Australian Society of Exploration Geophysicists
AUGUST 2021 • ISSUE 213
ABN 71 000 876 040 ISSN 1443-2471

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ASEG federal executive 2020–21

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

Emma Brand: President Elect
Tel: +61 455 083 400
Email: president-elect@aseg.org.au

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

Yvette Poudjomi Djomani: Treasurer (Finance Committee Chair)
Tel: + 61 2 6249 9224
Email: treasurer@aseg.org.au

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

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

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

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

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

Kate Selway (Education Committee Chair)
Tel: +61 491 237 572
Email: education@aseg.org.au

Janelle Simpson (Branch Liaison Committee Chair)
Tel:
Email: branch-rep@aseg.org.au

The ASEG Secretariat

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

Standing committee chairs

Finance Committee Chair: Yvette Poudjom Djomani
Tel: +61 2 6249 9224
Email: treasurer@aseg.org.au

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

Branch Liaison: Janelle Simpson
Tel:
Email: branch-rep@aseg.org.au

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

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

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

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

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

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

Professional Development Committee Chair:
Vacant - enquires to fedsec@aseg.org.au
Tel: +61 8 6436 8746
Email: continuingeducation@aseg.org.au

Education Committee Chair: Kate Selway
+61 491 237 572
Email: education@aseg.org.au

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

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

Communications Committee Chair:
Mosayeb K. Zahedi
Tel: +61 421 874 597
Email: communications@aseg.org.au

Specialist groups

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

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

ASEG branches

Australian Capital Territory

President: Andandaroop Ray
Tel:
Email: actpresident@aseg.org.au

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

New South Wales

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

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

Queensland

President: James Alderman
Tel:
Email: qldpresident@aseg.org.au

Secretary: Nick Josephs
Email: qldsecretary@aseg.org.au

South Australia & Northern Territory

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

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

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

Tasmania

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

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

Victoria

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

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

Western Australia

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

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

ASEG honorary editors

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

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

ADVERTISERS INDEX

ASEG CORPORATE PLUS MEMBERS

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

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

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

ASEG CORPORATE MEMBERS

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

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

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

DUG Technology
Tel: +61 8 9287 4100
Email: sales@dug.com support@dug.com
Web: https://dug.com/

Australian Geophysical Services
Tel: +61 (0) 410529992
Email: info@australiangeophysicalservices.com
Web: https://www.australiangeophysicalservices.com/

FRONT COVER

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

ISSN: 1443-2471 eISSN: 1836-084X

CONTENTS

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

Assistant Editor
Theo Aravanis
Email: taravanis2011@gmail.com

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

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

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

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

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

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

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

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

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

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

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

Editor's desk

The 3rd Australasian Exploration Geoscience Convention (incorporating the ASEG 28th International Conference and Exhibition) is upon us, and this issue of *Preview* includes all the information that you will need to make the most of this virtual conference. Yes, sadly the latest outbreaks of COVID in Australia have left the long suffering conference organising committee with no option but to switch to a virtual format. At least we still have a conference – the good citizens of Brisbane are still reeling from the last minute cancellation of the Ekka (the Royal Queensland Show). Not only do we still have a conference, we still have most of our speakers – the upside of the virtual format. There will be something for everyone with presentations that are not only engaging and entertaining, but also thought-provoking and, occasionally, downright exciting – just the tonic for those COVID blues!

In addition, this issue of *Preview* includes a comprehensive update on activities in the geological surveys (state and federal). There is so much new data available that there is no excuse for not using your time in lockdown profitably!

Our regular commentators have also delivered in spades. David Denham (*Canberra observed*) introduces us to the Australian Treasury's take on our future. Marina Pervukhina (*Education matters*) introduces us to Kate Selway, the new Chair of the ASEG's Education Committee who, in turn, introduces us to the results of the latest survey of education in geophysics at Australian universities. Mike Hatch (*Environmental geophysics*) shares his optimism about the future of environmental geophysics – a new golden age no less! Terry Harvey (*Mineral geophysics*) reflects on conventional wisdom in mineral exploration and encourages us to break some of the rules. Mick Micenko (*Seismic window*), prompted by Reg Nelson, takes another look at seismic in hard rock terrains. Tim Keeping (*Data trends*) checks out what QGIS has to offer, and Ian James (*Webwaves*) sounds the death knell for Internet Explorer – there are plenty of alternatives available so don't despair!

The Editor taking time off to explore our industrial heritage in the vicinity of the abandoned Mt Molloy copper mine and smelter in far North Queensland.

If you are new to *Preview* then I would encourage you to take a look at some of our previous editions https://www.aseg.org.au/publications/preview-digital-library. *Preview* is freely available online and is read by geoscientists in industry, government and academia throughout Australia and around the world. We focus on the availability of new geophysical data and advances in geophysical techniques, but also report on matters of general interest. You can subscribe via the ASEG website https://www.aseg.org.au/publications/PVCurrent and never miss a word.

Enjoy!

Lisa Worrall
Preview Editor
previeweditor@aseg.org.au

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

Kate Robertson

There are not many people to whom I could suggest a two-hour meeting at 6 am on a Sunday morning and receive the enthusiastic response: 'Sounds perfect.' Luckily for me, our President-Elect is one of them. And that is how my day started today, with Emma Brand surviving off a few hours' sleep after getting up to watch Ash Barty's Wimbledon win, and me chucking a hoodie over PJ's; business ready… and the strategising begins. Each year, the Federal Executive (FedEx) hold a Strategy Day, where we make plans for the year/s ahead and have focussed discussions. Developing an agenda for this year's strategy day was the focus of today's meeting, and this is how it went.

We started the morning talking about Member value - what are we doing right, what can we improve on, and how can we solidify our Member value proposition to broaden our appeal? In recent years we have had a slow decline in membership numbers, and we would like to turn this decline around. We want to ensure that our Members are receiving such good value, satisfaction and sense of belonging that each year at renewal time it's a no-brainer to renew. We're investigating how to eliminate renewal hurdles - considering options such as auto-renewal of membership and one-click pay methods. We also want to ensure that every decision we make and every action we take considers all our Members, and makes every under-represented group know that they belong in the ASEG. On that note, I'm proud to announce the initiation of the ASEG's Diversity Committee, to initially be chaired by our President-Elect. If you would like to join the committee, please send an email to president-elect@aseg.org.au, and keep an eye out when we release our plans. On that topic, have a read of an article Emma recently wrote about women in STEM https://bit.ly/3eatNmG.

Despite all our efforts to ensure Member satisfaction, our membership may still decline, which begs the question how do we expand? Not just how do we expand, but who do we expand to? It's in our name and our constitution that we are the society of 'exploration geophysicists' but what does this really encompass in this day and age? We all know resources are becoming harder to find, and it's become apparent that the exploration geophysicist needs to encompass a much broader skillset, so who do we target? Data scientists? Physicists? Mathematicians? Solid-earth geophysicists? Or do we continue to represent strictly exploration geophysicists?

Existential questions aside, we need to evolve, and keep up with the rapidly changing times, to be a society that adheres to the sustainability journey toward a Net-Zero future. On Friday night I sat down and watched Professor Alan Jones' presentation 'The perfect storm - Canada's future in peril,' where he walks the predominantly non-geoscientist audience through the stark increase in resources and rate of extraction required if we are to achieve a 2-degree scenario (global average increase in temperature of 2°C). As my partner wandered in and out of the room watching parts of the presentation, I was able to see what parts surprised or shocked him, and what parts prompted him to ask questions. It was a valuable experience that underscored the importance of having a toolkit of facts at the ready in support of our industry and the work that we do. Are you prepared to answer the tough questions if needed? I urge you to inform yourself on these matters, and can highly recommend the course Geologize (https://training.geologize.org/) to make a start.

This leads to the next discussion point for Strategy Day - the importance of the voice of the ASEG - we want to develop an actionable plan for proactive communication on societal matters that affect our Members. Here's an example from the SEG who have recently released a position statement on climate change (https://seg.org/About-SEG/Climate-Change), which also succinctly highlights a number of important roles geophysicists will play in the continued fight against climate change, and this article highlighting the criticality of our profession in responding to the UN Sustainability Goals https://library.seg.org/doi/full/10.1190/tle40010010.1.

Another key discussion to be had is how we deal with the decline of geophysics education. That is an article in itself- read on in this issue of *Preview* for Dr Kate Selway, our Education Committee Chair's summary of geophysics education in Australia, spoiler alert: it's looking bleak. While job prospects are high in Australia right now, geophysics education opportunities are low, and the discussion point is how can the ASEG help to fill this gap.

Then finally, onto a discussion about *Exploration Geophysics*, our Society's technical journal. A shout-out to our long-term hardworking editor Dr Mark Lackie, and our associate editors who give their precious time to handle the submissions. Despite their best efforts, a gradual decline in impact factor has occurred over the last couple of years (in part due to bulk publishing of a backload of papers in the changeover in publishers in 2019). But the question is, how do we really determine the success of our journal? Is it the number of downloads? The number of citations? The number of Members who value our journal? The number of Members who publish in our journal? How well we are getting our Members' research out into the public? I would love to hear any thoughts you might have on this, or in fact any of these questions, and this is the last topic planned for our Strategy Day in September.

By the time you're reading this, the Australasian Exploration Geoscience Conference will be upon us. A huge thank you to the outstanding conference organising committee. The mammoth task of organising a conference during a pandemic cannot be understated. They had to reorganise after it was postponed from April to September and then, just weeks before the conference, do a rapid switch from a hybrid to a fully virtual format. It is very disappointing not to meet in person but it is now clear that their decision to move to a virtual format was the right one. If you have any comments, ideas, and critiques on anything I've mentioned, don't hesitate to email or chat to me virtually at the AEGC.

Lastly, I'm delighted to announce another (and final) addition to the FedEx. Dr Janelle Simpson makes up our 11th member as Branch Liaison, and a big thanks to immediate past-President Dr David Annetts who has been covering this role in the interim.

Kate Robertson
ASEG President
president@aseg.org.au

Executive brief

AGM

The Federal Executive of the ASEG is the governing body of the ASEG. It meets once a month via teleconference, to deal with the administration of the Society. This brief reports on the monthly meeting that was held in July 2020. If there is anything you wish to know more about, please contact Leslie at fedsec@aseg.org.au.

Finances

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

Year to date income - $167 434

Year to date expenditure - $129 801

Net assets - $1 236 430

Membership

As of 8 July 2021, the Society had 799 financial Members, compared to 831 at this time in 2020. The ASEG currently has eight Corporate Members, including three Corporate Plus Members. A huge thanks to all our Corporate Members for your continued support into 2021. Don't forget to have a look for our Corporate Members on the contents page of *Preview* and support them as much as you can. Our state branches also have additional local sponsors, which are shown at all branch meetings and at the beginning of all webinars.

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

Member survey

You should have received an email asking you to take part in our Member survey. This information is important to the Federal Executive for strategic planning purposes. Please take the time to fill out the survey. It should only take you a few minutes, and all Members who take part and leave their details will go into the draw for a $500 gift card. To be eligible for the draw you will need to complete the survey by 31 August, 2021.

AEGC 2021

The 3rd Australasian Exploration Geoscience Conference was to be held in Brisbane on 17-19 September 2021, after being postponed from April 2021. The recent increase in COVID-19 related lockdowns due to spreading of the Delta variant prompted the conference organisers to move to a fully virtual format. They did not want to postpone the conference any further, nor did they want to cancel the event. Their decision will enable the all-important technical talks to be disseminated through the geoscience community, and will make the conference more accessible to our international Members who cannot travel to Australia. The AEGC 2023 conference will be held in Brisbane, most likely in Q2 2023, thereby returning to the "normal" 18-month conference cycle. We are hoping to get as many people to Brisbane in 2023 as we can.

Positions vacant

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

Social media

Stay up to date with all the happenings of your Society on social media. You can connect to us on in facebook for all the latest news and events.

Online events

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

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

Leslie Atkinson
ASEG Secretary
fedsec@aseg.org.au

Welcome to new Members

The ASEG extends a warm welcome to 24 new Members approved by the Federal Executive at its June and July meetings (see Table).

First name	Last name	Organisation	State	Country	Membership type
Aj	Ajrish	University of Adelaide	SA	Australia	Student
Finnegan	Birch	University of Adelaide	SA	Australia	Student
Alex	Browne	CGG	VIC	Australia	Associate
Thuany	Costa de Lima	ANU	ACT	Australia	Student
Joanne	Demmer	Seequent	WA	Australia	Active
Bronwyn	Djefel	Epiroc	WA	Australia	Associate
Claire	Faulkner	University of Adelaide	SA	Australia	Student
Daniel	Gamble	University of Adelaide	SA	Australia	Student
Adam	George	University of Adelaide	SA	Australia	Student
Oliver	Iving	University of Adelaide	SA	Australia	Student
Christian	Kamleh	University of Adelaide	SA	Australia	Student
Joel	Kumwenda	Monash University	VIC	Australia	Student
Piers	Lewis	University of Adelaide	SA	Australia	Student
Richard	Lynch	Sisprobe/Viotel Ltd	TAS	Australia	Associate
Nicholas	Mathews	University of Adelaide	SA	Australia	Student
Tom	McNamara	University of Melbourne	VIC	Australia	Student
Savio	Paimpillikunnel Kuriakose	Wimmera Catchment Management Authority	VIC	Australia	Associate
George	Marfo	University of NSW	NSW	Australia	Student
Kate	Nelson	GeoDiscovery Group	QLD	Australia	Active
Ted	Schmaal	University of Adelaide	SA	Australia	Student
Ron	Schop	HiSeis	WA	Australia	Associate
Georgie	Thorpe	University of Adelaide	SA	Australia	Student
Kate	Wilson	University of Adelaide	SA	Australia	Student
Norman	Wise	Retired	NSW	Australia	Associate

The ASEG in social media

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

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

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

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

Twitter: https://twitter.com/ASEG_news

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

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

ASEG branch news

Victoria

What an eventful first-half of 2021 the Victoria Branch has had to endure! If I was able to do it all again I would climb back out of the rabbit hole and choose the set of steak knives - LOL. Onto business… a performance worthy of an Oscar was needed to convince Members to come along to our second in-person branch meeting for the year, two-days out from Lockdown 4.0. In the end, countless die-hard Members did brave Melbourne's wet and gusty weather on the night of 24 May to hear a talk by **Dr Fabian Kohlmann** (Lithodat) at The Kelvin Club. Fabian spoke about the quiet revolution he is undertaking in that one area we so often take for granted - data verification and integrity. Lithodat has undertaken to QC and standardise all manner of geological datasets for clients, including industry titans and universities, enabling quick and intuitive navigation of datasets within a cloud-based environment. For those that have spent thankless hours collating, verifying and merging data within our professional roles, this talk was more than a bit revelatory. A keen cross section of participants recounted anecdotes of data failures past and present, and were no doubt imagining the benefits of the work Fabian shared during his talk.

With unworkable restrictions still in place, it was a little tricky navigating our way around hosting our June meeting. Your committee remained steadfast and refused to reschedule the Tech Night that was due to be held on 16 June. We hoped that case numbers would fall and that further easing of restrictions would be announced. We made the right call and our stubbornness prevailed. A record number of mask-wearing Members turned out on the night to welcome **Mark Grujic** (Solve Geosolutions) deliver a presentation on 'Advances in geoscientific application of computer vision'. We allowed Mark to unashamedly promote Geosolve's latest gadget – Datarock – a data-driven image analysis tool to ultimately help improve and aid in the interpretation of core photos through the use of self-supervised-learning and digital in-painting methods. Examples of the methods used on photos of famous personality faces and priceless works of arts showed how remarkable Artificial Intelligence can be in restoring photos affected by image resolution and typical artefacts such as blurriness, blemishes and other obfuscations. Mark even brought up potential ethical issues concerning the boundaries of using computer vision to restore or recreate/replicate/counterfeit/falsify imagery, which raised genuine discussion among the audience. Only a week later, when a deepfake video of actor Tom Cruise playing golf was released on TikTok, did Mark's words begin to reverberate in my head.

Finally, it is my pleasure to reveal the winners of the ASEG Victoria scholarship/sponsorship awards available to help students and young professional Members attend the upcoming AEGC 2021 in Brisbane in September. Applicants were asked to tell us in 100 words or less why they *must* attend the AEGC 2021. We received a flurry of submissions and while every hopeful deserved financial assistance to attend the conference, there were two outstanding candidates. I am pleased to announce the winners are PhD candidate **Ms Fatemeh Amirpoorsaeed** and young professional **Mr Matthew Shrimpton**. A short bio of each of our recipients follows.

Matthew Shrimpton

GBGMAPS is diverse in their acquisition of many geophysical datasets, and I have been very fortunate to start my young professional career with them. I'm learning from highly skilled geophysicists, and I've also been given the responsibility in processing and reporting on geophysical datasets for clients. However, the most fortunate part of my job is that I get to travel to so many parts of Australia to work. The most notable parts of my job so far include working in Olympic Dam, Mount Gambier, Adelaide Hills, the beach town of Warrnambool and travelling on the Spirit of Tasmania for the first time to work in Tasmania.

Fatemeh Amirpoorsaeed

My research studies the link between craton margin geometries in relation to basin development and mineral systems endowment, focussing on the North Australian Craton (NAC). I am applying potential field geophysics, seismic reflection and structural geology to help characterise the geometry of the craton margins and its related structures. The goal is to understand the link between the geometry and the structures developed along the margins of cratons. Thus far, I have been able to ascertain that the NAC's inward and outward dipping margins show distinct structural networks, potential minerals system distributions, and a likely unique link between major sutures and shallow structures. I aim to further test our understanding using analogue modelling experiments. Furthermore, the association between the identified mineral systems and craton margins will be quantified using statistical analyses.

So, as I suspected all along, things were far too good to be true. At the time of writing, widespread border closures, lockdowns and growing COVID risk and uncertainty across most of Australia have prompted the AEGC organising committee and participating societies to agree to move the AEGC 2021 conference to virtual format. Coincidentally, Melbourne was due to host the next AEGC in 2023, but AEGC 2023 will now take place in Brisbane. The FedEx have assured me a very large briefcase stuffed with cold hard cash would arrive at my doorstep any day now if I agreed to let Brisbane have that conference. I totally consented, of course :)

I know everyone is a little fatigued if not broken by so much on-screen time, but the AEGC 2021 virtual programme looks to be a cracker, and I hope you will take advantage of the unique situation to attend online.

Thong Huynh
vicpresident@aseg.org.au

Western Australia

We've had a fairly busy May and June in WA, and things should continue like that through the rest of the year. First up, we hosted two webinars in May: the first by **Per Avseth** and the second by **Shuvajit Bhattacharya**, both very interesting and informative talks. In that same month, in spite of a COVID-19 change-up (just a month delay), we were finally able to host our first social event since last Christmas: WA's Social Networking and Lawn Bowling event that came off darn well. Special thanks to **Darren Hunt** who organised this for our local Members - and to the Leederville Sporting Club for a nice venue.

Next up in June, two of our WA committee members (Darren Hunt and **Tom Hoskins**) attended and presented at St Stephen's School Career Expo on 1 June, and explained to the young students just how cool it was to be geophysicists. Not a bad start for the month.

Following that, in the same month, was a successful face-to-face Tech Night at Yagan Square. We started that off with **Tom Hoskin**, our WA Student Award Chair, who presented our 2020-2021 (WA) Student Award certificates to three of the four awardees: **Partha Pratim Mandal** of Curtin University, **Mahtab Rashidifard** of UWA, and **Sofya Popik** of Curtin University (**Muhammad Atif Iqbal** also of Curtin University was unable to attend the ceremony, unfortunately). These four deserving students were given grants to go to this year's AEGC in Brisbane.

The rest of the night (except for the food and drinks) was given over to **Dave Lawie** of Imdex, who presented both an interesting and thought-provoking talk with his take on the future of mining and what Imdex is developing for that future. Not doing that talk justice, I'm afraid.

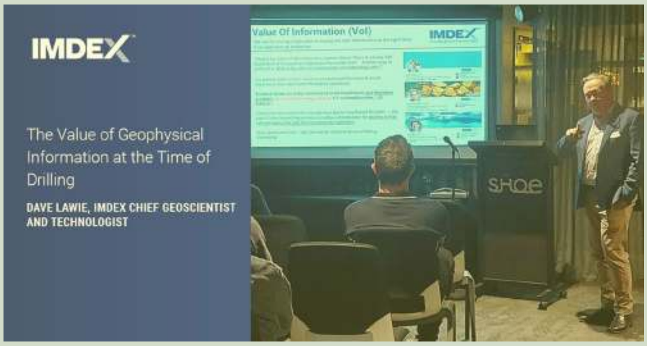
Stay safe and healthy everyone.

Todd Mojesky
wapresident@aseg.org.au

*Winners at the WA Branch social networking and lawn bowling event. Left to right: **Regis Neroni, Kath McKenna** and **Helen Anderson.***

Darren Hunt and Tom Hoskins at the School Career Expo

WA Branch Student Award Ceremony. Left to right: Todd Mojesky (MC), Partha Mandal (awardee), Mahtab Rashidifard (awardee), and Sofya Popik (awardee).

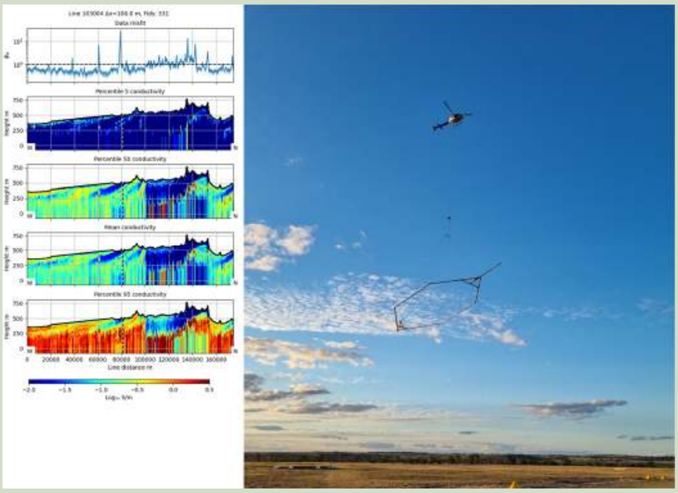


WA Branch Tech Night presenter, Dave Lawie of Imdex

ASEG news

Australian Capital Territory

In news from the ACT and Geoscience Australia (GA) - the AEM survey for the Great Artesian Basin was completed in June, comprising 4500 line-km flown by SkyTEM. In newly developed probabilistic inversion code at GA, regional intake beds are clearly visible from the QC inversions on field data (see photo). GA will be in possession of all processed data by mid-August and the release is scheduled soon after. In other news, work on dynamic mantle topography done by GA in collaboration with researchers at the Australian National University and the University of Cambridge has been published in G3, available at https://doi.org/10.1029/2021GC009717.



SkyTEM in action over the GAB and some of the preliminary data

In a timely presentation, given our ongoing situation with COVID, **Michelle Henderson**'s ASEG talk on 'Managing through (constant) change and uncertainty' was quite the success with a hybrid online/in-person audience at GA's Raggatt theatre on 8 June. Michelle's major point about how our brain works (or doesn't) in periods of prolonged stress was well taken. Self-care through exercise, mindfulness, a better diet and regular work breaks, though seemingly obvious, go far in allowing us to think creatively, avoid burnout and make better decisions.

Michelle Henderson presenting to the ACT Branch

Anandaroop Ray
actpresident@aseg.org.au

New South Wales

ASEG NSW was getting into the rhythm of 2021; the committee was organising in-person monthly meetings (see summaries below for the May and June meetings), we made the successful switch to pizzas as the light refreshment on offer – which may, or may not, have contributed to a slight uptick of in-person attendees, with our meeting numbers already effectively doubled as we live-stream the presentations. Then there was a break. As we write this the lockdowns in the greater Sydney area have been extended, and we suspect we are all rediscovering the joys (and/or perils) of working from home. Our fingers are crossed that COVID safe, in-person events will return sooner rather than later.

In May, PhD student, **Christopher Alfonso** (USYD), presented a talk entitled 'The influence of dynamic topography, climate, and tectonics on the Nile River source-to-sink system'. Chris used the numerical modelling software package, *Badlands*, to explore the possible relationships between the influences of climate change and tectonics, to the river's course and dynamic topography of Northeast Africa. We were walked through generic and realistic models of the initial topography, lithology, horizontal and vertical motions, climate change and sea level changes. The findings show that while climate change and dynamic topography did indeed influence the Nile, a tectonic event – mainly the eruption of the Ethiopian Plateau flood basalts – was the single most important event in the Nile's history. This caused much discussion amongst the audience and the presentation was enjoyed by all.

June saw us treated to a joint presentation from **Stuart Clark** and **Patrick Makuluni** (UNSW), 'Tilting of the Australian continent: New evidence from the subsidence and deposition history of the Northern Carnarvon Basin'. Stuart introduced the topic while Patrick went through the methodology and findings. Backstripping and de-compaction techniques were used to develop subsidence, sedimentation, and porosity evolution models for the Carnarvon Basin. From this, Stuart and Patrick were able to study the accommodation space for sediments and ascertain that the Australian continent has been tilting northeastward since the Late Cretaceous. The presentation then related these findings to the Northern Carnarvon Basin evolution and hydrocarbon occurrences. The audience enjoyed the presentation and asked the speakers many questions.

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to be in town at the time. Most talks are livestreamed on Zoom and uploaded to ASEG's YouTube page later, so you also have the option to join us online. Meetings are generally held on the third Wednesday of each month from 5:30 pm at Club York. News, meetings notices, addresses and relevant contact details can be found at the NSW Branch website. All are welcome.

Stephanie Kovach and Jim Austin
nswsecretary@aseg.org.au
nswpresident@aseg.org.au

The ASEG NSW audience intently listening to Chris' presentation

The audience at the NSW Branch June meeting, the presenters - Stuart and Patrick, can be seen in the photo (front and right).

Queensland

The Queensland ASEG were pleased to host two face-to-face talks in June with presentations by **Oli Gaede** and **Irwan Djamaludin**. Dr Oliver Gaede's presentation focussed on the differences in the Precipice and the Springbok Sandstones as aquifers of the Great Artesian Basin, and the traps of using basic well logs alone to distinguish sandstones. Dr Gaede showed ternary geochemistry diagrams and geophysical logs proving that the Precipice Sandstone is a clean and porous sandstone, making it a good Carbon Capture and Storage (CCS) reservoir. This was in contrast to the Springbok Sandstone that, under basic logs, would be classified as a clean sandstone but with deeper analysis is quite shaley, and should not be considered a good reservoir for CCS projects.

We continued the CCS theme with our second talk in June, which was held in partnership with Queensland PESA. **Irwan Djamaludin** presented a talk on the Glenhaven conventional and passive 3D seismic surveys for the EPQ7 CO_2 sequestration demonstration project in the Surat Basin. Irwan showed how the structure, thickness, lithology, and porosity mappings were undertaken using the prestack inversion volumes. Both talks were well attended.

We have a full pipeline of talks and events planned for the remainder of the year. In the near future we'll be welcoming two recent graduate geophysicists, **Dale Harpley** and **Callum Kowalski** to present on their recent thesis projects.

Aside from technical talks, plans are in place for our Zoeppritz night. This is our annual social gathering where we practice long-offset bar hopping, examine contrast between liquid media properties and finally, at the end of the night, hopefully don't experience too many angles of incidence. Our other social night is the annual ASEG-PESA Trivia night hosted by **Henk van Paridon**. This is slated for October so keep an eye out for announcements in upcoming emails.

Finally, preparations are being finalised for the upcoming AEGC conference in September. We look forward to seeing as many of you as possible online.

Nick Josephs and James Alderman
qldsecretary@aseg.org.au
qldpresident@aseg.org.au

South Australia & Northern Territory

Recently we sponsored the inaugural Earth Science Networking Night, hosted by the Adelaide University Geological Society (AUGS) at the Belgian Beer Café. Our state committee member **Nick Jervis-Brady** and Federal Education Committee Chair **Kate Selway** both gave wonderful presentations and answered questions for all the budding young geophysicists/geoscientists in SA. By all accounts it was an incredibly successful night and we hope to build on a blossoming relationship with both AUGS and students in SA going forward.

ASEG news

We are currently in the process of selecting the best applicants to receive our 2021 student travel scholarships. Each applicant has been asked to submit a short piece on their research projects and there have been a number of great submissions from each of the three major universities in SA. It never ceases to amaze just how widespread the application of geophysics can be throughout both research and industry. The winners of the scholarship will have up to $1000 to put towards travel, registration or workshops at the upcoming AEGC. The committee will have a tough time deciding this year that's for sure. Best of luck to all applicants!

Looking forward, we have presenters lined up but we are working on what times will best suit everyone given recent COVID restrictions. We are also in the planning stage for this year's Spring Fling event, which we will host alongside both PESA and SPE.

If you're based in SA, or willing/able to travel, keep your eye out for the upcoming Copper to the World Conference on 31 August. #C2TW is hosted by one of our major state sponsors this year, the SA Department of Energy and Mining, who coincidentally have also provided us with our newest committee member – petrophysicist **Rahman Elkhateeb.** Welcome Rahman!

We are also currently on the hunt for a willing geophysics/geoscience student from any of the local universities to join us as our Communications Officer. If you know of anyone that might suit the position, please prompt them to get in contact with our Branch President Ben Kay (sa-ntpresident@aseg.org.au).

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

Sam Jennings
ASEG SA/NT Branch Treasurer on behalf on Ben Kay
sa-ntpresident@aseg.org.au

Tasmania

Hobart-based **Richard Lynch** of Sisprobe will be talking to us about application of the passive seismic technique to exploration on Thursday 26 August 2021 at the University of Tasmania in Sandy Bay. In a first for the Tasmania Branch, Richard's presentation will be streamed as an ASEG webinar for all Members to enjoy. The presentation will take place in the Physics Lecture Theatre 3 (room 315) at 1800

Richard Lynch

Meeting notices, details about venues and relevant contact details can also 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

ASEG national calendar

Date	Branch	Event	Presenter	Time	Venue
ASEG Branch face-to-face meetings have been suspended in many states due to COVID outbreaks. Some branches are still hosting webinars. Registration is open to Members and non-members alike, and corporate partners and sponsors of state branches are acknowledged before each session. Recorded webinars are uploaded to the ASEG's website (https://www.aseg.org.au/aseg-videos), as well as to the ASEG's YouTube channel (https://bit.ly/2ZNglaZ). Please monitor the Events page on the ASEG website for the latest information about upcoming webinars and other on-line events					
10–11 Aug	National	DISC	Dave Monk	10:00	https://seg.org/shop/products/detail/287093232
18 Aug	NSW	Tech talk	TBA	17:30	Club York, York St, Sydney
26 Aug	Tas	Tech talk	Richard Lynch	18:00	University of Tasmania, Sandy Bay
Oct	QLD	Trivia night	Henk van Paridon	TBA	TBA

Geoscience Australia: News

Geoscience Australia has continued its aggressive continental geophysical acquisition programmes into the new (financial) year in collaboration with our key State Agency partners of Western Australia, South Australia, Northern Territory, Queensland, New South Wales, Victoria and Tasmania. In the last quarter, we have overseen the completion of the East Resources Corridor AEM, the MinEX Mundi AEM survey, and the Tasmania Tiers magnetic and radiometric survey (AusLAMP). Locations and details are provided in Figure 1 and the tables in the following section. Some highlights are presented below.

Exploring for the Future - East Resources Corridor AEM survey

The 32 000 line km regional East Resources Corridor Airborne EM survey was completed on June 20. Straddling the borders of South Australia, Queensland, New South Wales and Victoria (Figure 1, brown polygon and Figure 2 below) the programme expands continental regional airborne EM coverage across a 500 km-wide belt of terrain for district-scale base-metal, energy and groundwater investigations. The dataset, including Geoscience Australia inversion routines, will be released in September at the AEGC.

Mundi Airborne EM survey

The 1900 line km Mundi Airborne EM survey was completed in April this year. Located to the north of Broken Hill (Figure 3), the survey covered approximately 5000 km^2 at 2.5 km line spacing, as a collaborative programme between the Geological Survey of NSW (GSNSW) and Geoscience Australia. The area is considered prospective for base metals and is largely under-explored due in part to the remoteness and thickness of cover (Figure 4). Complementing existing AEM coverage to the west and south, this dataset will be released jointly by GSNSW and GA in August (including Geoscience Australia in-house constrained inversions).

Tasmanian Tiers magnetic and radiometric survey

See section from Mineral Resources of Tasmania (MRT) in this issue of *Preview* for an update of the survey results and data.

In addition to the standard set of deliverables, GA and MRT have contracted Minty Geophysics to review the impacts of rugged topography on the radiometric data; a process not covered under the standard data reduction routine described in IAEA (2003).

With conventional processing, airborne elemental count rates (cps K, cps U and cps Th) are simply scaled on a

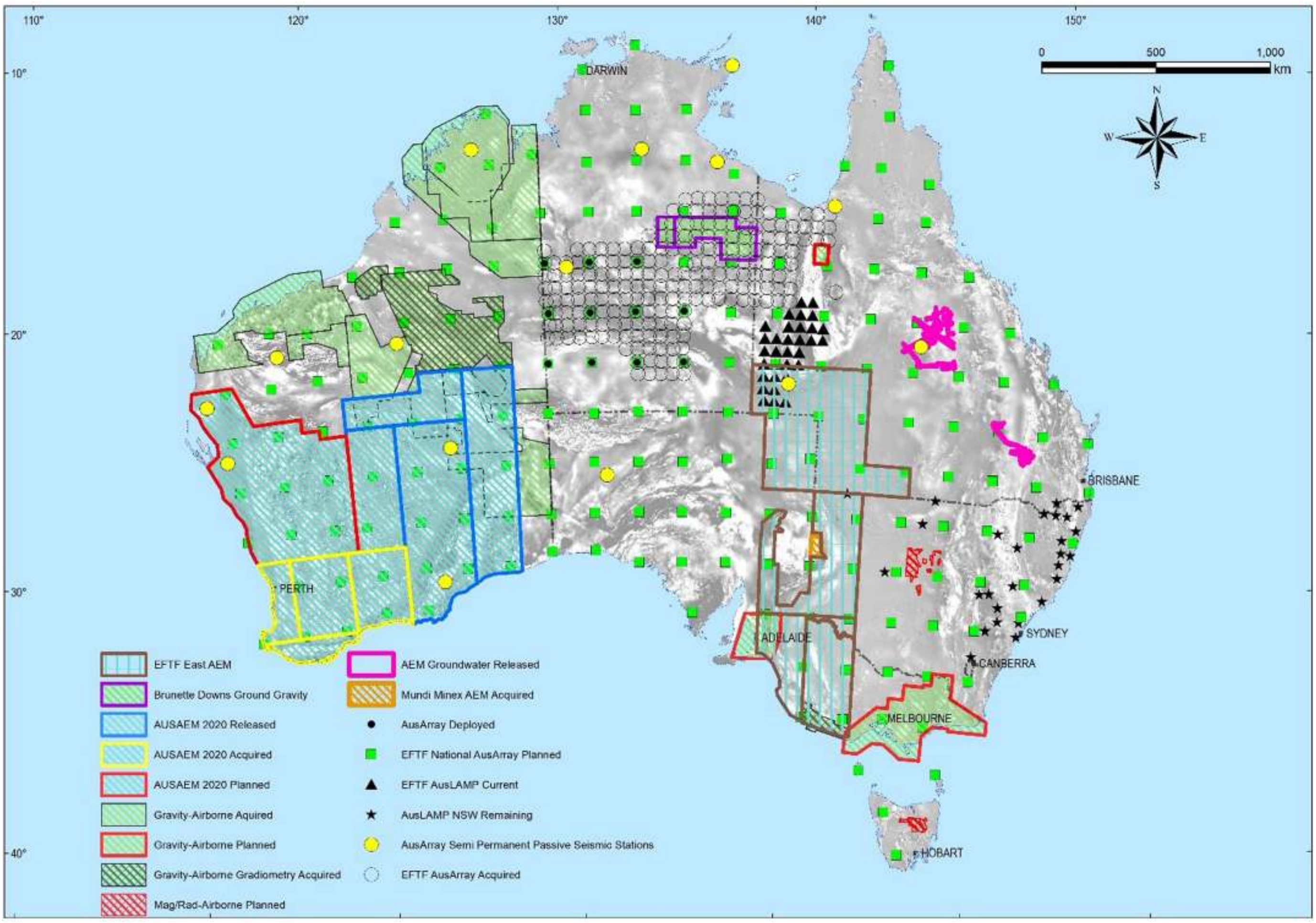


Figure 1. *2019 -2021 geophysical surveys – in progress, planned or still for release by Geoscience Australia in collaboration with State and Territory agencies.*

News

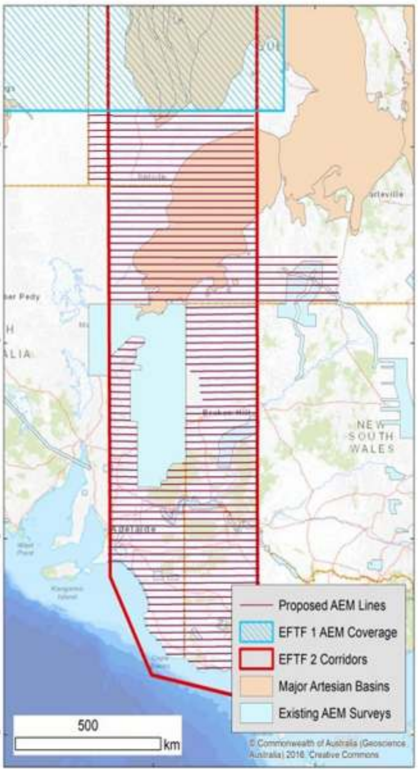


Figure 2. *Regional AEM survey across the East Resources Corridor, Exploring for the Future Program. At 20 km line spacing, the 32 000 line km survey was completed in less than 3 months by CGG (now XCalibur Multiphysics). Note that the proposed survey gap in South Australia has already been covered with AEM as part of the regional Frome survey (data available from Geoscience Australia). Line plans are schematic only and do not reflect the final flight path map.*

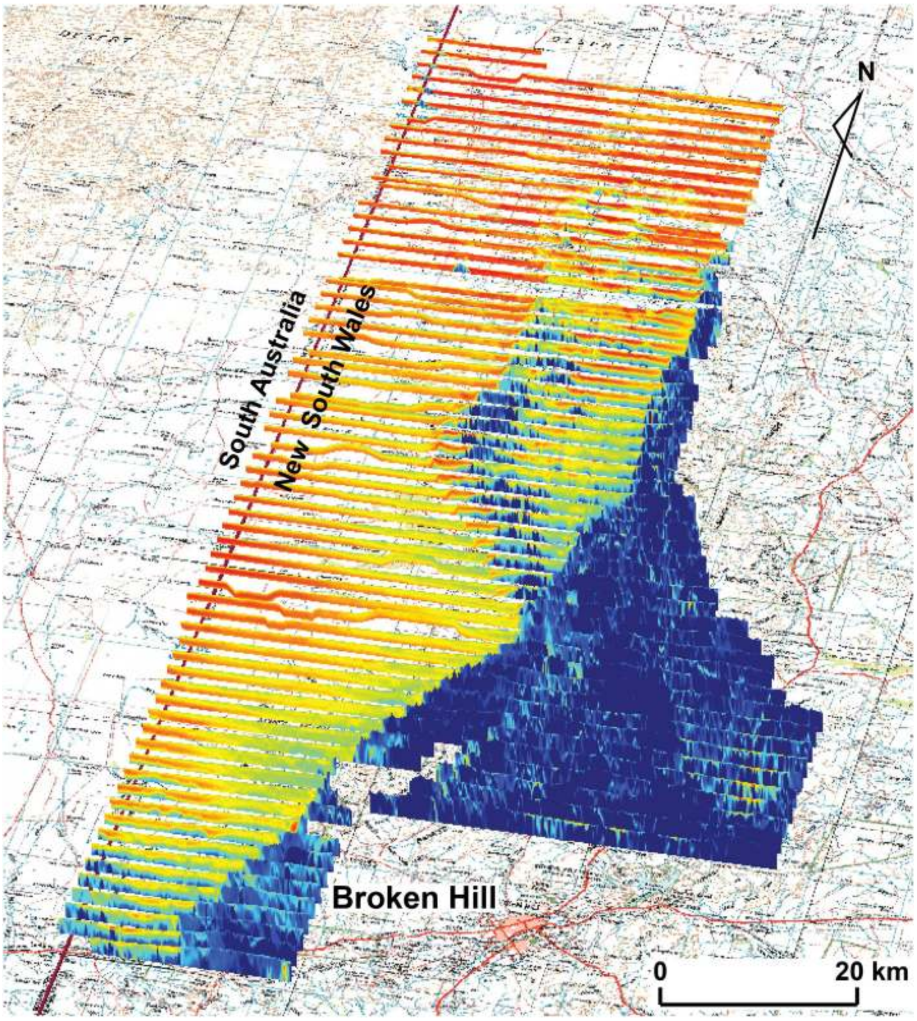


Figure 4. *Preliminary inversion results for Mundi Airborne EM survey, 2021. Straddling the NSW/SA border, the survey complements existing AEM coverage to the west and south. In the image above, blue colours represent resistive terrain and red/yellow colours represent conductive terrain and features. The depth of investigation varies (depending on the resistivity) but is typically around the 300 to 500 m mark.*

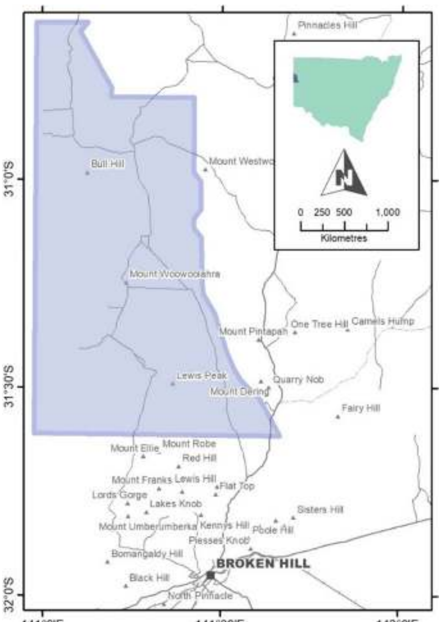


Figure 3. *Approximate area of coverage, Mundi Airborne EM survey, 2021*

point-by-point basis using so-called "sensitivity factors" to produce estimates of the elemental concentrations (% K, ppm U and ppm Th) on the ground. The correction *assumes* flat-earth topography. However, abrupt changes in elemental concentrations on the ground – including those caused by change in height of sources stemming from topography, produce broad anomalies at airborne heights, and this should be corrected for during the data processing using deconvolution, or a similar method.

Minty and Brodie (2015) developed a method for the rigorous inversion of airborne line data to a regular grid of elemental concentrations on the ground. The method accounts for the degradation of the gamma signal with distance from the source, the errors in the data, the distribution of radioelement sources in the ground, the response function of the detector, and the 3D topographic variations in the area. The method thus replaces gridding, and incorporates both a topographic correction and deconvolution of airborne count rates to elemental concentrations on the ground.

The full 3D inversion of gamma-ray spectrometric data using the method of Minty and Brodie (2015) is a significant improvement on the conventional processing procedure. In particular, the full inversion shows sharper images, with better anomaly definition, due to the deconvolution. There are several areas where the correction is greater than 50 % (Figure 5).

References

IAEA, 2003. Guidelines for radioelement mapping using gamma-ray spectrometry data: IAEA-TECDOC-1363,

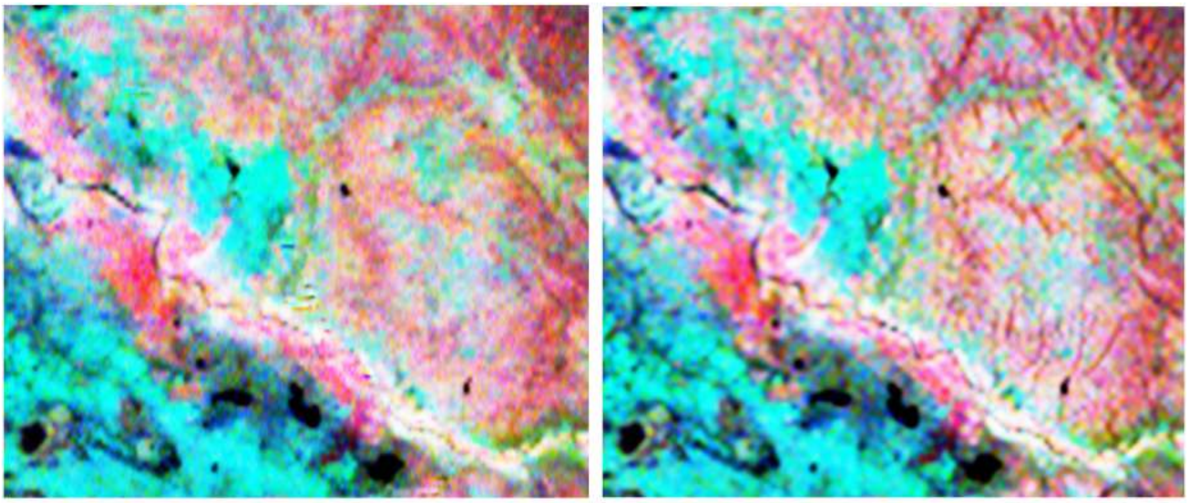


Figure 5. *Selected radiometric window from the 2021 Tasmanian Tiers airborne magnetic and radiometric survey. Shown as ternary images with K – red, U – blue and Th – green, the original processed data (left hand side) is missing the sharpness of the 3D processed image (right hand side). Additionally, several areas with high counts and steep topography generate corrections in concentrations of over 50%. The full report with processed gridded data will be released through GA and MRT portals.*

International Atomic Energy Agency, Vienna.

Minty, B and Brodie, R., 2015. The 3D inversion of airborne gamma-ray spectrometric data. Extended Abstract, ASEG 24th International Geophysical Conference and Exhibition, Perth, 15 - 18 February 2015.

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

Henderson byte: How old is magnetism?

An astronomer at CSIRO in Perth, Dr Tessa Vernstrom, is aiming to find out just how old is magnetism. Prior to coming to Australia in 2015, Vernstrom conducted her postdoctoral research at the Dunlap Institute at the University of Toronto, where a Sydney-born astronomer Dr Bryan Gaensler has been the Director since 2014. Dr Gaensler is a leader in the field of cosmic magnetism and is well known in Australia.

As described in *New Scientist* (26 June, 2021), earlier this year astronomers led by Vernstrom detected magnetic field lines between two galaxies 50 million light years apart. The sheer extent of their existence suggests the fields could be relics from the birth of the universe. However, these fields are weaker the further the search goes back in time. This is where another Australian asset, the powerful Australian Square Kilometre Array (ASKA) telescope becomes vital. Gaensler says the field strength that we can now measure using ASKA is 100 times weaker than before.

There is not sufficient space here to explain in detail the fascinating methods used to detect magnetic fields in the cosmos. A common way is to observe the alteration of certain characteristics caused by the presence of the fields. In one case recently discovered Fast Radio Bursts (FRBs) are polarised and twisted by the magnetic field as they pass through, causing what is known as Faraday rotation. More of these FRBs are being detected by ASKA and other arrays to provide the vast amounts of data needed to allow for the detection of magnetism earlier in time. Gaensler suggests that ultimately, with enough measurements, a map of the magnetism of the universe may be produced.

The latest paper on the above discovery by Tessa Vernstrom and co-authors, to be published in August, is: Vernstrom, T, et al., 2021. Discovery of magnetic fields along stacked cosmic filaments as revealed by radio and X-ray emission**.** *Monthly Notices of the Royal Astronomical Society*, **505** (3).

While colleagues of Vernstrom and Gaensler, in North America and Italy, are collaborating in this study, it is pleasing to note the strong Australian presence in this quest to find the age of magnetism.

Roger Henderson
rogah@tpg.com.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 July 2021).

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

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Line spacing Terrain clearance Line direction	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Tasmanian Tiers	MRT	GA	MAGSPEC	Mar 2021	Up to an estimated 25 000	200 m 60 m N–S or E–W	4300	Apr 2021	May 2021	See Figure 1 in previous section (GA News)	Jul 2021
Cobar	GSNSW	GA	GPX	Jun 2021	58 000	200 m	11 600	Aug 2021	TBA	See Figure 1 in previous section (GA News)	TBA

TBA, to be advised.

Table 2. Ground and airborne gravity surveys

Survey name	Client	Project management	Contractor	Start survey	Line km/ no. of stations	Line spacing/ station spacing	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Canobie	GSQ	GA	TBA	~ Aug 2021	TBA	1–2 km	5300	Sep 2021	TBA	See Figure 1 in previous section (GA news)	TBA
Brunette Downs Ground Gravity	NTGS	GA	TBA	Aug/ Sept	~ 12 000	2 x 2 km grid	55 000	TBA	TBA	TBA	TBA
Melbourne, Eastern Victoria, South Australia	AusScope GSV DEL WP	GA	Sander Geophysics	TBA	137 000	0.5–5 km	146 000	TBA	TBA	See Figure 1 in previous section (GA news)	TBA
Kidson Sub-basin	GSWA	GA	CGG Aviation	14 Jul 2017	72 933	2500 m	155 000	3 May 2018	15 Oct 2018	See Figure 1 in previous section (GA news)	Set for release 2021
Little Sandy Desert W and E Blocks	GSWA	GA	Sander Geophysics	W Block: 27 Apr 2018 E Block: 18 Jul 2018	52 090	2500 m	129 400	W Block: 3 Jun 2018 E Block: 2 Sep 2018	Received by Jul 2019	195: Aug 2018 p. 17	Set for release 2021
Kimberley Basin	GSWA	GA	Sander Geophysics	4 Jun 2018	61 960	2500 m	153 400	15 Jul 2018	Received by Jul 2019	195: Aug 2018 p. 17	Set for release 2021
Warburton-Great Victoria Desert	GSWA	GA	Sander Geophysics	Warb: 14 Jul 2018 GVD: 22 Jul 2018	62 500	2500 m	153 300	Warb: 31 Jul 2018 GVD: 3 Oct 2018	Received by Jul 2019	195: Aug 2018 p. 17	Set for release 2021
Pilbara	GSWA	GA	Sander Geophysics	23 Apr 2019	69 019	2500 m	170 041	18 Jun 2019	Final data received Aug 2019	See Figure 1 in previous section (GA News)	Set for release 2021
SE Lachlan	GSNSW/ GSV	GA	Atlas Geophysics	May 2019	303.5 km with 762 stations	3 regional traverses	Traverses	Jun 2019	Jul 2019		Set for incorporation into the national database in 2021

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
East Resources Corridor	GA	GA	CGG	Apr 2021	32 000	20 km	640 000	Jun 2021	Jul 2021	See Figure 1 in previous section	Sep 2021
Mundi	GSNSW	GA	NRG	Mar 2021	1900	2.5	~ 5000	Apr 2021	Jun 2021	See Figure 1 in previous section (GA News)	Aug 2021
Surat-Galilee Basins QLD	GA	GA	SkyTEM Australia	2 Jul 2017	4627	Variable	57 366	23 Jul 2017	Nov 2017	188: Jun 2017 p. 21	TBA
AusAEM20	GSWA	GA	CGG & SkyTEM	Aug 2020	62 000	20 km	1 240 000	Dec 21	TBA	See Figure 1 in previous section (GA News)	TBA. Survey in production

TBA, to be advised

Table 4. Magnetotelluric (MT) surveys

Location	Client	State	Survey name	Total number of MT stations deployed	Spacing	Technique	Comments
Northern Australia	GA	QLD/ NT	Exploring for the Future – AusLAMP	366 stations deployed in 2016–19 32 stations deployed in 2021	50 km	Long period MT	The survey covers areas of NT and Qld. Data to be released early 2021. Acquisition of 32 new sites in SW Qld is complete.
AusLAMP NSW	GSNSW/ GA	NSW	AusLAMP NSW	~300 stations deployed 2016-21	50 km	Long period MT	Covering the state of NSW. Acquisition and nearing completion. Phase 1 data release: http://pid.geoscience.gov.au/dataset/ga/132148.
Southeast Lachlan	GSV/GSNSW/ GA	VIC/ NSW	SE Lachlan	Deployment planned to commence early/mid-2021	~4 km	AMT and BBMT	~160 stations in the Southeast Lachlan. Acquisition delayed due to COVID-19 travel restrictions.
AusLAMP TAS	GA	TAS	King Island MT	4 stations completed	<20 km	Long period MT	Covering King Island. Acquisition completed.
Cloncurry	GSQ/GA	QLD	Cloncurry Extension	500 stations have been acquired	2 km	AMT and BBMT	Data acquisition complete. Survey data published https://geoscience.data.qld.gov.au/magnetotelluric/mt099998
Spencer Gulf	GA/GSSA/ UofA/ AuScope	SA	Offshore marine MT	12 stations completed	10 km	BBMT	This is a pilot project for marine MT survey https://www.auscope.org.au/news-features/auslamp-marine-01

TBA, to be advised

Table 5. Seismic reflection surveys

Location	Client	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
Central Darling Basin	CINSW	NSW	Central Darling seismic survey	~208	10 m	10 m	6-16 sec	2D high resolution and deep crustal seismic	GA and CINSW signed MoU to acquire and process 2D high resolution and deep crustal seismic data in Central Darling Basin. New seismic data will be acquired, processed and interpreted to assist in proving up a geological resource in NSW for the safe and permanent storage of CO_2 emissions. The additional seismic data obtained will provide greater certainty in the future drilling exploration programme. The data acquisition was completed in May 2021 and processing is due to start in mid-Jul 2021, and aimed to be completed by Sep 2021.

(Continued)

Table 5. Seismic reflection surveys (*Continued*)

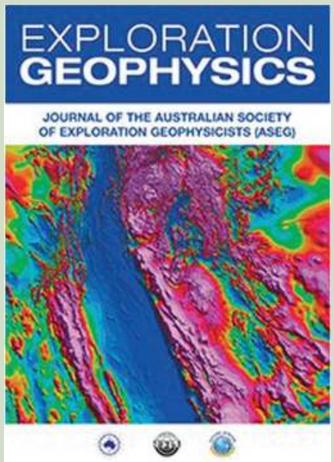
Location	Client	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
Officer Basin	GA	SA	Shallow legacy data	~2000	Varies	Varies	3-6 sec	2D shallow legacy data, explosive, vibroseis	GA commissioned reprocessing of selected legacy 2D seismic data in the Officer Basin, SA, as part of the Exploring for the Future (EFTF) programme. The objective of the seismic reprocessing is to produce a modern industry standard 2D land seismic reflection dataset. The data will be available as pre-competitive information to assist industry to better target areas likely to contain the next major oil, gas and mineral deposits. GA contracted Velseis to reprocess the dataset. Reprocessing of these data started in April 2021with the aim of completion by Jul 2021.
Officer Basin	GA	SA	L137 Officer Basin	550	40 m	240 m	20 sec	2D deep crustal seismic explosive reflection seismic	GA commissioned reprocessing of 2D legacy deep crustal seismic data in the Officer Basin, SA, as part of the Exploring for the Future (EFTF) programme. The objective of the seismic reprocessing is to produce a modern industry standard 2D land seismic reflection dataset. The data will be available as pre-competitive information to assist industry to better target areas likely to contain the next major oil, gas and mineral deposits. GA contracted Velseis to reprocess the dataset. Reprocessing of these data started in April 2021with the aim of completion by Jun-Jul 2021.
Pedirka Basin	GA	SA	Shallow legacy data	~2000	Varies	Varies	3-6 sec	2D shallow legacy data, explosive, vibroseis	GA commissioned reprocessing of selected legacy 2D seismic data in the Pedirka Basin, SA, as part of the Exploring for the Future (EFTF) programme. The objective of the seismic reprocessing is to produce a modern industry standard 2D land seismic reflection dataset. The data will be available as pre-competitive information to assist industry to better target areas likely to contain the next major oil, gas and mineral deposits. GA contracted Geofizika to reprocess this dataset. Reprocessing of these data started in May 2021 with the aim of completion by Sep 2021
Eastern Goldfields	GSWA	WA	L132 1991 Eastern Goldfields Seismic	260	40 m	160 m	20 s	2D deep crustal seismic explosive reflection seismic	GSWA and GA have been working with Velseis to reprocess legacy explosive data acquired by the BMR G&G in 1991. The data has been released on the GA website http://pid.geoscience.gov.au/dataset/ga/74951

Table 6. Passive seismic surveys

Location	Client	State	Survey name	Total number of stations deployed	Spacing	Technique	Comments
Australia	GA	Various	AusArray	About 180 temporal seismic stations	~200 km spacing	Broad-band ~18 months of observations	The survey will cover all of Australia to establish continental-scale model of lithospheric structure and serve as a background framework for more dense (~50 km) movable seismic arrays. It started in NT as an initial 11 seismic stations deployment and will progress to other States and Territories depending on pace of land clearance processes
Northern Australia	GA	QLD/NT	AusArray	About 135 broad-band seismic stations	50 km	Broad-band 1 year observations	The survey covers the area between Tanami, Tennant Creek, Uluru and the Western Australia border. The first public release of transportable array data is expected by the end 2020. See: http://www.ga.gov.au/eftf/minerals/nawa/ausarray Various applications of AusArray data are described in the following Exploring for the Future extended abstracts: http://pid.geoscience.gov.au/dataset/ga/135284 http://pid.geoscience.gov.au/dataset/ga/135130 http://pid.geoscience.gov.au/dataset/ga/135179 http://pid.geoscience.gov.au/dataset/ga/134501
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

Exploration Geophysics Special Issue: Call for papers

We are delighted to announce a special issue of the ASEG's technical journal *Exploration Geophysics,* entitled 'Lithospheric to deposit scale magnetotellurics advancements including AusLAMP in Australia'.



We invite you to submit your expressions of interest to the Special Editors by 31 August, 2021. Accepted expressions of interest will be due for submission to *Exploration Geophysics* by 31 March, 2022.

Scope of issue

Although the magnetotelluric (MT) technique was first used in Australia in the 1960s, it has only been widely adopted by academia, government, and industry over the last two decades, bolstered by the realisation of its important role in mineral and energy exploration undercover.

To date, there are many MT surveys and associated innovations across Australia. The national MT programme - Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP), which is half way to covering the continent, has revealed major insights into the tectonic evolution and mineral systems of Australia, and inspired subsequent 'infill-surveys' for further investigations.

This special issue invites papers that focus on MT studies in Australia, including but not limited to applications in resource exploration, modeling/inversion, interpretation, innovations, and representative case studies.

Special editors

Kate Robertson Kate.Robertson2@sa.gov.au
Graham Heinson Graham.Heinson@adelaide.edu.au
Jingming Duan Jingming.Duan@ga.gov.au

Geological Survey of New South Wales: New South Wales – a great place to explore

New South Wales (NSW) is currently experiencing a mineral exploration boom as more companies interested in base, high-tech and precious metals recognise the attractions of NSW as a destination for exploration and investment. The traditional mineralised terrains of NSW are relatively under-explored compared to those in other Australian states, and new ideas about tectonic evolution and mineral systems are yielding high-quality drilling targets for innovative explorers. Exciting recent discoveries in the Palaeozoic Macquarie Arc and Cobar Basin, which host giant and super-giant deposits, have motivated geologists to take a second look at these terrains. The current global boom in high-tech metals has also created opportunities for explorers in the Proterozoic Curnamona Province and the Palaeozoic New England Orogen (Figure 1).

New South Wales has a strong mining regulatory framework and robust, workable legislation regarding environmental and community obligations. NSW also has excellent road, rail, port and power networks to support regional development, and a well-established mining and exploration services industry. Further, the NSW Government makes all pre-competitive government data and open-file industry data freely available through its easy to use online portals, including MinView (explained further below).

The Mining, Exploration and Geoscience (MEG) group, part of the Department of Regional NSW aims to make NSW the number one mining investment destination in Australia. With a variety of government incentives such as the co-operative drilling programme publicly available world class pre-competitive data, and a significant and diverse resource endowment, there has never been a better time to invest in NSW exploration and/or mining.

Geological Survey of New South Wales

The Geological Survey of NSW (GSNSW) branch of MEG is responsible for leading the group's large scale geoscientific data acquisition, interpretation and dissemination programmes to deliver world class geoscientific data that enables NSW to become the number one mining investment destination in Australia. The branch is also responsible for providing advice for land use planning, and natural resource and environmental management.

GSNSW is the authoritative source of current knowledge about the geology,

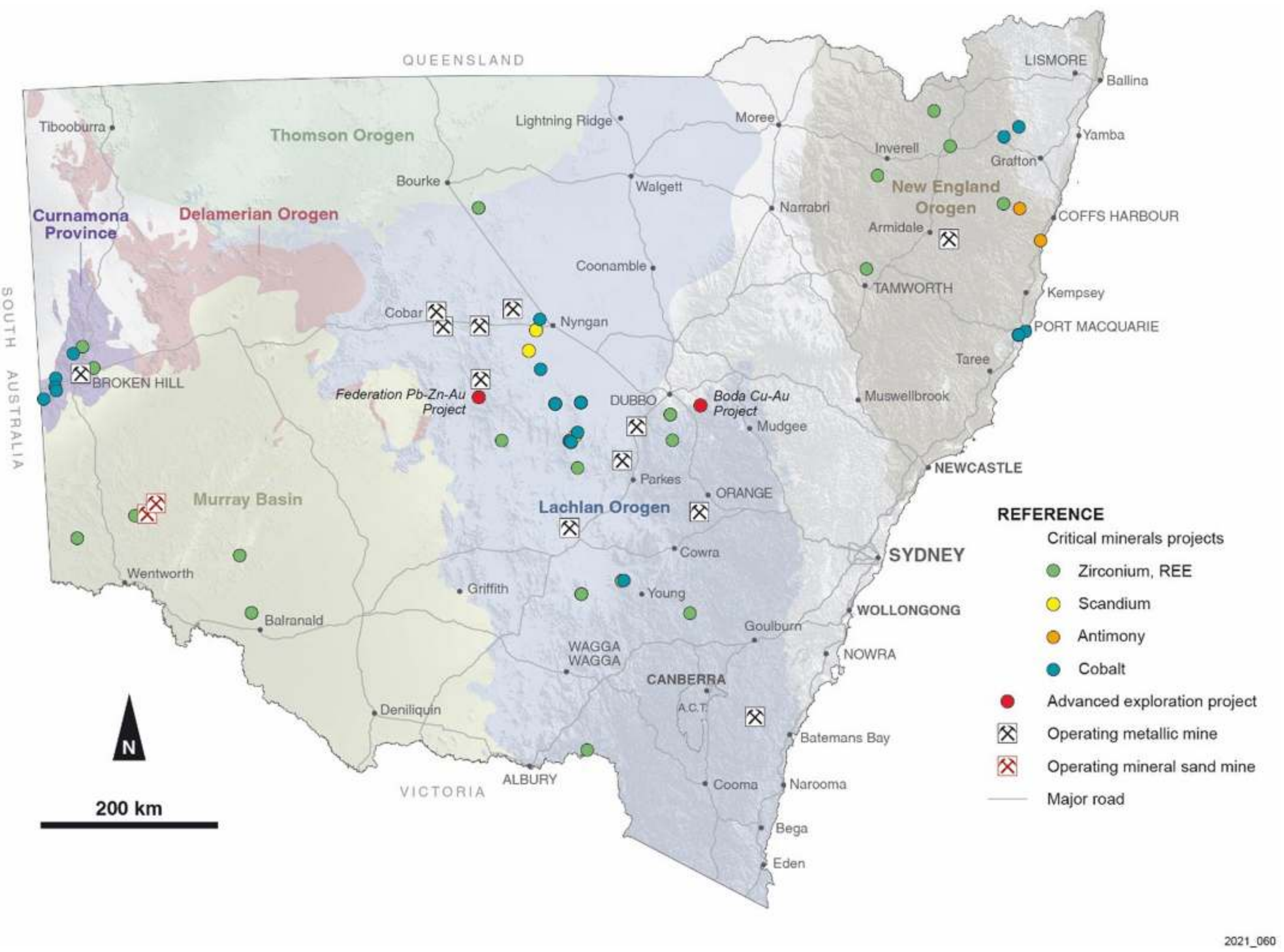


Figure 1. *Geological regions and major projects and discoveries in NSW.*

tectonic evolution and the mineral and energy resources of NSW. Some of the current data acquisition and interpretation programmes products and services are detailed below, as well as an overview on the NSW Government's geological database/ digital platform for geoscientific data, Minview.

What is MinView?

As the gateway to NSW geoscience data and products, MinView is a simple-to-use, versatile online GIS tool for integrating data and creating finished maps. Some key features include:

- The availability of over 500 data and map layers
- Up-to-date layers of mining and exploration titles with versatile searching functions
- GSNSW Seamless Geology (Colquhoun et al. 2021) maps that combine surface geology and 11 geological time slices
- A 3D display capability for viewing surface elevation, depth to prospective basement layers (Spampinato 2019), as well as conductivity-depth sections from the Cobar AEM survey
- The ability to add your own local data from shape files or KMZ files
- A drawing function to add linework and annotation to maps and images
- The functionality to save views, share views and print maps to pdf files.

Results from all key NSW Government geoscientific data acquisition and synthesis projects are made publicly available via MinView (Figure 2). Readers are encouraged to try MinView by following the link below. Start by loading one of the pre-set views from the 'Add View' button on the left. To learn about the full range of MinView capability, click on the 'help' icon on the top right.

https://minview.geoscience.nsw.gov.au/#/?lon=148.5&lat=-32.50000&z=7&l=

MinEx CRC

The MinEx Cooperative Research Centre (MinEx CRC) is the world's largest mineral exploration collaboration and brings together industry, government, research organisations and universities to further our understanding of geology, mineral deposits and groundwater resources in areas under cover. The collaboration has identified three specific programmes – Drilling Technologies, Data from Drilling and the National Drilling Initiative (NDI).

The NSW Government is a major participant in the NDI programme and has committed $16 million to the programme over ten years. Work commenced in 2018 in NSW and focuses on five areas that are known extensions of mineralised terrain under cover. Eight geophysical surveys are planned (see Figure 3), with two completed and another underway.

As these surveys are completed and interpreted, this data is released via the MinView platform for public use.

Cobar MinEx CRC airborne electromagnetic survey

In 2019 GSNSW and Geoscience Australia (GA) conducted an airborne electromagnetic (AEM) survey in central NSW around the Cobar–Lake Cargelligo region. The survey covered two MinEx CRC focus areas in the state. Four areas of infill were funded by private companies (see above figure) with the entirety of the data being publicly available for download and viewing through MinView.

New Resolutions Geophysics' (NRG™) helicopter-borne Xcite™ time-domain electromagnetic system acquired 7000-line km of AEM data. The helicopter flew along east–west lines typically 55 km long and between 2.5 km and 5 km apart, at a height of 60 m, with the Xcite™ system suspended 30 m below (example of the lines shown in Figure 4). Lines were diverted to go over water bores, drillholes and seismic lines to aid interpretation of the data.

GSNSW and GA have interpreted the data over the focus areas. A 3D model and a report will be released later in 2021 focusing on the depth of weathering, potential mineral conductors, possible groundwater anomalies, faults and geological units. For further information on

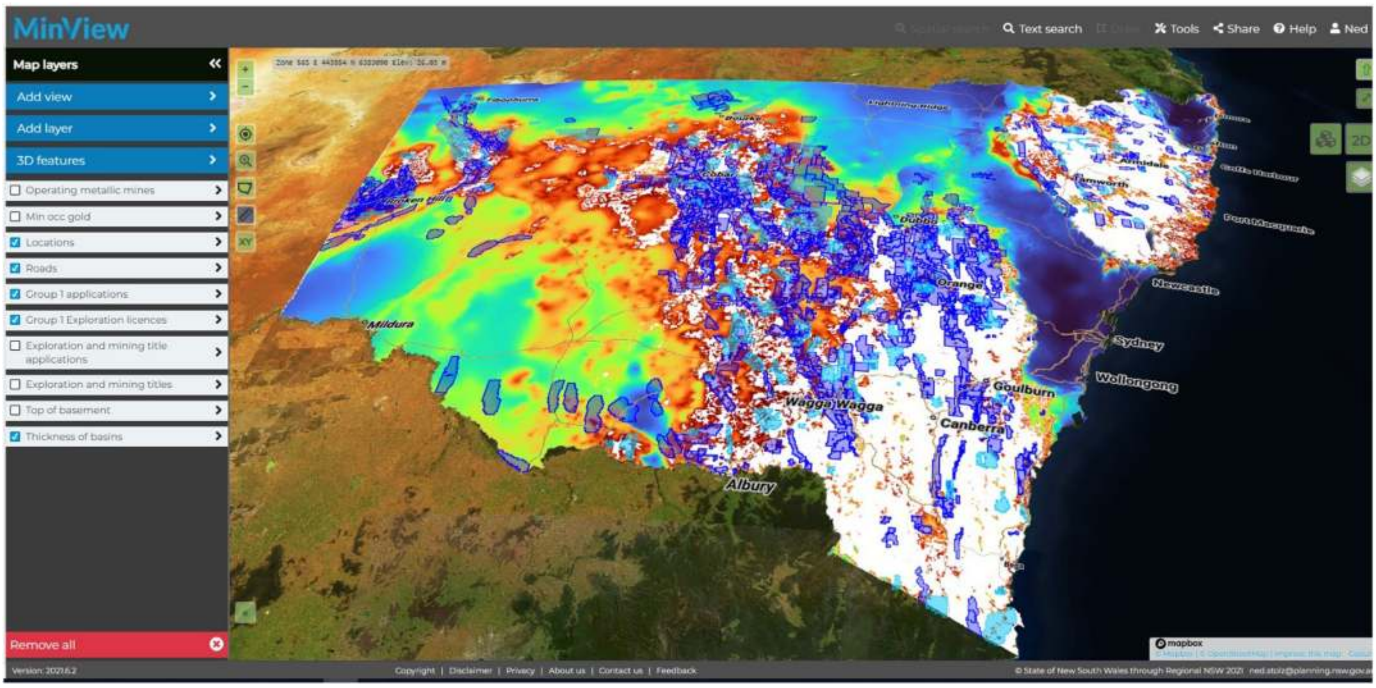


Figure 2. *Screenshot of MinView showing a 3D view of the thickness of post-Carboniferous cover (thick = blue, thin = red, absent = white) overlain by mineral exploration titles and title applications, major roads and towns.*

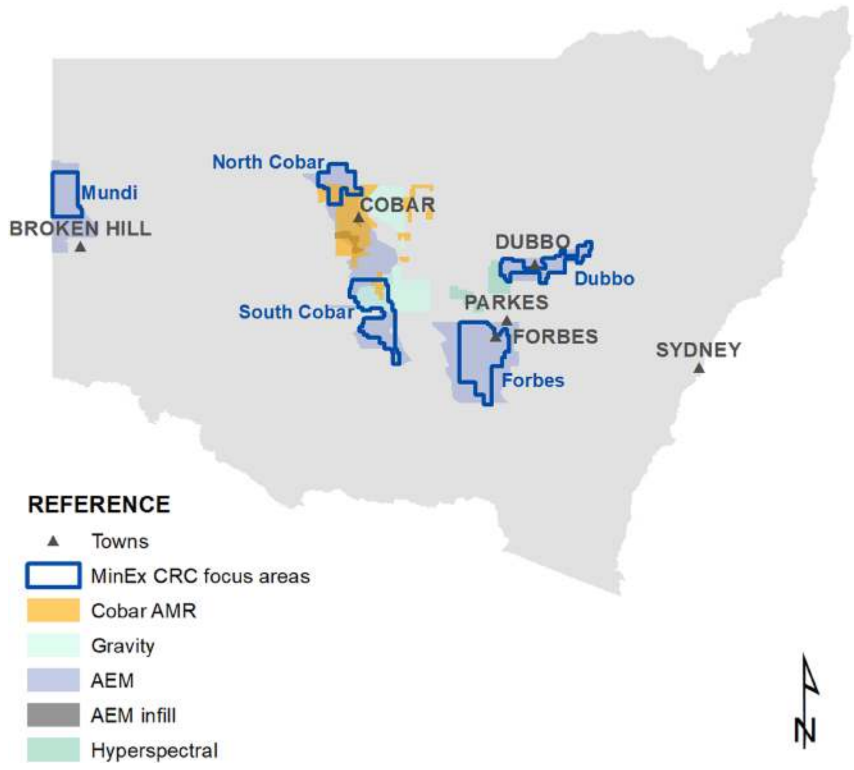


Figure 3. *Map of MinEx CRC focus areas and associated geophysical surveys.*

the report, how the data can be accessed, downloaded or further explained - please contact minex.crc@planning.nsw.gov.au.

Cobar MinEx CRC airborne magnetic and radiometric survey

In June 2021 GSNSW and GA started an airborne magnetic and radiometric (AMR) survey over the greater Cobar and Nyngan region. This involved flying an airplane 60 m above the ground along east–west-oriented lines spaced 200 m apart.

The survey will improve the resolution of, and fill gaps in, our existing coverage in the Cobar region which already comprises significant surveys from government and private companies, spanning 50 years.

The data acquired will be incorporated into the next statewide merge with suitable open-file data from private companies as there is considerable high-resolution coverage (50 m line- spacing, 40–60 m terrain clearance) available.

The data acquired will be publicly available in the second half of 2021 through MinView. To receive a copy of the data please email minex.crc@planning.nsw.gov.au.

Mundi MinEx CRC airborne electromagnetic survey

In April 2021 GSNSW and GA also conducted an airborne electromagnetic (AEM) survey north of Broken Hill, over the Mundi Mundi Plains. NRG's™ Xcite™ time-domain electromagnetic system acquired 3000-line km over an area of approximately 7300 km^2. The helicopter flew along east–west lines 40 km long, about 2.5 km apart, at a height of 60 m, with the Xcite™ system suspended 30 m below. Lines were diverted to go over water bores and drillholes to aid interpretation of the data. The data acquired will be publicly available in August through MinView. To receive a copy of the data please email minex.crc@planning.nsw.gov.au.

Statewide magnetic merge update coming soon

Most of New South Wales' airborne geophysical data acquired by private

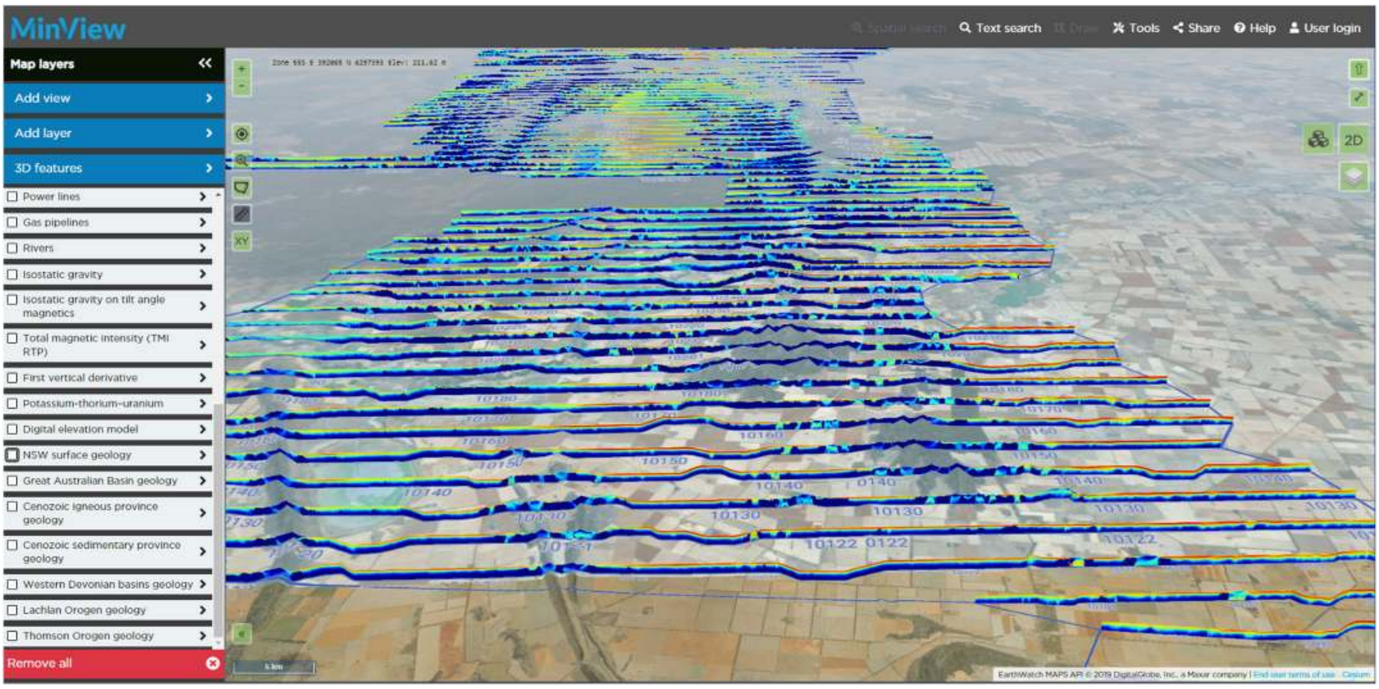


Figure 4. *Cobar MinEx CRC AEM curtains in MinView 3D with aerial photography in the background.*

companies before 2016 will become open file in the first half of 2022 under the NSW Government's 'sunset clause' Mining Regulation Amendment (2016). The GSNSW will incorporate these new data (if quality is acceptable) into an updated suite of magnetic imagery that greatly improves anomaly resolution over the previous magnetic maps.

The statewide magnetic imagery is a merge of over 60 regional government surveys flown at 200–400 m line-spacing. The addition of over 100 company surveys flown at 50–200 m line-spacing in the 2020 update has improved the image quality and allowed the data to be gridded at a smaller cell size (25 m vs 50 m). This prevents under-sampling of complex magnetic signatures. Over 100 additional company surveys have been selected for inclusion in the 2022 update once their data becomes open file under the sunset clause.

The merged statewide TMI grid is the building block to create a series of enhancements. Reduction to the Pole, First and Second Vertical Derivative, and Tilt Angle filters were applied to the grid and then reprojected into a suite of projections relevant for NSW. The grids were used to create the high-quality magnetic imagery available through MinView, delivering best-available image resolution over the entire state, especially in regions covered by the company surveys. This allows for more comprehensive delineation of magnetic features, which aids both geological interpretation and geophysical exploration with the overarching aim of de-risking exploration through better upfront resource targeting and greater overall investment in the sector for NSW.

Statewide radiometric merge update coming soon

Adopting the same merge procedure and using the same algorithmic approach to survey selection, The GSNSW is updating the radiometric merge for the first time since 2014. The recently completed Cobar AMR survey was carefully designed to fill the gaps in radiometric coverage in the Cobar area. The merge will also include other government-flown surveys since 2014, as well as many of the highest quality company-flown surveys. The resolution of the merge will be greatly enhanced by adopting a 50 m grid cell size compared to the 100 m grid cell size of the existing merge. The merged data will be publicly available in the second half of 2021 through MinView.

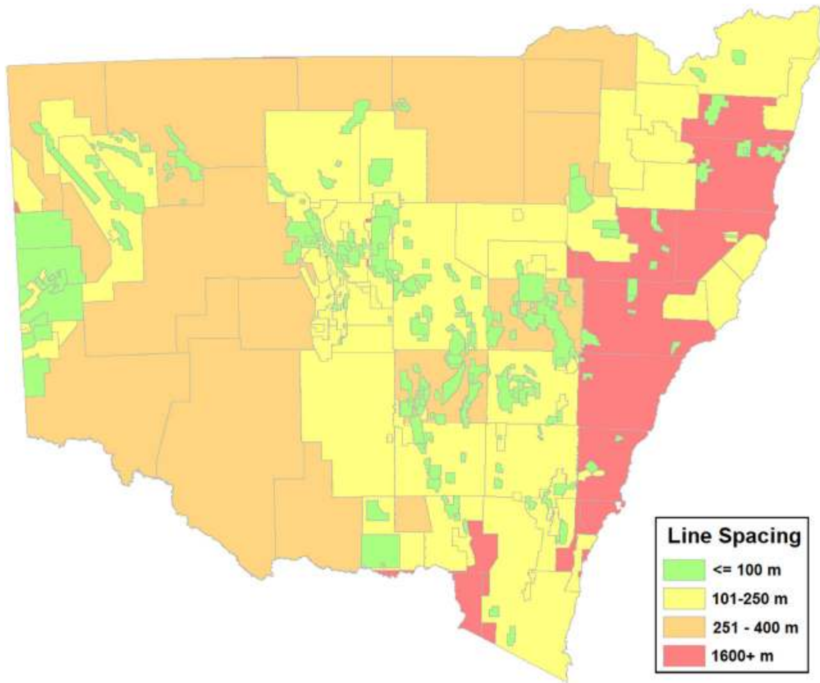


Figure 5. *Map of the 2020 and planned 2022 NSW state wide magnetic merges, coloured by survey line-spacing. Most of the Precambrian and Palaeozoic terranes will be covered by 250 m line-spacing or better.*

AusLAMP field data acquisition completed in NSW

This project commenced in 2016 and is a collaboration between GSNSW and GA. Long-period magnetotelluric (MT) measurements have been recorded at 315 sites on a 55 km grid across NSW (Figure 6). These data were combined with 70 stations from Victoria and inverted using the ModEM code (Egbert and Kelbert 2012) on a high-performance computer to create a 3D model of the resistivity of the crust from 5–150 km depth (Kirkby et al. 2020). Preliminary results and models are available through

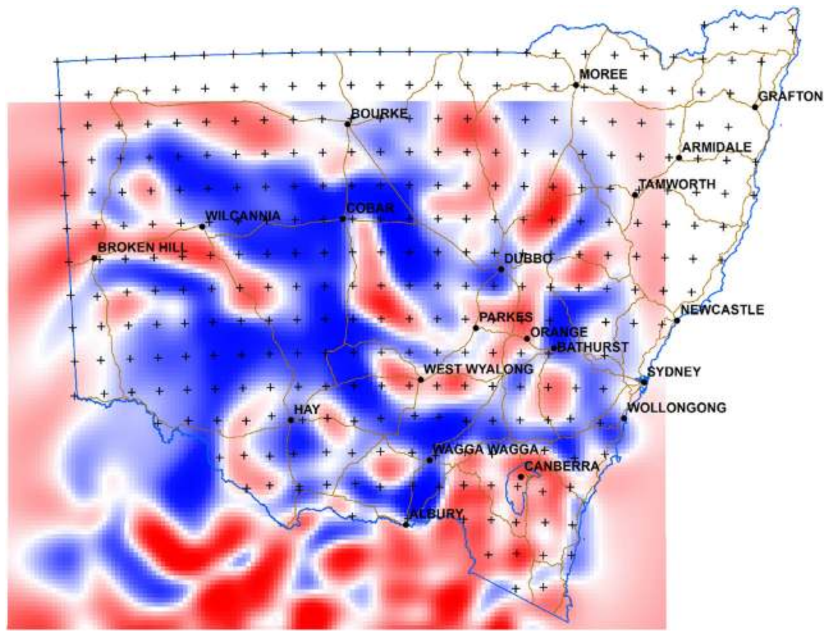


Figure 6. *Map showing AusLAMP long-period MT station locations in NSW (black crosses), the state boundary (blue line), major roads (brown lines) and major towns. The background image is the 30 km depth slice from the resistivity model created by Kirkby et al. (2020). Low resistivity is shown in red and high resistivity is shown in blue. This image shows conductors in the deep crust that may indicate the presence of heat and/or fluids, which could drive mineralising processes.*

News

MinView. Final results are expected to be released in 2022.

All NSW geophysical data now available in MinView

After two years of meticulous work, all airborne, ground (including seismic) and remotely sensed geophysics data held by the NSW Government has been quality-checked/quality-controlled, metadata harvested and archived within a data repository. Going forward, all new geophysical survey data acquired by the NSW Government or submitted by companies will be catalogued and added to the repository.

Most of these surveys are displayed in MinView layers, where they can be discovered using text and spatial searches. Data from government surveys and non-confidential company surveys can be immediately downloaded through the MinView portal. Users can also view and download the following geophysical products: statewide grids of magnetic data; radiometric and gravity data; conductivity cross-sections from airborne electromagnetic (AEM) surveys; and resistivity depth slices from the AusLAMP MT survey. Rock properties measured from samples taken throughout NSW, including magnetic susceptibility, density and (where applicable) remanent magnetisation, will be available through MinView before the AEGC conference.

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Ned Stolz
Geological Survey of New South Wales
ned.stolz@planning.nsw.gov.au

Henderson byte: Anders Celsius

We can add Anders Celsius to the list of scientists whose names are used as SI units, Anders Celsius (1701 - 44) was a Swedish astronomer, physicist and mathematician. He gave his name to the SI quantity of temperature with a unit of degree Celsius. This is appropriate as he proposed, in 1742, a temperature scale that is considered to be more useful than that of Daniel Gabriel Fahrenheit. It had a range of 100 degrees and, strangely, he assigned the value of zero to the boiling point of water and a value of 100 to the freezing point of water. Originally called the Centigrade scale, it was later renamed the Celsius scale in his honour. In 1745, a year after Celsius' death, the scale was reversed to its current usage by Carl Linnaeus (who was then known for formalising the modern system of naming organisms).

It is interesting that some of Celsius' other activities were of a geophysical nature. He was the first to suggest a connection between the aurora borealis and changes in the magnetic field of the Earth. He observed the variations of a compass needle and found that larger deflections correlated with stronger auroral activity. In 1733 Celsius published a collection of 316 observations of the aurora borealis, made by himself and others from 1716 to 1732.

Celsius was also involved in debate about the shape of the earth. He lived at a time when there were two opposing theories as to the Earth's shape. A French school believed it to be prolate, but Isaac Newton's calculations showed it to be oblate. One way to resolve this debate was to measure the length of a degree of latitude at or near the equator and compare it to the corresponding length at or near the poles. An expedition involving Pierre Bouguer made measurements near the equator in Ecuador (see *Preview*, **208**, 39-43) and one year later, in 1736, Celsius participated in an expedition to Lapland to make a similar measurement near the North Pole. This expedition was organised by the French Academy of Sciences and led by the French mathematician Pierre Louis Maupertuis (1698–1759). The result from Lapland confirmed that the Earth's shape was oblate.

Roger Henderson
rogah@tpg.com.au

Geological Survey of Queensland: Strategic Resources Exploration Program concludes, New Economy Minerals Initiative and geophysical programmes commence, and MT results released

Strategic Resources Exploration Program concludes

In August the GSQ marked the conclusion of the 4-year (2017 - 21) Strategic Resources Exploration Program (SREP) with a workshop in Mount Isa to present all the final reports and datasets completed as part of the programme. The SREP delivered multiple geophysical and geochemical surveys, regional geological syntheses, mineral systems projects within the North West Mineral Province and funded collaborative programmes between GSQ, university and other research institutions. The final outputs for all the SREP projects can be found on the GSQ open data portal: https://bit.ly/GSQ-SREP

While the SREP programmes have been completed, the GSQ focus now shifts to the next programme, the New Economy Minerals Initiative (NEMI) which aims to drive the exploration for and understanding of the range of metals and minerals found in Queensland that will be required for emerging technologies. NEMI's scope covers many varied programmes including new geophysical data acquisition, re-analysing older core for critical minerals potential, regional studies on peralkaline volcanics and the REE potential of phosphates and work on secondary prospectivity of tailings.

Airborne geophysical programmes

The Kamilaroi airborne magnetic and radiometric survey has been completed and data is due for release shortly. This survey, located to the north of the Central Isa and Cloncurry North surveys (see Figure 1), consisted of over 61 000 line km over an area of 5600 km^2 and continues the coverage of 100 m line spaced (or better) airborne magnetic and radiometric data in the North West Mineral Province. Once the data is published an updated merge of the recent high-resolution datasets along with larger open-file datasets will be completed.

The airborne Canobie gravity gradiometry survey acquisition is well under way to the north of Cloncurry. The survey covers an area of 4600 km^2 and is being flown to improve the gravity resolution in the area, currently at 2 km, as well as to integrate the airborne gravity derived data with the ground data and determine the value of future airborne coverage in this region. The survey is located to the east of the outcropping Mount Isa eastern succession geology over a covered area including the intersection of the Mt Margaret and Quamby faults. Data will be published on the Open Data portal once the survey and QA/QC is finalised.

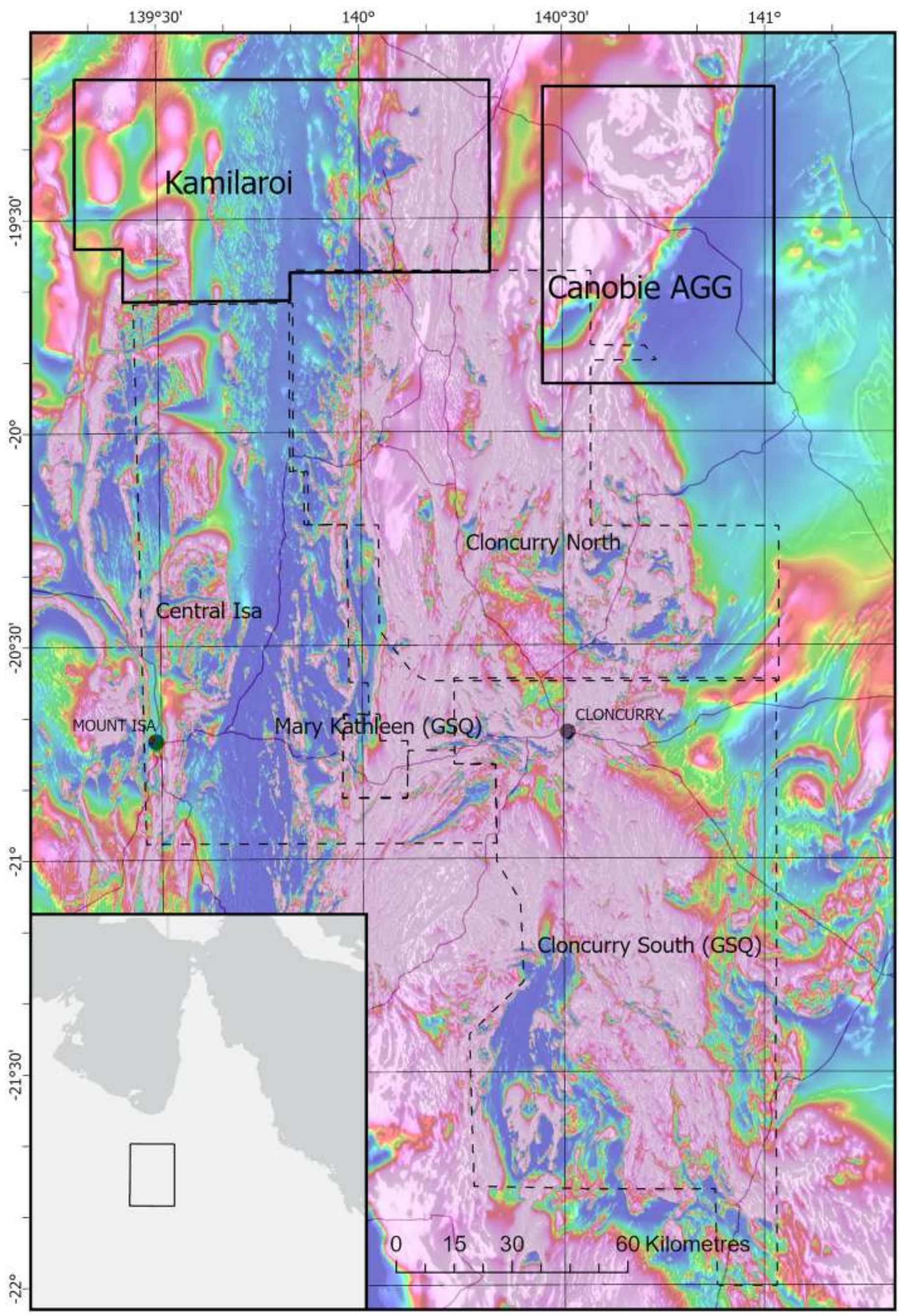

Figure 1. *Outlines of the two new geophysical surveys (Kamilaroi airborne magnetic and radiometric survey and Canobie airborne gravity gradiometry survey) in black outlines. Dashed outlines are recent GSQ 100 m or better line interval airborne geophysical surveys.*

MT in Queensland

In April to June this year a group of geologists and geophysicists from

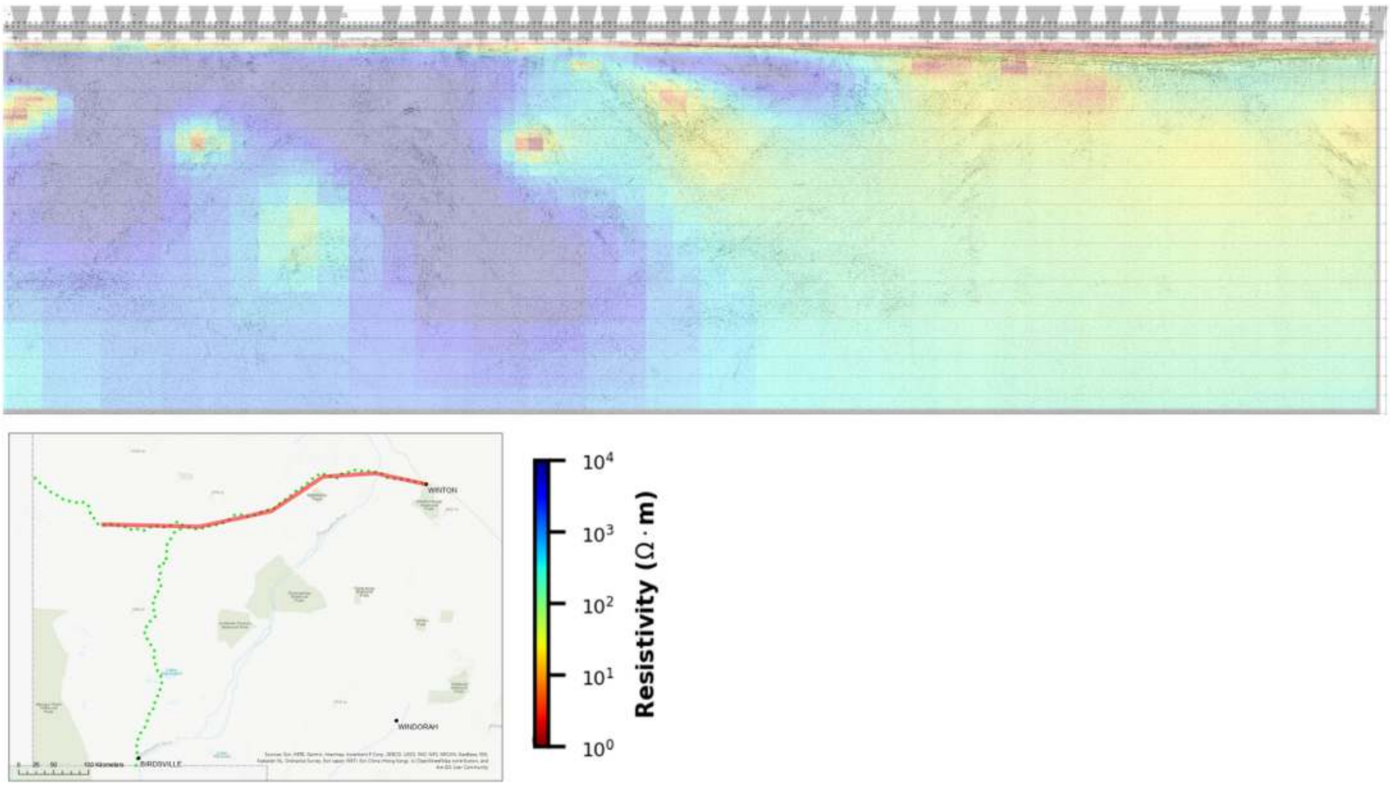

Figure 2. *Comparison between new MT inversion results to the 14-5GA-CF3 deep crustal seismic data; section depth is 20 s TWT – approx. 60 km; location of MT sites indicated as black triangles along top of section. Location of section displayed on map in red. New MT sites indicated in green.*

the GSQ's Minerals Geoscience team carried out a 100 site magnetotelluric (MT) survey in far western Queensland. This survey aimed to provide new insight into the location of the elusive Carpentaria Conductivity Anomaly (CCA) in the south of the Mount Isa Province. The survey data was collected to provide complementary information for historic deep crustal seismic data collected in the area, and as reconnaissance for a larger survey planned in 2022.

Early inversion results from the new MT data are shown in Figure 2. The new data were collected at 10 km station spacing along the major highways between Winton, Boulia and Birdsville using Phoenix equipment borrowed from Geoscience Australia. Sites were left to record for one to two nights, providing data to approximately 1000 s at most sites. Data are available through our Open Data Portal.

Preliminary inversion results from this survey are also discussed in the "Mount Isa Province Seismic interpretation" technical notes report, part of a new series of shorter reports released by the GSQ. This work was done in collaboration with the Sustainable Minerals Institute at the University of Queensland. The new report features interpretations and gravity modelling of the legacy deep crustal seismic network across the Mount Isa Province. New interpretations were produced by integrating seismic, gravity, magnetic and magnetotelluric data across the province to understand large-scale structures.

The MT survey planned in 2022 aims to better characterise the CCA along the Eastern Succession of the Mount Isa Province. Thought to be associated with crustal scale faults that facilitate moment of fluids associated with mineralisation, the CCA is of great interest to many. The survey is in the planning stage and a tender for its acquisition will be released in late 2021 or early 2022. Planned as a semi-regional grid, it is hoped the new survey will be able to better define the location and nature of the CCA.

Finally, a report to accompany the Cloncurry Extension MT survey results and analysis is now available on the GSQ Open Data Portal. The report contains data analysis and some preliminary inversions. Work is ongoing to produce a 3D inversion of this dataset in the future

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

Geological Survey of Western Australia: Geological Survey of Western Australia's Accelerated Geoscience Program

During 2020–21, the Geological Survey of Western Australia (GSWA) reprioritized its work programme due to the impact of travel and operational restrictions imposed by the COVID-19 pandemic. By using its extensive geoscience datasets and outstanding rock and palaeontology collections, GSWA's Accelerated Geoscience Program (ACP) aims to aid economic recovery and stimulate the exploration industry. In three digital packages GSWA has delivered new interpretive datasets across all areas of geoscience in key regions of the State, accelerating understanding of the regions' geology and mineral prospectivity.

To date, the ACP has delivered close to a hundred new interpreted datasets across the four projects, consisting of about 1080 interpreted data layers that comprise original work by GSWA and repurposed or reprocessed data originating from other organizations.

Publication of existing data into GIS layers

The ACP has delivered previously non-digital datasets as new spatial datasets. The majority of the new datasets are delivered at the state scale including new whole rock Sm-Nd and zircon Lu-Hf and oxygen isotope maps and a new 1:250 000 major crustal boundaries layer (Figure 1) which utilises some critical new geophysical datasets and captures the nuances of State-based geological interpretations. The major crustal boundaries layer integrates the most recent geophysical data with current understanding of the geological evolution of the State at a significantly improved level of detail. For the purposes of this interpretation, a major crustal boundary is defined as 'a lithospheric-scale structure that is interpreted to transect the crust to the Moho, and/or a structure within the crust that forms the boundary between interpreted tectonic units at the terrane or province scale'. The major crustal boundaries were then modeled in 3D in order to better constrain the complexities of the crustal architecture and assembly of Western Australia (Figure 2).

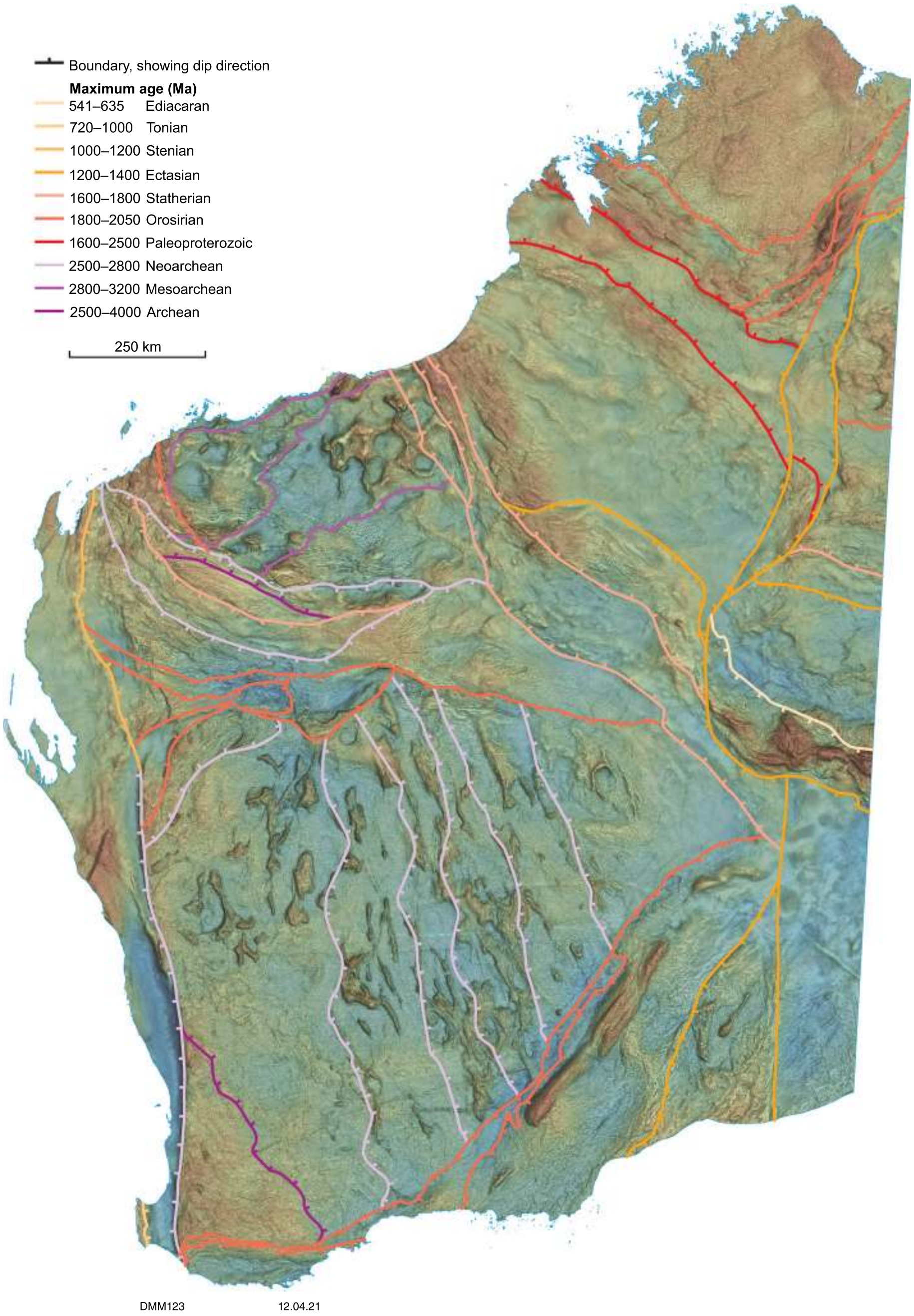

Figure 1. *Major crustal boundaries of Western Australia overlain on composite potential field data consisting of isostatic residual gravity (colour) and first vertical derivative, reduced to pole aeromagnetics (texture). Boundaries are symbolized and coloured according to dip direction and maximum age, respectively*

Yilgarn Craton

The Yilgarn Craton is one of Western Australia's most prospective regions and contains significant deposits of gold, nickel, lithium, copper–zinc, iron ore, tantalum, aluminium and uranium. Recent high-grade gold and nickel discoveries in the craton's far eastern (Gruyere, Tropicana, Neale) and southwestern margins (Julimar), have shown that these two poorly exposed and geologically not well-understood regions are likely to be as prospective as the craton's interior (i.e. Eastern Goldfields). Despite both regions being covered by a thick blanket of regolith, GSWA holds a vast amount of geoscientific data relating to the bedrock and regolith geology with the potential for uncovering significant, new mineral deposits. The minerals

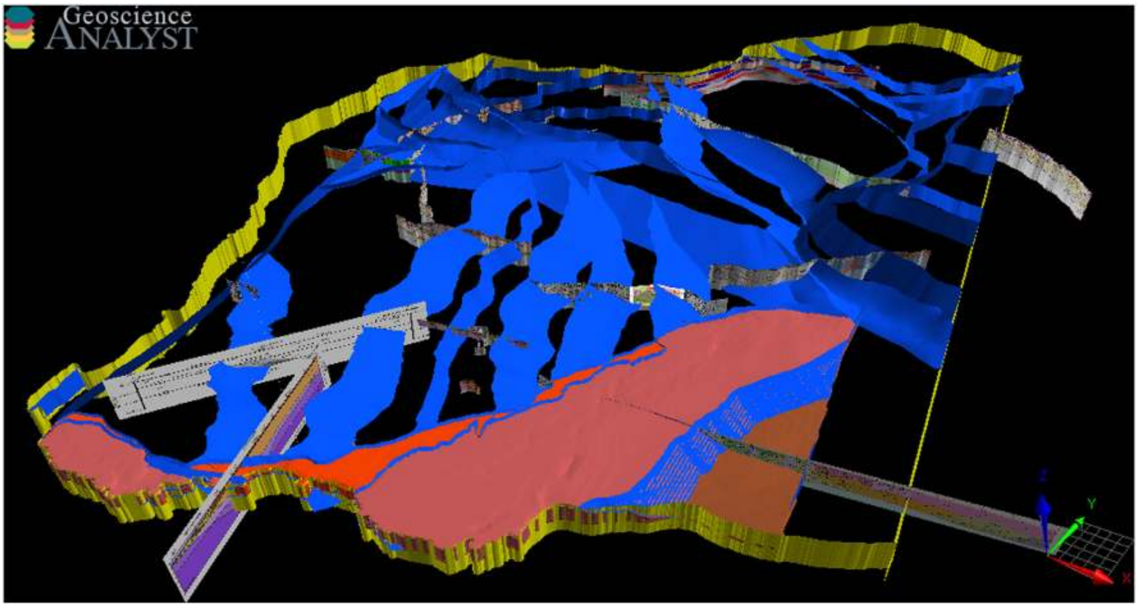

Figure 2. *Screen shot from the Geoscience Analyst project of the 3D State model showing the major crustal boundaries complete with their dip direction and orientation and the images of the interpreted seismic lines from which these dips were inferred. The water-tight model is subdivided into tectonic blocks as indicated by the areas of solid colour.*

industry is increasingly aware that the new era of Tier 1 deposits is likely to be under deep cover. Working to the UNCOVER plan, the AGP has delivered 55 new integrated geoscience datasets for the southwestern and far eastern Yilgarn Craton margins. Highlights of the Yilgarn datasets include Pre-Mesozoic interpreted bedrock geological of the Southwest Yilgarn and Far East Yilgarn. The programme has also incorporated the results of ongoing work in the Eastern Goldfields, and performed new analyses on archived samples.

Statewide critical minerals prospectivity study

The State and Federal Governments have both outlined a list of minerals that are deemed critical for emerging high-tech applications and are considered essential for economic and industrial development over the next decade. Western Australia is well placed to capitalise on increasing demand for critical minerals as we transition globally to low-carbon technologies. Knowledge of the geological settings where these deposits are likely to be located not only reveals emerging exploration plays but allows the government the foresight to manage land for strategic industrial purposes such as downstream processing. The aim of this project was to catalogue the known critical mineral resources of the State to better understand the mineral systems in which they occur and the associated alteration systems. The project has delivered new datasets for 21 commodities that will help to define new exploration targets and to stimulate and increase investment in the critical minerals sector by releasing new parts of the State to exploration.

Energy systems including petroleum, geothermal, and carbon capture and storage

This project has created new datasets that define critical elements of petroleum and geothermal systems to enhance regional understanding of the prospectivity of the State's potential energy resources, including those supporting a transition to low-carbon technologies. The petroleum industry has been one of the most affected by COVID-19, having a simultaneous supply and demand shock caused by an oil price war that coincided with the start of the pandemic. The goals of this project were to produce a graphic summary of the State's well data and structural maps of the Western Australian basins, in addition to other GIS layers, that will directly benefit petroleum industry exploration.

Data availability

GSWA also focused on improving its databases, in particular the Western Australian Mineral Exploration (WAMEX) company geochemistry database, as well as providing accessibility to the online WAMEX reports. The WAMEX drillholes database was harmonised and is now publically accessible online and more than 260 000 WAMEX reports have been digitally captured which are now accessible and searchable.

Many of the mentioned layers have been published online and are available through the Data and Software Centre, GeoVIEW.WA and the WA Petroleum and Geothermal Information management system (WAPIMS). Alternatively, most of the data are available within three standalone Geological Exploration Packages: Southwest Yilgarn, 2021; Far East Yilgarn, 2021; and Critical minerals, 2021, which are available at no cost from the 1st floor counter in Mineral House and at events attended by the GSWA, including AEGC.

Ruth Murdie
Geological Survey of Western Australia
ruth.murdie@dmirs.wa.gov.au

Geological Survey of South Australia: Curnamona Cube and Gawler Challenge II

Curnamona Cube project

The Curnamona Cube project is officially underway. Goran Boren, Sam Jennings and Dr Kamini Bhowany from the University of Adelaide, and Dr Kate Robertson from the GSSA, deployed the first 35 magnetotelluric (MT) stations via helicopter and 4WD from Arkaroola to the SA-NSW border.

The project, which is funded by AuScope, is led by Prof Graham Heinson and managed by Ben Kay, both from the University of Adelaide. It is planned to acquire data at over 150 co-located MT and passive seismic sites in a 25 km spaced grid that will cover the whole Curnamona Province (~90 000 km^2). In addition, a grid of 9 km sites at 1 km spacing will comprise the Curnamona Supersites - where ultra-long time-series MT, passive seismic and heat-flow data will be acquired, creating a long-term observatory platform (over many years) to probe deep into the Earth. For more details: https://www.auscope.org.au/news-features/1m-for-curnamona-project

Kate Robertson deploying a MT instrument by helicopter as part of the Curnamona Cube project (photo taken by Samuel Jennings).

Gawler Challenge II - Next Generation Mineral Systems Mapping project

On the back of the Explore SA: The Gawler Challenge, the Geological Survey of South Australia (GSSA) is embarking on a follow-up pre-competitive geoscience data initiative to flesh out the learnings from the numerous challenge entries. The $5M Gawler Challenge - Next Generation Mineral Systems Mapping project encompasses three main components, data acquisition, data science and insight.

The key aims are to:

- Future proof the delivery of geoscience data by the GSSA to support current and future machine learning and artificial intelligence applications to mineral exploration (data science).
- Open and define new search spaces through filling key gaps in geoscience data in underexplored parts of the state (acquisition).
- Generate new mineral system knowledge, particularly in underexplored parts of the state identified as prospective in Explore SA: The Gawler Challenge results and other prospectivity studies (insight).
- Foster a strong exploration data science community and partnerships between mineral explorers, data scientists and government.

New geophysical data will include gravity and magnetotellurics to unlock new mineral system search spaces within South Australia in a bid to reduce risk for greenfields explorers. Together with geochemistry and geochronology programmes, the geoscience data acquisition will be analysed using artificial intelligence and machine learning techniques in addition to traditional interpretation methods to provide insight into underexplored parts of the state.

Kate Robertson and Stephan Thiel
Geological Survey of South Australia,
Kate.Robertson2@sa.gov.au
Stephan.Thiel@sa.gov.au

News

Mineral Resources Tasmania: Tiers airborne magnetic and radiometric survey data released

The data obtained by the Tiers airborne magnetic and radiometric survey in February-April 2021 have now been finalised and are available for download via the Mineral Resources Tasmania (https://www.mrt.tas.gov.au/) and Geoscience Australia (http://www.ga.gov.au/) websites. As outlined in the last edition of *Preview*, due to the highly variable topography the survey was flown with a combination of fixed wing and helicopter platforms, on 200 m-spaced east-west flight lines at a nominal terrain clearance of 80 m. The project was a collaboration between MRT and GA, with both organisations contributing funding and GA overseeing contractors MagSpec.

As shown in Figures 1 and 2, both the magnetic and radiometric data sets are very feature-rich, revealing a great deal about both surface geology and deeper features. The most striking contrasts in the radiometric image are between relatively high thorium and uranium (cyan) associated with Cenozoic sediments of the Longford Basin in the centre, against the more subdued but potassium-dominated (reddish) signal of Jurassic dolerite intrusions mainly to the east and west. The dolerites together with Cenozoic basalts are responsible for much (though notably not all) of the highly magnetic character visible.

The radiometric data have been processed to regular grids of equivalent radioelement concentration via the full 3D inversion (including topographic correction) method developed by Brian Minty and Ross Brodie (2015). With vertical relief well in excess of 1 km across the survey area, this has resulted in significant improvements. More detail appears in the Geoscience Australia update in this edition of *Preview*.

Reference

Minty, B and Brodie, R., 2015. The 3D inversion of airborne gamma-ray spectrometric data. Extended Abstract, ASEG 24th International Geophysical Conference and Exhibition, Perth, 15 - 18 February 2015.

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

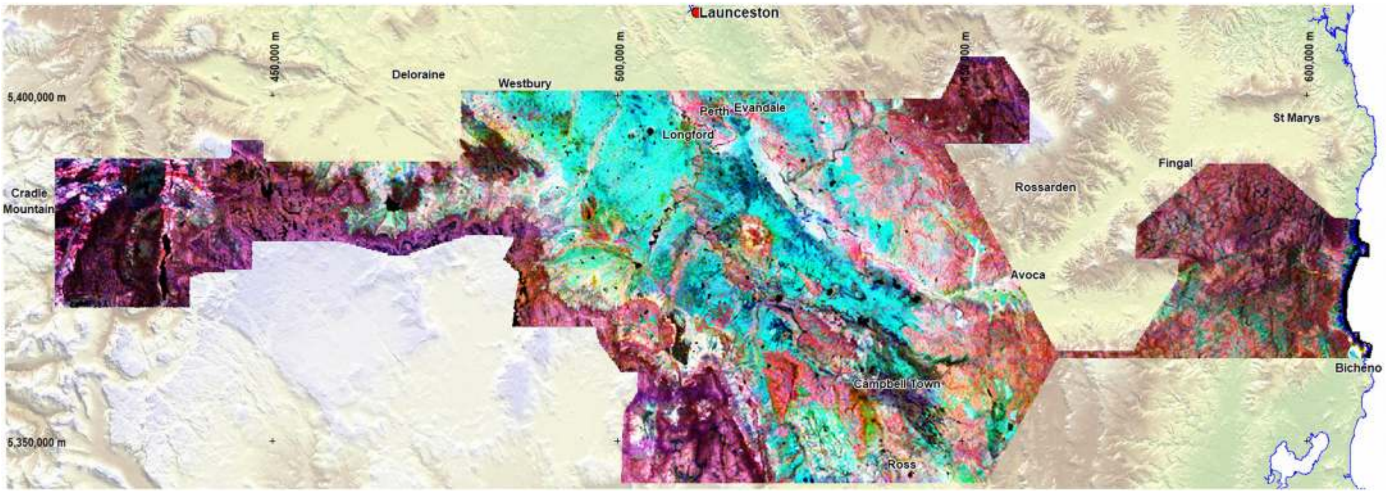

Figure 1. *3D-inverted ternary image of radioelement equivalent ground concentration, histogram equalised. Red = potassium, green = thorium, blue = uranium. The background image is the MRT statewide 10 m digital elevation model.*

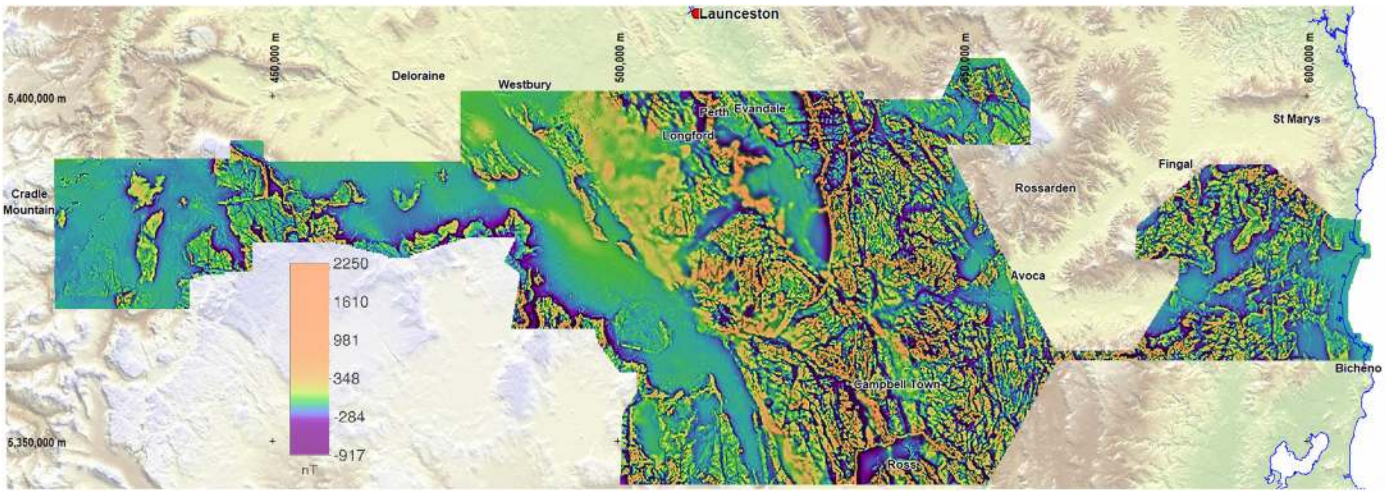

Figure 2. *Total magnetic intensity reduced to pole, with first vertical derivative intensity overlay. The background image is the MRT statewide 10 m digital elevation model.*

Geological Survey of Victoria: Onshore conventional gas industry in Victoria restarts and new 3D models available

Onshore conventional gas industry in Victoria restarts

The restart of Victoria's onshore conventional gas industry commenced on 1 July 2021. The restart follows three years of detailed scientific investigations by the Victorian Gas Program (VGP) to scientifically understand the potential for new onshore conventional gas discoveries and the risks, benefits and impacts of allowing the industry to continue.

The results indicate that there are likely to be commercially feasible onshore conventional gas resources yet to be discovered in the Otway and Gippsland basins (see *Preview* 205 for locations). Regional environmental studies undertaken by the programme showed that developing these gas resources would not compromise the state's groundwater supplies or agricultural sector.

The programme's geoscientific investigations concluded in early 2020 and nearly 70 VGP technical reports are available from Earth Resources Publications at www.earthresources.vic.gov.au/geology-exploration/maps-reports-data and through the programme's webpages www.earthresources.vic.gov.au/projects/victorian-gas-program. A couple of examples are provided below:

New 3D geological framework models for Otway and Gippsland basins

New regional 3D geological framework models have been built for the Otway (Romine et al., 2020) and Gippsland (Powell et al., 2020) basins using existing seismic and well data held by the Geological Survey of Victoria (GSV). A new velocity model was subsequently developed for the Otway Basin (Dunne & Boyd, 2020), extending the depth converted 3D geological framework model to the west and south across the Penola Trough and to the base of the continental slope.

3D modelling of Otway Basin airborne gravity data incorporates basement structures and the Moho

As part of the VGP, the Geological Survey of Victoria (GSV) conducted an airborne gravity and gravity gradiometry survey (Full Spectrum Falcon®) over the on- and near-shore Otway Basin (Figure 1, Carter et al., 2019). See *Preview* 201 for location.

The 3D geometries of geological structures were tested quantitatively against these new gravity data using a 3D forward modelling and inversion approach (Figure 2, McLean et al., 2021). The geometries of geological bodies and structures were constrained using a variety of datasets including density

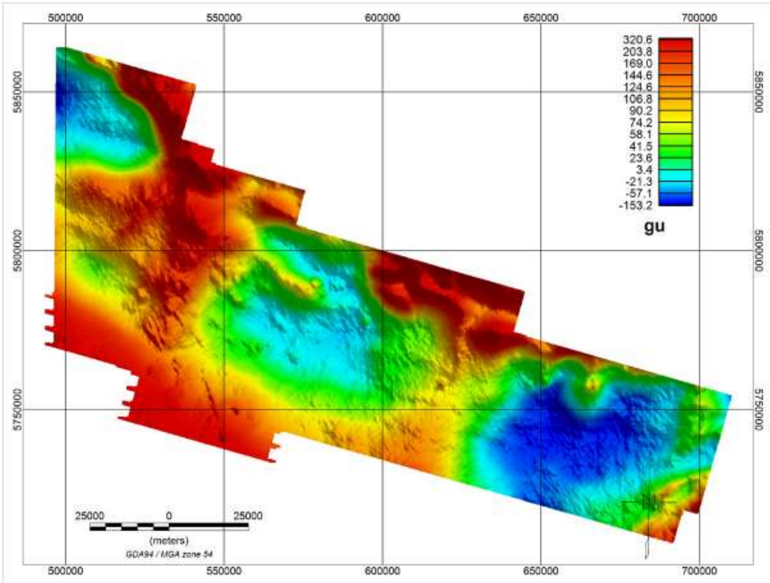

Figure 1. *Map showing Full Spectrum Falcon® terrain corrected (1.80 g/cc) vertical gravity results (gD) from the Otway Basin Airborne Gravity Survey.*

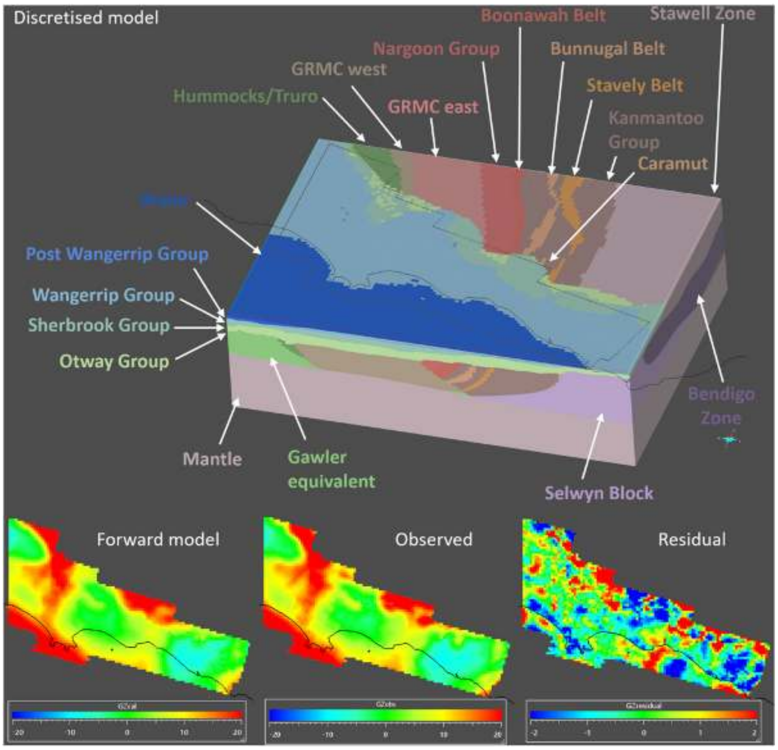

Figure 2. *Discretised basement and basin model showing all geological units with forward model, observed and residual gravity response below.*

data, surface observations, well data, magnetic data and seismic reflection interpretations.

Pre-existing seismic reflection interpretations of the basin were used as a starting model. However, high amplitude gravity signatures, most likely attributed to the diversity of geology in the basement, needed to be modelled first. Previous models of Victoria's crustal architecture were used with the addition of new surfaces to build structures within the basement. This was followed by refinements to the interface between the sedimentary basin and top of the basement. Forward and inversion modelling results suggest that significant gravity anomalies are also caused by the shape of the Moho. The Moho depth was therefore incorporated into the model to account for its influence on the gravity signature.

This study has improved the understanding of the basement structures below the Otway Basin. It has also refined the geometry of the top of basement interface, which plays a key role in petroleum prospectivity. Specifically, inversion results suggest that the Portland Trough in the southwestern region of the onshore Otway Basin is significantly deeper than previously thought.

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

CSIRO: The Cloncurry METAL project delivers

The Cloncurry METAL (multi-element toolkit and laboratory) project, a three year $1.13M multi-disciplinary collaborative project, was completed on 30 June. The project addresses a fundamental problem in geoscience data integration, the issue of scalability. By adopting a scale-consistent approach the project made advances in generating methodologies that convert geological and geochemical processes into scalar physical properties, vectors to mineralisation, which are critical to underpin both big data and regional geophysical approaches to resource exploration. The project developed methods utilising magnetic fabric analyses to quantify structural controls on mineralisation and geophysical methods for mapping redox gradients, fresh ideas to help industry find the next big deposit in one of Australia's most important mineral provinces.

Vectors to mineralisation: Geophysicist and project lead Jim Austin, structural geologist Helen McFarlane and mineralogist Tobias Schlegel undertaking scale integrated, multidisciplinary field work atop the Starra Ironstone, south of Cloncurry.

Cloncurry METAL was underpinned by intensive field sampling, laboratory work and substantial data processing, which lead to a unique scale-integrated relational database, characterising the 23 deposits and their host sequences across the Cloncurry Mineral System. The project generated methodologies to integrate this data with more traditional geoscience and will culminate in a series of toolkits which will be presented to industry in two major workshops in Mount Isa (26 August) and at the AEGC conference in Brisbane (20 September). The project was a truly collaborative effort, involving staff from the Geological Survey of Queensland, staff from the Sustainable mining institute (UQ) the Centre for Ore Deposits and Earth Sciences (UTas) and senior staff from the major mines in the district. It drew on a diverse range of researchers across multiple disciplines, including CSIRO teams: Ore Body Geoscience, Potential Fields Geophysics, Hydrothermal Footprints, Mineral Footprints, Geodynamics/Geology, and Minerals and Water.

Jim Austin
Mineral Resources, CSIRO
james.austin@csiro.au

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

Canberra observed

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

No new normal with the Delta variant of COVID-19 running rampant

Back in November 2020 it looked like we would return to near normal in 2021. Even the Prime Minister was optimistically saying "We can look forward to a much better 2021". But then came the Delta variant of the COVID-19, the scare over the link between blood clots and the AstraZeneca vaccine, the failure of our quarantine system, the low uptake of vaccines, the argy-bargy between the States, and between the Feds and the States. The current system might have coped with any one of these challenges on their own – but not altogether.

The Australian Government is responsible for the supply of vaccines and quarantine. When we thought the virus was under control there seemed to be no urgency to order the jab juice, but now there is a huge shortage, and we are not doing well.

We were more than four months behind US, UK, Japan and Canada in securing supplies from Pfizer. They had all signed agreements before September 2020 and it was expected that 1.3 billion doses would be produced to satisfy global demand. The Australian order was small, only enough to vaccinate one-fifth of Australia's population. Fortunately we are told that additional deliveries will be made in the next three months, but we could have done with them now.

According to the New York Times Vaccine Tracker, and at the time of writing, Australia is positioned 77th in the vaccination stakes, between Albania and Afghanistan, with only 8.6% of the population fully vaccinated. Nowhere near the 70-80% needed for herd immunity.

The State governments are blaming the Federal Government for the shortages, but nobody anticipated the problems with the AstraZeneca vaccine and blood clots. According to the *health.gov.au* website, the chance of clots occurring is estimated to be 4-6 people in every million after being vaccinated. An exceptionally low chance, but it has not stopped over ten European countries banning the vaccine, and most Australians are choosing Pfizer if it is available.

Then there is quarantine. Remember the Ruby Princess, when all 2700 passengers were allowed to disembark in Sydney in March 2020 without proper screening. More than 100 of them felt unwell. At least 900 people later tested positive and 28 died. An inquiry found "serious errors" by New South Wales Health in its handling of suspected cases on board, but quarantine is a Federal responsibility – was poor delegation at fault?

Anyway, most cases of COVID in Australia have originated from people arriving from overseas and everybody agrees that hotels are not suitable places to serve a 14 day stay in isolation. If China could build a COVID hospital for 1000 patients in one week, we should have been able to, at least, start on new quarantine facilities to supplement the Centre for National Resilience in Howard Springs, near Darwin.

While the above issues are mainly managed by the Federal Government, the States and Territories have had to deal with the lock downs, tracings, and health care. Overall, they have done a good job, but it would have been even better if there had been more vaccine shots available, if the Federal Government had not tried to bully some of the states into shortening lockdowns, and if it had provided better financial support to businesses and workers after Job Keeper came to an end.

So, what should the Australian Government be doing to improve the current situation? I have five suggestions:

1. Build more special purpose quarantine facilities.
2. Continue to investigate the possibility of making vaccines in Australia.
3. Change the priorities for who gets vaccinated first so that the people who deliver services, be they health, transport or even retail outlets are at the front of the queue.
4. Get more vaccines ASAP.
5. Have a separate support budget for any future lockdowns.

We are going to have to live with this thing for a long time!

Oil price on upward trend

In a good sign for petroleum explorers, in June 2021 the monthly West Texas crude price finally rose back to above US$70/bl. Figure 1 shows the quarterly numbers for the oil price and the production estimates for Australia.

According to the Resources and Energy Quarterly for June 2021 (https://publications.industry.gov.au/publications/resourcesandenergyquarterlyjune2021/index.html), Australian crude and condensate output is forecast to decline marginally to 330 000 barrels a day, as condensate output was affected by the temporary shutting of the Prelude FLNG project. Prelude was offline between February 2020 and January 2021, affecting Australian crude and condensate production for most of 2020–21. Gorgon is also experiencing ongoing technical issues, affecting Australia's condensate production. These setbacks will result in an 11% decrease in production from 2019/20.

According to the June 21 report, export values are forecast to decline by 14%, reflecting low oil prices at the beginning of the period in 2020–21. However, exports are forecast to rise to $10.9 billion in 2021–22, driven by higher prices, but will decline to $10.1 billion in 2022–23 as both prices and output decline. It is not sure how this will work out because of the price volatility in petroleum products.

Income from iron ore forecast to decline

The Resources and Energy Quarterly 2021 also forecasts a decline in income from iron ore from $149 billion in 2020/21 to $113 billion in 2022/23. The volume of exports is forecast to increase, but the

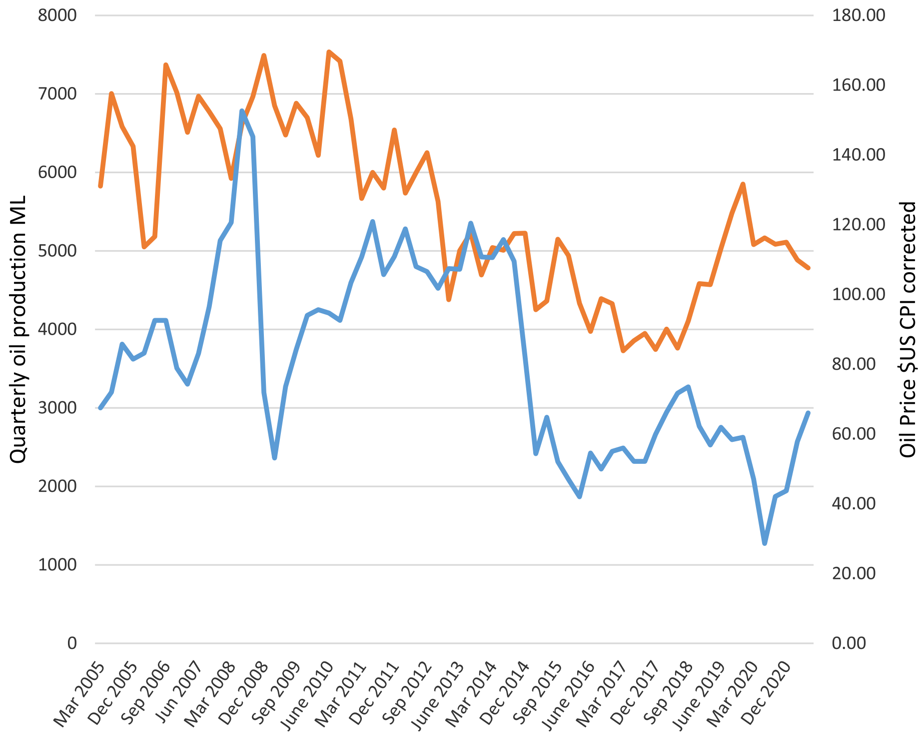

Figure 3. *Total Australian Oil and Condensate quarterly production 2005-2021 in ML per quarter (orange line) and West Texas crude oil price in $US/bl (blue line), normalised to June 2021 dollars. Sources: http://www.environment.gov.au/energy/petroleum-statistics and http://www.economagic.com/em-cgi/data.exe/var/west-texas-crude-long*

price of iron will fall. Even with the fall in price, its export value is worth about the same as the sum of all the other resource exports, apart from LNG. You can add together the value of gold, coal, other base metals and all the others and you only reach about $112 billion. LNG exports in 2022/23 are estimated to be about $2 billion.

Given these numbers the importance of improving our relationship with China is obvious.

Forecasting the future – the view from the Australian Treasury

Every five years from 2002 the Australian Treasury has embarked on a fascinating exercise to forecast what the economy and the Commonwealth budget will look like over the next 40 years. These Intergenerational Reports (IGRs) examine the long-term sustainability of current policies and how demographic, technological and other structural trends may affect the economy and the budget. COVID delayed the 2020 document by a year (https://treasury.gov.au/sites/default/files/2021-06/p2021-182464.pdf) but the 180-page report is now available.

While recognising that you cannot predict the future, it describes a useful path for the next 40 years. It is easier to change a plan than to have no plan at all. Let us look at three issues:

The environment

The natural environment is critical to quality of life and the state of the economy. The IGR recognises that Australia will have to respond and adapt to environmental challenges that will affect the economy and the budget. Rising global temperatures will impact on everyone.

The IGR recognises that climate change will have significant implications for Australia's export income. But it predicts demand for clean energy, critical minerals and hydrogen will increase, creating "new opportunities for Australia".

All good, but we need political, social and cultural engagement with the issues to make change happen effectively.

Population

Population growth is forecast to slow down. This is a downward revision from previous IGRs, because of the impact of COVID-19 pandemic on migration, as well as lower fertility rates, currently trending to below the level required to sustain the size of the population. Continued growth, albeit at a slower rate, means Australia's total population is projected to reach 38.8 million in 2060-61. This is more than one million less than the estimates in the 2015 IGR.

The age profile of the population will change significantly. According to the current IGR, between 2019-20 and 2060-61 the number of Australians aged 65 and older will double to 8.9 million. In 2019-20 there were 6400 centenarians, but by 2060-61, that cohort is projected to be 40 900. Something to look forward to?

Health and aged care

An ageing population may reduce the number of working-age people as a share of the population. However, if labour productivity improves and fewer people are needed to provide the services we require, this may not be a problem.

Australian government health spending is projected to continue to increase as a share of GDP from 4.1 per cent in 2018-19 to 6.2 per cent in 2060-61. This is lower than the earlier estimates, which forecast about 9% GDP health spending by 2050. The annual per-capita costs are projected to increase from $3250 in 2018-19 to $8700 in 2060-61 (2021 $s).

Aged care spending is expected to increase substantially as a share of the economy, from 1.2 per cent of GDP in 2020-21 to 2.1 per cent of GDP in 2060-61 (or $113 billion in 2021$s). This signifies population growth and ageing, as the baby boomer generation enters aged-care eligibility age. The annual per capita aged-care spending is projected to increase from $5460 to $12 500 for people aged 65 and over.

Education matters

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

A cohort of well-educated geophysicists is a must for any modern country given the increasing global demand for energy-critical metals, carbon dioxide and hydrogen underground storage solutions, and geotechnical characterisation of onshore and offshore sites for wind and solar photovoltaic farms. Concerns about geophysics education in Australia have been raised on the pages of *Preview* more than once in recent times. In each of the last three issues, I have briefly described the situation and depicted emerging online alternatives to traditional classroom-based education. However, the technical, multidisciplinary nature of exploration geophysics renders comprehensive online-based education difficult, if not impossible. Face-to-face tuition is still required in laboratories and in the field.

Dr Kate Selway is the new Chair of the ASEG's Education Committee and one of the first things she did on assuming the position was to conduct a survey of what geophysics is being taught where in Australia in 2021. The survey data will assist the ASEG to establish a baseline for further analysis.

Geophysics education in Australia – survey results

Kate Selway
ASEG Education Committee Chair
Education@aseg.org.au

Table 1. Geophysics education in Australia

		Undergraduate			Postgraduate (coursework)		Trends	
State	Institution	Geophysics major (or equivalent)	Number of stand-alone geophysics subjects	Subjects with geophysics components	Named Masters degree	Any postgraduate geophysics teaching	Recent changes (positive/ negative)	Planned changes (positive/ negative)
ACT	*ANU*		5	4				
NSW	*Macquarie*		1	1				
	UNSW		1	3				
	U of Sydney		0	2				
	U of Wollongong		0	1				
Qld	*James Cook U.*		0	2				
	QUT		1	1				
	U of Queensland		0	1				
SA	*Flinders*		0	2				
	U of Adelaide		3	2				
Tas	*U of Tasmania*		0	4				
Vic	*Monash*		1	0				
	U of Melbourne		1	0				
WA	*Curtin*		12					
	UWA		0	2				

In order to understand the state of health of geophysics education in Australia the ASEG surveyed all Australian universities that teach geophysics in May 2021. The results are shown in Table 1, where green shading signifies that the designated major or degree is offered or that a change has been positive, and red shading signifies that the major or degree is not offered or that a change has been negative. Honours coursework has been included in the postgraduate teaching category. The term 'subject' is used for an undergraduate unit of study, which is variably also called a unit or a course at different universities.

Only three Australian universities – the ANU, the University of Adelaide and Curtin University – currently offer an undergraduate geophysics major. Of the remaining universities, only five – Macquarie, UNSW, QUT, Monash, and the University of Melbourne – offer stand-alone undergraduate subjects that focus on geophysics, and a total of 12 universities offer some undergraduate geophysics content within other subjects. At the postgraduate level, Curtin is the only university to offer a dedicated Masters degree in geophysics, and an additional eight universities incorporate geophysics teaching into other postgraduate coursework degrees.

Recent trends have seen a substantial decline in geophysics at Australian universities, both in the loss of academic staff and the loss of undergraduate geophysics teaching. Undergraduate majors in geophysics have recently been cut at the University of Queensland, Macquarie University and the University of Tasmania (RMIT cut their geophysics program prior to 2021). With the exception of the ANU, eastern states universities now offer very little geophysics, and current offerings at both Macquarie and the University of Melbourne are expected to decrease over the coming one to two years. This concerning situation, which is likely to exacerbate the shortage of skilled geophysicists for the Australian workforce, is a result of the intersection of low undergraduate student numbers with current university funding models. Industry-wide efforts to raise the profile of geophysics, encourage students to study geophysics, and to lobby universities and government to retain our geophysics capability, are encouraged to help to reverse these trends.

Environmental geophysics

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

A golden age of environmental geophysics

Welcome readers to this issue's column on geophysics applied to the environment. In this column I review the presentations on offer at AEGC 2021 (now digital), and am inspired to suggest that environmental geophysics is entering a "golden age".

So, what's hot in the environmental/archaeological/engineering/near surface part of geophysics, and how does this add up to a golden age? I think that we are witnessing significant progress in both the development and the evolution of new techniques. On top of that we are witnessing significant improvements in our ability to invert and image large data sets. Improvements that have come with improved computer processing.

One of the most widely-discussed techniques at the upcoming AEGC will be Passive Seismic (PS). As most of us know, the PS technique is not used just to collect the "shallow" data sets that I'm mostly interested in (at least so far as this column is concerned). That fact is rather obvious if you look through the titles and abstracts in the programme for the presentations that involve PS. Of the eleven presentations that use PS, only one is strictly an environmental story; the rest are split between oil and mineral exploration and deep crustal studies. Nevertheless, based on the range of subjects (and the range of depths), I'm pretty sure that PS is going to be used more and more at all of these scales. Any technique that can provide useful information at so many depth scales (with some differences in instrumentation of course), relatively quickly and without a "source" is going to continue to be a story.

Still in data acquisition, I was very happy to see that one of my favourites over the last year or two, the Loupe EM system, is getting attention at the conference (including a poster from yours truly). In one of the presentations (Van Dam et al.) Loupe data are collected along with other geophysical data (including passive seismic) to characterise environmental problems in a near-mine setting. It seems that all of the data sets were complementary, and that likely flow paths from an "environmental" pond could be identified.

It is also good to see techniques like Multi-channel Analysis of Surface Wave (MASW) getting increased attention. There are two presentations highlighting MASW data sets being acquired for engineering projects that I think are definitely worth a look. Sometimes it seems electrical techniques just don't get you the info that you need (who would have thought) and when that happens it may just be time to turn to MASW and passive seismic (among other possibilities). I can't wait to see widespread joint inversion of electrical data with shallow seismic data; it seems so obvious that the various (different) ambiguities in all of these data sets could be minimised by looking at them together.

In the interest of making these shallow data sets more useful, both in a spatial sense (i.e. are features in the correct location, and are conductivities right, etc.?) as well as in the temporal sense (i.e. can we compare data sets collected at different times over the same area to be able to interpret how the underlying ground conditions have changed?) I think that calibration of equipment will become more and more important. There is one presentation by Brodie et al. (Geoscience Australia) on the Menindee AEM calibration range. Whilst there is only one presentation on this topic, I think that the subject is under-represented in our work and research. Personally, I am trying to figure out how to "locally calibrate" ground data so that I can be confident that observed changes are not just minor instrument drift over time.

There are a few other talks that I think will be interesting. Fiandaca and Viezzoli are giving presentations on the inversion of IP effects in airborne EM (AEM) data. Whilst I think that it is important that we get better at recognising induced polarisation (IP) effects in AEM, and am pleased to see inversion for the source of IP in the data, what really got me going was that Fiandaca and Viezzoli think that their approach has the potential to improve our ability to incorporate any prior data (even though it may be sparse) into the much less sparse AEM inversion problem. I've never been quite happy with how borehole and other data are incorporated into AEM inversions, and am hoping to see a better approach evolve.

Having worked in Laos a few times over the years, I was both personally and professionally interested in Speer et al.'s work on the Plain of Jars Archaeological Research Project. It seems that they used ground penetrating radar to successfully identify at least one ancient burial site with two partial skeletons.

Taylor et al. from the CSIRO present the results of combined AEM and hydrological studies at Goulburn Island in the Gulf of Carpentaria, NT. The local indigenous population is completely dependent on local groundwater supplies, which runs low in dry years. This study determined that there is likely to be enough water in the system (and that recharge is sufficient) and that what is needed is infrastructure improvement, as well as improved management.

Finally, Anton Kepic will present a talk titled "The Do-It-Yourself-geophysicist". To me this talk looks interesting at a number of levels. Firstly it discusses how the evolution of UAV's will be important to our science (I suspect that most of us are already convinced of this). Secondly it describes some of the new tools out there (that are mostly free) that will allow the more mechanically and electronically apt among us to actually make our own instruments in close to real/useable time. While I may not be appropriately apt at the moment, I'm definitely interested.

Roll on the golden age!

Minerals geophysics

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

Conventional wisdom in mineral exploration

When I see the term 'conventional wisdom' or the like used in the context of mineral exploration geophysics, I can become a little uneasy. Yes, there are petrophysical properties you can rely upon: magnetite is magnetic, galena is dense, graphite is electrically conductive, pyrite is IP-anomalous, pitchblende is radioactive, etc. But there is more to an orebody's geophysical response than a simple sum of the petrophysical properties of the constituent minerals.

In the same vein (sorry about that), type examples of orebody geophysical signatures are really just that - examples for individual orebodies. While they unarguably provide valuable information, a slavish, in particular quantitative, adherence to such type examples in geophysical exploration and interpretation can lead to missed opportunities and unwanted outcomes.

Both of these concerns are a function of the inherently wide variations in both mineralisation styles and the geological environments in which they occur. Let's illustrate this theme with a few examples.

Electromagnetics (EM) cannot be used for disseminated sulphide mineralisation.

At first glance this 'conventional wisdom' seems a given; disseminated sulphides are not interconnected electrically and therefore cannot support the flow of the induced electric currents necessary for the EM method to work. And, by following this 'conventional wisdom', the use of airborne EM, for instance, for rapid and systematic investigation of your area of interest appears to be off the table. However, there are other factors to consider – particularly the environment of the mineralisation.

The increased sensitivity of modern EM techniques does offer possibilities for indirect detection of disseminated mineralisation where, for instance, environmental resistivities have been lowered by mineralising processes. Furthermore, where deep weathering (typical of much of Australia) is present, preferential weathering of disseminated sulphides, and the development of an associated supergene enrichment zone, may provide targets for direct detection with EM. The Ernest Henry IOCG deposit, first identified from a ground EM anomaly derived in part from native copper within a supergene zone associated with the palaeo-weathering profile beneath younger transported cover, is an excellent example.

IP-Resistivity should not be used for massive sulphide mineralisation.

The thinking here in part harks back to early concerns about the diminution of IP effects with decreasing resistivity. Remember the Metal Factor (defined as IP/resistivity multiplied by a constant) which was designed to compensate for this problem? By following the 'conventional wisdom', access to the capability that IP offers to potentially discriminate between mineralised and un-mineralised conductors is denied to you.

In practice, massive sulphide mineralisation still contains boundaries between regimes of metallic and ionic electrical conduction. While the associated IP effects may be less anomalous than might be expected from the sulphide content, some IP anomalism can be expected. In addition, the presence of a strongly conductive zone in the accompanying resistivity results should alert you to the presence of possible massive sulphide targets. The down side is that IP-resistivity does not provide the degree of source body geometry delineation that is typically derivable from the results of a detailed electromagnetic survey.

One flow-on from this thinking is that, under appropriate circumstances, there may be merit in considering IP-resistivity as a possible follow-up technique for airborne EM surveys, rather than ground EM as 'conventional wisdom' would have you do.

Gravity is <u>the</u> method for massive zinc mineralisation; zinc ore minerals aren't electrically conductive therefore electrical methods, including EM and IP-resistivity, aren't going to work.

This 'conventional wisdom' can be misleading on two counts:

With respect to gravity, while all common zinc ore minerals are anomalously dense, the environments in which they occur, particularly the carbonate sediment environments associated with some styles of zinc mineralisation, can generate density variations which may mask gravity anomalies directly attributable to zinc orebodies. For example, recognition of relatively subtle orebody-related gravity anomalies within major gravity gradients associated with the margins of carbonate sequences can be problematic.

Geophysical exploration in the Northern Flinders Ranges in South Australia for massive hydrothermal willemite (zinc silicate) mineralisation, for which gravity really is the "go to" method, illustrates the need for lateral thinking (Groves and Carman, 2003). Here the Beltana orebody is associated with a discrete gravity high as would be expected, but the nearby Reliance orebody is associated with a discrete gravity low! The confounding effect is the karsting of the carbonates hosting the mineralisation, or more specifically the nature of the karst fill – mineralised material at Beltana, sand at Reliance.

With respect to electrical methods, while it is true that the zinc sulphide sphalerite is not a metallic conductor, ore-grade sphalerite rarely occur in isolation, and the typically associated sulphides such galena, pyrite, marcasite, chalcopyrite, etc. are most definitely metallic conductors. Electrical and EM geophysical techniques therefore have the potential for detection of zinc mineralisation via the directly associated suite of conductive, IP-anomalous sulphide minerals.

In summary, I most certainly am not suggesting that the 'conventional wisdom' is wrong, just that it should guide rather than constrain our thinking, and that the bigger picture should be considered when selecting geophysical techniques for an exploration programme.

Reference

Groves, I. and Carman, C., 2003. Geophysics as an exploration tool for willemite - a case study of the Beltana-Reliance-Aroona zinc deposits, Northern Flinders Ranges, South Australia, *ASEG Extended Abstracts*, 2003:3, 223-232, DOI: 10.1071/ASEGSpec12_1

Seismic window

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

Hard rock seismic

Following my article on seismic for mineral exploration (*Preview* Feb 2021) I received a note from Reg Nelson describing briefly his experiments in recording seismic over mineral bodies when he worked with the SA Mines Department some time ago. Reg recorded data over Olympic Dam and various areas on the Stuart shelf, and even ventured as far as Mt Isa.

The results were underwhelming, but one survey at Lake Torrens recorded reflections that correlated with some volcanics when, in desperation, Reg applied a 250 Hz low cut filter (Figure 1). In a paper published in 1984 Nelson noted that targets were becoming deeper and more elusive such that the depths were at the limit of investigation of conventional electrical methods. In this environment only seismic reflection surveys could image the geology - if there were sufficient contrasts in acoustic impedance. His modelling showed ore bodies had a characteristic signature with density variations having more contrast than velocity. He concluded seismic could be useful if the signal bandwidth was at least 2 octaves and the upper frequency was greater than 200 Hz. These early efforts were hampered by the recording instrument that had only 24 channels, which is primitive compared to today's instruments that record thousands of channels.

Reg's letter prompted me to have another look at seismic for mineral exploration. I contacted Antony Brockmann and he took me through technology that has progressed significantly in the last ten years. He explained that his company, HiSeis, wanted to provide clients with the big picture - an interpreted product – to help the client understand the geology. It is no surprise that hard rock mining geophysicists are not familiar with interpreting seismic data (I must admit I would be lost if asked to do something with EM data) so HiSeis aim to use their expertise to provide a model that also incorporates all the available gravity and magnetic data. Australian mining is faced with declining grades and resource depletion and as the search moves deeper traditional methods struggle. Seismic is the only method that can provide good results at depths greater than 2 km. The application of the seismic method is not limited to surface seismic, and some surveys have recorded downhole methods such as vertical seismic profiles (VSP) and cross hole imaging. A robust workflow has been developed for describing possible outcomes and includes sonic logging in wells – something that has generally not been acquired in minerals exploration. But good sonic logs are a prerequisite for modelling the contrasts associated with expected rock types.

As I understand it, mineral deposits are precipitated from mineralised fluids (magmatic or hydrothermal) that transport the extracted minerals from depth (Figure 2). The fault distribution is important because it may focus the transporting fluid or act as a barrier to flow. The search for minerals starts with a structural model which includes a 3D fault framework. Then, based on modelling seismic amplitude variations, an understanding of the signature of hydrothermal alteration (or some other characteristic) is used to determine the probability of key rock types to guide exploration to areas of high potential (Figure 3). With this volume of data requiring analysis, Machine Learning (ML) is being used to interpret the data and determine probabilities. The seismic signature is often not an obvious solid anomaly with clear edges, but a fuzzy zone of higher probability caused by subtle changes in density and perhaps P wave velocity.

Historically seismic was used at the end of mine life, if at all, to check if

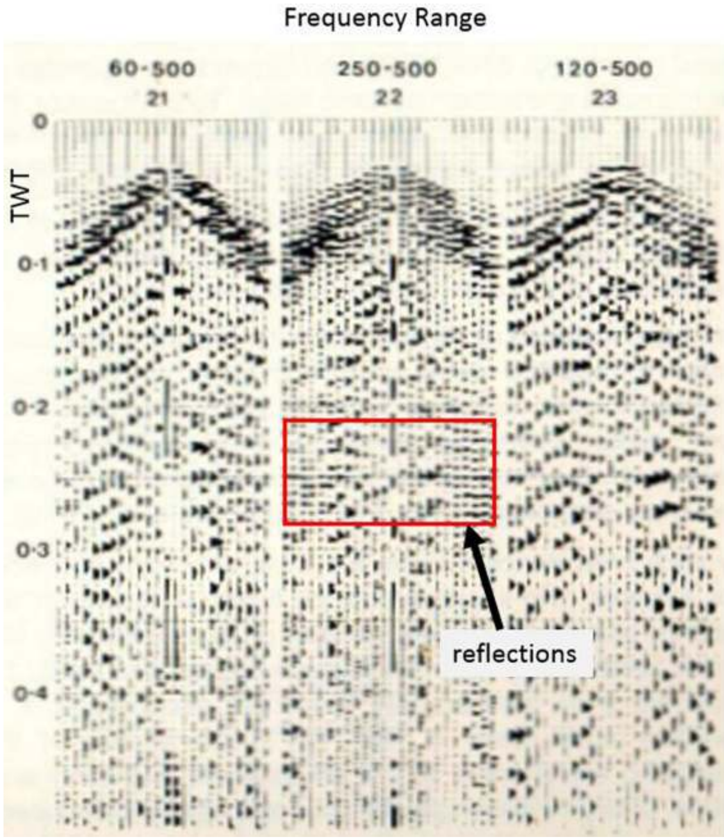

Figure 1. *Shot records from Stuart Shelf trials varying low cut filter – 60 Hz (left), 250 Hz (centre) and 120 Hz (right) – with 500 Hz high cut (modified from Nelson 1984). Correlatable reflections are only apparent on the high frequency record (centre).*

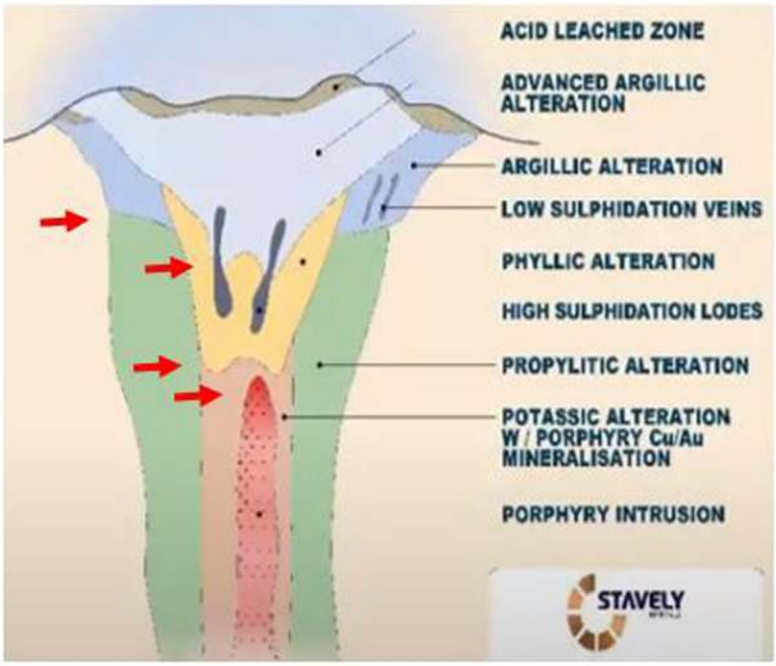

Figure 2. *Porphyry alteration and mineralisation model (after Silitoe 1995). Sub horizontal reflections seen on seismic are thought to be boundaries between alteration zones (indicated by red arrows).*

any deposits had been missed before a mine is closed. Now it is being used more often in the exploration cycle and in project planning so that mine developments are designed optimally – too big and the process is inefficient, too small and there is little room for expansion. The economics of a mine depend on an optimally sized development, but smaller details like placement of the tailings dam away from a fault are also important.

The seismic industry needs to move on from the petroleum business, with its ever growing list of constraints, and moving into the search for minerals may be just what it needs to survive. The use of seismic surveys is just becoming established in the mining sector and this brings new challenges and opportunities for geophysicists.

To sum up, Antony Brockmann says "Technology advances in seismic processing and cloud technologies (AI/ML) in recent years are driving step changes in hard rock seismic quality, efficiency and savings that we believe will move hard rock seismic from a 'Nice to have' to an 'industry standard practice' in minerals exploration, similar to oil & gas. One of the biggest issues we face is people basing their opinion of hard rock seismic on vintage data and out of date processing using standard oil and gas workflows; which are not fit-for-purpose in a hard rock environment. This is where HiSeis have changed the game through IP developed in hard rock processing from 2D and 3D projects around the world over last decade."

References

Nelson R.G., 1984. Seismic reflection and mineral prospecting. *Exploration Geophysics* **15**, 229-250.
Sillitoe, R. H., 1995. Exploration of porphyry copper lithocaps. In: Mauk JL, St George JD (eds) 1995 Pacrim Congress, Auckland, Proceedings, Australasian Institute of Mining and Metallurgy, Melbourne, pp 527–532.

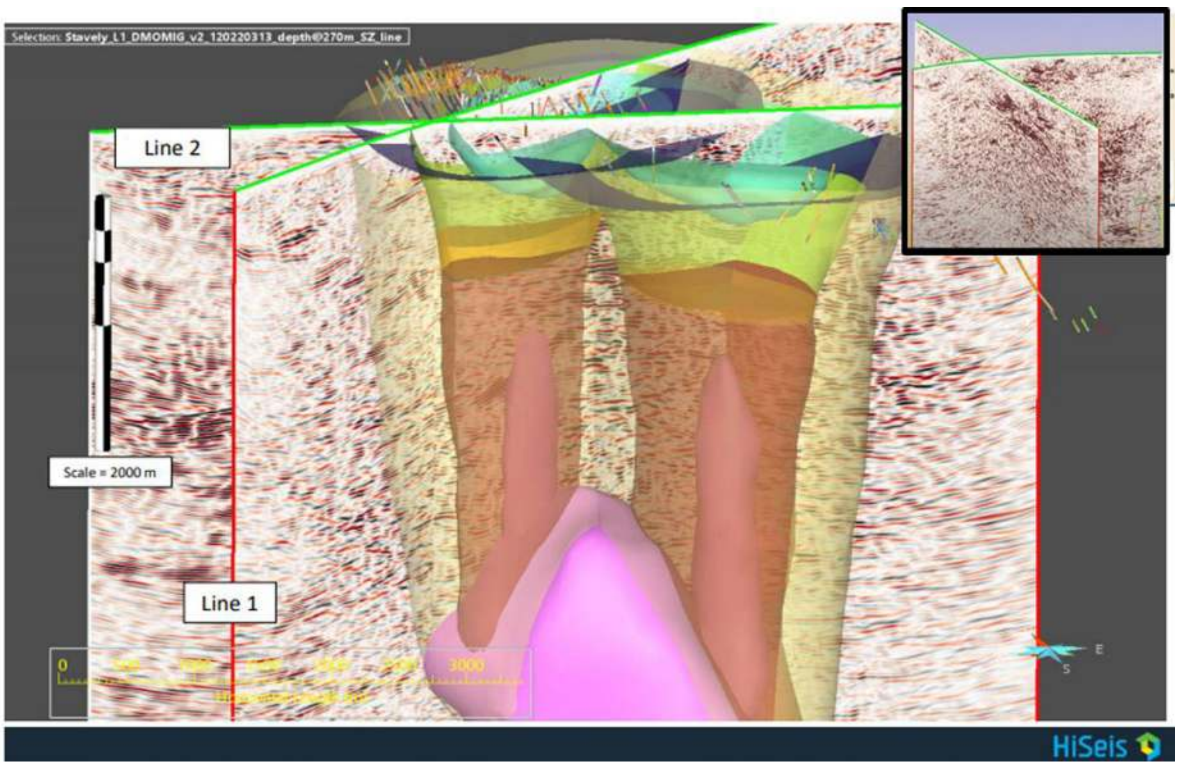

Figure 3. *Interpreted model of porphyry intrusives and their associated alteration haloes. Seismic data supports the presence of two porphyry intrusions separated by about 1400 m. Inset: uninterpreted seismic lines.*

Data trends

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

Playing with open source software

QGIS is the hot, free GIS kid in town and is proving very popular with explorers, so I thought I'd try it out. QGIS is not a polished proprietary GIS (like some I could mention) but exploration is not a shape-file orientated profession, and open source software may offer better file interoperability.

QGIS uses the GDAL (Geospatial Data Abstraction Library) raster and vector standard, an open standard dedicated to open file formats, which is right up the ASEG Technical Standards Committee's alley. The *Raster -> Translate* menu turned my *ers* file (our beloved archive format) into an industry favourite - *grd*.

But, it was not all a love-in for QGIS, as making 3 band radiometric files proved baffling. The process was annoying and the results were inconsistent. At the most fundamental level I was unable to verify which input raster was assigned to which band. Needless to say, I could not expect Gary to make a state radiometric grid with those results, and it was easier to code my own procedure in Python.

There are two plugins available that might be useful for geophysicists and explorers – *Geoscience* for drill hole visualisation and the *Archaeologists Geophysical Toolbox (AGT)*.

Geoscience offers to de-survey your drill holes and make cross sections (https://www.spatialintegration.com/). This is a useful function.

AGT is designed for archaeologists collecting electrical and magnetic gradiometry data in xyz text format, but I did not have a magnetic gradiometry dataset to hand to test the plugin (https://plugins.qgis.org/plugins/AGT/). Coincidently, the lack of gradiometry data in Australia was noted at our last Technical Standards Committee meeting.

As an alternative, I tried to find a function to create a magnetic grid, and I stumbled across the *Slope* function help page and and saw this equation

$$Slope = Atan\sqrt{\frac{dz}{dx}^2 + \frac{dz}{dy}^2}$$

which reminded me of this equation

$$THD = \sqrt{\frac{dz}{dx}^2 + \frac{dz}{dy}^2}$$

So, there is a (almost) Total Horizontal Derivative (THD) function in this open source program.

As a quick comparison I ran the same magnetic data through both functions and normalised the results for comparative purposes. The result of the *Slope* function (Figure 1) produces a close likeness to the result of the THD (Figure 2). The small difference (grey) is likely to be the tangent scaling (Figure 3).

Ignoring the tangent scaling of the *Slope* function, the common Pythagorean result contrasts *Slope's* comparison of immediate neighbours and the THD "least squares fitting of a third order surface to a 5x5 window" (Lyatsky *et al.*, 1992). While it's an unusual method, I'm sure that there is worse magnetic domain mapping out there!

Reference

Lyatsky, H.V, Thurston, J.B., Brown, R.J., Lyatsky, V.B., 1992. Hydrocarbon-Exploration Application of Potential Field Horizontal-Gradient Vector Maps, CSEG Recorder, pp 10 – 14.

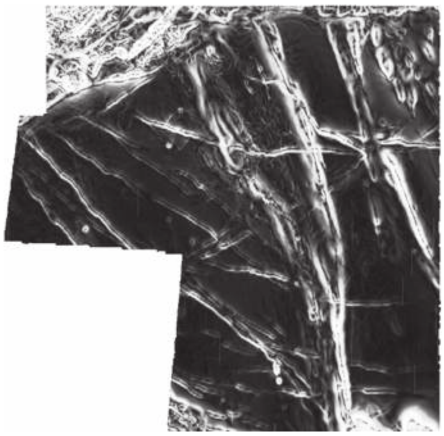

Figure 1. *Normalised TMI generated using the* Slope *function with a histogram equalised greyscale stretch for range 0 (dark) – 1 (light).*

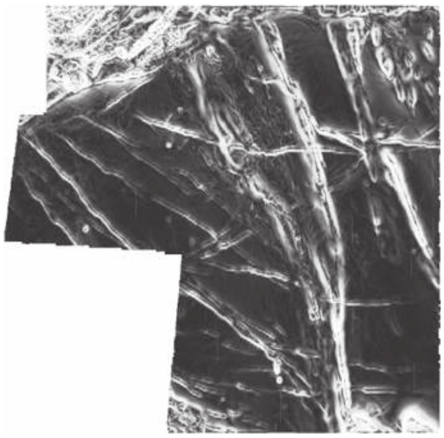

Figure 2. *Normalised Total Horizontal Gradient of TMI with histogram equalised greyscale stretch for range 0 (dark) – 1 (light).*

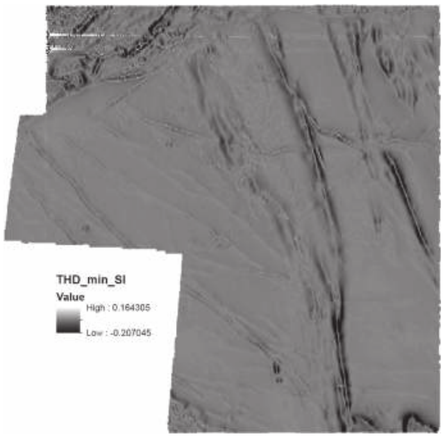

Figure 3. *Difference between normalised THD and* Slope *files with standard deviation greyscale stretch of range -0.16 (dark) to 0.2 (light).*

Webwaves

Ian James
ASEG Webmaster
webmaster@aseg.org.au

The slow death of Internet Explorer

In late June this year Microsoft unveiled their latest version of Windows: Windows 11. This newest version of the operating system will no longer have Internet Explorer (IE) installed. Internet Explorer 11, released in 2013 with Windows 8.1, is officially the last version. It has passed on! This browser is no more! It has ceased to be! It has expired and gone to meet its maker! It is a stiff! Bereft of life, it rests in peace! (modified from Monty Python http://montypython.50webs.com/scripts/Series_1/53.htm).

On 15 June 2022, IE will be officially retired (https://docs.microsoft.com/en-us/lifecycle/faq/internet-explorer-microsoft-edge#what-is-the-lifecycle-policy-for-internet-explorer). Microsoft Teams is already incompatible with IE and, from 17 August 2021, the remaining Office365 applications will cease to work with IE as well (https://techcommunity.microsoft.com/t5/microsoft-365-blog/microsoft-365-apps-say-farewell-to-internet-explorer-11-and/ba-p/1591666). For those who have websites that only work in IE, Microsoft Edge will continue to have an IE mode that will be supported until 2029.

For the vast majority of us, the passing of Internet Explorer will go unnoticed; for web developers, there will be a huge sigh of relief. IE has been on the decline for over a decade, with the release of Google Chrome in 2008 resulting in a precipitous reduction in usage (Figure 1). Microsoft's successor to IE is called Microsoft Edge, now a Chromium based browser using the same code base as Google Chrome. However, it has struggled to get adoption from users, with only 8.1% of worldwide market share in June 2021 (https://gs.statcounter.com/browser-market-share/desktop/worldwide/#monthly-202106-202106-bar).

The ASEG website continues to have users accessing content on Internet Explorer; however, the decline in use of IE is quite evident from our numbers (Figure 2). In June 2021, 0.7% of visits were from IE, this compares with 6.25% in June 2020 and 16.2% in June 2019. When visits from Microsoft Edge and Internet Explorer are combined, this decline is less evident, with 13.5% of users in June 2020 and 11% of users in June 2021. Despite the initial release of Microsoft Edge back in 2015, it wasn't until 2020 that more users accessed the ASEG website using Edge rather than IE. The majority of visits to the ASEG website come from Chrome, Safari and Firefox.

For users looking to move away from using Internet Explorer, there are various options available now:

- Microsoft Edge, the successor to Internet Explorer. Available here www.microsoft.com/edge
- Google Chrome, currently the most popular web browser, and based on the Chromium source code, which is free and open-source. Available here www.google.com/chrome/
- Firefox, the phoenix that rose from the Netscape ashes. Competing with Google by focussing more on privacy. Available here www.mozilla.org/en-US/firefox/new/
- Brave, a free and open-source browser that has a focus on privacy - automatically blocks adverts and trackers but gives users the option of allowing adverts in return for a share in the revenue through the BAT cryptocurrency. Available here https://brave.com/
- Safari, for users in the Apple ecosystem, the Safari browser comes pre-installed.

Updates on the ASEG website

This month, the donations page of the ASEG website (https://www.aseg.org.au/foundation/donate) was updated to allow users to optionally specify that donations should be directed to the *Richard Lane Scholarship*. We also implemented an option to choose to make anonymous donations, or to make donations on behalf of someone (e.g. in memory of). Donations to the ASEG Research Foundation can also be made via the webpage and promote research in applied geophysics by providing grants at the BSc (Honours), MSc and PhD level. A list of sponsored projects can be found here https://www.aseg.org.au/foundation/sponsored-projects.

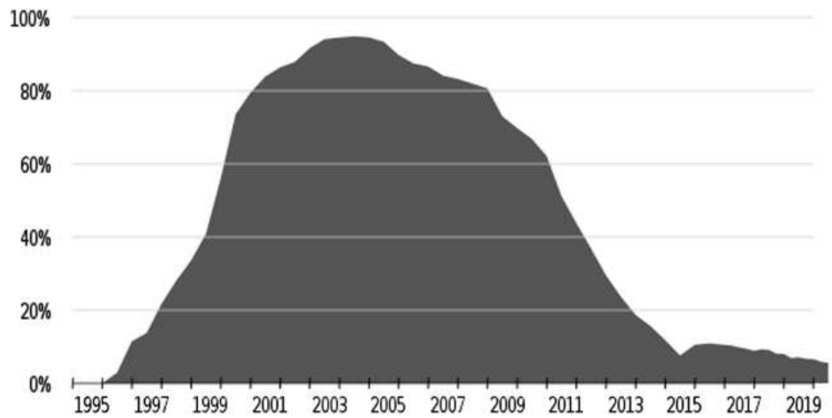

Figure 1. *Internet Explorer usage 1995-2019 (from https://en.wikipedia.org/wiki/File:Internet-explorer-usage-data.svg).*

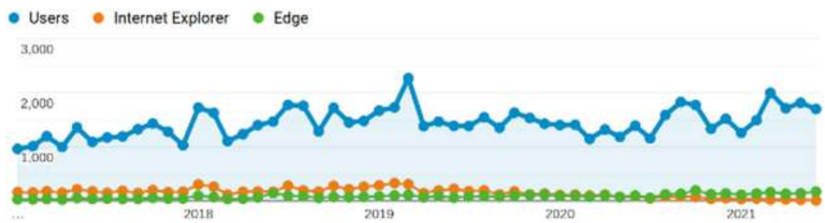

Figure 2. *ASEG website visits from Jan 2017 - June 2021. IE in orange and Edge in green.*

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CONFERENCE HANDBOOK

Welcome to the third Australasian Exploration Geoscience Conference

The Australian Society of Exploration Geophysicists, the Australian Institute of Geoscientists and the Petroleum Exploration Society of Australia, would like to welcome you to the third Australasian Exploration Geoscience Conference (AEGC 2021). The organising committee are excited to bring delegates together virtually at this tumultuous time, offering a high calibre technical programme that can be accessed from anywhere via a state-of-the-art digital platform.

This year the conference theme is 'Geoscience for a Sustainable World' with a focus on geology, geophysics, and geochemistry and how these are applied in exploration for both petroleum and mineral systems in Australasia and the wider Asia-Pacific region. The conference features concurrent streams covering a diverse range of topics such as geoscience of new economy minerals, regional province studies, machine learning, data visualisation and integration, footprint mitigation techniques and all aspects of exploration.

The technical programme features a mix of live keynote speakers, pre-recorded technical papers, live Q&A and panel sessions. Delegates can look forward to eight engaging keynote speakers, more than 120 oral papers and 25 virtual posters on display across the platform. Access to the platform will remain after the core days of the conference, giving delegates the chance to access as much of the content as they can.

In addition to the core technical programme, there will be a live panel session discussing diversity in geoscience. Students and early career geoscientists will also be participating in the GeoPitch – a fast paced presentation competition giving them the chance to present their research or project work and take questions from the audience. Members of AIG and PESA will be able to get an update from their executives with the chance to ask questions, whilst ASEG Members can look forward to their annual awards ceremony albeit in a slightly different format to usual.

The virtual exhibition will give delegates the chance to interact with our exhibitors within the platform, whilst other chat and meeting functionality will support networking with colleagues across the world. Eight virtual workshops are offered in the days preceding or during the conference. These workshops cover a variety of topics including machine learning, petrophysical formation evaluation and geoscience for CO_2 storage.

For those that had already registered for the in-person event, you should have received an invitation to change your registration to virtual and organise a refund. If you take no action, this will automatically occur. If you have yet to register, there is still time, please visit the website https://2021.aegc.com.au/registration/ and feel free to get in touch with any questions.

Whilst the organising committee have worked hard over the last two years to deliver an in-person event, the ongoing restrictions and uncertainty around interstate travel have driven the decision to move to a virtual event this year. This is not a decision that has been taken lightly, we know it impacts all and we are so grateful to the presenters and sponsors who have supported us on this journey. A big thank you also to our volunteer conference organising committee and to Arinex who have worked so hard to pull the event together, especially as we pivot to the fully virtual format. We are already looking forward to AEGC 2023, which will hopefully see us able to welcome you all to Brisbane.

A big thank you also to our generous sponsors who continue to support and join us on our journey to AEGC 2023, listed on the following pages.

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AEGC 2021: General information

How to access the online platform

- You may use the event platform on both desktop or tablet. We recommend using the latest version of Google Chrome to access the platform. Access information (link and pin) to sign into the platform will be sent to you via email one week prior to the Conference.

Technology assistance

- If you need technical support, simply click on the "Live Support" icon on the top right-hand side of the platform and explain in a few words the issue you are experiencing. The conference managers will endeavour to assist as soon as possible.

How to access programme sessions

- Once you are logged in, scroll down the programme schedule to view the sessions and click on "Join" to access them. If you would like to view the presentation description and speakers prior to going into the session, you may do so by clicking on the name of the session. This will bring up the information on the right hand side of the webpage. Please note, sessions will be made accessible at the designated session time.
- To go back to the programme schedule, do not click the "back" arrow in your browser, but instead, click the "Back to timeline" option at the top left-hand side of the platform

Features within a session

- Once you have selected a session to attend, you will have the option to view the "Session Information", view the presenter's short abstract and extended abstract under "Handouts", ask questions under the "Q&A" section, participate in the "Poll", talk to other delegates of the session in the "Discussion Forum" and take notes in "My Session Notes".
- The "Q&A" will be moderated by the chair of the session. This will mean that even if you write a question, the moderator will enable the question to appear under the 'top' and 'recent' section of the Q&A tab. All questions in these two tabs can be liked by selecting the thumb icon that appears. Once the Q&A is occurring, the Chair will tick off the question and they will appear in the 'answered' tab.
- The "Discussion Forum" is an area where delegates within the session can interact with each other if it's not question related.
- To export your notes, simply click on the "Export" icon on the top right-hand side of the platform and select "Export My Notes".

Utilising the Meeting Hub

- The "Meeting Hub" is a space in which you can connect with other attendees by messaging, live chat, live video call or organising a meeting during the event once connected. To connect with a delegate, click on their profile in the attendee list and then the "Connect" button next to their profile information.
- If you have connected with other attendees, you can export these details to your registered email address by selecting the "Export" icon on the top right-hand side of the platform and select "Export my Contacts". Note that all attendees set their own privacy options in their profile, thus some fields may be empty.

Virtual posters

- A "Poster Gallery" will be displayed so that you can view the accepted posters. This can be found on the right-hand side of the portal. Once you have selected to enter the gallery, you will be able to see all the posters in one section including the name of the poster, the authors name and organisation.
- To view the poster, hover over the snapshot of the poster and click on "View Presentation". You will be able to view the poster, download the poster and enter your notes about the poster that you can export at a later date.

Virtual exhibition

- Our sponsors and exhibitors are an integral part to the success of the conference. Please be sure to visit them in our virtual exhibition.
- Within the virtual exhibition, you will be able to view all sponsors and/or exhibitors names, logos and profiles. To view their "booth", please click on "View" at the bottom of their profile. Within their "booth" you will be able to not only view their electronic brochures and videos, but also request to meet with the exhibitor.
- When you are in the exhibitors "booth", if you would like to meet with an exhibitor, you will be able to "Request Live Meeting" or "Request Live Chat". You will then be advised that you are in a queue until the exhibitor is available to meet.
- Please note, that if you are in a live meeting, live chat with an exhibitor or are in a queue waiting for an exhibitor, this will finish at the exact time the virtual exhibition closes. Due to this, it is a good idea to monitor the time and connect with the exhibitors in the meeting hub.
    - Visiting during opening hours
      To visit the virtual exhibition during the opening hours, please click on the "Meet with Exhibitor" button. The opening hours to meet with exhibitors will be:

Wednesday 15 September 2021	10:00 - 15:00 (AEST)
Thursday 16 September 2021	10:00 - 15:00 (AEST)
Friday 17 September 2021	10:00 - 15:00 (AEST)

    - Visiting out of opening hours
      The exhibition will still be accessible out of the opening hours, however you will only be able to download the brochures and view the video gallery that the exhibitors have within their virtual booth. Outside of the opening hours, the button will be a grey "Visit" button.

3rd Australasian Exploration Geoscience Virtual Conference

15 - 17 September 2021

PROGRAMME OUTLINE

**Please note the programme is current as of 19 August and is subject to change. Programme times are based on Australian Eastern Standard time (AEST)*

	Wednesday 15 September 2021					
	Opening Plenary Session					
10:00	Welcome to Country					
10:00	Opening Welcome from Queensland Minister of Resources (10 Minutes) **Honourable Scott Stewart, MP**					
10:00	Welcome to AEGC 2021 - Official Opening					
	Keynote Presentations					
10:30	Address from Federal Minister for Resources and Water **Honourable Keith Pitt, MP - Sponsored by Geoscience Australia**					
10:35	Geoscience for a strong economy, resilient society and sustainable environment **Dr Andrew Heap - Sponsored by Geoscience Australia**					
11:15	The role of the geoscientist in our sustainable future **Dr Marita Bradshaw**					
12:00-12:45	Lunch Break (45 minutes)					
	Concurrent Sessions					
	Geophysics - Electrical and EM Method I	***Geoscience - Deep Crustal Studies***	***Geoscience - Hydrogeology and Groundwater I***	***Geoscience - Archean and Proterozoic Terranes/ Structural Geoscience***	***Data Visualisation and Integration***	***Geophysics - Coal Geophysics I***
12:45	261: Inversion of Airborne IP data with a multi-mesh approach for parameter definition **Gianluca Fiandaca**	256: Next-generation velocity model of the Australian crust from synchronous and asynchronous ambient noise imaging **Erdinc Saygin**	191: An integrated hydrogeophysical and hydrogeological approach, to underpin the long-term water security of a remote tropical island **Andrew Taylor**	20: Rock property and depth mapping from magnetic data applied to greenfields exploration targeting in the Cloncurry District **David Pratt**	116: Seismic network modelling and design in an interactive web-based environment **Pavel Golodoniuc**	82: Overburden measurement for coal mine management with 3D high resolution compressional and shear velocity seismic inversion **Martin Bayly**
1:00	206: Towards standard technical Deeds for (airborne) geophysical surveys in Australia **Yvette Poudjom Djomani**	230: Deciphering the building blocks of the eastern North Australia Craton **Karen Connors**	269: Complex recharge mechanisms creating contradictory tracer signals in a large karst aquifer in northern Australia elucidated by a multi-tracer study. **Axel Suckow**	164: Australian Proterozoic thermal aureole gold mineral systems: The critical role of high crustal geothermal gradients and the insights of Vic Wall **Lesley Wyborn**	78: Vertically integrated geoscientific data at the Geological Survey of New South Wales **Ned Stolz**	3: Mapping coal seam roof and floor by using in-seam borehole radar: Results from numerical modelling **Binzhong Zhou**
1:15	174: Ground Penetrating Radar investigation as part of a multidisciplinary archaeological project, The Plain of Jars, Lao PDR. **Jamie Speer**	215: The resistivity structure of the Gidyea Suture and its relationship to the Carpentaria Conductivity Anomaly **Janelle Simpson**	121: 3D Bedrock model utilising multi-channel analysis of surface waves to assist the land development industry in Greater Melbourne, VIC. **Tavis Lavell**	134: Overprinting of remanence in Paleozoic rocks of the Lachlan Orogen in southeast Australia. **Umer Habib**	23: Detailed geophysical mapping and 3D geological modelling to support urban planning: A case study of Ny Rosborg, Denmark **Theis Andersen**	211: Maximising the value of high-definition 3D coal seismic data **Matt Grant**
1:30	55: Radio image mapping at the Polymetallic Rosebery Mine in North-Western Tasmania **Asbjorn Christensen**	66: Interpretation of magnetotelluric and airborne electromagnetic inversions from the Proterozoic basins of the Capricorn Orogen, WA **Sasha Banaszczyk**	224: Predicting fluid pathways in large discontinuity systems using graph theory **Ulrich Kelka**	59: How do detachment properties influence the kinematics of normal growth faults? Insights from 3D seismic reflection data from the Ceduna sub-basin **Monica Jimenez**	91:Australian geomagnetic observatory network monitors space weather hazard – 180 years on **Matthew Gard**	246: Subsurface characterization using full waveform inversion of vertical seismic profile data: Example from the Curtin GeoLab well **Sana Zulic**

1:45-2:15	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A
2:15-2:45	Afternoon break (30 minutes)					
	Concurrent Sessions					
	Geophysics - Electrical and EM Method II	***Geophysics - Seismic Processing and Interpretation I***	***Geoscience - Hydrogeology and Groundwater II***	***Geoscience - New Economy Minerals***	***Machine Learning I***	***Geophysics - Coal Geophysics II***
2:45	220: Gaining value from historical AEM data Shane Mulè	35: Case study from NW Carnarvon using WEB-AVO inversion to map low saturation gas and unravel geology using "noisy" seismic. John Coffin	22: Groundwater and gas sampling informing hydrogeological conceptualisation of the Precipice and Hutton Sandstone aquifers of the southern Surat Basin Julie Pearce	129: Hydrogen versus sales gas Max Williamson	183: Seismic inversion by hybrid machine learning Yuqing Chen	107: A brief history of 3D seismic acquisition in BHP Coal and some predictions for the future Tim Dean
3:00	279: Using modern downhole EM to discover high-grade, narrow vein lodes in an historical gold field, Bellevue Gold Project, Western Australia Anne Tomlinson	38: Intergrated modelling of seismic velocities and impact on prospect valuation Jarrod Dunne	178: Modelling the impact of fault damage zones on fluid flow localisation Thomas Poulet	195: Halloysite nanotubes: The New Economy Mineral to ensure every organisation achieves Net Zero carbon emissions Antonio Belperio	85: Digitalising the mining industry - core scanner for geochemistry, images, RQD, structures, specific gravity and volume bulk density Augus Tod	135: Optimising 3D coal seismic imaging with pre-stack depth migration Alan Meulenbroek
3:15	79: Results from the largest Airborne Electromagnetic (AEM) survey ever flown in NSW Astrid Carlton	177: Simultaneous inversion of teleseismic P- and converted S-waves to constrain the seismic structure of the crust Mehdi Tork Qashqai	281: Constraining regional-scale groundwater transport predictions using multiple geophysical techniques Michael Hatch	234: An inventory of peralkaline rocks in Queensland for evaluation of REE enrichment potential David Purdy	14: Almost automatic geological mapping from AEM surveys David Annetts	130: Optimising slip-sweep Vibroseis in high-production coal surveys Shaun Strong
3:30	7: Case studies from Loupe – new technology in portable TEM for near-surface measurements Gregory Street	227: Analysis of teleseismic earthquakes on nodal seismic surveys. Steve Hearn	197: Probabilistic modelling of groundwater salinity using borehole and AEM data Neil Symington	149: Noble gases: a versatile exploration tool for water, minerals and hydrocarbons Axel Suckow	108: Automated fracture detection and characterisation from unwrapped drill-core images using Mask R-CNN Fatimah Al-Zubaidi	128: High density seismic finally accessible to all industries Amine Ourabah
3:45-4:15	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A
4:15-5:00	Keynote Presentation					
	The role of mine waste in the fight against climate change Dr Anita Parbhakar-Fox					

3rd Australasian Exploration Geoscience Virtual Conference

15 - 17 September 2021

PROGRAMME OUTLINE

**Please note the programme is current as of 19 August and is subject to change. Programme times are based on Australian Eastern Standard time (AEST)*

	Thursday 16 September 2021					
	Keynote Presentations					
10:00	20 years of seismic acquisition - a semi-autobiographical review, and predictions for the future **Dr Tim Dean**					
10:45	Mineral systems and data integration as part of the foundation for the future of mineral exploration **Dr Sandra Occhipinti**					
11:30 -12:30	Lunch Break (1 hour)			ASEG Meeting	PESA Meeting	AIG Meeting
	Concurrent Sessions					
	Geophysics - MT	***Geoscience - Undercover Exploration I/Geophysics - 3D Seismic for Mineral Exploration***	***Geophysics - Seismic Acquisition***	***Geoscience - Petroleum Exploration I***	***Geoscience - IOGC Deposits***	
12:30	132: Multi-scale magnetotelluric surveys – mapping from the lithosphere to the near surface for mineral systems **Wenping Jiang**	258: Lithospheric-scale magnetotellurics over the Eastern Goldfields Superterrane, Yilgarn Craton **Kate Selway**	65: Optimizing land seismic acquisition for modern noise suppression in processing **Graeme Eastwood**	229: Diagenetic controls on the reservoir quality of organic-rich shales of the Mesoproterozoic Velkerri Formation (Beetaloo Basin) **Claudio Delle Piane**	109: Geophysical proxies for redox gradients in IOCG systems: Cloncurry District, Qld, Australia. **James Austin**	**Hinman-Wall Symposium**
12:45	216: Continental shelf marine MT feasibility study in the Spencer Gulf, South Australia **Kate Robertson**	123: The role of geophysics in the discovery of the Gonneville PGE-Ni-Cu-Co-Au Deposit, Julimar, Western Australia. **Jacob Paggi**	112: The evaluation of alternatives to pre-acquisition positioning for land seismic surveys **Matt Grant**	81: Towards a 3D model of the South-Nicholson Basin region, Northern Australia, for mineral, energy and groundwater assessment **Nadege Rollet**	214: Magnetic characterisation of the Osborne IOCG deposit: Magnetic fabrics, self-demagnetisation and remanence: Cloncurry District, QLD **Andreas Bjork**	
1:00	168: Nonlinear, 2D uncertainty estimation in magnetotelluric inversion using trans-dimensional Gaussian processes **Anandaroop Ray**	182: Robust 3D models of geochemical and petrophysical properties from combining borehole and seismic reflection data: A case study from the Tropicana Gold Mine **Anton Kepic**	37: Onshore seismic acquisition: out with the old, in with the new **Denis Sweeney**	179: Permeability modelling using digital rock images from micron scale **Lionel Esteban**	88: New mineral system vectors for revitalised copper-gold discovery in the Gawler Craton **John Anderson**	
1:15	136: Using the NCI Gadi Supercomputer to revolutionise processing of MT time series data: Results from the GeoDeVL experiment **Lesley Wyborn**	150: Yaouré Seismic Survey: Defining a complex 3D structural framework with high resolution seismic data **Greg Turner**	72: 3D Modelling and synthesis of geophysical data in Nash Creek, New Brunswick, Canada. **Alexander Furlan**	114: Impacts of minimum horizontal stress uncertainty on wellbore stability **Matthew Musolino**	34: Exploring for gold using radiometrics, magnetics and petrophysical information in the Warrawoona greenstones of the east Pilbara, Western Australia. **Yvonne Wallace**	
1:30-:2:00	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	

2:00-2:30	Afternoon break (30 minutes)					
	Concurrent Sessions					
	Geophysics - Mining Geophysics	***Geoscience - Mineral Exploration I***	***Geophysics - Inversion I***	***Geoscience - Petroleum Exploration II***	***Geophysics - Borehole geophysics and petrophysics***	
2:30	95: Transformative geophysics: Alternatives to the reduction-to-pole transformation of magnetic data **Richard Smith**	207: The Delamerian Orogen-An overview of the resistivity structure across scales **Kate Robertson**	148: Attenuation of ice-sheet reverberations in teleseismic P-wave receiver functions **Dale Harpley**	264: Recognition of igneous rocks encountered in wells in the Carnarvon Basin: implications for drilling and petroleum systems. **Michael Curtis**	126: Integration of high-resolution HyLogger spectral scanner and TESCAN Integrated Mineral Analyser for mineralogical characterisation of shale **Muhammad Iqbal**	**The GeoPitch** A fast-paced 3-minute presentation competition by students and early-career geoscientists. All conference delegates are welcome to attend
2:45	111: Environmental site assessment at a mining operation in Western Australia using the Loupe TEM profiling system **Remke Van Dam**	118: Structural controls on late Cambrian mineralisation in the Stavely Arc **Robert Holm**	247: Magnetic inversion constrained by probabilistic magnetotellurics models: methodology and application **Jeremie Giraud**	29: New age dating of evaporites in Canning Basin, WA, Australia: A case study based on samples from the Frome Rocks Salt Diapir **Fionna McNee**	238: Estimate elastic moduli of arenites from micro-tomographic images with digital rock physics **Jiabin Liang**	
3:00	231: The Do-It-Yourself Geophysicist **Anton Kepic**	113: AIP Effects in the airborne EM fixed wing systems: A Spectrem Theoretical Study **Andrea Viezzoli**	153: Why we should not report unconstrained inversion output in densities or magnetic susceptibilities **Clive Foss**	86: Quantifying uplift using compaction methods; A case study from the Exmouth Plateau, Northern Carnarvon Basin **Patrick Makuluni**	236: Practical aspects of wavefield decomposition for permanent seismic rotatory sources **Roman Isaenkov**	
3:15	40: Examples of integrating hyperspectral, geochemical and petrophysical drill core data using Australia's National Virtual Core Library infrastructure **Carsten Laukamp**	184: AusArray: Uncovering major crustal features using passive seismic data **Alexei Gorbatov**	163: Application of facies based seismic inversion in developing shallow gas fields in Cooper-Eromanga Basin **Satyabrata Mishra**	158: Stratigraphic drilling in the era of EFTF: The Barnicarndy 1 and NDI Carrara 1 wells **Adam Bailey**	188: Designing a magnetic resonance Logging-While-Drilling tool for Reverse Circulation minerals exploration **Keelan O'Neill**	
3:30-4:00	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	
4:00-4:45	Keynote Presentation					
	The role of geophysics in supporting sustainability **Ms Andrea Rutley**					

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	Friday 17 September 2021`					
	Keynote Presentation					
10:00	The future of geoscience education **Dr Richard Lilly**					
10:45	Diversity in Geoscience Panel Discussion Sponsored by Geoscience Australia					
12:15-12:45	Lunch Break (30 minutes)					
	Concurrent Sessions					
	Geophysics - Potential Fields I	***Geoscience - Stratigraphy and Sedimentology***	***Machine Learning II***	***Geoscience - Petroleum Exploration III***	***Geophysics - Passive seismic and microseismic I***	***Geoscience - Regional Province Studies/Geoscience - Hydrology and Groundwater III***
12:45	41: UAV magnetic survey planning, QAQC and data processing **Brett Adams**	87: Automated facies classification in borehole log data. **Roman Beloborodov**	10: Inferring geological features masked by artefacts in core photography using neural networks **Yasin Dagasan**	167: Northern Lawn Hill Platform – modelling the 'great-grandparent' emerging region **Tehani Palu**	44: Earthquake monitoring in the Southwest Seismic Zone, Western Australia **Ruth Murdie**	24: Application of LiDAR for hydrocarbon exploration in logistically and geologically challenging environments: examples from the Papuan Fold and Thrust Belt, Papua New Guinea **Luke Mahoney**
1:00	117: A beautiful sunset (clause): enhancing statewide geophysics with high resolution company data **Sam Matthews**	100: A regional marker tool for the Walloon Coal Measures (Surat Basin) using detrital zircon U-Pb geochronology **Pascal Asmussen**	125: Recognising the impact of uncertainty in resource models **Steven Sullivan**	221: The transformation of Australia's first commercial CSG field into a major gas project: How innovation and subsurface understanding have driven success **Mike Martin, Justin Gorton**	103: An automated system for preventing hydraulic vibrator tip-over during land seismic surveys **Richard Barnwell**	187: Calibrating BMR T2 Distribution logs to well test data **Keelan O'Neill**
1:15	146: CRC-P57322 high-resolution real-time airborne gravimetry **Andrew Gabell**	270: Post-rift magmatism on the continental shelf of the Otway Basin and implications for the igneous plumbing style in sedimentary basins **Yakufu Niyazi**	102: Knowledge-guided machine learning for komatiite-hosted nickel prospectivity mapping **Minsu Kwon**	32: Petroleum systems model for source- rock-reservoir evaluation in the Beetaloo Sub-basin **Moinudeen Faiz**	255: Laboratory study of temperature variation effects on Distributed Acoustic Sensing measurements. **Evgenii Sidenko**	239: Targeting fractured rock aquifers using magnetic data **Karen Gilgallon**
1:30	243: Enhancing interpretation of geophysical models using petrophysical logging **Cericia Martinez**	31: Controls on organic matter accumulation in the Mesoproterozoic: Insights from the stratigraphic modelling of the Velkerri Formation of the Beetaloo Basin (Northern Territory, Australia) **Vincent Crombez**	272: Using comment field entries in drill hole database to automatically re-log lithologies: Application of latent semantic analysis and supervised learning **Jean-Phillipe Paiement**	63: Data geo-science approach for modelling unconventional petroleum ecosystems and their visual analytics **Shastri Nimmagadda**	244: Curtin in-situ GeoLab – advancing geophysical sensing **Konstantin Tertyshnikov**	245: Comparative hydrogeological characterisation of the Springbok and Precipice Sandstones **Oliver Gaede**
1:45-2:15	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A

Time					
2:15-2:45	Afternoon break (30 minutes)				
	Concurrent Sessions				
	Geophysics - Potential Fields II/ Geochemistry Exploration	***Geoscience - Mineral Exploration II***	***Geophysics - Inversion II***	***Geoscience - Petroleum Exploration IV***	***Geophysics - Passive seismic and Microseismic II/ Seismic Processing***
2:45	226: A new era for the Australian National Gravity Grids - adding airborne data to the mix **Yvette Poudjom Djomani**	144: The Winu Cu-Au-Ag deposit in the Great Sandy Desert of Western Australia **Hilke Dalstra**	260: Inversion-based automatic processing of AEM data **Gianluca Fiandaca**	27: Hidden in plain sight: The Bamaga Basin **Wolfgang Fischer**	99: The role of passive seismic imaging in near-mine exploration **Gerrit Olivier**
3:00	80: The North Australian Craton 3D gravity and magnetic inversion models: A trial for first pass modelling of the entire continent **James Goodwin**	228: Lithospheric resistivity structures and mineral prospectivity from AusLAMP data in northern Australia **Jingming Daun**	89: Constraining gravity inversion with lower-dimensional seismic information: Imaging the eastern Yilgarn Craton **Mahtab Rashidifard**	133: Compositional control on frictional properties of Goldwyer shale reservoir rocks **Partha Pratim Mandal**	193: Full waveform refraction imaging of the regolith **Derecke Palmer**
3:15	251: Evaluation of ore deposit models using geophysical, geological and geochemical inputs and the implications for exploration activities **Robert Hearst**	205: Geology of the shear zone hosted Dugald River Zn-Pb-Ag deposit, Mt Isa Inlier, NW QLD **Corey Jago**	203: 3-D gravity geometry inversion of the Matheson Area, Abitibi greenstone belt: Maintaining the contacts of one of the geological unit fixed for obtaining superior results **Fabiano Della Justina**	151: Petroleum source rocks, generation and primary migration: Revolutionary insights using new nano-scale non-destructive Tof-Sims SEM analysis. **Gregory Smith**	190: A new method for determining drill-bit signal emission time **Zixing Qin**
3:30	266: Geochemical signatures and critical metal contents of key deposit types in the Mount Isa Province, Queensland, Australia **Vladimir Lisitsin**	254: Closing the gap between ground and airborne IP data modelling **Andrea Viezzoli**	235: How deep does ground EM see? **Andrew Fitzpatrick**	120: Exploring links between thermal maturity and electrical properties of organic-rich shales **Claudio Delle Piane**	141: Seismic velocity analysis in the presence of AVO polarity reversals by fuzzy c-mean clustering **Duy Thong Kieu**
3:45-4:15	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A	30 minutes Q&A
4:15-5:00	Keynote Presentation				
	Geology for the future: geology = (numbers/algorithms) ± knowledge **Dr June Hill**				
5:00-5:15	Closing Session & Presentation of Awards				

AEGC 2021: Keynote speakers

Andrea Rutley, Head of Geoscience, Anglo American's Metallurgical Coal Business Unit

Andrea Rutley is Head of Geoscience for Anglo American's Metallurgical Coal Business Unit based in Brisbane. She is responsible for leading the integration and interpretation of geoscience data across exploration, geological modelling, operational geology and specialist technical disciplines of structural geology and geophysics with the focus on improving the future performance of Met Coal's operations. Whilst the majority of Andrea's career has been in geoscience and geophysics, she took on the role of Head of Safety and Sustainable Development (S&SD), for three years from 2017 - 20 where she was responsible for coordinating the delivery of Met Coal's S&SD strategy.

Andrea has a BSc (Hons) degree with a major in geology and Post Graduate Diploma in Secondary Education and has also been President of the Australian Society of Exploration Geophysicists.

Dr June Hill, Principal Research Scientist, CSIRO Mineral Resources

In her early career, June pursued field-based geological research throughout Australia, Papua New Guinea and New Zealand. Her PhD documented the extraordinary history of the rapid exhumation of deep crustal metamorphic core complexes in a remote part of Papua New Guinea.

With the onset of the digital revolution in the geosciences, June changed her focus to bridging the gap between geology and mathematics, utilising the power of modern computing. Her research has resulted in the development of algorithms and software that allow non-mathematical geologists to apply advanced mathematical and machine learning approaches to large and complex data sets. The aim of her work is to facilitate fast, consistent logging of drill holes using data generated by laboratories and portable analytical machines.

June currently leads a CSIRO research team in the MinEx CRC, which is developing new algorithms for assisting objective logging of structural information in drill core. In her talks and training courses, June is able to successfully communicate complex mathematical and machine learning concepts in terms of geological solutions for a geological audience.

Dr Marita Bradshaw, Leading Petroleum Geologist, National Geoscience Champion

Marita Bradshaw is a petroleum geologist with over 30 years of experience in government and industry. With Geoscience Australia she had a series of technical, managerial, and executive roles with a focus on revealing and promoting the petroleum prospectivity of Australia. This included leading a programme of new data acquisition in offshore frontier basins, responsibility for the geotechnical content of the annual offshore petroleum acreage releases and establishing the continent-wide framework of Australian petroleum systems.

Within industry Marita has worked in exploration for several multi-national and Australian companies, including ESSO Australia and WMC. She has been recognised by the Australian Geoscience Council as a National Geoscience Champion and is a member of the National Rock Garden Steering Committee.

Dr Richard Lilly, Program Leader and Co-Founder, National Exploration Undercover School

Richard Lilly is the Program Leader for the National Exploration Undercover School (NExUS), which he co-founded in 2016 at the University of Adelaide. Additionally, through his role as a Minerals Industry Embedded Research Fellow, he lectures economic geology at undergraduate level and coordinates a range of applied economic geology research projects for companies including Mount Isa Mines, OZ Minerals, SIMEC and Hillgrove Resources.

Richard completed his PhD on the northern Oman ophiolite at Cardiff University (UK) in collaboration with the British Geological Survey and worked with Rio Tinto and Chevron before joining Mount Isa Mines (formally Xstrata Copper) exploration in 2007 based in Mount Isa, Queensland. In his role as senior exploration geologist he instigated and co-supervised a wide range of applied research projects with the aim of improving exploration targeting, before returning to an industry funded academic role in 2015. Richard is involved with national initiatives relating to both mineral exploration and geoscience/STEM education.

Richard is passionate about rocks, advancing our understanding of ore systems, geochemical exploration through cover and teaching/mentoring the next generation of geoscientists.

Dr Sandra Occhipinti, Research Director, Discovery CSIRO Mineral Resources

Sandra Occhipinti is the Research Director of Discovery CSIRO Mineral Resources. Sandra is a structural geologist with over 30 years of experience. Discovery is focussed on solving challenges faced in the mineral industry through innovative science and technology, through collaborative research and development through the integration of a multidisciplinary and diverse team. Sandra has worked across the government, industry and academia sectors – most notably for the Geological Survey of Western Australia, The University of Western Australia and AngloGold Ashanti. Her recent work in mineral systems science uses key concepts and understanding of the development of mineral deposits through geologic history, dependent on factors such as the operating tectonics, local conditions (including climatic zones), controls on fluid flow, to name a few. Discovery partners with Data 61 and groups such as the Deep Earth Imaging Future Science Platform to find the best solutions to problems we face today, and provide solutions that we can use in the future in exploration for minerals and water, and for more efficient and sustainable, and environmentally responsible mining.

Dr Tim Dean, Specialist Geophysicist, BHP Coal

Tim is a Specialist Geophysicist for BHP Coal, which he joined in 2019. Prior to joining BHP he was a Research Fellow within the Department of Exploration Geophysics at Curtin University. This followed an extensive career at Schlumberger/WesternGeco/Western Geophysical in a variety of roles including marine and land field operations, software development, and research located in Saudi Arabia, England, Norway and Australia. Following his final position within Schlumberger as Principal Research Geophysicist at the Schlumberger Fibre-Optic Technology Centre, Tim joined HawkEye Technology (a division of Sony) as a Project Advisor for the introduction of goal-line technology into the UEFA Champions League. He also conducted research into the use of sensors within sports as diverse as Cricket, AFL, and Volleyball.

Tim has an Honours degree in geophysics from Curtin University and a PhD in physics from the University of New South Wales. His research interests include land acquisition, particularly vibroseis sources, land data processing, and distributed fibre-optic sensing.

Dr Anita Parbhakar-Fox, Senior Research Fellow, W.H. Bryan Mining and Geology Research Centre

Anita is a Senior Research Fellow in geometallurgy and applied geochemistry at the W.H. Bryan Mining and Geology Research Centre within the Sustainable Minerals Institute. Anita's research is focussed on mine waste characterisation to improve mine planning and waste management practices where she has worked with mining industry, METS sector and government stakeholders. She has developed new tests and protocols for improving waste characterisation and is also involved in identifying remediation options for abandoned/ historical mine sites. Most recently, Anita has led industry and government funded projects characterising a range of mine waste materials to evaluate their economic potential.

Dr Andrew Heap, Chief of the Minerals, Energy and Groundwater Division at Geoscience Australia

Andrew graduated 1st class Hons in earth sciences from the University of Auckland (New Zealand) in 1996, after which he completed his PhD at James Cook University in 2000.

Andrew has more than 20 years of professional experience in leading pre-competitive geoscience research within the Australian Government, with responsibility for energy and mineral resources, carbon capture and storage, marine geoscience and groundwater programs. Andrew has published over 100 scientific and technical papers and is a member of 12 professional organisations.

Andrew has responsibility for building a national prospectus of energy and mineral groundwater resources across Australia through regional geological framework studies, and delivery of pre-competitive scientific data and information. A key outcome is to stimulate new exploration investment in frontier areas through an improved understanding of under-explored regions and sustainable water management.

As a member of the Australian Government's Ocean Policy Science Advisory Group Andrew had a lead role in drafting *A Marine Nation 2009* and *Marine Nation 2025* as blueprints for coordinating investment in marine science in Australia. Andrew represents Australia in the International Ocean Discovery Program (IODP) as Council Member of the Australia–New Zealand IODP consortium, is a member of the CO2CRC board and Program Advisory Committee, and is the Federal Government's representative on the Geoscience Working Group of the Energy National Cabinet Reform Committee.

AEGC 2021: Keynote speaker abstracts

The role of geophysics in supporting sustainability

Andrea Rutley
Anglo American Metallurgical Coal
andrea.rutley@angloamerican.com

Geophysics has had an enduring influence on society and has demonstrated its ability to grow and adapt to a variety of challenges. As a science, the term "geophysics" was first used in Germany in the mid 1800s. Since then, geophysics has been a key contributor to society being applied in world wars, enduring commodity cycles and changing community expectations and has seen a rapid acceleration of technology. Geophysics has been part of the sciences that attempt to unravel how we humans interact with the planet from water to energy, mineral resources, and natural hazard management.

The current focus on sustainability is significantly impacting the global mining industry. It is no longer an addendum to how we operate, but it is the expectation that all global resource companies should be leading in sustainability. As geophysicists, we are ideally placed to guide and support sustainable resource exploration and environmental management.

In January 2016 the seventeen Sustainable Development Goals (SDG) of the United Nations' (UN) 2030 Agenda for Sustainable Development, adopted by world leaders in September 2015, officially came into force. It is the intent of the UN, that the SDGs provide a "shared blueprint for peace and prosperity for people and the planet, now and into the future".

There is recognition that the resource industry needs to address the critical challenges of safety, productivity and the way in which mining uses the land, energy, and water. With continued global population growth, the demand for energy, metals and minerals that make up the core components of products and services essential for human progress, also grows.

In 2018, Anglo American launched its global Sustainable Mining Plan, focused on environmental, social and governance (ESG) challenges, to ultimately ensure we leave a much- reduced physical footprint. Aligned with the UN's SDGs, the plan's three pillars of Healthy Environment, Thriving Communities and Trusted Corporate Leader map to ESG factors. The Plan is designed to foster innovation and deliver step change results across the entire mining value chain, from mineral discovery through to marketing.

In an article in *The Leading Edge*, in January 2021, Maria Capello, Anna Shaughnessy and Emer Caslin presented the Geophysical Sustainability Atlas, which maps geophysics to the UN SDGs. This mapping shows that geophysics has a key role to play in adopting and furthering the outcomes of SDGs. Anglo American is leading in utilising the science and technology to achieve these by applying geophysics to understand mine footprints, water supplies and hazard delineation.

Geology for the future: Geology = (numbers / algorithms) ± knowledge

June Hill
CSIRO
June.Hill@csiro.au

The 3D geology model is an essential product of geological analysis because it provides a complete spatial prediction of subsurface geology from spatially sparse data. The amount of digital data available to the geologist now well exceeds the geologist's capacity to use traditional manual interpretation methods. Manual interpretation is too slow for large data sets and the results are often insufficiently consistent to be useable in 3D modelling software. As a result, geologists are now turning to mathematical, statistical and machine learning techniques to help interpret large or complex geological data sets. Automated analysis allows the geologist to produce rapid, consistent results. Geologists can experiment with different interpretations by using their geological knowledge to select appropriate data or modify parameters.

Unfortunately, most geologists lack adequate training in mathematics and computer science to be able to assess the various techniques available. Having a good understanding of the strengths and weaknesses of various techniques can provide the geologist with the confidence to make appropriate choices. I have spent many years experimenting with various approaches to automating the interpretation of drill hole data and would like to share with you the insights I have gained along the way. I will provide you with a geologist's perspective of various techniques and the types of data you require to make these techniques work.

The role of the geoscientist in our sustainable future

Marita Bradshaw
Geoscience Australia
maritabradshawgeologist@gmail.com

The United Nations (UN) Brundtland Commission (1987) defined sustainability as meeting the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability has become the stated aim of many industries and has been elaborated into the 17 UN Sustainable Development Goals (SDGs) with their 169 targets. However, many indicators of environmental health have deteriorated over the life of the generation that has come of age in the intervening decades. Examination of the SDGs highlights the crucial role of the geoscientist in achieving these goals, especially the targets focused on water resources, energy services, economic growth and climate change. For example, expansion of new energy and transport systems will rely on exploration geologists and geophysicists finding new deposits of metals including copper, nickel and lithium. Geoscientists are also needed to build a deep knowledge of the subsurface to enable the management of groundwater and gas resources, and to provide the option of long-term carbon storage. But geoscience is said to be "woefully underrepresented" in global sustainability discussions despite its vital role in understanding the operation of earth systems over both short and long timescales. This perspective is doubly important now that humanity is a significant geological agent in shaping the Anthropocene, and geoengineering interventions are being mooted. Geoscientists work every day in the field, the laboratory, and the office to create a sustainable future, but we also need to communicate our insights more effectively to decision makers and the public. The complex challenges confronting us also demand stronger interdisciplinary links within the geosciences, and with engineering, ecological and social sciences.

The future of geoscience education

Richard Lilly
University of Adelaide - NExUS
richard.lilly@adelaide.edu.au

Australia produces world-class geoscientists, but there is a growing skills gap between what students are taught at university and what industry requires. How do we ensure student engagement and sustainable employment? The minerals industry is changing fast and is facing a prolonged period of increased demand of all commodities, with exploration success and industry best practice paramount in meeting the need for raw materials to build our sustainable energy future. Geoscientists have never been so crucial to society.

However, enrolments are falling nationally in all STEM subjects and universities are burdened with a broken business model resulting in severe financial pressures. The results are stark, with esteemed geoscience departments closing in Australia, increased vulnerability for those that remain and unrelenting pressure on an ever-reducing number of teaching staff. The student experience is also changing, with remote and on-demand learning coming to the forefront, challenging the traditional learning experience, often resulting in graduates with less practical experience.

Where are the geoscientists of the future going to come from? What skills will they need? How can we best prepare them for employment? How can companies recruit and retain the best talent? Collaboration between academia and industry has never been more important to forming integrated learning pathways through school, university and supporting life-long learning, but any solution requires sustained support, coordination and leadership.

Mineral systems and data integration as part of the foundation for the future of mineral exploration

Sandra Occhipinti
CSIRO
sandra.occhipinti@csiro.au

As exploration focuses on defining new resources under large Phanerozoic basins and thick unconsolidated cover, generic exploration models, following a mineral systems approach, will be vital to future exploration programmes. Specific ore deposit models may not be that helpful in the early stages of exploration in these regions, as distinct geological signatures usually sought, like those in soil geochemistry, will be challenging to attain.

Sampling material at particular regolith interfaces or unconformities will be necessary to map geochemical dispersion. Understanding landscape evolution and palaeoenvironments will be beneficial when determining the length scales of dispersion and their direction. Geophysical signatures mostly mapped and understood in 2D planar surfaces will have to be inverted in 3D, with an understanding of uncertainty to estimate aspects such as the extent of cover, regolith, sedimentary or volcanic interfaces, the 3D architecture of prospective basins as well as linking known geological 'piercing points' observed in a 1D drill hole (and data collected from it) into a vast 3D volume.

A mineral systems approach to exploration uses known critical elements that contribute to ore deposit formation through mapping their geological proxies. Geophysical data is abounding in Australia and can link what is understood from drill core together with mapped geology. However, its resolution or pixel size is not comparable to the detail of petrophysics measured in a drill log. This inhibits data-driven mineral systems analysis and the development of machine learning techniques for the analysis in covered regions.

20 years of seismic acquisition – a semi-autobiographical review, and predictions for the future

Tim Dean
BHP
tim.dean@bhp.com

The fortunes of the seismic acquisition industry during the last 20 years have followed the oil price, which itself has varied by a factor of more than 7 during this period, but 'on steroids' as exploration tends to be one of the first budget lines to suffer once oil prices fall.

At the turn of the century the marine seismic acquisition industry was relatively stable, with a number of large international contractors. The steady increase in the oil price in the mid-2000s drove demand, and the major contractors began to look to expand capacity, acquiring a number of smaller, often newly established, contractors. 2010 was the start of a relatively stable period in the oil price that continued up to 2014, with little major change in the industry. The next major fall in the oil price in 2015, which continues to the present, precipitated a period of major consolidation, leaving Shearwater and PGS as the only major international marine seismic acquisition contractors. The trajectory for land acquisition has been similar, but steeper, there are no longer any major international acquisition contractors, the industry instead being dominated by local companies.

In technology terms, both areas have seen drives to increase quality and/or productivity. For marine streamer surveys this has involved the use of streamers with higher sensor density, and increasingly multiple sensor types, coupled with larger spreads and multiple source arrays. Coincident with this has been the increased popularity of ocean bottom nodes and lately, dual nodal/streamer surveys. On land we have seen steadily increasing channel counts allowing larger, denser, spreads with productivity boosted through the use of a variety of high productivity vibroseis techniques.

In this paper we discuss the last 20 years of seismic acquisition, both from an industry and personal perspective, before making some predictions about what the future holds.

The role of mine waste in the fight against climate change

Anita Parbhakar-Fox
1W.H.Bryan Geology and Mining Centre, Sustainable Minerals Institute, The University of Queensland
a.parbhakarfox@uq.edu.au

The global response to climate change, initiated by the Paris Agreement, has been to encourage countries to transition to low-carbon economies. New technologies such as electric vehicles, low-emission power sources and products for the medical and defence sectors are required to support this. The manufacture of these products requires resources of 'new economy metals' including cobalt, tungsten, rare earth elements, indium, gallium and germanium. Traditionally, these metals were considered unwanted by-products of base metal and precious metal mining operations, and consequently are concentrated in mine waste.

Mine waste reprocessing is business proposition that is increasingly being adopted in many countries, including several in Australia e.g., the Hellyer, Century, Mt Carbine, Mt Morgan and Tick Hill Mines. However, these materials are mineralogically heterogeneous thus, a 'one approach-fits all' will not optimise value-recovery or indeed, guarantee that the waste is environmentally de-risked. Fundamentally materials must be thoroughly characterised adopting similar practices as undertaken in geometallurgical studies.

This research, funded by the Queensland Government, focusses on secondary prospectivity in the state, where at least 40 significant metalliferous mining operations produce mine waste streams containing unknown quantities of new economy metals. Additionally, there are 120 state-managed abandoned mines. Many of these sites contain reactive sulphide-rich mine waste with associated acid and metalliferous drainage risks. Ongoing management of these sites is costly, but their potential new economy metal content – as yet uncharacterised – presents a unique opportunity to rehabilitate these sites through reprocessing waste. The new economy metal fertility of 16 sites was examined. Hosting of Co in sulphides and Mn- and Fe-oxides was observed in tailings, waste rock and spent heap leach materials collected in NW Queensland with REEs hosted by allanite, stillwellite and Fe-oxides. Mine waste collected in NE Queensland confirmed chalcopyrite and sphalerite as hosts. Metallurgical extraction methods are now being tested.

AEGC 2021: Virtual posters

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49	Gravimetric measurements of high pressure and temperature C1, C2 and C3 adsorption isotherms on Beetaloo Sub-basin shales.	Dr Mohinudeen Faiz
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253	Microbial methane production in the Surat Basin, Queensland	Ms Bronwyn Campbell
259	The uplift history of the Kidson Sub-Basin	Mr George Marfo
265	Geochemical landscape evolution and pattern similarity analysis at tenement scale for gold exploration in Forrestania, Yilgarn craton	Dr Ignacio Gonzalez-Alvarez
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AEGC 2021: Virtual workshops

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Applied machine learning for geoscientists. Organiser: Solve Geosolutions. (Full day workshop) *Sponsored by Datarock* DATAROCK	Unlocking the value of structural geology in mining, exploration and 3D modelling. Organisers: SRK Consulting and Seequent. (Full day workshop) Geoscience for CO_2 geological storage. Organiser: Curtin University. (Full day workshop) VOXI: Integrating geological and geophysical data with constrained 3D inversion. Organiser: Seequent. (Full day workshop) Petrophysics: Formation evaluation introduction. Organiser: Halliburton Australia. (Half day workshop) Frontiers of AEM inversion and interpretation for minerals, energy and groundwater applications. Organiser: Geoscience Australia. (Full day workshop)	Ancient rocks, ancient culture, and you: Enhancing Australian First Nations engagement and participation in Australian geoscience programmes. Organisers: AuScope, Geoscience Australia & CSIRO Mineral Resources (Half day workshop)

AEGC 2021: Virtual exhibitors

List of virtual exhibitors

Exhibitor
Advanced Logic Technology & DMT
Anglo American
ASEG
AusThai
AXT
Borehole Wireline
CoRMaGeo Instruments
CSIRO
Delft Inversion
Dept of Energy and Mining SA
Department of Regional NSW (Geological Survey of NSW)
ElectroMagnetic Imaging Technology
Expert Geophysics
GBG Group
Geological Society of Australia (QLD)
Geological Survey of Queensland
Geological Survey of Western Australia
Geoscience Australia
Geosensor & Scintrex
Geoteric

Exhibitor
HiSeis
Katalyst Data Management
Loupe Geophysics
Epiroc
NMR Services Australia
Planetary Geophysics
Qeye Labs
RIG Technologies International
Robertson Geo
Seequent
Shearwater GeoSevices
SkyTEM Australia
Spectrem Air
STRYDE
Surtech Systems
Tensor Research
Xcalibur Multiphysics
ZEISS

Note: Virtual exhibitors listed are current as of 19 August 2021

AEGC 2021: The GeoPitch: Fast-paced presentations from university students and early-career geoscientists

The AEGC 2021 will, for the first time, will be hosting fast-paced 3-minute presentations, held concurrently to the rest of the conference proceedings. The GeoPitch is open to all students and early-career geoscientists to present their research, project work, and new ideas related to earth science.

AEGC 2021 GeoPitch presentations

Western Australia presenters:

Roman Isaenkov (PhD, Curtin University): *Automated real-time monitoring of carbon dioxide storages.*

Muhammad Atif Iqbal (PhD, Curtin University): *Petrophysics in mineral exploration?*

Lance Karlson (PhD, University of Western Australia): *Geological modelling with Measure-While-Drill data*

Lauren Found (Discover Geoscience): *A Peru-se of Subandean petroleum systems*

South Australia presenters:

Fernando Fagundes Fontana (PhD, University of South Australia): *Near real-time downhole geochemical analysis by LIBS (Laser-Induced Breakdown Spectroscopy)*

Yuexiao Shao (PhD, University of Adelaide): *Calibration of alkaline earth metal isotope tracers in semi-arid coastal environments*

New South Wales presenters:

Tom Zhao (PhD, University of New South Wales): *Serve farmers with geophysical data!*

Bronwyn Campbell (PhD, Macquarie University): T*he microscopic life hundreds of metres beneath your feet*

Tasmania presenters:

Wei Xuen Heng (GHD): *Geophysical investigation of the legacy Endurance Mine, NE Tasmania*

Queensland presenters:

Davina Rabadia (Santos, presenting Honour's thesis): *Unravelling the mystery of Martian meteorites*

Lisa Kearney (PhD, Queensland University of Technology): *Towards automation of microfacies analysis: Holocene carbonate diagenesis in the southern Great Barrier Reef.*

Corinna Schuetz (Msc, Queensland University of Technology): *From passive to active margin: before seds hit the fan.*

Tianjiao Yu (PhD, University of Queensland): *Keeping it local: the Permian origin of recycled clays in Cenozoic channels, Queensland*

Jack Ward (PhD, University of Queensland): *Late Cenozoic alkaline magmatism in East Asia and Indonesia: Tectonic controls on melt generation and implications for mineral prospectivity*

AEGC 2021: Short abstracts

3: Mapping coal seam roof and floor by using in-seam borehole radar: Results from numerical modelling

Dr Binzhong Zhou[1], Dr Jianjian Huo[2], Prof Iain Mason[3] and Mr Matthew van de Werken[1]

[1] CSIRO
[2] Ningbo University
[3] The University of Sydney

Longwall automation depends on the development of automatic coal seam (horizon) tracking and lateral guidance systems to keep mining the target coal seam while steering to the desired target. While inertial sensing has provided some success for lateral control of mining machinery, horizon control, i.e. establishing a "flight plan" for the longwall shearer, is a critical component of longwall automation that requires spatial accuracy for changes in a horizon's depth of the order of 10 cm, and positions of structures (faults and rolls) within fractions of a metre tens of metres ahead of the longwall machine. However, securing this is still largely unachieved. Much depends on our precise prior knowledge of the coal seam's location.

Coal is electrically resistive compared with its surrounding rocks. Therefore, we can use electromagnetic waves to image coal seam boundaries (roof and/or floor) and its relevant structures. Here we propose to use borehole radar profiles of in-seam drill holes to map the seam roof or floor accurately. This will help to fill the gap between coarse scale and relatively inaccurate exploration data (drilling, borehole logging and seismic) available and the detailed seam knowledge (ground penetrating radar, thermal and optical data) at the longwall face and gate roads. Integrating these datasets should provide a more accurate horizon model that can be used for longwall machine automation and guidance.

In this paper, numerical modelling is used to investigate the feasibility of and factors affecting in-seam borehole radar imaging. We show that in-seam borehole radar imaging can be used to map the coal seam roof and floor position accurately with an estimated error of less than 10 cm. Such accuracy requires the central frequency of the borehole radar to be no less than 100 MHz and the offset of the transmitter and receiver no more than 1 m.

7: Case studies from Loupe – New technology in portable TEM for near-surface measurements

Mr Gregory Street[1] and Mr Andrew Duncan[2]

[1] ASEG AIG GSA
[2] EMIT,Loupe Geophysics

A portable, broadband TEM system, Loupe, has been developed for the purpose of measuring the distribution of near-surface electrical conductivity. The system records continuously using a three-component coil receiver mounted on an ergonomic backpack from signals generated from a small (660mm) diameter transmitter loop mounted on a similar backpack.

The Loupe system is designed to measure primarily in the top 25 m of the ground, previously the charter of frequency-domain EM systems. Using modern electronics and software we have been able to overcome many of the problems associated with the broad bandwidth needed to define near surface conductivity with a time domain system. Sampling at around 500 000 samples per second and processed to produce a measurement of secondary field every second, the Loupe system provides very high spatial resolution. Data can be viewed as the operators walk, allowing survey redesign as necessary.

During 2019 and 2020 trial surveys have been conducted with Loupe in a number of near-surface applications including mineral exploration on surface and underground, geological / regolith mapping, study of groundwater around tailings storage facilities and the mapping of structural features in open-cut mines. We see a wide application for Loupe in mapping seepage both from mine tailings and acid mine drainage.

The Loupe system has proved to be extremely versatile working in difficult terrain and areas with high electromagnetic interference such as mine sites and urban sites. Special challenges are presented when working underground due to power reticulation, vehicle movement, infrastructure and particularly steel mesh reinforcing. We will give examples showing data collected in these challenging circumstances.

During this presentation, we will summarise the Loupe system and show results from several recent surveys.

10: Inferring geological features masked by artefacts in core photography using neural networks

Dr Yasin Dagasan[1], Mr Harvey Nguyen[1,2] and Mr Mark Grujic[1]

[1] Solve Geosolutions
[2] Datarock

Computer vision is considered to be the theory and supporting technology to extract information from imagery or multi-dimensional data, with the goal of automating tasks that would otherwise be performed by humans.

The application of computer-vision technologies to geological datasets has previously been shown to objectively verify existing datasets (e.g. automated calculation of geotechnical parameters) as well as provide new datasets (e.g. fracture orientation data for an entire deposit).

When visually inspecting core, a geologist will infer geological features that are masked by artefacts like hand-drawn mark up; a vein is not intersected by an orientation line and the geologist knows this. Similarly, physical inspection of core means that interpretation is not affected by artefacts that can manifest in photography, including shine from lighting in the core shed. A computer vision model does not initially know the relevance of these non-geological artefacts and must be trained accordingly.

We introduce the application of neural network architectures to identify and infer geological information that is hidden by non-geological artefacts in core photos, including; a) core markup such as orientation or cut lines and handwriting, b) joining rock pieces either side of mechanical/drillers breaks, and c) lighting effects including shine in wet photos taken using non-diffuse light sources.

First, a deep convolutional neural network instance segmentation model is trained to identify cohesive zones within core photos that are associated with the desired artefacts to be masked. Following this, a convolutional neural network that is capable of inferring geologically reasonable textures in place of the irregularly-shaped masked artefacts is trained, using partial convolutions that are conditioned on valid pixels.

The improvement that these image-preprocessing algorithms have on image-based geological modelling will be presented.

14: Almost automatic geological mapping from AEM surveys

Dr David Annetts[1] and Dr Juerg Hauser[2]

[1] CSIRO Mineral Resources
[2] CSIRO Minerals

Qualitative interpretation of airborne electromagnetic surveys is generally focused toward determining the geology represented by the inversion result for each station. However, it is a time consuming and often subjective process. It is well known that machine learning algorithms excel at the automatic classification of features in images after training. Here we test a supervised learning approach for airborne electromagnetic data collected in the La Grange groundwater area, Western Australia. We use machine learning to identify the most likely geological setting at each station and use this to derive the probable extent of the seawater interface. We employ standard techniques, such as cross validation, to benchmark machine learning algorithms such as nearest-neighbour, naive Bayes and support vector networks. The good agreement between a qualitative interpretation and the best-performing machine learning algorithm, here a random forest algorithm, for the seawater interface extents suggests that automatic classification has the potential to speed up the interpretation of large airborne electromagnetic surveys. Our results also suggest that careful use of machine learning algorithms trained on high-quality interpretations can lead to more objective geological maps particularly when airborne electromagnetic data are collected in order to map regional geology.

20: Rock property and depth mapping from magnetic data applied to greenfields exploration targeting in the Cloncurry District

Dr David Pratt[1], Dr James Austin[2] and Dr Clive Foss[2]

[1] Tensor Research
[2] CSIRO Mineral Resources

A new method for building a model of the rock property distribution on an unconformity surface (Pratt et al., 2019) presents new opportunities for greenfield exploration in complex geological environments. The method uses the inherent 3D information present in the magnetic tensor to create a model segment on the unconformity surface for every magnetic anomaly on every line in the aeromagnetic survey. Because the tensor is a 3D spatial derivative of the magnetic field, it automatically reduces the influence of regional magnetic field changes to focus the inversion process on the unconformity surface. An expert AI system builds a coherent 3D geological model from the individual model segments, which it then uses to constrain the joint inversion of the tensor data.

We explore the ways in which the maps and rock properties can be used to enhance greenfields exploration by applying the technique to the Cloncurry region of the Mount Isa Inlier. We evaluate the effectiveness of using the compact magnetic rock property estimates to define targets that might otherwise have been missed in the early phase of exploration. Historical airborne data acquired prior to mining of most deposits helps us to design appropriate strategies for targeting similar prospect styles.

Key words: magnetisation, depth, IOCG, skarn, AI.

21: Experimental investigation of the impact of cross-flow on immiscible CO_2 versus $WACO_2$ displacement efficiency in permeability heterogeneity sandstone porous media

Dr Duraid Al-bayati[1], Dr Quan Xie[1] and A/Prof Ali Saeedi[1]

[1] Curtin University

Reservoir rocks are rarely homogeneous, however, instead, variations in permeability and porosity occur on a variety of length scales. Geologic heterogeneity exerts a major influence on multiphase flow in the reservoir over many length scales, from the micron scale up to the kilometre scale. This is of great importance in many industrial and environmental contexts, such as enhance hydrocarbon recovery and geologic CO_2 storage. The most common and characteristic structure in porous sedimentary rocks is layering (i.e. the continuous parallel layers of different lithologic and physical properties) is considered as. Layers are observed at many different length scales, including; lamination (millimetre-thick layers), and bedding (centimetre- to metre-thick layers). The presence of heterogeneities inevitably influences the formation of viscous fingers and play a major role for generating of channelling through preferential path. This manuscript presents the results of an experimental investigation into the effect of crossflow on displacement efficiency during immiscible continuous CO_2 and water alternating CO_2 ($WACO_2$) in layered sandstone porous media. A manufactured core sample constructed by attaching two half-cylindrical homogeneous natural sandstone plugs of different permeability. Core flooding tests were conducted at a constant temperature of 343 K and pressure of 9.6 MPa. The results from this paper are very important to overcome the current challenges in capturing the importance of crossflow influence as well as mitigating the effect of geological uncertainties on current and future CO_2 storage projects.

22: Groundwater and gas sampling informing hydrogeological conceptualisation of the Precipice and Hutton Sandstone aquifers of the southern Surat Basin

Dr Julie Pearce[1], Dr Harald Hofmann[1], Mr Iain Rodger[1], A/Prof Phil Hayes[1], Prof Sue Golding[2] and Ms Kim Baublys[1]

[1] University of Queensland
[2] School of Earth and Environmental Sciences, University of Queensland

The southern Surat Basin in Queensland, Australia, may be a prospective region for geological storage of CO_2 within the Precipice Sandstone with the Evergreen Formation acting as a sealing cap-rock of the reservoir. The Hutton Sandstone, a major regional aquifer, overlies the Evergreen Formation. Understanding the baseline current hydrogeological and geochemical processes and potential impacts to water resources from CO_2 injection are important factors. Data from newly collected field samples of groundwater from the Precipice Sandstone and Hutton Sandstone in the southern Surat Basin are presented, focusing on the stable isotope component of a broader study. Initial results show that the Precipice Sandstone has a wider range of salinity than the Hutton Sandstone, with the highest values in the region east of the Burunga-Leichhardt fault zone. The majority of dissolved methane and carbon dioxide samples from Precipice Sandstone bores have a mixed origin isotopic signature, with δ^{13}C-DIC also indicating methanogenesis. Samples from the Moonie oil field, including the Precipice Sandstone and Evergreen Formation have a mixed thermogenic signature. The majority of Hutton Sandstone dissolved gases, however, indicate *in situ* primary microbial CO_2 reduction producing methane. Water stable isotopes in the two aquifers span large ranges and are more depleted than modern rainfall consistent with recharge during colder climates. Initial results from DST analyses in the project also indicate flow components from north to south, and a potential pathway east to the Clarence-Moreton Basin. Analysis of groundwaters are ongoing to understand processes and flow paths.

23: Detailed geophysical mapping and 3D geological modelling to support urban planning: A case study of Ny Rosborg, Denmark

Dr Theis Andersen[1]

[1] VIA University College

In Denmark, as in many other parts of the world, the population density is currently increasing, making un-used land sparse for urbanisation. As cities grow, areas formerly considered unsuited to urbanisation are now undergoing urbanisation e.g. former industrial areas and wetlands. The objective of this talk is to present a comprehensive interpretation strategy showing how planning maps can be created exemplifying the risk and opportunities one area holds. The investigations were conducted on a 1.5 km^2 area at Ny Rosborg, Denmark. Within the area, borehole information, geotechnical data (*in situ* vane tests and standard penetration tests), electromagnetic data (DUALEM-421S) and electrical resistivity tomography data (ERT) were collected and analysed. The first steps of the interpretation strategy involve a review of the purpose of the project. This is followed by the acquisition of high-density geophysical data. Hereafter, geophysical data in conjunction with GIS data are used for constructing a detailed high-resolution 3D geological voxel model. The specific geotechnical properties are assigned to the interpreted geological units. In the final step of the interpretation strategy, planning maps are created demonstrating the recommended use of different parts of the area for future urbanisation. An isopach map showing the depth of the layers suitable for the foundation is combined with a map showing the areas flooded by the nearby Vejle Stream during a 50- and 100-year climate event as well as habitat protected areas. Thus, the resulting planning maps show the most suitable locations of blue areas (lakes, wetlands), green areas (parks, etc.) and grey areas (buildings, roads) for future development.

The adopted interpretation strategy can be successfully applied in similar situations to reduce the risks associated with urban development.

24: Application of LiDAR for hydrocarbon exploration in logistically and geologically challenging environments: examples from the Papuan Fold and Thrust Belt, Papua New Guinea

Mr Luke Mahoney[1], Mr Mitch Furnass[1] and Mr Pedro Restrepo-Pace[1]

[1] Oil Search

The Papuan Fold and Thrust Belt (PFTB) in Papua New Guinea hosts the prolific Papuan Basin petroleum system yet remains underexplored compared with other fold and thrust belts worldwide. The underexplored nature of the PFTB results from its remoteness, inhospitable karst topography and thick tropical vegetation, which combine to create an exceedingly difficult and expensive area to explore for hydrocarbons. There are, however, significant rewards awaiting those able to overcome these challenges, with an estimated 40 tcf of gas and 550 million barrels of oil Yet-to-Find. The history of exploration success in the PFTB has been closely linked to technological advancements aimed at overcoming these challenges. In the 1980s, the introduction of heli-transportable drilling rigs provided access to highly prospective areas of the interior PFTB that were previously inaccessible. In the 1990s, significant advancements in 2D seismic acquisition techniques facilitated much-improved imaging through the karst topography, subsequently resulting in several discoveries. The most recent advancement of comparable significance has been LiDAR (Light Detection and Ranging), a remote sensing technology that provides the ability to "see" through the thick tropical vegetation, revealing previously obscured geological outcrops and revolutionising surface operation planning. LiDAR data are used to create high-resolution 3D digital elevation models of the earth's surface that have a myriad of exploration applications from geological mapping to seismic planning and processing. LiDAR has significantly improved our understanding of rock deformational characteristics and structural styles within the PFTB, which has led to an improved understanding of the subsurface trapping styles and provided a stimulus for the identification of new exploration plays. In this paper, we discuss some of the ways that LiDAR is being used to explore within one of the most challenging yet underexplored areas in the world.

27: Hidden in plain sight: The Bamaga Basin

Mr Wolfgang Fischer[1]

[1] Gulf Energy Limited

The Gulf of Carpentaria was extensively explored in the 1970s and 1980s targeting the Carpentaria (Jurassic-Cretaceous) and Karumba (Tertiary) sag basins, the sediments of which show no structuring. This activity failed to recognise the presence of the deeper and older Bamaga Basin and in 1984 Duyken-1, the only well so far in the Gulf of Carpentaria, tested the Carpentaria and Karumba sediments without success, but missed the unrecognised Bamaga Basin 120 km to the northeast.

Poor quality seismic data and preconceived ideas 'masked' the Bamaga Basin and it was only in 2012 that modern 2D regional seismic data followed by an infill seismic survey in 2014, revealed the presence of a sedimentary succession in the Bamaga, probably of early-middle/late Paleozoic age. The carefully processed new seismic data uncovers an intriguing, complex structural history, and large potential petroleum traps.

Basin modelling in the centre of the Bamaga Basin where the sedimentary section is deepest shows that the sediments are mature for petroleum generation with the hydrocarbon phase being either oil or gas, although gas is more likely, especially below 2000m.

Analysis of the available data indicates that in the oil generation zone there are many targets each of which has the potential to hold Prospective Resources of more than 250 MMstb of oil, the largest of which could hold 660 MMstb oil. In the gas generation zone, there are also numerous targets, each with the potential to hold Prospective Resources of 1 Tcf or more gas, the largest of which could hold as much as 2.5 Tcf gas.

The water depth (60 m), closeness to shore (150 km) and reasonable target depths means exploring the Bamaga Basin is operationally and commercially attractive.

29: New age dating of evaporites in Canning Basin, WA, Australia. A case study based on samples from the Frome Rocks salt diapir

Miss Fionna McNee, Mr Frank Glass, Mr John Gorter, Mr Mark Devereux, Mr David Long, Mr Sam Oldham and M iss Amy Millar

The age of evaporitic units in the Kidson Sub-basin of the Canning Basin have been assigned to be of Late Ordovician to Early Silurian age through the dating of the sedimentary sequences within the Mallowa Salt.

The Frome Rocks 1 exploration well was drilled in 1959 on the Jurgurra Terrace on the southern margin of the Fitzroy Trough and encountered 600 m of salt down to a total depth (TD) of the well at 1220 mMD (1137 mTVDSS). Based on seismic data, this salt sequence is interpreted to be part of a diapiric structure that resulted from the rapid deposition of Carboniferous/Permian sediments over a thick evaporitic sequence. It is generally accepted that the evaporite sequence encountered in the Frome Rocks 1 well was deposited contemporaneously with the Mallowa Salt in the nearby Kidson Sub-basin.

This paper presents an alternative model that suggests that an evaporitic salt sequence over the Jurgurra Terrace was deposited during the initial opening of the Fitzroy Trough during the Middle Devonian and prior to the deposition of the carbonate/claystone sequences of the Gogo and Pillara Formations.

The presence of several evaporitic deposits within the Mellinjerie Formation of Middle Devonian age encountered in wells surrounding the Fitzroy Trough supports this age interpretation, while global indications for a major sea level drop in the Early to Middle Devonian allow for the development and generation of evaporitic conditions in an isolated shallow marine basin that predates the opening of the Fitzroy Trough.

Ongoing work includes palynological and radiogenic dating of samples of the salt and overlying sediments from several recent mineral holes drilled on the Frome Rocks salt diapir.

The confirmation of evaporites of Middle Devonian age would significantly increase the hydrocarbon prospectivity of the Jurgurra Terrace structural province, with good quality reservoirs of Devonian age proven in this area.

31: Controls on organic matter accumulation in the Mesoproterozoic: Insights from the stratigraphic modelling of the Velkerri Formation of the Beetaloo Basin (Northern Territory, Australia)

Dr Vincent Crombez[1], Dr Mohinudeen Faiz[2], Dr Claudio Delle Piane[1] and Dr Marcus Kunzmann[2]

[1] CSIRO Energy, Deep Earth Imaging
[2] CSIRO

Ability to understand and predict the distribution of primary organic content in a basin is key when exploring for unconventional hydrocarbons. Many pathways lead to the formation of organic-rich rocks through numerous combinations between rate of primary productivity, organic matter preservation, and dilution that occur in sedimentary basins. It is likely that: (1) primary productivity will vary temporally and spatially, (2) preservation will be affected by the basin's physiography (e.g., open vs. restricted) and the burial efficiency, and (3) dilution will be a function of the stratigraphic evolution. If the vertical and lateral variations of each of these factors is not understood, it is difficult to quantify the impact of their interaction on organic matter accumulation.

In the present work, we focus on the Meso-Proterozoic Velkerri Formation, an unconventional hydrocarbon self-sourced shale reservoir currently being the target of exploration and appraisal activities in the Beetaloo Sub-basin. Using well data and geochemical analyses, we reconstruct the stratigraphic architecture of this interval and suggest a geological model for the accumulation of organic matter. Then, using stratigraphic modelling, we simulate the evolution of the basin in the Proterozoic and feed the new results into the previously established geological model for organic-matter accumulation. In a last step, we run multiple realisations of the model while changing the input parameters that influence primary productivity, oxygen renewal in water column, and sediment supply, which allows for the quantification of their effects on organic matter accumulation. This study emphasizes that while being deposited in the Meso-Proterozoic, high primary productivity is necessary to establish organic richness of the shale. In addition, this study shows that the controls on organic matter varies spatially and temporarily, depending on the location within the basin and the stratigraphic interval.

32: Petroleum systems model for source- rock-reservoir evaluation in the Beetaloo Sub-basin

Dr Moinudeen Faiz[1], Dr Vincent Crombez[2], Dr Claudio Delle Piane[2], Mr Nicholas Lupton[1] and Mr Michael Camilleri[1]

[1] CSIRO Energy
[2] CSIRO Energy, Deep Earth Imaging

The Beetaloo Sub-basin comprises the oldest known petroleum system in the world with the Mesoproterozoic shales being prolific source rocks and proven as productive unconventional reservoirs. The main unconventional reservoir targets include gas- to liquids mature shales of the Velkerri

Formation and liquids- to wet-gas mature shales of the Kyalla Formation. A comprehensive 3D basin model has been developed, incorporating critical elements of the petroleum system, that can be utilised as a valuable tool for play characterisation as well as to high grade areas for exploration, testing and development.

The primary organic matter in the shales are derived from primeval cyanobacteria and, despite being ~1.3 billion years old, the thermal maturity varies from immature (Hydrogen Index ~800 mgHC/gTOC) along margins to over-mature (Hydrogen Index <1 mgHC/gTOC) in deepest parts of basin. Calibration of the basin model against observed temperatures, thermal maturity and hydrocarbon fluid compositions suggests that the variations in regional source rock maturation are likely caused by a combination of heat-flow and burial depths. Source rock parameterization for the model was conducted using stratigraphic forward modelling, accounting for variations in palaeogeography, bathymetry and the sedimentary facies, to map geochemical inputs from sparse well data across the basin. Fluid migration behaviour within the source rocks was simulated through a combination of parameters including diffusion, Darcy flow and invasion percolation which affects fluid saturation and sites of hydrocarbon accumulation across the basin. The simulation outcomes including pore-pressure, porosity, adsorbed gas content and Poisson's ratio were further tested against values determined from core analyses or measured through well tests. The model can be readily updated with improved input data and calibrated against new data that becomes available as exploration in the basin progresses. The results can be directly used as input parameters/maps for sector-based production forecasting models and uncertainty analyses.

34: Exploring for gold using radiometrics, magnetics and petrophysical information in the Warrawoona greenstones of the east Pilbara, Western Australia.

Mrs Yvonne Wallace[1], Mrs Heather Ballantyne[2] and Mr Steve Sheppard[3]

[1] Southern Geoscience Consultants
[2] SGC
[3] Calidus Resources Limited

The Warrawoona Gold Project is located 25 km southeast of Marble Bar in the east Pilbara region of Western Australia. Key prospects include the Klondyke deposit, which forms the main share of the 1.25 Moz gold resource, owned by Calidus Resources Limited.

Intense deformation is localised in the narrow zone between the Mount Edgar and Corunna Downs batholiths and which manifests as strong shearing, steeply dipping lineations, sheath folds and steeply plunging isoclinal fold hinges. Physical property measurements and IP surveys have shown that ore-bearing structures containing sericitic alteration may be identifiable at the regional to project scale using potassium from radiometric data. Magnetite-destructive alteration and structural complexities relating to the compression and elongation of the greenstone units are also associated with mineralisation.

The project area is well exposed with minimal regolith cover. A regional 25 m line-spaced airborne magnetic and radiometric survey was acquired across the project in 2020 with a north-south orientation, greatly superseding previous regional data of 100 m – 400 m line spacing. The detailed datasets have been used to identify radiometric potassium anomalies, which are generally mappable as stratigraphy-parallel elongate zones across the project area. Using the magnetic data, these zones were then graded for structural complexity as a proxy for mineralisation traps, and for evidence of magnetite destruction as a proxy for alteration.

The magnetic and radiometric interpretation was integrated with published outcrop geology maps and local topography information. A total of 95 target areas were identified, including an untested trend to the west of the Klondyke deposit.

Key words: radiometrics, magnetics, potassium, deformation, alteration

35: Case study from NW Carnarvon using WEB-AVO inversion to map low saturation gas and unravel geology using "noisy" seismic

Mr John Coffin[1], Ms Angie Kelsay[2] and Mr Shahid Ur Rehman[3]

[1] PESA / ASEG
[2] Delft Inversion
[3] Chevron Australia Pty Ltd

In the case study we apply wave equation based AVO inversion (WEB-AVO) to a prospective area of the NW Carnarvon Basin with three specific technical challenges. The first being how to map low saturation gas, the second on how to map the lithology and the third on what to do when the seismic data in the interval is contaminated with interbed multiples, mode conversion and transmission effects.

The paper will explain the novel method used and how the use of compressibility (inverse of bulk modulus) and shear compliance (inverse of shear modulus) together with seismic data in the ray parameter domain can unlock this seismic door. Rather than trying to remove the "noise" from the seismic data we invert for this as well as the primary energy using the wave equation. The result is an inversion product in the engineering domains of compressibility and shear compliance which are much more sensitive than our normal AVO inversion products of acoustic impedance, shear impedance and Vp-Vs ratio.

In our case study we begin by looking at the Cretaceous interval and applying the method in a traditional blind test application. A single well is used to predict a blind well to build confidence in the scheme. Next, we move to the Upper Triassic where there is only one penetration into a shallower gas reservoir and a deeper low saturation gas. Some areas of this key upper Triassic gas reservoir are possibly contaminated by multiples / mode conversions and residual acquisition footprints. Seismic processing has always struggled to effectively remove this "noise". With WEB-AVO we embrace this "noise' and use it to unravel the geology, get a good understanding of the lithology and map the low saturation gas.

37: Onshore seismic acquisition: out with the old, in with the new

Mr Denis Sweeney[1], Dr Tim Dean[2], Mr John Hughes[3], Dr Claudio Strobbia[4] and Mr Martin Bayly[1]

[1] SuperSeis
[2] BHP
[3] John R Hughes Geophysical Pty Ltd
[4] Realtimeseismic

We start from the premise that the move from cable-based telemetry seismic acquisition systems with connected strings of geophones to nodal, single sensor recording, has not been fully developed (or "exploited"?) by the seismic industry. Despite the dramatic changes of the last decade being reflected by the plethora of nodal systems on offer and their increased use globally, the benefits of the shift in technology have not been fully realised. We will present that opportunity exists to be more creative in the approaches taken in acquisition and quality control of surface seismic nodal data and subsequent data processing.

Data processing techniques have also evolved to encompass geometry irregularity using real world coordinates rather than nominal assumed regular spacing. These methods, particularly multi-dimensional regularisation and interpolation, enables more freedom for both macro and micro geometry and thereby opportunity for more efficient acquisition.

The use of automation is discussed along with challenging the linear approach typically taken in project execution, also the movement of some field-based support tasks to the town office and a new look at implementation of field quality control measures along with their related specifications.

This paper therefore explores the entire seismic survey process from the planning stages, including the setting of quality control specifications and how in field activities automation can be implemented, examples will be given.

The objective of this new collective approach is primarily to make onshore seismic data acquisition more relevant to overall onshore exploration/development objectives. This is achieved by maximising data quality (thereby reducing well expenditure) while driving down the costs of seismic acquisition and delivering new critical information more quickly through reduced project duration.

38: Integrated modelling of seismic velocities and impact on prospect evaluation

Dr Jarrod Dunne[1] and Dr James Parsons[1]

[1] QIntegral Pty Ltd

When a good quality seismic image is formed it is often assumed that the associated velocities can be used directly for time-to-depth conversion; for pore-pressure prediction and perhaps even as a driver for seismic amplitude interpretation. However, such applications require seismic velocities to be properly integrated with velocities derived from well-data using relevant geological insights to increase the utility of this type of geophysical data. Forward modelling can help to manage the different scales involved and to force consistency between the different sources of velocity data.

Seismic velocities, irrespective of the method used to obtain them, should be compared to and where possible calibrated to well-data. Well-based velocities include edited VSP data; time-depth tables derived over intervals with a quality synthetic/seismic tie; and rock physics depth trends derived from sonic and other wireline logs. Geological insight can be obtained from inspection of velocity trends and by making use of well markers; stratigraphic mapping; and basin modelling insights. Integration software can help manage such data by converting between common velocity types and by deriving regional burial trends and depth-dependent calibrations between different velocity sources.

An example from the Campos Basin, Brazil, shows how well data alone can underpin time-to-depth conversion to reveal hidden structures below shelf-slope breaks and salt diapirs, while simultaneously addressing the interpretation of amplitudes for prospect definition and derisking. An example from the Browse Basin, Australia shows how velocities derived from well-data can help to QC processing velocities, which can then be more confidently used to identify likely overpressured zones. More efficient, and thus sustainable, exploration could result from treating velocities as a valuable geophysical dataset rather than solely as a by-product of seismic processing.

40: Examples of integrating hyperspectral, geochemical and petrophysical drill core data using Australia's National Virtual Core Library infrastructure

Dr Carsten Laukamp, Dr Jessica Stromberg, Mr Neil Francis, Mr Shane Mulè[1], Ms Monica LeGras, Dr Juerg Hauser[2] and Dr Ian Lau[3]

[1] Mineral Resources, CSIRO
[2] CSIRO Minerals
[3] CSIRO

Drill core analytical tools are used for objectively measuring geoscience parameters that aid mineral exploration or groundwater research. Multiple types of geoscience parameters are frequently compared alongside each other, but underlying physicochemical relationships are seldom explored. If the relationships between different parameters are understood, 1) expensive measurements can be inferred from more cost-effective measurements and 2) workflows can be developed that enable fast and objective selection of samples for further, more time-consuming sample analysis. Ultimately, linking geophysical, geochemical and mineralogical parameters could also give rise to a new generation of higher-level geoscience products reconciling different sources of information.

AuScope's National Virtual Core Library (NVCL) infrastructure programme provides opportunities to explore the feasibility of extracting geoscience parameters from multiple types of drill core data and understanding their interrelations. Here we discuss the findings of a set of case studies from a wide range of geological environments that are based on NVCL drill core data sets available via AuScope's Discovery Portal. The case studies highlight multiple challenges and opportunities with regards to extracting geoscience parameters from drill core data, such as 1) the requirement for understanding the limitations and potential of the respective drill core analytical technologies, 2) the underutilised potential for extracting geochemical exchange vectors from hyperspectral data, 3) lack of spatial co-registration of different drill core analytical measurements, 4) significant issues related to different sampling volumes and intervals of the respective drill core analytical techniques, and 5) the potential and limitations of PLS-modelling based prediction of geochemical and petrophysical data from hyperspectral data. Many of the issues described in the case studies are faced by geologists daily. The NVCL infrastructure and database provides plentiful opportunities for developing new methods to solve the challenges related to drill core data interpretation and make real progress towards extracting improved and novel geoscience parameters.

41: UAV magnetic survey planning, QAQC and data processing

Mr Brendan Ray[1]

[1] Southern Geoscience Consultants (SGC)

UAVs have been deployed increasingly to collect magnetic data, however acquisition using these systems often lacks QAQC checks that are typically expected from fixed-wing or helicopter based acquisition. Furthermore, survey parameters such as line spacing and mean terrain clearance are often not given enough thought, leading to data that is unnecessarily over-sampled (line spacing much closer than flying height) or flying heights that are too low, leading to data that is littered with spurious surface noise.

UAVs are not immune to system noise, instrument noise and GPS issues that also arise in their larger, fixed-wing and helicopter counterparts and these need to be addressed prior to acquisition. Due to the commercial infancy of these systems, delivered products are often sub-optimal as they lack contractual agreements of data quality and noise levels. Factors such as deviation from planned survey height, deviation from planned lines, noise levels above a threshold etc. need to be pre-agreed on in a way that's fair and transparent to both the UAV operator, as well as the client.

Processing of UAV data from its raw state can be thought of in two stages, the first being spatial data processing – checking and correcting for GPS positioning errors as well as altitude information, breaking up the data into unique lines or blocks, etc. The second stage is the assessment and correction of magnetic data – removal of spikes, dropouts, correction of base station data etc. UAV data tends to be delivered as grids, images, and ASCII line data which oftentimes, have only undergone the minimum processing in this two-stage process. The data needs to be further enhanced to reduce the appearance of near-surface noise, or artefacts in the grids which are related to line-directionality to allow for clearer interpretation of the data without adversely affecting the underlying geology.

44: Earthquake monitoring in the Southwest Seismic Zone, Western Australia

Dr Ruth Murdie[1], Ms Lucy Brisbout[1], Dr Hugh Glanville[2], Dr Trevor Allen[2], Dr Craig Bugden[2] and Mr Vic Dent[3]

[1] Geological Survey of Western Australia
[2] Geoscience Australia
[3] Curtin University Associate

Five new seismic monitoring stations have been added to the Australian National Seismograph Network (ANSN) in Western Australia with the aim of better locating the small earthquakes of the Southwest Seismic Zone of southwest Western Australia.

The Southwest Seismic Zone, one of the most seismically active onshore areas in Australia, is an area known for its seismicity by the local people who regularly experience small cupboard rattlers. These often occur in swarms as documented by Dent (e.g. 2009, 2014, 2017, 2019, 2020). It is more widely known for the M6.5 Meckering earthquake of 1968 which destroyed many houses in Meckering, produced a 37 km long and 2 m high fault scarp and dramatically bent the railway line. There is no obvious tectonic reason for earthquakes to be occurring in this area as it is in the middle of an Archean cratonic region although the scarps from surface rupturing events, such as the Meckering event, mainly trend approximately north-south and appear to lie along trends in the magnetic data (Dentith et al 2009).

Until mid-2020 the ANSN had a fairly sparse coverage of the area. A secondary Public Seismic Network (PSN) is also monitoring in the area. Inclusion of the PSN data has quite an effect on the calculated locations, as exampled by the tighter clustering of the Beacon swarm of 2009 (Dent, 2009) rather than the linear trend from just using the ANSN data.

In mid-2020 four more semi-permanent stations were installed in the area and one in the Goldfields and added to the data streaming into the National Earthquake Alerts Centre (NEAC) and incorporated into the location algorithm. This presentation looks at seismicity of the area, the small swarms that have been detected since then and the relationship of the seismicity to the geology.

47: Multi-purpose utility of constructing 3D static geomechanical model in the Ichthys field, Browse Basin

Mr Partha PratimMandal[1], Ms Iman Essa[1], Mr Sankhajit Saha[2] and Prof Reza Rezaee[1]

[1] Curtin University
[2] Baker Hughes

The petroleum industry progressed significantly to develop 3D/4D geomechanical models (GMs) to make efficient field development planning which reduces the uncertainty of 1D GM in the field scale. In this paper, we demonstrated how to build a high-resolution 3D static GM in a stratigraphic structural setup with a combination of wireline logs, drilling data, structural objects, and laboratory rock mechanical data from 21 core samples in the Ichthys field of the Browse Basin, North West Shelf so that spatial distribution of pore pressure and stress behaviour can be understood across the Brewster Member sandstone reservoir. The workflow incorporates calibrated 1D GM of seven wells. 1D GM analysis confirmed strike-slip faulting regime throughout the stratigraphic column and the orientation of maximum principal stress is nearly towards the E-W direction. The 1D model also indicates a sharp pressure ramp within Jamieson reaching a maximum to the middle of the layer and then regressed below Aptian and near to hydrostatic pressure at top of the upper Vulcan formation. 3D modelling is performed by incorporating interpreted seismic surfaces and unconformities in line with the geological understanding of the subsurface and stratigraphic variation from the seabed to lower Vulcan formation. A geostatistical technique is adopted to map and interpolate rock properties throughout the grid which is tied with the field's stratigraphic unit. A seismic velocity cube is used to compute density profile based on acoustic-density correlation and thereafter vertical stress. Pore pressure is modelled by defining the pressure depth relationship from the 1D reference pore pressure profile and honouring the structural layering. Due to its inherent property of structural consistency, this 3D model efficiently captures the lateral heterogeneity over the 1D model validated at Prelude-1A well location.

Key words: Geomechanical model, stress regime, rock strength, pore pressure, strutural grid, Ichthys

49: Gravimetric measurements of high pressure and temperature C1, C2 and C3 adsorption isotherms on Beetaloo Sub-basin shales

Mr Nicholas Lupton[1], Mr Michael Camilleri[1] and **Dr Mohinudeen Faiz**[2]

[1] CSIRO Energy
[2] CSIRO

Exploration in Australia's Beetaloo Sub-basin focuses on the liquids, wet-gas, and dry-gas mature shales of the Kyalla and Velkerri formations. Gas storage in these reservoirs occurs as free gas or additionally through adsorption to the surface of organic matter pores and clay minerals. The adsorbed gas component may represent between 20 and 85% of total gas-in-place for shales, and in the Beetaloo the co-production of wet gas components (e.g. ethane, propane) is also expected to improve the economics of gas production. Accurate characterisation of the adsorption of these hydrocarbons is critical to developing accurate resource estimates and understanding production behaviour.

A gravimetric isotherm rig and measurement methodology was developed enabling accurate HPHT adsorption measurements on shales. Adsorption measurement on shale presents a challenge due to the low sorption capacity, as well as the requirement for high pressure and temperature characterisation to approximate *in situ* conditions. For example, an inter-laboratory comparison by Gasparik et al. (2014) observed discrepancies of approximately 25% in CH_4 sorption measurements in the high pressure range, and significant variation in C_2H_6 measurements above 5 MPa.

Gravimetric isotherm measurements avoid cumulative errors of the volumetric method, and are less sensitive to the presence of leaks, an important consideration for HPHT measurements. Equipment design allowed the CSIRO gravimetric rig to overcome reported shortcomings of the method at high pressures due to sample buoyancy and low sample mass, and a calibration methodology using material with a known adsorption isotherm validated rig performance. The method was applied to measure CH_4, C_2H_6 and C_3H_8 adsorption isotherms of four Beetaloo Sub-basin shales, with a range of organic matter content, thermal maturity and temperatures. The measurements were repeated using a volumetric isotherm method to enable comparison. The measured isotherms present the first published C2 and C3 isotherms for Australian shales.

55: Radio Image Mapping at the Polymetallic Rosebery Mine in North-Western Tasmania

Dr Asbjorn Christensen[1], Mr Jon McLoughlin[1] and Mr Roland Hill[1]

[1] MMG

In 2019 MMG conducted a suite of thirteen deep-seated cross-hole Radio Image Mapping (RIM) tomographic surveys along the northern extension of the polymetallic Rosebery Mine in North-Western Tasmania.

The RIM method is based on the attenuation of an electromagnetic wave in a material. A transmitter is located in one drill hole and a receiver in a nearby drill hole. The system measures the amplitude and phase difference between the transmitted and the received signal. This determines the attenuation rate, which can be used to estimate the conductivity of the rock between the transmitter and the receiver. The positions of the transmitter and the receiver are varied to produce a tomographic data set.

The survey was conducted with the Russian-built FARA borehole system containing several electrical dipoles transmitting or receiving radio signals in the kHz range.

The thirteen cross-hole panels were designed to test the range of the RIM system and to search for additional mineralisation along a prospective zone between the Rosebery Fault and Mt. Black Fault in the Cambrian-age Mount Reid volcanic belt. The mineralisation, consisting of sphalerite and galena, is significantly more conductive than the surrounding volcanoclastic host rock.

The high electrical resistivity of the volcanoclastic host rock assured an effective range of the transmitter-receiver system in excess of 400 m.

Tomographic imaging of the survey data has identified several tabular, down-dipping zones of low resistivity. There was relatively little variation in the tomographic imaging with frequency.

Follow-up drilling intersected sulphide mineralisation in the vicinity of the RIM target zones.

The RIM system provided a cost-effective mechanism to either upgrade or sterilise large volumes of the exploration search space between existing drill holes in a brownfields settings. The imaging capabilities of the RIM system could be improved with monitoring capability of the time-variations in transmitter strength.

59: How do detachment properties influence the kinematics of normal growth faults? Insights from 3D seismic reflection data from the Ceduna sub-basin

Mrs Monica Jimenez[1], A/Prof Simon Holford[2], A/Prof Rosalind King[3] and Dr Mark Bunch[2]

[1] University of Adelaide
[2] Australian School of Petroleum and Energy Resources, University of Adelaide, Australia
[3] The University of Adelaide

The growth of gravity-driven normal faults exerts a critical control on multiple elements and processes of the petroleum system. However, there is still a poor understanding of the interactions between the properties of detachment layers and the evolution of growth faults in delta systems underlain by mechanically-weak detachments. This study is focused on the White Pointer Delta system in the Ceduna sub-basin, which detaches on an overpressure shale layer deposited during the Albian-Cenomanian. Using the Ceduna 3D seismic survey, we present evidence of how changes in thickness, dip angle and geometry of the Albian-Cenomanian detachment influences the kinematics of overlying, detachment-linked growth faults. In the proximal region of the study, the detachment is relatively thin (0.2 to 0.5 s) with basal dips of 5°-10°. Normal faults located at this region, show constant growth during the Cenomanian-Maastrichtian. In central and distal areas of the seismic survey, the thicker detachment has basal dips <2° with thrust faulting and 'dome' structures. Faults at this area grew by dip-linkage. Our study shows that a more consistent and active evacuation of the detachment resulted in non-interrupted fault growth, while a thicker and more complex detachment can outcome in minimum accumulation that caused irregular fault growth.

61: Expanding the reserve base of operating mines: Insights from an airborne MobileMT survey in the Omsukchan depression, Russian Far East

Mr Petr Kordi[1], **Mr Alexander Prikhodko**[2], Dr Andrei Bagrianski[2] and Mr Sergei Trushin[1]

[1] Polymetal International PLC
[2] Expert Geophysics Limited

The Dukat silver-gold ore field occurs in the central section of the Omsukchan (or Balygychan-Sugoi) rift-like trough formed in the Early Cretaceous period along a North-South fault system. The framework of the graben-shaped depression (~150 km long) is intruded by numerous Early and Late Cretaceous granitoid polyphase stocks and plutons, porphyry, and dykes. A number of known epithermal silver-gold deposits and occurrences form the Dukat ore field including the eponymous world's third-largest silver deposit. Currently, four deposits are under mining operations in the Polymetal's Dukat hub with a predicted end-of-life of 2026.

The geology of the region has been explored and well studied from the surface during the last 50 years. The central part of the epithermal-type Au-Ag ore field Dukat contains a dome-like structure (a granite-granodiorite pluton) which is intersected by drill holes at a depth of 1200-1500 m below the surface. The main elements of the Dukat deposit that govern the ore bodies' structure are sub-vertical zones consisting of systems of sub-parallel shear cracks, zones of mylonite along faults, veins controlled by faults, and individual large fractures.

In order to develop an exploration concept based on the deep structures, a MobileMT survey was carried out over part of the trough structure covering about 1325 km^2. The airborne MobileMT EM technology was able to identify: 1) the deep dome structure as the main controlling factor of the known Au-Ag mineralization system; 2) other deep dome structures in the depression — potential for new, near-surface, and buried discoveries; 3) the sub-vertical fault zones as feeding, fluid transport channels from deep magmatic bodies to near-surface host rocks, and the resultant alteration and ore zones. The survey results were presented in 2D resistivity sections, depth slices up to 2.5 km depth from surface, 3D isosurfaces, and a voxel.

62: MobileMT for porphyry exploration – model studies and field examples

Mr Alexander Prikhodko[1] and Dr Andrei Bagrianski[1]

[1] Expert Geophysics Limited

Resistivity methods are an important part of the arsenal of geophysical techniques for the exploration of porphyry-copper style mineralization. MobileMT technology, an airborne, electromagnetic system utilizing natural electromagnetic fields, has a depth of investigation of up to 2.5 km, significantly exceeding any controlled-source airborne electromagnetic system. MobileMT is sensitive to a wide range of resistivities and to geological formations of any arbitrary geometry. The advantages offered by the MobileMT technology make it especially useful for studying the wide variety of complex porphyry systems.

There is no unifying or common geophysical model for porphyry systems. The different host rock lithologies and compositions, the extent and degree of specific following alteration processes and fracture/faulting system development, possible superimposed infiltrations, post-ore tectonic events, and a current erosion level are all factors which affect the resistivity pattern of porphyry assemblages.

We investigated several known porphyry models with different geoelectrical patterns by calculating the natural electromagnetic field response from the models followed by the model's recovery from the noise-added data. The results of the investigation of the synthetic models demonstrated that the MobileMT technology has many capabilities for detecting porphyry-ore systems, including those that are deeply located or masked by challenging post-mineral conductive cover.

The field examples presented several areas which have been flown by the MobileMT system and are prospective for porphyry-style mineralization. The field data yielded the characteristic patterns of porphyry systems which were analyzed in relation to the synthetic models.

63: Data geo-science approach for modelling unconventional petroleum ecosystems and their visual analytics

Dr Shastri Nimmagadda[1], Mr Andrew Ochan[2], Dr Neel Mani[3] and Dr Torsten Reiners[1]

[1] Curtin University
[2] PAU
[3] Amity IT

Storage, integration and interoperability are critical challenges in the unconventional exploration data management. With a quest to explore unconventional hydrocarbons, in particular, shale gas from fractured-shales, we aim at investigating new petroleum data geo-science approaches. The data geo-science describes the integration of geoscience-domain expertise, collaborating mathematical concepts, computing algorithms, machine-learning tools, including data and business analytics. Further, to strengthen data-science services among producing companies, we propose an integrated multidimensional repository system, for which factual instances are acquired on gas shales, to store, process and deliver fractured-data views in new knowledge domains.

Data dimensions are categorized to examine their suitability in the integrated prototype articulations that use fracture-networks and attribute dimension model descriptions. The factual instances are typically from seismic attributes, seismically interpreted geological structures and reservoirs, well log, including production data entities. For designing and developing multidimensional repository systems, we create various artefacts, describing conceptual, logical and physical models. For exploring the connectivity between seismic and geology entities, multidimensional ontology models are construed using fracture network attribute dimensions and their instances. Different data warehousing and mining are added support to the management of ontologies that can bring the data instances of fractured shales, to unify and explore the associativity between high-dense fractured shales and their orientations.

The models depicting collaboration of geology, geophysics, reservoir engineering and geo-mechanics entities and their dimensions can substantially reduce the risk and uncertainty involved in modelling and interpreting shale- and tight-gas reservoirs, including traps associated with Coal Bed Methane (CBM). Anisotropy, Poisson's ratio and Young's modulus properties corroborate the interpretation of stress images from the 3D acoustic characterization of shale reservoirs. The statistical analysis of data-views, their correlations and patterns further facilitate us to visualize and interpret geoscientific metadata meticulously. Data geo-science guided integrated methodology can be applied in any basin, including frontier basins.

64: Big Data guided digital petroleum ecosystems for visual analytics and knowledge management

Dr Shastri Nimmagadda[1], Mr Andrew Ochan[2], Dr Neel Mani[3] and Dr Dengya Zhu[1]

[1] Curtin University
[2] PAU
[3] Amity IT

The North West Shelf (NWS) interpreted as a Total Petroleum System (TPS), is Super Westralian Basin with active onshore and offshore basins through which shelf, -slope and deep-oceanic geological events are construed. In addition to their data associativity, TPS emerges with geographic connectivity through phenomena of digital petroleum ecosystem. The super basin has a multitude of sub-basins, each basin is associated with several petroleum systems and each system comprised of multiple oil and gas fields with either known or unknown areal extents. Such hierarchical ontologies make connections between attribute relationships of diverse petroleum systems. Besides, NWS has a scope of storing volumes of instances in a data-warehousing environment to analyse and motivate to create new business opportunities. Furthermore, the big exploration data, characterized as heterogeneous and multidimensional, can complicate the data integration process, precluding interpretation of data views, drawn from TPS metadata in new knowledge domains. The research objective is to develop an integrated framework that can unify the exploration and other interrelated multidisciplinary data into a holistic TPS metadata for visualization and valued interpretation. Petroleum digital ecosystem is prototyped as a digital oil field solution, with multitude of big data tools. Big data associated with elements and processes of petroleum systems are examined using prototype solutions. With conceptual framework of Digital Petroleum Ecosystems and Technologies (DPEST), we manage the interconnectivity between diverse petroleum systems and their linked basins. The ontology-based data warehousing and mining articulations ascertain the collaboration through data artefacts, the coexistence between different petroleum systems and their linked oil and gas fields that benefit the explorers. The connectivity between systems further facilitates us with presentable exploration data views, improvising visualization and interpretation. The metadata with meta-knowledge in diverse knowledge domains of digital petroleum ecosystems ensures the quality of untapped reservoirs and their associativity between Westralian basins.

65: Optimizing land seismic acquisition for modern noise suppression in processing

Mr Graeme Eastwood[1] and Mr Christof Stork[1]

[1] Land Seismic Noise Specialists

Noise, particularly distortion of signal, is often the dominant problem with land seismic data and much data redundancy and expense is incurred during acquisition to address noise issues. Acquisition must sample the subsurface sufficiently that noise can be effectively handled during processing, particularly when using powerful new noise removal algorithms that take advantage of noise sparsity. This is especially important for shallow scattering noise, being difficult to sample unaliased. New algorithms, using the same principals as compressive sensing, utilize sparsity to handle aliased noise, so optimizing acquisition for these algorithms is, effectively, compressive sensing for the noise.

Modern dense acquisition helps with noise removal, but alone does not solve the whole problem because the noise can have very short wavelengths, tight sampling doesn't solve signal distortion, some noise doesn't require ultra-dense sampling and the gain from signal-to-noise ratio diminishes as we increase fold. However, this dense acquisition does provide flexibility to optimize seismic acquisition to aid processing.

In terms of handling noise issues inherent in seismic data, the success of any acquisition-processing combination is based on several factors - the amplitude of the noise relative to signal, the types of noise observed, the multi-dimensional sampling of the noise, the ability of processing algorithms to address the noise and the seismic objective (frequency, inversion, AVO, subtle faults, complex structure).

Seismic noise and energy transmission vary dramatically by frequency. At low and high frequencies , data are often more than 10 times noisier than in the prime frequency range. Moreover, the noise at different frequencies can have vastly different characteristics. Low frequencies are often affected by trapped surface waves and macro-scattering while higher frequencies are affected by guided waves and micro-scattering. We cannot eliminate this noise in acquisition, but we can record the data sufficiently well to aid removing it in processing.

66: Interpretation of magnetotelluric and airborne electromagnetic inversions from the Proterozoic basins of the Capricorn Orogen, WA

Dr Sasha Banaszczyk[1,2], Prof Mike Dentith, Dr Perla Piña-Varas[3,4,1,2] and Dr David Annetts[5]

[1] Centre for Exploration Targeting
[2] The University of Western Australia
[3] Dinàmica de la Terra i dels Oceans
[4] Universitat de Barcelona
[5] CSIRO Mineral Resources

The Bryah and Yerrida Basins of the Capricorn Orogen, WA, comprise sedimentary sequences that are prospective for base metals and which can be mapped using airborne electromagnetic (AEM) and magnetotelluric (MT) techniques. A regional MT survey (50 km – 100 km station-spacing) and a regional AEM survey (5 km line-spacing) have been acquired across the Capricorn Orogen for this purpose. Unfortunately, the AEM and MT surveys provide information at vastly different scales (local-basin versus orogen, respectively), which, in addition to the paucity of MT data, complicates comparisons between the two datasets. Indeed, few studies compare AEM and MT results and interpretations thereof, particularly within prospective sedimentary basin terrains. Two newly acquired MT survey lines proximal to several Capricorn Orogen AEM survey lines over the

Bryah and Yerrida Basins provide an opportunity to evaluate the electromagnetic responses from the near surface and deeper sedimentary basin packages. In this research we produce new 3D MT and 1D AEM inversions of these survey responses and jointly interpret the two inversion types in conjunction with recent geological interpretations of the Bryah and Yerrida Basins. The new MT and AEM inversions resolve detailed local-scale faulting and folding of the Yerrida Basin sediments, and the northern contact of the Bryah and Yerrida Basins with the Archean Marymia Inlier as a resistor where previous regional-scale MT results have recovered this contact as a conductive linear feature. However, inversions over potentially conductive shales and siltstones within the Bryah Basin are inconclusive due the geological and electrical complexity of the deformed Bryah Basin sediments, which are poorly resolved in the new 3D MT inversions.

69: A method for the downward continuation of gravity data using Padé approximation

Dr Chong Zhang, Prof Qingtian Lü, Dr Wenna Zhou and Prof Jiayong Yan

Downward continuation which can enhance weak information of the data is useful to process gravity anomaly data. Because of its inherent instability, methods that are performed directly in the wavenumber or the space domain are not popular anymore. We present a stable and accurate downward continuation method of gravity anomaly data using Padé approximation expansion with the derivatives calculated by the ISVD method in the wavenumber and space domains. Because the Padé approximation is a sum of polynomials in the formation of a rational function, whose possible degree is infinite, we limit the highest degree for downward continuation. Apart from the Padé method with the derivatives calculated by the ISVD method, the Taylor method with the derivatives calculated by the FFT and the Taylor method with the derivatives calculated by the ISVD are also used for comparison in our article. Tested on the synthetic model, the Padé method is more accurate than the other two methods with the same summation degrees. Besides, the proposed method is applied to a real example with airborne gravity data and we obtain reliable results. It demonstrated that the Padé approximation can be used to downward continue precise and stable results, which might be used to identify geological structures of mineral systems.

72: 3D Modelling and synthesis of geophysical data in Nash Creek, New Brunswick, Canada

Mr Alexander Furlan[1], Mr Hernan Ugalde[2,1], Mrs Alzbeta Ondercova[3] and Prof Bernd Milkereit[3]

[1] Brock University
[2] Dip Geosciences
[3] University of Toronto

'Hotspot' geophysical exploration has passed its zenith. In areas like New Brunswick, where this exploration style has been successful, deposits with a more complex signature have been left behind. Using improved computational power and geophysical modelling, deposits like those found at Nash Creek can be reinvestigated. Nash Creek hosts a Zn-Pb-Ag deposit on the western limb of the Jacquet River Syncline and is truncated by the N-S trending Black Point Arleau Brook (BPAB) Fault. While regional mapping was the goal, the Archibald Settlement and Sunnyside formations which host the deposit were looked at more in depth as well. Previously collected geophysical surveys, surficial mapping efforts, borehole logs, petrophysics, and local perspective were all considered in the modelling process. Using this information, 2D cross sections were created of the survey area. These sections were employed to match geophysics first and elucidate what could be modellable. These sections were then used to derive a 3D geological model that was supported by geophysical data rather than derived from it. This model was inverted to investigate the optimized subsurface structure. The final model and inversion had mixed results. While a regional model could not be derived, BPAB fault and the Archibald Settlement formation were discerned to a reasonable degree. The Archibald Settlement formation had a distinct contrast with the surrounding units which was clear in the inverted data. BPAB fault was found to have a steep (70-80°) westward dip, unlike previous research which suggested a near vertical or eastward dip. It is recommended that a more extensive survey be conducted with the express purpose of constraining the fault. An E-W seismic survey would provide both overburden thickness and fault structure over Nash Creek.

78: Vertically integrated geoscientific data at the Geological Survey of New South Wales

Dr Ned Stolz[1]

[1] ASEG

The Geological Survey of New South Wales (GSNSW) has a vertically integrated structure for geophysics data and products. Raw geophysics data are directly acquired through regional scale surveys such as the Cobar AEM; statewide and national surveys such as AusLAMP; laboratory measurement of petrophysics properties; and harvesting of industry geophysical data submitted with annual exploration licence reporting. These data are compiled, quality assured and catalogued in a repository for delivery to clients via the GSNSW MinView web-based search and delivery tool. GSNSW geoscientists subsequently synthesise the data into a range of products including statewide merges, structural interpretations, 2D and 3D models of geophysical data and ultimately 3D geological models. This presentation will explain the high-level strategy for pre-competitive geophysical data delivery at GSNSW and give some examples of the latest innovative datasets, tools and products.

79: Results from the largest Airborne Electromagnetic (AEM) survey ever flown in NSW

Miss Astrid Carlton[1]

[1] ASEG

In 2019 the Geological Survey of New South Wales (GSNSW) and Geoscience Australia (GA) conducted an AEM surveyover the greater Cobar Basin. This survey was part of NSW's contribution to the National Drilling Initiative (NDI) of the MinEx Cooperative Research Centre.The NDI aims to improve geological knowledge and define the potential for mineral systems in five areas across NSW that are undercover extensions of known mineralised terranes. The Cobar survey is the largest AEM survey ever flown in NSW, covering an area of 19,000 km^2, equivalent to two and a half times the Greater Sydney area. Under the guidance of experts from GA, an team of GSNSW geoscientists has interpreted these data. They have mapped conductive saprolite, faults, aquifers, groundwater, bedrock conductors associated with possible mineralisation, palaeo-channels and anthropogenic anomalies. The geological interpretation has utilised GA layered Earth inversions, probabilistic inversions and 2-5D inversions. AEM conductivity–depth sections were integrated with drilling information and other datasets using 3D geological modelling applications. This presentation will summarise results from an interpretation report released earlier this year.

80: The North Australian Craton 3D gravity and magnetic inversion models - A trial for first pass modelling of the entire continent

Dr James Goodwin[1] and Mr Richard Lane[1]

[1] Geoscience Australia

As part of the Exploring for the Future initiative, whole-of-crust 3D gravity and magnetic inversion models have been produced for an area encompassing the North Australia Craton (NAC). These models were created to aid 3D geological mapping and identification of large-scale mineral systems such as iron oxide copper-gold (IOCG) systems.

The inversion models were derived using the University of British Columbia Geophysical Inversion Facility (UBC-GIF) MAG3D and GRAV3D programs. We used reference models that had layers for Phanerozoic sediments, Proterozoic sediments, undifferentiated crust and the mantle. The reference model for the magnetic inversion incorporated a Curie depth surface below which magnetic susceptibility was set to zero.

To facilitate cross-referencing of the density and magnetic susceptibility models, we used identical meshes for the two inversions. The spacing of the available gravity data dictated a horizontal cell size of 1 km. We used 61 vertical layers of thickness increasing with depth. The area of interest was 2450 km by 1600 km which meant that the mesh for the NAC models had ~240 million cells.

It was not possible to invert a model of this size. Instead, we broke the problem down into a grid of overlapping "tiles" with 8 rows and 10 columns. Each tile was independently inverted.

When the overall model was reconstructed using the core region of each tile, some low-level edge effects were observed, increasing in significance with depth. These effects were satisfactorily attenuated by applying cosine weighting from the centre of each tile out to the edge of the data padding zone during reconstruction.

The success of the NAC modelling exercise has given us confidence that we can expand the coverage to produce coincident gravity and magnetic inversion models for the entire Australian region.

81: Towards a 3D model of the South-Nicholson Basin region, Northern Australia, for mineral, energy and groundwater assessment

Dr Nadege Rollet[1], Dr Michael Doublier[1], Mr Chris Southby[1], Mr Ross Costelloe[1], Dr Tanya Fomin[1], Ms Lidena Carr[1], Dr Marie-Aude Bonnardot[1], Dr John Wilford[1], Mr Sebastian Wong[1], Mr Malcolm Nicoll[1], Dr Karol Czarnota[1], Dr Donna Cathro[1] and Mr Stephen Hostetler[1]

[1] Geoscience Australia

The Exploring for the Future Programme facilitated the acquisition of major geoscience datasets in northern Australia, where rocks are mostly undercover and the basin evolution, mineral, energy and groundwater resource potential are, in places, poorly constrained. In an effort to support sustainable, regional economic development and build stronger communities in these frontier areas, integration of new and legacy data within a consistent sub-surface platform could enhance the recognition of cross-disciplinary synergies.

Here we present a case study in the South-Nicholson Basin, located in a poorly exposed area between the highly prospective Mt Isa Province and the McArthur Basin. Both regions host major base metal deposits, contain units prospective for hydrocarbons, with significant groundwater resources in the overlying Georgina Basin. In this study we interpret a subset of new large-scale data, which include ~1 900 km of deep seismic reflection data and 60 000 line kilometers of AusAEM1 airborne electromagnetic survey, with legacy information and new tools. This interpretation refines a semi-continental geological framework, as input to national coverage databases and inform decision-making for exploration and groundwater resource management.

This study provides a 3D chronostratigraphic cover model down to the Paleoproterozoic basement. We mapped the depth to the base of geological eras, as well as deeper pre-Neoproterozoic Superbasin sequence boundaries to refine the cover model. The depth estimates are based on the compilation, interpretation and integration of geological and geophysical datasets that inform on the basement architecture control on the basin evolution with the key outcomes:

1) expanded the size of the basin, increasing prospectivity for hydrocarbons and basin-hosted mineralisation, 2) correlation of stratigraphic units across the region, 3) identified major crustal boundaries and structures associated with localisation of springs and mineralisation resulting from crustal fluid flow, 4) support future investigation of groundwater resources in shallow and deeper aquifers.

82: Overburden measurement for coal mine management with 3D high resolution compressional and shear velocity seismic inversion

Dr Claudio Strobbia[1], **Mr Martin Bayly**[2], Dr Tim Dean[3], Mr Denis Sweeney[2], Mr Matthew Grant[3] and Mrs Margarita Pavlova[3]

[1] Realtimeseismic
[2] SuperSeis
[3] BHP

High resolution surface seismic surveys can provide useful images of coal bed reflections to depths as shallow as 50 to 100 metres. There is also a need, to gain information of the overburden properties above these depths. This information gap can be addressed by inversion of both the refractions and surface waves ('ground-roll', normally considered to be noise) generated along with reflections as part of the regular survey acquisition. Recent advances in acquisition such as finer spatial sampling, single sensor recording and lower frequency vibroseis sweeps all serve to improve the quality and utility of these data.

In addition to their direct use to infer the petrophysical and hydrodynamic properties of the overburden prior to stripping and mining, the results can be used in reflection seismic imaging. As the compressional velocity (Vp) result is in depth, it can be used for both statics computation and directly as the shallow part of a depth imaging velocity model where reflection-based velocity derivation is poor. The shear velocity (Vs) information can also be used to create a model for subtractive attenuation of the ground-roll for subsequent reflection imaging.

This paper demonstrates how detailed 3D volumes of both Vp and Vs velocities have been co-operatively inverted from diving and surface waves respectively, directly into the depth domain over coal mining leases in Queensland, Australia.

83: A time-lapse feasibility workflow incorporating core calibrated 4D rock physics models

Mr Christian Proud[1] and Mr Rob Ross[1]

[1] Qeye

Proud et. al. (2020) demonstrated the (frequently neglected) effect of pressure depletion on the 4D seismic response.

The pressure response is a combination of the change of fluid properties with pressure and the change of matrix properties with pressure.

THe pressure effects are seen to be significant in the reservoirs investigated.

In this paper the authors extend this work with reference to empirical models we illustrate how this method can be applied if core calibration is not available and draw conclusions on the uncertainty in the pressure effect modelling.

85: Digitalizing the mining industry - 3D scanning of core trays to produce volumetric bulk densities

Mr Mikael Arthursson[1], Mrs Annelie Lundström[2] and **Mr Angus Tod**[1]

[1] Minalyze Pty Ltd
[2] Minalyze AB

Minalyzer CS is a scanner which in a contactless non-destructive way generates geochemistry, high-resolution images, rock quality designation (RQD), structures, specific gravity and bulk density for drill cores and other drill samples.

The patented scanner is designed for handling large volumes of drill samples and is capable of scanning drill cores directly in core trays. A laser (LiDAR) generates a 3D-model of the topology of the core and trays, enabling the control and precision of the continuous XRF scanning. RQD and structures are also be derived based on the 3D-model.

The objective, continuous and consistent nature of the datasets and the high but compact data density generated by the scanning technology is paramount in machine learning and deep learning applications and approaches to geology. Machine learning and deep learning have been demonstrated to be effectively used, based on the data from the scanning, for prediction of host rock lithologies.

A cloud-based software www.minalogger.com for visualisation and generation of datasets through digital tools facilitates remote access to a digital version of the drill sample. Remote access to data has become critical in order to keep project and operations moving forward when travel has become impossible and/or risky due to the pandemic.

The bulk density can be derived based on measured volume from the LiDAR, combined with the weight of the core tray. The method is suitable for friable sediment core where a true representation of the friable sample through manual measurements and estimates can be error prone. The new method has been tested and applied in live application by Iron ore companies in Western Australia where extensive comparisons between the new method and the traditional have been made. The method has also been tested on known volumes and densities for verification and demonstrate both a high level of repeatability and accuracy.

86: Quantifying uplift using compaction methods; A case study from the Exmouth Plateau, Northern Carnarvon Basin

Mr Patrick Makuluni[1], Dr Juerg Hauser[2], Dr Laurent Langhi[3] and Dr Stuart Clark[4]

[1] School of Minerals and Energy Resources, University of New South Wales, Sydney, Australia
[2] CSIRO Minerals
[3] CSIRO
[4] UNSW

Uplift events have caused the failure of hydrocarbon seals resulting from subsequent deformation and fault development or reactivation. On the other hand, escaping hydrocarbons from the breached seals may accumulate in new traps, and fracturing of brittle reservoir rocks during uplift enhances reservoir productivity. These and other factors justify the importance of quantifying and constraining the distribution of uplift within sedimentary basins for hydrocarbon exploration purposes. Multiple studies have discovered evidence of uplift in the Exmouth Plateau of the Northern Carnarvon Basin; however, the temporal and spatial distribution of this uplift has not been fully quantified. Common methods use sediments' thermal properties to estimate maximum burial depth and subsequently quantify and constrain sediment uplift. However, these thermal-based methods lack accuracy where sediments have been heated by magmatic intrusions, for example, the Triassic Mungaroo formation sediments in the Northern Carnarvon Basin. In this work, we use compaction-derived methods to quantify and constrain the distribution of uplift and its impact on the hydrocarbon systems in the Exmouth Plateau, Northern Carnarvon Basin. We used porosity data (corrected for digenesis) from 68 wells of the Australian National Offshore Petroleum Information Management System (NOPIMS) to accurately estimate maximum burial depths and subsequently estimate uplift. Results indicate larger uplift (up to 1.4km) in the central and southwestern part of the Exmouth Plateau from mid-Triassic to the present. The spatial distribution of uplift correlates with the distribution of magmatic intrusions in the region. We suggest that, in addition to compression, the multiple Late Triassic to Early Cretaceous rifting events in the Northern Carnarvon Basin triggered magmatic intrusions that produced permanent uplift. Uplift results from Vitrinite Reflectance are slightly higher than those from compaction-based methods, suggesting extra heat input from these intrusions. This uplift majorly controlled the distribution of Jurassic source rocks in the Northern Carnarvon Basin.

87: Automated facies classification in borehole log data

Dr ROMAN BELOBORODOV[1], Dr James Gunning[2], Dr Marina Pervukhina[3], Dr Michael Ben Clennell[2], Dr Irina Emelyanova[2] and Dr Juerg Hauser[4]

[1] CSIRO Deep Earth Imaging Future Science Platform
[2] CSIRO Energy
[3] CSIRO
[4] CSIRO Minerals

Solving geophysical inverse problems typically involves supplying prior information to tackle the non-uniqueness and tighten the distribution of possible solutions. A library of rock physics models is a very specific type of prior information that is for example required in seismic inversion algorithms that simultaneously recover facies distributions and physical rock properties (e.g. Joint Impedance and Facies inversion). Among the features captured by these models are the depth dependency of rock properties and associated uncertainties. But where do these rock physics models come from and how can we derive their parameters objectively? In this work, we approach rock typing (i.e. rock physics model selection) and fitting of property depth trends as a joint problem. In our rock physics models, we account for the depth dependency of common petrophysical properties due to compaction and diagenetic effects such as cementation, variable clay content, and overpressure. Rock type-specific depth trends are modelled by the most appropriate rock physics model selected from the supplied library. The joint problem is solved using the Expectation Maximisation algorithm which simultaneously performs classification of the supplied borehole data into the rock types and fitting of the selected models. In this manner, the identified facies for an appraisal well in the North West Shelf of Australia are consistent with the geological interpretation and rock physics model trends accurately fit them. Further to this the selected and fitted rock physics models also capture the stiffening of the shales with depth which is a known feature of the rocks in this region. Our results emphasise the objectivity of our approach, its ability to capture the underlying geology, and illustrate its direct relevance for downstream seismic inversion algorithms.

88: New mineral system vectors for revitalised copper-gold discovery in the Gawler Craton

Mr John Anderson[1]

[1] GSA

The combination of a new strato-tectonic model for the Olympic Metallogenic Event (OME) and zircon-based geochemical tool is a significant step-change for ore vectoring for a spectrum of IOCG and coeval deposit styles in the Gawler Craton.

The revised model proposes the Paris-Nankivel epithermal-porphyry belt is formed at the same time as Olympic Dam on the margins of a super caldera filled with upper Gawler Range Volcanics (GRV). Prior subduction tectonics produced precursor epithermal-porphyry conditions on the southern shoulder of the caldera, whereas IOCGs formed on the northern and eastern margins with haematite- or magnetite-dominated systems respectively forming on the shoulder or in hotter more reduced conditions under the GRV blanket within the caldera.

The epithermal/porphyry and IOCG belts are both fluorine-anomalous and connected by a conductive magneto-telluric corridor proposed as a fossil transfer fault and metal source along the mantle interface.

A stratigraphic marker of the caldera collapse enables correlation of the spectrum of mineral systems including conglomerate facies that collapsed into IOCG systems.

The Zircon Alteration Index (ZAI = 40 – Zr/Hf) is a robust search tool that is universally applicable to the OME spectrum of deposit styles and hosts requiring less assay samples and drilling for future targeting. The exclusive association of Hf with Zr in zircon enables wholerock analysis of the Zr/Hf ratio to measure the amount of hydrothermal overprinting of the inherited volcanic or detrital zircon in a host rock and hence proximity to a mineral target. Downhole variation of ZAI and lithologies enables lateral or vertical target vectors to be often added to the proximity measure.

The ZAI Tool and strato-tectonic vectoring have been validated for the Stuart Shelf IOCG systems with a comprehensive study of 35 holes in varying proximities to known IOCG deposits. Preliminary target ranges are assigned to the ZAI values.

89: Constraining gravity inversion with lower-dimensional seismic information: Imaging the eastern Yilgarn Craton

Missmahtab Rashidifard[1], Dr Jeremie Giraud[2,3], Dr Mark Lindsay[4,5], Prof Mark jessell[4,5] and Dr Vitaliy Ogarko[6]

[1] Centre of Exploration Targeting (School of Earth Sciences), University of Western Australia, 35 Stirling Highway, Crawley, WA, 6009, Australia
[2] Centre of Exploration Targeting (School of Earth Sciences), The University of Western Australia, 35 Stirling Highway, Crawly, WA, 6009, Australia
[3] Mineral Exploration Cooperative Research Centre, School of Earth Sciences, The University of Western Australia, 35 Stirling Highway, WA Crawley 6009, Australia
[4] Centre of Exploration Targeting, School of Earth Sciences, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia
[5] Mineral Exploration Cooperative Research Centre (MinEx CRC), School of Earth Sciences, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia
[6] International Centre for Radio Astronomy Research, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia

Boundary parametrization of the subsurface from geological observations and geophysical inversions is one of the main goals of 3D geological modelling. Several approaches have been developed for geometric inversion and joint inversion of geophysical datasets. However, the robust, quantitative integration of models and datasets with different spatial coverage, resolution, and levels of sparsity remains challenging. One promising approach for recovering the boundary of geological units is the utilisation of potential field level-sets inversion method. We focus on constraining 3D gravity inversion with sparse 2D seismic images that allow us to account for uncertainty in interpretations.

We use a level-set approach to recover the geometry of an arbitrary number of geological bodies using data from the geologically complex Yamarna terrane (Yilgarn craton, Western Australia). The study focuses on the eastern zone of the area which characterise the granite-greenstone association. In this study, 2D seismic sections have been used for constraining the location of rock unit boundaries being solved during the 3D gravity geometric inversion. The proposed work is the first we know of that proposes a 3D level-set inversion considering different geophysical datasets with different spatial coverage. In the proposed method, the utilisation of seismic data results in a reduction of the ill-posedness of the gravity inversion problem by creating a model consistent with images provided by sparse seismic sections. It also allows interpolating seismic information away from the 2D lines consistently with gravity measurements.

In many hard-rock geoscientific investigations, seismic data is sparse and our results indicate that unit boundaries from gravity inversion can be very well constrained with seismic sections sparsely distributed within the model. Thus, we conclude that it has the potential to bring the state of the art a step further towards building a 3D geological model incorporating several sources of information in similar regions of investigation.

91: Australian geomagnetic observatory network monitors space weather hazard – 180 years on

Dr Liejun Wang[1], Mr Andrew Lewis[1], Mr Bill Jones[1], Mr Jingming Duan[2], Dr Adrian Hitchman[1] and Mr Matthew Gard[1]

[1] Geoscience Australia
[2] Mineral Systems Branch, Geoscience Australia

Geoscience Australia's geomagnetic observatory network covers one-eighth of the Earth. The first Australian geomagnetic observatory was established in 1840 in Hobart. This almost continuous 180 year period of magnetic-field monitoring provides an invaluable dataset for scientific research.

Geomagnetic storms induce electric currents in power lines, causing instabilities and sometimes blackouts in electricity transmission systems. Power outages to business, financial and industrial centres cause major disruption and potentially billions of dollars of economic losses. The intensity of geomagnetically induced currents is closely associated with geological structure.

Geomagnetic storm events across three decades have been analysed to develop a statistical model of geomagnetic storm activity in Australia and the model used to predict the intensity of geomagnetically induced currents (GICs) in Australia's modern-day power grids. Modelling shows the induced electric fields in South Australia and Victoria caused by an intense magnetic storm in 1989. Real-time forecasting of geomagnetic hazards using Geoscience Australia's geomagnetic observatory network and AusLAMP magnetotelluric data helps develop national strategies and risk assessment procedures to mitigate space weather hazard.

95: Transformative geophysics: Alternatives to the reduction-to-pole transformation of magnetic data

Prof Richard Smith[1]

[1] Laurentian University

Magnetic data is difficult to interpret due to the bipolar nature of the anomalies, as there is generally a high and a low associated with each source body, or source edge. Further, the relative sizes of these highs and lows varies depending on the magnetic latitude or inclination of the Earth's field. There are two common methods of dealing with this issue, one is to mathematically transform the data to what it would be if the survey were at the magnetic pole, but this process can be unstable at low magnetic latitudes or the transformation is of little value if remanent magnetization adds a dipolar anomaly that is not in the assumed direction. The second method is to transform the data to the analytic-signal amplitude (ASA), which creates a monopolar feature for each body (or edge) and the shape of the feature is independent of remanent magnetization in any direction. However, the ASA anomaly can appear broader than the total-field anomaly, so features sometimes merge together on map views. It is possible to further transform the ASA to the total field of a body that is at the pole and has a vertical dip, using an appropriate local phase or tilt angle. The transformation is exact for contacts when calculated from the first-order ASA (calculated from the vertical and horizontal derivatives), but there are issues with the sign of the transformed data depending on whether you are over one edge or the other edge of a discrete source body. However, an approximate transformation of the zeroth-order ASA does not have this issue and gives good results on synthetic data if the noise in the local phase is handled appropriately. The resulting maps outline the magnetic source bodies and have amplitudes proportional to the magnetic susceptibility.

99: The role of passive seismic imaging in near-mine exploration

Dr Gerrit Olivier[1], Mr Andrew Foley[2], Miss Nicola Ramm[3], Dr Philippe Dales[3], Dr Martin Gal[3], Mr Tjaart de Wit[3,4], Mr Francois Malan and Mr Olaf Goldbach[3]

[1] Institute of Mine Seismology, University of Tasmania, GSA, ASEG
[2] Gold Fields
[3] Institute of Mine Seismology
[4] Colorado School of Mines

The future of the mineral mining industry relies on the ongoing success of exploration projects. In this paper, the use of near-mine passive seismic imaging is discussed as a solution to exploration demands. We explore the issues currently being faced by mines worldwide and the advances in technology that have led to an increase in passive seismic imaging abilities. Traditional shortcomings with passive seismic imaging are presented, along with proposed solutions by utilising these methods specifically in a near-mine environment. We performed a multi-scale imaging experiment at an underground gold mine in Western Australia. Here we installed a dense, temporary surface geophone array and used these stations in conjunction with an existing permanent in-mine seismic array to produce high resolution images adjacent to and below the existing mine. Ambient noise surface wave tomography, reflection seismic and travel time tomography were applied to both the surface and in-mine arrays. The resulting images were used to delineate the orebody near the existing mining infrastructure and to identify drilling targets below and adjacent to the current mine. We show that passive seismic methods have the potential to reduce the amount of drilling needed for mineral deposit detection and delineation.

100: A regional marker tool for the Walloon Coal Measures (Surat Basin) using detrital zircon U-Pb geochronology

Dr Pascal Asmussen[1,2], Dr Oliver Gaede[2], Dr Thomas Flottmann[3] and Mr Brett Pidgeon[3]

[1] University of Queensland
[2] Queensland University of Technology
[3] Origin Energy

The coal seams within the Walloon Coal Measures (WCM, Surat Basin, Australia) are a significant target for Coal Seam Gas (CSG) production and the identification of the boundary with the overlying Springbok Sandstone (SST) is critical to the stratigraphic framework of the basin, as well as the identification of groundwater flow units potentially associated with this boundary. Identification of the contact on a local (tenement) and regional (basin) scale between the SST and WCM is challenged by (i) overall lithological similarity of the units (macro- and microscopically, whole rock geochemistry, wireline signature), (ii) lateral heterogeneity of lithologies on a regional scale due to lateral facies and depositional environment variation in the uppermost WCM and lowermost SST and (iii) lack of consistent regional stratigraphic markers like erosion surfaces or correlated tuff beds. Sediment provenance analysis via detrital zircon U-Pb geochronology allows to constrain spatial and temporal changes in sediment provenance by sampling across stratigraphic units along a lateral transect. Here we present the results of detrital zircon distributions from 27 samples that were sampled from four wells along a 300 km transect from the eastern Eromanga Basin to easternmost extent of the Surat Basin. Our data show a brief pulse of basement derived material at the base of the SST which is interrupting the volcaniclastic dominated sediment provenance in the SST and WCM. This brief change in zircon provenance is interpreted as a precursor to fluvial dominated environments in the SST and can be utilised as a regional marker across the Surat and Eromanga basin, suggesting a potential change in source provenance and basin dynamics associated with the SST – WCM boundary.

102: Knowledge-guided machine learning for komatiite-hosted nickel prospectivity mapping

Mr Minsu Kwon[1]

[1] ENERZAi

Thanks to the brilliant progress in machine learning, many research works have conducted data-driven mineral prospectivity mapping. However, it is challenging to integrate highly multidisciplinary geoscientific data with machine learning algorithms. Especially, geological data are heterogeneous and non-numerical even though they are crucial for mineral exploration.

In this work, we introduce how to preprocess the geoscientific data and design a machine learning model based on knowledge in order to make the best use of both geoscientific information and the advantages of machine learning. We focus on the region-scale prospectivity mapping for the komatiite-hosted nickel in Yilgarn craton, Western Australia. We extract second and third-order features from geophysical data to enable machine learning models to capture various patterns of mineral deposits. In terms of geology, faults, interpreted geology, and isotopic mapping data are converted into numerical features that could be related to the komatiite-hosted nickel deposits. Based on domain knowledge, we design a deep learning model that systemically combines geophysical and geological features. First, our model generates a feature map and initial prospectivity map using geological data and geophysical worms which could reveal the crustal structures. Next, the model produces a final prospectivity map that delineates potential komatiite-hosted nickel deposits using whole data including geophysics. The model is trained with the locations of the known nickel deposits.

We divide the Yilgarn craton area into a train and test region to validate our model. We adopt the AUC score and prospectivity score percentile of known deposits to evaluate our model in various aspects. Our model achieved a high AUC score and percentile score and it can be efficiently used for early-stage nickel exploration. The suggested workflow could be applied to the exploration of the other mineral types with a slight modification reflecting the characteristics of the mineralizations.

103: An automated system for preventing hydraulic vibrator tip-over during land seismic surveys

Mr Richard Barnwell[1], Mr Damien Barry[1], Miss Megan Nightingale[1], Dr Tim Dean[2], Mr Hagay Haviv[2] and Mr John Giles[3]

[1] Terrex Seismic
[2] BHP
[3] Seismic Source

Hydraulic vibrators are the preferred source for land seismic surveys. The energy from the vibrator's signal (commonly referred to as a sweep) is transmitted into the ground via a baseplate that is coupled to the surface by loading it with the weight of the vehicle. The baseplate is lowered into position by a stilt structure which continues to apply hydraulic pressure to ensure that the baseplate does not become decoupled from the surface during the sweep (the ground beneath the baseplate often becomes slightly compacted). If the vibrator is operated on a slope, or if the ground gives way in a significant and uneven manner, then the vibrator can continue to extend the stilt structure which in extreme cases can cause the vibrator to tip-over.

In this paper we describe a system developed by Terrex and Seismic Source, consisting of two inclinometers and an articulation sensor that can be fitted to a vibrator to automatically retract the baseplate when the vibrator becomes overly-tilted. The system was recently deployed on a large 3D survey consisting of over 100,000 source points. Of these source points, 171 were skipped due to the tilt of the vibrator exceeding the safe limit. Analysis of a LiDAR dataset showed that of these 171 points, less than 3.5% of crossline and 3.1% of inline dips exceeded this safe limit. Indicating that if the LiDAR data had been utilised during the planning phase of the survey the majority of these positions would not have been excluded.

The success of the system on this initial survey has led to it being adopted throughout the Terrex fleet

107: A brief history of 3D seismic acquisition in BHP Coal and some predictions for the future

Dr Tim Dean[1], Mrs Margarita Pavlova[1] and Mr Matt Grant

[1] BHP

BHP Coal acquired their first 3D seismic survey in 1998 at the Goonyella mine site. The survey covered an area of 1.6 km^2 and utilised a 360 channel cabled recording system and an explosive source to record 15 fold data. Since then BHP has acquired an additional 25 3D surveys across its various coal assets.

In this paper we show how 3D seismic surveys have changed over the years, both at BHP coal and within the larger context of general developments in land seismic technology. Such developments include the move from arrays to point receivers, from explosive to Vibroseis sources, and from coarse geometries aimed at defining structure, to higher-density geometries giving far higher-resolution results as well as being suitable for more advanced quantitative analysis. As well as discussing the changes in acquisition parameters over the years we also show data comparisons that show their impact.

We finish by discussing the latest advances in seismic acquisition and how we see these improving Coal 3D seismic surveys in the future.

108: Automated fracture detection and characterisation from unwrapped drill-core images using Mask R-CNN

Miss Fatimah Al-zubaidi[1], Mr Patrick Makuluni[1], Dr Stuart Clark[2], Dr Jan Erik Lie[3], A/Prof Peyman Mostaghimi[1] and A/Prof Ryan Armstrong[1]

[1] School of Minerals and Energy Resources, University of New South Wales, Sydney, Australia
[2] UNSW
[3] Lundin Energy Norway AS, Lysaker, Norway

Drill cores provide the most reliable fracture information in subsurface formations as they present a clear and direct view of fractures. Core observation and image log interpretation are usually integrated for fracture analysis of underground layers. There has been a strong move towards developing automated fracture detection methods, however, the focus has been on extracting fracture information from log images, such as acoustic or resistivity image logs. Such efforts using core images are significantly less. This study presents a machine learning-based approach for automatic fracture recognition from unwrapped drill-core images. The proposed method applies a state-of-the-art convolutional neural network for object identification and segmentation. The study also investigates the feasibility of using synthetic fracture images for training the model by creating two types of synthetic data using masks of real fractures and creating sinusoidal shaped fractures. The trained model is then used to detect fractures in real core images from two different boreholes and achieved a precision of 94.80%. The identified fractures are further analyzed and compared to manually segmented fractures in terms of fracture dip angle and dip direction, which achieved average absolute errors of 2.18° and 10.58°, respectively. Overall, the study presents a novel application of an advanced machine learning algorithm for fracture detection and analysis from unwrapped core images.

109: Geophysical proxies for redox gradients in IOCG systems: Cloncurry District, Qld, Australia

Dr James Austin[1], Dr Tobias Schlegel[1], Mr Andreas Bjork[1] and Dr Clive Foss[1]

[1] CSIRO Mineral Resources

Geophysical signatures in and around iron oxide-copper-gold (IOCG) deposits are frequently associated with changes in redox. IOCG systems, in a geophysical sense, include a spectrum of styles from reduced, pyrrhotite-dominant examples, sometimes referred as iron sulphide copper-gold (ISCG) deposits, to intermediate, magnetite-pyrite dominant, and more oxidised, hematite dominant lithologies. Magnetite-rich IOCG deposits, such as Osborne are relatively geophysically simple, commonly displaying coincident reduced to pole (RTP) magnetic and gravity anomalies. In pyrrhotite-rich systems such as Eloise, remanent magnetisation may cause offsetting of the RTP magnetic anomaly relative to the associated gravity anomaly. In hematite-rich systems such as Starra the magnetic signature may be subdued or even absent where bulk hematite is of primary, hypogene origin. Whilst these basic geophysical principles are accepted, the recognition of redox gradients within mineral systems is more meaningful and can be related to geochemical processes involved during mineralisation. Redox gradients have predictable geophysical signatures, but direct targeting of redox gradients using integrated petrophysical and geophysical methods still is not common in IOCG exploration.

Systematic, scale integrated petrophysical data (including density, magnetic susceptibility, remanent magnetisation, radiometrics and conductivity), mineralogical, and geochemical data were collected from twenty-three deposits and prospects as part of the Cloncurry METAL project. The data from numerous sites show clear relationships between redox gradients, indicated by transitions between pyrrhotite, magnetite and hematite bearing lithologies, and steep gradients in magnetic susceptibility and/or remanent magnetisation. Moreover, coincident Uranium-radiometric spikes were shown to highlight zones of complex mineralogy related to transitional redox. This diagnostic radiometric signature together with coincident magnetic gradients provides a more rigid geophysical proxy for differentiation of IOCG related signatures from false positives. Finally, the data provides new insights into economic IOCG mineralisation and new tools for targeting IOCG and related deposits in both surface geophysical and downhole datasets.

111: Environmental site assessment at a mining operation in Western Australia using the Loupe TEM profiling system

Dr Remkevan Dam[1], Mr Greg Maude[1], Mr Brendan Ray[1], Mr Graham Jenke[1] and Mr Russell Mortimer[1]

[1] Southern Geoscience Consultants (SGC)

The Loupe TEM is a transient electromagnetic profiling system for efficient mapping of near-surface ground conductivity. The system is operated by a two-person crew who carry the transmitter coil and 3-component receiver coils on backpacks. Benefits of the system include the high productivity and the ability to survey in various types of terrain and through dense vegetation.

In mid-2020, we utilised the Loupe TEM system in the Pilbara region of Western Australia to investigate potential fluid pathways and contamination around an environmental pond. A total of 23.5 km line kilometres of data was acquired on a dense grid with 20 m line spacing. We used a 75 Hz base frequency and stacked 300 transients to improve the

signal-to-noise ratio. Data were gridded to highlight spatial features and modelled to create conductivity depth images. Supporting information included a frequency-domain EM survey using Geonics EM-34 equipment, passive seismic data obtained using the Sara GeoBox, and information from groundwater monitoring bores.

The results identified various laterally coherent zones with elevated electrical conductivities, some of which related to or appeared to originate from the environmental pond. Features of interest included a shallow clay layer, a likely bedrock shear zone, and possible contamination. The Loupe TEM data correlated well with EM-34 bulk conductivity values, while passive seismic data provided useful supplementary information on bedrock depth. Groundwater sampling data did not always correlate with EM survey results, but without conclusive evidence as to the cause of the discrepancy.

112: The evaluation of alternatives to pre-acquisition positioning for land seismic surveys

Dr Tim Dean[1] and **Mr Matt Grant**

[1] BHP

Accurate positioning for sources and receivers is a fundamental requirement for land seismic survey acquisition. The introduction of 'stake-less navigation' systems, where the vibrator driver uses a GPS guided display to navigate into position, has removed the need for source point surveying, but receiver positioning is still required. Depending on the receiver spacing this tends to take place either on foot or from a vehicle.

The latest generation of self-contained recording nodes include a GPS positioning capability that offers the potential to remove the need to accurately survey receiver positions prior to node planting. There remains a requirement for accurate height, however, that standard GPS devices are not capable of meeting. Airborne Light Detection And Ranging (LiDAR) technology is now well developed and offers a simple way to measure ground elevation across large areas which may meet this requirement.

In this paper we use results from a recent high-density 3D survey to determine the accuracy of node position and LiDAR altitude measurements. Using these results we determine if these measurements are capable of negating the requirement for accurate surveying prior to layout, and how the layout process might change as a result.

113: AIP effects in airborne EM fixed wing systems: A SPECTREM theoretical study

Drand Reaviezzoli[1], Mr Francesco Dauti, Mrs Nirocca Devkurran[2] and Mr Brad Pitts[2]

[1] Aarhus Ge ophysics
[2] Spectrem Air

IP effects can distort airborne EM data, usually producing faster decays and, under certain conditions, changes in signal polarity. These effects, if not recognized and treated with a dispersive resistivity model, often lead to artifacts in the resistivities recovered.

Historically, the IP effects in fixed-wing AEM systems have been put in the "too hard basket". This was mainly due to their geometric configuration (and its monitoring) that prevented unambiguous relation between negative voltages and IP effects. Another deterrent was the high ground clearance, expected to make possible IP effect insignificant. The rapidly accumulating experience on IP effects in helicopter EM systems, however, warrants further research on fixed wing EM and IP. With this work we therefore investigate the fixed wing EM systems sensitivity to induced polarization effects, presenting numerical experiments on the SPECTREM system. We carried out a great number of forward responses, associated with different combinations of Cole Cole parameters in both homogeneous halfspaces and 2 and 3 layered models. The SPECTREM system resulted sensitive to the presence of chargeable material, in several Cole & Cole parameters domains. These effects vary non monotonically with resistivity, and become more marked varying the layering, i.e., adding a purely resistive basement under a shallower chargeable layer. Deep conductors' responses can also be widely affected by shallow chargeable strata.

The result demonstrate that IP effects are, at times, detectable by the fixed wing EM systems. As for the helicopter EM systems, taking IP into consideration during processing and modelling may increase the accuracy of both data and derived resistivities.

114: Impacts of minimum horizontal stress uncertainty on wellbore stability

Mr Matthew Musolino[1], A/Prof Simon Holford[2], A/Prof Rosalind King[1] and Prof Richard Hillis[1]

[1] The University of Adelaide
[2] Australian School of Petroleum and Energy Resources, University of Adelaide, Australia

Accurate estimation of in-situ stress magnitudes is critical for multiple subsurface exploration and development applications, including enhanced recovery and ensuring wellbore stability. Unproductive time related to the aforementioned practices costs operators US $8 billion each year globally. Predictive geomechanical models of stress are typically provided as estimates, and uncertainties are rarely fully quantified. Based on data from the Cooper Basin, Australia, our study examines uncertainty relating to estimates of minimum horizontal stress (Shmin) magnitudes through (a) leak-off test pressure-time curve interpretation and (b) calculation method of Shmin dependent on assumption of tensile or shear failure. The magnitude of Shmin varies considerably at depths of ~900 m, within the Cretaceous Winton Formation. Based on the interpretation of 115 leak-off tests, the range of estimates of Shmin magnitude is 9 MPa. We identify a subset of 23 high-quality tests, which are associated with a narrower range of Shmin estimates (3 MPa). Leak-off tests outside the higher-quality subset were interpreted to suffer from engineering complications. Uncertainties in Shmin quantification also arise relating to interpolation, when determining the data point indicating fracture initiation. Using different techniques to ascertain fracture initiation pressures resulted in a difference of 0.34 MPa Shmin in the Moomba 1well 45 and 0.86 MPa in Moomba 151 at a depth of 911 m. Traditional methods for calculating Shmin magnitude do not allow for the interpretation of a reverse faulting regime. By applying a new approach for Shmin calculation, we observe a 2 MPa increase in the lower bound of Shmin compared to traditional methods at depths of ~900 m. Finally, wellbore breakout models show that at reservoir depths of 2.6 km, a range of mud weights between 8.35ppg and 10ppg are required to avoid breakout, depending on the approach taken for Shmin estimation.

116: Seismic network modelling and design in an interactive web-based environment

Dr Pavel Golodoniuc[1], Dr Januka Attanayake[2], Mr Abraham Jones[2] and Mr Samuel Bradley[1]

[1] CSIRO
[2] University of Melbourne

Detecting and locating earthquakes relies on seismic events being recorded by a number of deployed seismometers. To detect earthquakes effectively and accurately, seismologists must design and install a network of seismometers that can capture small seismic events in the sub-surface.

A major challenge when deploying an array of seismometers (seismic array) is predicting the smallest earthquake that could be detected and located by that network. Varying the spacing and number of seismometers dramatically affects network sensitivity and location precision and is very important when researchers are investigating small-magnitude local earthquakes. For cost reasons, it is important to optimise network design before deploying seismometers in the field. In doing so, seismologists must accurately account for parameters such as station locations, site-specific noise levels, earthquake source parameters, seismic velocity and attenuation in the wave propagation medium, signal-to-noise ratios, and the minimum number of stations required to compute high-quality locations.

AuScope AVRE Engage Programme team has worked with researchers from the seismology team at the University of Melbourne to better understand their solution for optimising seismic array design to date: an analytical method called SENSI that has been developed by Tramelli et al. (2013) to design seismic networks, including the GipNet array deployed to monitor seismicity in the Gippsland region in Victoria, Australia. The underlying physics and mechanics of the method are straightforward, and when applied sensibly, can be used as a basis for the design of seismic networks anywhere in the world. Our engineers have built an application leveraging a previously developed Geophysical Processing Toolkit (GPT) as an application platform and harnessed the scalability of a Cloud environment provided by the EASI Hub, which minimised the overall development time. The GPT application platform provided the groundwork for a web-based application interface and enabled interactive visualisations to facilitate human-computer interaction and experimentation.

117: A beautiful sunset (clause): enhancing statewide geophysics with high resolution company data

Dr Sam Matthews[1]

[1] Geological Survey of New South Wales

Most New South Wales (NSW) airborne geophysical data acquired by industry before 2016 became open file on 1 June 2021 under the NSW Government's Mining Regulation Amendment (2016), which introduced a 5 year 'sunset clause' on confidential company reports. The Geological Survey of New South Wales (GSNSW) has now incorporated the 'new' data into an updated suite of magnetic imagery with much greater anomaly resolution than previous versions. The statewide imagery is based on more than 60 regional government surveys flown at 200–400 m line-spacings. Adding approximately 250 private company surveys flown at 50–200 m line-spacings has improved the image quality and has allowed the data to be gridded at a smaller cell size (25 m vs 50 m) to prevent under-sampling of complex magnetic signatures.

The project started with the quality assurance of more than 800 company geophysical surveys acquired in NSW. An algorithm was derived allowing a quantitative assessment of each survey, which applied a weighted score to aspects such as line-spacing, flight height, sampling interval and survey size. A baseline score was calculated for the previous statewide products based on the regional government surveys. It became the cut-off for the company data, excluding all surveys falling below that mark.

The merged Total Magnetic Intensity (TMI) grid was used as the building block to create a series of enhancements. Reduction to the Pole (RTP), First and Second Vertical Derivative (1VD & 2VD), and tilt angle filters were applied to the data, which were then re-projected into a suite of projections relevant for NSW. The grids were used to create the high-resolution magnetic imagery available on the GSNSW portal – MinView – delivering best-available image resolution statewide, especially in regions with company data. This allows for more comprehensive delineation of magnetic features to aid geological interpretation and geophysical exploration.

118: Structural controls on late Cambrian mineralisation in the Stavely Arc

Dr Robert Holm[1], Mr Chris Cairns[2], Ms Jennifer Murphy[2], Mr Hamish Forgan[2], Dr Michael Agnew[2] and Mr Ian Stockton[1]

[1] CSA Global
[2] Stavely Minerals

The middle-late Cambrian Stavely Arc forms the eastern boundary of the Delamerian Orogen in Victoria, Australia. A pulse of mineralised magmatism at ca. 500 Ma coincided with the collision of VanDieland and related deformation. Porphyry intrusion during this event has previously been inferred, from tectonic reconstructions, to coincide with a change from D1a transpression to D1b transtension, with intrusions having exploited transtensional structures. The outcropping area of the Stavely Arc is a small proportion of the total terrane, and informative outcrops and data are sparse, providing limited supporting evidence to date.

This work presents new insights into the structural geology of the Stavely Arc during porphyry emplacement. A bottom-up approach is informed by structural observations and exploration activity from the Thursday's Gossan-Cayley Lode Project of Stavely Minerals Limited. This data-orientated approach utilises measured structures and assay results from exploration drilling, as opposed to a top-down approach interpreted from the regional geodynamics.

An evaluation of mineralised versus non-mineralised structures was used as a proxy for active versus inactive structures, where active structures represent pathways for migration and deposition of mineralising fluids exsolved from an intrusive porphyry system at depth. Faults and shear zones variably host elevated Cu-Au-As ± Ag ± Ni ± Co dependant on orientation during the porphyry emplacement event; veins do not appear to host substantial metal anomalism.

By comparing the orientations of active versus inactive structures, an overall NW-SE directed axis for maximum compressive stress is interpreted at the time of mineralisation. The results of this work imply that porphyry intrusion and mineralisation occurred within a compressive D1a stress regime, during VanDieland collision, and prior to D1b extensional tectonism. The collision event and associated disruption to subduction zone processes are therefore implicated in triggering porphyry emplacement. These findings will be important for understanding the prospectivity of the Stavely Arc and targeting future exploration activity.

120: Exploring links between thermal maturity and electrical properties of organic-rich shales

Dr Claudio Delle Piane[1], Dr Matthew Josh[2], Dr Julien Bourdet[2], Dr David, N. Dewhurst[2] and Dr M. Ben Clennell[2]

[1] CSIRO Energy, Deep Earth Imaging
[2] CSIRO Energy

The petrophysical signature of organic-rich shales is determined by their mineral and organic matter assemblage and the nature and distribution of fluids in the pore space. Electrical properties have been widely used as an effective proxy for detection of organic matter and hydrocarbons in shales via interpretation of wireline logs. Up to thermal maturities within the oil window, the so-called delta log R method (Passey et al., 1990) is used to estimate organic richness of potential source rocks from the sonic and the resistivity wireline log curves. However, at higher thermal maturities, the organic components of the sediments undergo chemical and structural reorganization involving loss of hydrogen and oxygen and aromatization of the organic component leading to changes in density and to dramatic decreases in electrical resistivity. These influences, especially at thermal maturities consistent with and beyond the gas generation window, are not effectively accounted for in petrophysical log interpretation. It follows that an in-depth understanding of the links between thermal maturity and petrophysical properties is desirable to achieve meaningful interpretation of downhole logs acquired in organic-rich shales spanning a wide range of thermal maturity.

We show examples of hydrocarbon prospective shales characterized through an integrated petrophysical, petrological, and nanoanalytical approach showing how anomalously low resistivity is related to a conductive, connected network of partially graphitised bitumen and not to commonly assumed accessory conductive minerals such as pyrite. This interpretation is verified by several case studies on prospective organic-rich shales that have been exposed to high thermal maturation induced by either deep burial conditions (Appalachian Basin, USA; Sichuan Basin, China), or contact metamorphism (Beetaloo Basin, Australia). These results can help better define prospective areas of hydrocarbon accumulation in sedimentary basins as well as potentially identify false positives in the geophysical signature of mineralization under cover.

121: 3D Bedrock model utilising multi-channel analysis of surface waves to assist the land development industry in greater Melbourne, VIC

Mr Tavis Lavell[1]

[1] GBG Maps Pty Ltd

A common problem across greater Melbourne's expanding land development, both residential and commercial, is encountering sites that have incredibly stiff and undulating bedrock. This is experienced on sites with Newer Volcanic Basalt which accounts for two thirds of greater Melbourne, the weathered profile of these once lava flows produces a highly variable depth and strength bedrock interface.

The acquisition of bedrock survey data has been shown to reduce site uncertainty, unforeseen earthwork costs and financial risk. Working hand in hand with traditional intrusive geotechnical methods, the Multi-channel Analysis of Surface Waves (MASW) method can connect the dots between boreholes generating 2D geological cross-sections of the subsurface. These 2D cross-sections when combined can create a 3D subsurface model of the bedrock.

This data can be presented in a variety of ways, including contour plots in either elevation or depth below ground level (BGL), overlying clay volumetric calculations to user friendly 3D AutoCAD files which can be encompassed with a topography model. Producing a very comprehensive site classification package, a useful tool for the investigatory stage for any land development project.

123: The role of geophysics in the discovery of the Gonneville PGE-Ni-Cu-Co-Au Deposit, Julimar, Western Australia

Mr Jacob Paggi[1], Dr Kevin Frost[2] and Mr Bruce Kendall[2]

[1] Armada Exploration Services
[2] Chalice Mining Limited

The Gonneville deposit is a significant new PGE-nickel-copper-cobalt-gold sulphide deposit discovered by Chalice Mining in 2020. Located only 70 km northeast of Perth, Western Australia, it represents the first major discovery of magmatic sulphide mineralisation within the Julimar Complex, in the newly defined Western Yilgarn Ni-Cu-PGE Province.

Geophysics has played a major role in the initial discovery, delineation and understanding of the Gonneville deposit under lateritic cover. Chalice originally staked the project in 2018 on the basis of a previously unrecognised, 26 km long, mafic-ultramafic intrusive complex interpreted from open-file aeromagnetic surveys. In 2019, a moving-loop electromagnetic survey conducted over a discrete 1.6 km × 0.8 km magnetic anomaly detected multiple EM conductors, some of which were interpreted to represent a massive sulphide source. An RC drilling programme commenced in March 2020, with the first hole drilled into the strongest conductor intersecting massive, matrix and stringer sulphide mineralisation reporting 19 m @ 8.4g/t Pd, 1.1g/t Pt, 2.6% Ni, 1.0% Cu and 0.1% Co from 48 m downhole. Multiple high-grade massive-matrix-heavy disseminated sulphide zones have since been intersected in the Gonneville Intrusion, along with widespread, lower-grade disseminated sulphide mineralisation.

Subsequent geophysical methods include detailed ground gravity, airborne magnetics, down-hole (DHEM) and airborne electromagnetic (AEM) surveys. DHEM has identified multiple conductors associated with known, and potentially mineralised zones. Gravity and magnetic survey data and inversions have improved the understanding of the geology and structure of the intrusion. An AEM survey flown in late 2020 highlighted known mineralisation at Gonneville as well as identifying multiple new anomalies to the north within the broader Julimar Complex.

Geophysical techniques will continue to provide a key role in exploring the Gonneville deposit, targeting extensions of known mineralisation as well as delineating new areas for continued exploration within the Julimar Complex.

124: Geographic quantile regression forest: a new method for spatial modelling of mineral commodities

Mr Kane Maxwell[1,2], Dr Mojtaba Rajabi[2] and Prof Joan Esterle[3]

[1] Matrix Geoscience
[2] University of Queensland
[3] School of Earth and Environmental Sciences, The University of Queensland

Spatial interpolation (modelling) is required for resource estimation in all mineral commodities. For spatial modelling of most commodities, geostatistical methods such as kriging and hybrid kriging are most popular because they are generally more accurate than deterministic methods, can quantify uncertainty and use auxiliary information to improve predictive accuracy. However, geostatistical methods have the primary disadvantages that they have onerous pre-processing steps such as variogram modelling and the incorporation of additional auxiliary information which has non-linear relationship with the target variable is difficult. To address this, a machine learning method based on quantile regression forest algorithm is proposed as an alternative approach for spatial modelling. This newly proposed method (termed geographic quantile regression forest), does not require variogram modelling, and can also quantify uncertainty and incorporate auxiliary information. To evaluate the performance of the new method, the accuracy of predictions of specific coal properties is compared to inverse distance weighting (popular in the coal industry), and two geostatistical methods. Data from an active mine site in the Bowen Basin, Queensland Australia is used for the comparison. In addition, the accuracy of the predictions in two geological domains of the mine site, which have different spatial variation due to the impacts of intrusion, is also compared. Using evaluation metrics from leave-one-out cross-validation, this paper demonstrates that geographic quantile regression forest method has the highest accuracy, lowest bias and highest precision of all methods across all coal properties and geological domains. Disadvantages of the new method compared to deterministic and geostatistical methods are that the method is more computationally demanding, less intuitive and is not available in existing geological packages. However its high accuracy and advantage over geostatistical methods makes it a candidate for future inclusion in geological model packages.

125: Recognising the impact of uncertainty in resource models

Mr Steven Sullivan

Measuring uncertainty in resource models provides mine planners and potential investors with a quantitative assessment of risk.

The sensitivity of a project to changes in geological interpretation has been neglected in the past, due to a lack of time to generate and develop different geological models. A resource model should portray the best understanding of geological processes and observations. To report a resource from a geological model requires three components - volume, density and grade or quality, each carrying a degree of underlying uncertainty.

A volumetric interpretation of geological observations is only as good as the knowledge, experience, bias and patience of the geoscientist building the model. In reality, several possible interpretations could be generated by multiple geologists. Geological uncertainty is just as important as grade uncertainty, yet often gets overlooked, primarily because unlike grade uncertainty, there is no easy way of capturing or communicating it.

Advances in machine learning have opened up new possibilities, and this presentation outlines a new method for recognising domain uncertainty. Using a case history with data from the Lisheen base metal mine in Ireland, the author will show how several possible interpretations for geological domain boundaries were generated from the same drilling data. All solutions honour the data, highlighting the underlying uncertainty that exists in most geological settings.

Recognising that uncertainty exists is the first step towards a more realistic resource statement. The ability to measure the variation in interpretation of the resource models provides mine planners and potential investors with a quantitative assessment of risk.

126: Integration of high-resolution HyLogger spectral scanner and TESCAN Integrated Mineral Analyser for mineralogical characterisation of shale

Mr Muhammad Iqbal[1], Prof Reza Rezaee[2], Prof Gregory Smith[2] and Mr Hasnain Ali Bangash[3,4]

[1] Western Australia School of Mines, Curtin University, Western Australia
[2] Curtin University
[3] University of Western Australia, Perth, WA
[4] Rio Tinto Exploration, Perth, WA

The mineralogy of shales is a fundamental parameter because it has a direct influence on petrophysical and geomechanical properties. However, thick shales comprise a heterogeneous succession of very fine-grained strata in which only some thin beds are optimum for production of hydrocarbons. Hence, more continuous high-resolution mineralogical information is crucial to obtain a better understanding of the heterogeneity and fill the gaps between samples. This study aims to solve this problem for the Goldwyer Formation shale in the Canning Basin, Western Australia. A continuous mineralogical evaluation over the core interval was carried out using the Hylogger spectral scanner. The spectra are validated with detailed core logs and TESCAN integrated mineral analyser (TIMA) analysis. The total organic carbon content (TOC) was determined by Rock-Eval pyrolysis. The results indicate that the Goldwyer Formation shale is heterogeneous in terms of mineralogy and organic richness. Four main rock types are identified in the Goldwyer Formation (RT1-4), each with distinct Hylogger spectra, TIMA based mineral distribution maps and TOC values. The RT-1 is an argillaceous shale with TOC ~2.5 wt% dominated by illitic clay minerals (>50%). The RT-2 is an organic rich black shale with TOC >4 wt%

and >80% clays. The RT-3 is a heterolithic shale with TOC ~3.5 wt % and almost equal proportions of clay, quartz and carbonate minerals. The RT-4 is a calcareous shale with TOC ~1 wt % and more than 50% carbonate minerals. The results indicate that RT-1 and RT-3 should be organic-rich and brittle than RT-2 and RT-4 based on different proportions of TOC and brittle minerals. This study provides a new workflow for rapid and accurate recognition of optimum rock types for hydraulic fracturing in shales. Continuous very high-resolution hyperspectral core log data, combined with core logging and petrography, provides a better understanding of heterogeneity in shales.

128: High density seismic finally accessible to all industries

Mr Amine Ourabah[1]

[1] Stryde Limited

High density seismic has been a synonym of high-quality subsurface images and attributes for a long time, and although firstly made available by innovative source technologies like blended acquisition, which converted vibroseis fleet into very efficient autonomous single sources points, the receiver side was lagging behind with bulky heavy cables, and later, bulky heavy nodes, preventing it from spreading the sensors efficiently and reaching the full potential of an unlimited channel count system. BP, in collaboration with Rosneft and Schlumberger, have developed a new nodal system revealed to the industry in 2018, the smallest and lightest fully autonomous node for land seismic acquisition, specifically designed to tackle the most extreme land environments and make unlimited channel systems an affordable solution for high trace density surveys. Several successful field trials in different types of environments were completed prior to its commercialization, the latest being the densest 3D land seismic survey in the world acquired by ADNOC in 2019, achieving 184 million traces/km2 with 50 000 nodes. After these successful trials, BP invested in STRYDE, an independent start-up that is bringing the "nimble node technology" to the broader seismic community aiming to make high density seismic affordable to all industries. Since its commercialization in late 2019, this system has been successfully used for many applications including Oil&Gas exploration, Geothermal, Seismic Risk, Passive Seismic, Microseismic, and even Archaeology, and showed exceptional performance both on seismic quality and operational efficiency, giving access to a much better seismic data to various industries.

Thanks to its exceptional size, weight, and agility, this new generation of nodal systems is making high density seismic finally affordable to all industries. In this era of re-focus on low carbon energy resources, this new nodal system can make seismic play a major role in supporting numerous industries leading this way.

129: H2- From scientific research to commercialised energy

Mr Max Williamson[1]

[1] PESA

The abstract looks briefly at the technical aspects of hydrogen as a gas with a adequate depth for scientists to accept. It examines a range of technical questions such as:

1/ how can hydrogen be created in a form that is available for sale;

2/ how can the costs of producing hydrogen be driven down to achieve a position in the costs curve to make it economic as against other fuels;

3/ will there be a transition situation so that hydrogen can fill gaps in the gas consumption markets;

4/ is hydrogen old technology that has already passed its day or is it about to re-open old firmly closed doors;

5/ which markets are where it is logical to use and consume hydrogen in the early adoption transition before it is consumed more widely; and

6/ its problems with use in transport and high people density areas.

The abstract does dampen immediate enthusiasm for hydrogen, but if the technical and commercial advances can be made it is likely to be a major transformer of entire industries and a massive disrupter to existing industries such as the oil and gas industry.

It is apparent that if hydrogen is the technical answer to how the planet, most particularly the developed countries, deal with climate change we will need to re-think many issues in our country including massive sunk investments into other energy fuels, people skills and workforce issues, distribution and use of hydrogen (because of its volatility) and so many others not yet even considered.

130: Optimising slip-sweep Vibroseis in high-production coal surveys

Mr Dale Harpley[1,2] and **Dr Shaun Strong**[3]

[1] Velseis
[2] The University of Queensland
[3] Velseis Pty Ltd

In the last decade the Australian coal industry has significantly increased the size of their 3D seismic surveys. This has necessitated rapid advancements in acquisition, and processing. This includes adoption of nodal systems and high productivity Vibroseis techniques. Many of these techniques have been well developed in petroleum surveys. However, coal-scale targets generally offer some unique challenges.

In this presentation we investigate slip-sweep Vibroseis in the particular

context of broadband coal-scale exploration. This acquisition technique employs multiple Vibrators. These are configured such that sweeps from separate source points are allowed to overlap to some degree. This increases productivity but introduces noise.

Some of noise generated by Vibrators is caused by imperfect hydraulic control. This causes higher order harmonics of the desired sweep. For the standard correlation method with an upsweep, harmonics occur earlier in the record for each event. These tend to have much lower energy than the desired reflectors and have little impact. However, for slip-sweep they have the potential to contaminate the later arrivals of earlier sweeps.

In the petroleum industry it has been well documented that this harmonic noise can have a negative impact on the data if the slip times are too short. Coal-scale targets have the advantage that shorter sweeps with wider bandwidth are used. This theoretically reduces the strength of the harmonics, suggesting potentially more aggressive slips. Conversely, coal targets usually contain more near offsets and groundroll, and require more high frequency signal for desired resolution. These factors imply that harmonics may have a greater relative impact.

To determine which factors are most important this investigation has utilised modelling, ground force analysis, and real data. This has allowed us to gain an understanding of the characteristics of Vibroseis harmonics in coal-scale environments and from this develop a methodology for optimising high-production seismic surveys.

132: Multi-scale magnetotelluric surveys – mapping from the lithosphere to the near surface for mineral systems

Dr Wenping Jiang[1], Mr Jingming Duan[2], Mr Anthony Schofield[1], Dr Ross C Brodie[1] and Mr Andy Clark[1]

[1] Geoscience Australia
[2] Mineral Systems Branch, Geoscience Australia

Magnetotellurics is one of few techniques that can provide multi-scale datasets to understand mineral systems. We have used long-period data from the Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) as a first-order reconnaissance survey to resolve large-scale lithospheric architecture for mapping areas of mineral potential in northern Australia. A 3D resistivity model reveals a broad conductivity anomaly extending from the Tennant Region to the Murphy Province in the lower crust and upper mantle, representing a potential fertile source region for mineral systems. We then undertook a higher-resolution infill magnetotelluric survey to refine the geometry of major structures, and to investigate if the deep conductive structure is connected to the near surface by crustal-scale fluid pathways. Resistivity models reveal two prominent conductors in the resistive host whose combined responses result in the lithospheric-scale conductivity anomaly mapped in the AusLAMP model. The resistivity contrasts coincide with major structures preliminarily interpreted from seismic reflection and potential field data. Most importantly, conductive structures coinciding with major faults in this region extend from the lower crust to the near surface. This observation strongly suggests that the major faults are deep-penetrating structures that potentially acted as pathways for transporting metalliferous fluids to the upper crust where they could form mineral deposits. This result indicates high prospectivity for major mineral deposits in the vicinity of these major faults. In addition, we used high-frequency data to estimate cover thickness to assist with stratigraphic drill targeting which, in turn, will validate the models and improve our understanding of basement geology, cover sequences and mineral potential. This study demonstrates that integration of geophysical data from multiscale surveys is an effective approach to scale reduction during mineral exploration in covered terranes.

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133: Compositional control on frictional properties of Goldwyer shale reservoir rocks

Mr Partha Pratim Mandal[1], Prof Reza Rezaee[1], Dr Mustafa Sari[2] and Dr Joel Sarout[2]

[1] Curtin University
[2] CSIRO

Production from ultra-low permeable gas shale reservoirs is feasible only through hydraulic fracturing stimulation. Slip along a pre-existing natural network of fractures/faults with the injection of hydraulic fluid is mostly controlled by the frictional properties of the shale. We studied the deformation characteristics of the Goldwyer shale formation at in-situ stress conditions by performing a series of multistage triaxial tests to understand compositional controls on fault slip accompanying hydraulic fracturing. The Coulomb friction coefficient is derived from the post-failure axial displacement and the angle of the final failure plane. When the clay and total organic content (TOC) of the studied shale samples are above ~40% by volume, the friction coefficient approaches a value of 0.6, while below this threshold it is higher. This change suggests a transition from a grain-bearing to a clay-bearing structure. Therefore, we can directly estimate the slip tendency of natural faults and fractures in gas shale reservoirs from their clay and TOC content.

Keywords: frictional coefficient, deformation, clay, TOC, fault slip, Goldwyer shale

134: Overprinting of remanence in Paleozoic rocks of the Lachlan Orogen in southeast Australia

Mr Umer Habib[1], Dr Robert Musgrave[2] and Dr Sebastien Meffre[1]

[1] University of Tasmania
[2] Geological Survey of New South Wales

The Lachlan orocline hypothesis has been proposed to explain the tectonic evolution of southeast Australia where the Lachlan Orogen has been transformed into an N-shaped curve due to convergence and rotation about a vertical axis driven by the slab retreat and indentation of a micro-continent during middle Palaeozoic. A recent positive palaeomagnetic orocline test suggests ~ 90° of clockwise relative block rotation occurred during the Late Silurian/Early Devonian. This study was undertaken to test the orocline hypothesis using a detailed palaeomagnetic analysis aided with x-ray study for magnetic mineralogy in Palaeozoic rocks of Victoria and New South Wales. Four demagnetisation behaviours have been established (labelled A, B, C and D). The behaviour "A" is associated with loss of most natural remanent magnetisation (NRM) around of 200ºC, whilst the 'B' express loss of NRM at 450°C, indicating that NRM is possibly carried by a low-temperature weathering product, most likely maghemite. Behaviour "C" is attributed to the high temperatures of distinct unblocking (520 °C-690 °C). Samples with 'D' behaviour exhibit a complete NRM loss at 100 C, suggesting very poor magnetic stability. Hysteresis data confirmed that the NRM behaviour B and C specimens have elevated coercivities and remain unsaturated above 300 mT, implying that hematite carries a significant proportion of the remenace. The principal aim of the study failed due to the presence of an overprint which masked the original depositional remanence. The sites in the Ordovician rocks for central Victoria and Macquarie Arc plot within the confidence error limit of Devonian palaeopoles for the Australian continent. Back-scattered electron images and X-ray analysis of the selected samples from each site suggested that detrital magnetite/titanomagnetite, and (diagenetic?)/altered hematite carries magnetic remanence. This alteration could be the result of massive fluid expulsion events during late Bindian-Tabberabberan orogenic event in Devonian which reset the original remanence.

135: Optimising 3D coal seismic imaging with pre-stack depth migration

Mr Xiaodong Lu[1], **Mr Alan Meulenbroek**[1] and Mr Karel Driml[1]

[1] Velseis Pty Ltd

PSDM is used routinely in the oil and gas industry. However, seismic processing in the coal industry does not routinely exploit this more advanced imaging technique. This paper discusses the application of PSDM to a 3D coal volume acquired in the Bowen Basin in Qld in 2018.

The target coal seams in the case-study area vary in depth from <5 0m to ~300 m. The data quality varies significantly over the survey area. The poor data quality area is caused by a combination of higher surface elevation and thick tertiary cover. Time processing provided a high-quality image where data quality was good but not where data quality was poor. Poor statics meant that NMO velocity picking was problematic in this area.

PSDM was utilised to derive a velocity model which aimed to improve the imaging of the target seams in the poor-data area. Two different initial velocity models were tested. The first used the PSTM velocity. The second aimed to include velocity information of the near-surface. It was derived by performing PSDM on a set of shallow constant velocity models with the aim of imaging the base-of-weathering reflector. The associated velocities which maximized the stack response were picked and interpolated to create the initial model.

Final PSDM stacks derived from the different initial models produced images superior to the PSTM stack. Reflectors which were uninterpretable on the PSTM stack were imaged well on both PSDM stacks. Additionally, imaging of reflectors was subtly improved in the good-data area. The PSDM stack derived using the near-surface model produced the best image. Anisotropy parameters calculated from this model were also more realistic.

While the workflow used to image the base-of-weathering reflector has been used to derive an initial velocity model, the workflow can also be used as an alternative method for deriving a statics solution.

136: Using the NCI Gadi supercomputer to revolutionise processing of MT time series data: results from the GeoDeVL experiment

Dr Nigel Rees[1], Mr Sheng Wang[2], Dr Ben Evans[1], Dr Bruce Goleby[3], **Prof Lesley Wyborn**[4], Dr Tim Rawling[5], Dr Kelsey Druken[1] and Dr Rui Yang[1]

[1] National Computational Infrastructure
[2] Australian National University
[3] OPM Consulting Australia
[4] Research School of Earth Sciences/Australian National University
[5] AuScope

MagnetoTelluric (MT) time series datasets are expensive to acquire, can be high volume (100s of terabytes), and the time taken to publish (measured from collection to release) often takes more than two years. Time series datasets have been notoriously hard to access: most data providers only make derivative MT transfer functions (EDI files) and model outputs accessible online. Hence, MT practitioners can be reliant on the data processing from raw data to be conducted by others, which may or may not meet their target depth or processing requirements. There is a growing demand for time series datasets to be more accessible to facilitate alternative processing methods, particularly on HPC infrastructures, which enable processing of time series datasets at full resolution and running of larger models with more ensemble members and uncertainty quantification.

To address these issues, the GeoDeVL project experimented with a rapid open, transparent field-to-desktop-to-publication workflow to process and publish MT time series datasets using the new 15 Petaflop Gadi supercomputer at NCI. To do this, parallelised codes were developed to automate the generation of Level 0 to 1 time series data. Creating time series data levels for 95 Earth Data Logger stations now takes minutes, versus days and weeks previously taken using more traditional processing methods.

The process developed under the GeoDeVL project showed how geophysicists can now work with less processed data and transparently develop their own derivative products that are more tuned to the specific parameters of their use case. Further, as new processing methodologies and/or higher capacity computers become available, the rawer forms of earlier surveys are still available for reprocessing. Comparable trials in HPC processing decades ago led to widespread use of HPC in the petroleum exploration industry: will these results lead to similar uptake of HPC in the minerals exploration industry?

141: Seismic velocity analysis in the presence of AVO polarity reversals by fuzzy c-mean clustering

Dr Javad Khoshnavaz[1], Dr Duy Thong Kieu[2], Prof Hamidreza Siahkoohi[3] and Mr Andrej Bona[4]

[1] Formerly at Curtin University
[2] Hanoi University of Mining and Geology
[3] Institute of Geophysics at the University of Tehran
[4] Curtin University

Routine seismic imaging algorithms often require velocity models. Therefore, velocity analysis plays a crucial role in the accuracy of velocity models and imaging. Seismic velocity analysis in CMP domain has been dominated by the use of a powerful coherency measurement tool, called semblance. Although this works quite reasonable for most of practical cases, it is incapable of dealing with polarity variations across moveout curves caused by faulting or AVO anomalies of class II. In this research, we proposed an inversion-based velocity analysis algorithm that is based on fuzzy c-means clustering, which has been recently considered in geophysical concerns. We apply the proposed algorithm of a synthetic data example and a field CMP gather and compare the corresponding outcomes with the results obtained by semblance analysis. The results suggest the effectiveness of the proposed algorithm in the case of polarity variations.

142: Application of seismic imaging to target the Paleozoic basement underneath Tertiary basalts in the northwest Tasmania for exploration and mining

Mr Chuang Wang[1], Dr Gerrit Olivier[1] and Dr Martin Jutzeler[1]

[1] University of Tasmania

In Tasmania, high-resolution reconstruction of lithospheric structure is of great significance. The application of seismic imaging methods in this region can recover the younger cover sequences undermined by the basement. Tasmania hosts numerous significant minerals in the west/northwestern region owing to the Cambrian age Mount Read Volcanics (MRV). The Mt Lyell (Cu-Ag-Au), Henty (Au), Rosebery (Zn-Pb-Ag), Hercules (Zn-Pb-Cu-Ag-Au), Que River (Zn-Pb with subordinate Cu), Hellyer (Zn-Pb with subordinate Cu) and Fossey (Zn-Pb with subordinate Cu) mines are spread across this volcanic complex.

The area of interest covers Yellow Marsh Road mines (about 10 km north of Hellyer Mine) which sit opposite Mt Cripps on the other side of Belvoir Rd. It falls at the northern margin of the Dundas element, which is a 10-35 km wide belt zone between Elliott Bay in the south and Deloraine in the north bounded by Henty Fault (dipping east and having a displacement of 1.5 km) to its east. The underlying basement consists of Late Proterozoic sequences. Permian strata are overlain by Tertiary beds dominated by basaltic lava flows. The first filling of the drainage by the basalts covered the bottom of the valley (deeper than 600 m from surface), on top of which many of the lava successions has been more clear and reached 400 m in depth. The volcanism was together with associated sedimentary sequences and mafic complexes.

This project will conduct a 5 km by 4.5 km survey with 97 seismometers in order to target the Paleozoic basement underneath Tertiary basalts. This study is based on a dataset from a dense array combined with velocity profiles obtained from drill cores. The objective is to visualise how deep the basaltic volcanic succession is, and thus where the mineralised Paleozoic basementis potentially accessible for exploration and mining.

144: The Winu Cu-Au-Ag deposit in the Great Sandy Desert of Western Australia

Dr Hilke Dalstra

In the mid 2010's using a small "porphyry style" copper-gold deposit near Telfer gold mine in the Paterson province of Western Australia as an example Rio Tinto Exploration (RTX) saw an opportunity for discovery of a much larger tonnage Cu-Au deposit under shallow cover in the Anketell Shelf, the northern continuation of the Paterson Province. RTX's review of the Paterson Province identified three main areas of interest, each containing several selected targets. Of these the Mtambo targets, initially defined based on geological setting and aeromagnetic character were selected for further geophysical surveys and drilling in December 2017. The first drillhole RC17PAW0001 which eventually turned out to be the discovery hole intersected visible copper mineralization in a sequence of quartzites and siltstones all the way down to the end of hole at 174 m. Since then RTX has completed more than 70 000 m of drilling and defined a maiden resource at Winu Central. More recently significant additional mineralisation has been drilled at Winu Southeast and Ngapakarra, approximately 2 km east of Winu.

Winu consists of at least four en-echelon left stepping Cu-Au lodes with strike lengths between 350 and 750 m, northerly trends and moderate easterly dips hosted in a sequence of massive sandstones and siltstones. The deposit structure is dominated by a gently SSE plunging inclined monocline with a steep WSW-dipping western flank and a subhorizontal to gently E-dipping eastern flank. In the southeastern part of Winu, two gold rich lodes strike roughly E-W towards a gold rich satellite deposit called Ngapakarra. In detail Cu-Au mineralisation is hosted by several generations of quartz-K feldspar-sulphide and quartz-sulphide veins as well as sulphide rich breccias. Element associations and vein and alteration textures and mineralogy classify Winu as an intrusion related Cu-Au deposit of Neoproterozoic age genetically related to an as yet unidentified granitoid pluton.

146: CRC-P57322 High-resolution real-time airborne gravimetry

Dr Andrew Gabell[1], Dr Timothy Crain[2], Dr Glenn D Hines[3], Dr Farzin Amzajerdian[3], Mr Bruce W Barnes[3], Dr David Becker[4], Ms Helen Tuckett[1], Dr Jack McCubbine[5], Mr Shaun Stewart[2], Mr Geoff Wells[1], Mr Wayne Hewison[1], Dr Andrew McGrath[6], Prof Will Featherstone[7], Mr Mathew Tubb[8], Mr Scott Moore[9] and Dr Jamin Greenbaum[10]

[1] Transparent Earth Geophysics
[2] Intuitive Machines
[3] NASA Langley Research Center
[4] pva-g
[5] Geoscience Australia
[6] Airborne Research Australia
[7] School of Earth and Planetary Sciences, Curtin University
[8] Airship Solutions
[9] Seequent
[10] Scripps Institution of Oceanography, University of California, San Diego

The major limitation of airborne gravimetry stems from Einstein's "equivalence principle", which prescribes that no inertial sensor can distinguish between spatial variations in the gravity field (the signal) and variations in the acceleration of the aircraft (undesired noise). GNSS is currently used to determine the aircraft's inertial accelerations, which are then subtracted from the total accelerations as measured by a gravimeter, to determine the spatial variations due to gravity.

The required accuracy is achieved by applying filters of the order of 100 seconds to the GNSS data, resulting in a spatial resolution measured in kilometres. Advances in GNSS technology alone are unlikely to improve the resolution greatly.

NASA Langley Research Center scientists developed a Navigation Doppler Lidar ("NDL") for the US Space Program. This NDL measures velocities at the 1 mm/sec level in the laboratory, so such devices may be able to measure the inertial accelerations of an aircraft much more accurately than is possible with GNSS. If so, determination of spatial gravity variations at significantly lower noise levels, or with improved spatial resolution, or both, might be possible.

CRC-P57322 "High-resolution Real-time Airborne Gravimetry" was funded by the Australian Government to investigate this possibility. One of NASA's prototype NDLs was made available to the CRC-P project team, then integrated with state-of-the-art airborne scalar gravimeter systems to acquire data in three airborne campaigns firstly in Utah, then twice in South Australia.

The CRC-P project demonstrated that it is possible to consistently produce gravity data with lower noise over repeat lines by including NDL data with GNNS and gravimeter data in a Kalman filter, compared to using GNNS and gravimeter data alone. The project also produced gravity data at sub-mGal noise levels using the NDL and gravimeter data, even without including GNNS data in the Kalman filter.

148: Attenuation of ice-sheet reverberations in teleseismic P-wave receiver functions

Mr Dale Harpley[1] and Dr Steve Hearn[2]

[1] Velseis
[2] Velseis Pty Ltd

Teleseismic P-waves receiver functions (PRFs) in ice-covered regions are contaminated by reverberations within the ice sheet. The density contrast at the ice-bedrock boundary causes these events to appear with very high amplitudes on the PRFs. The crustal conversion events which are commonly used for identifying lithospheric structure are concealed by these ice reverberations.

The measured lag-times (time with respect to the initial P arrival) of the ice phases provide an opportunity for a Generalised Linear Inversion (GLI) to predict ice-layer parameters (thickness, P- and S-wave velocities). The ice-phase lag-times can be matched to a synthetic ice-layer PRF created with the Thomson-Haskell matrix formalism. Non uniqueness is overcome using constraints on the body-wave velocities.

A non-causal Wiener filter is designed to compress the ice-layer model PRF into a peak at zero-time. When applied to a synthetic ice-crust model PRF, ice phases are significantly reduced, and crustal phases are shifted to lag-times of an ice-free crust PRF. In theory, the filter assumes that the PRF of a multi-layered earth is the convolution of individual layer PRFs. The receiver function does not strictly satisfy this assumption and some noise is produced. However, the signal-to-noise of filtered crustal-phase events is significantly improved. The filtering of real-data stacked PRFs is successful at attenuating ice-phase events. It is possible to identify the Ps conversion from the Moho.

These two algorithms provide a practical approach to predicting ice and crustal thicknesses in ice-covered regions, such as Antarctica and Greenland. For example, at Concordia Base, Antarctica, our GLI algorithm predicts ice thickness of 3.15 km, within 4% of measurements from core data. Wiener filtering of PRFs suggest crustal thickness of around 43 km.

149: Noble gases: a versatile exploration tool for water, minerals and hydrocarbons

Dr Axel Suckow[1], Dr Cornelia Wilske[2], Dr Christoph Gerber[1], Dr Alec Deslandes[1], Mr Punjehl Crane[1] and Dr Dirk Mallants[1]

[1] CSIRO Land and Water
[2] University of Adelaide

Noble gases are applied as a standard tool in Australian groundwater research since the CSIRO noble gas facility went into operation in 2016. We expand this facility to support mineral and hydrocarbon exploration.

A new vacuum mineral crushing system in operation since 2020 allows the measurement of noble gases and their stable isotope composition in fluid inclusions entrapped in mineral grains. Some of the noble gas isotopes (^{20}Ne, ^{22}Ne, ^{36}Ar, ^{38}Ar…) contain signatures characterising mantle fluids or meteoric waters, while radiogenic isotopes (^{4}He, ^{21}Ne, ^{40}Ar, ^{136}Xe…) allow the assessment of fluid ages. Measurements from fluid inclusions indicate the origin of the fluids the mineral precipitated from, useful to characterize the genesis of ore bodies, and provide evidence about different stages of the evolution of minerals or rock formations, such as pressure-temperature conditions during formation and provenance, evolution history and ages of geofluids.

The new vacuum mineral crushing system uses the same fully automated noble gas analysis system used for groundwater samples since 2016, which since 2019 operates with a High-Resolution Noble Gas Mass Spectrometer (Helix MC Plus). The preparation system purifies the noble gas fractions and measures the rare isotope ratios in groundwater and pore fluids, including ^{3}He/^{4}He ^{21}Ne/^{20}Ne and the stable isotopes of xenon.

An external getter system added this financial year will enable the measurement of samples from natural gas or crude oil for their noble gas content and isotopic composition. Such measurements characterise the origin of the noble gases (mantle, crustal, meteoric) and radiogenic time scales of fluid movement and can assess the extent of water contact of the hydrocarbon phases. This information is not available with other conventional methodologies and characterizes the migration pathways of the hydrocarbon fluids before and during accumulation in hydrocarbon reservoirs.

150: Yaouré seismic survey: Defining a complex 3D structural framework with high resolution seismic data

Mr Graeme Hird[1], Dr Peter Turner[2], **Dr Greg Turner**[1] and Dr Doug Jones[2]

[1] HiSeis Pty Ltd
[2] Perseus Mining Ltd

HiSeis conducted a high-resolution 3D seismic survey over the Yaouré gold deposit in Côte d'Ivoire in early 2020 for Perseus Mining. The survey extended over a 3 km x 6 km area and imaged the geology to depths beyond 4 km. A 20 km 2D seismic survey complementing the 3D survey was acquired to provide broad context for the 3D survey and test for similar structural settings beyond the main survey area.

The Yaouré deposit is hosted within a thick basalt sequence comprised of massive and pillow basalts. The basalt is not magnetic and therefore magnetic surveying provides limited structural insight into the Yaouré mineral system. The seismic survey clearly images a series of low-angle east and north dipping thrust faults, linking structures between thrusts and a conjugate set of sub-vertical faults.

The highest grade gold discovered to date at Yaouré is found in the low-angle east-dipping faults and the seismic shows how these continue beyond current drilling.

In our paper we will show how the faults at Yaouré are imaged via several mechanisms: These are:

- Reduced rock competency associated with the disruption of the rock mass proximal to the faults;
- Alteration haloes proximal to the faults, where mineralising fluids are interpreted to have utilised the permeability enabled by faults; and

- Porphyritic intrusions utilising pre-existing planes of weakness created by the faults and/or within likely bedding planes.

We will also show how the seismic data very clearly shows the presence of a large, previously unknown intrusive body at 1.2km depth which may be aa critical component of the mineral system at Yaouré.

151: Petroleum source rocks, generation and primary migration: Insights using new direct nano-scale Tof-Sims SEM analysis and Re-Os radiometric dating

Prof Gregory Smith[1], Dr William Rickard[1], Mr Zhen Li[1] and Ms Svetlana Tessalina[1]

[1] Curtin University

The literature is full of countless papers discussing the maturation, generation and primary migration of hydrocarbons from organic matter. Yet no one has actually seen how this works under the microscope. The theory is based on destructive organic geochemical studies derived by pulverising, dissolving or pyrolysing organic matter and then trying to recombine the organic geochemical fragments into entities that can be typed to possible starting components.

The latest generation of Tof-SIMS electron microscopes are now capable of producing mass-spectrometry of elements, isotopes and molecules across the full range of atomic numbers from the light elements upwards including Carbon and Oxygen. Importantly, this means for the first time organic matter can be analysed down to the nano-scale under the microscope without disintegrating the component macerals and can simulataneously analyse the associated inorganics.

Samples of typical organic source rocks have been analysed using the new IONTOF machine at Curtin University with startling results across a range of source rocks. Some examples will be shown demonstrating maturation and actual primary migration for the first time. Other examples show how the various organic matter types can be distinguished from each other by their mass spectral fingerprints directly in the sample (eg acritarchs, spores, *G. prisca*, Tasmanites, vitrinite, inertinite, bitumen) and how Carbon, Sulphur and Oxygen isotopes can be done at the nano-scale including for reservoir cementation.

This analytical technology is revolutionary and truly sets a new paradigm for source and reservoir petrology that has profound implications for petroleum exploration and development.

153: Why we should not report unconstrained inversion output in densities or magnetic susceptibilities

Dr Clive Foss[1] and Dr James Austin[2]

[1] CSIRO
[2] CSIRO Mineral Resources

Many gravity and magnetic inversions are of far-field data acquired at an elevation above the property distribution at which there is little or no information about the details of its distribution. Despite this the current practice is to report inversion results which purport to illustrate that distribution with no means to separate what reliable information there is from apparent detail which non-uniqueness reduces to be worthless or even worse, misleading. Parametric modelling safely produces geometrical property distributions that are in most cases clearly not geologically acceptable, but voxel inversions report property values across a three-dimensional matrix of subsurface addresses with often seductive apparent detail possibly suggestive of a particular geological preference. Well-run gravity and magnetic inversions (both parametric and voxel) can provide valuable and reasonably reliable information, but to maximise the value of that information it must be separated from misleading aspects of the models. The reliable information is the centre location and total anomalous mass or magnetization for anomalies confidently separated from a background field. We propose that these statistics should be extracted and presented as inversion results. The models themselves or any subsequent derivatives from them can then be separately presented as interpretations without the implication that the inversion favours or justifies that model. It is becoming increasingly important to address these issues as the ease of running an inversion is increased, as critical evaluation of computer output is relaxed, and as methodologies such as AI and machine learning further distance computer output from the fundamental physics that is the foundation of geophysical methods. We present case studies to illustrate our proposed process and highlight variation in the confidence of information derived from gravity and magnetic field inversions.

157: Airborne geophysical surveys uploaded to SARIG in 2020: Industry focus

Dr Philip Heath[1]

[1] Geological Survey of South Australia

The Covid-19 pandemic has given the geophysicists at the Geological Survey of South Australia the opportunity to revisit historical geophysical data that had not yet been uploaded onto the South Australian geoserver web portal: SARIG (South Australian Resources Information Gateway). Since April 2020, over 30GB of data have been uploaded to the portal and are now available for free download. This poster summarises all these data released in 2020 via SARIG (excluding survey data acquired as part of the Gawler Craton Airborne Survey (GCAS)). Instructions for how to locate and download geophysical data – including data not yet uploaded to SARIG as ASCII and gridded datasets – are included.

158: Stratigraphic drilling in the era of EFTF: The Barnicarndy 1 and NDI Carrara 1 wells

Dr Adam Bailey, Dr Emmanuelle Grosjean[1], Dr Amber Jarrett[1], Dr Chris Boreham[1], Ms Lidena Carr[1], Dr Dianne Edwards[1], Dr Liuqi Wang[1], Dr Susannah MacFarlane[1], Dr Chris Carson[1], Mr Chris Southby[1], Dr Jade Anderson[1], Dr Kamal Khider[1] and Dr Paul Henson[1]

[1] Geoscience Australia

Exploring for the Future (EFTF) is an Australian Government initiative that gathers new data and information about potential mineral, energy and groundwater resources. Commencing in 2016 with a focus on northern Australia, an extension was recently announced extending EFTF though to 2024 and expanding coverage to include the whole of Australia. The EFTF energy component aims to improve our understanding of the petroleum potential of frontier onshore Australian basins and has acquired significant pre-competitive datasets, including the recently drilled Waukarlycarly 1 deep stratigraphic well in Western Australia's Canning Basin (in partnership with the Geological Survey of Western Australia), and the just completed Carrara 1 deep stratigraphic well in the South Nicholson region of the Northern Territory (in partnership with the MinEX CRC). These are the first stratigraphic wells drilled by Geoscience Australia in a petroleum basin since its formation in 1997 from its predecessor agencies, and both were sited along major new two-dimensional, deep crustal seismic surveys acquired by Geoscience Australia as part of EFTF, providing stratigraphic control for the imaged geology.

The Waukarlycarly 1 and Carrara 1 wells intersected significant successions of sedimentary fill and were both extensively cored and logged with a broad suite of wireline tools, providing substantial new data in two frontier areas. These data provide insights into regional stratigraphy and local lithology. Geochronology, petrographic, organic and inorganic geochemistry, petrophysical rock properties, petroleum systems elements, palaeontological and fluid inclusion studies have been undertaken that allow for inferences on regional prospectivity to be made in these data-poor regions. Moving into the next phase of EFTF, these crucial wells provide a template for new pre-competitive data acquisition by Geoscience Australia, expanding our knowledge of frontier regions and attracting new investment for resource development.

162: The present-day state of tectonic stress in eastern Australia

Dr Mojtaba Rajabi[1]

[1] School of Earth and Environmental Sciences, The University of Queensland

Knowledge of the present-day stress is important to understand the dynamics of earthquakes, and to manage the safe and sustainable usage of the underground during storage and exploitation. Eastern Australia hosts several sedimentary basins with large coal-seam gas reserves as well as mines that are critical for Australia's energy and resources. Some of the eastern Australian basins such as the Surat, Gippsland and Otway basins have been proposed as potential CO_2 storage sites. In addition, the Sydney Basin in New South Wales is one of Australia's most seismically active areas.

This paper examines the state of present-day stress in eastern Australia from variety of sources including wellbore data, focal mechanism solution of earthquakes, hydraulic fracturing and overcoring tests. In particular, this paper presents the state of stresses in the Bowen, Surat, Clarence-Moreton, Sydney, Gunnedah, Gippsland, Galilee, Cooper, Eromanga, Darling and Otway basins. Analysis of stress data in northeastern Australia (i.e., Bowen and Surat basins) shows a regional orientation of NNE-SSW for the maximum horizontal stress (SHmax), which rotates to ENE-WSW in the Clarence-Moreton, Gunnedah, and Sydney basins. The SHmax orientation is E-W in the Galilee, Eromanga and Cooper basins, and rotates to NW-SE in the Gippsland and Otway basins in southeastern Australia. In addition to regional variability, significant stress changes (both orientation and magnitudes) at local scales have been observed due to presence of geological structures, which highlight the importance of geology for geomechanical assessment of the basins.

163: Application of facies based seismic inversion in developing shallow gas fields in Cooper-Eromanga Basin

Mr Satyabratamishra[1], Mr Shane Squire[1] and Mr Thomas Massey[1]

[1] Santos Ltd

This paper presents a case-study of the application of facies-based seismic inversion in the Cooper-Eromanga Basin, South Australia. The technique has been used to support the development of shallow gas fields in the Cretaceous reservoirs of the Coorikiana Sandstone.

Key features of the Coorikiana gas play are polygonal faults that compartmentalise the field and Class II/IIp seismic amplitude variation with offset/angle. The field compartmentalisation poses a significant challenge in development. Forward seismic modelling explained the impact of various aspects of the geology and fluid types on the seismic wave-forms. A facies-based inversion was undertaken to support field development planning and it ultimately provided a better definition of the compartments. A retrospective value of information analysis showed that value is maximised by combining the new seismic inversion information with the prior seismic knowledge (seismic amplitude).

164: Australian Proterozoic Thermal Aureole Gold mineral systems: The critical role of high crustal geothermal gradients and the insights of Vic Wall

Prof Lesley Wyborn[1]

[1] Research School of Earth Sciences/Australian National University

Thirty years ago, Wall (1990) proposed the name 'Thermal Aureole Gold (TAG)' for a distinctive class of pluton-related gold deposits (now more commonly known as Intrusion-related Gold (IRG)). Initially based on the Pine Creek, Tanami and Paterson Provinces, Wall (2005) later included significant deposits such as Murantau, Obuasi, Campbell-Red Lake, Fort Knox, and Pogo, showing it is not just restricted to the Australian Proterozoic.

Revisiting the Pine Creek, Tanami and Telfer areas, a specific type of granite is spatially associated with these Au-dominant deposits. The granite type is fractionated, has dominantly >65 wt% SiO_2 and anomalously high concentrations of K, Th, U and Rb: pluton compositions are variable. These granites are believed to have formed at <30 kms as a product of anomalously high regional geothermal gradients of between 30 to 60 degrees per km.

Gold is commonly related to magnetite-bearing granites, but as Wall noted (2005), IRG deposits are often associated with reduced granites (e.g., Pine Creek, Tennant Creek and Telfer). This phenomena is common where granites intrude reduced hosts, particularly carbonaceous rocks, indicating that there has been interaction between the granite and its host rock. The high geothermal gradients, combined with anomalously high regional heat flow suggests that once hydrothermal fluids leave the granite they may mix with free convecting meteoric fluids and that precipitation may occur sometime after the date of intrusion, often in structurally controlled sites that are unrelated to the granite intrusion process.

Etheridge and Wall (1994) argued that compositional and higher thermal structures of the Proterozoic led to less marked partitioning of deformation, with extensional and compressional deformation occurring much further into the continental interior than at present. The wide spatial extent of Proterozoic Granites supports this and opens up exploration parameter space to much wider areas than are currently being considered.

167: Northern Lawn Hill Platform – modelling the 'great-grandparent' emerging region

Ms Tehani Palu[1], Dr Amber Jarrett[1], Dr Susannah MacFarlane[1], Dr Christopher Boreham[1] and Dr Barry Bradshaw[1]

[1] Geoscience Australia

The northern Lawn Hill Platform (nLHP) is considered an emerging region with less than 15 wells drilled to date. With renewed interest in unconventional gas, new exploration opportunities exist in this early Proterozoic region. Petroleum systems analysis is presented here to improve the understanding of burial history, source rock richness and maturity of the nLHP of the Isa Superbasin, far NW Queensland.

A pseudo-3D geological model was built and calibrated, in combination with 1-D burial and thermal history modelling of Desert Creek 1 and Egilabria 1. These were combined with source rock characteristics (e.g., Rock Eval and kerogen kinetics) which helped assess the hydrocarbon generation potential by source rock, allowing a broader assessment of petroleum prospectivity of the nLHP.

The study focussed on two potential source rocks; the Lawn 4 Sequence and the River Supersequence. Maturity modelling of the Lawn 4 Sequence at Desert Creek 1 and Egilabria 1 predicted equivalent vitrinite reflectance (EqVR) of over 1.2% and 2%, respectively. The River Supersequence was modelled as overmature at both wells. Combining these results with the pseudo-3D model and source rock characteristics demonstrates that the highest maturities are encountered in the deepest depocentres to the east and gradually decrease in maturity to the west, indicating some potential for wet gas.

Modelling results show generation of varying amounts of gas and oil from each potential source rock. Overall, due to the age of the sediments, maximum depth of burial and high palaeotemperatures, the most likely hydrocarbon phase is gas from primary generation and supplemented by secondary gas from oil cracking. In spite of high maturities, encouraging gas shows from the Egilabria prospect support continued exploration interest in this region for unconventional hydrocarbons.

168: Nonlinear, 2D uncertainty estimation in Magnetotelluric inversion using trans-dimensional Gaussian processes

Dr Daniel Blatter[1], **Dr Anandaroop Ray**[2] and Dr Kerry Key[3]

[1] Scripps Institution of Oceanography, University of California San Diego
[2] Geoscience Australia
[3] Lamont-Doherty Earth Observatory, Columbia University

Inversion of Magnetotelluric (MT) data for electromagnetic resistivity yields insights into earth processes related to mineral formation and geodynamics, can be used to map thickness of sediments for energy resource exploration, locate areas for geothermal development, as well as map deep earth structure. However, the presence of data noise, non-linear physics and sparse receiver coverage lead to uncertainties in the inverted resistivity. Bayesian inversion can produce crucial uncertainty information on the inferred subsurface resistivity, but has largely been restricted to 1D earth models. This is due to their large computational cost as well as dimensionality of the resistivity model space. We render this problem tractable from the dimensionality standpoint by using a stochastic interpolation algorithm known as a Gaussian process (GP). This allows for a parsimonious model parameterisation within a standard, trans-dimensional Bayesian framework. The Gaussian process links a trans-dimensional, parallel tempered Markov chain Monte Carlo (McMC) sampler to MARE2DEM, a parallel adaptive finite element forward solver. MARE2DEM computes the model response using a dense parameter mesh with resistivity assigned via the Gaussian process model.

We demonstrate the trans-dimensional Gaussian process (TDGP) sampler by inverting both synthetic and field magnetotelluric data for 2D models of electrical resistivity on a HPC cluster. For the Gemini field Gulf of Mexico real data inversion, our algorithm achieves a parameter reduction of over 32x. Resistivity probability distributions computed from the ensemble of models produced by the inversion yield credible intervals and interquartile plots that quantitatively show the 2D uncertainty. This uncertainty can also be propagated to other physical properties that impact resistivity such as bulk composition, porosity and pore-fluid content.

174: Ground Penetrating Radar investigation as part of a multidisciplinary archaeological project, The Plain of Jars, Lao PDR

Mr Jamie Speer[1], Dr Dougald O'Reilly[2] and Dr Louise Shewan[3]

[1] GBG Australia
[2] Australian National University Canberra
[3] University of Melbourne

The Ground Penetrating Radar (GPR) investigation was undertaken within the multidisciplinary team undertaking the "Plain of Jars Archaeological Research Project", a joint Lao-Australian project funded by the Australian Research Council. The international project team comprising university and industry based archaeologists, a geologist, a geophysicist and geospatial experts.

The Plain of Jars in Central Laos comprises numerous megalithic sites with some sites containing over 400 stone "Jars". The region was unknown to European Archaeology prior to the work of Madeline Colani and her sister Eleonore in the 1930's.

The first stage of the GPR project work took place in February 2016 at Site 1, with data collection undertaken on other sites (Sites 2, 3 and 52) in 2017.

Processing of the data produced 3D data blocks for imaging and evaluation of potential excavation sites. During the initial site visit, one location was selected as a dig site with the most potential, this became the excavation "Unit 2". The resulting finds included marker stones and a burial site containing two partial skeletons. Investigation of anomalous GPR signals in the data collected from Site 2 revealed a large broken buried pot, and a partial stone disc.

The results of the GPR investigation proofed by excavation verified the value of using GPR within the project for the location of burials, burial features and artefacts.

177: Simultaneous inversion of teleseismic P- and converted S-waves to constrain the seismic structure of the crust

Dr Mehdi Tork Qashqai[1] and Dr Erdinc Saygin[2]

[1] Deep Earth Imaging Future Science Platform, CSIRO
[2] Deep Earth Imaging, Future Science Platform, CSIRO

Traveltimes of P and mode-converted S-waves and their reverberations place a tight constraint on the Vp/Vs ratio and their amplitude ratio provides tight bounds on the P and S wave velocity jumps across the main discontinuities in the subsurface structure below a seismic receiver. Seismic P-to-S converted waves have been used for decades to estimate the shear-wave velocity of the subsurface and depths of major discontinuities below a seismic receiver through a method known as the P wave receiver functions. Here, a new and alternative approach is presented using P and all mode-converted shear waves in a probabilistic joint inversion framework to simultaneously estimate seismic properties of the crust (Vp, Vs, and Vp/Vs). These waves are extracted by the autocorrelation of the teleseismic P-wave coda recorded on the radial and vertical component of a three-component (3C) seismic receiver. In the application of the methodology, we image the crust along a north-south oriented passive seismic line (BILBY) in central Australia, which traverses multiple geological domains. The overall trend of our inferred Moho follows the long-wavelength pattern of the Moho interpreted from the deep seismic reflection line-GOMA parallel to the BILBY experiment. It is also consistent with the reflectivity changes seen at the base of the crust in the GOMA seismic section. Our approach is a cost-effective method and can be used in conjunction with the deep active seismic reflection profiling to obtain additional information, especially at depths where the deep seismic reflection method cannot image.

178: Modelling the impact of fault damage zones on fluid flow localisation

Dr Thomas Poulet[1], Dr Ulrich Kelka[1], Dr Vincent Crombez[2], Dr Marcus Kunzmann[1], Dr Teagan Blaikie[3], Dr Heather Sheldon[1] and Dr Martin Lesueur[4]

[1] CSIRO
[2] CSIRO Energy, Deep Earth Imaging
[3] Mineral Resources, CSIRO
[4] Lawrence Berkeley National Laboratory

Faults are essential geological features controlling subsurface fluid flow and often play a critical role in geological models for different applications, including mineral exploration, geothermal energy, nuclear waste disposal and reservoir engineering. Their effects range from representing flow conduits to barriers, with all combinations in between. Their complex nature also makes it particularly challenging to account for their impact realistically. Indeed, considering spatial variations in fault properties can drastically alter the resulting flow, yet data sparsity often forces modelers to consider simplified systems with constant properties.

In this contribution we focus on predicting flow patterns associated with generic fault architecture comprising damage zones adjacent to a thin low permeability fault gouge. We analyse the characteristics of such fault systems and the sensitivity of the flow field to various parameters. We investigate the factors influencing fluid flow localisation and showcase general scenarios with widely different outcomes for the flow depending on the level of details considered. These results demonstrate the necessity to model such fault systems appropriately and consider thin geological features that are often neglected.

In particular, we apply our findings to the Proterozoic McArthur Basin of northern Australia, one of the most endowed Zn-Pb provinces in the world. We aim at accounting for the complex structural framework and sedimentary facies distribution within the basin to link conceptual model studies with more geologically realistic scenarios. This will ultimately lead to a better understanding of the geological processes related to economic mineralisation.

179: Permeability modelling using digital rock images from micron scale

Dr Lionel Esteban[1], Dr Mojtaba Seyyedi[1], Mr Cameron White[1], Dr Ausama Giwelli[1], Dr Valeriya Shulakova[1], Dr Marina Pervukhina[1], Dr Samuel Jackson[1], Dr Amir Aryana[1], Dr Yoshitake Kato[2], Dr Mai shimokawara[2], Prof Takeshi Tsuji[3], Dr Arata Kioka[3], Dr Tatsunori Ikeda[3], Dr Joel Sarout[1] and Dr Fei Jiang[3]

[1] CSIRO
[2] JOGMEC
[3] Kyushu University

Rock permeability is a pivotal input for fluid flow simulations in various geological settings and impacts a broad range of applications in the fields of energy security, gas underground storage, water and mineral resources utilisation, to name a few. Recent technology improvements allow gaining a digital 3D replica of natural rock using fast and non-destructive tomographic techniques. Combining 3D images from medical and micro-CT scanners, natural rocks can be scanned at different scales reproducing micrometre details of the meter-long cores. Successful benchmarked laboratory experiments studies of permeability upscaling to meter scale, typically used for reservoir simulations, are still in their infancy.

In this study, a Boise reservoir sandstone is chosen to study permeability upscaling both experimentally and numerically from a few millimetre-long micro samples to a meter-long core. This sandstone does not exhibit complex geological structures and the mineralogy consists of 45% quartz, 50% feldspar, and 5% clay minerals. The porosity and permeability measured on the meter-long core are 31± 3 % and 4.4 ± 0.5 Darcy, respectively.

Boise sandstone is X-ray imaged at three scales from dry to full water saturation state: meter-long core (voxel resolution 100 µm), plug scale (voxel resolution 100 µm and 15 µm) extracted along with the meter-long core, and mini-plug scale (voxel resolution 1 µm) extracted from the previous plug samples. At full saturation, the water permeability is measured at all three scales. The X-ray images in the dry and water-saturated state (meter, plug, and mini-plug scales) are then used to numerically model permeability and to upscale permeability from mm to meter scale. The validated digital rock images up-scale modelling of permeability can then be tested in the future toward more complex rocks and with the multi-phases flow for relative permeability along with reservoirs in cost and time-efficiency manner.

182: Robust 3D models of geochemical and petrophysical properties from combining borehole and seismic reflection data: A case study from the Tropicana Gold Mine

Dr Duy Thong Kieu[1], **Dr Anton Kepic**[2], Mr Jai Kinkela[3], Mr Ockert Terblanche[4] and Mr Stephen Brown[4]

[1] Hanoi University of Mining and Geology
[2] RoqSense
[3] HiSeis
[4] AngloGold-Ashanti

The creation of 3D models of ore zones and geotechnical properties is typically performed by the interpolation of borehole data. Kriging and other interpolation methods have serious sampling issues, including bias from borehole orientation. Interpolation and data projection would be better if guided by geophysical imaging. We propose, and show by example, to use seismic reflection data to automatically and robustly interpolate and project data from logged boreholes. Firstly, a small number of sonically logged boreholes are used to provide missing sonic velocity data via data prediction. In our example, we use Specific Gravity, Magnetic Susceptibility and core-scanned XRF data with machine learning to create a "smooth" 3D model of sonic velocity from the many boreholes that have elemental and petrophysical data, but no sonic logging. Then inversion of 3D post-stack seismic data builds a robust 3D model of acoustic impedance. Along borehole trajectories, relationships between acoustic impedance and geochemical or petrophysical data are built and/or refined by machine learning algorithms. The relationships are then used to map the 3D model of acoustic impedance into the desired 3D geochemical/petrophysical model.

183: Seismic inversion by hybrid machine learning

Dryuqingchen and Dr Erdinc Saygin[1]

[1] Deep Earth Imaging, Future Science Platform, CSIRO

We present a seismic inversion method which uses the latent space (LS) features of a convolutional autoencoder (CAE) for the subsurface velocity model estimation. The LS feature is an effective low-dimensional representation of the high-dimensional seismic data and contains its key information. We use automatic differentiation (AD) to connect the perturbations of the LS feature to the subsurface velocity perturbations. We denote this hybrid connection as hybrid machine learning (HML) inversion. The HML misfit function measures the LS feature differences between the observed and predicted seismic data in the low-dimensional latent space of a CAE network. The LS features mainly contain the kinematic information of the input seismic data, such as the traveltime, when the latent space dimension is small. Here the LS features are automatically generated by a CAE network and no picking is required. Moreover, the dynamic information, such as the waveform variations, of the seismic data can be also preserved into the LS feature when the latent space dimension becomes larger. Therefore the HML inversion can recover the subsurface velocity model in a multiscale approach, where the HML inversion first inverts the low-dimensional LS features for the low-wavenumber velocity information. Then recovers the higher-wavenumber velocity details by inverting the higher-dimensional LS features. Based on the different ways of utilizing AD to compute the velocity gradient with respect to the LS feature misfit, we propose a full-automatic and semi-automatic approach to solve this problem. These two approaches are mathematically equivalent, but the former approach is easier to implement and the latter approach is computationally more efficient. Numerical tests on both synthetic and real datasets show that the HML inversion can effectively recover both the low- and high-wavenumber information of the subsurface velocity model by inverting the LS features with different dimensions.

184: AusArray: uncovering major crustal features using passive seismic data

Dr Alexei Gorbatov[1], Dr Andrew Medlin[1], Dr Michael Doublier[1], Dr Karol Czarnota[1], Dr Tanya Fomin[1], Dr Paul Henson[1] and Prof Brian L.N. Kennett[2]

[1] Geoscience Australia
[2] RSES, ANU

It is generally accepted that improvements in mineral exploration are required to meet the rising demand for minerals associated with a transition to lower carbon energy sources. There is growing consensus in mineral exploration that the distribution of fertile mineral camps is controlled by major lithospheric structures, yet there is a paucity of case studies with adequately distributed datasets to test this view. Here, we test the relationships between variations in the Mohorovičić discontinuity (Moho) and iron oxide-copper-gold and sediment-hosted mineral deposits in the regions between the Arunta and Mount Isa Provinces. We primarily utilise datasets from the Australian passive seismic array (AusArray) and pre-existing academic seismometer deployments supplemented by deep reflection seismic profiles. The 55–70 km seismometer interstation distance provides an almost continuous imaging of the Moho interface using back projected receiver functions. We observe that the Moho surface undulates at depths of ~35 to ~50 km deep, reflecting the complex regional tectonic framework of the area. Sharp steps in Moho depth are observed to coincide with major crustal structures such as the Willowra Suture and the Cork Fault. Other changes are gradual, but on the first order correspond to lithospheric thickness variations. Inspection of the Moho surface and the spatial distribution of base metal deposits suggests that significant deposits (>2 Mt) are distributed along the edges of second-order north–south to northeast–southwest-trending thicker crustal blocks. Our results indicate that passive seismic methods are a powerful tool to generate continuous datasets across large regions from which important architectural features can be identified to support exploration under cover in frontier regions. Higher-resolution seismic surveys would be useful to link these structures with mineral camps in the near surface.

187: Calibrating BMR T2 distribution logs to well test data

Dr Keelan O'Neill[1], Dr Benjamin Birt, Dr Timothy Hopper and Mr Mario Reyes[2]

[1] University of Western Australia
[2] NMR Services Australia

Borehole magnetic resonance (BMR) is a wireline logging technique used to provide in-situ formation evaluation. BMR responds to both the volumes of fluids present in a rock, and the geometry of the pores in which this water resides. As such, it is a powerful addition to any borehole geophysical characterisation aimed at evaluating the storage and flow capacity of subsurface formation or aquifer.

BMR is highly advantageous due to its' ability to provide a lithology independent measurement of formation porosity. A further application of BMR is to estimate the formation permeability. Semi-empirical models have been developed which quantify the relationship between the pore size distribution captured using BMR and formation permeability. The parameters which are used within these models are formation dependent. Thus, the parameters must be calibrated to the geology of interest to ensure that the BMR permeability model is tuned to provide appropriate permeability estimates. Historically this has been through coring programmes, however this is often not available in a hydrogeological context due ability to retrieve core in unconsolidated formations and the availability of pump test data on existing bores. This paper reviews a process that uses a combination of packer tests, pump tests and lugeon tests to calibrate the coefficients to calculate hydraulic conductivity from a T2 distribution. The process will be discussed and its applications to set of data will be presented.

188: Designing a magnetic resonance Logging-While-Drilling tool for reverse-circulation minerals exploration

Dr Keelan O'Neill[1], Mrs Sravani Mukkisa[2], Prof Michael Johns[1] and Dr Timothy Hopper[2]

[1] University of Western Australia
[2] RIG Technologies International Pty Ltd

We outline a nuclear magnetic resonance (NMR) logging-whilst-drilling (LWD) tool targeted at the minerals exploration industry. The tool allows real-time geological assessment during reverse-circulation (RC) drilling. NMR logging captures the porosity, pore size and permeability in the formation of interest enabling advanced formation evaluation. This information can then be used to assist real-time decisions for drilling operations (e.g. geo-steering) and resource evaluation.

In this work we outline the challenges involved in designing the prototype NMR LWD tool. The mechanical structure of the tool needs to be highly robust to survive the shocks and vibrations experienced during RC drilling operations, whilst ensuring there is minimal impact on magnetic resonance measurements. The tool magnetic physics must ensure that the probe is measuring at the appropriate depth into the adjacent formation at sufficient accuracy. The measurement must also be designed to be insensitive to the array of motions experienced during drilling operations. The device requires high-powered electronics which must be capable of handling the tool power supply as well as signal excitation and detection requirements.. The resultant design optimises the inherent trade-offs which exist between each of these physical components: (mechanical structure, magnetic components and electronic hardware) to fit within the dual-wall drill-rod in the RC drill string without compromising the drilling operation. Current experimental analysis of the prototype is ensuring that the probe is demonstrating the required measurement specifications and is field-ready.

In the near future, the probe will be tested across a series of field trials. Further work involves extending the measurement capabilities of the probe and looks towards commercialisation of the tool.

189: *In-situ* stress pattern along the Jellinbah Fold Thrust Belt in the Bowen Basin, Australia

Mr Saswata Mukherjee[1], Dr Mojtaba Rajabi[1], Prof Joan Esterle[1] and Dr Renate Sliwa[2]

[1] School of Earth and Environmental Sciences, The University of Queensland
[2] Integrated Geoscience Pty Ltd

The Permo-Triassic Bowen Basin hosts numerous thick coal seams, and it is a prolific basin for coal mining and gas production. The development of coal seam gas (CSG) reservoirs in different parts of the Bowen Basin emphasizes the potentiality of the basin as the next major gas province in eastern Australia, albeit with challenges for permeability. The Jellinbah Fold Thrust Belt in the Bowen Basin is one such area, and the current CSG development in this structurally complex area shows the significant influence of *in-situ* stress on the wellbore stability, gas production and well completion design. Therefore, a comprehensive analysis of *in-situ* stress pattern is required in order to better understand the localised stress perturbations for further appraising CSG reservoirs potentiality in this part of the basin. Herein, we compile and analyse different datasets including conventional well logs, borehole image logs and seismic data to understand the *in-situ* stress field across the study area and characterise the role of geological structures on the stress pattern within the Bowen Basin sedimentary sequences.

Analysis of 19.3 km of borehole image logs from 29 vertical wells corroborated an overall NE-SW for the maximum horizontal stress (S_{Hmax}) orientation within the study area. Although *in-situ* stress data showed a predominant thrust faulting stress regime in most parts, evidence of strike-slip stress regime was also observed within the region. Significant stress rotations were observed spatially and along depth, highlights the influence of folds, faults, fractures, and lithological contrast on the present-day stress pattern at local scales. This suggests that existing geological structures are one of the key controlling parameters on the *in-situ* stress patterns observed within the study area.

190: A new method for determining drill-bit signal emission time

Dr Zixing Qin[1], Prof Milovan Urosevic[1], Mr Andrej Bona[1], Prof Roman Pevzner[1] and Dr Konstantin Tertyshnikov

[1] Curtin University

In 2019, we acquired the first ever seismic while drilling (SWD) data with distributed acoustic sensing (DAS) fibre optic cable permanently installed behind the casing. After analysing the signal characters, we utilized shift and stack technique to increase signal strength at selected waveform locations. Data quality obtained is encouraging after such an initial processing step. However, a fundamental problem inherited from the raw SWD dataset still remains, which relates to unknown zero timing. This limits the applicability of the drill bit technique for investigations of the geological space between two or more boreholes. Conventionally, approaches for obtaining zero reference time are by mounting a seismometer at the top of a drill-string or plant geophones near a drilling rig and then by cross-correlating seismometer/geophone data with recorded drill-bit signals. In our research, we propose a new method to address the timing issue. After the newly drilled well installed with DAS fibre optic cable, we use a handful of surface VSP shots that lie in the same plane with the two wells to obtain the zero reference time for different drill-bit positions. The procedure is explained below:

1. At a particular drill-bit depth, we first use shift and stack to increase signal strength and then pick the relative first arrival times.
2. Cross-correlate the DAS recording from surface VSP shots at the drill-bit position with recordings in another well and find out the time lags with each channel
3. By comparing the picked first arrival times and cross-correlated time lags we can predict the zero reference time.

We have carried out computer simulations and tested this methodology on field dataset. The results achieved are promising. This processing technique further empowers the SWD dataset to unleash its full potential in exploring the subsurface, such as cross-hole tomography construction, cross-hole imaging and anisotropy study.

191: An integrated hydrogeophysical and hydrogeological approach, to underpin the long-term water security of a remote tropical island

Mr Andrew Taylor[1], Dr Tim Munday[1], Mr Chris Turnadge[1], Dr Joanne Vanderzalm[1], Mrs Tania Ibrahimi[1], Mr Shane Mule[2], Dr Axel Suckow[1] and Dr Sebastien Lamontagne[3]

[1] CSIRO
[2] Mineral Resources, CSIRO
[3] CSIRO Land and Water

Groundwater resources that sustain small Indigenous communities in remote parts of northern Australia are often poorly characterised. This is mostly due to their remoteness and the practicalities and economics of undertaking field investigations. The Warruwi community on South Goulburn Island in the Northern Territory is completely reliant on groundwater for its livelihood. Recent consecutive poor wet seasons highlighted both: (i) the sensitivity of the islands' water resources to short-term rainfall variability, and (ii) the inadequacy of the islands' water infrastructure for meeting water demand during dry periods. Although hydrogeological assessments have been undertaken across discrete parts of the island in the past, an integrated approach was required to provide long-term water security for the community.

To better characterise and quantify the islands' water resources and water infrastructure requirements, targeted field investigations were combined with desktop analyses including: (i) an airborne electromagnetic (AEM) survey supported by ground-based geophysical measurements, (ii) environmental tracer sampling of groundwater and (iii) desktop analyses including an evaluation of the annual groundwater mass balance. The inverted AEM data constrained using spatial analyses of lithology, groundwater levels and salinity identified a thin (~20 m) storage-limited unconfined aquifer hosting a freshwater 'lens' system overlying a regional aquitard. Groundwater level analyses combined with tracer interpretation characterised a hydrodynamic flow system with short flow paths (<2.5 km) and residence times (~15 years). A mean annual groundwater mass balance for a revised extent of the freshwater system, confirmed that community water demand can be met with the existing resource, though additional water infrastructure and a more strategic management approach was required.

The integrated hydrogeophysical and hydrogeological approach was fundamental for underpinning long-term water security for the community. Specifically, it helped: (i) identify options for siting new production and monitoring bores and (ii) designing an adaptive groundwater extraction strategy and an improved monitoring programme.

192: Inverting the head wave coefficient with the Werth equation

Dr Derecke Palmer[1]

[1] ASEG

The head wave coefficient, the refraction analogue of the reflection coefficient, is a complex function of the densities and the P- and S-wave velocities in both the weathered and sub-weathered regions. In general, the head wave coefficient increases with increasing P- and S-wave velocities in the weathered layer, but it decreases with increasing P- and S-wave seismic velocities in the sub-weathered layer.

Unscaled S-wave velocities in the weathering and sub-weathering can be computed with a new approximation of the head wave coefficient and the detailed P-wave seismic velocities in each layer. In general, there is excellent agreement between the measured and computed values after ten iterations. However, a traveltime-based estimate of the S-wave velocities is required to calibrate the amplitude-based estimates.

193: Full waveform refraction imaging of the regolith

Dr Derecke Palmer[1]

[1] ASEG

Full waveform refraction imaging with the common intercept gather (CIG) is a simple application of the stacking procedures routinely employed with seismic reflection data processing to the standard intercept time method. Accordingly, the stacked full waveform CIG is the refraction equivalent of the CMP stack with reflection methods. The CIG recasts the processing of refraction data into a format which is analogous to standard reflection data processing methodology.

Stacking with the CIG addresses the two most important challenges with near surface refraction seismology. It significantly improves the signal-to-noise ratios of both P- and S-wave images (and therefore, the time models) of the base of the weathering, and it enables the convenient investigation of the head wave coefficient.

The CIG can be stacked on either common receiver gathers or common shot gathers. As a result, the CIG exhibits the unique ability to separate the refraction signal into the up-going and down-going components. The stacked CIG waveforms approximate time model shifted versions of the source and receiver functions.

195: Halloysite NanoTubes – The new economy mineral to ensure every organisation achieves Net Zero Carbon Emissions

Dr Antonio Belperio[1]

[1] Minotaur Exploration Ltd

Natural Nanotech Pty Ltd (NNT) is a research and commercialisation joint venture, jointly owned by Minotaur Exploration (ASX: MEP) and Andromeda Metals (ASX: ADN), formed to investigate nanotechnology applications for halloysite. Halloysite is the nanotubular version of the common, platy clay mineral kaolinite. Halloysite is globally-rare, but present in great abundance in several world-class kaolin-halloysite resources recently defined on western Eyre Peninsula. NNT is working with the University of Newcastle's Global Innovation Center for Advanced Nanomaterials (GICAN) on new high-tech applications for this halloysite nanotube material.

The research with GICAN has confirmed the natural nanotubes, and engineered nanoporous materials produced therefrom, including Fullerenes, have remarkable selective adsorptive properties that can be used in a range of potential industrial applications.

These include Carbon capture and conversion; Hydrogen storage; Remediation of wastewater; Detoxification of pollutants; Energy storage technologies; Antibacterial applications; and Herbicide and pesticide applications.

The unique properties of NNT's nanomaterials that make them so amenable to these applications are their enormous surface area per unit weight, their porous nature and differential charge capabilities between inner and outer surfaces. Indeed the natural nanotubes have proven to be superior to highly expensive synthetic carbon nanotubes in this wide variety of environmental applications. The deposits of western Eyre Peninsula, hosting the greatest known global concentration of halloysite nanotubes, provide an invaluable new technology base for Australian industry.

Having demonstrated potential applications at the laboratory scale the research partners are building a pilot plant for commercial scale sample preparation and industrial testwork, with particular reference to CO_2 capture and conversion into clean fuels. The aim is to provide any organisation with the technology to capture CO_2 at their industrial output scale thereby providing a pathway for them to achieve Net Zero Carbon Emissions without unduly impacting their industrial process route.

196: How to enhance magnetotellurics (MT) resistivity model resolution using passive seismic HVSR depth models to identify the cover-basement interface

Mr Nuwan Suriyaarachchi[1,2], Dr Jeremie Graud[1,2], Dr Hoel Seille[3], Dr Mark Lindsay[1,2], Dr Vitaliy Ogarko[4], Dr Lachlan Hennessy[5] and Prof Mark Jessell[1,2]

[1] Centre of Exploration Targeting, School of Earth Sciences, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia
[2] Mineral Exploration Cooperative Research Centre (MinEx CRC), School of Earth Sciences, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia
[3] CSIRO, Deep Earth Imaging FSP, Australian Resources Research Centre, 26 Dick Perry Avenue, Kensington WA 6151, Australia.
[4] International Centre for Radio Astronomy Research, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia
[5] 4 Anglo American Group Discovery and Geosciences, 201 Charlotte Street, Brisbane 4000 QLD, Australia

Magnetotellurics (MT) and passive seismic are geophysical methods commonly used to characterise the cover-basement interface. This study investigated a new approach to bring passive-seismic horizontal-to-vertical spectral ratio (HVSR) model constraints into MT resistivity models to reduce uncertainties in estimating cover-basement interface.

Inverting MT apparent resistivity and phase data using Occam's inversion algorithm yields the smoothest model that describes the observations with an acceptable misfit. However, the resulting smoothest model is not sensitive for sharp resistivity contrasts, which is critical to identify the cover-basement interface. HVSR interface-depth model, which detects possible cover-basement interface depth ranges, is used to control the MT inversion regularisation to support the depth interface prediction in MT inversion. It is assumed that the prior interface-depth model generated from passive seismic HVSR models can detect possible interfaces up to 1500m depths.

We created a two-layer synthetic model with 20 Ω m cover resistivity, 1000 Ω m basement resistivity and cover-basement interface at 1000m depth. The 1-D MT forward response (with frequencies ranging from 10^4 to 10^{-3} Hz) was calculated using the impedance recursive approach, and 5% random noise was added to the synthetic responses. We assumed a cover-basement interface predicted by the HVSR modelling to be in the range between 750 m and 1250 m depth.

The new constraining method was tested with the unconstrained methods minimum gradient support regularisation and depth weighted regularisations. The new approach was able to recover steep resistivity contrasts at predicted depths. Minimum resistivity model oscillations were detected close to the correct (cover-basement interface) depth prediction, and interface detection uncertainty was reduced significantly.

197: Probabilistic modelling of groundwater salinity using borehole and AEM data

Mr Neil Symington, Dr Anandaroop Ray[1], Mr Chris Harris-Pascal, Dr Kok Piang Tan, Dr Ley-Cooper Yusen, Dr Brodie Ross Colin and Dr Taylor Richard

[1] Geoscience Australia

Groundwater is a critical resource across Australia for supporting human consumption, stock water, agricultural use, and mineral or energy extraction. However, the quality of Australian groundwater varies enormously from potable to hyper-saline. To evaluate the suitability of a groundwater resource, the spatial distribution of salinity within an aquifer is typically estimated by measuring the electrical conductivity (EC) of groundwater samples from within boreholes or extracted from aquifer material. However, drilling is a logistically and economically challenging task, and we are usually left with a sparse set of measurements from which to infer groundwater salinity over large spatial extents.

Airborne electromagnetic (AEM) surveying is a geophysical technique for estimating the bulk electrical conductivity of the near-surface. AEM can be flown rapidly and cost-effectively over large swathes of land providing data with high-lateral resolution. Where AEM bulk conductivity are well correlated with groundwater salinity in aquifers, AEM can be used to model groundwater salinity in the data sparse areas between the boreholes.

We present here a probabilistic method for modelling salinity and case study from the Keep River Plains in the Northern Territory. Co-located probabilistic AEM inversions and EC measurements on pore fluids at coincident locations were fused to calculate an empirical joint probability density function. This function allowed us to estimate salinity away from the bores by sampling the ensemble of AEM conductivities. Unlike deterministic methods that provide a single estimate of salinity, our method generates an ensemble of estimates, which can be used to quantify predictive uncertainty. The results provided by our method can feed into decision making while accounting for uncertainty, enabling remote communities to manage their land and water resources more sustainably.

203: 3-D Gravity geometry inversion of the Matheson Area, Abitibi Greenstone Belt: maintaining the contacts of one of the geological unit fixed for obtaining superior results

Mr Fabiano Della Justina[1] and Prof Richard Smith[1]

[1] Laurentian University

Gravity Inversion is an important tool for interpreting and understanding geological structures in the subsurface. The main goal of an inversion is to perturb a geophysical/geological model to accomplish an acceptable level of reproducibility of the model data with the observed data. There are several inversion techniques described in the literature. Some of them are well established and have been used extensively in the geophysical-data-interpretation workflow; others are still developing. Regardless of which technique is utilized more realistic results are usually achieved when geological constraints are taken into account. Using measured density values and surface geology as constraints, and a compilation of two data sets of ground gravity as observed data, 3D inversions using the VPmg algorithm was used to estimate the subsurface model in the Matheson area, which is located in the southern part of the Abitibi Geenstone Belt, Canada. Besides the aforementioned constraints, the contacts of the Porcupine metasedimentary assemblage (one of the 9 geological units presented in the study area) were fixed during the inversion. This was because priori 2D forward modelling had derived a model also consistent with reflection seismic data. When the Porcupine assemblage contacts were free to move, the thickness was judged to be geologically unrealistic. However, when the Porcupine assemblage contacts were fixed, the model was realistic and there was a smaller misfit between predicted and observed data. The geological likelihood of the geometries and depths of the geological unit bases obtained from an inversion, were used as the criteria to judge whether a model was realistic or unrealistic.

205: Geology of the shear zone hosted Dugald River Zn-Pb-Ag deposit, Mt Isa Inlier, NW QLD

Mr Corey Jago[1], Mr Pieter Creus[2] and Mr Shaun Neal[1]

[1] MMG Ltd.
[2] James Cook University

Dugald River is a world-class deposit with a resource of 68 Mt @ 11.6 % Zn and 1.2 % Pb, 26.1 g/t Ag. The deposit has experienced a protracted history of polyphasal folding, shearing, boudinage and brecciation with mineralisation governed by a prominent shear zone. This has caused the orebody to become attenuated, anastomose, pinch and swell into a complex array of ore textures with varying sulphide distribution and alteration occurrence. The deposit is hosted within the Dugald River Slates and consists predominantly of sphalerite with a variable distribution of galena, Ag and gangue pyrrhotite, pyrite and carbonate. The key ore texture types include banded, transposed ore, milled breccias with massive sulphide matrix, sulphide bearing carbonate crackle breccias and lesser low-grade sphalerite to pyrrhotite-pyrite stringers. Chalcopyrite occurs in the hangingwall of the orebody within quartz vein breccia, with pyrrhotite-pyrite stringers and the brecciated margins of localised albitite. The Cu resource sits at ~10Mt and is discontinuous due to data paucity but contains strategic value due to the association with Au, Co and Mo. The Dugald River Slates are enriched in K, Ba and Mn as widespread K-feldspar, hyalophane and manganiferous variants of carbonate, garnet and sphalerite. Carbonate and Fe-sulphides are extensive throughout the slates and are considered paragenetically pre-, syn- and post- mineralisation. The deformation history includes S_1 preserved within altered porphyroblasts, which are aligned parallel to the pervasively developed S_2 cleavage, whilst an S_3 crenulation cleavage is localised to the hangingwall micaceous schists and mafic porphyry. Past research presents conflicting deposit origins from exhalative formation, to the structural modification of exhalative sulphides to a pure epigenetic origin post-dating peak metamorphism within the lithologically controlled shear zone. The deposit remains open along strike and at depth with significant opportunities for growth possible based on current orebody knowledge.

206: Towards standard technical Deeds for (airborne) geophysical surveys in Australia

Dr Yvette Poudjom Djomani[1] and Dr James Goodwin[1]

[1] Geoscience Australia

Geoscience Australia (GA) and its predecessors have been conducting geophysical surveys since early 50's and processing data for many years. GA's role has changed from being a pioneer in the acquisition and processing of data to focusing on setting standards for the geophysical industry in Australia. The experience gained from conducting surveys in the 1990s with modern geophysical equipment is now used to ensure that any government survey is conducted to a level of quality that ensures the collected data is world-class and fit for purpose.

Since 2003, GA has supervised the processing of several geophysical surveys collected under contract to the States/NT agencies. This degree of exposure to various contractors, survey configurations and environments provides GA with an unprecedented level of insight into ideal processing routines and survey parameters to deliver quality pre&checkhyphenorendash;competitive products for interpretation.

Deeds of Standing Offer were introduced in 2003. Suppliers on the Deed have been pre-approved to provide geophysical data , processing and supply services to GA, meaning the process of tendering has been streamlined from several months to several weeks. Additionally, quality controlled reference products and deliverables have been incorporated into the Deed to ensure that the standards are routinely followed and easily verified. The process is further checked by having all contractor systems flown across calibration ranges prior to the commencement of surveys and when significant adjustments or equipment replacements are made. Well established now for the magnetic, radiometric and ground gravity surveys, the same approach has recently been applied to AEM systems and is being developed for airborne gravity and gradiometry.

GA ensures that all geophysical data acquired within Australia comply with seamless technical requirements, instruments are calibrated appropriately, and data delivered by contractors have been rigorously quality controlled according to guidelines set by GA and agreed with the contractors.

207: The Delamerian Orogen- An overview of the resistivity structure across scales

Dr Kate Robertson[1], Mr Tom Wise[2], Ms Stacey Curtis[2,3], Dr Alison Kirkby[4], Dr Stephan Thiel[2,5], Mr Jingming Duan[4] and Prof Graham Heinson[5]

[1] University of Adelaide
[2] Geological Survey of South Australia, Department for Energy and Mining
[3] STEM, University of South Australia
[4] Mineral Systems Branch, Geoscience Australia
[5] School of Physical Sciences, University of Adelaide

The Delamerian Orogen marks the transition from the eastern extent of Proterozoic Australia to the oldest of a series of Phanerozoic orogens comprising the Tasmanides. The Delamerian Orogen spans parts of the Paleo-Mesoproterozoic Curnamona Province, the Neoproterozoic Flinders Ranges and into the covered regions of eastern South Australia and western New South Wales and Victoria, where the potential for a range of mineral systems has been demonstrated.

Here we present 3D and 2D resistivity models of the lithosphere beneath an area of southeast Australia, derived from the Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) and a subsequent infill broadband MT transect collected in October 2020.

The Flinders Ranges is a zone that has been weakened by multiple Precambrian rift cycles related to the breakup of Rodinia, which has possibly lead to the utilization of this lithosphere for the focussing of fluid alteration causing high conductivities in crust and upper mantle depths in this region, as imaged in the AusLAMP 3D resistivity models. The northwestern end of a 100 km MT transect traverses this region and 1.5 km MT site spacing resolves high conductivity pathways that broadly correlate with previously identified mineral prospects. These pathways straddle the resistive granodiorite rocks of the Anabama pluton, a known to host porphyry-style mineralisation. To the southeast, the transect images the onlapping Mesozoic Murray Basin sediments, and Cambrian rocks beneath, where the crust exhibits high resistivities and seismic velocities, suggesting a depleted lithosphere.

211: Maximising the value of high-definition 3D coal seismic data

Mrs Margarita Pavlova[1], Mr Matthew Grant[1] and Dr Tim Dean[1]

[1] BHP

The acquisition of seismic data over coal mining leases in Queensland's Bowen Basin first commenced over 20 years ago. Since then, seismic data has predominantly been utilised for structural interpretation, particularly fault delineation. In the last decade advances in 3D land seismic data acquisition and processing have provided seismic interpreters with improved datasets which can now also be used for quantitative analysis in addition to structural framework definition. Whilst the majority of seismic technologies have been developed for the oil and gas industry, they can be adopted to shallow 3D seismic surveys over coal mine leases. This paper reviews the application of current key seismic processing and interpretation techniques within BHP, including examples of how seismic data can be used to both improve coal mine operational efficiency and mitigate safety risks.

Firstly we will show the advantages of pre-stack depth migration (PSDM) when compared to time migration, particularly in areas affected by complex shallow velocity anomalies. We will then demonstrate how automatic fault extraction can reduce interpretation time, and how seismic attributes can aid seismic interpretation. Finally, an overview of QI techniques will be provided, and it will be explained how their outputs can be integrated with borehole log data and utilised for coal seam burden characterisation, which is especially important for mine planning.

214: Magnetic characterisation of the Osborne IOCG deposit: magnetic fabrics, self-demagnetisation and remanence: Cloncurry District, QLD

Mr Andreas Bjork[1], Dr Jim Austin[1], Mr Ben Patterson, Miss Renee Birchall and Dr Helen McFarlane[2]

[1] ASEG
[2] CSIRO

Integrated petrophysics linked with structural geology and minerology are powerful tools for mineral system characterisation. In this study, open pit samples and drill core from the Osborne IOCG deposit were measured for anisotropy of magnetic susceptibility (AMS) and remanence. This study focused on the relationships between petrophysical properties and the geophysical high amplitude anomaly of the deposit.

The magnetite rich "iron formation" typically has high density and magnetic susceptibility, which show a near linear relationship, related to magnetite content ($R^2 = 0.77$). Samples are magnetically anisotropic, with P-factors ranging from 1.15 to 1.25 and define a NNW-SSE oriented magnetic foliation. However, the K1 principal component of the AMS ellipsoid is close to horizontal, and therefore does not add to the vertical component of the magnetic field or contribute significantly to the TMI anomaly over the deposit.

Koenigsberger ratios (Q) are commonly < 0.5. Some Q-values above 2 are observed in the mineralised Intermediary Ironstone. However, there is no monoclinic pyrrhotite and the elevated Q-ratio is instead a result of the very low magnetic susceptibilities (mean 0.04 SI), likely associated with pseudo single domain magnetite. Remanence is subordinate to magnetic susceptibility at Osborne because multidomain magnetite grains are the main carrier. Therefore, remanence does not contribute significantly to the total magnetisation of the deposit.

Statistical relationships between density and magnetic susceptibility (R^2 of 0.87 or better), breaks down at high K-values of 1.5 ≥ SI i.e. parts of the Lower and Intermediary Ironstone. This suggest that neither the AMS fabric, nor remanence is the cause of the mismatch between the location of the ore body and the TMI magnetic anomaly, which subsequently made the initial drill siting difficult. It is instead related to the self-demagnetisation effect, and/or local modification of the magnetic field, which are both due to the extreme magnetic susceptibilities observed.

215: The resistivity structure of the Gidyea Suture and its relationship to the Carpentaria Conductivity Anomaly

Dr Janelle Simpson[1], Mr Dominic Brown[2] and A/Prof Karen Connors[3]

[1] ASEG
[2] Geological Survey of Queensland
[3] W.H.Bryan Mining & Geology Research Centre

The Gidyea Suture is a structure that lies on the eastern margin of the Mount Isa Province. It was first recognised in deep crustal seismic, and subsequent authors have used magnetotelluric (MT) data to further support its existence. It is considered to be a highly conductive zone that is part of the broad-scale Carpentaria Conductivity Anomaly (CCA). New, high-resolution MT data in the Cloncurry region, together with a more detailed interpretation of the location of the Gidyea Suture from the deep crustal seismic data provides additional constraint on the conductivity structure of the Gidyea Suture.

The crustal conductivity feature typically attributed to the Gidyea Suture varies considerably along the strike of the suture. The conductivity feature typically sits in the Numil terrane, which underlies the suture to the east. The conductivity feature extends into the upper crust. In contrast, to the west of the suture in the Cloncurry area, there is a resistive upper crust and a broad region of conductive lower crust that is largely confined between the suture and Quamby Fault. To the north where the Gidyea Suture is offset laterally by the Quamby Fault, the upper crustal conductor is present both to the west and east of the suture. A significant conductivity feature was also imaged in the mid to upper crust along the Quamby Fault. This feature may be associated with upper crustal graphitic shale basins or alteration along the fault. All these different conductive structures are within the zone typically considered to be the CCA. The complex and variable nature of resistivity structures along and around the Gidyea Suture indicates it cannot simply be thought of as an anomaly related solely to the suture.

216: Continental shelf marine MT feasibility study in the Spencer Gulf, South Australia

Prof Graham Heinson[1], **Dr Kate Robertson**[2], Mr Goran Boren[1], Prof Steven Constablè[3], Mr Jake Perez[3], Mr Ben Kay[1], Dr Stephan Thiel[4], Mr Jingming Daun[5] and Mr Darren Kyi[5]

[1] School of Physical Sciences, University of Adelaide
[2] University of Adelaide
[3] Scripps Institution of Oceanography
[4] Geological Survey of South Australia, Department for Energy and Mining

[5] Mineral Systems Branch, Geoscience Australia

With the completion of AusLAMP in South Australia, we have a good understanding of the resistivity structure across the State. An outcome of AusLAMP is the identification of a major arcuate-shaped high conductivity feature that follows the northern and eastern extents of the boundary of the Gawler Craton. The eastern part of this conductor is interpreted as the fossilised fluid pathways of the Olympic Domain, a world-class region for IOCG mineralisation.

To the south-west lies the roughly N-S crustal Eyre Conductivity Anomaly (~250 km in length and ~50 km wide), and to the east, two major parallel conductivity anomalies that together contribute to the major Flinders Conductivity Anomaly, ~300 km in length and ~50 km in width, extending from mid-crust to shallow upper mantle depths. At the point of vergence between these three major elongated conductivity anomalies, a lack of MT station coverage due to the shallow gulf waters has so far hampered efforts to constrain the offshore extents of these conductivity features.

A previous land-based broadband MT survey just south of Mt Hope on western Eyre Peninsula to Tumby Bay at the eastern edge of the Eyre Peninsula resolved the Eyre Conductivity Anomaly in detail, with correlations to known graphite deposits suggesting grain-boundary graphite films as the primary conductive cause. This transect has now been extended eastward into the Spencer Gulf- completing an amphibious MT transect, ~240 km in length, with 36 terrestrial MT sites (~2 km spacing) and 12 marine MT (~10 km spacing). We discuss the resistivity structure of the Spencer Gulf and the implications for constraining the aforementioned three major conductivity anomalies and their associated mineral systems. We also touch on the logistics of deploying the first marine MT deployments in over 15 years, and the scope for future offshore MT ventures.

220: Gaining value from historical AEM data

Mr Shane Mulè[1] and Dr Timothy Munday[2]

[1] Mineral Resources, CSIRO
[2] CSIRO

Australia is covered with a significant number of AEM surveys, primarily acquired over the last three decades. Most of these data were collected with now obsolete systems or system variants. Unfortunately, many of these historical datasets contain unknown, uncertain or poorly measured system parameters and undocumented or poorly documented metadata such as acquisition and processing methods. With an increased emphasis being put on getting more information from AEM datasets, their quantitative use requires that they be interpreted using full non-linear inversion methods. Unfortunately, that requires information on system geometry, transmitter waveform, and other processing parameters. Where this information is lacking, uncertainties in derived models for the conductivity structure increase. In recent years, state geological surveys, and government water departments along with Geoscience Australia have been acquiring large spatially extensive AEM surveys with more modern AEM systems. Most recent of which, the AusAEM programme, has been acquiring AEM over large regions of Australia. Although these large AEM surveys are typically acquired with relatively large line spacing which limit their application for fine-scale mapping, they do provide a basis for standardising historical datasets, therefore providing more accurate estimates of subsurface conductivity and extending their value and relevance.

Here, we present methodologies and results from recent AEM interpretation projects in which historical AEM datasets have been applied to address mapping tasks for groundwater and mineral exploration applications. In addition to historical data, modern regional AEM data is integrated to assist with modelling historical data and to extend the application of regional AEM data to finer scale domains.

221: The transformation of Australia's first commercial CSG field into a major gas project: How innovation and subsurface understanding have driven success

Dr Mike Martin[1] and **Mr Justin Gorton**[1]

[1] Westside Corporation

The discovery of coal seam gas (CSG) in what was known as Dawson Valley Area dates to 1991, when it was operated by Mt Isa Mines. It was the first commercial coal seam gas field in Australia, with production and sales of gas commencing in 1996, then operated by Conoco and known as Meridian SeamGas.

In 2010, Westside Corporation transitioned from explorer to producer by acquiring a 51% operating interest in Meridian SeamGas from Anglo American (Anglo) and Mitsui Moura Investment Pty Ltd (MMI). Over the last 10 years that Westside has taken production from <5 terajoules per day (TJ/D) to 42 TJ/D with gas being sold to both domestic and export markets. Further acreage acquisition to the north and south effectively doubled the acreage; now known as The Greater Meridian Fields.

The steep rise in gas demand, complex market dynamics, regulatory environment, and competition from large global oil and gas operators makes it a challenging environment for smaller gas producers in Australia. The ability to remain agile and employ innovative approaches to optimize field development are key success factors for Westside's growth. In particular, the utilisation of pad-based drilling of multi-lateral wells has reduced cost and surface footprint, whilst enabling more efficient drainage of reservoirs.

To support these approaches in field development, a more robust subsurface framework was required. Adequate knowledge on the distribution and variability of coal thickness, gas content/composition, structure, geomechanics, and geohazards forms the basis of the static model. It is used both for resource definition and for the optimal planning and execution of multi-lateral wells; reducing drilling risks.

This talk will describe elements of the subsurface static model, the advancement of drilling and completion approaches and how these have contributed to further optimization of economic development and production of gas from the Greater Meridian Fields.

224: Predicting fluid pathways in large discontinuity systems using graph theory

Dr Ulrich Kelka[1], Dr Stefan Westerlund[1], Dr Thomas Poulet[1] and Dr Luk Peeters[1]

[1] CSIRO

Large scale discontinuity patterns such as regional scale fault- and fracture networks are a first order control to subsurface flow. Being able to predict dominant flow pathways in such networks has implications for mineral exploration, geothermal energy extraction, nuclear waste disposal, and groundwater management. Reliable numerical simulations assessing dominant fluid pathways, are however computationally expensive.

Here we present an approach based on graph theory to predict dominant fluid pathways in natural discontinuity systems derived from solving a maximum flow problem on graph representations. Maximum flow algorithms are usually applied for solving flow in pipes or communication networks and we assume the analogy to open fractures or highly permeable fault zones hosted in low porosity rocks. By comparing the predictions obtained from maximum flow with detailed numerical simulations of fluid flow we show how to obtain useful information by utilizing graph algorithms and identify when full numerical simulations must be performed. For this, we numerically solve the fluid flow on different discontinuity networks that either represent open flow conduits or comprise the generic fault zone architecture built up by permeable damage zones surrounding a thin low-permeability fault core. We conclude by pointing out limitations and implications of classical network theory to fluid flow in natural discontinuity networks.

226: A new era for the Australian National Gravity Grids - adding airborne data to the mix

Mr Richard Lane[1], **Dr Yvette Poudjom Djomani**[1] and Mr Phillip Wynne[1]

[1] Geoscience Australia

Since 1976, Geoscience Australia has produced grids of gravity anomalies to support geological mapping and exploration applications. The five editions of the national grids up to 2016 have been based on ground gravity observations, supplemented on several occasions by marine gravity derived from satellite altimetry and once with marine ship track gravity data. Airborne gravity surveys of significant size have been carried out for government organisations across Australia over the past few years. These surveys were carried out for a variety of reasons that included a need to acquire data for areas with land access issues, a desire to reduce the observation spacing over large areas, and where we wished to acquire data offshore. In the planning for the sixth edition of the national grids in 2019, the decision was made to supplement the ground gravity observations with airborne survey data and marine gravity derived from satellite altimetry. The addition of airborne data required a completely different processing sequence to be devised. An important part of this processing was to vertically continue all observations to a single smooth drape surface defined across the entire extent of the grids. A further important aspect of the processing was to ensure that all operations took into account the low pass filtering inherent in airborne gravity data. The results showed clear benefits stemming from the inclusion of the airborne data.

This outcome points to further airborne data being acquired and included in future national grids. Data from airborne surveys acquired by non-government organisations that meet size and quality criteria will also be considered for inclusion.

227: Analysis of teleseismic earthquakes on nodal seismic surveys

Dr Steve Hearn[1], Mr Bodee Bignell[2], Mr John McMonagle[1] and Dr Shaun Strong[1]

[1] Velseis Pty Ltd
[2] University of Queensland

In the past few years, nodal sensors have emerged as the default for seismic exploration. These systems record continuously, and hence record a range of passive events. Although the sensor is designed for higher-frequency events, with appropriate pre-processing it is possible to extract high quality records of teleseismic (distant) earthquakes which are of potential interest in analysis of the crust and upper mantle near the receivers. Aspects of the pre-processing are of interest. Cross-correlations of the earthquake P-wave reveal inter-node time variations which resemble statics contours from conventional reflection processing. Examination of time-distance variation across the nodal array provides an estimate of apparent slowness of the arriving P-wave. This is useful for confirmation of theoretical travel-time models, and for inferring basement dip. Because of the large channel counts in modern surveys, stacking the teleseismic event can provide significant improvement in signal-to-noise. We have used stacked nodal records to infill between recordings made at permanent seismographs in Queensland. Relative travel-time residuals are of order 1-2 s. Teleseisms arriving from different azimuths produce conflicting relative-residual patterns. However, ray-path back projection to upper-mantle depths reveals coherent delay patterns. The observations would be consistent with velocity variations of order 10% occurring in the depth zone 200-300km. This supports lateral variation in the degree of development of an upper-mantle low-velocity zone, with low velocities resulting from increased temperature and partial melting.

228: Lithospheric resistivity structures and mineral prospectivity from AusLAMP data in northern Australia

Mr Jingming Daun

Magnetotellurics (MT) data allow geoscientists to investigate the link between mineralisation and lithospheric-scale features and processes. Given the importance of these data, Geoscience Australia, state/territory geological surveys and academia have acquired long-period MT data across the Australian continent under the Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP). We use AusLAMP data in northern Australia to demonstrate the power of the MT method as a mapping tool for lithospheric-scale features that aids in identifying prospective areas for mineral exploration undercover.

AusLAMP data that were collected in northern Australia under Geoscience Australia's Exploring for the Future (EFTF) programme cross many under-explored and covered regions. We utilise AusLAMP data as a first-order reconnaissance survey to resolve large-scale lithospheric architectures. The highly conductive structures imaged by MT data map the pathways of large-scale palaeo-fluid migration, which is an important element of several mineral systems. In particular, the data reveal conductivity anomalies at lower crustal and lithospheric mantle depths that show remarkable spatial correlations with major suture zones and known gold and copper deposits (e.g. Ernest Henry Mine and The Granites gold mine). These correlations provide evidence that large-scale, highly conductive features may control the localisation of mineral deposits in these regions. These results also identify regions with similar features in several other under-explored areas that may be prospective for minerals.

229: Diagenetic controls on the reservoir quality of organic-rich shales of the Mesoproterozoic Velkerri Formation (Beetaloo Basin)

Dr Claudio Delle Piane[1], Mr Colin MacRae[2], Dr William Rickard[3], Dr Vincent Crombez[1], Dr Moinudeen Faiz[4] and Dr David, N. Dewhurst[4]

[1] CSIRO Energy, Deep Earth Imaging
[2] CSIRO Mineral Resources
[3] Curtin University
[4] CSIRO Energy

Despite more than a decade of sustained production in the U.S., extracting hydrocarbons from unconventional reservoirs remains an enormous economic, engineering and scientific challenge. This challenge results from these geological materials being highly heterogeneous and poorly characterised. Efficiently extracting resources from such reservoirs requires a detailed knowledge of where porosity is located within the target units and how this evolved after deposition during sediment burial and thermal maturation, in order to predict rock property distributions across sedimentary basins and the expected response to reservoir stimulation.

This contribution focuses on the organic rich intervals of the prospective Velkerri Formation from the Beetaloo Sub-basin (Northern Territory), part of the greater McArthur Basin. Due to their age (Proterozoic, ca. 1.3-1.4 Ga), burial history and proximity to faults and magmatic intrusions, the organic-rich units currently targeted as potential hydrocarbon reservoirs can be locally affected by diagenetic geochemical alteration that cannot be predicted based on our understanding of more modern analogues. Specifically, we show how intervals of intense diagenetic quartz cementation are widespread throughout the Beetaloo Basin and preferentially affect the organic-rich intervals of the Velkerri Formation. Quartz cementation manifests as a pervasive nano-crystalline matrix interspersed with clays and is inferred to have positive effects on reservoir quality properties like stiffness and potential for porosity preservation.

This presentation will focus on the quantitative characterization of quartz cement via the integration of micro and nano-structural analysis, geochemical and petrophysical logging as well as sequence stratigraphy, to discuss our ability to predict diagenetic effects on the bulk physical properties of the sediments.

230: Deciphering the building blocks of the eastern North Australia Craton

Dr Karen Connors[1], Dr Janelle Simpson[2] and Mr Dominic Brown[3]

[1] PESA
[2] ASEG
[3] Geological Survey of Queensland

Interpretation of the nature and extent of basement rocks in many regions is hampered by lack of exposure and because potential field data tend to reflect the signatures of overlying upper crustal units, highlighting the need for tools that image deeper. In Northwest Queensland (NWQ) numerous crustal-scale seismic lines were collected from 1994 to 2019 within the eastern North Australia Craton. Although multiple interpretations have been published for some lines, definition of the underlying basement terranes has remained elusive. This project presents a new understanding of the basement terranes that form the fundamental building blocks of the Mount Isa region based on crustal-scale interpretation of all the major seismic lines, integrated with magnetotellurics and tomography, in the mid to lower crust. Surface geology and potential field data helped constrain the upper crustal interpretation.

The major lower crustal blocks beneath the outcropping Mount Isa region include a broad, trapezoidal, N-S trending basement terrane (Pitta Pitta) that reaches its shallowest level beneath the Kalkadoon-Leichhardt Belt, and a 24-30 km thick terrane (Central Isa) that overlies Pitta Pitta and extends east beneath the Eastern Fold Belt. The wedge-shaped, eastern margin of these two terranes has been thrust over Numil crust along the Gidyea Structure. The large Pitta Pitta terrane has been overthrust from the west by the Altjawarra crustal block, and, the Central Isa terrane was later thrust west across the Pitta Pitta and Altjawarra basement terrane. The seismic data indicates that the Tennant basement terrane underlying the Tennant Creek region has limited depth extent as it forms an E-W trending, bivergent block overlying the Altjawarra to the south and Murphy basement terranes to the north.

231: The Do-It-Yourself geophysicist

Dr Anton Kepic[1]

[1] RoqSense

Today we are spoilt for choice when it comes to the ability to make our own measuring instruments and analysis of data. This is not obvious to most of us who have mostly lived in a "production environment" in our professional careers. There are many occasions where a bit of customisation makes a huge difference in capability and marketability for the entrepreneurial. An example is the migration to drone platforms with "strap on" instruments. The proliferation of open software and hardware, such as Micropython and other GNU-based licensing of generic embedded computing platforms provides a data acquisition and data fusion platform that allow many geophysicists to make the measurements they need to transform themselves to new markets or reinvent old practices. In addition, the free availability of production-ready CAD software such as KiCad and FreeCad allows even the novice to create complex electronic/mechanical devices in 3D by sending a CAD file for manufacture directly. These CAD filesmay be slight variants of designs openly published. Thus, a new cottage industry of DIY geophysicists. The open-source hardware and software revolution also alters the ability to educate the "next generation" of geophysicists as it facilitates and empowers self-directed learning.

234: An inventory of peralkaline rocks in Queensland for evaluation of REE enrichment potential

Mr David Purdy[1], Mr Dominic Brown[1] and Mr Bob Bultitude[1]

[1] Geological Survey of Queensland

Igneous rocks are important sources of rare earth elements (REE) and other rare or critical metals. Demand for such elements is currently met by few deposits but is expected to continue to rise as their importance for technological development is realised. Of the igneous rocks, carbonatites and peralkaline rocks are considered the most prospective for high field strength elements, including REE. Many of these rocks host known resources, including in Australia. Resources can be hosted in the primary igneous rocks or within the products of hydrothermal alteration or weathering. Peralkaline igneous rocks are considered favourable sources due to their relative enrichment in the more valuable heavy REE.

Peralkaline rocks predominantly result from extensive fractional crystallisation (i.e. >85%) of very low degree partial melts of enriched or metasomatised mantle. Such circumstances are commonly associated with rifting or mantle plumes in intracontinental environments. Eastern Queensland has experienced episodes of rifting and plume magmatism since the late Triassic. Felsic rocks resulting from this activity stretch between Mackay in the north and the southern border ranges. They include large A- and I-type plutons as well as clusters of smaller rhyolitic to trachytic domes, lavas and shallow intrusions. Some are well-known but the majority have very little geochemistry, geochronology or detailed mapping available for study. Despite this, the few rocks investigated as potential sources of REE have shown considerable promise.

REE and other rare or critical metals are non-traditional commodities and our current knowledge of the distribution of favourable lithologies and potential for economic deposits is limited. We now require a better understanding of these factors to aid both mineral exploration and land use planning. The inventory of peralkaline rocks in Queensland is a compilation of all known information and is an important first step in evaluating the potential for primary or secondary REE enrichment.

235: How deep does ground EM see?

Dr Andrew Fitzpatrick[1], Mr Mike Whitford[1] and Mr Anthony Huizi[1]

[1] IGO Limited

Nickel exploration routinely utilises electromagnetic techniques as a direct detection tool. In the Australian context, conductive regolith dominated terrains reduces the depth of penetration of electromagnetic techniques. Modelling is typically performed to determine the depth of investigation for basement conductors. These can be modelled as plates of various geometries, size, dip and conductance, leading to an infinite number of scenarios. IGO Limited has been exploring for nickel deposits in the Albany Fraser Orogeny in Western Australia at belt scale. This has generated a large number of ground electromagnetic targets to form a significant database. This paper presents an empirical approach of depth of investigation using this comprehensive EM plate database, in conjunction with a conductance grid derived from a belt-scale AEM survey. The results provide a more practical tool for depth of investigation approach that can assist geologists determine effectiveness of EM in their given project area.

236: Practical aspects of wavefield decomposition for permanent seismic rotatory sources

Mr Roman Isaenkov[1], **Dr SINEMYAVUZ**[1], Prof Roman Pevzner[1], Dr Konstantin Tertyshnikov, Dr Julia Correa[2] and Dr Barry Freifeld[3]

[1] Curtin University
[2] Lawrence Berkeley National Laboratory
[3] Class VI Solutions

Continuous and automated reservoir monitoring has the potential to bring a new level of longevity and data quality into seismic monitoring. In addition, compared to surface seismic, borehole-based monitoring has higher repeatability and is much less invasive. In this approach, distributed acoustic sensing can serve as permanent receiver for the entire length of the well, while surface orbital vibrators can provide a continuous alternative to mobile Vibroseis sources. In the Stage 3 of the Otway Project, the 15 000-tonne CO2 injection will be continuously monitored with multi-well offset DAS VSP. To test this approach, the continuous acquisition of the multi-well DAS VSP data using SOVs was commenced in May 2020. We optimise the multi-well DAS VSP data processing for automated data processing and imaging. The sections for 2D transects of each well-SOV pair are consistent with 3D VSP. The sections for 2D transects of each well-SOV pair provide good illumination of the subsurface.

238: Estimate elastic moduli of arenites from micro-tomographic images with digital rock physics

Mr Jiabin Liang, Prof Boris Gurevich[1], Prof Maxim Lebedev[1], Dr Stephanie Vialle[1], Mr Alexey Yurikov[1] and Dr Stanislav Glubokovskikh[1]

[1] Curtin University

Numerical computation from high resolution 3D micro-tomographic images of rocks (known as digital rock physics) has the potential to predict elastic properties more accurately. However, successful examples are limited to samples with simple structure and mineralogy. The physical size of sample is often too small to present heterogeneities at a larger scale and the image resolution is insufficient to characterize the details of rocks. Also, the greyscale values of different minerals in micro-tomographic images are often similar, and previous attempts to segment them as separate phases are not very successful. Here, we propose a practical digital rock physics workflow for somewhat more complex and ubiquitous rocks, namely, sandstones that contain mostly quartz and a small fraction of dispersed clay (known as arenites). Based on a set of images, we obtain a suite of post-computation corrections to compensate for the effects of sample size and resolution of the micro-tomographic images. Furthermore, we build a segmentation workflow that effectively detects feldspar and clay minerals, despite their grey-scale similarity to quartz. A moduli-porosity trend is derived from the subsamples of the original digital images. Bulk moduli agree well with the ultrasonic measurements on the dry samples at 40 MPa. Shear moduli remain overestimated, which is likely caused by poor knowledge of the mineral stiffness. We compensate for this effect using a heuristic correction to the matrix moduli. The final version of the workflow provides accurate elastic moduli trends with porosity and clay content based on only two samples of Bentheimer sandstone.

239: Targeting fractured rock aquifers using magnetic data

Mrs Heather Ballantyne[1] and Ms Karen Gilgallon[2]

[1] SGC
[2] Southern Geoscience Consultants Pty Ltd

Fractured Rock Aquifers are an important source of water, providing supply for mining, irrigation, town water and stock watering. Approximately 40% of groundwater in Australia is present in fractured rock, with one third of all water extraction bores located in fractured rock systems.

Important aspects of exploring for Fractured Rock Aquifers include the ability to assess the size and fracture interconnectedness of a potential aquifer and being able to accurately identify sites for bore targeting.

Airborne magnetic data is a highly effective tool for identifying the location of faults, fractures and potential water traps along dykes and other aquatards. Existing free or low-cost airborne magnetic data previously acquired by government geological agencies and mining-exploration companies covers large parts of Australia and is readily available for download. The survey line spacing varies from wide-spaced 400m to very detailed 25m and can be imaged in a variety of ways to highlight relevant features using filtering such as vertical and tilt derivatives.

Case studies illustrate the use of magnetic data to identify the location of potential Fractured Rock Aquifers. A 25 m line spaced survey in the Pilbara was used to determine the most prospective drill sites for a water bore to supply a mining-related processing plant. The interpretation was completed in collaboration with the company and hydrologists. An 80m line spaced survey in southwest Western Australia was interpreted to identify priority drilling targets close to existing infrastructure for town supply.

In summary, magnetic data filtering and interpretation is a highly cost-effective solution for identifying targets for fractured rock aquifer exploration by drill targeting.

242: Laboratory measurements of seismic properties and forward seismic modelling at the Thunderbox gold mine

Mr Andre Eduardo Calazans Matos de Souza[1], Dr Stephanie Vialle[1], Dr Joel Sarout[2] and Dr Mustafa Sari[2]

[1] Curtin University
[2] CSIRO

Seismic methods are not widely deployed in the mining industry. However, the increasing interest in deeper gold deposits, especially in Australia where the deposits are concealed under a thick cover of sediments, makes seismic methods an appealing tool for gold exploration and mining planning due to their capacity to couple resolution and depth of investigation. At Brownfield gold deposits, such as the Thunderbox gold mine, seismic methods could be integrated with the existing geological knowledge of the mine to help establish new exploration opportunities that extend the known mineralization at depth. However, seismic interpretation remains largely speculative in hard-rock environments due to: (1) highly complex geologic structures, (2) scarcity of boreholes logs, (3) poor database documenting the petrophysical properties of gold-bearing host rocks. To better understand the seismic properties at the Thunderbox gold mine, we characterized in the laboratory over 100 core samples from the mine. Rock Physics laboratory measurements include bulk and grain densities, and ultrasonic P- and S-wave velocities at ambient conditions, in the axial and radial directions of the cores. In addition, four samples were selected to investigate the pressure dependence of P-wave velocity. We found that the seismic reflectivity between the lithological units is low, except for the massive basalt and the talc schist (shear zone) that show a notable acoustic impedance contrast with all lithologies. Given that most of the gold-host rocks at the mine seem to be only economically mineralized when they are in the vicinity of the shear zone, the delineation of this structure at high resolution can be attractive for Thunderbox mine planning. To further assess the use of seismic methods at this mine site, we complemented this study with forward seismic modeling using the laboratory measurements and representative geological sections as inputs.

243: Enhancing interpretation of geophysical models using petrophysical logging

Dr Cericia Martinez[1], Mr Shane Mulè[2], Dr Jelena Markov[1] and Dr Teagan Blaikie[2]

[1] Deep Earth Imaging Future Science Platform, CSIRO
[2] Mineral Resources, CSIRO

Direct petrophysical measurements, such as density and magnetic susceptibility, may prove useful in improving the interpretability of geophysical models. With measurements becoming more abundant and the capability to measure petrophysical properties across the entirety of drill core, there is a need to explore to what extent such measurements may enhance or improve physical property models derived from geophysical inversion.

Towards that goal, we seek to explore and develop a workflow for using petrophysical data in 3D potential-field inversion. The Stavely Arc region is selected as a study area where drill core petrophysics and regional potential-field data are available. We apply 3D gravity inversion to a subset of the region and use the available density measurements as constraints in the inversion. Results indicate that using petrophysical measurements in inversion may help to further constrain the recovered physical property values in areas away from the borehole locations.

244: Curtin *In-Situ* GeoLab – advancing geophysical sensing

Dr Konstantin Tertyshnikov, Mrs Sana Zulic[1], Dr Alexay Yurikov[1], Dr Sinem Yavuz[1], Mr Evgenii Sidenko[1], Mr Roman Isaenkov[1] and Prof Roman Pevzner[1]

[1] Curtin University

Developments and advancements in geophysical instrumentation and sensing is ever going process. The Distributed Acoustic Sensing (DAS) is a novel approach in sensing which constantly increasing its presence in various geophysical applications. It is paramount to understand the measurements, what are the limitations and performance of the technology for proper utilisation. Benchmarking emerging technologies against conventional receivers and cross challenging different equipment designs in is also essential. Curtin University has built the In-Situ GeoLab Research facility and accumulated a comprehensive reference dataset that includes data with conventional geophones as well as new distributed sensors. The Curtin GeoLab based on a deep well instrumented with fibre optics, surface deployed helical fibre cables, a number of controlled sources. Here we present results of recent DAS borehole trials and DAS surface experiments at the facility.

245: Comparative hydrogeological characterisation of the Springbok and Precipice Sandstones

Dr Oliver Gaede[1], Dr Pascal Asmussen[2,1] and Dr David Murphy[1]

[1] Queensland University of Technology
[2] The University of Queensland

The Springbok Sandstone (Surat Basin, Australia) overlies the Walloon Subgroup, which is a significant target for Coal Seam Gas (CSG) production. In order to assess and mitigate possible groundwater impact of CSG production, it is critical to define groundwater flow units. This is challenging for the Springbok Sandstone due to the significant heterogeneity of its mineralogy and lithology as well as hydrogeological properties. This contribution aims to reduce the uncertainty of the hydrogeological characterisation of the Springbok Sandstone through a comprehensive comparison with a well-understood aquifer in the Surat Basin: the Precipice Sandstone. For the systematically comparison of both formations new geochemical, mineralogical, and porosity and permeability data has been acquired. Here we present the results from over 200 samples. The laboratory results are used to calibrate petrophysical models for the Springbok and Precipice Sandstones. Our results show, that a petrophysical model of the Springbok Sandstone needs to take into account a suite of minerals (in particular clays) in order to accurately predict the porosity of the formation. The petrophysical models can be used to identify zones of high and low permeability and therefore help improve the accuracy of groundwater impact assessments and mitigation strategies.

246: Subsurface characterisation using full waveform inversion of vertical seismic profile data: Example from the Curtin GeoLab well

Ms Sana Zulic[1,2], Mr Andrej Bona[1], Prof Roman Pevzner[1], Dr Konstantin Tertyshnikov[1] and Dr Alexey Yurikov[1]

[1] Curtin University
[2] HiSeis Pty Ltd

Full waveform inversion (FWI) utilises the complete seismic wavefield (transmitted, reflected and converted waves) to build the models of subsurface physical properties. In this abstract, we show results from a feasibility study of 2D FWI applied to synthetic multi-offset vertical seismic profile (VSP) dataset based on the subsurface model of Curtin Geolab Well-01. The workflow is tested on the synthetic data and then applied to the field multi-offset VSP data acquired at the Geolab facility. For the forward problem of FWI, we use finite difference modelling, while for inverse problem we use L-BFGS optimisation method for the minimisation of the misfit function. The test on the synthetic data demonstrated that the workflow is robust and can be successfully applied to the field multi-offset VSP data acquired at the Geolab facility.

247: Magnetic inversion constrained by probabilistic magnetotellurics models: methodology and application

Dr Jeremie Giraud[1], Dr Hoël Seillé[2], Dr Vitaliy Ogarko[3], Dr Gerhard Visser[4], Dr Mark Lindsay[5,6] and Prof Mark Jessell[5,6]

[1] Centre of Exploration Targeting (School of Earth Sciences), The University of Western Australia, 35 Stirling Highway, Crawly, WA, 6009, Australia
[2] CSIRO, Deep Earth Imaging FSP, Australian Resources Research Centre, 26 Dick Perry Avenue, Kensington WA 6151, Australia.
[3] International Centre for Radio Astronomy Research, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia
[4] CSIRO Deep Earth Imaging Future Science Platform, 26 Dick Perry Av., Kensington, WA 6155, Australia
[5] Centre of Exploration Targeting, School of Earth Sciences, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia
[6] Mineral Exploration Cooperative Research Centre (MinEx CRC), School of Earth Sciences, University of Western Australia, 35 Stirling Highway, Perth 6009 WA, Australia

We present a cooperative inversion workflow that integrates magnetotelluric-based electrical resistivity models into gravity inversion. The sensitivity of these two geophysical methods complement well, the gravity being suitable to resolve lateral variation of density, while the magnetotelluric (MT) is primarily sensitive to variations of the electrical conductivity across horizontal interfaces. Considering petrophysical and structural prior information, we developed a workflow that leverages stand-alone inversions and knowledge about the resistivity and density of rocks observed in the studied area.

The workflow consists in 1) performing 1-D probabilistic inversions of MT data for each sounding to create an ensemble of 1D resistivity models, all compatible with the data within uncertainty. We then 2) cluster the models from these ensembles to derive lithologic classes, which are used to calculate interface probabilities between rock units. We interpolate these probabilities over the whole survey area and, given the established petrophysical relationships between density and resistivity, we define spatial and petrophysical constraints to 3) perform gravity inversion. In such case, inversion applies spatially-varying multiple bounds constraints using the alternating direction method of multipliers as implemented in the Tomofast-x engine.

The workflow is first tested against a realistic synthetic model. The resulting MT-constrained gravity inversion model shows the presence of the deep horizontal interfaces as suggested by the MT models but unrecoverable using stand-alone gravity inversion as well as clear vertical contacts that were not well defined by the MT models only. This demonstrates the potential value of cooperative inversion of geophysical datasets with different sensitivity and resolution such as MT and potential field data. We then apply our workflow to an E-W profile crossing the Eucla Basin and Albany-Fraser Range (Western Australia), where we model over 130 broadband MT soundings and high-resolution gravity data.

248: The 3D inversion and integration of geophysical data in an active mine environment

Mr Robert Hearst[1] and Ms Karen Gilgon[1]

[1] Southern Geoscience Consultants Pty Ltd

Often during the development of a mining operation there is a need to identify if additional mineral resources are in the vicinity and if the resources identified can be explained by existing geophysical data. There is also the additional complication whereby the development of the mine results in a higher degree of complexity than expected initially and can these areas be detected within existing data sets.

In this case history we look at several generations of geophysical data acquired over a large time period over a mine site in Finland. The data sets include several generations of gravity, magnetic (ground and airborne), Induced Polarisation, magnetotelluric and seismic data. Care has been taken to reduce all data to a common projection, where necessary and possible combine smaller surveys into a unified data set, and obtain time specific topographic data valid for the survey acquisition and mine development at the time.

All data has been inverted in 3D primarily as unconstrained 3D inversions. Limited constrained inversions have also been completed. The efficacy of the inversions is evaluated and the results combined to provide an unique view of the physical properties of not only the deposit, but the surrounding geology as well.

251: Evaluation of ore deposit models using geophysical, geological and geochemical inputs and the implications for exploration activities

Mr Robert Hearst[1], Mr George Brabec[1] and Ms Karen Gilgon[1]

[1] Southern Geoscience Consultants Pty Ltd

A common question often being asked at the present time by many mineral prospects for which ore deposit models have been created prior to development is:

Do the ore deposit models faithfully reflect the ore potential present? This can be a difficult question to answer given the nature of drilling to determine the deposit models. In this case study we set out to take existing ore deposit models and the rock physical properties assigned and complete forward and inverse modelling of the geophysical properties assigned in the deposit model and compare the results to the actual acquired geophysical data sets available.

The most geophysical datasets used in the case histories consist primarily of gravity and magnetic data. The ore deposit models generated from drilling activities and the associated rock physical properties from cores specimens and assay values are used to first generate 3D forward geophysical models. The results of the 3D forward modelling are then inverted to attempt to recover the ore deposit model. The acquired field geophysical data is inverted in 3D as both unconstrained and constrained by the ore deposit model. The results are then evaluated, compared and analysed using geophysical, geological and geochemical data sets.

The results of the analysis have an impact on near deposit exploration in addition potential optimising of exploration techniques and providing realistic type models for target identification along the same or similar trends.

253: Microbial methane production in the Surat Basin, Queensland

Ms Bronwyn Campbell[1], Dr Se Gong[2], Dr Paul Greenfield[2], Dr David Midgley[2], Prof Ian Paulsen[1] and Prof Simon George[1]

[1] Macquarie University
[2] CSIRO

A large proportion of the methane found in coal seams is produced by microbial communities. Despite coal seam methane being a valuable resource for human energy security, little is known about the microbial communities responsible for much of its production. Previous literature has identified many of the microbes present in coal seams internationally and which broad coal characteristics lead to greater methane production, however our understanding of the interactions between these microbial communities and coal is mainly speculative. The present study aims to determine which microbes are performing the final step in coal degradation to methane within the Walloon Subgroup in the Surat Basin, Queensland. Two datasets of coal seam microbial community DNA were processed in order to identify a specific region of a gene (known as mcrA) required for methane production. Closest known relatives and probable methanogenic pathways of the detected mcrA genes were then determined and compared across both datasets. Increased understanding of coal seam microbial community structure and function has the potential to enhance gas production at existing wells, and also to assist in the exploration stage of coal seam gas extraction by providing a clearer guide of which aspects of the coal or which microbes are most important to have present.

254: Closing the gap between ground and airborne IP data modelling

Drandreaviezzoli[1] and Prof Gianluca Fiandaca[2]

[1] Aarhus Geophysics
[2] Department of Earth Sciences, Università di Milano

Modelling of Induced Polarization in AEM data (AIP) has recently been used more often in exploration. Which demands for more research to address the fundamental question "how does AIP compare to ground IP?". Beside some of the well-known differences in terms of, e.g., frequencies deployed and expected to be recoverable or depth of investigation, one recurring issue hampering the comparison is the use of different modelling approaches for ground versus IP. Reconciling them is the first step to address the question above. To that effect, we use TEM data together with full-decay time-domain ground IP data and we adopt the same Cole Cole modelling for both. We produce a suite of simple synthetic examples that illustrate the sensitivity of the two methods to the Cole-Cole spectral parameters and their potential complementarity. The results suggest that ground and airborne IP data can be modelled with the same approach, providing a much more robust IP model, based on their combined influence. Moreover, AIP can help designing more efficient (faster, cheaper, less risky) ground IP surveys, without compromising, often improving, the accuracy of the final output models

255: Laboratory study of temperature variation effects on Distributed Acoustic Sensing measurements

Mr Evgenii Sidenko[1], Prof Roman Pevzner[1], Dr Konstantin Tertyshnikov and Prof Maxim Lebedev[1]

[1] Curtin University

Distributed fibre-optic sensing is being actively used in various exploration and reservoir monitoring applications. Understanding of how exactly distributed acoustic (DAS) measurements can be affected by changing of the temperature conditions is paramount to avoid or/and eliminate noise related to these temperature variations. This can be particularly critical for the DAS time-lapse seismic and passive monitoring.

For this study we utilised the Curtin University Geolab (NGL) research facility and Rock-Physics Laboratory to estimate temperature's effect on three various DAS cables. Two fibres were tested in the laboratory and one cable (installed in the NGL well) was examined at the site. We showed that DAS is sensitive to long-period temperature changes and its response is proportional to a time derivative of temperature. We also estimated strain-temperature dependencies (thermal coefficients) in all three tests. Our study shows that by using DAS and temperature data together, it is possible to estimate strain – temperature change dependency (coefficient – microstrain/°C) for a particular cable. Coefficients estimated in three tests indicate that cable design can affect DAS response to temperature changes. Temperature change can have a significant effect on DAS measurements and must be taken into account in time-lapse DAS seismic monitoring applications and especially for passive monitoring with the utilisation of low frequencies.

256: Next-generation velocity model of the Australian crust from synchronous and asynchronous ambient noise imaging

Dr Yunfeng Chen[1] and Dr Erdinc Saygin[1]

[1] Deep Earth Imaging, Future Science Platform, CSIRO

The proliferation of seismic networks in Australia has laid the groundwork for improved probing of the continental crust. Despite ever-growing seismic instrumentation across the country, the last major effort of mapping continental-scale structures with ambient noise was conducted more than a decade ago. In this study, we develop a new crustal model using a large dataset that consists of nearly three decades (1994-2019) of continuous seismic recordings from over 1600 stations. This unprecedented dataset is further exploited with the recently developed ambient noise imaging workflow of Chen & Saygin (2020) that integrates results from temporary seismic arrays deployed at different times. The new approach enables extracting 1-3 times more noise correlation function (NCFs) than available from the conventional method. As a result, we obtain over 200,000 high-quality NCFs to image the crustal structures, significantly improved upon the most recent model constructed from 7500 measurements.

The final 3D shear velocity model reveals fine-scale structures in the Australian crust. The low velocities at shallow depths (<10 km) are in excellent agreement with the distribution of known sedimentary basins. On the other hand, the long period dispersion data enable resolving to the first time the lower crustal structures with ambient noise imaging. The Moho depths of our model agree well with the values from AusMoho, a reference model complied with point-based Moho depth estimates. Our model also provides new information for the Moho depth in previously poorly sampled regions. For example, our model shows a deeper Moho than previously reported near the northeastern edge of the Gawler craton in South Australia. In conclusion, this study provides significantly improved constraints on the shear velocity structures and builds a new basis for the next-generation crustal model of the Australian continent.

258: Lithospheric-scale magnetotellurics over the Eastern Goldfields Superterrane, Yilgarn Craton

Dr Kate Selway, Prof Mike Dentith and Dr Klaus Gessner

The Eastern Goldfields Superterrane, in the Yilgarn Craton, Western Australia, is one of the most highly mineralised regions on Earth, hosting world-class orogenic gold and nickel-sulfide deposits. Mineral systems models for both of these deposit types suggest that lithospheric-scale processes are involved in their formation. Therefore, lithospheric-scale geophysical imaging is a promising tool to improve understanding of the formation of the deposits and to aid future exploration.

Long-period magnetotelluric (MT) data were collected over the western Eastern Goldfields Superterrane and the eastern Youanmi Terrane. The survey region covers the Kalgoorlie and St Ives gold camps and the Kambalda nickel camp, as well as the isotopic boundary between the older Nd model ages of the Youanmi Terrane and the younger Nd model ages of the Eastern Goldfields Superterrane. A 3D conductivity model of the data has good resolution to 150 to 200 km depth

Results show that the lithospheric mantle is more conductive beneath the Youanmi Terrane than the Eastern Goldfields Superterrane. Crustal conductivity is more heterogeneous but most of the strongly conductive regions (<100 ohm m) are located in the Eastern Goldfields Superterrane. Anomalously conductive zones in tectonically stable mantle often indicate past metasomatism, either through the hydration of nominally anhydrous minerals or the growth of conductive mineral phases such as amphibole or phlogopite.

Quantitative interpretation of the MT model shows that the mantle conductors in the Youanmi Terrane are too conductive to be explained purely by hydrated peridotite and imply the presence of hydrous metasomatic minerals. The observed patterns of lithospheric conductivity suggest a more complex relationship between mantle metasomatism and gold and nickel mineral systems than expected from previous studies, which may inform future exploration.

259: The uplift history of the Kidson Sub-Basin

Mr George Marfo[1], Dr Stuart Clark[2] and Ms Tehani Palu[3]

[1] University of New South Wales (UNSW), Sydney.
[2] UNSW
[3] Geoscience Australia

The Canning Basin, offshore Western Australia, is highly prospective for conventional and non-conventional hydrocarbons as well as Uranium and Zinc-Lead mineral deposits. The Basin has evolved since Early Ordovician undergoing both extensional and transpressional tectonic regimes since then. The transpression events have been associated with significant uplift and has impacted heatflow and fluid migration pathways in the basin. Although the Kidson sub-basin is the largest block in the Canning Basin, the uplift history is not as well understood due to sparse data collection in that region. The recent acquisition of seismic line 18GA-KB1 in 2018 across the Kidson Sub-basin in addition to existing wells provide opportunity to investigate the uplift history of the sub-basin. In this project, we use seismic and well data to calculate a detailed uplift history of the Kidson Sub-Basin. Seismic data reveal two major unconformities, namely pre-Mesozoic and pre-Devonian unconformities and these are interpreted as erosional periods resulting from uplift. Using well data, the decompaction method is used to restore sedimentary units (including source/reservoir rocks) to their maximum burial depths and the difference between the maximum burial depths and present depths is used to estimate the amount of uplift. Results indicate that, up to 200 m of uplift occurred during the Middle Silurian (the Prices Creek Movement). Up to 350 m of uplift occurred during the Middle Carboniferous (the Meda Transpression). Up to 600 m of uplift occurred during the Early Jurassic (the Fitzroy Transpression). In general, the Kidson-Sub-Basin appears to have undergone relatively less uplift compared to other regions within the Canning Basin.

260: Inversion-based automatic processing of AEM data

A/Prof Gianluca Fiandaca[1]

[1] University of Milano

Data processing is a mandatory step before inversion for any geophysical inversion, because data outliers significantly affect the inversion process, often forbidding to reach reasonable inversion models and misfits. In the processing of Airborne Electromagnetic (AEM) data, the specificity consists in the necessity to cull out capacitive and galvanic coupled data, with the latter more difficult to recognize in data space alone.

In this study I propose to use a generalization of the minimum support norm, namely the asymmetric generalized 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 can be identified after the AGMS inversion computing a classic L2 misfit from the final inversion model.

Inversions on AEM data with and without manual processing are compared, with the AGMS inversion able to recognize outliers in the same areas in which data are manually culled out because of coupling, with comparable final inversion models. Moreover, the processing scheme can recognize not only data which are affected by noise, but also data that are not modelled correctly, for instance because of the dimensionality of the forward response: in this case, it can be used for identifying the appropriateness of the modelling within the inversion area.

This inversion-based automatic processing scheme is very robust and works well also with a significant number of outliers; furthermore, it is fully general and can be applied not only to AEM data, but to any geophysical problem simply using the appropriate forward modelling.

261: Inversion of Airborne IP data with a multi-mesh approach for parameter definition

A/Prof Gianluca Fiandaca[1] and Dr Andrea Viezzoli[2]

[1] Department of Earth Sciences "Ardito Desio", University of Milano (Italy)
[2] Aarhus Geophysics

The interest on Induced Polarization 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.

In this study we present a novel approach for model space definition, in which the AIP inversion parameters are defined on model meshes which do not coincide with the forward meshes used for data modelling: the link between model and forward meshes is obtained interpolating the model mesh parameters into the forward mesh discretization. This spatial decoupling allows for defining the AIP model parameters, e.g. the Cole-Cole ones, on different model meshes, for instance one for each inversion parameter. In this way, it is possible to define the spectral parameters, like the time constant and the frequency exponent in the Cole-Cole model, on meshes much coarser than the resistivity and chargeability ones, both vertically and horizontally, with a significant improvement in parameter resolution. However, the novel approach is completely general, and allows for incorporating any kind of prior information through the definition of parameters in problem-taylored meshes.

Examples of the novel inversion approach are presented on different AIP surveys, highlighting the improvements in model resolution, conversion rate and dependence on the starting model when compared to standard inversion approaches.

264: Recognition of igneous rocks encountered in wells in the Carnarvon Basin: implications for drilling and petroleum systems

Mr Michael Curtis[1], A/Prof Simon Holford[1], Dr Mark Bunch[1] and Dr Nick Schofield[2]

[1] Australian School of Petroleum and Energy Resources, University of Adelaide, Australia
[2] Department of Earth Sciences, University of Aberdeen, Scotland

The Carnarvon Basin formed during the separation of Greater India and Australia in the Mesozoic. Rifting was associated with the generation of large volumes of melt (possibly related to a hotspot beneath the Cape Range Fracture Zone), which was emplaced into the upper crust of the Exmouth Plateau and Exmouth Sub-basin from the late Jurassic until breakup in the early Cretaceous. Despite the magmatic system spanning 50 000 km^2 across the Exmouth Plateau and Exmouth Sub-basin, few wells have intersected igneous rocks. Of those that have, we find that the majority of igneous rock penetrations are unintentional.

In this contribution, we evaluate the impact of igneous rocks on drilling operations, and petroleum systems, for each well known to have passed through igneous rocks in the Carnarvon Basin.

265: Geochemical landscape evolution and pattern similarity analysis at tenement scale for gold exploration in Forrestania, Yilgarn craton

Dr IgnacioGonzalez-Alvarez[1], Dr Oscar Rondón-González[2], Mrs Tania Ibrahimi[1], Dr Ian Lau[1], Ms Monica LeGrass[1], Mr Dean Goodwin[3], Dr Vasek Metelka[1], Mrs Tenten Pinchand[1] and Ms Carmen Krapf[4]

[1] CSIRO
[2] Snowden Group
[3] Classic Minerals Ltd.
[4] GSSA

Exploration through transported cover is a fundamental challenge for the mineral exploration industry in Australia. This context is driving the redefinition of approaches and strategies of mineral exploration.

The present study investigates the Forrestania area, located in the Yilgarn Craton, Western Australia as a case study to combine geochemical landscape evolution and pattern similarity analysis techniques. In the research area within Forrestania, dioritic basement and saprock are overlain by the saprolitic package of (1) a lower mottled unit; (2) a middle smectite/nontronite unit; and (3) an upper kaolinitic unit. Lacustrine cover, which is between 6 and 15 m thick, overlies the basement and saprolitic package, and the depth to basement varies from 40 and ~85 m.

The saprock and the lower/mottled saprolite unit preserve the basement geochemical footprint. However, metallic vertical dispersion processes in the area are not efficient due to the presence of three geochemical barriers/gradients (Fig. 1A). These barriers/gradients are (1) the smectite/nontronite and kaolinitic units, (2) the lacustrine and fluvial sediment transported cover, and (3) the soil. In the basement, Au correlates with As ($r^2 = 0.90$); in the lower saprolite unit Au correlates with Ba ($r^2 = 0.91$), and in the soil Au is associated with carbonates.

The landscape regimes in the area are both erosional and depositional. Overall, Au mines and prospects in the region are located within erosional landscape regimes, and the main Au soil anomalies are also located on the slopes of landscape erosional landforms. Pattern similarity analysis was conducted based on the evaluation of the relationship between the mineralisation and covariate data (digital elevation model, flatness, structures, geology, airborne magnetics, and soil geochemistry). Standard geological data integration and data analytics have highlighted three prospective areas for Au exploration in the Forrestania Greenstone Belt with respect to the best Au drilling intersection.

266: Geochemical signatures and critical metal contents of key deposit types in the Mount Isa Province, Queensland, Australia

Dr Vladimir Lisitsin[1], Ms Courteney Dhnaram[1] and Dr Matthew Valetich[1]

[1] Geological Survey of Queensland

Geological Survey of Queensland (GSQ) has undertaken a large-scale programme of systematic geochemical and mineralogical characterisation of key deposit types and mineral systems in the Mount Isa Province, with a particular focus on their critical metal contents. This work contributed to and expanded multi-year collaborative projects between GSQ and CSIRO. The programme encompassed: acquisition of representative drill core and ore samples from multiple deposits of different types (donated by exploration and mining companies); hyperspectral and XRF scanning of continuous core; multi-element geochemistry on multiple samples from each deposit (from ore to distal alteration footprints and background). Target deposit types (and deposits) include: Iron-oxide copper-gold (IOCG - Ernest Henry, E1, Mount Elliott - SWAN, Eloise, Little Eva, Kalman, Osborne and Starra), sediment-hosted Zn-Pb-Ag (Mt Isa Zn-Pb, George Fisher, Dugald River, Cannington), sediment-hosted (*sensu lato*) Cu (Mt Isa Cu, Capricorn Cu, Lady Annie) and phosphorite (Phosphate Hill, Ardmore).

Samples from each deposit were generally collected from multiple boreholes, at a downhole spacing ranging from continuous (phosphorites) to 10-50 m (base metal deposits - to characterise the entire range from high-grade mineralisation to distal alteration and background). Major and trace element geochemistry (for up to 67 elements) was consistently characterised using a combination of exploration industry-standard digestion methods and analytical techniques: four-acid digestion and ICP-MS / OES (48 elements), lithium metaborate fusion and ICP-MS / OES (31 elements), fire assay and ICP-MS (Au, Pt. Pd), Leco furnace (C, S), KOH fusion - ion chromatography (F) and Aqua regia - ICP-MS (Hg, Se, Te).

Sediment-hosted Cu deposits are generally significantly enriched in Co; IOCG – in Co (and sometimes – REEs, Re, In); sediment-hosted Zn-Pb – in Ge (In, Ga) and phosphorites – in REE.

The programme is ongoing in North-east Queensland, expanding the largest internally consistent public database of Queensland's mineral deposit geochemistry.

269: Complex recharge mechanisms creating contradictory tracer signals in a large karst aquifer in northern Australia elucidated by a multi-tracer study

Dr Axel Suckow[1], Dr Alec Deslandes[1], Dr Christoph Gerber[1], Dr Cornelia Wilske[2], Dr Sebastien Lamontagne[1], Dr Yang Guo-Min[3] and Dr Jiang Wei[3]

[1] CSIRO Land and Water
[2] University of Adelaide
[3] University of Science and Technology of China (USTC)

The Beetaloo Sub-Basin in the Northern Territory of Australia has one of the largest Australian prospective resources of shale gas in the Velkerri formation at 2 km to 2.5 km depth. The shallowest aquifer covering this basin is the up to 300 m thick Cambrian Limestone Aquifer (CLA), extending over more than 800 km, with groundwater flow direction from the dry savanna climate in the southeast to the monsoon-dominated climate in the northwest. Both the pastoral industry of the region as well as shale gas industry will use water from the CLA and a robust water balance for this aquifer is needed.

Tracer findings in the karstified CLA are counter-intuitive: radiocarbon concentrations increase instead of decreasing in groundwater flow direction. Tritium is generally low, but detectable in the north, whereas modern gas tracers CFCs, SF_6 and H1301 are high throughout the aquifer, indicating high excess air and suggesting more recent recharge than tritium. Radiogenic helium is present in several bores, indicating upward fluid flow that cannot be further quantified due to a lack of observations in deeper formations. To shed further light on the recharge conditions, samples for ^{85}Kr and ^{39}Ar were taken. ^{85}Kr results indicate a wide range of concentrations from detection limit to modern.

The recharge model in best agreement with the data suggests a strong regional recharge gradient from south to north, further complicated locally by direct recharge into sinkholes. This creates water level fluctuations over wide areas, causing large excess air and allowing the anthropogenic gas tracers to exchange with the recent atmosphere in the unsaturated zone, while recharge is not actually happening. Tritium and ^{85}Kr are therefore considered as the most reliable recharge indicators, whereas CFCs, SF_6 and H1301 mainly indicate the gas exchange process.

270: Post-rift magmatism on the continental shelf of the Otway Basin and implications for the igneous plumbing systems in sedimentary basins

Mr Yakufu Niyazi[1], Dr Mark Warne[1] and Dr Daniel Ierodiaconou[1]

[1] Deakin University

Various types of igneous rocks have been frequently encountered during hydrocarbon exploration of sedimentary basins along rifted passive margins, and their impacts on the hydrocarbon maturation and migration processes are diverse. Buried volcanoes generally act as migration pathways, whilst magma intrusions are often associated with source rock maturation. Importantly, the high acoustic velocity and density of igneous intrusions, introduces imaging problems. Therefore, understanding the igneous plumbing styles within the sediments, remained crucial for hydrocarbon exploration for frontier basins. Combining the seismic reflection surveys with magnetic datasets, in this study we identified six intrusive sills, seven lava flows and feeder dykes beneath them. Thirty cones to trapezium-shaped and twenty-seven dome to eye-shaped mounds are also identified and based on their magnetic and seismic-geomorphic attributes, are interested as monogenetic volcanoes and hydrothermal vents, respectively. The igneous complexes were emplaced between mid-Eocene to mid-Miocene, while the hydrothermal vents are mainly of mid-Eocene. Most of the volcanic/hydrothermal vents are linked to the underlying rift related faults via vertical zones of disruption, which are interpreted as feeder dykes or hydrothermal fluid pipes, respectively. The scattered distribution of sills and dyke-dominated volcanoes of this study, contrasts to most of the recent studies that highlight the importance of the lateral magma transportation in sedimentary basins. Our comparison with the neighbouring Bight Basin, suggests that he thin crust but relatively thick sediment layers of the Bight Basin, facilitated the lateral transportation of magma and promoted sill-fed volcanism, while the magma ascending through thick crust but relatively thin sediment layers of the Otway Basin, produced sufficient magma pressure and promoted the predominantly dyke-fed igneous plumbing system. This work highlights the critical role of basin structures, such as continental crust, sedimentary thickness, and faults, in controlling the distribution, morphology and style of post-rift igneous plumbing processes in magma-poor margins.

272: Using comment field entries in drill hole database to automatically re-log lithologies; application of Latent Semantic Analysis and Supervised Learning

Mr Jean-philippe Paiement[1]

[1] Mira Geoscience Ltd

Often times, geological modelling on projects with extensive historical data is plagued by over complexified lithological dictionaries and inconstancies in the logging. In order to be able to properly interpret and model the geology, geologists often have to reclassify the lithological entries into a new legend by a combination of re-logging, reading of comments and a certain amount of guessing. Coming up with an automated way of reclassifying the lithological entries to a consistent legend that is meaningful for modelling as always been a challenge.

By using Latent Semantic Analysis (LSA), a technique that uses natural language processing in order to analyze relationships between a set of entries and the words they contain to interpret a set of more general concepts, we propose a workflow to relog drill hole databases into new lithological classes using textual comments. This approach uses drill hole database comments to extract general topics that can then be used as learning features in a supervised machine learning approach. The features are used in combination with a few re-logged control holes, with the desired lithological labels, to produce a new set of lithological entries.

The extracted concepts from the LSA model give key insights into the geological relationships and the supervised learning model produces consistent lithological entries to a set of control holes. This novel approach could greatly benefit exploration projects with considering historical data by unifying thousands of disparate and inconsistent entries into a new usable lithological legend.

273: Spatio-temporal distribution of igneous rocks and seismic facies analysis of buried volcanoes of the Prawn Platform, offshore Otway Basin

Mr Yakufu Niyazi[1], Dr Ovie Emmanuel Eruteya[2], Dr Mark Warne[1] and Dr Daniel Ierodiaconou[1]

[1] Deakin University
[2] University of Geneva

Volcanic rocks occur in different types of sedimentary basins, especially those evolving from lithospheric stretching. While volcanoes and other igneous rocks are widespread in the onshore Otway Basin, well-preserved volcanoes have not been documented in the offshore portion of the basin. Here, we analysed high-quality 2D and 3D seismic reflection datasets to investigate the origin and spatio-temporal distribution of the igneous rocks in the Prawn Platform, offshore Otway Basin. Nineteen volcanoes, ranging from ~90–400 m in height and 1.8–6 km in diameter, occur at three stratigraphic levels: late Eocene, mid-Oligocene, and early Miocene. While the igneous sills are relatively small (~0.2–11 km^2), and located immediately beneath the volcanoes, implying a synchronous intrusion activity with the volcanoes. Seismo-geomorphological analysis indicates these are shield volcanoes fed by dykes. Distinct seismic facies characterise these buried volcanoes, including the chaotic central face that represents the main volcanic eruption centre, outward-dipping moderate amplitude reflections of tuff cone, and chaotic reflections at the distal flanks representing the pyroclastic mass-wasting deposits. Interestingly, seismic facies of interbedded extrusive and sedimentary rocks are mainly observed within volcanoes over 250 m high, and are associated with gullies along their flanks, indicating these volcanoes may have been subject to erosion. The discovery of these buried volcanoes extends our understanding of magmatism in the Otway Basin, especially regarding the offshore extension of the Older Volcanics.

279: Using modern downhole EM to discover high-grade, narrow vein lodes in an historical gold field, Bellevue Gold Project, Western Australia

Ms Anne Tomlinson[1] and Mr Gregory John Maude[2]

[1] AIG, ASEG
[2] Southern Geoscience Consultants

Bellevue Mine is located 35 km northwest of Leinster within the highly gold- and nickel-endowed Agnew-Wiluna greenstone belt of WA's North Eastern Goldfields. Gold was first discovered in the mid-1890s predominantly from underground operations active between 1987 and 1997 when the mine closed. Several factors culminated in the mine's closure including a diminishing resource and a prevailing (incorrect) model that the Highway Fault terminated mineralisation. Minor exploration was carried out for 20 years until the project's revival by Bellevue Gold Limited in 2017.

With a new geological model and during their maiden drill programme, the project's potential was confirmed with shallow, high-grade intercepts down-plunge of historical lodes. Gold mineralisation at the Tribune lode was discovered in the second drill programme, followed shortly after by the Viago and Deacon discoveries.

Mineralisation is hosted in Archean tholeiitic basalts, with minor sediments and felsic intrusions, metamorphosed to upper greenschist to amphibolite facies. Gold occurs in gently plunging, high-grade ore shoots associated with semi-massive to massive pyrrhotite ±chalcopyrite, and folded and boudinaged quartz veins, developed within steeply west-dipping shear zones and conjugate low-angle shears.

High pyrrhotite content and its correlation with gold mineralisation is an uncommon characteristic of orogenic lode gold deposits in the Eastern Goldfields. Petrophysical testing of historical core samples was completed in 2017 and confirmed the strong conductivity and chargeability contrast between the target mineralisation and host rock.

DHEM surveys acquired in 1992-1993 included significant anomalies from off-hole conductors located below and to the south of the mine that remained untested until 2019. These are now known to be associated with the Viago lode.

Acquisition of modern high-powered DHEM data has become standard practice to identify strongly conductive, high-grade gold mineralisation and to vector drilling. Over 200 drillholes have been surveyed over a 2km strike length. Deacon is a direct DHEM discovery.

280: Investigation of old pollution site along the Swan River, Perth, Western Australia using the Loupe TEM system

Dr Michael Hatch[1], Mr Gregory Street[2], Mr Andrew Duncan[3], Dr Aaron Davis[4] and Mr Gavan McGrath[5]

[1] University of Adelaide
[2] ASEG AIG GSA
[3] EMIT,Loupe Geophysics
[4] CSIRO
[5] WA Department of Biodiversity, Conservation and Attractions

In this study, data were collected using a new transient-electromagnetic system (TEM) over an area in Perth, along the Swan River, that was polluted by industry in the 1960s and 1970s, and then remediated by the Western Australian government in the 1990s. A fertiliser plant and a landfill were located approximately 1 km to the northwest of the study site (upgradient for the groundwater in the area) and the groundwater was heavily affected by both. Other geophysical data sets have been collected over the area recently and will be compared with the Loupe results as part of this study.

Loupe is a backpack-portable, two-person, time-domain electromagnetics (TEM) system that uses a Slingram configuration to allow resistivity sounding data to be collected "continuously" at walking pace. The signals from the receiver coils are carried to the transmitter via an "umbilical" cable that also serves to maintain a set distance between the receiver and transmitting antennae. At a typical walking speed of 5 km/hr, data are collected at ~3 m intervals. Data are typically windowed into 22 approximately logarithmically-spaced window intervals, ranging from ~6 µsec to ~2.3 msec after transmitter shutoff. The data were inverted using Aarhusinv in a 12 layer smooth-model configuration.

Examination of the inverted data suggests that it is unlikely that there is a sizeable conductive plume originating from the northwest in this data set (based on the expectation that there might still be conductive contaminant still in the groundwater, from the old plant and landfill sites). There are intriguing conductive features in the data that are worth investigating although these may be related to natural salt accumulation along the river, as is seen at other sites along the river.

281: Constraining regional-scale groundwater transport predictions using multiple geophysical techniques

Dr Michael Hatch, Prof Graham Heinson[1], Mr Ben Kay[1], Mr Chris Li[2] and Ms Rebecca Doble[2]

[1] School of Physical Sciences, University of Adelaide
[2] CSIRO

It is becoming more common to incorporate geophysical data sets in groundwater models, thereby not just relying on often spatially sparse data from traditional geohydrological techniques. Not only are the geophysical data sets usually spatially far less sparse, but they can often be collected non-invasively. A disadvantage is that there may be no consistent/obvious link between the geophysical data and properties that the groundwater model is simulating. It is therefore necessary to derive coupling relationships between the geophysical data and the underlying hydrogeology. This is usually performed in a deterministic manner and the uncertainty inherent in the geophysical data (as well as in the coupling) is rarely incorporated. In this study we collect a number of geophysical data sets, including audio-frequency magnetotellurics (AMT), time&checkhyphenorendash;domain electromagnetics (TEM) and nuclear magnetic resonance (NMR), and then by combining these information sets with scattered and sparse hydrological measurements, the geophysical information can be coupled with other data in a stochastic groundwater modelling framework. These geophysical techniques provide constraints on hydraulic conductivity, water table depth, hydrostratigraphy and porosity. When using geophysical data as parameters in groundwater model inversion, it is critical to quantify and account for their uncertainty to avoid incorrectly biasing model outcomes. This study shows how this can be achieved using an ensembler-smoother modelling method incorporating PESTPP-IES. This approach is illustrated using geophysical and hydrological data from Kapunda, South Australia, to evaluate the impact of a simulated In-Situ Recovery (ISR) copper mining operation.

285: Reversible jump sequential Monte Carlo for model inference of airborne Induced Polarisation

Mr Laurence Davies[1], Dr Alan Yusen Ley-Cooper[2], Prof Christopher Drovandi[1] and Dr Matthew Sutton[1]

[1] Queensland University of Technology
[2] Geoscience Australia

Exact methods of Bayesian model selection require exhaustive computation of normalising constants or sampling of the joint posterior of parameters and models via reversible jump Markov chain Monte Carlo (RJMCMC). Until recently, the latter has been favoured in geophysics applications where there is a mid-to-high cardinality of the set of candidate models. However, RJMCMC schemes alone do not easily lend themselves to parallel computing. The focus of this talk is to explore the potential efficiencies of cross-dimensional proposals within the embarrassingly parallelisable static Sequential Monte Carlo (SMC) class of algorithms as applied to parameter and model inference in electrical properties of the Earth. Of particular interest is the detection of induced polarisation effects in airborne electromagnetic data. Advantages of this approach will be investigated numerically in a simulation study followed by an application to real data.

286: Helicopter airborne Electromagnetics at low base frequencies - Western Australia case studies

Dr Adam Smiarowski[1]

[1] CGG Multi-Physics

Low-base frequency (less than 25 Hz) airborne electromagnetic surveying has only been available for a few years. The advantages are longer measuring time to better discriminate strong conductors and to see through conductive cover, as well as utilising a long time-duration transmitter to better energise strong conductors. Low base frequency AEM is more difficult because of increased sensitivity to system motion/rotation noise and fewer available stacks. For strong conductors, the extra signal from the wider pulse available with low-base frequency more than compensates for the reduction in stacking. A comparison of field data from a 30 Hz and 7.5 Hz system showed significantly better detection to a conductive body at 400 m depth with the low-base frequency system. Here, we show a case study from a graphite exploration survey using 12.5 Hz data. The low-base frequency AEM data provides better definition of a known mineralization zone and identifies areas with further mineralization potential. The AEM data show distinct anomalies over graphite-rich zones and agreed with depths to mineralization from drilling.

298: The role of mine waste in the fight against climate change

Dr Anita Parbhakar-Fox[1]

[1] W.H.Bryan Geology and Mining Centre, Sustainable Minerals Institute, The University of Queensland

The global response to climate change, initiated by the Paris Agreement, has been to encourage countries to transition to low-carbon economies. New technologies such as electric vehicles, low-emission power sources and products for the medical and defence sectors are required to support this.

The manufacture of these products requires resources of 'new economy metals' including cobalt, tungsten, rare earth elements, indium, gallium and germanium. Traditionally, these metals were considered unwanted by-products of base metal and precious metal mining operations, and consequently are concentrated in mine waste.

Mine waste reprocessing is business proposition that is increasingly being adopted in many countries, including several in Australia e.g., the Hellyer, Century, Mt Carbine, Mt Morgan and Tick Hill Mines. However, these materials are mineralogically heterogeneous thus, a 'one approach-fits all' will not optimise value-recovery or indeed, guarantee that the waste is environmentally de-risked. Fundamentally materials must be thoroughly characterised adopting similar practices as undertaken in geometallurgical studies.

This research, funded by the Queensland Government, focusses on secondary prospectivity in the state, where at least 40 significant metalliferous mining operations produce mine waste streams containing unknown quantities of new economy metals. Additionally, there are 120 state-managed abandoned mines. Many of these sites contain reactive sulphide-rich mine waste with associated acid and metalliferous drainage risks. Ongoing management of these sites is costly, but their potential new economy metal content – as yet uncharacterised – presents a unique opportunity to rehabilitate these sites through reprocessing waste. The new economy metal fertility of 16 sites was examined. Hosting of Co in sulphides and Mn- and Fe-oxides was observed in tailings, waste rock and spent heap leach materials collected in NW Queensland with REEs hosted by allanite, stillwellite and Fe-oxides. Mine waste collected in NE Queensland confirmed chalcopyrite and sphalerite as In hosts. Metallurgical extraction methods are now being tested.

300: Geology for the future: geology = (numbers / algorithms) ± knowledge

Dr June Hill[1]

[1] CSIRO

The 3D geology model is an essential product of geological analysis because it provides a complete spatial prediction of subsurface geology from spatially sparse data. The amount of digital data available to the geologist now well exceeds the geologist's capacity to use traditional manual interpretation methods. Manual interpretation is too slow for large data sets and the results are often insufficiently consistent to be useable in 3D modelling software. As a result, geologists are now turning to mathematical, statistical and machine learning techniques to help interpret large or complex geological data sets. Automated analysis allows the geologist to produce rapid, consistent results. Geologists can experiment with different interpretations by using their geological knowledge to select appropriate data or modify parameters.

Unfortunately, most geologists lack adequate training in mathematics and computer science to be able to assess the various techniques available. Having a good understanding of the strengths and weaknesses of various techniques can provide the geologist with the confidence to make appropriate choices. I have spent many years experimenting with various approaches to automating the interpretation of drill hole data and would like to share with you the insights I have gained along the way. I will provide you with a geologist's perspective of various techniques and the types of data you require to make these techniques work.

AEGC 2021: Presenter biographies[1]

3. Dr Binzhong Zhou *Binzhong.Zhou@csiro.au*

Binzhong Zhou received his BSc and MSc from Chengdu University of Technology (CDUT), China and a PhD from Flinders University of South Australia. He is currently a Senior Principal Researcher with CSIRO, Australia. Before joining CSIRO, Binzhong lectured at CDUT, worked as a software engineer for Wiltshire Geological Services, and was an Elf research fellow at Oxford University. His research interests include the use of geophysical measurements to improve the mining industry's ability to delineate orebodies and geological structures, and better understand geotechnical characteristics of host rocks, improve mine design, reduce mine safety risks, and increase production and profitability.

7. Mr Gregory Street *gstreet@iinet.net.au*

Gregory Street graduated with a BSc (Hons) in geology (UNE, 1974) and a MSc in geophysics (Univ of London, 1980). Following eight years of mineral geophysics surveys with Scintrex Australia he finished as Operation Manager. He joined the Geological Survey of WA in 1983 where developed an interest in application of geophysics in shallow environmental problems. From 1991 to 2000 he was Director of Environmental Services at World Geoscience Corporation where he was involved in the development of airborne geophysical methods for environmental applications and in particular studies of dryland salinity for which his team were awarded a National Landcare Award. Greg ran his own consultancy company from 2001 to 2006 and was General Manager of Sandfire Resources from 2006 to 2008, leading to the discovery of the DeGrussa deposit now a large copper/gold mine in WA. He has lectured in environmental geophysics as a Senior Lecturer at Curtin University. Greg has twice been President of the Australian Society of Exploration Geophysicists, run three geophysical conferences for the Society and was the inaugural recipient of the Lindsay Ingall Memorial Award for geophysical applications in the wider community. He is currently Director of Tin Htay Pty Ltd carrying out mineral exploration in Myanmar and Loupe Geophysics, an R&D company developing geophysical instrumentation.

10. Dr Yasin Dagasan *yasin.dagasan@solvegeosolutions.com*

Yasin works as a data scientist consultant at Solve Geosolutions. He mainly works on extracting information from core photography using machine learning methods to assist in geological or geotechnical projects. Prior to joining Solve, he worked as a researcher at the University of Neuchatel to improve hydrogeological inversions through machine learning techniques. He is originally a mining engineer and has gained experience in geostatistics and mining boundary optimisation through postgraduate studies. He also worked as a drill and blast consultant for controlled blasting projects for two years.

14. Dr David Annetts *david.annetts@csiro.au*

David Annetts is a research scientist who has been with CSIRO since 2007. A forward-modeller by inclination, he specialises in the application of airborne, ground and down hole frequency-domain and time-domain electromagnetic prospecting methods to marine CSEM, CO_2 sequestration, minerals and groundwater exploration. David is the immediate past President of the ASEG.

20. Dr David Pratt *david.pratt@tensor-research.com.au*

Manager Research & Development, Tensor Research. He holds a BSc (Hons) and MSc from the University of Sydney in geology and geophysics and a PhD in physics from the University of Newcastle. His early career started with the NSW Geological Survey, and then he worked as a geophysical consultant until 1984 when he co-founded Encom Technology. He was Managing Director from 2001 until it was acquired by Pitney Bowes Software in 2007. In 2010 he started Tensor Research with two colleagues to focus on advanced potential field research. He received the ASEG's Grahame Sands Award in 2010 and Laric Hawkins Award in 2013.

22. Dr Julie Pearce *j.pearce2@uq.edu.au*

Dr Julie Pearce is a geochemist with international experience in the UK, Japan, and Australia on interdisciplinary projects. She is currently a Research Fellow with the University of Queensland Centre for Natural Gas, and School of Earth and Environmental Sciences. Pearce has worked with the CO_2CRC and ANLEC R&D to understand the impacts of potential CO_2 storage. Pearce is an expert on gas-water-rock interactions with a focus on the Surat Basin, QLD, Australia. She is additionally working on field monitoring techniques for measurement of methane and understanding its sources through isotopic techniques; and geochemical processes in gas and oil shale. Pearce has published 28 articles in peer reviewed international journals, including three in the top 3% cited for the field of geochemistry. She has collaborated externally in research projects with colleagues in Canada, New Zealand, USA, ANU, Arrow Energy, Origin, Santos, CTSCo Pty Ltd, etc. and provided expert opinion to the Queensland Government. Pearce has secured ~ $ 4.3 million in nationally and internationally competitive funding.

21. Dr Duraid Al-bayati *d.al-bayati@postgrad.curtin.edu.au*

Duraid Al Bayati is a PhD researcher in WA School of Mines: Minerals, Energy and Chemical Engineering at Curtin University. He holds a BSs and MSc in petroleum engineering from Baghdad University/Iraq. He worked at Kirkuk University in Iraq for more than five years as an associated lecturer and laboratory tutor before he got a scholarship to pursue his PhD studies. His research interests include enhance hydrocarbon recovery (CO_2 EOR), multiphase flow in porous media, and reservoir numerical simulation. Al Bayati is a Member of the SPE Western Australian Section as well as the European Association of Geoscience and Engineering (EAGE).

23. Dr Theis Andersen *Thra@via.dk*

Since March 2019, This has been Head of Research and Development at the Center for Built Environment, Energy,

[1]Note presenters are listed using their paper ID number

Water and Climate. The center employs over 50 teachers and researchers. The Research and Development Center contributes to developing, producing and disseminating new knowledge that can contribute to new technological solutions. The centre conducts applied and practical research in collaboration with private and public partners both nationally and internationally.

24. Mr Luke Mahoney *luke.g.mahoney@gmail.com*

Luke graduated from The University of Melbourne, Australia, in 2011 after completing a BSc (Hons) in geology, and has subsequently worked on minerals and energy exploration projects throughout Australia and PNG. Since 2014, Luke has also been completing a PhD, supported by Papuan Oil Search, on the structure, evolution, and hydrocarbon potential of the Papuan Fold Belt in PNG, where he has spent significant time in the field. Luke joined Oil Search full-time in 2018, where he is a member of the PNG Exploration Team.

27. Mr Wolfgang Fischer *wolfgang@petroventures.com.au*

Wolfgang's career in petroleum exploration and development has spanned nearly 47 years during which he has identified attractive, early stage business opportunities, overlooked or mis-appraised by industry. Wolfgang was involved in exploration which led to the discovery of the massive Bayu-Undan gas-condensate field in the Timor Sea. He was also one of the few who, in the late 1990s, recognised early on the potential of coal seam natural gas in Queensland and was instrumental in building and developing an acreage portfolio part of which was sold to a major energy company for hundreds of millions of dollars.

29. Miss Fionna McNee *fionnamcnee@buruenergy.com*

Fionna McNee received a Bachelor of Science in earth science with Honours from The University of Glasgow, UK in 2015 and completed a Masters degree in basin analysis and petroleum geoscience at Curtin University in 2016. Following an internship at Transerv in Perth, Fionna joined Buru as a geophysicist in late 2016 where her roles have been focused on exploration, drilling operations and field development. Fionna is an active Member of PESA and AAPG.

31. Dr Vincent Crombez *vincent.crombez@csiro.au*

Vincent Crombez is a geoscientist with a sedimentology, geochemistry and numerical modelling background. His research mainly focusses on sedimentary basins with a special interest in understanding the distribution of sedimentary heterogeneities within basins. Throughout his work and academic career, he has gained a breadth of experience working with integrated workflows, combining field geology, laboratory analysis, and numerical modelling. Previously, he has worked on different basins, located in various countries including Canada, Argentina, Greece, Morocco and Australia. Vincent currently works for the CSIRO in Perth as a research scientist. He holds a PhD in geosciences from Sorbonne Université (Paris, France) and a MSc in petroleum geology from UniLaSalle (Beauvais, France).

32. Dr Moinudeen Faiz *mohinudeen.faiz@csiro.au*

Dr Mohinudeen Faiz is a petroleum geoscientist with ~30 years experience in both the industry and R&D projects. Faiz holds a PhD and MSc from the University of Wollongong (Australia) and a BSc with Honours from the University of Peradeniya, Sri Lanka. He is currently a Principal Research Scientist at CSIRO Energy, where he focuses on integrated petroleum systems analyses for both conventional and unconventional reservoirs. Previously, Faiz worked at Origin Energy, where he was an organic geochemistry and petroleum systems modelling subject matter expert and contributed to various exploration and development projects of the company based in Australia and overseas. He is a member of AAPG, PESA, and ICCP.

34. Mrs Yvonne Wallace *Yvonne.wallace@sgc.com.au*

Yvonne has over 15 years' experience in mineral exploration projects in Australia, PNG and further afield. She specialises in the integration and interpretation of magnetic and radiometric data supplemented with gravity, sub-audio magnetic, and seismic data. She has worked on projects at prospect through to regional scale and uses modelling techniques to provide quantitative metrics for targeting. Yvonne has presented on AEM and magnetics topics at past ASEG events, and has delivered several aeromagnetic interpretation workshops to site-based geologists.

35. Mr John Coffin *coffin@delft-inversion.com*

John Coffin in the Business Manager Asia-Pacific for Delft Inversion. He is a graduate in geophysics from the University of Leicester (1989) and has worked in the oil and gas industry for over 30 years. John has worked for Digicon, SSL, Schlumberger, Hampson-Russell, Veritas and CGG in a variety of roles across the full spectrum of seismic acquisition, processing, and interpretation. In 1993 he started the first overseas office for Hampson-Russell in London and has been directly involved in the geophysical software business ever since. In 2004 he moved to Perth, Australia and continued to develop the Hampson-Russell business as the Director for the region. When CGG purchased Fugro-Geosciences in 2013 he then became responsible for the Hampson-Russell and Jason business in the newly formed GeoSoftware group covering Australia, NZ, PNG, Timor, and the Philippines. In 2020 with CGG restructuring and the impact of COVID-19 he was made redundant. He then joined Delft Inversion in an exciting new position looking after the Asia-Pacific region. John is an active member of ASEG, SEG, APPG, EAGE, PESA, SEAPEX and the PESGB.

37. Mr Denis Sweeney *denis.sweeney@superseis.me*

Denis has enjoyed a forty-year career in seismic acquisition that commenced in a technical field capacity and expanded to senior management roles across the full spectrum of operations, business development, sales, technical development, and training. Denis has held roles with global responsibility and has lived and worked in Europe, Asia, and the Middle East. The majority of Denis' career was with Schlumberger, WesternGeco until recently taking up the role of Director of Realtimeseismic (Aust) Pty Ltd.

38. Dr Jarrod Dunne *jarrod.dunne@gmail.com*

Jarrod has more than 25 years' experience in seismic amplitude interpretation, reservoir characterization and seismic processing, applied throughout the world, having worked for Shell, Woodside and some smaller oil companies, including his current part-time role at Karoon Energy. He has remained actively involved in R&D throughout his career: writing numerous papers; developing software; and through university collaborations. In 2018, he founded QIntegral with the aim to be recognized as a leading provider of specialist geophysical services, software, and training.

40. Dr Carsten Laukamp *Carsten.Laukamp@csiro.au*

Carsten Laukamp is a Principal Research Geoscientist at CSIRO Mineral Resources, based in Perth, Australia, and leads the AuScope National Virtual Core Library infrastructure programme. Carsten has 15 years experience in applying a combination of mineralogy, geochemistry, geophysics and remote sensing to mineral resources exploration and mining in Australia, Southern Africa and South America. Cost-effective and low-footprint exploration for critical metals through cover is Carsten's current focus.

41. Mr Brendan Ray *brendan.ray@sgc.com.au*

Brendan Ray graduated from Curtin University, Western Australia in 2017 with a BSc in applied geology and geophysics, as well as a BSc (Hons) in geophysics (1st Class). Since graduation, he has worked at Southern Geoscience Consultants (SGC) where he has gained experience in survey acquisition and design, processing, modelling and interpretation of a wide range of airborne and ground geophysical methods. Brendan's involvement with drones began a few years before graduation whilst working in the military, where he was involved in the day-to-day operations of a number of large-scale UAV systems. Fast forward (and scaling down) to now, his involvement with drones has been centred around mineral exploration applications where he has been handling the QC, assessment, and processing of more than 20 UAV-borne magnetic datasets, acquired across 6 countries, over a range of deposit styles.

44. Dr Ruth Murdie *Ruth.Murdie@dmirs.wa.gov.au*

Ruth is currently with the Geological Survey of Western Australia as the 3D geological modeller

47. Mr Partha Pratim Mandal *p.mandal@postgrad.curtin.edu.au*

Partha Pratim Mandal is a current PhD researcher and sessional academic at the Western Australia School of Mines (WASM), Curtin University. His research focuses on creating geomechanical workflows to conduct laboratory measurements of the deformation aspect of shale gas, including the viscoelastic deformation, stress partitioning factor of rock composition, multi-channel active and passive wave velocity recording and elastic anisotropy. He is also interested to transfer geotechnical skill from energy industry to deep earth mining activity for safer operation. He is the recipient of several scholarships and research grant such as RTP Scholarship, EAGE student fund, PESA Federal Post-graduate scholarship and AAPG Grant-in-Aid. He was the founding member and the president of EAGE-SEG student chapter at Curtin University and currently serves as Secretary of the ASEG, WA branch. Previously he worked for six years as imaging geophysicist at PGS both in India and Australia. He received his first-class BSc degree in physics (Hons) from the Presidency College, University of Calcutta, India and MSc Tech degree in applied geophysics from the IIT (ISM), Dhanbad, India.

49. Dr Moinudeen Faiz *mohinudeen.faiz@csiro.au*

Dr Mohinudeen Faiz is a petroleum geoscientist with ~30 years experience in both the industry and R&D projects. Faiz holds a PhD and MSc from the University of Wollongong (Australia) and a BSc with Honours from the University of Peradeniya, Sri Lanka. He is currently a Principal Research Scientist at CSIRO Energy, where he focuses on integrated petroleum systems analyses for both conventional and unconventional reservoirs. Previously, Faiz worked at Origin Energy, where he was an organic geochemistry and petroleum systems modeling subject matter expert, and contributed to various exploration and development projects of the company based in Australia and overseas. He is a member of AAPG, PESA, and ICCP.

55. Dr Asbjorn Christensen *asbjorn.christensen@nordicgeoscience.com*

Asbjorn Norlund Christensen is the owner of Nordic Geoscience Pty. Ltd., consulting world-wide on ground and airborne geophysics for resource exploration. For over 20 years Asbjorn has worked on minerals and petroleum exploration projects in Australia, Asia, Africa and the Americas. He has managed research groups and technology companies. His areas of interest are: the integrated interpretation of geophysical data for minerals and petroleum exploration, and geophysical technology development and deployment, He has an MSc in geophysics from University of Aarhus, Denmark and a PhD in geophysics from Colorado School of Mines, USA. He is a member of EAGE, SEG and ASEG. Asbjorn is based in Melbourne, Australia.

59. Mrs Monica Jimenez *monica.jimenezlloreda@adelaide.edu.au*

Monica holds a Bachelor (Hons) degree in geology from the National University of Colombia and a Masters degree in petroleum geosciences from the Royal Holloway where she obtained a merit dissertation. She has seven years of experience in the oil and gas industry, working on both exploration and development projects. Her areas of expertise lies in seismic interpretation, structural and synthetic modelling. In 2019, Monica started a PhD in ASPER at the University of Adelaide. Her research is focused on the fault evolution in deltaic settings and its implications for petroleum systems.

61. and 62. Mr Alexander Prikhodko *alexander@expertgeophysics.com*

Alexander (PhD, PGeo, EMBA) has over 35 years of professional experience in the acquisition, processing, and interpretation of airborne and ground geophysical data for a wide range of applications. Alexander has been directly involved in the management and supervising many geophysical surveys for mineral exploration. He is an author and co-author of many publications dedicated to airborne EM. In 2019 he was awarded the Barlow Medal for Best Geological Paper published in CIM publications (Canadian Institute of Mining, Metallurgy, and Petroleum).

63. and 64. Dr Shastri Nimmagadda *shastri.nimmagadda@curtin.edu.au*

Shastri is presently Research Fellow in the School of Management (Business Information Systems) Curtin University, Australia. Shastri worked for Schlumberger Company in multiple geo-markets worldwide as an expert in geosciences. Shastri worked for several petroleum operating and service companies in India, Australia, Uganda, Kuwait, Abu Dhabi, Egypt, Malaysia, Colombia, Indonesia and Russia for more than 25 years. He did his PhD in information systems with a Master of Information Technology, PhD, and M Tech in geophysics in Australia. Current research interests include Big Data support in industry environments, supply chain business data modelling, data integration, warehouse modelling, processing, interpretation and knowledge mapping.

65. Mr Graeme Eastwood *graeme@perseusconsulting.com.au*

Graeme is a Business Development Consultant for, among others, land seismic noise specialists. He has a BSc in geology and geophysics from Liverpool University and an MSc in exploration geophysics from Leeds. He has worked for WesternGeco, Fugro and ION Geophysical in the UK, Malaysia, Indonesia, Azerbaijan, the UAE and now resides in Perth.

66. Dr Sasha Banaszczyk *sasha.banaszczyk@gmail.com*

Sasha is a geologist and geophysicist, and recently completed her PhD at the Centre for Exploration Targeting at The University of Western Australia. Her research focused on extracting reliable geological information from electromagnetic datasets acquired over the Capricorn Orogen, WA. Sasha's areas of interest include potential field, airborne electromagnetic and magnetotelluric inversion, the integration of different geophysical, geological and petrophysical datasets, and geophysical and geological interpretation for minerals exploration. She is also an avid white-water kayaker!

69. Dr Chong Zhang *zchong_chn@163.com*

Chong Zhang received a BS (2012) and a PhD (2017) in geophysics from Jilin University. Now he is a geophysicist working at the Chinese Academy of Geological Sciences. His major research interests include deep structures and geodynamic processes of the earth and links to the metallogenic systems, 3D geophysical modelling of ore districts, and gravity and magnetic methods and their applications in resource exploration. He is the PI of an NFSC Project and has published more than 15 peer-reviewed papers. He won the Innovation Achievement Award of the Chinese Academy of Geological Sciences (2018, 2019) and the Macao Young Scholars (2020).

72. Mr Alexander Furlan *afurlan@brocku.ca*

Alex Furlan is a current MSc student at Brock University in Ontario, Canada. He completed his undergraduate degree at the University of Toronto where he compiled and maintained the Nash Creek GIS database among other projects. After spending a summer as a project geophysicist, he started his Masters focusing on Extremely Low Frequency (ELF) electromagnetics.

78. Dr Ned Stolz *ned.stolz@planning.nsw.gov.au*

Ned received an Honours geophysics degree from Adelaide University in 1985, spent five years on greenfields uranium and base-metals exploration with CRA and then completed a PhD on electromagnetics at Macquarie University. The next ten years were on brown-fields exploration in the WA Goldfields at gold and nickel mines where he gained experience with mining, management, databases, technology development and business strategy. During this period, Ned learnt about ore-deposit geology and began mapping mineral systems using 3D modelling to integrate geophysics, geology and geochemistry. Ned then joined Geoscience Australia where he led the geophysics capability in planning and implementing regional-scale seismic, MT and airborne electromagnetic surveys. He joined the Geological Survey of New South Wales in 2016 and currently manages the geophysics and 3D modelling programmes.

79. Miss Astrid Carlton *astrid.carlton@planning.nsw.gov.au*

Astrid is a senior geophysicist in the Geoscience Acquisition & Synthesis unit of the Geological Survey of NSW (GSNSW). Since joining GSNSW in 2007, Astrid has undertaken geophysical modelling, geological/geophysical interpretation and many geophysical acquisition projects, including seismic, magnetotelluric, passive seismic, airborne magnetic-radiometric and ground gravity surveys. She is currently responsible for geophysical acquisition and interpretation for GSNSW MinEx CRC projects as part of a collaborative project to improve geological mapping in under cover.

80. Dr James Goodwin *james.goodwin@ga.gov.au*

James Goodwin joined Geoscience Australia (GA) in 2010 where he continues to work as a senior geophysicist within the Geophysical Acquisition and Processing Section. James is passionate about supporting the responsible development of a diverse mineral resources sector that will benefit all Australians. In line with this, James manages the acquisition of airborne magnetic and radiometric surveys, and ensures their high quality, before making them freely available as part of GA's national compilations. Similarly, James undertakes 3D inversion modelling of gravity and magnetic datasets to aid mineral potential assessments.

81. Dr Nadege Rollet *nadege.rollet@ga.gov.au*

Dr Nadege Rollet is a senior geoscientist at Geoscience Australia. Nadege graduated from the University of Paris – Pierre et Marie Curie, France where she obtained a MSc and a PhD (1999) in geology and geophysics. Her studies focused on structural framework and geodynamic of the Ligurian Sea, Western Mediterranean. Since joining Geoscience Australia, she contributed to assessments of the petroleum prospectivity, seepage studies, CO_2 storage and cover mapping of Australian sedimentary basins. Nadege is currently investigating depositional framework and groundwater systems in the Great Artesian Basin.

82. Mr Martin Bayly *martin.bayly@superseis.me*

Martin has been involved in seismic surveys since 1977. He joined GSI in Sydney in 1981 and has since worked for its successor companies until 2017. Prior to semi-retirement, he was the Chief Regional Area Geophysicist and Advisor for Asia Pacific for Schlumberger / WesternGeco. He is now an Advising Geophysicist for SuperSeis.

83. Mr Christian Proud *cp@qeye-labs.com*

Christian obtained a Bachelor of Science (geophysics) with first-class honours from Curtin University. He has been working as a senior geophysicist at Qeye and has been involved in a variety of quantitative interpretation studies including probabilistic, multicomponent, 3D and 4D simultaneous AVO inversions within Australia, New Zealand, West Africa and Malaysia.

85. Mr Mikael Arthursson *mikael.arthursson@minalyze.com*

86. Mr Patrick Makuluni *p.makuluni@unsw.edu.au*

Patrick Makuluni is a PhD candidate in minerals and energy resources engineering at the University of New South Wales, Australia. He received a BSc in civil engineering from the University of Malawi in 2012 and an MSc in mineral exploration and mining geology from Curtin University, Australia, in 2017. His PhD work combines computer science with geodynamics, sedimentary basin analysis, and seismic exploration to unravel the kinematic evolution of sedimentary basins. His research focuses on improving the accuracy of minerals and hydrocarbon exploration methods to minimize unnecessary excavations and drilling, thereby saving costs and the environment. In 2018, Patrick received the UIPA and the CSIRO Deep Earth Imaging Future Science Scholarships. He won the Best Student Energy Poster Award at AEGC 2019. In 2020, Patrick got the UNSW Postgraduate Council Outstanding Research Student Award, recognizing his contribution to the research environment and higher degree research community. Besides research, Patrick is the current president of the UNSW African Students Union.

87. Dr Roman Beloborodov *roman.beloborodov@csiro.au*

Dr. Roman Beloborodov is a research scientist at CSIRO Deep Earth Imaging Future Science Platform based in Perth. He holds MSc in engineering geology and hydrogeology from the Moscow State University and PhD in geophysics from Curtin University. His research is focused on the development of cross-disciplinary workflows and algorithms for quantitative geophysical interpretation. Roman is actively involved in commercial and research projects where he is responsible for rock physics and petrophysical analysis driven by machine learning algorithms.

88. Mr John Anderson *nanderso@bigpond.net.au*

Geologist by training; minerals explorer in passion. Formerly Aberfoyle, MIM, Investigator. Currently Principal Consultant - Austrike Resources

89. Miss Mahtab Rashidifard *mahtab.rashidifard@research.uwa.edu.au*

Mahtab is a PhD student in earth sciences (geophysics) working on methodology development of integrated inversion of gravity and reflection seismic data with different spatial coverage. Her background is in petroleum engineering with a developed interest in exploration geophysics.

91. Dr Liejun Wang *liejun.wang@ga.gov.au*

Liejun Wang is a senior geophysicist with over 20 years of experience working in Geoscience Australia. Liejun completed his MSc at Flinders University in 1995 and PhD at the Australian National University in 1999. His research interests lie in the area of electromagnetic induction in the Australian continent using magnetotelluric and geomagnetic data. He has collaborated actively with researchers in other organisations, particularly in the area of geomagnetic storms and induction hazards to the grounded technological infrastructure.

95. Prof Richard Smith *rssmith@laurentian.ca*

Educated at the Universities of Adelaide and Toronto, Richard has worked in Australia and Camada. He has been active in the ASEG (Victoria Branch and Federal Executive in the 1990s) and more recently an ASEG representative to the SEG Council. His interests are geophysics for mineral exploration and near-surface applications. Richard is currently a professor at Laurentian University in Sudbury.

99. Dr Gerrit Olivier *gerrit.olivier@imseismology.org*

Gerrit completed his MSc in theoretical physics at the University of Stellenbosch (South Africa) and his PhD in geophysics at the Université Grenoble Alpes (France). He started working at the Institute of Mine Seismology (IMS) in 2011 in Stellenbosch (South Africa). He moved to Hobart in 2014 to take up the role of Head of Applied Geophysics at IMS' Australian office. During his career at IMS, he has pioneered the use of ambient seismic noise based methods for use in the mining industry. Gerrit also serves as an Adjunct Senior Researcher at the University of Tasmania and an Associate Researcher at the Université Grenoble Alpes.

100. Dr Pascal Asmussen *pas.asmussen@gmail.com*

102. Mr Minsu Kwon *minsu.kwon@enerzai.com*

BS in electrical and computer enineering, Seoul National University MS in computer science, KAIST Researcher, ENERZAi

103. Mr Richard Barnwell *rbarnwell@terrexseismic.com*

Richard Barnwell joined Terrex Seismic in 2010 as the Senior Geophysicist after a three-year break from the seismic industry working on various greenhouse gas and renewable energy projects. Richard started his seismic career as an observer on a crew in Algeria in 1990 then moved into data processing and special projects, initially for Western Geophysical and later as a consultant to various Oil and Gas companies. Richard holds a BSc (Hons) in applied physics and electronics from Lancaster University (UK), and a BAppSc in energy studies (2002) and an MSc in renewable energy (2007) from Murdoch University (WA).

105. Mr Danny Li *dli@fmgl.com.au*

Danny Li graduated in 2011 with First Class Honours in exploration geophysics from Curtin University and has recently attained a Graduate Diploma in mineral exploration geoscience from Curtin University. He started his career at a large geophysical consulting company before joining Fortescue Metals Group in 2016 where he is currently a Senior Project Geophysicist providing geophysical support to FMG Exploration's Pilbara iron ore and Western Australian lithium exploration teams.

107. Dr Tim Dean *tim.dean@bhp.com*

Tim has an Honours degree in geophysics from Curtin University and a PhD in physics from the University of New South Wales. He spent more than twelve years working for WesternGeco and Schlumberger in a variety of roles related to surface and borehole seismic acquisition including field operations, software development and research located in Saudi Arabia, England, Norway and Australia. After leaving Schlumberger he worked as a Sports Technology Project Advisor at Hawk-eye innovations (a division of Sony) before spending three years as a Research Fellow in the Department of Exploration Geophysics at Curtin University. He subsequently joined BHP Coal in June 2019.

108. Miss Fatimah Al-zubaidi *f.al-zubaidi@unsw.edu.au*

F. Al-Zubaidi is a PhD candidate in Minerals and Energy Resources Engineering at the University of New South Wales, Australia. She was awarded a MSc in petroleum engineering from the same institution. She holds an Australian Government Research Training Programme Scholarship. Her major research interest is rock typing using machine learning.

109. Dr James Austin *james.austin@csiro.au*

James Austin is a geoscientist specialised in structural geology and potential fields geophysics. His main interests are in the interrelationships between geochemical and physical processes in the crust from sub-grain to global scales. His research is primarily focussed on understanding the crustal processes which lead to deposition of resources; the manifestation of those processes in geological, geophysical and remote sensing data; and the implications for resource exploration. His most recent work is focussed on developing scale consistent approaches to data integration using machine learning, and the development of technology for mapping mineral systems.

111. Dr Remke van Dam *remke.vandam@sgc.com.au*

Remke van Dam is a principal geophysicist with Southern Geoscience Consultants in Perth, Australia, where he promotes geophysical solutions for a broad range of environmental, engineering, and groundwater applications. He received his PhD from VU University (2001) in Amsterdam and specializes in the use of electromagnetic and electrical geophysical methods. He has published over 30 peer-reviewed papers and has extensive field experience around the world. He is a Past President of the SEG Near-Surface Technical Section and is currently an Associate Editor of the Journal of Environmental and Engineering Geophysics.

112. Mr Matt Grant *matthew.grant@bhp.com*

113. Dr Andrea Viezzoli *av@aarhusgeo.com*

Andrea Viezzoli has a PhD in geophysics and has managed Aarhus Geophysics since 2008. He is interested in all aspects of AEM and its applications. In the last five years, he has been heavily involved in studying and modelling IP effects in AEM data.

114. Mr Matthew Musolino *matthew.musolino@adelaide.edu.au*

Matthew Musolino obtained a BSc (Hons) in geophysics from the University of Adelaide. For his thesis, he evaluated geophysical survey design. The data was used to characterise potentially mineralised faults and geological boundaries in Kimba, South Australia, Australia. Following this, he worked as a contractor in exploration geophysics. Matthew conducted ground base magnetic surveys across the state before returning to The University of Adelaide to pursue a PhD in geomechanics. His PhD research focused on evaluating the effect methodological approaches have on uncertainty in principal stress and rock stress magnitudes. Wellbore stability analysis and fracture modelling were utilised to demonstrate how uncertainty in input data may lead to a different interpretation of models and potentially different wellbore designs or decisions. Since completing his PhD, Matthew has been utilising his understanding of stresses and rock strength to characterise ore body response to block cave mining operations.

116. Dr Pavel Golodoniuc *pavel.golodoniuc@csiro.au*

Dr Pavel Golodoniuc is trained in computer sciences with an emphasis on system architectures and numerical modelling and holds a PhD in exploration geophysics (2016) from Curtin University, Western Australia. Before joining CSIRO in 2008, he gained extensive experience in system design of various innovative solutions for commercial, industrial, and governmental sectors. He has held technical leadership roles in national spatial data infrastructure projects in Australia involving multi-disciplinary collaborators from Australian geological surveys, universities, and the international Open Geospatial Consortium (OGC) community. His extensive software engineering experience includes the development of hardware drivers, SCADA systems, software for mobile platforms, and scientific software for numerical modelling and simulation.

In CSIRO, Dr Golodoniuc worked with various research teams within minerals and oil and gas exploration contexts. He proactively sought to apply his computer science background and expertise in the development of numerical algorithms to a range of science disciplines. His early engagement in petrophysics research and professional interest in numerical modelling has led to the pursuit of a PhD degree in exploration geophysics from Curtin University.

His professional focus is on data-intensive cross-disciplinary sciences, data and system integration, scientific data visualisation, Cloud computing, and human/computer interaction. He is now Research Team Leader of the Informatics Platforms team at CSIRO – Australia's national science agency. In his spare time, Pavel is a passionate aviator. He pilots sailplanes and powered fixed-wing aeroplanes.

117. Dr Sam Matthews *samuel.matthews@planning.nsw.gov.au*

Sam is a geophysicist working for the Geological Survey of NSW. His core roles centre on the cataloguing, quality control, and management of all geophysical data in NSW. He also creates large-scale products such as the updated NSW statewide magnetic and gravity merges, and upcoming statewide radiometric merge, as well as providing geophysical input into geological mapping programmes.

118. Dr Robert Holm *robert.holm@csaglobal.com*

Robert Holm (BSc Hons, PGDip EngGeol, PhD, MAIG) is a senior geoscientist at CSA Global with a diverse background encompassing both the minerals and oil and gas sectors. He specialises in structural geology, drawing on experience ranging from Archean gold systems to recent and actively forming analogues across the Southwest Pacific, to investigate mineral systems across multiple spatial and temporal scales. Robert has expertise in unravelling the metallogenesis and prospectivity of complex tectonic settings through multidisciplinary methods coupled with strong analytical and problem-solving skills to deliver integrated geological solutions in project generation and deposit targeting.

120. Dr Claudio Delle Piane *claudio.dellepiane@csiro.au*

Claudio Delle Piane is a geologist with a background in structural geology and rock deformation and Principal Research Scientist at CSIRO Energy in Perth. He has a degree in earth sciences from the Roma III University in Italy and a PhD in geology from the Swiss Polytechnic Institute (ETH) of Zurich. He joined CSIRO in 2008 specializing in the integration of microstructural analyses with petrophysics, geomechanics, structural geology and rock physics for the characterization of subsurface porous rocks and the understanding of their geological history.

121. Mr Tavis Lavell *tavis.lavell@gbgmaps.com.au*

123. Mr Jacob Paggi *jacob@armadex.com.au*

Jacob completed a BSc geophysics degree at Curtin University, graduating with Honours in 2005. He joined Independence Group (IGO) in late 2005 and worked 3 years at the Long Nickel mine in Kambalda, conducting and advancing in-mine electromagnetic surveys, and culminating in a key role in the discovery of the Moran nickel deposit. Moving back to Perth, his role involved providing geophysical support for nickel, gold, and base metal exploration in a wide variety of geological terrains across Australia and Sweden. He was a key member of the teams that discovered the Rosie nickel deposit in Western Australia, and the Eureka VMS lens at the Stockman Project in Victoria. In 2015, he started his own business, Armada Exploration Services, working for major and junior exploration and mining companies by planning, supervising and interpreting geophysical data for nickel, gold and base metal exploration programmes.

124. Mr Kane Maxwell *kane.maxwell@outlook.com*

Kane is currently Director and Principal consultant of Matrix Geoscience, a geoscience and data analytics consultancy that specializes in exploration, resource estimation, and database management. Kane has a passion for investigating the use of innovative technologies within the exploration and mining sector. In addition to his extensive experience in geology and resource estimation, he also has a background in machine learning and data science.

125. Mr Steven Sullivan *jane.ball@maptek.com.au*

Steve Sullivan, Senior Technical Sales Specialist, Maptek, has 35 years industry experience with expertise in geological modelling and resource management throughout Australia and Asia. As a resource geologist he has worked across a diverse range of metalliferous and energy commodities applying his expertise in different estimation techniques and methods. Steve is Technical Lead for DomainMCF, the commercial application of machine learning to geological domain classification and resource estimation.

126. Mr Muhammad Iqbal *m.iqbal14@postgrad.curtin.edu.au*

Mr. Muhammad Atif Iqbal is a PhD candidate in Western Australia School of Mines, Curtin University. He has BSc (Hons) and MSc degrees in geosciences. His PhD research is focused on high-resolution mineralogical and petrophysical characterisation of shale reservoirs. He is solving a research problem about heterogeneity understanding through multiscale (analytical and statistical) rock typing and its influence on total gas content of marine shale reservoirs. This research is timely needed and will be helpful for accurate reserve estimations in shale. He has more than five years industry and research experience as geoscientist for petroleum and mineral exploration companies. His expertise lies in core logging, petrophysics, geological and geochemical characterisation and well logs analysis. He is a winner of different research scholarships throughout his academic career.

128. Mr Amine Ourabah *amine.ourabah@strydefurther.com*

Amine is a geophysicist with 16 years experience in the oil & gas industry. He has a research MSc degree from EOST (Strasbourg, France). He started his career with Veritas-DGC as a land processor then joined BP complex imaging R&D team where he became Land seismic SME providing support to BP assets as well as working on R&D projects. Amine was a part of the development team that created the "nimble node" which led to the creation of STRYDE where he holds now the position of head of processing. Amine has a particular interest in high density seismic acquisition and processing.

129. Mr Max Williamson *wiltaxconsulting@bigpond.com*

Chartered Accountant with 50 years experience in the resources industry. Former Federal President of PESA and PESA Member for 30 years plus. Regular speaker at resources conferences around Australia on all matters resources including fracking, electric vehicles and industry developments. Chair of AEGC 2019 conference in Sydney.

130. Dr Shaun Strong *sstrong@velseis.com*

Worked in seismic exploration since 2004 with a strong focus in research and field techniques. Received a PhD in multicomponent land seismic in 2016. Recipient of the 2018 Shanti Rajagopalan Award.

132. Dr Wenping Jiang *wenping.jiang@ga.gov.au*

Dr Wenping Jiang joined Geoscience Australia in 2012 after completing a PhD at the University of Sydney. Currently she is a senior geophysicist working on magnetotelluric data processing, modelling and interpretation in the Minerals, Energy, Groundwater Division.

133. Mr Partha Pratim Mandal *p.mandal@postgrad.curtin.edu.au*

Partha Pratim Mandal is a current PhD researcher and sessional academic at the Western Australia School of Mines (WASM), Curtin University. His research focuses on creating geo-mechanical workflows to conduct laboratory measurements of the deformation aspect of shale gas, including the viscoelastic deformation, stress partitioning factor of rock composition, multi-channel active and passive wave velocity recording and elastic anisotropy. He is also interested to transfer geotechnical skill from energy industry to deep earth mining activity for safer operation. He is the recipient of several scholarships and research grant such as RTP Scholarship, EAGE student fund, PESA Federal Post-graduate scholarship and AAPG Grant-in-Aid. He was the founding member and the president of EAGE-SEG student chapter at Curtin University and currently serves as Secretary of the ASEG WA branch. Previously he worked for six years as imaging geophysicist at PGS both in India and Australia. He received his first-class BSc degree in physics (Hons) from the Presidency College, University of Calcutta, India and MSc Tech degree in applied geophysics from the IIT (ISM), Dhanbad, India.

134. Mr Umer Habib *umer.habib@utas.edu.au*

Umer Habib is a PhD student at the Centre for Ore Deposit and Earth Sciences, University of Tasmania and is working on "Tectonic reconstruction of Paleozoic rocks in Lachlan Orogen south-east, Australia" under the Lachlan ARC Linkage project. Umer did his bachelors and masters degrees in Pakistan and has published articles on the tectonics and structural modelling of the Upper Himalayas. Apart from geology, Umer likes to play cricket, badminton and go hiking in the bush.

135. Mr Alan Meulenbroek *alanm@velseis.com*

136. Prof Lesley Wyborn *lesley.wyborn@anu.edu.au*

Lesley Wyborn is an Honorary Professor at the Research School of Earth Sciences and the National Computational Infrastructure at ANU. She previously had 42 years experience from 1972 to 2014 in Geoscience Australia in scientific research (geochemistry and mineral systems research) and in geoscientific data management. She is currently Chair of the Australian Academy of Science 'National Data in Science Committee' and is on the American Geophysical Union Data Management Advisory Board. She was awarded the Australian Government Public Service Medal in 2014, the 2015 Geological Society of America Career Achievement Award in Geoinformatics and became a Fellow of the Geological Society of America in 2016.

141. Dr Javad Khoshnavaz *mj.khoshnavaz@graduate.curtin.edu.au*

Axel is a Senior Research Scientist, CSIRO Land and Water and manages the noble gas facility of CSIRO. Axel has a background in geochronology, isotope hydrology, laboratory management and the development of rare and complicated measurement systems. His more than 30 years of experience make him an expert in environmental multi-tracer applications on groundwater (2H, 18O, CFCs, SF6, 3H, 3He, 4He, noble gases, 85Kr, 39Ar, 14C, 36Cl, 81Kr). Axel worked in phreatic, confined, fractured and Karst aquifers, applied the multi-tracer methodology to contaminated groundwater, palaeowater and saltwater-freshwater interaction. Integrating multiple, often contradicting, tracer results into a joint conceptual model interpretation and quantitative evaluation is his interest, challenge and joy. Axel's research interests resulted in detailed expertise in assessing the time scales of groundwater movement, mixing of water bodies, evaporation, infiltration conditions, palaeoclimate and age distribution modelling.

142. Mr Chuang Wang *chuang.wang@utas.edu.au*

144. Dr Hilke Dalstra *hilke.dalstra@riotinto.com*

Hilke Dalstra, initiated his career in geoscience at the University of Utrecht, The Netherlands, where he attained a 'Doctoraal' (MSc equivalent) in structural and economic geology. He then moved to Australia to commence PhD studies relating to Archean lode gold deposits at the Key Centre for Strategic Minerals, University of Western Australia, completed in October 1995. In 1995, Hilke moved to Hamersley Iron commencing what would prove to be a long- lasting association with Rio Tinto. From early on his main interests have been ore body knowledge, structural geology and target generation covering a wide range of commodities.

146. Dr Andrew Gabell *andy@transparentearth.com.au*

Andy has a BSc (Hons I) and PhD in geology from the University of Adelaide and more than 40 years experience in remote sensing and geophysics. He was a post-doctoral research fellow at NASA's Jet Propulsion Laboratory in the 1980s and shares 2 NASA achievement awards. Andy was then a senior manager at CSIRO before becoming the Chief Scientist and Product Development Manager at World Geoscience Corporation, then the global R&D Manager at Fugro Airborne Surveys in 2000. Andy was on the Board of Management of the CRC AMET (Australian Mineral Exploration Technologies) and oversaw development of the TEMPEST AEM system before leaving Fugro to co-found Canadian Micro Gravity, then Transparent Earth Geophysics and associated companies. Andy was the project manager of CRC-P57322 "High-resolution Real-time Airborne Gravimetry".

148. Mr Dale Harpley *daleh@velseis.com*

Dale Harpley joined the R&D team at Velseis late 2019 and began working as a field geophysicist during 2020 as a data observer. He then graduated with first-class honours in geophysics from the University of Queensland in 2020. He is currently working on multiple projects including teleseismic earthquake studies in ice-capped regions extending on his honours thesis.

149. Dr Axel Suckow *Axel.Suckow@CSIRO.au*

Axel is a Senior Research Scientist, CSIRO Land and Water and manages the noble gas facility of CSIRO. Axel has a background in geochronology, isotope hydrology, laboratory management and the development of rare and complicated measurement systems. His more than 30 years of experience make him an expert in environmental multi-tracer applications on groundwater (2H, 18O, CFCs, SF6, 3H, 3He, 4He, noble gases, 85Kr, 39Ar, 14C, 36Cl, 81Kr). Axel worked in phreatic, confined, fractured and karst aquifers, applied the multi-tracer methodology to contaminated groundwater, palaeowater and saltwater-freshwater interaction. Integrating multiple, often contradicting, tracer results into a joint conceptual model interpretation and quantitative evaluation is his interest, challenge and joy. Axel's research interests resulted in detailed expertise in assessing the time scales of groundwater movement, mixing of water bodies, evaporation, infiltration conditions, palaeoclimate and age distribution modelling.

150. Dr Greg Turner *g.turner@hiseis.com*

Greg graduated with a BSc (Hons) in earth science from Monash University in 1987 and received a PhD from Macquarie University in 1994. His previous roles have included being Geoscience Manager for WMC's Technology Group and a co-founder of the Geoforce geophysical service company. Greg Turner is currently General Manager Technical Solutions at HiSeis.

151. Prof Gregory Smith *gregory.c.smith@curtin.edu.au*

Gregory Smith is Adjunct Professor of Petroleum Geology at Curtin University in the School of Earth and Planetary Sciences. He has over 40 years experience in petroleum geology, geophysics and geochemistry involving technical, research and managerial positions at Exxon, ARCO, BHP, Woodside/Shell and the Herman Research Laboratory. Initial research into 3D modelling of basins, sediments and organic geochemistry was followed by successful coal, oil shale and petroleum exploration. This included several major discoveries and field developments leading to production for many large projects in Australia and overseas. Greg undertakes research with Honours, Masters and PhD students on interpretation, organic geochemical and geostatistical analysis of large seismic, well log, core and production datasets. The results are used to build 3D structural and property models of sedimentary basins or petroleum fields, and analysed using machine learning and multi factor scenario modelling, to estimate the probable geology and associated resource estimates. Specific interests include low T-P burial and thermal history modelling, organic matter petrology and geochemistry, and characterisation of sediments and their diagenesis with Curtin University departments of statistics and engineering, the WA Organic and Isotope Geochemistry group and the John de Laeter Centre. Greg is a member of AAPG, PESA, TSOP, ICCP, past corporate member of AusIMM, and has held various positions in GSA, PESA, APPEA and ASA.

He worked for Anglo American in South Africa, on combined seismic and potential field interpretation for the Wits basin, followed by research on fast inversion of airborne electromagnetic (AEM) data. He wrote the "autopick" software that Spectrem Air used for their data processing for many years.

Andrew left Anglo to do a PhD in electromagnetic geophysics at Macquarie University, where he was supervised by Prof Jim MacNae. He joined CSIRO in 2000, working at QCAT in Brisbane on microseismic monitoring for mine safety. Following a three-year fellowship in the USA, also in seismic monitoring in mines, he returned to CSIRO, this time in Perth, where he has worked on passive seismic projects associated with CO_2 sequestration, as well as AEM inversion for mineral exploration. He is currently focussed on combining geological information with geophysical inversion of AEM, resistivity, and seismic data to better understand both the regolith and specific orebody fingerprints.

153. Dr Clive Foss *clive.foss@csiro.au*

Clive is a senior research scientist and potential fields team leader in CSIRO Mineral Resources based at Lindfield, Sydney. Clive joined CSIRO in 2009 after working for 14 years with Encom Technology as principal consultant and leading the ModelVision software development team. Clive has a BSc in geophysics from the University of Reading and a PhD from Leeds University for palaeomagnetic and rock magnetic studies of Archaean rocks in southern Africa.

157. Dr Philip Heath *philip.heath@sa.gov.au*

Philip Heath is a principal geophysicist with the Geological Survey of South Australia, a group within the Department for Energy and Mines, SA Government. He is involved in numerous projects, first and foremost being the processing and uploading of geophysical data to the South Australian Resources Information Gateway, SARIG. Prior to working with the SA Government he worked for Canadian Micro Gravity as an operator and processor.

158. Dr Adam Bailey *adam.bailey@ga.gov.au*

Adam H.E. Bailey is a petroleum geoscientist at Geoscience Australia, with expertise in petroleum geomechanics, structural geology and basin analysis. He graduated with a BSc (Hons) in 2012 and a PhD in 2016 from the Australian School of Petroleum at the University of Adelaide. Working with the Onshore Energy

Systems team at Geoscience Australia, Adam is currently working on the flagship Exploring for the Future Programme, and is the geology discipline lead for the Geological and Bioregional Assessment Programme.

160. Mr Tom Wise *tom.wise@sa.gov.au*

Tom Wise is a senior geologist at the Geological Survey of South Australia, and the Technical Lead for the Delamerian Project.

162. Dr Mojtaba Rajabi *m.rajabi@uq.edu.au*

Dr Mojtaba Rajabi is an ARC DECRA Fellow at the School of Earth and Environmental Sciences, the University of Queensland. He has over 12 years of extensive experience in crustal stress analysis, geomechanics, and geomechanical-numerical modelling. Since 2012, Dr Rajabi has worked on the geomechanical analyses of >30 sedimentary basins from across the world, and currently is the Deputy-Head of the World Stress Map project.

163. Mr Satyabrata Mishra *satya.mishra@santos.com*

164. Prof Lesley Wyborn *lesley.wyborn@anu.edu.au*

Lesley Wyborn is an Honorary Professor at the Research School of Earth Sciences and the National Computational Infrastructure at ANU. She previously had 42 years experience from 1972 to 2014 in Geoscience Australia in scientific research (geochemistry and mineral systems research) and in geoscientific data management. She is currently Chair of the Australian Academy of Science 'National Data in Science Committee' and is on the American Geophysical Union Data Management Advisory Board. She was awarded the Australian Government Public Service Medal in 2014, the 2015 Geological Society of America Career Achievement Award in Geoinformatics and became a Fellow of the Geological Society of America in 2016.

167. Ms Tehani Palu *tehani.palu@ga.gov.au*

Tehani Palu is a geoscientist at Geoscience Australia. She holds an MSc from the University of Waikato. She has been involved with various projects including greenhouse gas monitoring for carbon capture, and storage and petroleum acreage release. Tehani has been in her current role since 2013 which sees her undertaking petroleum systems analysis within Australian basins.

168. Dr Anandaroop Ray *anandaroop.ray@ga.gov.au*

Anandaroop Ray (Anand) is a statistically minded geophysicist who has worked in industry, academia and government. His main interests are in using mathematics to improve existing scientific techniques that feed into natural resources management, exploration and conservation.

174. Mr Jamie Speer *jamie@gbgoz.com.au*

Jamie is experienced in and responsible for the management of major geophysics projects on the eastern seaboard of Australia and overseas. He generally undertakes start up and supervision of projects or, if particularly challenging, may be completely involved in the fieldwork. He is responsible for planning, reviewing, processing and interpreting the data collected either in a hands-on way or a supervisory capacity, training younger staff members. Jamie prepares project proposals, advises clients on the appropriate investigative techniques to utilise, prepares technical reports and imaging output for projects and signs off on work under his supervision.

177. Dr Mehdi Tork Qashqai *mehdi.torkqashqai@csiro.au*

In November 2012, Mehdi joined the PhD programme at Geodynamic and Geophysics group at Macquarie University in Sydney, Australia. His research focused on the development and implementation of a multi-parameter geophysical inverse modelling tool known as "LitMod". In August 2016, Mehdi completed his PhD thesis entitled "Multi-observable Probabilistic Inversion for the Thermochemical Structure of the Lithosphere". Prior to his doctoral study, he was working in the oil and gas exploration industry for six years as a seismic processing and team leader geophysicist, delivering processing, imaging, and quantitative interpretation of seismic data. Mehdi joined the CSIRO Deep Earth Imaging Future Science Platform (DEI FSP) in July 2017 as a postdoctoral fellow. He is currently a research scientist at the CSIRO Deep Earth Imaging Future Science Platform (DEI FSP). His main research in the "Geoscience Imaging" pillar of the Deep Erath Imaging is focused on the developing and application of new passive seismic imaging approaches to obtain better tomographic models of subsurface structure across multiple scales (e.g., from exploration-scale to lithospheric-scale).

178. Dr Thomas Poulet *thomas.poulet@csiro.au*

Thomas Poulet is a research scientist at CSIRO Mineral Resources. He graduated in 2000 from the Ecole Polytechnique (France) and in 2002 from the French National School of Telecommunications. Since joining CSIRO in 2003 he has been working on various projects aiming at transforming mineral deposits' formation understanding from a qualitative to a quantitative and predictive science, leading to a PhD in geology on modelling multi-physics geological processes at the University of Western Australia in 2012. His research focuses on multiphysics instabilities in porous media. His expertise includes theoretical and numerical modelling, geomechanics, applied mathematics, software engineering and high-performance computing

179. Dr Lionel Esteban *lionel.esteban@csiro.au*

Lionel Esteban is principal petrophysicist in CSIRO (Perth, WA). He develops and tests petrophysical experimental laboratory approaches and integrate them to logs analysis to characterize and understand the physical properties responses of unconventional and conventional reservoirs at different scales using a wide spectrum of petrophysical tools including by instance: X-ray imaging, electrical, nuclear magnetic resonance, mechanical, and core flooding under (or not) HP/HT. His current research focuses on low permeability reservoirs to understand clay mineral relationships, hydrocarbon and hydrogen storage and sealing capacity, CO_2 -rock interactions and core flooding in carbonates, drilling mud effects on rock properties in conventional reservoirs.

182. Dr Anton Kepic *awkepic@gmail.com*

183. Dr Yuqing Chen *yu.chen@csiro.au*

Yuqing Chen received a Bachelor's degree in geophysics from China University of Petroleum (Qingdao) in 2012 and received a Master's degree in geophysics from China University of Petroleum (Beijing) in 2015. He received a PhD degree in geophysics from King Abdullah University of Science and Technology in 2019. He is currently a Postdoctoral fellow in Deep Earth Imaging Future Science Platform, CSIRO, Australia. His research interests include seismic imaging, seismic inversion, and machine learning. Dr. Yuqing Chen is a Member of the Society of Exploration Geophysics (SEG) and the American Geophysical Union (AGU).

184. Dr Alexei Gorbatov *alexei.gorbatov@ga.gov.au*

Alexei Gorbatov is a passive seismic activity leader in Onshore Seismic and Magnetotelluric Section, Geoscience Australia, and has fostered application of passive seismic methods in mineral potential studies. His scientific interests also include theory of seismic imaging, inversion methods, seismotectonics, and seismic source generation process. For fifteen years Alexei has worked in multiple international research organisations before joining Geoscience Australia in 2004 to establish Australian Tsunami Warning Centre. With initiation of Exploring for the Future programme, he leads AusArray project, which aims to create a three-dimensional national seismic velocity model. Integration of this model with other geophysical observables will bring new insights into the structure and composition of the Australian lithosphere. It will be used not only for mineral potential assessment but also forecast economic viability for resource development.

187. and 188. Dr Keelan O'Neill *keelan.oneill@uwa.edu.au*

Keelan is a Research Associate in the UWA Fluid Science and Resources (FSR) division. Keelan's research focusses on developing low field nuclear magnetic resonance (NMR) instruments for industrial applications. He is currently involved in a CRC project in collaboration with RIG Technologies International which involves developing a NMR module for implementation in a logging-while-drilling instrument with application in the Australian mining industry. Prior joining the FSR, Keelan worked at Qteq as a physicist involved in developing and operating NMR tools for wireline logging. Keelan completed his PhD at UWA on the development of an Earth's Field NMR multiphase flow meter.

189. Mr Saswata Mukherjee *s.mukherjee@uq.edu.au*

Mr. Saswata Mukherjee is a PhD candidate at the University of Queensland. His PhD research incorporates geological characterisation of Coal Seam Gas reservoirs, in-situ stress and fracture characterisation from image logs and understanding the impact of stress and fracture on the reservoir flow behaviour. Prior to PhD, Mr. Mukherjee has more than 13 years of research and professional experience in all stages of unconventional reservoir life cycle management, reservoir modelling and prospect evaluation in diverse geological settings, including onshore Eastern Australian basins, Niger Delta, Botswana, Germany, South Sumatra, India, and China.

190. Dr Zixing Qin *zixing.qin@postgrad.curtin.edu.au*

Zixing Qin is currently a PhD candidate from Western Australia School of Mines (WASM), Curtin University. His research mainly focuses on drill-bit seismic source in cross-hole survey for mineral exploration and rock characterisation. Zixing also has a mining engineering background from his Master's and Bachelor's degrees obtained from the University of Adelaide (Australia) and Henan Polytechnic University (China), respectively.

191. Mr Andrew. Taylor *andrew.r.taylor@csiro.au*

Andrew Taylor is a senior hydrogeologist in the Groundwater Characterisation and Management research group in CSIRO Land and Water. His primary research activities include integrating the analysis and interpretation of hydraulic, hydrogeochemical and environmental tracer data for characterising and understanding groundwater systems. Andrew has a background in soil and groundwater hydrology with 14 years of experience in field and desktop evaluation of hydrogeological systems throughout Australia. His research interests include vadose zone hydrology, the coupling of environmental tracers, hydrogeochemistry and hydraulics for characterising the scale of groundwater flow systems, quantifying groundwater flow processes (recharge, throughflow and discharge) characterising the nature of groundwater – surface water interactions, and understanding inter-aquifer exchange. In addition, Andrew is using the new knowledge gained by the collection of new data to constrain the inputs and boundary conditions for water balance and risk assessment models. Recently, Andrew has been involved in a number of regional scale groundwater assessments applying novel drilling techniques, as well as the application of environmental tracers and geophysics to characterise hydrogeological systems for economic development in data sparse regions. Andrew has been fortunate to collaborate with the Helmholtz Centre for Environmental Research – UFZ, Leipzig Germany, where Andrew gained valuable insight and experience in to the application of direct-push (DP) technology for characterising surficial shallow aquifers. This work has led to Andrew pioneering the use of DP technology in Australia for characterising groundwater systems, enabling new sampling techniques in remote regions with limited infrastructure and evaluating salinity in the landscape. Currently, Andrew is leading the groundwater hydrology activities for the Northern Australia Water Resource Assessment (NAWRA) and the Norfolk Island Water Resource Assessment (NIWRA). In remote data sparse regions, Andrew has led numerous groundwater projects including the groundwater components of the Flinders and Gilbert Agricultural Resource Assessment (FGARA) and the Goyder Facilitating Long-term Outback Water Solutions projects. Andrew has 74 publications including seven journal papers, 24 conference papers and 43 technical reports with 235 citations (Google Scholar, h-index 8).

192. and 193. Dr Derecke Palmer *d.palmer@unsw.edu.au*

Derecke Palmer has received a full suite of undergraduate and post graduate degrees from the University of Sydney and the University of New South Wales. He started his career at the Geological Survey of New South Wales and finished it at UNSW. He received the Grahame Sands award from the ASEG in 1992, the Reginald Fessenden award from the SEG in 1995, and the Ludger Mintrop award from the EAGE in 2016, for his contributions to near surface refraction seismology. His current research interests are focused on the application of full waveform refraction imaging and inversion of the regolith.

195. Dr Antonio Belperio *tbelperio@minotaurexploration.com.au*

Tony has an Honours Degree in geology from The University of Adelaide and a PhD from James Cook University of North Queensland, and a career spanning a broad range of disciplines including marine and coastal geology, regional mapping, exploration geology and clay mineralogy. Tony Is a Director of Minotaur Exploration, with a track record of gold and copper-gold discoveries over the past two decades. More recently, Tony has been the driving force behind Minotaur's R&D efforts into natural clay nanotubes, now culminating in development of the world's largest known halloysite nanotube mineral deposit on Eyre Peninsula.

196. Mr Nuwan Suriyaarachchi *nuwan.suriyaarachchi@research.uwa.edu.au*

197. Mr Neil Symington *neil.symington@ga.gov.au*

Geophysicist/ geologist working in groundwater, interested in data fusion, Bayesian modelling and data visualisation.

203. Mr Fabiano Della Justina *fjustina@laurentian.ca*

PhD student, Mineral Deposits Precambrian Geology at Laurentian University. Fabiano has worked in geophysical airborne surveys (magnetic, gravity and radiometric) in South America and Africa. His research interests include - 2D and 3D modelling, geophysical inversion, potential methods, integration of geophysical methods and petrophysics.

205. Mr Corey Jago *Corey.Jago@mmg.com*

Corey is a professional geologist with 14 years industry experience in the remote and near-mine exploration and resource development of base and precious metal resources throughout Australia and the DRC. His experience extends across multiple deposit types including VHMS, sediment-hosted base metal deposits, porphyry Cu-Au, epithermal, skarn and IOCG deposits. Corey is currently completing a Masters in economic geology from CODES. His current role is focused on accumulating orebody knowledge at Dugald River and incorporating it into the various aspects of the mining value chain such as geology, mining, processing, environment and growth.

206. Dr Yvette Poudjom Djomani *yvette.poudjomdjomani@ga.gov.au*

Yvette is a senior geophysicist within the Geophysical Acquisition and Processing team at Geoscience Australia (GA). She joined GA in 2016 after working in academia, government and industry. Yvette has over 25 years of experience in the QAQC of gravity and magnetic data, and more recently radiometric data processing.

207. Dr Kate Robertson *kate.robertson2@sa.gov.au*

Kate is a senior geophysicist in the Lithospheric Architecture team at the Geological Survey of South Australia, Department for Energy and Mining. Kate completed her PhD at the University of Adelaide in 2016, investigating the electrical resistivity of the southeast Australian lithosphere using magnetotellurics. Kate is a passionate volunteer for the Australian Society of Exploration Geophysics and is thrilled to serve as President this year on a motivated committee.

211. Mrs Margarita Pavlova *margarita16p@gmail.com*

Margarita started her career with Schlumberger Information Solutions in Adelaide, where she consulted on a variety of geological and geophysical projects and trained geoscientists in Petrel and Geoframe software. She went for one year to the UK with Schlumberger, consulting to various companies (Nexen, BP, ENI and Anadarko). In 2010 she joined Origin Energy in Brisbane where she worked on both CSG and conventional assets, including Spring Gully, Fairview, Yolla, Greater Poseidon, Kupe and Waitsia. After Origin sold their conventional assets to Beach Energy Margarita joined the BHP coal business where she worked to maximise the value of BHP's 3D seismic program by implementing best structural interpretation practices and applying quantitative interpretation. Recently, she joined Santos as a CSG exploration geophysicist.

214. Mr Andreas Bjork *andreas.bjork@csiro.au*

Andreas Bjork is a geophysicist and lab technician in petrophysics at CSIRO. His focus is on providing quantitative databases of rock properties, magnetic fabrics and radiometrics. These are used as constraints in forward and inverse modelling to link geophysical data with interpreted geology. His work enables qualitative interpretation and visualisation of correlations with scale-consistent geochemistry and minerology. He is leading the digital upgrade of the petrophysics laboratory at the CSIRO Lindfield Site, NSW. Prior to joining CSIRO he worked remote at the LKAB Kiruna mine in Sweden and central parts of the Northern Territory in Australia.

216. Dr Kate Robertson *kate.robertson2@sa.gov.au*

Kate is a senior geophysicist in the Lithospheric Architecture team at the Geological Survey of South Australia, Department for Energy and Mining. Kate completed her PhD at the University of Adelaide in 2016, investigating the electrical resistivity of the southeast Australian lithosphere using magnetotellurics. Kate is a passionate volunteer for the Australian Society of Exploration Geophysics and is thrilled to serve as President this year on a motivated committee.

221. Dr Mike Martin *mike.martin@westsidecorporation.com*

Mike has a degree in earth sciences and PhD in sequence stratigraphy and sedimentology. He has spent the last 30 years working around the world in a variety of consulting and operated oil and gas company roles. He moved out to Australia in 2012 and has pored over the Surat and Bowen Basin sediments since 2009 and is now the Geoscience Manager at Westside Corporation overseeing the development of their Greater Meridian CSG field in the Bowen Basin and appraisal and development of their oil and gas fields in the Taranaki Basin. A Member of AAPG and a fellow of, and chartered through, the Geological Society.

227. Dr Steve Hearn *steveh@velseis.com*

Steve Hearn graduated from the University of Queensland in 1975, with B Sc App (geophysics)(Hons) and a University Medal. He received a PhD in seismology, also from UQ. He has worked for multi-national and Australian seismic companies, as a consultant, and as an academic. He is currently Managing Director and Chief Geophysicist at Velseis.

229. Dr Claudio Delle Piane *claudio.dellepiane@csiro.au*

Claudio Delle Piane is a geologist with a background in structural geology and rock deformation and Principal Research Scientist at CSIRO Energy in Perth. He has a degree in earth sciences from the Roma III University in Italy and a PhD in geology from the Swiss Polytechnic Institute (ETH) of Zurich. He joined CSIRO in 2008 specializing in the integration of microstructural analyses with petrophysics, geomechanics, structural geology and rock physics for the characterization of subsurface porous rocks and the understanding of their geological history.

231. Dr Anton Kepic *awkepic@gmail.com*

234. Mr David Purdy *david.purdy@dnrme.qld.gov.au*

Dave Purdy is a principal geoscientist at the Geological Survey of Queensland. He has worked on many geological mapping, geochronology and geochemistry projects across the state.

235. Dr Andrew Fitzpatrick *andrew.fitzpatrick@igo.com.au*

Andrew Fitzpatrick is currently Chief Geophysicist of IGO Limited. He has over 20 years experience in the application of geophysics for mineral and groundwater exploration working across government, academia, applied research, and the private resource and mining sector. He received a BSc Hons in geophysics from Curtin University and a PhD in geophysics from the University of Tasmania. He is also an Adjunct Associate Professor in Exploration Geophysics at the WA School of Mines, Curtin University.

236. Dr Sinem Yavuz *sinem.yavuz@curtin.edu.au*

Sinem is a Research Fellow with over ten years of combined experience in applied geophysics; with skills in seismic data analysis, processing and interpretation. Sinem received her MSc in geophysical engineering from Istanbul Technical University in 2011 and her PhD in exploration geophysics at Curtin University in 2015. She contributes significantly to several collaborative research projects, including an ongoing research project with CO_2CRC that focuses on carbon dioxide geosequestration and involves multiple industry and international partners. She has participated as a key researcher in DET CRC and Southwest Hub geosequestration projects funded by the Australian National Low Emissions Coal Research and Development (ANLEC R&D). Sinem has experience in providing consultancies on designs data management, analysis and processing with conventional geophones and distributed acoustic sensors.

238. Mr Jiabin Liang *jiabin.liang@postgrad.curtin.edu.au*

Jiabin Liang is a geophysicist, data scientist and software engineer, specializing in geoscience-related data analysis with mathematical, physical and computer science technologies. He has five years of experience in the industry and six years of experience in the academia. His publications on highly acknowledged peer-reviewing journals show that he has deep understanding of his expertise and the ability to produce new insights. He has broad knowledge about machine learning and did real-life projects in the area of computer vision, business and natural language processing. In addition, he has strong programming skills using python, C++, Matlab and VBA. He owns a software patent showing that he can apply his programming skills to develop a product to solve real world problems.

239. Mrs Heather Ballantyne *heather.ballantyne@SGC.com.au*

Heather is qualified in both geophysics and geology, with over 15 years experience throughout Australia and overseas. She has worked as both a geologist and geophysicist equally throughout her career, with experience ranging from mine geology through to brown and greenfields exploration. During her career, she has gained experience working in a range of deposit styles. Heather specialises in integrated interpretation of magnetic, radiometric and gravity data. Heather has presented at SEG workshops in the US and presented at local ASEG meetings.

242. Mr Andre Eduardo Calazans Matos de Souza *a.calazans@postgrad.curtin.edu.au*

I am a PhD student in the Exploration Geophysics Department (Curtin University). In my thesis, I have been investigating the effects of mineral replacement and textural development associated with gold deposits on the seismic signature, using laboratory measurements, rock physics modeling, and seismic modeling.

243. Dr Cericia Martinez *cericia.martinez@csiro.au*

Cericia is a research scientist at CSIRO. Her current research is focused on exploring ways to relate geophysical models and petrophysical measurements. She received her PhD in geophysics from the Colorado School of Mines where her research focused on processing, inversion, and interpretation of airborne gravity gradiometry data. Prior to joining CSIRO, Cericia was a Mendenhall Fellow with the U.S. Geological Survey where she developed an algorithm to quantify potential impacts of developing unconventional petroleum resources given probabilistic models of the subsurface petroleum potential.

244. Dr Konstantin Tertyshnikov *konstantin.tertyshnikov@curtin.edu.au*

Dr Konstantin Tertyshnikov received degrees in geophysics from the Moscow State University in 2002. Konstantin worked a geophysicist and project leader on a number of geophysical exploration projects in Russia, Europe and the Middle East. In 2014 he received a doctorate in geophysics from Curtin University (Western Australia). At the present time, Konstantin is a Lecturer/Research Fellow in the Department of Exploration Geophysics at Curtin University. His main research focus is CO_2 geosequestration, borehole seismic, distributed acoustic sensing technologies, mineral exploration and seismic acquisition.

245. Dr Oliver Gaede *oliver.gaede@qut.edu.au*

246. Ms Sana Zulic *sana.zulic@postgrad.curtin.edu.au*

Sana is MPhil student at Curtin University. She is interested in borehole seismic imaging techniques which can improve the imaging methods for mineral exploration. Her work focuses on optimising vertical seismic profiling survey design and processing workflows to better suit mineral exploration application. She works as a geophysicist at HiSeis.

247. Dr Jeremie Giraud *jeremie.giraud@uwa.edu.au*

Jérémie Giraud received his BSc and MSc Eng in applied geophysics from the School and Observatory of Earth Sciences, University of Strasbourg (Strasbourg, France). He worked in the oil and gas sector for a few years and decided to start a PhD at the Centre of Exploration Targeting (CET), University of Western Australia (Perth, Australia), which he completed in 2018. Jérémie is currently a research fellow at CET as part of the Loop and MinEx CRC consortia. His research interests include the development of geophysical inversion techniques focusing on the interaction between geophysics, geology, and petrophysics.

248. and 251. Mr Robert Hearst *Robert.Hearst@sgc.com.au*

Robert has many years of project management experience in exploration geophysics. Having obtained his HBSc (geophysics with geology specialisation) from UWO in 1983, he commenced work with Paterson, Grant & Watson Ltd. (PGW) as a geophysical consultant. In 1993 he obtained a MSc (geology and geophysics) from McMaster University. During the ensuing years, Robert has held many roles, technical and management, both as a consultant and as Chief Geophysicist at McPhar Airborne Surveys, President and Chief Geophysicist at MPX Airborne Surveys, Manager Interpretation at Quantec Geoscience, Chief Geophysicist for Asperbras Congo, and Chief Geophysicist for Areva Resources Canada Inc. before joining Southern Geoscience Consultants (SGC) as Chief Geophysicist - Americas. He has worked on the ground in North America, West and Central Africa, the Middle East, China and India. He is a member of the PDAC, SEG, CSEG, ASEG, EAGE, CIMM and KEGS (Vice President) and is a registered Professional Geophysicist with PGO (and Council member), APEGS, APEGA and NAPEG.

253. Ms Bronwyn Campbell *bronwyn.campbell@mq.edu.au*

I am a third year PhD candidate completing a joint programme between CSIRO and Macquarie University, NSW. I have a Bachelor of Science majoring in geology and environmental geology and a Master of Research in organic geochemistry. My current research is in the areas of organic geochemistry and microbiology. More specifically, I investigate the activity of microbial communities in Australian coal seams.

254. Dr Andrea Viezzoli *av@aarhusgeo.com*

Andrea Viezzoli has a PhD in geophysics and has managed Aarhus Geophysics since 2008. He is interested in all aspects of AEM and its applications. In the last five years, he has been heavily involved in studying and modelling IP effects in AEM data.

255. Mr Evgenii Sidenko *evgenii.sidenko@postgrad.curtin.edu.au*

PhD student at Curtin University (exploration geophysics).

256. Dr Yunfeng Chen *yunfeng.chen@csiro.au*

Dr. Yunfeng Chen is an assistant professor at the Zhejiang University and is also a visiting scientist at Deep Earth Imaging, Future Science Platform, CSIRO. Dr. Chen is applying and developing passive seismic imaging techniques to resolve subsurface structures at various scales from shallow (sediment) to deep (mantle transition zone) earth.

258. Dr Kate Selway *kate.selway@mq.edu.au*

Kate is a specialist in magnetotellurics and particularly in the interpretation of magnetotelluric data. She received her PhD from the University of Adelaide in 2007 and has since worked in research positions at Yale University, Lamont-Doherty Earth Observatory, the University of Oslo and Macquarie University. She is currently a Senior Research Fellow with the MinEx CRC at the University of South Australia.

259. Mr George Marfo *g.marfo@unsw.edu.au*

George Marfo is a Masters by research (MPhil) student of University of New South Wales (UNSW), Sydney, Australia with special interest and background in seismic interpretation and basin modelling/evolution. He holds a MSc in petroleum geosciences from the Norwegian University of Science and Technology (NTNU), Norway and BSc in geology from the University of Ghana.

260. and 261. A/Prof Gianluca Fiandaca *gianluca.fiandaca@unimi.it*

Gianluca Fiandaca is Associate Professor in applied geophysics at the University of Milano (Italy). He obtained a PhD in applied geophysics from University of Palermo (Italy), and worked for ten years at the Hydrogeophysics Group, Aarhus University (Denmark). His main research interests are data acquisition, processing and inversion in electric and electromagnetic methods, with emphasis on Induced Polarization

264. Mr Michael Curtis *michael.curtis@adelaide.edu.au*

Michael graduated from the University of Bristol, UK, with an MSc geology degree in 2010. He moved to Perth shortly after to work in the West Australian mining industry. He worked as an exploration geologist with several small minerals exploration companies on nickel, copper, tungsten and potash projects. When the minerals industry collapsed in 2014, Michael transitioned into the petroleum industry, working at RISC Advisory as a geoscience consultant until 2017. Michael began his PhD at the Australian School of Petroleum and Energy Resources, University of Adelaide, in 2018, where he is currently researching the impacts of Late Jurassic to Early Cretaceous magmatism on petroleum systems of the Northern Carnarvon Basin. Michael has won several awards for the quality of his research including the PESA Postgraduate Scholarship and an ASEG Research Foundation Grant. Michael is a current and active Member of PESA, ASEG and GSA.

265. Dr Ignacio Gonzalez-Alvarez *ignacio.gonzalez-alvarez@csiro.au*

Ignacio is Spanish born and he completed his BSc and MSc specializing in stratigraphy and sedimentary basins analysis. His PhD focussed on the geochemical characterization of sedimentary packages. In the last 15 years, Ignacio has focussed on studying landscape evolution, geochemical dispersion processes within the cover and the applicability of this to the detection of distal footprints of ore deposits as a mineral exploration tool. Ignacio's research involves collaborators from China, India, South Africa, Spain, Portugal, and Australia.

266. Dr Vladimir Lisitsin *vladimir.lisitsin@dnrme.qld.gov.au*

Vladimir Lisitsin is the manager of the Mineral System team in the Geological Survey of Queensland. He holds PhD from the University of Western Australia. The team is working to document mineralisation signatures and alteration footprints of key mineral systems in Queensland. His broader research interests include mineral system analysis, exploration targeting and metallogeny of critical minerals

269. Dr Axel Suckow *Axel.Suckow@CSIRO.au*

Axel is a Senior Research Scientist, CSIRO Land and Water and manages the noble gas facility of CSIRO. Axel has a background in geochronology, isotope hydrology, laboratory management and the development of rare and complicated measurement systems. His more than 30 years of experience make him an expert in environmental multi-tracer applications on groundwater (2H, 18O, CFCs, SF6, 3H, 3He, 4He, noble gases, 85Kr, 39Ar, 14C, 36Cl, 81Kr). Axel worked in phreatic, confined, fractured and Karst aquifers, applied the multi-tracer methodology to contaminated groundwater, palaeowater and saltwater-freshwater interaction. Integrating multiple, often contradicting, tracer results into a joint conceptual model interpretation and quantitative evaluation is his interest, challenge and joy. Axel's research interests resulted in detailed expertise in assessing the time scales of groundwater movement, mixing of water bodies, evaporation, infiltration conditions, palaeoclimate and age distribution modelling.

270. Mr Yakufu Niyazi *yniyazi@deakin.edu.au*

Yakufu Niyazi received his BE (2012) in geological engineering from the China University of Petroleum (Beijing), China and MSc (2018) in marine geoscience from the University of Haifa, Israel. He has worked as oilfield engineer (2012-2015) and research assistant (2018-2019). Recently he joined the Marine Mapping Group, at the Deakin University, Australia, as a PhD student in marine environmental science. His main research interest is seismic stratigraphy and geomorphology of deep to shallow subsurface sequences, with special emphasis on submarine canyon/channels, mass-transport complexes, fluid flow, and igneous systems within the sedimentary basins. In 2018, he received the Carlos Walter M. Campos Memorial Award (Best International Student Paper) from the AAPG. He is an active Member of AAPG, IAS, GSA and PESA.

272. Mr Jean-Philippe Paiement *jeanphilippep@mirageoscience.com*

Jean-Philippe is Director of Global Consulting at Mira Geoscience. He has a wide range of experience in modelling of diverse mineral system. Jean-Philippe has more than 10 years of experience in geostatistics applied to structural, geological and geochemical modelling; specializing in non-linear interpolation and simulation. He also seeks new methods and technologies to aid and de-risk interpretation of geological data sets. Before joining Mira Geoscience Jean-Philippe was also the scientific driving force behind the success of SGS team in winning the Integra GoldRush Challenge; by application of Machine Learning to mineral deposit targeting.

273. Mr Yakufu Niyazi *yniyazi@deakin.edu.au*

Yakufu Niyazi received his BE (2012) in geological engineering from the China University of Petroleum (Beijing), China and MSc (2018) in marine geoscience from the University of Haifa, Israel. He has worked as oilfield engineer (2012-2015) and research assistant (2018-2019). Recently he joined the Marine Mapping Group, at the Deakin University, Australia, as a PhD student in marine environmental science. His main research interest is seismic stratigraphy and geomorphology of deep to shallow subsurface sequences, with special emphasis on submarine canyon/channels, mass-transport complexes, fluid flow, and igneous systems within the sedimentary basins. In 2018, he received the Carlos Walter M. Campos Memorial Award (Best International Student Paper) from the AAPG. He is an active Member of AAPG, IAS, GSA and PESA.

279. Ms Anne Tomlinson *anne.tomlinson@sgc.com.au*

Anne Tomlinson (formerly Morrell) graduated from the University of Auckland, New Zealand in 2002 with a Bachelor of Science (geophysics) and Bachelor of Arts (German). She continued her studies at Auckland graduating with a Master of Science majoring in economic geology and applied geophysics in 2004. Her thesis was a geophysical characterisation of low-sulfidation epithermal ore deposits of the southern Coromandel region, New Zealand using potential field methods integrated with geological and geochemical data. Anne began at SGC in 2005 following two years working as an exploration and mine geologist at epithermal and orogenic lode gold operations in North Queensland and Western Australia for Newmont. She has consulted on all aspects of geophysical exploration for gold, base metals, iron ore, REEs, and uranium in Australia, New Zealand, Southeast Asia, West and East Africa including survey planning and management, data processing, interpretation and target generation using potential field and electrical techniques in the air, at surface and downhole. She has also interpreted potential field datasets for on- and offshore oil and gas exploration. With her background in geology, she carries out integrated desktop evaluations of exploration projects including sourcing and using legacy data, as well as litho-structural interpretations of magnetic, radiometric, gravity, and electromagnetic data. Anne is part of SGC's training group delivering aeromagnetic interpretation workshops in Australia and internationally. In 2019, she was elected to SGC's Board of Directors. Anne is an active Member of the ASEG and AIG. She was a Councillor on the AIG Federal Committee responsible for Membership and Qualifications (2012-2017), has served on the AIG Membership and Education Committees, and is also a past President of the WA Branch of the ASEG. Anne has a strong interest in geoscience outreach to primary and secondary students and is actively involved in the CSIRO's Scientists in Schools programme.

280. and 281. Dr Michael Hatch *michael.hatch@adelaide.edu.au*

Michael Hatch has over 30 years of experience in geophysics, specialising in electrical and electromagnetic methods. He started in mineral exploration as a fieldie, working for Zonge Engineering in the US. Time out was taken for an MSc (1991) from the University of Arizona under Jon Sumner where they used high precision GPS data to investigate subsidence due to groundwater over-pumping for agriculture in the Tucson basin. A transfer to Zonge Australia in 1994 gave him the opportunity to start thinking about the use of electrical methods to environmental problems. He began applying these methods in earnest to groundwater issues along the Murray River in 2003. In 2004 through 2006, with Zonge, he participated in three projects that produced a continuous high-resolution resistivity-depth section image of the sediments under the Murray River between the end of the river at Lake Alexandrina in South Australia and Echuca in New South Wales – a total distance of almost 2000 river kilometres. Following his interest in environmental geophysics, Mike completed a PhD at the University of Adelaide in 2012, specialising in the application of near-surface geophysics to imaging the floodplain environments of the Murray. Since then he has held research positions at both the University of Adelaide and Flinders University in Adelaide, South Australia, working on projects around Australia, and other countries. These projects have ranged from using GPR to locate and image wombat burrows in far western South Australia, to imaging shallow soil structure in the Northern Adelaide plains to assess farmland for irrigation, and then to Laos to expose local geophysicists to new geophysical techniques that will help them find groundwater in their country. He is currently working with Professor Graham Heinson at the University of Adelaide on a project to use electrical geophysics to map hydrological properties at a proposed *in-situ* mining site in South Australia. Mike also works with Vista Clara Inc., an American company specialising in the application of NMR technology to the search for water, and continues to work for Zonge Engineering for Australia, both on mineral as well as environmental projects. He is an Associate Editor of the ASEG's magazine *Preview* looking after the Environmental Geophysics column since 2015.

285. Mr Laurence Davies *laurence.davies@hdr.qut.edu.au*

Laurence Davies is a PhD candidate at the Queensland University of Technology. His thesis title is "Bayesian model inference for geophysics applications", and he previously worked for Geoscience Australia, CRC-SI and Land and Property Information NSW. His current research interests are model selection, sequential Monte Carlo, MCMC methods, and airborne electromagnetic geophysics.

286. Dr Adam Smiarowski *adam.smiarowski@gmail.com*

Adam has been involved with electrical methods for environmental and exploration applications for 15 years. Adam completed an MSc in geophysics at RMIT University and a PhD in physics and geology at the University of Toronto. He has been involved with airborne EM research, both in frequency and time-domain, for the past 10 years.

Preview crossword #15

Across

1. The Aboriginal name for Brisbane referring to the 'place shaped like a spike'.

4. The Royal Queensland Show is otherwise known by this name.

5. Brisbane born aviator, Sir Charles Kingsford Smith, flew this plane for man's first transpacific flight from Oakland, California to Brisbane.

7. The oldest known cultivated tree of this kind was first planted in the Brisbane City Botanic Gardens in 1858.

11. The world's second largest sand island.

12. This heritage-listed building is the largest of its kind in Australia, owing to its 92 m high clock tower.

13. This decommissioned underground water reservoir is now a unique performance space and live venue.

Down

2. Story Bridge, Australia's longest cantilever bridge, is an inspirational 'twin' of this bridge in Montreal, Canada.

3. The most recognised vocals in the music industry, this band grew up in the Brisbane suburb of Redcliffe.

5. This stadium is built on the site of Brisbane's first cemetery, established in the 1840s

6. This Jackie Chan movie was partially filmed in Fortitude Valley's Chinatown.

8. The oldest and largest koala sanctuary in the world.

9. Naval officer, surveyor and explorer who named the Brisbane River and later identified Moreton Bay as the site for a new penal colony.

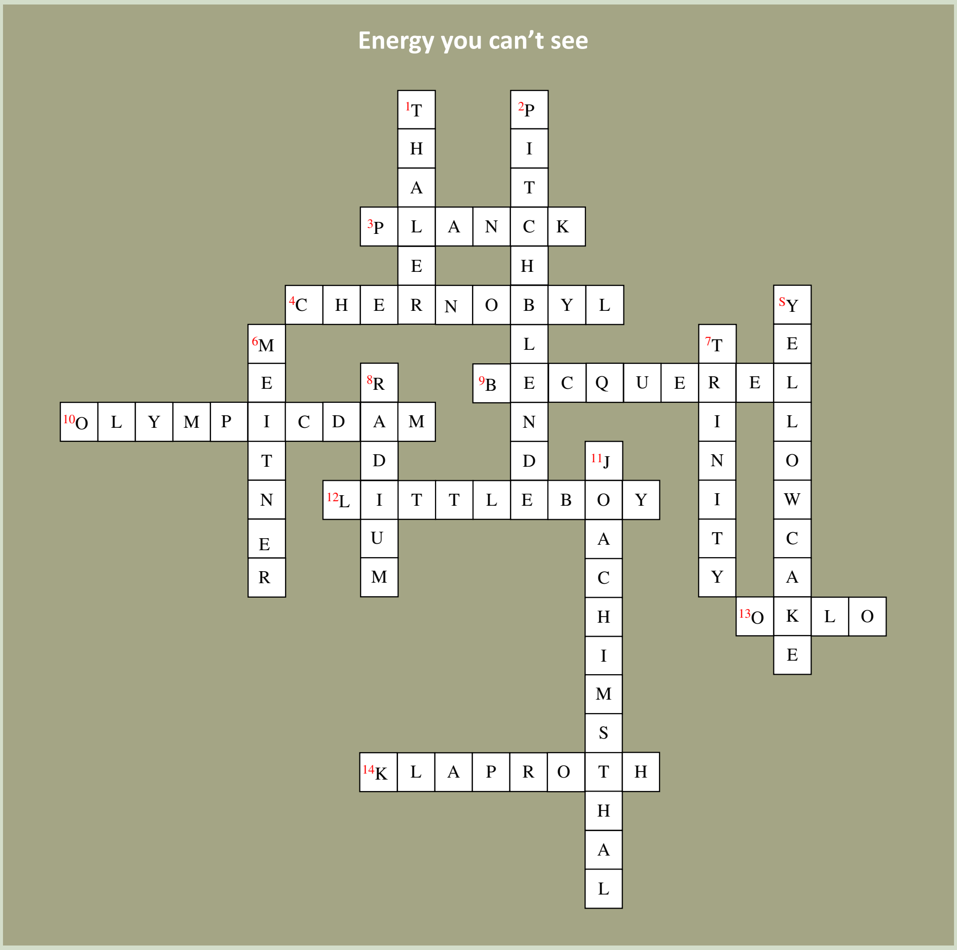
10. While debate surrounding the origins of this cake remains, it was supposedly first made at Old Government House and later named in honour of the visiting French patrons in 1900.

Play to win!!

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

Good luck!

Preview crossword #14 solution



Business directory

August	2021		
3–5	Machine Learning: The artificially intelligent Earth exploration	Kuala Lumpur	Malaysia
16–21	36th International Geological Congress https://www.36igc.org/	Delhi	India
23–27	Advanced Earth Observation Forum 2020 https://earthobsforum.org/	Brisbane	Australia
September	**2021**		
8–10	Mines and Wines 2021 Discoveries in the Tasmanides https://minesandwines.com.au/	Orange	Australia
15–20	Australasian Exploration Geoscience Conference (AEGC 2021) 2021.aegc.com.au		Virtual
26–1 Oct	SEG International Exhibition and 91st Annual Meeting https://seg.org/AM	Denver	USA
October	**2021**		
10–14	11th Balkan Geophysical Congress https://appliedgeophysics.ro/events/bgs2021/	Bucharest	Romania
13–14	Geophysics in Geothermal Energy – Today And Tomorrow https://seg.org/Events/Geophysics-in-Geothermal-Energy-Today-and-Tomorrow	Jakarta	Indonesia
18–21	82nd EAGE Annual Conference & Exhibition https://eage.eventsair.com/eageannual2021/	Amsterdam	Netherlands
18–21	Sapporo, Hokkaido, Japan 14th SEGJ International https://www.segj.org/is/14th/	Sapporo	Japan
25–28	Sixth International Conference on Engineering Geophysics (ICEG) https://seg.org/Events/iceg21	Al Ain	UAE
November	**2021**		
2–5	Summit on Drone Geophysics https://seg.org/Events/Summit-on-Drone-Geophysics-2021		Virtual
9–11	5th Myanmar Oil & Gas Conference https://eage.eventsair.com/fifth-aapg-eage-myanmar-conference/	Yagoon	Myanmar
15–17	Dorothy Hill Symposium https://absoluteevents.eventsair.com/dhweess-2021/	Brisbane	Australia
16–18	SPE/AAPG/SEG Asia Pacific Unconventional Resources Technology Conference https://www.spe.org/events/en/2021/conference/21apur/asia-pacific-unconventional-resources-technology-conference.html		Virtual
23–25	PETEX https://petex.pesgb.org.uk/	London	UK
30–2 Dec	EAGE 4th Asia Pacific meeting on Near Surface Geoscience & Engineering https://eage.eventsair.com/4th-ap-meeting-on-near-surface-geoscience-engineering/	Ho Chi Minh City	Vietnam
December	**2021**		
13–17	AGU Fall Meeting	New Orleans	USA
March	**2022**		
20–23	Geo-Congress 2022 https://www.geocongress.org/	Charlotte	USA
June	**2022**		
5–9	83rd EAGE Annual Conference & Exhibition https://eage.eventsair.com/eageannual2022/	Madrid	Spain
August	**2022**		
15–19	12th International Kimberlite Conference https://12ikc.ca/	Yellowknife	Canada
September	**2022**		
26–30	Australian and New Zealand Geomorphology Group Conference https://www.anzgg.org/conferences	Alice Springs	Australia

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

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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 10 September 2021.

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