 September 2023.

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



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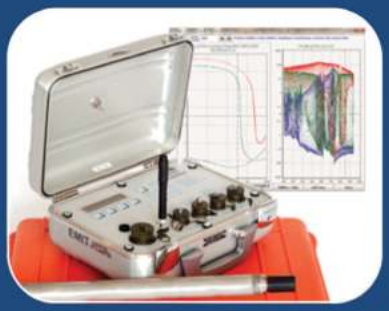

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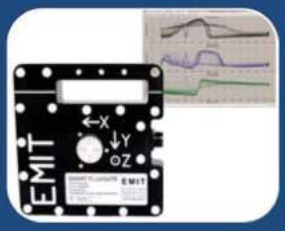

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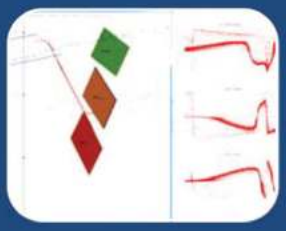

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