Australian Society of Exploration Geophysicists

JUNE 2018 • ISSUE 194
ABN 71 000 876 040 ISSN 1443-2471

PREVIEW

NEWS AND COMMENTARY

FEATURES

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FRONT COVER

Vibrator trucks in action in the Victorian Alps during the Southeast Lachlan crustal seismic transect. Source: Geological Survey of Victoria.

Preview is available online at www.publish.csiro.au/journals/pv
ISSN: 1443-2471 eISSN: 1836-084X

CONTENTS

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Editor's desk

Firstly, I must apologise for the delay in publication of this June 2018 edition of *Preview*. To paraphrase John Lennon, life is what happens when you are making other plans. As many of you will know, I returned to far north Queensland some years ago in order to be able to take a more active role in the care of some of my elderly relatives. They are a feisty lot and, needless to say, gave me as good as they got. Unfortunately the eldest, and most outrageous of my aunts, become very ill in the first week of May. She needed me and I nursed her round the clock until she died a couple of weeks later. As I said at her funeral, she did 'not go gentle into that good night'. She loved life, she loved people (she was teaching art until she had her first fall just before her 90th birthday) and raged against injustice up until the day before she died. She was one of many Australians redefining old age. And there are many geophysicists doing the same. They still have fire in their bellies and are the mainstays of organisations like the ASEG, as well as the light on the hill for those of us who can now see that an active working life does not need end at 60 or 65. Pffff…more like 90 or 95…

This issue of *Preview* features the Australian students who took out first and third place in the novice section of the inaugural Frank Arnott Award (FAA). The inaugural FAA was an outstanding success. The very positive feedback received from participants and from delegates to Exploration '17 has encouraged the FAA organising committee to look at ways of continuing the award, particularly as part of a mineral exploration education program for postgraduate students and junior geophysicists.

This issue also features an article by Roger Henderson that reviews the claim Broughton Edge is the father of Australian exploration geophysics. Well is he? You will have to read Roger's article to find out!

David Denham (*Canberra observed*) brings us up to speed on the outcomes of the Federal Budget, as well as taking a considered look at the Resources 2030 Taskforce, the new maritime boundary between Australia and East Timor and the lifting of the moratorium on fracking in the Northern Territory. Michael Asten (*Education matters*) introduces us to the SEG lecturers visiting Australia in July and August. Mike Hatch (*Environmental geophysics*) gets Esben Auken and the Aarhus team to tell us something about their new towed geophysical transient electromagnetic system for near-surface mapping. Terry Harvey (*Minerals geophysics*) muses about management styles appropriate for exploration. Mick Micenko (*Seismic window*) takes a look at full waveform inversion of seismic data at the request of a reader before having a bit of a spray about the misuse of statistics, and Dave Annetts (*Webwaves*) fills us in on the new data protection laws.

Plenty to get your teeth into so, enjoy!

Lisa Worrall
Preview *Editor*
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SI units in geophysics that are named after scientists

Many of the SI units used in geophysics are named after famous scientists; such as Ohm, Siemens, Hertz and Tesla. Wikipedia provides a complete list of all scientists whose names are used as SI units (https://en.wikipedia.org/wiki/List_of_scientists_whose_names_are_used_as_SI_units). There 29 SI units and 19 use the names of scientists, all of these are used in geophysics.

Of the list, Andre-Marie Ampere (1775–1836), whose name is the unit for electric current, is the earliest born. The latest born and last on the list is Louis Harold Gray (1905–1965), an English physicist whose name is the unit for absorbed dose of radiation; the Gray.

The Gray (Gy), first named in 1974, is used in the measurement of radiation exposure (strictly the dose of radiation energy absorbed by material of mass 1 kg when exposed to ionizing radiation bearing one joule, J of energy. 1 Gy = 1 J/kg). The corresponding cgs unit, still commonly used in the USA, is the 'rad', equivalent to 0.010 Gy.

As Gray was the last scientist to have his name applied to a unit of measurement, many of us may know very little about him. 'Hal' Gray came top of his class at Trinity College, Cambridge in 1925. His idol, Ernest Rutherford, was a member of the same class. This brilliance gained him a position in the 'holy-of-holies' of British natural science, the Cavendish Laboratory, in the company of Nobel prize winners Thomson and Chadwick. His PhD dissertation was on the absorption of hard gamma rays, and was supervised by Chadwick.

Gray wanted to put his knowledge into practice, and developed an interest in methods of treating cancer with ionizing radiation in the new field of radiobiology, which measures the effects of radiation on biological systems. He was based at the Mount Vernon Hospital in Middlesex for seven years and gathered an immense amount of data for the development of radiotherapy. After WW2 and a short spell at London's Hammersmith Hospital, he returned to the institute in Middlesex that now bears his name; the Gray Laboratory of the Cancer Research Campaign.

Later, the British Institute of Radiology elected the now Professor Gray as their President. He also became a Fellow of the Royal Society, and was awarded the Roentgen Prize and the Faraday Medal. He died in 1965, when he was only sixty years old, of a stroke brought on by overwork.

Roger Henderson
rogah@tpg.com.au

President's piece

Welcome to our 2018–19 Federal Executive. Thank you for volunteering. We have some new members including; Dr Kate Robertson, Dr Andrew Squelch and our President Elect Dr Ted Tyne. A very special thanks to Greg Street, a very very long term ASEG Federal Executive volunteer and two times ASEG President who has just stepped back. Greg, thank you for all of your hard work and for agreeing to continue to advise the Executive into the future.

I first joined the ASEG in the early 1990s and I had no idea that my career would steer me towards taking on the role of President of this learned society of professional earth scientists. I look forward to helping to ensure the ASEG moves with the times and remains relevant to all Members. What a privilege!

Most of you will know me as 'that lady' from Geoscience Australia (GA), I have been at GA nearly 12 years, and have had the privilege of working in areas as diverse as mining and mineral exploration, groundwater, critical infrastructure, earthquake and nuclear monitoring, and geomagnetism. Currently I lead the seismic and magnetotellurics team working on the Exploring for the Future program, a $100 million program that is aimed at boosting exploration investment in Australia's resources sector. The seismic and magnetotellurics team is undertaking large scale data acquisition, processing and modelling programs like AusLAMP (magnetotelluric), AusARRAY (passive seismic – northern component) and regional deep crustal seismic lines (Kidson and South Nicolson). Now, some of you oldies might also remember a much younger lady who used to work at Geoterrex in Artarmon in the 1990s (airborne EM, mag/rad mainly).

So what have I been up to since becoming President? My first duty was to develop a five-year strategic plan with the help of the Federal Executive. We held a planning day after the AGM in April, where we formulated three main aspirational strategic goals for 2018–2023. These were to:

- strengthen ASEG publications, promotions and member communications
- advance geophysics as a science of an applied nature to benefit our Members and the wider community
- advance our relevance in the Asia-Pacific region.

I think these are sound goals, in line with our constitution and the changing nature of the work we undertake. I would really like to hear from you, do you agree? What would you change?

In May I was invited by Bill Shaw to represent the AGC (www.agc.org.au) at the first Presidents and CEO Forum run by Science and Technology Australia (www.sta.org.au). The Forum was a really exciting opportunity to network with other science and technology societies, and to discuss the common challenges we are facing into the future. During the day we workshopped strategic priorities for STA, since the AGC represents approximately 10% of the STA members. In a nutshell, five key priorities were identified. These were:

- Investment (R&D and Infrastructure)
- STEM in the workforce (education, diversity, career security)
- Evidence based policy (a dedicated science minister, health, environment)
- Public confidence in science (science communication)
- Engaging industry and applying research (funding and IP)

As I type this I am watching the 2018 Federal Budget and am heartened to see significant investments in science, infrastructure and innovation. On that note, the Government will spend AU$41 million on the space industry, including funding a National Space Agency. Geoscience Australia was also funded to improve Australia's positioning capability. Positioning data accurate to 10 centimetres across Australia and Digital Earth Australia (DEA) will provide the high-quality satellite imagery, data and tools required for policy and investment decision-making, and enable businesses to develop applications and services for sectors across the entire Australian economy.

Reading the post budget analysis in *Mining News*, the Minerals Council of Australia interim CEO David Byers noted the Budget's heavy reliance on growth in resources exports. Byers said, 'With resources accounting for a record $207 billion in exports in 2017 – more than half Australia's total export earnings – it is clear that the minerals industry is critically important to economic prosperity. Treasury is forecasting growth in mining exports of 4% in 2017–18 and 6.5% in 2018–19. Mining industry capital expenditure is expected to grow by 3.5% in 2019–20 as mining companies maintain the capital stock built up during the mining investment boom.' Good news for exploration geophysics.

Finally, I hope you enjoyed our first ASEG newsletters, which were emailed to all Members on 4 May and 25 May. The communications team, mainly the wonderful Kate Robertson, has plans to send out a monthly newsletter to reduce the number of *ad hoc* emails you receive from us. If you would like to contribute to the newsletter or join the communications team please email communications@aseg.org.au.

Marina Costelloe
ASEG President
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Marina Costelloe, incoming ASEG President.

ASEG Federal Executive 2017–18

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Executive brief

The ASEG Annual General Meeting, held in Canberra in April, saw the election of new office bearers for 2018 and the departure of others. Marina Costelloe took over from Andrea Rutley as President, congratulations Marina! Thank you Andrea for your diligent efforts over the past 12 months, which will no doubt continue as you remain on the Federal Executive as Immediate Past President and Chair of the Promotions Committee.

Megan Nightingale and Danny Burns will continue in their roles as Secretary and Treasurer respectively. We thank them for their efforts, particularly Danny Burns who, in addition to being a Director of the Society and managing the Societies finances, has filled in as Chair of the Publications Committee over the last six months. Danny has been instrumental in negotiations for new publications contracts that will safeguard the continuing financial stability of our Society. Thank you for your fantastic work Danny!

This year we welcome Ted Tyne as President Elect for 2018. Throughout his career Ted has made great contributions to the ASEG and geophysics, particularly in South Australia. We look forward to the immense knowledge and experience he will bring and share with the Federal Executive team over the coming years. Ted will also take the reins as Chair of the Publications Committee.

We also welcome Kate Robertson (Communications Committee), Andrew Squelch (Education Committee) and Leslie Atkinson (Membership Committee).

Thank you to returning members of the Federal Executive; Kim Frankcombe (AGC Representative, Conference Advisory Committee and Technical Standards Committee), Katherine McKenna (Research Foundation and International Affairs Committee), Marina Pervukhina (State Branch Representative and Professional Development Committee) and David Annetts (Web Committee Chair) for continuing their hard work for the Society. An extra special thank you to Greg Street who stood down this year, after many years of service to the ASEG Federal Executive.

The day after the AGM the Federal Executive got together to discuss the short and long term issues facing the Society. The meeting was attended by the Federal Executive, the *Preview* Editor Lisa Worrall, and representatives from the Secretariat TAS.

The mission of the Society is to provide an environment for the science of applied geophysics to grow for the benefit of its Members and the wider community. Our aims are:

- to promote the science of geophysics, and specifically exploration geophysics, throughout Australia
- to foster fellowship and co-operation between geophysicists
- to encourage closer understanding and co-operation with other earth scientists
- to assist in design and teaching of courses in geophysics and to sponsor student sections where appropriate.

The Society, in line with its aims and the activities defined in the Constitution, has adopted the aspirational strategic goals listed below. These were agreed upon by the Federal Executive and will ensure that the ASEG retains vitality and relevance in an exploration industry that is continually changing.

Aspirational strategic goals for 2018–2023

- Strengthen ASEG publications, promotions and Member communications.
  - Future-proof publications, *Exploration Geophysics*, *Preview* and the ASEG newsletter and social media. Use flexible mobile options to deliver information, promote the Society and engage with our Members.
- Advance geophysics as a science of an applied nature to benefit our Members and the wider community.
  - Make the latest innovations and developments, future technologies, software, hardware, cloud computing and educational opportunities discoverable and accessible by all Members.
- Advance our relevance in the Asia-Pacific region.
  - Use, enhance and cross-promote courses, conferences and educational opportunities that drive science in the region. Tap into other societies' activities to cross-pollinate and grow synergies of value to Members.

Additional core business areas for improvement

- Promote geophysics as a science, career, and practical industry and government 'go to solution' for earth science problems
- Improve the value proposition for Corporate Members and enhance interaction with industry and other stakeholders
- Improve the value proposition for ordinary Members (including student, graduate and international Members). Attract and retain new Members from a broader base of companies, universities, government agencies and countries.

The Federal Executive would like to thank the ACT Branch of the ASEG for their assistance in organising, and Geoscience Australia for hosting, the 2018 AGM and Planning Day.

Megan Nightingale
Secretary
fedsec@aseg.org.au

Welcome to new Members

The ASEG extends a warm welcome to 28 new Members approved by the Federal Executive at its April and May meetings (see table).

First name	Last name	Organisation	State	Country	Membership type
Bradley	Baber	Macquarie University	NSW	Australia	Student
Julia	Correa	Curtin University	WA	Australia	Student
Maria	del Pilar Escobar Lopez	University of Western Australia	WA	Australia	Student
Patrick	Dikedi	Veritas University	Kubwa	Nigeria	Student
Silvia	Ferrer Suescun	Lloyds International College	NSW	Australia	Student
Blake	Goodfield	Curtin University	WA	Australia	Student
Allister	Griffin	University of Adelaide	SA	Australia	Student
Laurence	How	University of Adelaide	VIC	Australia	Student
Kathryn	Job	Westgold Resources Pty Ltd	WA	Australia	Active
Venkata Pavan	Katuru	University of Adelaide	SA	Australia	Student
Matthew	Linke	University of Adelaide	SA	Australia	Student
Liz	Mahon	University of Melbourne	VIC	Australia	Student
Andres	Martinez Hernandez	Lonsdale Institute	NSW	Australia	Student
Ryan	McAllister	University of Adelaide	SA	Australia	Student
Alexander	Otasevic	University of Adelaide	SA	Australia	Student
Thanh-Son	Pham	Australian National University	ACT	Australia	Student
Huzaifa	Rahman	Presidency University	Karnataka	India	Student
Teagan	Romyn	University of Adelaide	SA	Australia	Student
Huw	Rossiter	Kinetic Logging Services Pty Ltd	QLD	Australia	Active
Shivani	Sharma	Hindustan Zinc Limited	Rajasthan	India	Active
Jeremy	Smith	Hiseis Pty Ltd	WA	Australia	Associate
Alan	Spencer	University of Adelaide	SA	Australia	Student
Syed Usman	Syed	PIEAS Islamabad	Islamabad	Pakistan	Student
Dean	Tuck	Arrow Minerals	WA	Australia	Active
Sarah	Whitehouse	University of New England	NSW	Australia	Student
Joanne	Whittaker	University of Tasmania	TAS	Australia	Active
Jamieson	Woolcock	University of Adelaide	SA	Australia	Student
Bo	Yang	University of Adelaide	SA	Australia	Student

World famous nuclear physicist also lectured on geophysics

A newly published biography of Enrico Fermi (Schwartz, 2017), the Italian physicist who, in the nuclear age of the 1930s mastered all the sub-disciplines of physics including astrophysics, nuclear physics, and particle physics in both theory and experiment, reveals that he also taught geophysics.

The biography describes Fermi as 'The last man who knew everything [about physics]', when it was, perhaps, the last time that was possible. Today physicists are rarely able to master more than their particular sub-discipline.

In the year following his award of the Nobel Prize in Physics in 1938, Fermi became Professor of Physics at Columbia University, New York, where he taught courses in the first term, 'including a course on geophysics, one of his favourite subjects,…as well as higher level (*sic*) courses on quantum mechanics…'. At the 1940 Washington Conference on Theoretical Physics, 'he lectured on the geophysics of iron in the core of the earth'.

It is difficult to recover details of his geophysics courses as Fermi did not usually speak from a prepared text and used hand-written notes. Even so, he 'knew exactly what he was going to say and delivered each thought in full, complete, grammatically correct sentences'.

Fermi was an outstanding lecturer, which is not often the case with world-class research scientists. Students flocked to his sessions, as also did the most senior physicists. In 1954, at the University of Chicago, a huge commotion emanating from the physics department was found to be due to 'some hundred undergraduates on their feet, applauding and cheering Fermi, who had just delivered his final classroom lecture of the term'.

Reference

Schwartz, D. N., 2017, *The Last Man Who Knew Everything: the life and times of Enrico Fermi, father of the nuclear age*. Basic Books, New York.

Roger Henderson
rogah@tpg.com.au

ASEG committees

The ASEG has many talented, articulate, approachable professionals that help run a healthy and diverse society – through our specialist groups and committees. Over the next three issues of *Preview* we will highlight some of their amazing work. Remember, you can keep up to date with committee activity through social media, signing up to their specialist email lists as detailed below, or emailing the committee chair directly (details at https://www.aseg.org.au/committees). On behalf of all Members, all of the committee chairs and committee sub-groups are thanked for their passion, knowledge and accountability.

In this edition of *Preview* we take a look at the International, History, Young Professionals, President Nominating and Web Committees. More about our learned colleagues and other committees next month.

International Committee

Nick Direen.

Nick Direen is the Committee Chair, and there are many active members including Yusen Ley-Cooper, Hagay Haviv and Rob Hewson.

The International Committee serves as a point of contact with the ASEG for Members residing in countries other than Australia. They promote the ASEG beyond Australia – including the promotion of ASEG conferences, speakers, workshops, events, and journals to a wider international audience.

The International Committee provides a first point of contact and networking gateway for ASEG Members and members of sister societies moving to Australia for professional reasons, and provides a networking gateway for ASEG Members moving to other countries for professional reasons. The Committee also acts as a body of reference for the recommendation of ASEG awards to Members residing internationally and, via their networks, provides a reference pool of international reviewers for *Exploration Geophysics*. The Committee also promotes relevant international conferences, speakers and workshops to ASEG Australian Members. The Committee report monthly to the President via email and contributes to the new monthly email newsletter. To become a volunteer in the International Committee please email international@aseg.org.au.

Young Professionals Network

Megan Nightingale.

Jarrod Dunne.

Megan Nightingale and Jarrod Dunne are joint presidents of the Young Professionals Network, which is an ASEG specialist group. The group champions the interests of young employees in the profession of geophysics. There is no age limit, but is intended for people aged under 35, or those new to the profession

The group aims to:

- create an inclusive, relaxed and open atmosphere in which to share knowledge, ideas and experiences,
- facilitate networks with industry, academia and government to advance geophysics,
- provide opportunities for professional development and technical education,
- develop, implement and promote events targeted at young professionals.

There are a ton of benefits of becoming a Young Professionals Network member. These include meeting like-minded professionals, increasing your network and developing your professional and technical skills at our events. Plus, you might even have some fun!

Please sign up to the Young Professionals Network by emailing ypadmin@aseg.org.au or find us on social media to get updates, or to volunteer.

History Committee

Roger Henderson.

Roger Henderson is the Chair of the History Committee. The History Committee is one of our most active committees and is the convener of all matters of historical interest to Members, and an active promoter of new material. The ASEG has an important role to play in documenting and preserving equipment as well as society history and geophysical progress. The Committee run a very active page on the ASEG website, visit https://www.aseg.org.au/about-aseg/history to learn more. Leading up to the 50th anniversary all Members will be grateful for the knowledge that will come from the History Committee.

Please contact Roger Henderson at history@aseg.org.au if you have any historical item or ideas to contribute or merely wish to be on the mailing list.

President Nominating Committee

Marina Costelloe.

The incumbent President is always the Chair of the President Nominating Committee for any given year (between April 2017 and April 2018 Andrea Rutley was Chair, between April 2018 and April 2019 Marina Costelloe will be the Chair). The Committee is comprised of the current President and the two most recent Past Presidents (if either Past President is unable to participate then his/her place is taken by the Treasurer of the corresponding year). This Committee works toward securing a President Elect for February the following year in preparation for the AGM held in April. It is the responsibility of this Committee to find a new President who can help shape the future of the ASEG. Many factors are taken into account when nominating a new President Elect.

Web Committee

David Annetts.

David Annetts is the Web Committee Chair and members include Ian James, Karen Gilgallon and Chris Bishop. The Web Committee is responsible for the maintenance and development of the ASEG's web site (www.aseg.org.au), which is the portal to the Society on the internet. This active Committee works on strategies to allow for continuous improvement to the web site, thereby improving its value to ASEG Members and helping to promote the ASEG and exploration geophysics in the wider national and international community.

News from the ASEG Young Professionals Network

Since the AEGC conference in February YPN activity is picking up all across Australia, thanks to the efforts of our State Representatives and the continually hard working State Committees.

Queensland

Janelle Simpson took on the role as Queensland's Young Professional State Representative – thanks Janelle! Janelle and Megan have been in contact with fellow YPs at PESA and SPE and discussions are underway regarding the implementation of combined mentoring program/networking events in QLD.

Over coming weeks they will be asking all QLD ASEG Members if they would like to be involved in the QLD Mentoring Program, as either a Mentor or Mentee.

Janelle is also a volunteer on the Australian Geoscience Council Convention (AGCC) Early Career Professionals (ECP) committee and will be championing Diversity, as is our ASEG President Marina Costelloe.

South Australia

The South Australian – Northern Territory Branch held a student pizza night in April that was well attended. In addition, the SA YP representative Chris Li has been busy establishing collaborative links with the SEG Student Chapter at the University of Adelaide. Chris is also volunteering on the AGCC ECP committee and will be organizing a networking event to be held at the conference.

Victoria

On 26 April the Victorian YPs continued their seminar series with a seminar on seismic interpretation given by Jane Rodgers of Karoon Gas. Some excellent discussion was generated around the case studies presented.

Western Australia

The WA Branch launched its mentoring program, jointly hosted by PESA, on 11 April. The event was well attended by members of both societies. Nineteen mentee-mentor pairs have been created post the completion of the matching phase. Carolina Pimentel is one of the program coordinators and will keep us updated on how the program is progressing.

Finally, the AGCC will be held later this year 14–18 October (Earth Science Week) in Adelaide. The conference will be the largest geoscience event to be held in the Asia Pacific Region since 2012. It will feature a wide ranging scientific program, a range of pre- and post-Convention field trips, a large exhibition, expert training workshops and an education program. Numerous networking events are currently being organised for early career geoscientists including YP welcoming drinks, a trivia night, a networking event and a scavenger hunt through the exhibition. All young professionals are urged to attend the conference and make the most of the many networking opportunities available to them.

Genna McDonagh is coordinating the volunteer and early career delegate programs. These programs will ensure that we address the broad social themes that are important to all professionals in academia, industry, consulting and government. If you are passionate about diversity, representation, networking, STEM or just making a difference, please email her at genna.mcdonagh@gmail.com.

Megan Nightingale
ASEG Young Professionals Network
ypadmin@aseg.org

ASEG Research Foundation: Frequently asked questions

What is the ASEG RF?

The ASEG RF is a body independent of the ASEG but supported by the ASEG and its Members. On an annual basis it seeks applications from university geophysical supervisors for funding toward BSc (Honours), MSc and PhD projects in applied exploration geophysics. The goal is to attract high-calibre students into exploration geophysics, and thus to ensure a future supply of talented, highly skilled geophysicists for industry. ASEG RF is a registered tax exempt research foundation and contributions are tax deductible. Since inception in 1990 the ASEG RF has made over $1.3 million in grants to over 130 projects.

Who provides funding?

The main provider of funding to ASEG RF is the ASEG via the Federal Executive. Over the past few years annual funding has been typically $100 000 per year sourced from Members and conference proceeds. In the last couple of years this support has been reduced due to budget constraints. In addition, Members can make tax deductible donations during ASEG membership renewal or at any time. Companies can make donations and Corporate Plus Members make a significant annual contribution. The Committee is investigating additional sources of funding and is open to other ideas.

Who is on the ASEG RF Committee?

The ASEG RF Committee currently comprises 17 members from a range of mining, petroleum, engineering industries as well as academic members. The Chair is Phil Harman, the Treasurer is Peter Priest and the Secretary is Doug Roberts. The other members are Bob Smith, John Denham, Steve Mudge, Koya Suto, Binzhong Zhou, Lisa Vella, Bob Musgrave, Natasha Hendrick, Steve Hearn, Mike Dentith, Graham Heinson, Andrew Long, Barry Bourne and Howard Golden. The past president of the ASEG is an ex-officio member. We are always looking for enthusiastic new members with an interest in supporting the training of geophysicists.

What's happening in 2018?

This year the ASEG RF received five applications, and two grants for PhD projects have been approved. Subject to acceptance this will commit ASEG RF to $30 000 over 3 years for 2018 grants. Total current commitments are $79 590 over seven projects for the next 3 years. Details of current projects will be highlighted in future issues of *Preview*.

Doug Roberts
ASEG RF Secretary
research-foundation@aseg.org.au

ASEG Branch news

Queensland

The Queensland Branch held their AGM on Tuesday 8 May, alongside an excellent technical talk by SEG 2018 Honorary Lecturer – South Pacific, **Mazin Farouki**. **Ron Palmer** was nominated for the position of President by outgoing President **Fiona Duncan**. He was seconded by **Megan Nightingale** and elected unopposed. Ron took the batten and thanked Fiona for all her hard work over the past years. **James Alderman** was nominated for the role of Secretary by **Nick Josephs**, and seconded by Megan Nightingale, and **Henk Van Paridon** was nominated for the role of Treasurer by **Fiona Catherine** and seconded by Ron Palmer. James and Henk were both elected unopposed.

The evening was well attended and Mazin Farouki's talk on dense sampling in marine seismic, had something for everyone, from those of us who only remember marine seismic from our University days, to the current industry practitioners in the room. The evening finished with some good questions and discussion around the future of developments in marine seismic.

The QLD Branch is currently looking for speakers to fill our calendar for 2018, if you'd like to volunteer a talk please contact qldpresident@aseg.org.au or qldsecretary@aseg.org.au.

An invitation to attend Queensland Branch meetings is extended to all ASEG Members and interested parties. Meetings are usually held monthly and details of all upcoming Queensland events can be found on the Qld Events tab on the ASEG website. Our next technical talk is on 12 June; keep an eye on the calendar and your inbox for more details.

James Alderman
qldsecretary@aseg.org.au

South Australia & Northern Territory

Since the last update in *Preview*, the SA/NT Branch has held two events for local Members. In April we held our Annual Student Pizza Night in conjunction with the Adelaide University Geological Society, with two great presentations covering both petroleum and mineral perspectives of a geophysical career. **Josh Sage** is a geoscientist working for Beach Energy, and he provided the students with a great overview of a petroleum career with lots of great photos and stories. **Nick Jervis-Bardy** first spoke of his experiences as a Crew Chief for Zonge Engineering, which included a lot of fieldwork in exciting locations, and then his quite different current role as a geophysicist at Heathgate Resources. There was plenty of pizza to go around and we were very happy to sign up new student Members. Thanks to the ASEG Members who came and stayed to chat and share their experiences with the students after the presentations.

We started May with a fantastic talk by the SEG Honorary Lecturer, **Mazin Farouki**, on efficiency in marine seismic acquisition. Adelaide was Mazin's first stop in Australia on his tour and the event was very well attended. Feedback on the talk was positive by all, and there was a lot of socialising and networking to be had after the talk.

Our technical meetings are made possible by our very generous group of sponsors, including Beach Energy, Minotaur Exploration, Vintage Energy and Zonge. Of course, if you or your company are not in that list and would like to offer your support, please get in touch at the email below.

As usual, further technical meetings will be held monthly, at the Coopers Alehouse on Hurtle Square in the early evening. We will also be holding this year's SEG DISC, 'Seismic attributes as the framework for data integration throughout the oilfield life cycle' by **Dr Kurt Marfurt**, with the one day course scheduled for Monday 16 July at the Hotel Richmond. Kurt will also be giving a talk on the evening of Tuesday 17 July at the Coopers Alehouse. Further details will come so please keep an eye out for pricing and booking on the SEG website.

We invite all Members, both SA/NT and interstate, to attend and, of course, any new Members or interested persons are also very welcome to join us. For any further information or event details, please check the ASEG website under SA/NT Branch events and please do not hesitate to get in touch at sa-ntpresident@aseg.org.au.

Kate Robertson
sa-ntpresident@aseg.org.au

Tasmania

An invitation to attend Tasmanian Branch meetings is extended to all ASEG Members and interested parties. Meetings are usually held in the CODES Conference Room, University of Tasmania, Hobart. Meeting notices, details about venues and relevant contact details can be found on the Tasmanian Branch page on the ASEG website. As always, we encourage Members to also keep an eye on the seminar program 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

Mazin Farouki in Adelaide presenting 'Dense sampling in marine seismic: efficiency in acquisition without compromising data quality'.

ASEG news

Victoria

The old saying 'past performance may not be an indicator of future results' could very well sum up the lull in activity at the Victorian Branch over the past couple of months. Whilst your committee endeavours to bring both educational and entertaining events to its Members, the early Melbourne winter hiatus appears to have set in rather early this year! Notwithstanding, we are pleased to report that our May guest speaker was **Mazin Faruki**, who is this year's SEG 2018 South Pacific Honorary Lecturer. A small gathering braved the very inclement weather on Thursday evening to hear Maz present the latest technological improvements in marine acquisition, some of those quite fascinating! Stay warm, Melbournians!

Seda Rouxel
vicpresident@aseg.org.au

April Young Professionals Network launch of ASEG-WA's mentoring program, jointly run with PESA-WA. The members of the mentoring program organizing committee are (left to right) Ishtar Barranco (PESA), Carolina Pimentel (ASEG), and Simon Molyneux (PESA).

Western Australia

The WA Branch launched our mentoring program, jointly hosted with PESA, on 11 April. The event was well attended by Members of both professional societies. Our May Tech night was a *petroleum* stream presentation by SEG Honorary Lecturer **Mazin Farouki** on 'Dense sampling in marine seismic data: Efficiency in acquisition without compromising data quality'. This was followed by our June Tech night (*minerals* stream), when **Chris Wijns** of First Quantum Minerals presented 'Exploration geoscience inside the mine gate', which highlighted standard practices in exploration geoscience that can add value to resource definition and mining operations.

Upcoming WA events include:

- 12 June Tech night: *Minerals* – Nikhil Prakash (Rio Tinto) – 'The effective use of forward modelling and petrophysical analyses in the application of induced polarisation surveys to explore for disseminated sulphide systems in the Paterson Province, Western Australia'.
- 20 June Mentoring program meeting: *Young Professionals* – the joint ASEG-PESA mentoring program for 2018 will introduce matched mentors and mentees at a kick-off event. For any inquires please contact Carolina Pimentel on wa-mentoring@aseg.com.au.
- 12 July Tech night: *Petroleum* – Kurt Marfurt (SEG DISC lecturer 2018) will present on 'Seismic Attributes as the Framework for Data Integration throughout the Oilfield Life Cycle'.
- 17 July Career Expo: *Young Professionals* – the WA Branch will attend a career expo at a local Perth high school to discuss career pathways within the geoscience industry and the field of geophysics with interested students.
- 8 August Tech Night: *Minerals/groundwater* – three speakers from Southern Geoscience Consultants will present on the use of geophysics for hydrogeology applications.

*March Minerals stream Tech night in Perth. Presenter was **Regis Neroni** (Fortescue Metals Group).*

The Tech night schedule is subject to change due to speaker availability. Please check the website for up-to-date information.

Our monthly WA Branch's Tech nights are kindly sponsored by the following: Globe Claritas, First Quantum, Geosoft, GPX Surveys, HiSeis, NRG, Resource Potentials, Southern Geoscience, Teck, Western Geco, Atlas, CGG, ExploreGeo, NGI, and a private donation *in memoriam*. We could not put together the Branch's wide range of technical activities without the support of our sponsors, and we look forward to maintaining strong partnerships with these companies. **Branch sponsorship is based on the financial year, so if you are interested in sponsoring the WA Tech Night series please contact us** on wapresident@aseg.org.au or watreasurer@aseg.org.au.

We are excited about the program of events planned for the second half of 2018 and look forward to seeing our Members at the various technical, young professional, and networking events.

Heather Tompkins
wapresident@aseg.org.au

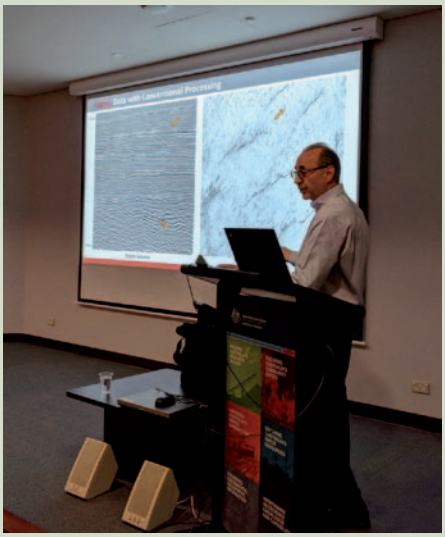
Simon van der Wielen in Canberra presenting his team's award winning work on SA3D.

Australian Capital Territory

The ACT Branch recently held its Annual General Meeting and **James Goodwin** was re-elected as the Branch's president, **Ross Costelloe** as the Treasurer, and **Adam Kroll** as the Secretary. Congratulations to all the new office bearers and to those continuing in their positions, without your hard work the ACT Branch would not be in a position to host so many interesting events and lectures.

As part of the AGM the Branch enjoyed a guest speaker presentation by **Simon van der Wielen**, who presented the results of his team's work on the South Australian 3D model (SA3D). SA3D integrates geological, geophysical, geochemical and mineralogical data in three dimensions and covers the entire state of South Australia to a depth of 250 km. The results of this work provide significant new contributions to the understanding of South Australia's geology and mineral systems and was awarded 3rd place for the Frank Arnott Award in the professional category.

In April, the ACT Branch was delighted to host an SEG workshop on 'Seismic anisotropy: Basic theory and applications in exploration and reservoir characterisation' presented by **Ilya Tsvankin**. The course provided background information on anisotropic wave propagation before delving into the modelling, inversion, and processing of seismic data in the presence of anisotropy.



Mazin Farouki in Canberra presenting on 'Dense sampling in marine seismic'.

Also in April, **Professor Malcolm Sambridge** delivered a fantastic presentation titled 'The story of nothing – geophysical inversion' discussing the latest developments in geophysical inverse theory and methods of inference from indirect observations, together with their application across the earth sciences.

Most recently, the Branch hosted the 2018 SEG Honorary Lecturer – South Pacific **Mazin Farouki** who presented an entertaining talk on 'Dense sampling in marine seismic: efficiency in acquisition without compromising data quality'. Mazin discussed modern acquisition approaches for towed streamer seismic currently offered in the industry and what, if any, are the associated limitations and concerns regarding the resulting data quality. Also the Branch hosted guest speaker Lachlan Hennessy who gave an excellent talk on 'Sferic signals for lightning sourced electromagnetic surveys'.

The ACT Branch is looking forward to a number of upcoming events including:

- 20 June: Guest speaker **Alison Kirkby**: 'Conductivity structure of the Georgina-Arunta region from MT data'.

James Goodwin
actpresident@aseg.org.au

New South Wales

In March, **Luke Smith**, with some help from **Tasman Gillfeather-Clark** from Macquarie University, presented a talk about working with large multivariate datasets using Self Organising Maps (SOM). Luke spoke about the background to SOM, how it was setup to run on a large dataset from Broken Hill, and then discussed the results from that analysis. Many questions followed.

As well, we celebrated **Keeva Vozoff**'s 90th birthday. Friends and colleagues reminisced. We had a cake. Keeva blew out 90 years' worth of candles and then we ate the cake and discussed the geophysical world. Happy Birthday Keeva!

In April, **Steve Hansen** from Macquarie University presented a talk about new insights into the deep structure of Mount St Helens provided by the iMUSH experiment. Steve delved into the imaging of magma under Mount St Helens, but utilising both active and passive source seismics. The active-source experiment included the deployment of 900 autonomous geophones along the road and trail system. Steve noted that the nodal seismometers being used are a technology that has been developed in the energy industry but are increasing being used in academic research. Much discussion followed, with more questions about the eruption being asked over a few reds.

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to be in town at the time. Meetings are generally held on the third Wednesday of each month from 5:30 pm at the 99 on York Club in the Sydney CBD. Meeting notices, addresses and relevant contact details can be found at the NSW Branch website

Mark Lackie
nswpresident@aseg.org.au

ASEG national calendar: technical meetings, courses and events

Date		Branch	Event	Presenter	Time	Venue
12	Jun	QLD	Tech night	Brad Cox	1730	XXXX Alehouse, Black Street, Milton
13	Jun	WA	Tech night	Chris Wijns	TBA	City West Receptions
13	Jun	SA-NT	Tech night	Simon Holford	1730	Coopers Alehouse, 316 Pulteney Street, Adelaide
20	Jun	ACT	Tech talk	Alison Kirkby	TBA	Sir Harold Raggatt Theatre, Geoscience Australia, Symonston, Canberra
20	Jun	WA	YPN Mentoring program meeting	Various	TBA	1 Ord Street, West Perth
20	Jun	NSW	Tech night	Ned Stolz and Bob Musgrave	1730	99 on York Club, York Street, Sydney
5–6	Jul	WA	EAGE Course	Tapan Mukerji	TBA	TBA
11	Jul	WA	SEG DISC	Kurt Marfurt	TBA	City West Receptions
12	Jul	WA	Tech night	Kurt Marfurt	TBA	City West Receptions
16	Jul	SA-NT	SEG DISC	Kurt Marfurt	TBA	Richmond Hotel Rundle Mall, Adelaide
17	Jul	SA-NT	Tech night	Kurt Marfurt	TBA	TBA
17	Jul	WA	Career Expo	Various	TBA	TBA
18	Jul	WA	EAGE Course	Cyrille Reiser	TBA	TBA
18	Jul	NSW	Dinner	TBA	1730	99 on York Club, York Street, Sydney
18	Jul	VIC	SEG DISC	Kurt Marfurt	TBA	Kelvin Club, Melbourne
19	Jul	VIC	Tech night	Kurt Marfurt	TBA	TBA
23	Jul	ACT	SEG DISC	Kurt Marfurt	TBA	Scrivener Room, Geoscience Australia, Symonston
24	Jul	ACT	Tech night	Kurt Marfurt	TBA	TBA
25	Jul	QLD	SEG DISC	Kurt Marfurt	TBA	Christie Centre, Brisbane
26	Jul	QLD	Tech night	Kurt Marfurt	TBA	XXXX Alehouse, Black Street, Milton
30	Jul	QLD	SEG/AAPG DL	Satish Singh	TBA	TBA
1	Aug	ACT	SEG/AAPG DL	Satish Singh	TBA	TBA
2	Aug	VIC	SEG/AAPG DL	Satish Singh	TBA	TBA
7	Aug	SA-NT	SEG/AAPG DL	Satish Singh	TBA	TBA
8	Aug	WA	Tech night	Southern Geoscience Consultants	TBA	City West Receptions
8	Aug	NSW	SEG/AAPG DL	Satish Singh	TBA	TBA
12	Aug	WA	Tech night	Alan Aitken	TBA	City West Receptions
14	Aug	TAS	SEG/AAPG DL	Satish Singh	TBA	TBA
15	Aug	WA	SEG/AAPG DL	Satish Singh	TBA	TBA

TBA, to be advised (please contact your state Branch Secretary for more information).

Exploration ’17: Integrating the geosciences, the challenge of discovery

Exploration ’17, the sixth decennial conference on mineral exploration technology, was organised by DMEC (Decennial Mineral Exploration Conferences) and held in Toronto, Canada from 21 to 25 October 2017 (http://www.dmec.ca). For half a century these meetings have provided a once-a-decade review of major developments in the fields of geophysics, geochemistry, remote sensing, and data management and processing as they relate to minerals exploration.

At Exploration ’17, the core program consisted of 6 plenary talks, 49 invited papers, 23 technical and special talks, and 29 posters. In addition, there were 15 workshops on topics related to the conference themes prior to, and after, the conference, and a field school held in Sudbury prior to the start of the conference. There were more than 1200 registered delegates from 46 countries.

Geophysical technology

Presentations at the conference demonstrated that a number of technologies were maturing and could handle more complex earth situations. Technologies included in this category are airborne gravity gradiometry and array-style IP technology. An important new addition was airborne natural fields (AFMAG), which became commercial shortly after the last decennial meeting.

In summary:

- Versions of Airborne Gravity Gradiometry (AGG) technology were available starting in the mid-2000s, but in late 2007 the entire BHP ‘fleet’ of Falcon AGG systems (including HeliFalcon) was sold to Fugro Airborne (now CGG Multi Physics). This sale significantly expanded the commercial availability of AGG surveys globally. While AGG technology is recognised as the most sophisticated of any mining geophysical technology, less complex technology such as Sander Geophysics’ AirGrav, has been shown to be very effective for a number of natural resource applications.
- 3D IP could be considered an outgrowth to 2D IP surveying, which emerged in the mid-late 1990s. The first survey was carried out in 2011 by a traditional 2D IP contractor, and now there are five groups offering 3D surveys. The value of such surveys is still be established by the industry, but they appear to be able to map targets deeper than in the past. Some contractors can also concurrently provide MT data.
- AFMAG developed in the 1950s and was used mainly as an airborne technique through to the 1970s. Airborne AFMAG became commercially available as ZTEM (Geotech Ltd) in 2008. In conductive environments ZTEM does not achieve a depth of investigation much greater than standard time domain EM systems, but in resistive terrains ZTEM has been able to map conductive/resistive zones to depths approaching 2 km. The technique has been applied to a range of deposit styles, but appears best suited to large targets such as porphyry copper deposits, and structurally controlled deposits such as SEDEX-style or unconformity-style uranium similar to those found in the Athabasca Basin (Saskatchewan) Canada.

Geochemical technology

Over the past decade the quest for technology improvements on a range of fronts appears to be more common in geochemistry than geophysics, where much of the focus has been on enhancements to existing technology, with possibly some reduction in cost. Paul Agnew, the plenary speaker, touched on the major topics of interest/pursuit, and subsequent speakers expanded on these themes. In no particular order they were:

- lower analytical detection limits with ICP-MS technology
- au in natural waters for deep exploration
- portable instrumentation techniques
- automated hyperspectral core scanning
- isotopic methods
- indicator mineral chemistry using laser ablation ICP-MS
- understanding metal mobility and mechanisms for exploration under cover
- advanced geo-statistics to review legacy regional geochemistry
- application of molar element ratio litho-geochemistry
- use of AI and machine learning

One of the major exploration innovations of the past decade has been the development of a tube drilling technology, which was discussed by Richard Hillis, Director of the DETCRC and one of the Exploration ’17 luncheon speakers. A key component of this technology is a system whereby rapid turn-around geochemical analysis can be achieved; sometimes termed ‘Lab-at-the-Rig’. This is potentially a ‘disruptive’ technology as detailed geochemistry (with mineral analysis) is available much faster than previously possible, requiring new means to process and assess the data. It is likely that the most challenging effect will be on the time frames for decision making, which may be reduced from weeks/months to hours in some situations.

Remote Sensing

The plenary paper by Dave Coulter on remote sensing captured the major changes in remote sensing over the past decade. According to Coulter, ‘Over the past decade the field of exploration remote sensing has undergone a fundamental transformation from processing images to extracting spectroscopic mineralogical information resulting in the broader field of Spectral Geology and Remote Sensing (SGRS), which encompasses technologies that contribute to the definition, confirmation, and characterisation of mineral deposits. SGRS technologies provide information on the mineralogical and alteration characteristics of a mineral orebody by assisting with the identification of features on the surface, in field samples, and in the subsurface through core spectroscopic measurements and imaging.’

Major points of development include:

- spectral geology has been used at all stages of exploration
- technical advances such as Core Scan enabled more effective, multi-scale, integrated applications
- multi-disciplinary integrated approaches should be applied from data collection, to data processing (information extraction), to synthesis analysis and integrated interpretation.
- Core Scan hyperspectral imaging provides alteration mineralogy for exploration, geometallurgy and mine planning
- recent development on thermal infrared hyperspectral imaging broadens mineral detection capability for exploration and beyond.

Data processing and visualisation

The various disciplines featured at Exploration ’17 dealt with processing issues. The catalyst for new processing approaches seems to be driven by new acquisition systems that challenge the current processing approaches and overall data processing capacity. An example of this is now unfolding with 3D IP surveys, where traditional inversion approaches (even 3D) are showing they lack the performance required to handle data sets an order of magnitude larger than for which they were first designed. The expectation is that the industry will respond and address these issues in fairly short order. However, the value proposition of conducting such surveys has yet to be established, as very often the service industry acts to provide new technology because it can, rather than because of a defined, client-driven need.

There is the emergence of a new class of processing termed AI and ‘Big Data’. This was not a topic of specific focus at Exploration ’17, but one paper by Desharnais and his colleagues looked at the subject. DMEC supported two workshops in early 2018 on AI/Big Data; these proceedings are available on the DMEC website (www.DMEC.ca) under Resources. At Exploration ’17 there was probably not enough long term experience with AI/Big Data to build a meaningful understanding of the technology. It is expected that the application of these approaches will be far greater in the coming decade.

Data visualisation technology appears to have reached a mature level, and little new was discussed at Exploration ’17. While some efforts have made in the past to blend sensory inputs to extract subtle levels of information, it is possible that difficulties in interacting with complex spatial environments, i.e. 3D visualisation, remains a barrier to the greater use of this technology or, more importantly, the recognition that these approaches can significantly enhance pattern recognition leading to discovery.

Geological modelling is an important field but one that has a limited user base. Mark Jessell and his colleagues ran a workshop at the conference that focused on modelling and inversion of geology, suggesting this field is more advanced than the pure geophysically orientated 3D modelling.

Case studies

A block of 12 case studies were organised and nine deposits were discussed. Together they highlighted the application of current geological model building, state-of-the-art geophysics, geochemistry and remote sensing. Of the deposit types, there were three gold, one IOCG (Cu-Au), one VMS, one a combination of layered UM (chrome) and magmatic Ni-Cu, and one a UM layered complex PGE. Geophysics played a major role in guiding drilling for all the non-gold deposits, including the first deposit attributed to discovery by a Falcon AGG survey (Santo Domingo, Chile). Geophysics was also used in the three gold discoveries, but in more of a secondary role. Several other excellent case studies were presented in the ‘Integrated Interpretation’ and ‘Targeting’ sessions.

While not technically a case study, some of the late-stage results from the Canada Mining Innovation Council (CMIC) Footprints program (ends in 2018) were presented as technical talks and workshops. The Canadian exploration industry invested heavily in this program over the past five years, and many will be watching to see how the outcomes are taken up by the sponsors and the industry as a whole.

Frank Arnott Award

The Frank Arnott Award was created to honour Frank Arnott, a geoscientist who pioneered the value of data integration and visualisation well in advance of the rest of the industry. The contest was created by friends of Arnott, and was designed to help the industry build skills in innovation and collaboration. Two categories of entrants were defined; novice and expert. The contest ran for several years prior to Exploration ’17. The competition winners were selected mid-2017 and their presentations and awards were incorporated into Exploration ’17. The top two presentations in each category are available on the DMEC website (http://www.dmec.ca/Resources/Exploration-17.aspx).

Outcomes

The decade-long assessment afforded the decennial conferences is unique, and offers the geoscience community a more in-depth vista on the recent past, but also allows for some speculation on the future. Much of what was ‘early days’ in 2007 is now common practice 10 years later. An anecdotal remark in 2007 was that there were 25 exploration geochemists working in the industry, and the sense is that there is less than that now. The Frank Arnott Award was designed as a one-off event to end at Exploration ’17, but given this contest’s strong support at Exploration ’17, especially amongst students, the Arnott Committee has worked since Exploration ’17 to build an on-going collaborative contest modelled after the oil industries Imperial Barrel award. Updates on what is being called FAA 2.0 can be found on the website www.FrankArnottAward.com.

A second outcome on the non-technical, sociological front related to the lack of gender balance in the make-up of the Exploration ’17 conference. While the mining industry as a whole appears to be making efforts to address this, it is much harder to see progress in applied geoscience in general. A small group of younger women were sufficiently concerned that they formed Women Geoscientists in Canada (WGC) www.WGCanada.org. They believe it is important to advocate for change and their hope is to see a more gender representative group who build and attend Exploration 2027 in 10 years time.

Ken Witherly
Condor Consulting
ken@condorconsult.com

Upcoming conference: AGGC 2018 – Big issues and ideas in geoscience

AGGC 2018 will highlight the fundamental role that geoscience has as a major field of science throughout the Asia Pacific Region. The conference will be the largest geoscience event to be held in Australasia since 2012. AGCC 2018 is supported by all eight member organisations of the Australian Geoscience Council, and is sponsored by Geoscience Australia, as Patron Sponsor, and Santos Ltd as Major Sponsor.

The AGCC 2018 third circular has been released and includes information about:

- the updated program with additional sessions
- new initiatives for young geoscientists
- the announcement of confirmed plenary and keynote speakers
- more details on the Big Issues and Ideas in Geoscience Day
- an expanded list of field trips and professional workshops, with information on costs and deadlines.

The deadline for abstract submission was midnight on Saturday 16 June. Formal notification of acceptance of abstracts will be by Saturday 28 July; presenters of accepted abstracts must pay for their full delegate registration by Saturday 18 August.

The deadline to register at the lower cost, early bird registration rate, is Saturday 7 July. After this date, registrations will increase by approximately $200 ($1000 to $1200 for Members). The cost of registration will increase again on 7 October ($1200 to $1400 for Members). If you are an Early Career Geoscientist, you may be able to take up AGCC 2018 special offer and pay $765 for a full delegate registration, saving up to $235 on the early bird Member rate. Be quick, the offer closes on Thursday 30 August!

The AGC want to make AGCC 2018 as accessible as possible to all geoscientists, including those with young children and who may need assistance with their care. The Steering Committee is investigating the possibility of having a child-minding facility set up at the Adelaide Convention Centre for the duration of AGCC 2018. The facility would be operated and managed by a licensed contractor and all arrangements would be made by parents with the contractor directly. It is intended to provide this facility on a cost-recovery basis.

If you are interested in this service, please complete the Expression of Interest form on the AEGC 2018 website or before Tuesday 14 August. The decision on whether or not to provide this facility will be based on the demand received via the Expression of Interest form by this date.

Kim Frankcombe
ASEG AGC representative
kfrankcombe@iinet.net.au

Upcoming conference: AEGC 2019 – Data to discovery

Planning is well underway for next years' AEGC Conference, AEGC 2019.

ASEG, AIG and PESA will join together again in September 2019 to host a four-day program. AEGC 2019 will be held at the wonderful Crown Perth, and feature technical sessions of the highest calibre. The conference has a focus on geology, geophysics and geochemistry, and how these sciences are applied to exploration in both petroleum and mineral systems in Australasia and the wider Asia Pacific region. As Perth is a hub for Australia's mining and petroleum sectors, AEGC 2019 is expected to attract over 1000 geoscience professionals involved in the exploration for energy resources, metals and industrial minerals, as well as near surface and ground water exploration. Representation from international and local companies, government and academia is anticipated.

AEGC 2019 will be held at the recently upgraded Crown Perth, located on the Swan River, only minutes from the city centre. Accommodation is available right at the conference venue and delegates will be spoiled for choice. They will be able to entertain clients and, in spare moments, check out the new Optus Stadium, which located a few minutes' walk from the venue. In addition to Perth's unique natural attractions, delegates will have the opportunity to join field trips and social functions which will be exceptional opportunities to network with peers and make new contacts.

With the theme 'Data to Discovery', the technical program has a large focus of 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.

To register your interest visit www.aegc.com.au.

Maud Kay
AEGC 2019 Publicity & Marketing Chair
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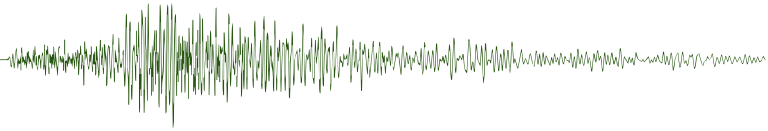

Update on geophysical survey progress from Geoscience Australia and the Geological Surveys of Western Australia, South Australia, Northern Territory, Queensland, New South Wales, Victoria and Tasmania (information current on 11 May 2018)

Further information on these surveys is available from Murray Richardson at GA via email at Murray.Richardson@ga.gov.au or telephone on (02) 6249 9229.

Table 1. Airborne magnetic and radiometric 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
Andamooka	GSSA	GA	Sander Geophysics	23 Feb 2017	81 396	200 m 60 m E–W	14 560	6 Jun 2017	Final data QA/QC in progress	183: Aug 2016 p. 34	Data released via GADDS 19 Apr 2018
Barton	GSSA	GA	Thomson Aviation	22 Jan 2017	111 758	200 m 60 m E–W	20 560	11 May 2017	Final radiometric data QA/QC in progress	183: Aug 2016 p. 34	Data released via GADDS 3 May 2018
Fowler	GSSA	GA	Thomson Aviation	18 Feb 2017	95 009	200 m 60 m E–W	17 360	2 Jun 2017	Final radiometric data QA/QC in progress	183: Aug 2016 p. 34	Data released via GADDS 3 May 2018
Torrens	GSSA	GA	Sander Geophysics	4 Mar 2017	79 990	200 m 60 m E–W	14 800	15 Jun 2017	Final data QA/QC in progress	183: Aug 2016 p. 34	Data released via GADDS 19 Apr 2018
Tasmanian Tiers	MRT	GA	TBA	TBA	Up to an estimated 66 000	200 m 60 m N–S or E–W	11 000	TBA	TBA	TBA	The National Collaborative Framework Agreement between GA and MRT is being updated
Isa Region	GSQ	GA	GPX	3 Jul 2017	120 062	100 m 50 m E–W	11 000	5 Nov 2017	Preliminary final point-located data were made available to GA on 26 Mar 2018	188: Jun 2017 p. 21	TBA
Tallaringa N (1A)	GSSA	GA	Thomson Aviation	26 Oct 2017	97 922	200 m 60 m E–W	17 320	26 Mar 2018	TBA	190: Oct 2017 p. 26	TBA
Tallaringa S (1B)	GSSA	GA	Thomson Aviation	26 Sep 2017	145 367	200 m 60 m E–W	26 010	99.2%	TBA	190: Oct 2017 p. 26	TBA
Coober Pedy (8A)	GSSA	GA	Thomson Aviation	18 Sep 2017	90 425	200 m 60 m N–S	16 140	21 Dec 2017	TBA	190: Oct 2017 p. 26	TBA
Billa Kalina (8B)	GSSA	GA	MAGSPEC Airborne Surveys	10 Oct 2017	90 353	200 m 60 m N–S	16 140	18 Dec 2017	TBA	190: Oct 2017 p. 26	TBA
Childara (9A)	GSSA	GA	MAGSPEC Airborne Surveys	5 Nov 2017	134 801	200 m 60 m N–S	23 910	2 May 2018	TBA	190: Oct 2017 p. 26	TBA
Lake Eyre (10)	GSSA	GA	MAGSPEC Airborne Surveys	2 Oct 2017	91 938	200 m 60 m E–W	16 180	22 Mar 2018	TBA	190: Oct 2017 p. 26	TBA
Streaky Bay (5)	GSSA	GA	TBA	TBA	90 279	200 m 60 m E–W	15 970	TBA	TBA	This issue (Figure 1)	TBA
Gairdner (6A)	GSSA	GA	TBA	TBA	103 167	200 m 60 m N–S	18 310	TBA	TBA	This issue	TBA
Spencer (7)	GSSA	GA	TBA	TBA	50 280	200 m 60 m E–W	8716	TBA	TBA	This issue (Figure 1)	TBA
Kingoonya (9B)	GSSA	GA	TBA	TBA	149 828	200 m 60 m N-S	26 650	TBA	TBA	This issue (Figure 1)	TBA
Cloncurry North	GSQ	GSQ	GPX Surveys	Mid-May 2018	101 597	100 m	8687	TBA	TBA	This issue (GSQ section – Figure 1). For more information about this survey please contact geophysics@dnrme.qld.gov.au	TBA

TBA, to be advised.

Table 2. Gravity surveys

Survey name	Client	Project management	Contractor	Start survey	No. of stations	Station spacing (km)	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Tanami-Kimberley	GSWA	GA	Thomson Aviation	16 Jun 2017	49 825	2500 m line spacing	110 000	31 Oct 2017	Preliminary final data made available to GA on 27 Feb 2018	The survey area covers the Billiluna (all), and parts of the Lucas, Cornish, Mount Bannerman, Mount Ramsay, Noonkanbah, Lansdowne, Lennard River, Derby, Charnley and Yampi 1:250 k standard map sheets	12 Apr 2018
Kidson Sub-basin	GSWA	GA	CGG Aviation (Australia)	14 Jul 2017	72 933	2500 m line spacing	155 000	TBA	3 May 2018	The survey area covers the Anketell, Joanna Spring, Dummer, Paterson Range, Sahara, Percival, Helena, Rudall, Tabletop, Ural, Wilson, Runton, Morris and Ryan 1:250 k standard map sheet areas	TBA
Lawn Hill	GSQ	GA	Atlas Geophysics	TBA	7878	1000 m line spacing	8024	TBA	TBA	This issue (Figure 2)	TBA

TBA, to be advised.

Table 3. AEM 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 Kimberley	GA	GA	SkyTEM Australia	26 May 2017	13 723	Variable	N/A	24 Aug 2017	Nov 2017	TBA	TBA
AusAEM (Year 1)	GA	GA	CGG	TBA	59 349	20 km with areas of infill	TBA	TBA	67.3%	186: Feb 2017 p. 18	TBA
Surat-Galilee Basins QLD	GA	GA	SkyTEM Australia	2 Jul 2017	4627	Variable	Traverses	23 Jul 2017	Nov 2017	188: Jun 2017 p. 21	TBA
Stuart Corridor, NT	GA	GA	SkyTEM Australia	6 Jul 2017	9832	Variable	Traverses	12 Aug 2017	Nov 2017	188: Jun 2017 p. 22	TBA
Olympic Domain	GSSA	GA	SkyTEM Australia	14 Nov 2017	3181	1.5 & 3 km E–W	33 200	21 Nov 2017	Preliminary final data received by GA 16 Mar 2018	190: Oct 2017 p. 27	TBA
Fowler Domain	GSSA	GA	SkyTEM Australia	Early Dec 2017	3057	5 km NW–SE	15 000	5 Dec 2017	Preliminary final data received by GA 16 Mar 2018	190: Oct 2017 p. 27	TBA

TBA, to be advised.

Table 4. Magnetotelluric (MT) surveys

Location	State	Survey name	Total number of MT stations deployed	Spacing	Technique	Comments
Northern Australia	Qld/NT	Exploring for the Future – AusLAMP	150 stations deployed in 2017	50 km	Long period MT	The survey covers the area between Tennant Creek and Mount Isa. The next field season resumes in mid-May 2018.
AusLAMP NSW	NSW	AusLAMP NSW	33 stations deployed in 2018 to date	50 km	Long period MT	Covering the state of NSW with long period MT stations at approximately 50 km spacing.
Olympic Domain	SA	Olympic Domain	320 total	Varied 1.5 to 10 km	AMT and BBMT	The survey area extends west of Lake Torrens and covers mineral prospects such as Carrapateena, Fremantle Doctor, Red Lake, Punt Hill, Emmie Bluff and Mount Gunson. At the end of May 65 sites have been collected.

Table 5 Seismic reflection surveys

Location	State	Survey name	Line km	Geophone interval	VP/SP interval	Record length	Technique	Comments
Northern Australia	Qld/ NT	South Nicholson Basin	1100	20 m	40 m	20 seconds	2D – Deep Crustal Seismic Reflection	The survey covers the region between the southern McArthur Basin to the Mt Isa western succession, crossing the South Nicholson Basin and Murphy Province. The data acquisition phase of the survey started on 23 May and was completed in Aug 2017. Raw data were released in Mar 2018.
South East Lachlan	Vic/ NSW	SE Lachlan	Approx. 450	10 m	40 m	20 seconds	2D – Deep Crustal Seismic Reflection	The survey covers the South East Lachlan Orogen crossing the Victorian–New South Wales border. The data acquisition phase of the survey commenced on 5 Mar 2018 near Benalla in Victoria. The survey completed data acquisition south of Eden in NSW on 29 Apr 2018.
Kidson	WA	Kidson Sub-basin	Approx. 900	TBA	TBA	TBA	2D – Deep crustal seismic reflection within the Kidson Sub-basin of the Canning Basin extending across the Paterson Orogen and onto the eastern margin of the Pilbara Craton	

South East Lachlan Crustal Transect Seismic line completed

Surveyblock	Surveyname	Spacing	Direction	Height	Area_km²
5	Streaky Bay	200	E-W	60	15,970
6A	Gairdner	200	N-S	60	18,310
7	Spencer	200	E-W	60	8,716
9B	Kingoonya	200	N-S	60	26,650

Figure 1. *Location of the Streaky Bay, Gairdner, Spencer and Kingoonya airborne magnetic and radiometric surveys.*

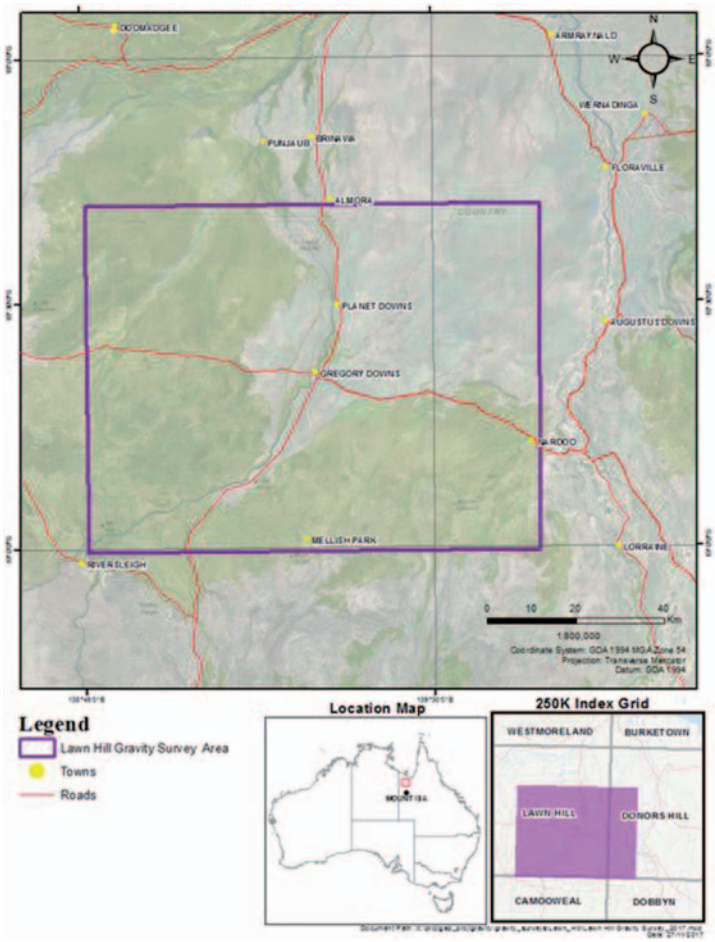

Figure 2. *Location of the Lawn Hill gravity survey.*

The South East Lachlan Crustal Transect Seismic line was completed on 29 April 2018 (Figure 3). The survey is a collaboration between the Geological Survey of Victoria, Geological Survey of New South Wales, AuScope Ltd and Geoscience Australia. The $4.5 million seismic survey (631 km) was acquired by Terrex Seismic and the data will be used with other geophysical data to interpret the geological architecture of eastern Victoria and south eastern New South Wales. The objectives of the survey were to investigate resource potential and natural hazards (State infrastructure) by mapping the full crustal thickness (up to 50 km depth), aid geological interpretation across the Delamerian and the Lachlan fold belts. The line was widely acknowledged as the most difficult logistically and operationally undertaken by Geoscience Australia and the State geological surveys.

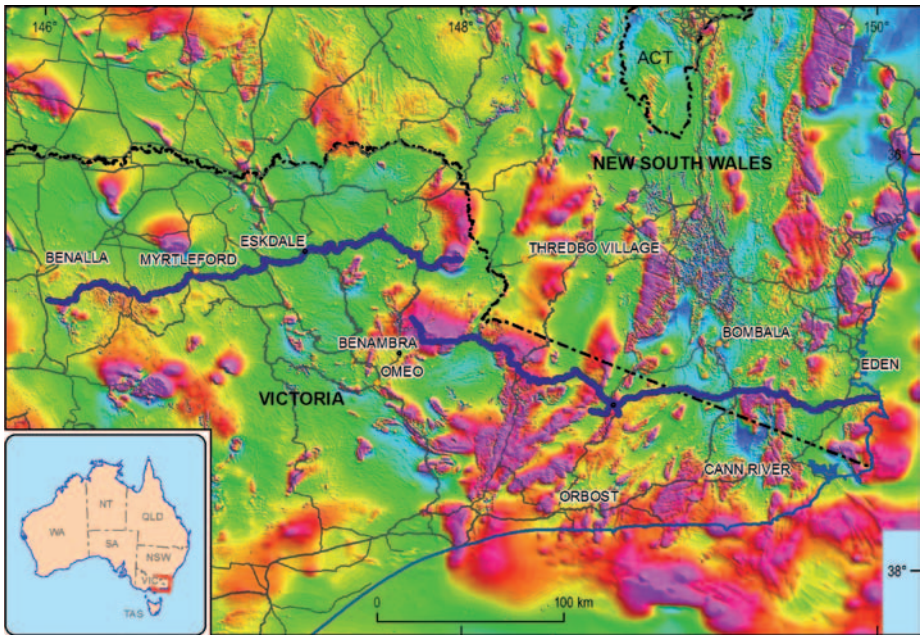

Figure 3. *Location of the South East Lachlan Crustal Transect Seismic line shown over a total magnetic intensity image.*

Geological Survey of Queensland: new and upcoming data releases for north-west Queensland

The first year of the Queensland Government's $27.125 million *Strategic Resources Exploration Program* has seen the commencement of several geophysical data programs aimed at promoting discoveries in north-west Queensland (see Figure 1) and the release of some keenly anticipated data.

The Cloncurry South and Mary Kathleen airborne magnetic and radiometric surveys have been released on QDEX Data. These high resolution surveys (100 m and 50 m spacing respectively) provide a seamless coverage over the area and show a marked improvement in data quality compared to the previous Mount Isa Mines Open Range survey acquired in the 1990s (see Figure 2).

The tender for a new survey located to the north of the Cloncurry South survey has been awarded to GPX Surveys, with acquisition starting in June and expected to take approximately 16 weeks. The Cloncurry North magnetic and radiometric survey will be flown at a 100 m line spacing and will cover outcropping and shallowly covered prospective Isa Eastern Succession geology. Data will be released on QDEX Data upon acceptance of final data.

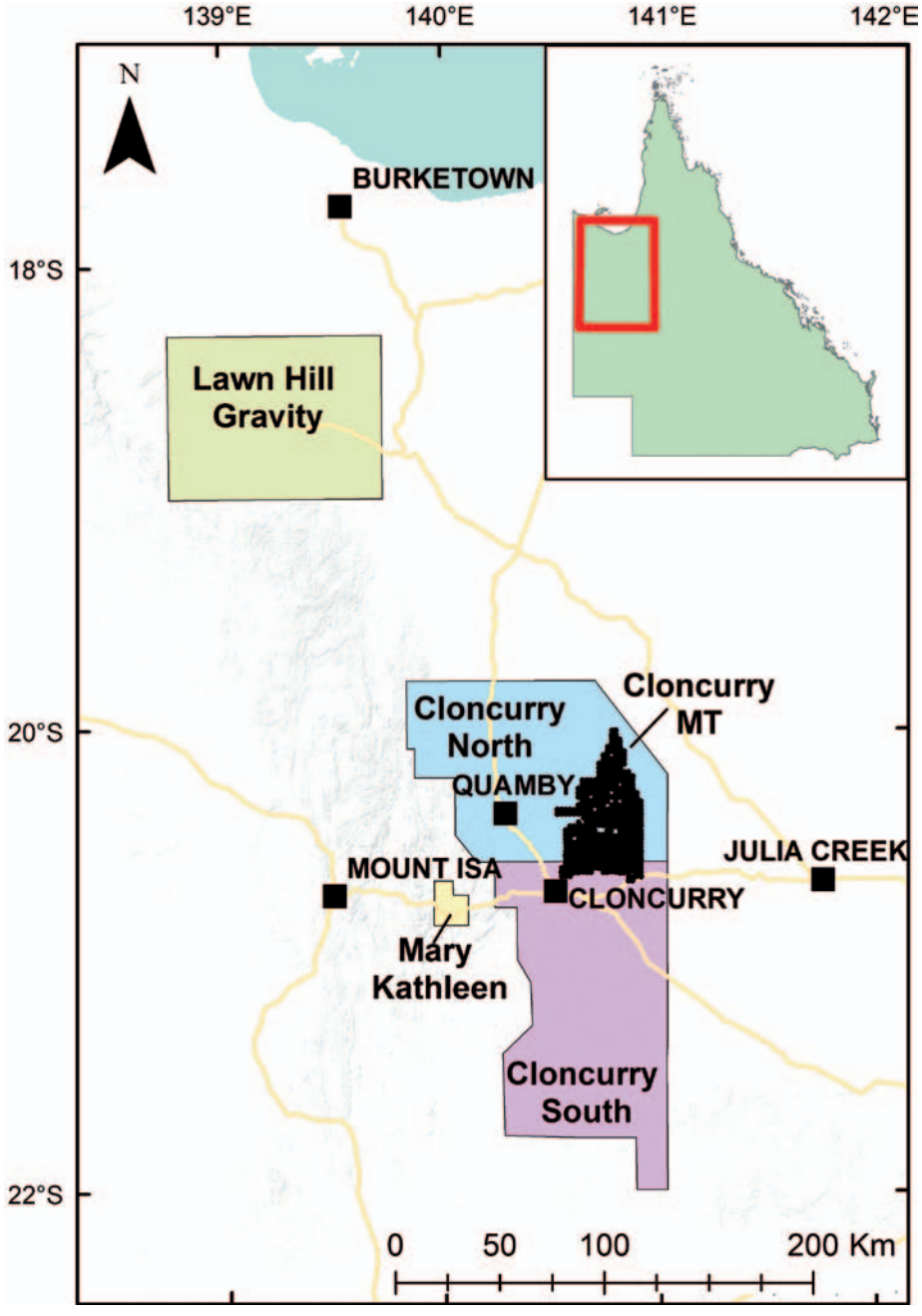

Figure 1. *Location of new geophysical survey data acquisition programs.*

In April 2018 the Geological Survey of Queensland, together with Geoscience Australia, released the report and models for the Cloncurry Magnetotelluric Survey. A combination of 2D and 3D inversion was used to investigate variation in crustal conductivity in the survey area. Several conductivity features of interest to explorers were imaged, including a highly conductive zone under the Ernst Henry Mine, which extend in excess of 10 km depth. A detailed report on the inversion modelling is included in the data package which can be downloaded from QDEX Data.

The release package contains:

- Located depth slices
- Inversion files (ModEM and GoCAD formats)
- Inversion model converted to a point dataset
- Inversion report
- Original data and acquisition reports

In response to the success of the Cloncurry Magnetotelluric Survey, work is underway scoping additional MT acquisition in the Eastern Succession. Scoping, clearances and acquisition for this survey are likely to occur over the next 18–24 months.

Following some late autumn wet weather in the north-west, acquisition of the Lawn Hill Gravity survey is finally underway (see Figure 1) and is expected to be completed by July. Eight thousand stations will be collected on a 1 km grid to improve the current 4 km regional gravity data in the area. The 8000 km^2 survey is located to the east of Century mine over shallow covered basement terrain.

The Petroleum and Gas Unit of the GSQ is investigating frontier petroleum basins in the north-west of the State. A first and major step forward is public release of an updated SEEBASE model of two key basins in the area, which are believed to have great potential to supply gas to domestic and export markets.

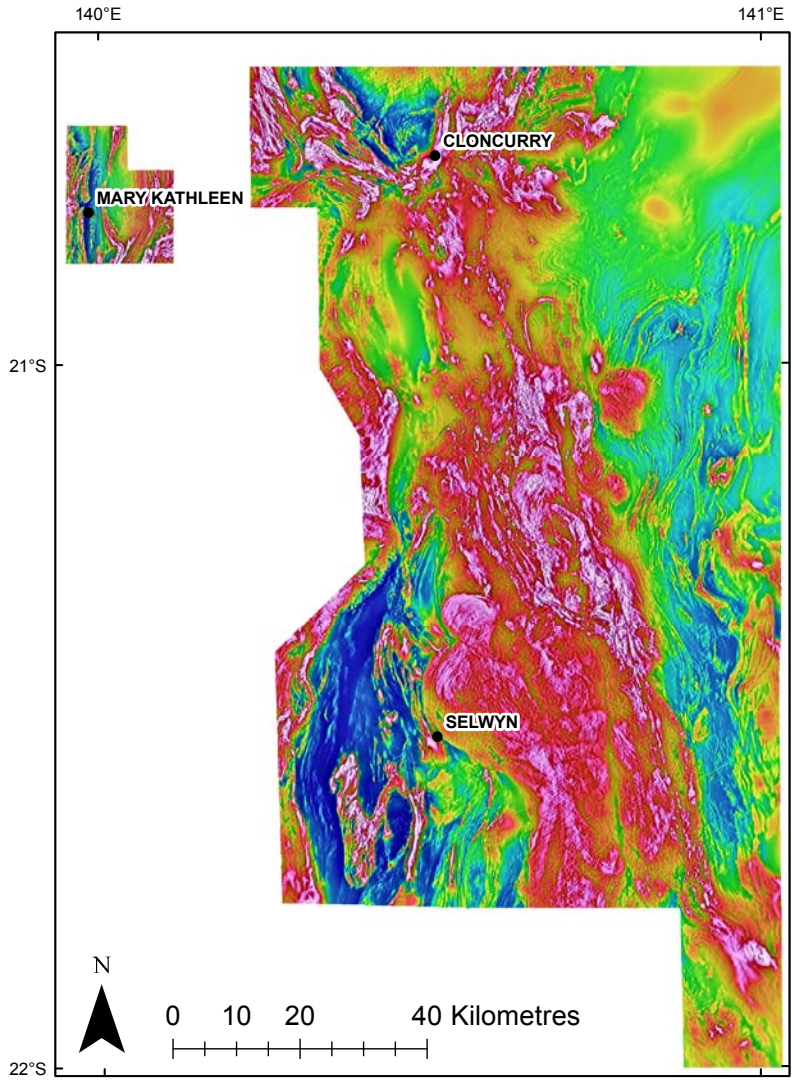

Figure 2. *Reduced-to-pole magnetic image with sun-shaded first vertical derivative overlay of the new Cloncurry South and Mary Kathleen airborne surveys.*

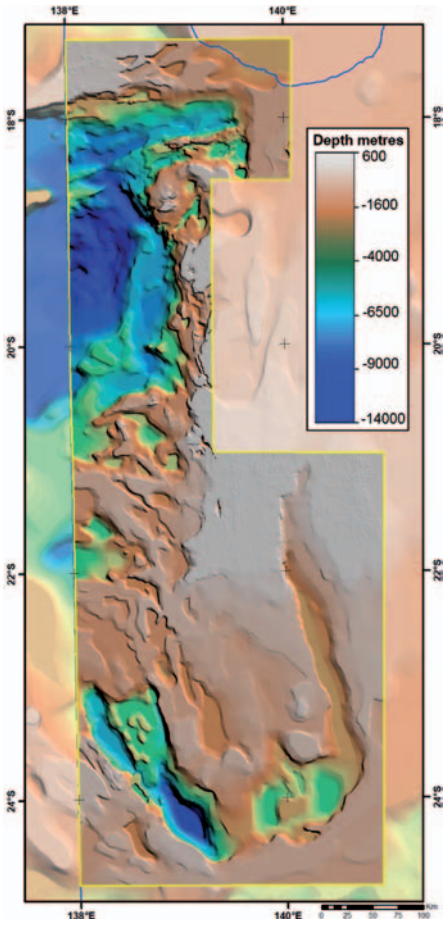

Figure 3. *Updated SEEBASE model of the eastern end of the South Nicholson Basin, and the south-eastern part of the Georgina Basin.*

The updated SEEBASE model (see Figure 3) covers the eastern end of the South Nicholson Basin in the north, and the south-eastern part of the Georgina Basin in the Queensland–Northern Territory border region. These basins have known potential for gas and/or oil but, there has been little previous exploration.

All the data and interpretations have been compiled into an integrated *ArcGIS* data package that, together with a report, provides an excellent summary of the key geological features within the study area. The report and GIS data package are available from QDEX Reports.

The first round of the *Collaborative Exploration Initiative* has closed and projects are underway at the moment. A second round of exploration grants designed to stimulate investment in under-explored parts of north-west Queensland, will be opening in mid-2018. Data from CEI projects will be released on QDEX Data (www.qdexdata.dnrm.qld.gov.au) once finalised.

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Mineral Resources Tasmania: new gravity data

Mineral Resources Tasmania personnel Kyen Knight and Tamara Coyte have acquired new gravity data in the central north of the State (Figure 1). Ninety-three new stations were observed across four days of field work in March, via vehicular access in the remote region of the upper Mersey River. This area was previously poorly characterised, with only a dozen or so stations in the database at spacings around 7 km, the most recent of these observed in 1973. The new data will define the sub-surface eastern extent of granites known to be associated with gravity lows to the west. Additional insights into the three dimensional geology of the region are likely, given extensive post-Devonian cover over a poorly understood metamorphosed Proterozoic basement.

The data has been processed to complete Bouguer anomaly. Terrain effects are significant, with Tasmania's dolerite-capped central plateau being incised over 1100 metres by Pleistocene and earlier glaciation (Figure 2). Correction values calculated for the new data range from 2.5 to over 9.8 mGal. Comparison of data from the old stations with data from the new stations has highlighted issues with the former in several instances (Figure 3). These will be reviewed and edited to ensure improved fidelity of the overall state coverage.

These new gravity data are now available from MRT.

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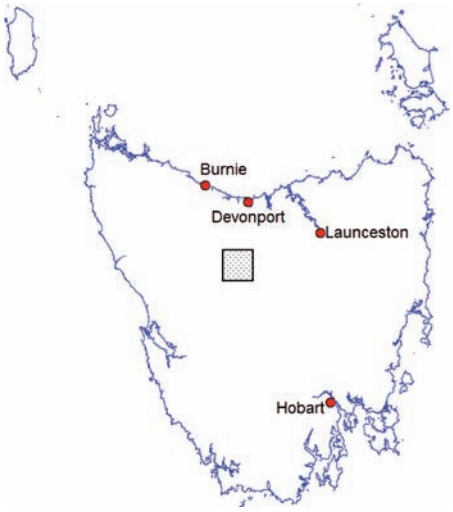

Figure 1. *Location of the new gravity survey.*

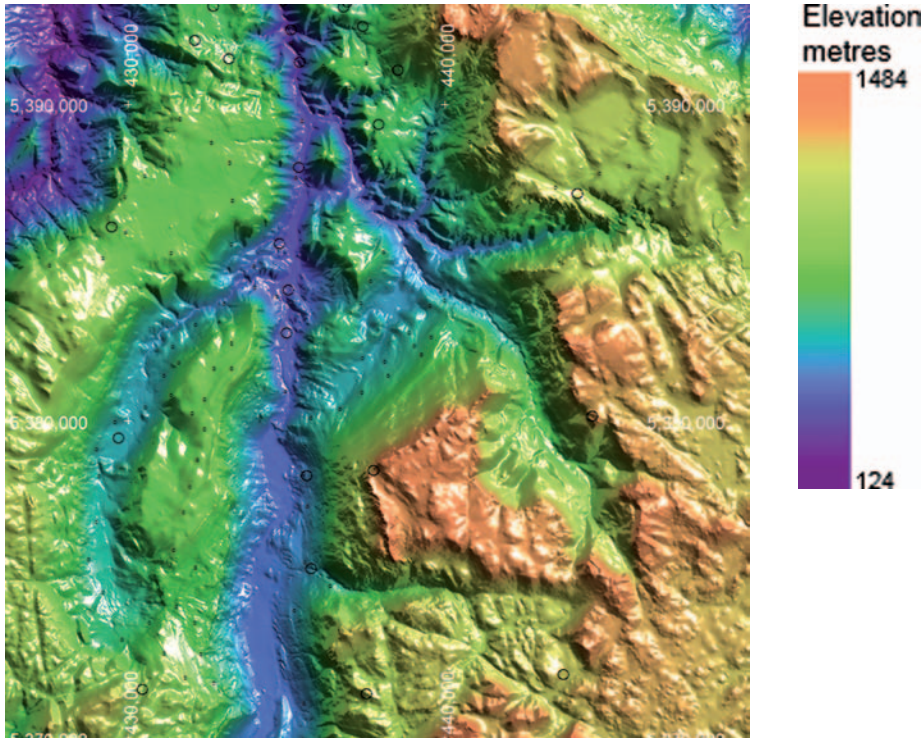

Figure 2. *Ground surface elevation in the survey area. Small black circles denote new gravity stations. The location of stations read in 1973 and earlier are indicated by larger black circles. MGA94 (zone 55) coordinates.*

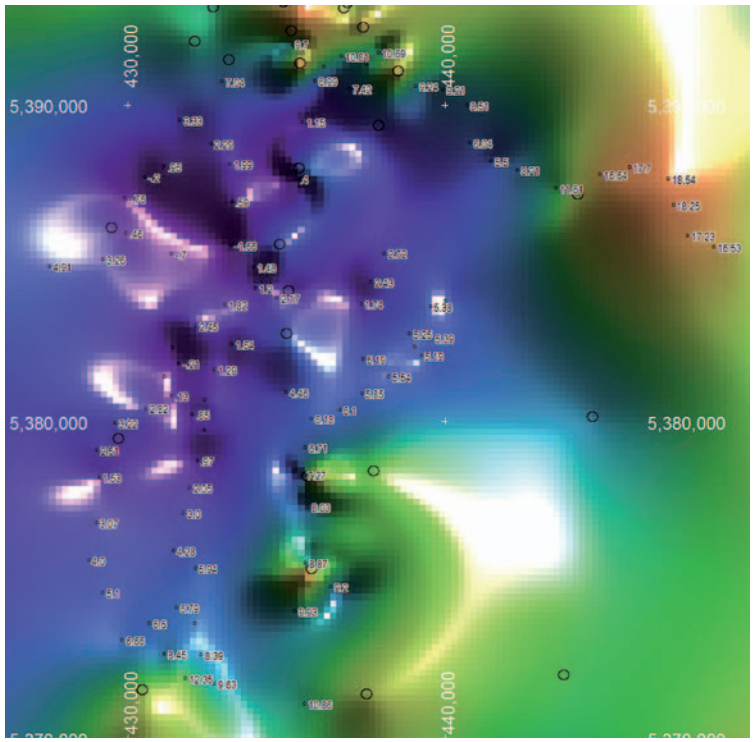

Figure 3. *New grid of complete Bouguer anomaly in the survey region, interpolated using minimum curvature. New gravity stations (smaller black circles) labelled with isostatic residual values. MGA94 (zone 55) coordinates.*

Geological Survey of South Australia: Gawler Craton Airborne Survey update

The first tranche of data for the Gawler Craton Airborne Survey (GCAS) is now available online via SARIG. Regions 2a (Murloocoppie) and 2b (Warrina) were flown by MagSpec Airborne Surveys, Regions 3a (Andamooka) and 3b (Torrens) were flown by Sander Geophysical Limited, and Regions 4a (Barton) and 4b (Fowler) were flown by Thomson Aviation.

Acquisition for Tranche 2 is complete, and data for blocks 1 and 8a (Thomson Aviation), and 8b, 9a, 10 (MagSpec Airborne Surveys) are currently undergoing QA/QC to ensure it is of the highest quality for stakeholders. At the time of writing the GCAS is 76% complete.

Acquisition for Tranche 3 (blocks 5, 6, 7, and 9b) should commence in June 2018.

The GCAS will capture approximately 1.8 million line km of new magnetic, radiometric and digital elevation data over an area of about 324 000 km^2. These new data will surpass the current patchwork of historical surveys and provide a single, uniform dataset that will be fundamental in reinterpreting the geological structure of the Gawler Craton. Data is being acquired along flight lines at 200 m apart at a height of 60 m.

More information regarding the survey can be found on the community information page on the internet: http://minerals.statedevelopment.sa.gov.au/gcas.

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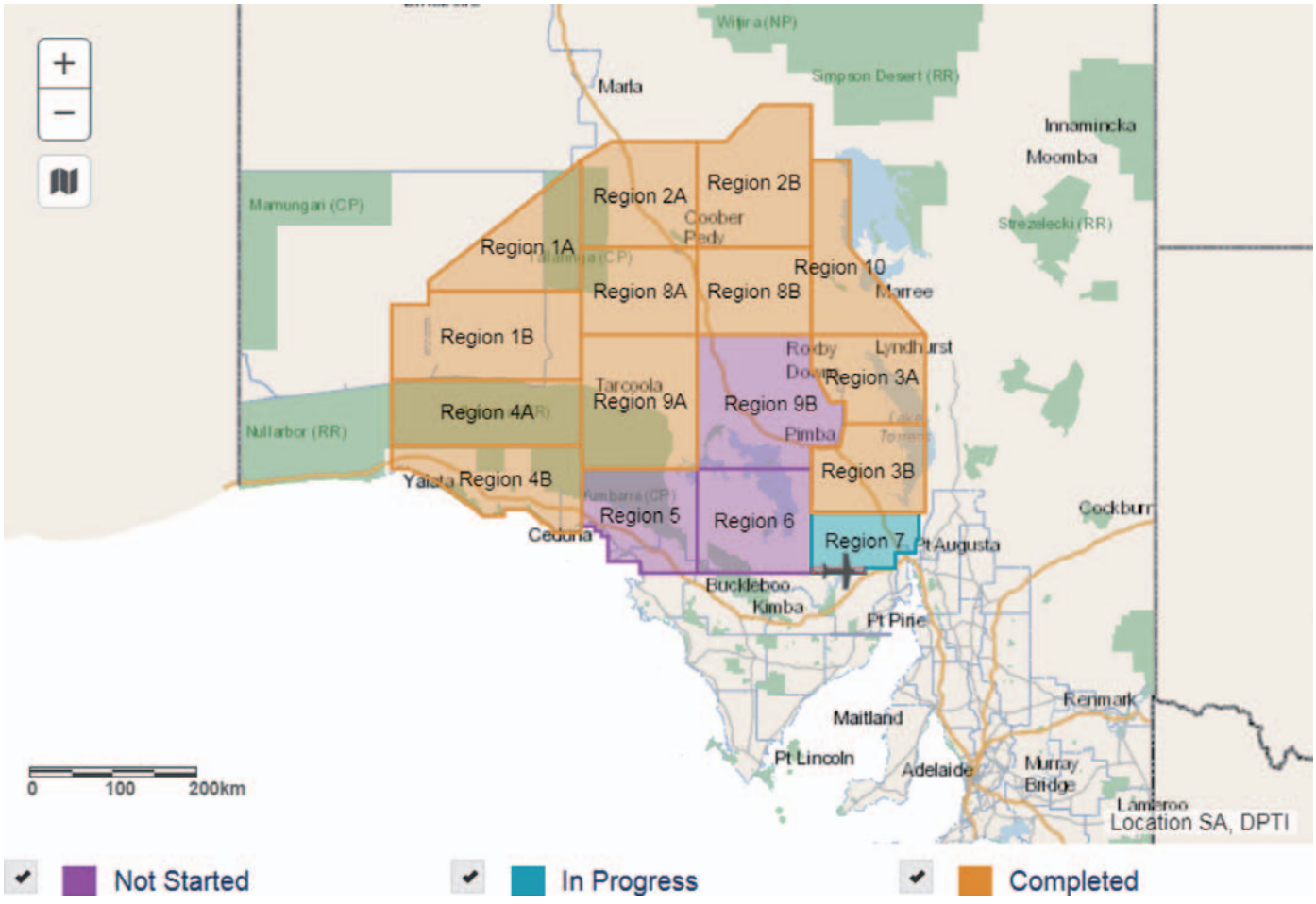

Figure 1. *The Gawler Craton Airborne Survey is 76% complete.*

Geological Survey of Western Australia: Status of regional aerogravity surveys in WA

The Department of Mines, Industry Regulation and Safety (DMIRS), in collaboration with Geoscience Australia (GA), has contracted Sander Geophysics to undertake three new airborne gravity surveys in the north and east of the State as part of its 2018–19 regional data acquisition program. At a line spacing of 2.5 km, the 175 000 line km of planned flight path cover an aggregate area of 450 000 km^2 (Figure 1, Table 1).

The contracts were awarded following a public tender issued by GA late in 2017 (see *Preview* December 2017). Acquisition began in the Little Sandy Desert survey area at the end of April, with work in the other two areas scheduled to begin before the end of July.

From the 2017–18 program, DMIRS and GA released data from the Tanami and Northeast Canning surveys (50 000 line km) on 12 April 2018, with data from the large, 70 000 line km Kidson survey anticipated to follow by the end of July 2018.

Weekly updates of the status of the surveys are posted at www.dmirs.wa.gov.au/geophysics.

Survey data releases are available from the national Geophysical Archive Data Delivery System at www.ga.gov.au/gadds, and from the department's GeoVIEW.WA system at www.dmp.wa.gov.au/geoview (under the 'Company Airborne Surveys' layer in the 'Geophysical Surveys' group, searching on the relevant survey registration number shown in Table 1).

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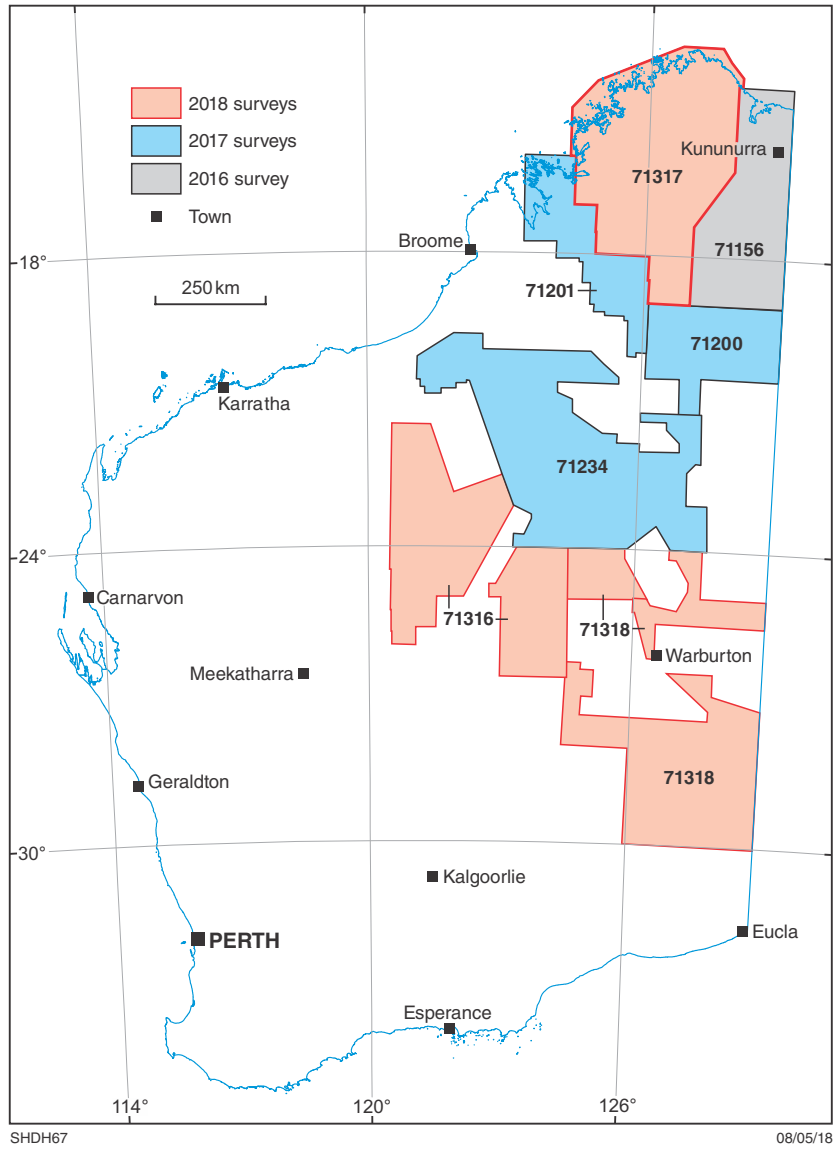

Figure 1. *Location of DMIRS aerogravity surveys.*

Table 1. DMIRS aerogravity surveys in Western Australia

Registration no.	Survey name	Size (line km)	Contractor	Technology	Status
71156	East Kimberley 2016	38 000	Sander Geophysics	AIRGrav	Data released February 2018
71200	Tanami 2017	25 000	Thomson Aviation/CMGO	GT-2A	Data released April 2018
71201	Northeast Canning 2017	25 000	Thomson Aviation/CMGO	GT-2A	Data released April 2018
71234	Kidson 2017	75 000	CGG Aviation	FALCON	Scheduled data release end-June 2018
71316	Little Sandy Desert 2018	52 000	Sander Geophysics	AIRGrav	Acquisition started April 2018
71317	Kimberley Basin 2018	61 000	Sander Geophysics	AIRGrav	Survey started June 2018
71318	Warburton – Great Victoria Desert 2018	62 000	Sander Geophysics	AIRGrav	Survey scheduled July 2018

Geological Survey of Victoria and Geological Survey of New South Wales: Southeast Lachlan Crustal Seismic Transect

The Geological Survey of Victoria (GSV) and the Geological Survey of New South Wales (GSNSW) have collaborated with Geoscience Australia (GA) and AuScope Limited to successfully complete a 629 km long transect of deep seismic reflection surveying across the Australian Alps between Benalla, in the east of central Victoria and Eden on the coast of southern NSW. Terrex Seismic's three-truck convoy of AHV-IV Vibrator trucks (Figure 1), along with support vehicles, and a crew of 40 people, acquired approximately 11 line km per day to complete the acquisition phase of the project within 60 days. Using the 62 000-pound peak-force vibrators at 40 m spaced vibe points and manually deployed and retrieved cable-less single-sensor nodes at 10 m spacing, the survey is expected to map to a depth of 40 km.

The survey travelled through a small number of private properties, as well as on local roads, and along roads in crown land and parks, including the Ben Boyd, South East Forests, Alpine, Mt Buffalo, Snowy River and Errinundra National Parks. Traffic management measures were in place for the duration of the survey. The topography of the Australian Alps presented some planning and logistical challenges for acquisition, however the route was designed to ensure the best geological and scientific outcome. Local communities along the route were kept informed of the survey's progress and scientific objectives through regular contact with local councils, local authorities and advertisements in the local press. The project has contributed approximately $250 000 directly to regional economies through local purchasing of items such as fuel, accommodation, food and supplies.

GSV, GSNSW and GA are planning ground gravity data acquisition along the transect to complement and support interpretation and modelling of the seismic data.

Initial results from the seismic data processing and preliminary interpretations are expected to be released in 2019. Further details, including data updates, will be available at:
http://earthresources.vic.gov.au/earth-resources/geology-of-victoria/gsv-projects/Eastern-Victoria-Geoscience-Initiative

https://www.resourcesandgeoscience.nsw.gov.au/miners-and-explorers/geoscience-information/projects/the-south-east-lachlan-crustal-transect-seismic-survey

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Figure 1. *Vibrator trucks in action in the Victorian Alps.*

Canberra observed

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Federal budget outcomes

No surprises for minerals explorers

The budget funds the Prime Minister's commitment to the Junior Minerals Exploration Incentive (JMEI) and makes $100 million of direct tax offsets available over the next four years. The JMEI is a tax credit arrangement that allows minerals exploration companies, which have no mining income to renounce, to pass future tax deductions (losses) to their investors, providing those investors are Australian residents. It is hoped that the JMEI will encourage investment in greenfields exploration for minerals.

The budget also continues funding of the Research and Development Tax Incentive, which encourages companies to invest in research and innovation in the mining and minerals exploration sector.

Win for Geoscience Australia

It was a great budget for Geoscience Australia (GA). GA has been allocated more than $260 million over four years in order to develop satellite data based infrastructure: http://www.ga.gov.au/news-events/news/latest-news/ceo-statement-on-budget-2018-19

Over the next four years GA will use $160.9 million to fund the development of a satellite-based augmentation system (SBAS). SBAS augments and corrects positioning signals transmitted to Australia by GPS, improving accuracy, availability and reliability. $64 million will be used to establish a national ground station network, improve coordination across government and the private sector, and ensure Australian industry has access to world-leading software tools for positioning. The goal of these two projects is to make reliable positioning data accurate to 10 cm available in every corner of Australia. Areas with mobile coverage will have access to positioning data accurate to 3 cm.

In addition, GA will spend $37 million over the next four years to develop the Digital Earth Australia program (www.ga.gov.au/DEA), and expand it to include providing industry with access to huge archives of government satellite data in a ready-to-use form. This funding will take GA's role as the national remote sensing agency to the next level.

The Federal Government has also topped up NCRIS, which means that AuScope will have an ongoing role in supporting research infrastructure for the geoscience community. The Government has committed additional funding of $1.9 billion to national research infrastructure, which complements the ongoing NCRIS program funding of $150 million per year announced in 2015. The projects will be delivered through an expansion of the existing NCRIS program, which brings the total investment in national research infrastructure projects to $4.1 billion over 12 years.

Minister Canavan establishes Resources 2030 Taskforce

What it will do

Minister for Resources, Matthew Canavan, announced on 28 March 2018 that he was setting up a taskforce to identify reforms to secure the future of Australia's resource sector.

In the Minister's words, 'We must look beyond current issues and short-term thinking. We need bold, yet attainable, new policies and reforms that will maintain us as a leading mining nation in the long-term'. He wants the Taskforce to 'focus on key areas that can attract investment, contribute to regional economic progress, build community support, find new minerals, and ensure that Australia remains competitive and gets best use of its mineral resources before they are exported'.

The Taskforce will consider potential reforms in line with the following policy areas:

- investment – business simplification and competitive investment settings
- communities – regional development and bolstering community support
- exploration and business development – new basins, markets, minerals and geological sciences
- innovation and technology – improving productivity, developing mining equipment, technology services and supply chains and
- environment – improving environmental performance.

The Taskforce will report to the Minister by the end of August 2018. It doesn't have much time!

Who will do it?

The Taskforce is chaired by Andrew Cripps, a former Queensland Minister for Natural Resources. He is supported by:

- Paul Flynn, CEO and Managing Director, Whitehaven Coal
- Mike Henry, President Operations, Minerals Australia, BHP Billiton
- Marcia Langton, Foundation Chair, Australian Indigenous Studies, Faculty of Medicine, University of Melbourne
- Joyce McCulloch, Mayor, Mount Isa City Council
- Chris Pigram, Chair of the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development
- Will Robinson, Managing Director, Encounter Resources Limited
- Adrienne Rourke, General Manager, Resource Industry Network
- Erica Smyth, Chair, NOPSEMA Advisory Board (NOPSEMA is a Commonwealth Statutory Agency regulating health & safety, structural integrity & environmental management of all offshore petroleum facilities in Commonwealth waters).

Will it help the resource industries?

Probably. The Taskforce comprises a group of talented and experienced people who understand the resource industry and therefore is likely to make sound recommendations.

Are there likely to be pitfalls or omissions? Yes. Here are some of questions to ponder on:

1. At present the minerals industry is re-bounding from the slump of early 2016, when exploration investment plunged to a 10 year low. With increasing demand for minerals resources needed to power the renewable energy sector, the future looks good. So, why is there a need for a minerals focused taskforce?
2. The petroleum sector is not healthy. Australian production of petroleum and condensate has more than halved since 2000, when it was about 3500 Ml/month, to 1300 Ml/month in October 2017. Furthermore, exploration expenditure in the last quarter of 2017, at $254 million, fell to its lowest level since 2004. So, why is the taskforce focused on the minerals sector, which is healthy, and not on petroleum, which is in dire straits?
3. The environment is recognised as an important policy area so, why is there no hydrologist, or land management scientist on the task force?
4. It might appear, from the chosen policy areas, that the taskforce should focus on providing jobs in rural Australia, rather than on finding more efficient ways to find and develop new deposits. If this is correct, will this help Australia's competitiveness?

We will have to wait until the end of August 2018 for answers to these questions.

Australia and East Timor agree on maritime border: but is it a good deal for Australia?

On 6 March 2018 Australia's Julie Bishop and Timor-Leste's Hermenegildo Pereira signed the *Treaty between Australia and the Democratic Republic of Timor-Leste establishing their maritime boundaries in the Timor Sea*.

This ended a long running dispute over the boundary that has been going on for over 30 years. In 1972, before Timor-Leste existed, Australia and Indonesia agreed to a boundary that essentially was at the edge of the continental shelf (see Figure 1). The Timor Gap Treaty was signed in 1989, when East Timor was still under Indonesian occupation. East Timor was therefore left with no permanent maritime border, and Indonesia and Australia shared the wealth in what was known as the Timor Gap.

In 2002 East Timor gained independence and the Timor Sea Treaty was signed, but no permanent maritime border was negotiated. East Timor had long argued the border should sit halfway between it and Australia, placing most of the Greater Sunrise oil and gas field in their territory, and Australia argued that, as the sediments on the continental shelf were derived from the Australian continent, the boundary should be at the edge of the shelf. Furthermore, Australia and Indonesia had already signed an agreement in 1972 to position the boundary at the edge of the continental shelf.

Meanwhile, in 1997, the United Nations Convention on the Law of the Sea was adopted and the boundary was to be half way between Australia and Timor-Leste. The exclusive economic zone (EEZ) would then be positioned as shown in Figure 1. This boundary was never ratified.

In 2004 East Timor re-started negotiations with Australia about the border and, in 2006, a treaty was signed to split the revenue from the Greater Sunrise oil and gas field evenly between the two countries but no permanent border was set. This led the five companies Woodside Petroleum Limited (operator and 33%), Royal Dutch Shell (27%), ConocoPhillips (30%) and Osaka Gas (10%) in the joint venture operating the Greater Sunrise resource to shelve the project. The value of the resource is estimated to be of the order of $50 billion, so the stakes were high!

Australia resisted adopting 1997 boundary but was caught in a bind over the Chinese territorial claims in the China Sea. How could Australia tell the China to abide by the rule of law when it wasn't complying with the UN Law of the Sea near Timor-Leste?

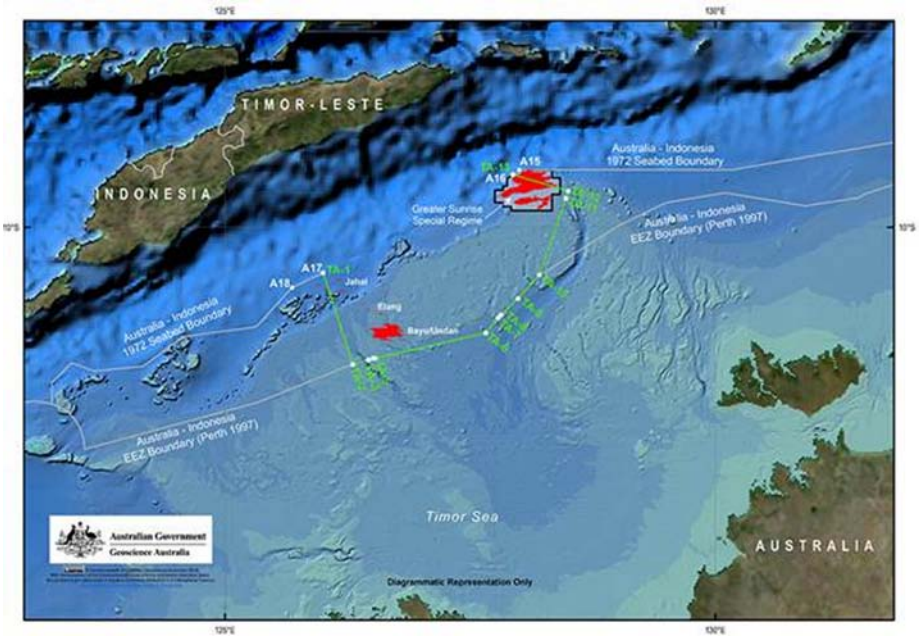

Figure 1. *Three boundaries are shown in this diagram: the 1972 Australia-Indonesia Seabed Boundary; the 1997 EEZ Boundary that complies with the United Nations Convention on the Law of the Sea (but never ratified); and the recently agreed boundary between Timor-Leste and Australia, shown in green. The area bounded by the green line and a straight line between TA1 and TA13 defines the Joint Petroleum Development Area, where the current commercial agreements shall continue unchanged.*

In 2017 Australia eventually agreed to accept Dili's formal notice to terminate the agreement to split petroleum revenue equally from the Greater Sunrise resource. The dispute was taken to the Permanent Court of Arbitration at The Hague and, as a result, the boundary shown in Figure 1 was agreed to.

However, the revenue sharing agreement from the Greater Sunrise resource depends on whether the pipeline from the resource goes to Australia or Timor-Leste. If the Greater Sunrise Fields are developed and the pipeline goes to Timor-Leste, the ratio of revenue will be 30 per cent to Australia and 70 per cent to Timor-Leste. If the pipeline goes to Australia then the ratio will be 20 per cent to Australia and 80 per cent to Timor-Leste. Either way it seems to be a good deal for Timor-Leste.

The next step might be that Indonesia will want to re-draw their boundary with Australia to comply with the United Nations Convention on the Law of the Sea. If that happened the 1997 boundary shown in Figure 1 would become the new boundary, and we could lose more of our continental shelf. Not a good deal at all!

Northern Territory lifts fracking moratorium

The process

The Northern Territory Government's Chief Minister, Michael Gunner, announced on 17 April 2018 that his government had accepted all the 135 recommendations made by the independent fracking inquiry he had established in December 2016. The process leading up to this decision started on 14 September 2016, when he announced a moratorium on hydraulic fracturing in onshore shale reservoirs in the NT, pending the appointment of an independent scientific panel to inquire into the impacts and risks associated with hydraulic fracturing.

In January 2017 Justice Rachel Pepper was appointed Chair of the Inquiry, along with eight scientists across a range of disciplines (www.frackinginquiry.nt.gov.au). It received more than 1250 submissions and held meetings with community groups, environmental groups, Land Councils, local councils, government agencies, industry and individual members of the public. The key issues were:

- the nature and extent of the risks identified with the hydraulic fracturing of onshore shale gas reservoirs, and its associated activities on the environmental (aquatic, terrestrial and atmospheric), social, cultural and economic conditions of the NT
- whether these risks can be mitigated to an acceptable level
- if they can, by what methodology or methodologies can these risks be mitigated and
- whether the existing regulatory framework is sufficient to implement these methodologies, and if not, what changes must be made to it and by when.

The outcomes

The overwhelming consensus of the participants argued that hydraulic fracturing for onshore shale gas in the NT is not safe, is not trusted and is not wanted. However, the panel decided that, with a rigorously enforced and improved regulatory regime, the onshore extraction of shale gas could be advantageous to the

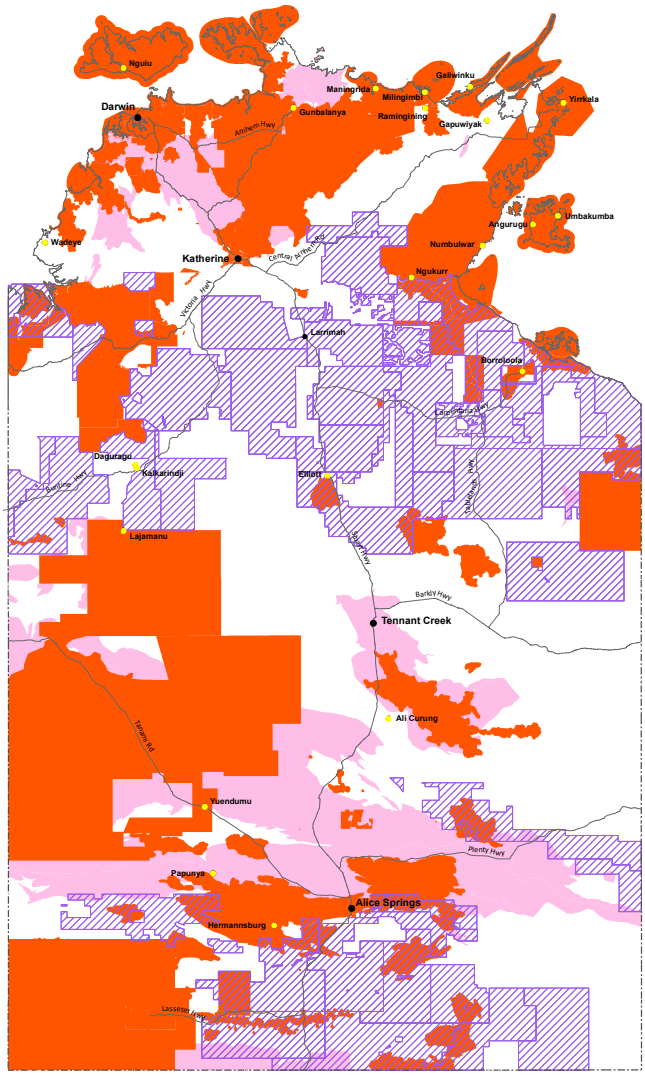

Figure 2. *Potential reserved areas from shale gas development are coloured red and the purple areas are considered to have no oil or gas potential. The cross-hatched areas already have exploration licences granted. Source: NT Department of Environment and Natural Resources.*

NT, creating short- and long-term employment opportunities and raising much-needed revenue for the Government and for Aboriginal and non-Aboriginal communities.

The final report of 505 pages, was tabled on 28 March 2018, and is a very impressive document. The government wasted no time in agreeing to all the 135 recommendations (https://frackinginquiry.nt.gov.au/inquiry-reports/final-report), and appointed David Ritchie as the independent officer to oversee implementation of the recommendations on 19 April. According to the Chief Minister some of the key elements of these new regulations include:

- ensuring all Environmental Management Plans for fracking must be assessed by the EPA and signed off by the Minister for the Environment
- strict new requirements that must be met before exploration approval is granted including codes of practice for well integrity and well decommissioning, development of wastewater management frameworks, the requirement for gas companies to obtain a water license
- strict new requirements that must be met before production can take place including the development of robust and transparent monitoring strategies, discussions with industry and pastoralists regarding land access requirements and compensation, and release of all environmental management plans for public comment
- broad standing to seek judicial and merits review of statutory decisions
- broad new powers to sanction non-compliance, civil enforcement proceedings and increased criminal penalties for environmental harm.

If anyone wants a readable review of hydrofracturing techniques, this report would be a good place to start. It provides an excellent analysis of the techniques, the costs and benefits, as well as a good background on the geology of the NT. One gets the impression that the panel appreciated the risks involved with hydrofracking and have put together a robust compliance regime to reduce these risks to a reasonable level. There is no claim that there are zero risks.

According to the Chief Minister, the reforms will require significant additional resources and he has approved $5.33 million over three years to implement all the recommendations. There is also a greenhouse gas emission issue and the NT Government is seeking offsets from the Australian Government for the emissions, generated by the fracking.

The government accepted the Inquiry's advice about no-go zones for fracking. If these are added to the areas where there is no petroleum potential, 49% of the Territory will be frack free. These areas include the National Parks, Conservation Areas, Indigenous Protected Areas, towns, residential and strategic assets, and areas of high cultural, environmental or tourism value. Figure 2 shows the areas that can be used for fracking.

The NT Government has tackled a very controversial issue in a responsible and effective way and should be commended for its actions.

Education matters

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Changes in how the ASEG is delivering educational opportunities

In the last issue of *Preview* it was reported that Marina Pervukhina had taken over as Chair of the ASEG Education Committee. She was chairing this committee in addition to acting as the State Branch Representative on the ASEG Federal Executive. Marina quickly realised that the Education Committee would function more effectively if it was split into a Professional Development Committee and an Education Committee. Marina will chair the Professional Development Committee and Andrew Squelch, a new member of the Federal Executive and a lecturer in geophysics at Curtin University, will chair the Education Committee. Marina will concentrate on bringing more high quality professional development courses and lectures to Australia. In the next couple of months the ASEG will host SEG Distinguished Instructor Kurt Marfurt and SEG/AAPG Distinguished Lecturer Satish Singh, as well as two EAGE short courses. If you have any questions about the nature of these courses, their timing or about how to register please contact Marina on marina.pervukhina@csiro.au.

ASEG welcomes SEG Distinguished Instructor Kurt Marfurt

Kurt Marfurt is the Frank and Henrietta Schultz Professor of Geophysics within the ConocoPhillips School of Geology and Geophysics, University of Oklahoma. He has a distinguished record of work in both academia and the seismic-petroleum industry and will be our guest in July. He is scheduled to give a series of talks at ASEG Branch meetings as well as formal one-day seminars on his topic 'Seismic Attributes as the Framework for Data Integration throughout the Oilfield Life Cycle'.

Professor Kurt Marfurt.

The seminars are pitched at a wide audience from seismic processors and interpreters, through to reservoir engineers and team leaders. Thanks to the SEG, and to Marina Pervukhina and the ASEG's Education Committee for setting up this opportunity in our education program.

Table 1. Kurt Marfurt's schedule

State	City	Date	Day	Talk/ DISC
WA	Perth	11 Jul	Wed	DISC
WA	Perth	12 Jul	Thu	Talk
SA	Adelaide	16 Jul	Mon	DISC
SA	Adelaide	17 Jul	Tue	Talk
VIC	Melbourne	18 Jul	Wed	DISC
VIC	Melbourne	19 Jul	Thu	Talk
ACT	Canberra	23 Jul	Mon	DISC
ACT	Canberra	24 Jul	Tue	Talk
QLD	Brisbane	25 Jul	Wed	DISC
QLD	Brisbane	26 Jul	Thu	Talk

The DISC registration is open at the SEG website:

11th July – Perth: https://seg.org/shop/products/detail/55090900

16th July – Adelaide: https://seg.org/shop/products/detail/55090906

18th July – Melbourne: https://seg.org/shop/products/detail/55090929

23rd July – Canberra: https://seg.org/shop/products/detail/55090947

25th July – Brisbane: https://seg.org/shop/products/detail/55090956

More detailed information about the DISC be found at: https://seg.org/Education/Courses/DISC/2018-DISC-Kurt-Marfurt

ASEG welcomes SEG/AAPG Distinguished Lecturer Satish Singh

Satish Singh will be the ASEG's guest in August. He is scheduled to give a series of lectures at ASEG Branch meetings on the topic 'Seismic Full Waveform Inversion for Fundamental Scientific and Industrial Problems'. The lectures should interest professionals working in the oil and gas sectors, and/or crustal studies and global seismology.

Satish was elected American Geophysical Union Fellow in 2010 and awarded the Grand Prix of the French Academy of Science in 2011. In 2012, he created the Paris Exploration Geophysics (GPX) Group, in collaboration with Les Mines ParisTech and other industry partners. Since 2013 he has been sharing his time between the Institut de Physique du Globe de Paris, France and Earth Observatory of Singapore, Nanyang Technological University, Singapore since 2013.

Satish Singh.

More detailed information about Satish Singh and the lecture he will be giving can be found at: https://seg.org/Education/Lectures/Distinguished-Lectures/2018-DL-Singh.

Table 2. Satish Singh's schedule

State	City	Date	Day
QLD	Brisbane	30 Jul	Mon
ACT	Canberra	1 Aug	Wed
VIC	Melbourne	2 Aug	Thu
SA-NT	Adelaide	7 Aug	Tue
NSW	Sydney	8 Aug	Wed
TAS	Hobart	14 Aug	Tue
WA	Perth	15 Aug	Wed

EAGE short courses

The EAGE will be running two short courses in Perth in July. The first course, on 'Rock physics for quantitative seismic reservoir characterization', is being delivered by Tapan Mukerji on 5 and 6 of July. The second course, on 'The benefit of broadband technology for reservoir characterization and imaging – the end-user value' is being delivered by Cyrille Reiser on 18 July.

More detailed information about both these courses can be found at:
https://events.eage.org/en/2018/education-days-perth-2018/programme/tapan-mukerji
https://events.eage.org/en/2018/education-days-perth-2018/programme/cyrille-reiser

Environmental geophysics

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Welcome readers to this issue's column on geophysics applied to the environment. This interesting piece from Esben Auken and his Aarhus University-based HydroGeophysics group (with contributions by researchers Jesper Bjergsted Pedersen and Pradip Kumar Maurya) came across my desk earlier this month. As many of you know, it is on a subject of great interest to me - the use of towed ground EM designed to resolve the shallow subsurface.

So, over to Esben and his team…

A new towed geophysical transient electromagnetic system for near-surface mapping

Esben Auken, Jesper Bjergsted Pedersen and Pradip Kumar Maurya

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In this article, we (the HydroGeophysics group) present a new towed geophysical transient electromagnetic system (tTEM), developed here at Aarhus University, Denmark, for mapping the top 50–70 m of the subsurface.

The development of this system has been driven by the fact that geophysical methods capable of imaging this zone either have limited efficiency when it comes to creating full 3D images, or they do not have sufficient imaging depth. Some examples of applications that require this high level of information include: optimal location of artificial recharge sites, assessment of contamination risk from point sources and landfills, road construction, development of flow models for surface-groundwater interaction, etc.

Traditionally, this zone is mapped using boreholes, electrical resistivity tomography (ERT) or airborne electromagnetics (AEM). However, these geophysical methods lack the capability to make cost-effective, high-resolution maps of areas ranging from just a few hectares up to a few thousand hectares. ERT is a proven method that covers this depth range with the needed resolution. However, ERT typically produces 2D profiles, and mapping more than a few hectares in 3D is time-consuming and expensive (Auken et al., 2014; Maurya et al., 2017). Ground Conductivity Meters (GCM) are efficient for mapping large areas but the depth of investigation is limited to 5 to 8 m (Christiansen et al., 2016). Airborne electromagnetic systems such as SkyTEM (Sørensen and Auken, 2004) are able to map extremely large areas, but are relatively expensive to mobilise for smaller areas, and in most cases do not sufficiently resolve very shallow layers, both vertically and horizontally (Auken et al., 2017). Hence, there is an unmet need for geophysical methods capable of characterising the shallow subsurface in full 3D. In the following sections, we will give an overview of the tTEM system design, demonstrate a case study, and discuss a few possible applications.

The basic design of the tTEM system is shown in Figure 1. The overall design goal was to develop a system capable of fast imaging, from the surface to a depth of 50 to 70 m with high vertical and lateral resolution. Data has to be bias-free and the system transfer function (STF) completely known. To achieve this goal the system uses a one-turn 2 x 4 m^2 transmitter loop mounted on a frame with sledges that is towed by an all-terrain vehicle (ATV). The receiver coil is a 650 kHz suspended induction coil towed behind the transmitter in a 9 m offset configuration. The system transmits a low and a high moment (LM, HM) to collect both shallow and deep information. The LM transmits at 2.8 amps with a turn-off time of 2.6 µs and a first usable gate at 4 µs (times from beginning of the ramp), while the HM transmits 30 amps. The repetition frequencies for the two moments are approximately 2000 Hz and 800 Hz. The transmitter is water-cooled in order to keep the current ramp completely repeatable; the temperature for the transmitter is kept at 45 degrees Celsius (+/– 2 degree Celsius) and the high moment current is kept at 30 amps +/– 1 amp. A full dataset is obtained every 0.8 sec - corresponding to a 3 to 4 m spacing between soundings, with a production speed of 15 to 20 km/h. Data are processed and inverted using methods directly adopted from airborne electromagnetics. Typically line spacings are 10–20 m (interestingly this corresponds to the distance between spraying tracks on farm fields). With this setup one can typically map an area of approximately one square km in a day.

The tTEM system was, in the example we are presenting here, used to investigate the geological setting for a 156 hectare farm in Gedved, Denmark. The survey was conducted as a part of the European Union funded project *Topsoil*. The *Topsoil* project addresses a number of

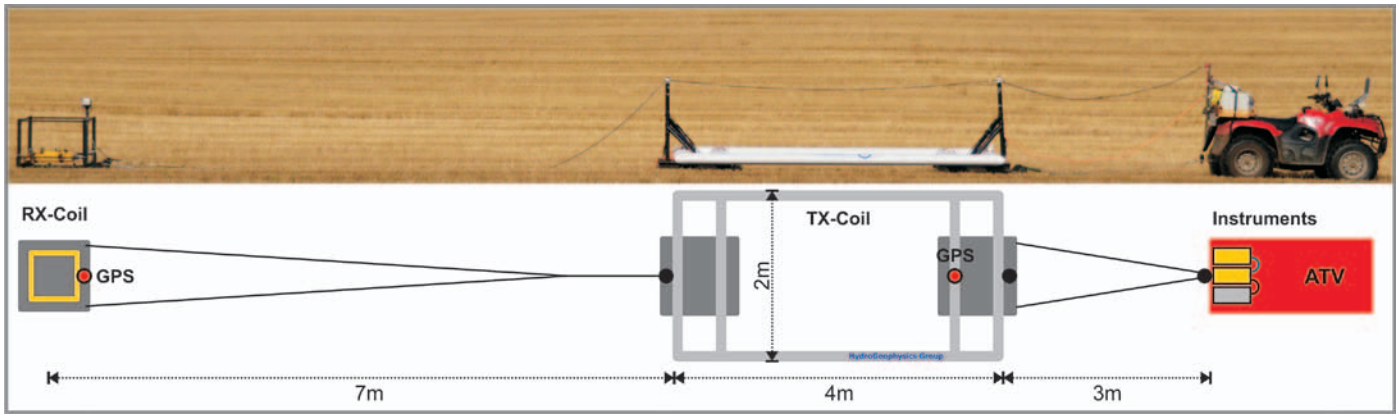

Figure 1. *The tTEM System.*

issues having to do with groundwater/surfacewater, including the improvement of both water quality and quantity. The aim of the survey was to obtain a detailed 3D image of the geological layers in the area in order to assess the vulnerability of the local aquifer to contamination from agricultural activity. As a rule of thumb, local aquifers are considered protected if there is more than 15 m of capping clay. Figure 2a highlights the survey area; the farmer owns all the mapped fields and lives right in the centre. The fields were mapped in less than two days, producing 11 925 tTEM soundings (red dots in Figure 2a). The line spacing was 20–30 m, while the model spacing along the lines was 10 m, resulting in a full 3D resolution of the farm fields. After data collection, noisy soundings (due to culture related mostly to nearby roads) were culled and the data was inverted using a spatially constrained inversion.

The models are visualised as mean-resistivity maps and profiles to obtain spatial and in-depth knowledge of the geological structures. Figure 2b shows a mean-resistivity map from 15 to 20 m depth and Figure 2c shows a profile located in the western part of the survey area. From the mean-resistivity map and profile it is evident that, even on local field-scale, the local shallow geology can be very complex. North of the farm there is a layer of Paleogene clay that is more than 40 m thick, which rises to within 5 m of the ground surface. If this were true everywhere one would consider the deep aquifers well protected (in Denmark groundwater is typically extracted from aquifers at around 70 m depth); however,

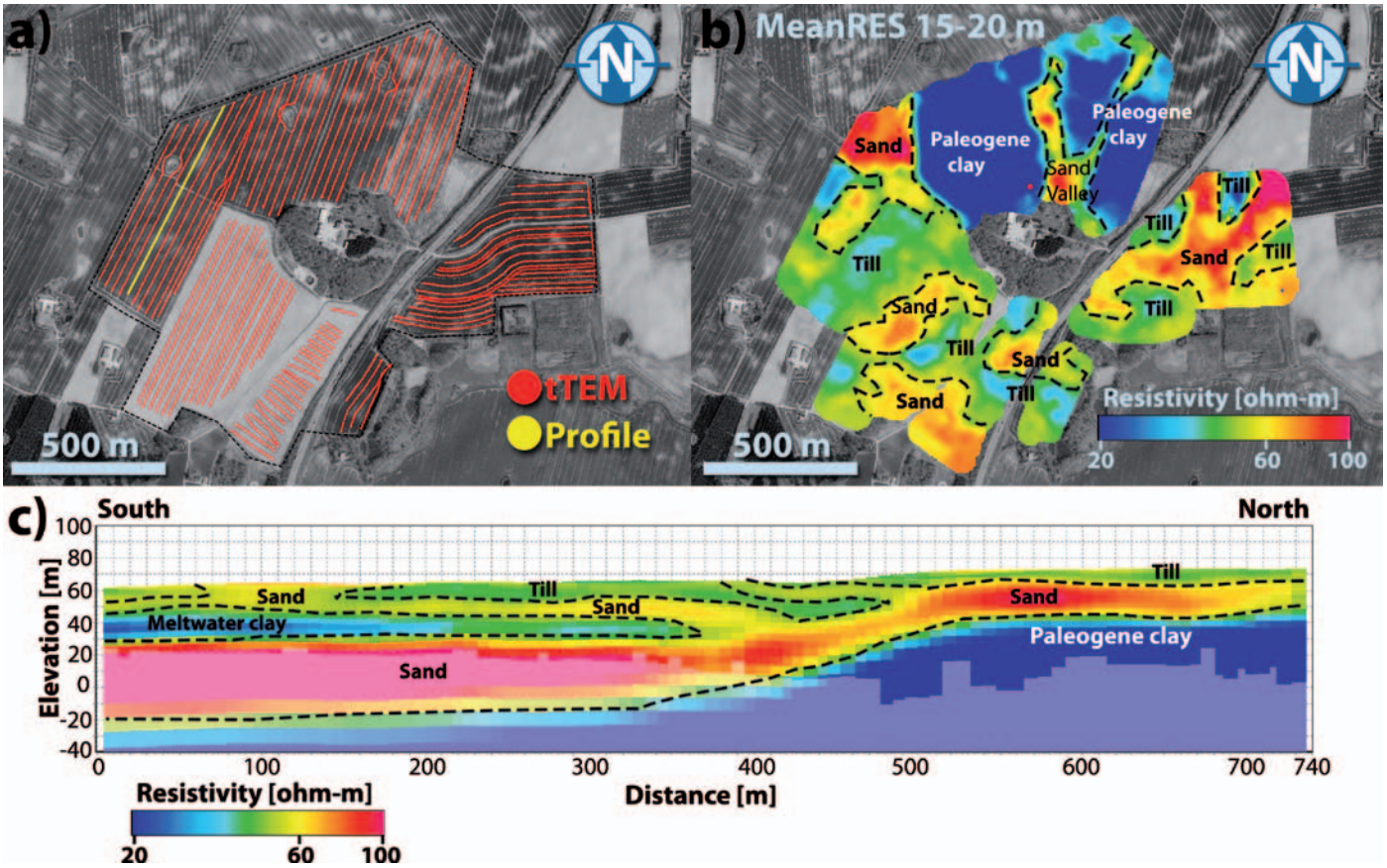

Figure 2. *Gedved tTEM survey. (a) Survey lines (red dots) and profile location (yellow line). (b) Mean resistivity map depth 15–20 m. (c) South-north striking profile. The location of the profile is highlighted in Figure 2a. The models have been 50% faded below the depth of investigation.*

as seen in the mean-resistivity map, the Paleogene clay has been affected by glacial processes, introducing incised sand valleys in the clay layer. These sand valleys act as pathways for water transport, and hence nutrients. As seen in the profile, the shallow and thin sand layers (both in thickness and in spatial distribution), connect with deeper sand aquifers, which act as fluid pathways from the surface that then pose a potential threat to drinking water quality. We only know this because of the large lateral and vertical resolution of the system; this much information would be difficult to obtain using other geophysical methods (line spacing of 20–30 m is not feasible with AEM, and providing the same coverage with ERT would be next to impossible and extremely costly).

We have used the tTEM system to collect high resolution data on a number of other studies. These include, for example, mapping the location and depth of raw construction materials (especially if underlain by low resistivity clay layers); investigating contaminated sites; mapping zones of nitrate retention in the shallow geology; investigating artificial recharge sites (see http://hgg.au.dk/projects/stanford-ttem/ for a description of some work we did in the Tulare Irrigation District in California); saltwater intrusion; and, of course, detailed geological input for hydrogeological modelling.

As seen in the case study, the system is effective at describing geological structures due to glacial processes and, obviously, would be useful in other complex geological settings. In an upcoming project, we will experiment with towing the system behind rubber dinghies to map the resistivity of the hyporheic zone.

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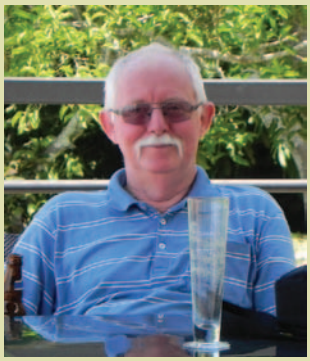
Minerals geophysics



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Hierarchy or anarchy?

One of the things that has intrigued me over my working career in mineral exploration is the strikingly different ways that an organisation's structure can impact on the way that entity operates, particularly with respect to the flow of ideas. At one end of the spectrum is the traditional rigid hierarchy where the organisational structure is strictly maintained; at the other extreme is the new-age free-for-all where the organisational structure counts for little – a virtual anarchy!

This set me thinking about what might be the best approach for mineral exploration. Our industry is by no means normal – we are not an industry of single processes and set ways of doing things – so some lateral thinking may be called for. Ideas are our lifeblood.

The strictly hierarchical approach ensures that ideas and procedures come from the top down. Don't question your superiors and do what you're told. Experience and knowledge obviously reside in the upper echelons, and these will dictate how things are done. Making use of all that experience and knowledge makes sense; it may have been hard-earned, incorporating lessons learned from past mistakes. But rigid adherence to an hierarchical structure can mean that fresh ideas and novel approaches may be stifled.

The anarchistic approach allows an unfettered free flow of ideas and approaches. We live in technically exciting times, where the dissemination of information is greater than ever - all ideas are on the table. Who's to say that one idea is any better than another? Old approaches have been tried and found wanting – time for something new and different. But is an uncritical approach the right answer? Is new necessarily better? Without structure there will be operational inefficiencies. Mistakes may be repeated again and again.

Not surprisingly, to my way of thinking, the optimum approach lies somewhere in the middle: strong encouragement of new ideas that have been evaluated by knowledge and experience. The young geologist can point to descriptions of a new geophysical technique or processing procedure and rightly say, 'Why aren't we using this?'. There may be very good reasons why we aren't, but let's at least thoroughly evaluate the suggestion and explain the reasoning, then everyone benefits.

So, bring on the suggestions, questions and comments, no matter how far out there they are. And, old hands, don't despair – there will always be the need for knowledge and experience.

Which brings me to the Frank Arnott Award winners featured in this issue of *Preview*. Theo's introduction sets the scene, followed by the University of Adelaide and Team Macquarie summaries of their submissions. If ever there was an award which championed innovative techniques, this is it.

Seismic window

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Full waveform inversion of seismic data

I received a note late last year asking for an article on Full Waveform Inversion (FWI), which is an almost mainstream part of the seismic processing sequence nowadays. This was a challenge because all I knew about FWI was that it is used to make detailed velocity models (and arguably that's about all an interpreter needs to know). To improve my understanding I spent some time reading seismic contractors' websites and watching educational YouTube movies, some of them about FWI.

Full Waveform Inversion compares pre-stack shot gathers and synthetic gathers derived using the wave equation to forward propagate a model. By using amplitude and phase information it can successfully resolve small scale features (unlike tomography, which uses only travel time) to create high resolution velocity models of the subsurface.

Essentially FWI is not very complicated and involves the following steps:

- Start with a recorded shot gather and initial model
- Compute a synthetic gather based on the model
- Calculate the difference between the recorded and modelled data to give residual errors
- Use the residuals to update the model

The updated model then becomes the input and the process is repeated until a satisfactory match is achieved.

The crux of FWI is the method of local optimisation used to minimise the misfit between recorded and model data. Because the process is iterative and highly non-linear the optimisation is used thousands of times, so it needs to be computationally efficient. The intensive computation required is one reason that the acceptance of FWI has been slow. A full description of the methods used to calculate model updates from the residual errors involves terms like Hessian and adjunct state method, all of which is beyond my mathematical prowess.

Implementation of FWI can be in either the time or frequency domain. The frequency domain allows multi-scale inversion where initially a low frequency version of the data is modelled to avoid cycle skipping and reduce the computation time. Higher frequencies can be progressively added to obtain a higher resolution velocity model, but this is mostly restricted to 10 Hz because of the computational grunt required for higher frequencies. For example, recently I was shown the results of a 100 Hz FWI. The detail in the velocity field was amazing, but the computation effort required was 10 000 times more than the 10 Hz model. In the time domain modelling can be more flexible by allowing time windowing of the data, but again it is computationally expensive.

Apart from computation time, a major limitation of FWI is that the depth of investigation is restricted to about one-third of the maximum source to receiver offset. There are, however, two immediate benefits of using full waveform inversion. First, the method produces accurate velocities that can be used in seismic processing instead of the slower velocity analysis processes. This can reduce processing time up to 50% and save many months. Second, the velocities are detailed enough to be used as an interpretation tool. Extra time and another attribute can only improve the quality of an interpretation.

Petrol, parking and plankton

A few months ago I noted the price of petrol for a week and the number of dark coloured cars parked at my local train station. The graph in Figure 1 has a line of best fit with a remarkable correlation and an R2 of 0.90. Why would coloured cars be more abundant in the car park on days of high petrol price?

Possibly there are many reasons but I suggest it is because coloured paint is heavier than white paint so coloured cars use more petrol and their owners are less likely to drive all the way into the city when fuel prices are high.

If you think this conclusion can be supported scientifically, I would recommend reading the papers listed below. The McCauley et al. (2017) paper warns that the world's plankton population is threatened by seismic surveying. The Richardson et al. (2017) paper is a response to McCauley et al. (2017) by leading environmental scientists that suggests the experiment and sampling that led to McCauley's conclusion could have been carried out more rigorously.

In a *New Scientist* article (Klein, 2017) McCauley is quoted as saying, 'It's unclear how the zooplankton died…'. The article then goes on to say he is now researching how airgun initiated declines in zooplankton populations affect other marine creatures. That will be interesting given zooplankton are much more likely to perish from other causes – for instance 19% of the zooplankton population dies each day from natural causes.

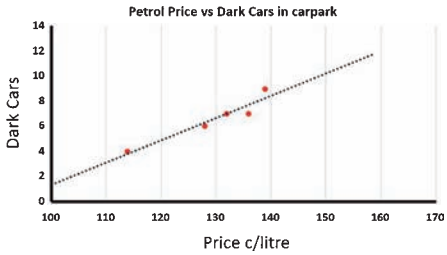

Figure 1. *Cross plot of petrol price and number of dark cars at a local railway station.*

Suggested reading

Klein, A., 2017, Oil-exploration airguns punch 2-kilometre-wide holes in plankton. *New Scientist*, Daily News 22 June 2017.

McCauley, R. D., Day, R. D., Swadling, K. M., Fitzgibbon, Q. P., Watson, R. A., and Semmens, J. M., 2017, Widely used marine seismic survey air gun operations negatively impact zooplankton. *Nature Ecology & Evolution* **1**, 0195.

Richardson, A. J., Matear, R. J., and Lenton, A., 2017, Potential impacts on zooplankton of seismic surveys. Australia: CSIRO.

Webwaves

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Data protection

On 25 May 2018 the European General Data Protection Regulations (GDPR) (European Union, 2018) came into effect. These are the second set of regulations that have been introduced in 2018 concerning data protection. The first was the Australian Notifiable Data Breaches Act (NDBA) (Commonwealth of Australia, 2018), which was introduced on 22 February 2018, two days after the first AEGC conference ended. In response to the NDBA and GDPR, the ASEG is developing a Data Collection Policy. When the policy is finalised around August, 2018, it will be published at https://www.aseg.org.au/data-collection-policy.

The NDBA is much less proscriptive than the GDPR. Briefly, it puts the onus on organisations to decide how to proceed should they discover that data they hold has been accessed inappropriately. How organisations proceed depends on whether three criteria are satisfied:

1. there is unauthorised access to, or unauthorised disclosure of, personal information, or a loss of personal information, that an entity holds;
2. this is likely to result in serious harm to one or more individuals; and
3. the entity has not been able to prevent the likely risk of serious harm with remedial action.

Thus, an organisation may not be required to notify affected parties in the event that they discover that data they hold has been accessed inappropriately.

The central tenet of the GDPR is that an individual's data belong to that individual. However, it may not be clear to an individual what they own. Information that has been provided in order to access services is something that is known. Such information could be requested under the GDPR, and individuals may be notified should organisations determine they are required to do so under the NDBA.

The website https://fivethirtyeight.com recently coined the term 'privacy of the commons', wherein one person's voluntary disclosure of personal information exposes the personal information of others who had no say in the matter. As shown in the recent scandal where Cambridge Analytica (*The Guardian*, 2018) were able to leverage information provided by users who downloaded the 'thisisyourdigitallife' application to profile some many (at least over 200) times more users who did not, companies can even build a profile of a person from birth based entirely on data-sharing choices made by others.

Thus, even if all searches are made using a specialised browser, all web cameras are covered, and privacy settings are monitored and updated regularly, personal data has probably still been collected, stored and used in unintended ways without an individual's knowledge. Perhaps one small mercy is that until scandals are uncovered, ignorance is blissful.

In addition to taking the measures outlined in the previous paragraph, individuals may also test whether their email address(s) are included in known data breaches. The website https://haveibeenpwned.com/ can show hacked websites associated with an email address and indicate the nature of the breach. This knowledge can help individuals decide their next actions, such as whether to change passwords or to stop using the service. Some password managers (e.g. LastPass) can audit collected passwords to ensure strength and uniqueness.

As governments are beginning to realise, it is not clear what to do regarding an individual's privacy now that the Pandora's Box of connectivity and social networks has been opened. For many, the benefits far outweigh the detriments that they can monitor. The cost of an individual's connectivity may easily be overshadowed by the profits. For many, that cost will be reduced by monitoring and maintaining security and privacy settings on all devices.

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Commonwealth of Australia, 2018, Notifiable Data Breaches scheme – Office of the Australian Information Commissioner (OAIC), https://www.oaic.gov.au/privacy-law/privacy-act/notifiable-data-breaches-scheme (accessed 9 May 2018).

European Union, 2018, EU GDPR Information Portal, http://eugdpr.org/eugdpr.org.html (accessed 9 May 2018).

The Guardian, 2018, The Cambridge Analytica Files, https://www.theguardian.com/news/series/cambridge-analytica-files (accessed 9 May 2018).

Frank Arnott Award: Australian students do us proud

Readers may recall, back in *Preview* 175 (April 2015), the announcement of the Frank Arnott Award (FAA) a global collaborative challenge for **innovation in visualisation and data integration**. The award was named in honour of Frank Arnott (1951–2009), an exceptional exploration industry leader who championed innovative techniques to maximise the value of the multidisciplinary data.

The FAA competition was open to industry and academia up until March'17 for teams categorised as either **Apprentice** (less than 5 years since obtaining undergraduate degree) or **Experienced**. The teams were required to work on one or more of the five high quality data packages assembled by the organisers, and were judged in terms of each of **Innovation**, **Exploration significance**, **Impact** and team **Collaboration**.

Following the judging phase in mid-2017, the top two teams in each category were invited to travel to Toronto in October to deliver a 20 minute presentation summarising their submission at the 6th Decennial Mineral Exploration Conference (aka Exploration '17). To add to the sense of the occasion, the teams were not told of their ranking but only that they had won a minimum of C$12 000 to assist their travel arrangements. In addition, DMEC funding of up to C$750 was available for students from all teams.

The announcement of the final team ranking was made at the Gala Dinner by Frank's widow, Virginia, who had travelled from Perth for the event. First prize (C$20 000) in the Experienced category was taken out by 'Logan's Legends' who investigated the Quesnel Trough, an alkalic porphyry Cu–Au terrain in British Columbia, Canada. Somewhat amusingly, the Logan's Legends team was made up of geoscientists from the Geological Survey of Canada, who, in accordance to Canadian government protocols, were unable to claim the prize money. Thus, the entire prize money in the Experienced category was claimed by the only student on the team.

The first prize in the novice category was taken out by the team 'On the Rocks' from the University of Adelaide. Guided by their team supervisor and mentor, Professor Graham Heinson, On the Rocks was made up of a combination 1st to 4th year of geology, geophysics and engineering students, bringing with them an eclectic range of non-traditional skills.

The third prize in the novice category was taken out by 'Team Macquarie' from Macquarie University in Sydney. This team was made up of Luke Smith, Tasman Gillfeather-Clark and Byron Gear, all master's students in geology and geophysics. The success of this small team was remarkable.

The winning entries of both teams are described in the following pages.

1st Place: On the Rocks, University of Adelaide, Australia

Innovations in 3D projections and presentation of geoscientific data

The On the Rocks team from the University of Adelaide was made up of: Ben Kay, Team Leader – data integration; Angus Nixon – data integration; Jamieson Woolcock – research; Jianan Chen – data integration; Kiryeong Lee – research; Larissa Collins – research, planning and organisation; Melissa Stinear – research; Mike Rieger – designer; Racheal Mahiknecht – research; Teagan Romyn – research; and Sarah Mc Donald – data visualisation.

The On the Rocks team in Adelaide.

The On the Rocks team drew on their multi-disciplinary skills to gain the favour of the judges with their über novel approach to the challenge. Recognising the difficulty geoscientists (let alone the general public) have when trying to understand the 3D earth as a series of 2D images, the team started by using a 3D printer to create semitransparent plastic models of the Gawler Craton and the Broken Hill elevation models. They next went about experimenting with wavelet transforms and fractal dimensions of the supplied magnetics, gravity and topography. In the final step, the team manufactured a projection system that allowed them to project their imagery to the underside of their 3D printed DEM, i.e. they created a 3D light table. The beauty of this low tech/ low cost solution, which is summarised in Figure 1, was that the team was able to jointly interpret the data in 3D.

Figure 1. *Innovative 3D projection and presentation of geoscientific data developed by On the Rocks.*

3rd Place Team Macquarie, Macquarie University, Australia

Self organising maps – A Broken Hill case study

Team Macquarie was a small team, which was made up of Luke Smith and Tasman Gillfeather Clark and Byron Gear. Luke and Tasman have generously described their work in detail for *Preview* readers. Over to you Luke and Tasman….

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Introduction

Team Macquarie's submission to the Frank Arnott Award was an application of Self Organising Maps (SOM) to the Broken Hill data provided. The data presented were extensive and detailed, and it was a challenge to isolate those that were well suited, or could be refined for use with SOM. The main challenge in the project was preparing the data for use in the SOM program – SOM Toolbox for Matlab 5 (Vesanto et al., 2000). After performing the SOM analysis, the second challenge was visualising the correlations effectively, and understanding the results.

Process overview

There were several key processes in the work. The first was data preparation, where we collated and rasterised all the individual components and generated a point-sampled CSV. This point dataset was then passed to MATLAB, where it was further organised into a data structure suitable for the SOM Toolbox. At this point, it is possible to select individual stratigraphic or regolith units, or the full map, on which to perform SOM analysis.

The output data structure was passed to the SOM toolbox functions within MATLAB, where SOM configuration and normalisation occurs. The SOM toolbox is also responsible for initialisation and training, as well as some visualisation functions such as generating component maps, K means colouring and suitable colour palettes.

As the final process, the Best Matching Unit (BMU) and Quantisation error (Qerr) data generated by the toolbox are reassigned to the original sample point location, and a map is produced by locating the points according to their original XY coordinates. Colour is assigned by the BMU value, which corresponds with a value determined SOM toolbox colour palette. It can also be assigned by Qerr value, or K means colouring to highlight unique clusters instead of BMUs.

The resulting map and component planes with colour key are then ready for investigation by the operator. The key outcome is that the SOM process rapidly identifies correlations within an area, across any number of data components, and across the full range of values within those components. No matter how skilled an interpreter is, they would not be able to examine a comparable range of data in similar detail within the same time constraints.

Data preparation

The final SOM structure contains 20 components. These are an elevation model, analytical signal, radiometric ppm, nine channels of Hymapper, and six common mineral occurrence zones. We also created a density model using the gravity data, however the regional nature of the data over the area was insufficient to generate a meaningful model, and it was discarded. We performed an analytical signal transform on the provided magnetic data. We finally mapped 200 m zones around the provided mineral occurrence sample points to extend the SOM influence of these points to their surrounding geology. These zones used a gaussian probability weighting with the highest weight at the sample location, falling to zero beyond 200 m. The Hymapper imagery provided within the dataset were not individual bands, so we were further provided with single component images by GSNSW, which were used without modification.

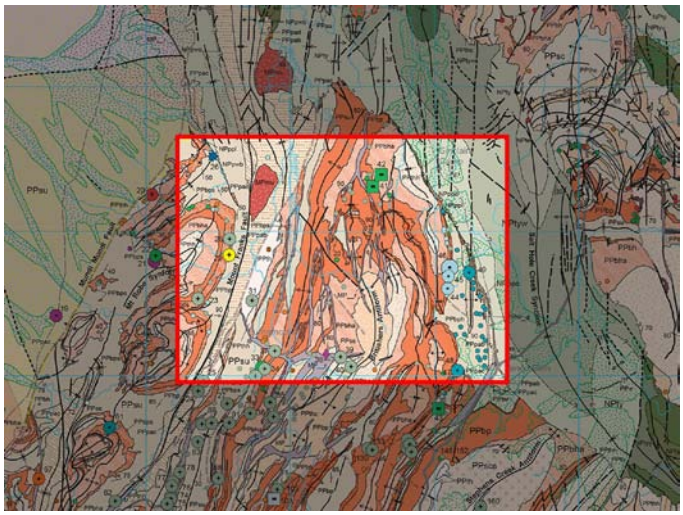

Figure 1. *Region of Broken Hill selected for SOM, indicated within red border. Modified from Fitzherbert et al., 2015.*

The above data were cropped to a 23 km by 17 km subset region of Broken Hill, highlighted in Figure 1. This area was selected as it had good data density across all layers chosen and contained interesting and varied geology. We decided to select a sub-region to keep processing times low while retaining a high resolution.

After all data layers were imported to MapInfo Discover, they were point sampled at 25 m spacing to generate a CSV of location and each component value at that point (Figure 2). Values can take any format, including numeric and text strings, as well as nulls. Nulls typically occur at the edges of the region, and can also occur where data is absent from the original survey. Nulls do not present a problem for the SOM toolbox, as they can be ignored without deteriorating the SOM output. Units and metadata are important to retain for post-SOM visualisation and analysis, however during the SOM process all values are normalised between 0 and 1, and units are not considered.

We initially included the stratigraphy and regolith maps as SOM components, with their classification having weight in the SOM calculations. However, we came to realise that these are a disparate type of information to the other layers, in that they are the result of a geologist's interpretation of data that form the other SOM inputs. That is, a geologist will consider outcrops, radiometric maps, magnetic maps, and other information when creating these geology maps. Including both the data and interpretation in the same SOM process was counter-intuitive, as it may over-represent certain components.

Figure 2. *Point cloud of our subset region produced after using the point sampling tool in Discover. Colour is derived from the stratigraphic classification of each point.*

To avoid discarding these maps altogether, we realised that they could be used to narrow the operator's focus to specific units of interest. The output of this effort is a processing step whereby the operator can choose a specific regolith or stratigraphic unit to isolate and analyse using SOM. In this process, the unit is isolated prior to the SOM calculations, and a unique SOM structure is generated using only the data from within that unit. This allows the clusters formed during the process to better represent relations present within the unit, rather than mapping to clusters that group regional trends, the difference being illustrated in Figure 3. The outcome of this is comparable to dynamic range, where finer details can be shown when fitting a colour map to a smaller set of data. It is important to note, however, that an entirely different SOM structure is formed during the training process, and different BMUs and clusters will result.

Visualising SOM

The SOM Toolbox provides several key visualisation methods, including component planes and K means colouring, as well as creating a colour map for best matching units, which was the key visualisation technique we employed for the Frank Arnott Award. Figure 3 presented above is an example visualisation, with each original point from the point sampled area assigned a

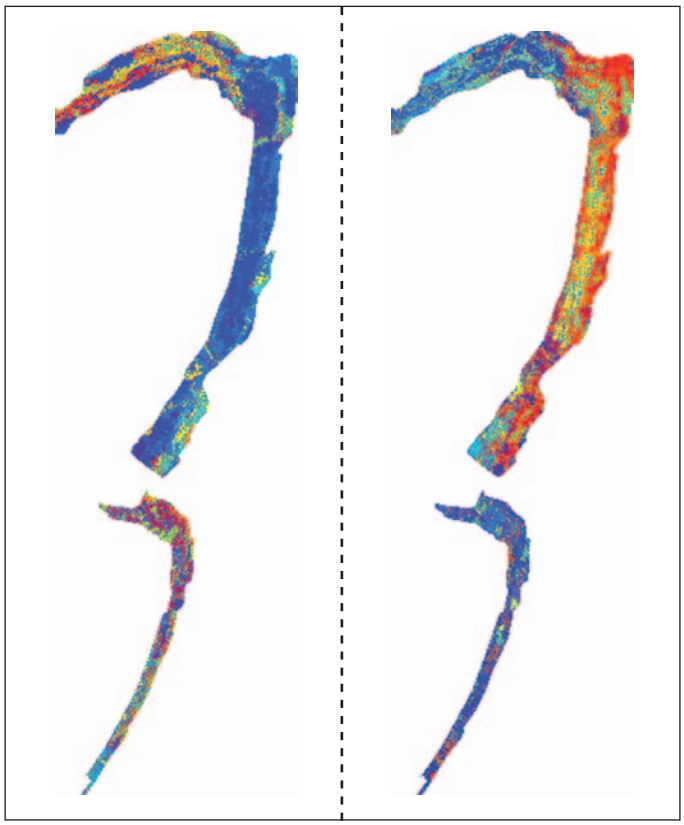

Figure 3. *The Silver King formation. The image on the left shows colours representing BMUs arising from relations across the entire region, while the image on the right shows colours representing BMUs arising from relations within only the Silver King Formation. Similar colours only indicate regions of similar components, and the left and right image do not share the same colour map. Interpreting this style of map is explained below.*

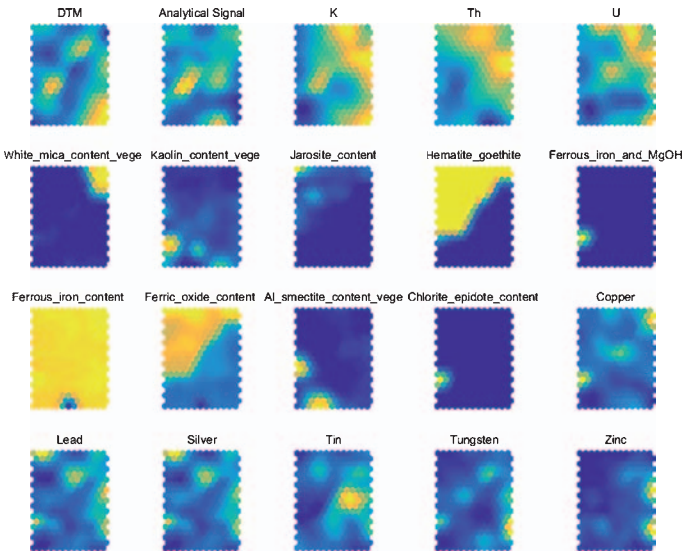

Figure 4. *SOM Component Planes for all input components across the full map extent.*

BMU according to the SOM output, and a colour for that specific BMU. When mapped, similar colours indicate similar regions. The nature of the relation between components is shown by SOM component planes, see Figure 4. This figure shows all 20 input components, labelled accordingly, for both the full extent SOM and for the SOM performed on just the Silver King formation.

To interpret the component planes shown in Figure 4, examine both the colour and location of the clusters. Yellow indicates values within the component data that are high, while blues indicate values within the data that are low. Their clustering indicates regions of data that are similar across all component planes – that is, each plane can be imagined as overlapping, with clusters in the same location on each plane being related to one another. As an example, examine the large yellow cluster to the left in the DTM component. It occurs in a similar location as the biggest yellow cluster in the Analytical Signal, indicating a specific correlation between high elevation and high magnetics within the data. However, note the upper right yellow cluster in the DTM does not have a correlating high in the analytical signal. This means there is a group of high elevation points in the data that do not have an associated magnetic high. To identify the spatial locations of these groups, we colour each hexagonal node of the component planes (Figure 5) and map each points assigned BMU (Figure 6).

As a second example, we can see high K, Th, and U values are associated in the upper right of their component planes Figure 4. These are assigned a bright green colour in Figure 5. Consulting the spatial map in Figure 6, we can see that this colour maps a large rounded body to the North West, which is shown on the interpreted geology map as a granitic body.

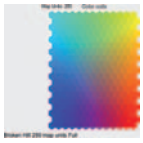

Figure 5. *Colour map. Each hexagonal node in the component planes is assigned a colour according to this key.*

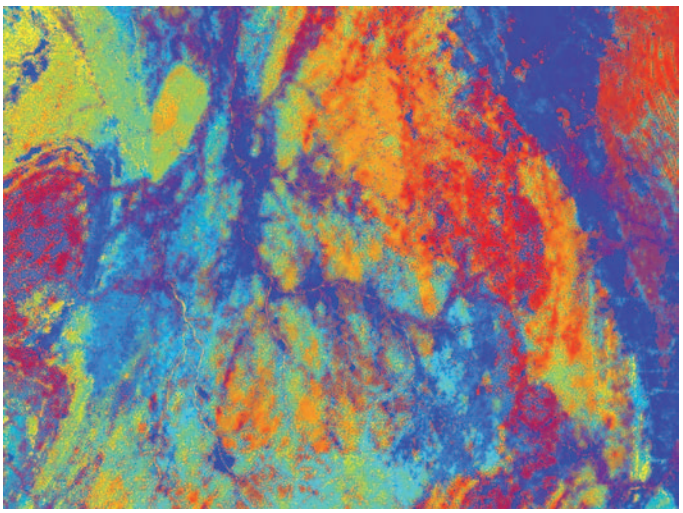

Figure 6. *Spatial SOM Map for the region of Broken Hill. Note no interpreted geology maps were used to generate the structures shown, only the input data layers. Colour is derived from the colour map in Figure 6, and reflects the nature of the data correlations shown in Figure 5.*

Conclusion

Team Macquarie applied self organising maps to a large dataset over Broken Hill, with the aim of integrating and visualising data from a complex geological province. The use of self organising maps was successful in creating a detailed and easy to interpret map, visualising the correlations between 20 different input layers.

As a closing remark on the Frank Arnott Award, participating in this challenge provided us with an opportunity to undertake an ambitious project with international attention and invaluable mentorship. We would like to thank everyone involved for their time and effort.

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Vesanto, J., Himberg, J., Alhoniemi, E., and Parhankangas, J., 2000, SOM toolbox for Matlab 5. Helsinki University of Technology, Finland.

Final remarks

The inaugural Frank Arnott Award was an outstanding success. The very positive feedback received from participants and from delegates to Exploration 2017 has encouraged the FAA organising committee to look at ways of continuing the award, particularly as part of a mineral exploration education program for postgraduate students and junior geophysicists. Stay tuned and for further information, contact the FAA organising committee:

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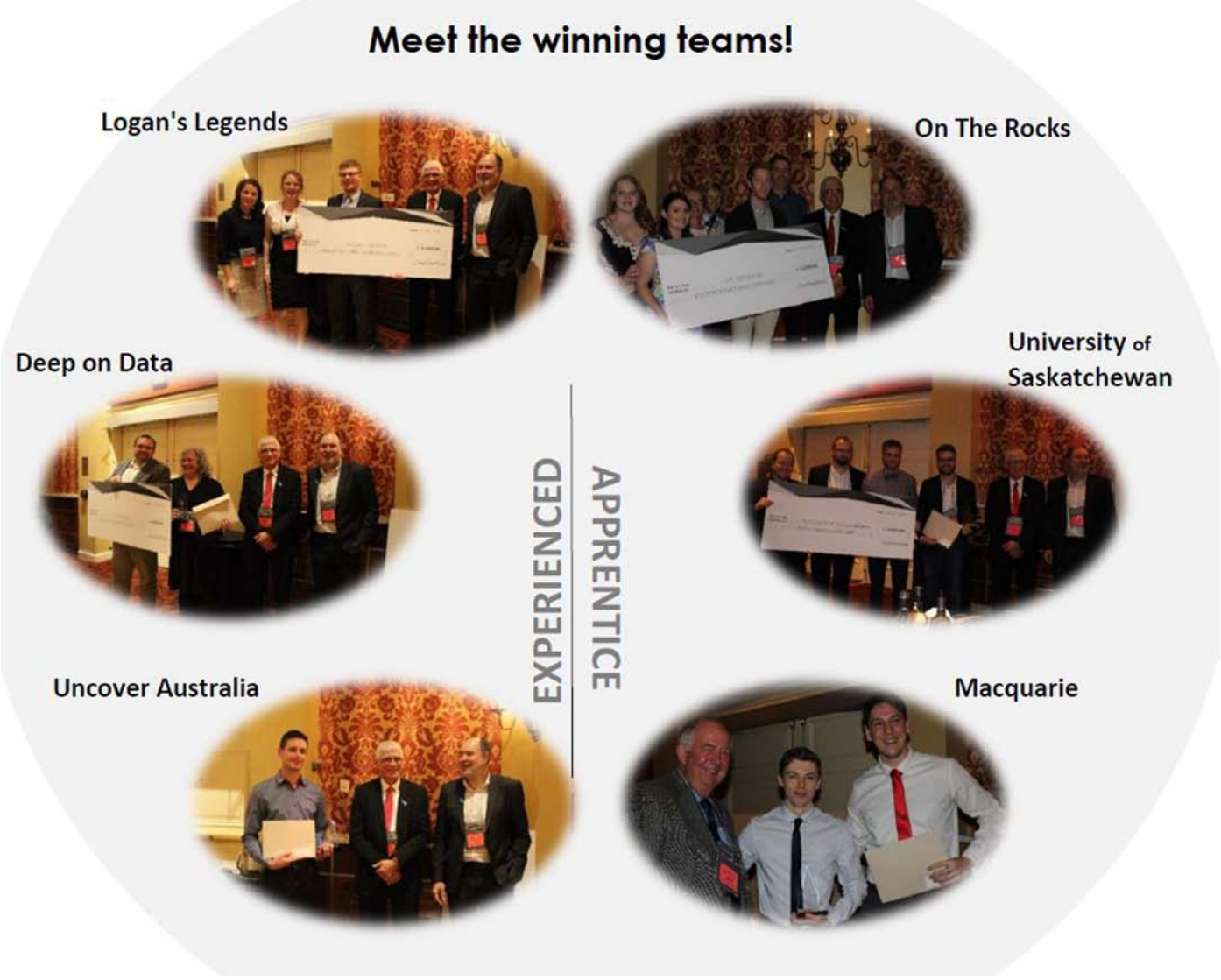

Frank Arnott Award 2018 – the winning teams receiving their awards at Exploration '17 in Toronto, Canada.

Broughton Edge: was he the father of exploration geophysics in Australia?

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Broughton Edge was the Director of the Imperial Geophysical Experimental Survey (IGES) (1928–30) and, subsequently, the co-author of the report on the IGES (Broughton Edge and Laby, 1931). As the IGES was responsible for the first serious use of a number of geophysical methods in Australia, does this make Broughton Edge the 'father of exploration geophysics in Australia'? Could the term 'father' refer to his production of 'sons' amongst the Australian staff of the IGES? This claim has been made of his behalf. Johan de Beer, in his review of early mining and mineral exploration geophysics in southern Africa, stated "Interestingly enough, Broughton-Edge is regarded as the father of exploration geophysics in Australia" (de Beer, 2011). Can this claim be substantiated?

To begin with, what is his name?

His name is variously written as:

'A B Broughton Edge', as in the title page and the "List of Contributors" to the report on the IGES (*op cit*).

'A Broughton Edge' as signed by himself in his Chairman's report to the IGES report and as referred to by A C D Rivett, in his Preface to the IGES report.

'Edge' only, by others (Day, 1966–67; Rayner, 2007). Rayner's reference to the report of the IGES is, 'Edge and Laby, 1931'. To extend the variations further, Day's reference to the report is "Edge, A B B, and Laby, T H (eds.), 1931".

The initial 'A' is for "Arthur" and, oddly, the other initial 'B' is also for Broughton. His full name is, therefore, Arthur Broughton Broughton Edge.

A UK Birth Index for his birth has, "Edge, Arthur Broughton" and a Death Register has "Edge, Arthur B B", with the second 'B'.

As a witness to his father's death in 1951, he is listed as Arthur Broughton Broughton-Edge", with a hyphenated family name. Johan de Beer (de Beer, 2011), also refers to "Arthur Broughton-Edge" with a hyphen.

In the index to the IGES report, "Broughton Edge' is included, but also 'Edge, Broughton'.

I choose to use 'A B Broughton Edge' as it appears to be the most common usage in Australia.

All but one Australian newspaper referred to him as "Mr Broughton Edge". The one exception was "Sir Broughton Edge", although he was never knighted.

Existing biographies of Broughton Edge

Being an Englishman, Broughton Edge attracted only short entries in Australian dictionaries and biographies. My intention in this article is to expand on his biography from his time in Australia, and with a geophysical emphasis.

The short entry for Broughton Edge in the *Encyclopedia of Australian Science* (1993), states that he was born in the United Kingdom in March 1895, and died in the UK in October 1953. During his life, he served in the Royal Artillery from 1914 to 1918, obtained his BSc in 1922 from the Royal School of Mines, and practiced as a "consultant geologist *(sic)*" from 1922 to 1940. In addition, he became a Member of the Institute of Mining and Metallurgy, and received an MBE. His full name with affiliations could, therefore, be shown as "A B Broughton Edge, MBE, BSc, ARSM, MIMM".

For 'Published Resources', the above encyclopedia refers to his entry in *Physics in Australia to 1945* (Home, 1995) and also an entry in *Trove* (2009), National Library of Australia. *Physics in Australia to 1945* adds to his biographical details with three references to publications: his paper to the AusIMM in 1928 (Broughton Edge, 1928), his paper to the *Chemical Engineering and Mining Review* (Broughton Edge, 1931), and his co-editorship of the report of the IGES (Broughton Edge and Laby, 1931).

A search of his name in *Trove* and www.newspapers.com provides seven newspaper items (see Appendix 1), and an additional reference to his co-authorship of a book with Bruckshaw and Rayner, both prominent appointments to the IGES (Broughton Edge et al., 1931*a*)[1]. A search for this reference in the State Library of NSW revealed, instead, another publication by Broughton Edge and co-authors Ferguson and Shaw - also members of the IGES (Broughton Edge et al., 1931*b*)[2].

Broughton Edge's experience before coming to Australia

In the Introduction to the IGES Report (Broughton Edge and Laby, 1931, pp. 2–3), written by Broughton Edge, it is claimed that the Survey was in a strong position with regard to electrical methods "since the advantage of several years practical experience in Spain, Portugal and South Africa was available".

[1]This reference is a reprint of those sections of the IGES report on the subject of Electrical methods (Part 1 Ch. 2 and Part 2 Ch. 3).

[2]This reference is a reprint of the section of the IGES report on Electrical prospecting surveys in Australia (Part 1 Ch. 3).

It is not made clear in this Introduction if Broughton Edge had experience in Spain and Portugal, either alone or with others[3].

As for Broughton Edge's experience in South Africa, the Report of the IGES (*op cit*) states in a footnote to page 50 that A Broughton Edge, in 1925, devised a "three contact ratio arm bridge" for the A.C. Potential Ratio method and it "was first used in N. Rhodesia [now Zambia] during that year". Furthermore, de Beer (2011) states, "In 1925 and 1926, the British geophysicist *(sic)* Arthur Broughton-Edge conducted experimental geoelectrical surveys in the Northern Rhodesian (Zambian) Copper Belt" and supports this claim with a publication on the history of mining in Northern Rhodesia.

Also, the Introduction to the IGES Report (*op cit*, p. 3) states that "Mr S. H. Shaw, BSc, ARSM, AIMM, and Mr J. C. Ferguson, BSc, were approved [for the IGES], both of whom had two years' previous experience in South Africa". It is believed that these men were assistants to Broughton Edge in Zambia.

A footnote to page 237 of the IGES Report indicates that Broughton Edge devised self-potential equipment for use in Cyprus[4].

Such experience, particularly as it was with the electrical method, qualified Broughton Edge to fill the position of Director of IGES, as one criterion developed by the Sub-Committee of the Committee of Civil Research (Sub-Committee, 1927) was that "the geophysicist-leader should have a special knowledge of the electrical method and of electricity generally"[5]. The committee later conceded that "The number of such geophysicists is, however, strictly limited" and securing "a leader possessing the necessary …qualifications", will be "The most difficult problem". The appointment of Broughton Edge would therefore seem to be to his credit.

On the other hand, B W Butcher (1984, p. 34) reveals that A C D Rivett, who was then Chief Executive Officer of CSIR, "was skeptical about…the professional competence of Broughton Edge". Rivett was, however, persuaded by his superiors that Broughton Edge was "a consultant and not connected with any commercial organization" (presumably meaning that he was acceptable as an independent scientist).

The ship's passenger log of the 'Windsor Castle' has "A B Edge" arriving in London from Cape Town on February 6, 1928 and gives his intended address as "Council of Scientific and Industrial Research [CSIR], Australia House, London". Could this be where he was to be interviewed, or briefed, for the directorship of the IGES?

Broughton Edge's movements in Australia

The ship's log of the 'ss Orsova', which arrived in Fremantle from London on May 1, 1928, lists "Mr A Broughton-Edge" as being on board, and gives his last permanent address as "Africa"[6]. Evidence of his movements in Australia after disembarkation is provided in newspaper reports (see Appendix 1). From these we learn that just three days after arrival he was in Kalgoorlie, and then Melbourne, via Adelaide, on May 8. There he met the Australian Geophysical Executive Committee, the body with oversight of the IGES in Australia and which included H W Gepp and E C Andrews (more on these men and their relationships to the IGES is provided in Henderson, 2013 and 2017). We also learn he was in Brisbane on July 26.

On the 17 August 1928, Broughton Edge gave a lecture in Melbourne to the Australasian Institute of Mining and Metallurgy[7]. The lecture was summarised in a paper in the *Proceedings of the AusIMM* titled 'Geophysical prospecting' (Broughton Edge, 1928). Almost half of the twelve pages was devoted to electrical methods, by far the largest discussion of the five methods named. Radioactivity was given a short mention, as well as gravity and magnetics, but seismic was only listed and not discussed.

There is no evidence that Broughton Edge had experience in methods other than electrical and electromagnetic methods, and certainly not seismic. In his Introduction to the report of the IGES (*op cit*), Broughton Edge wrote, "This branch of geophysical work [seismic methods] was entirely in the hands of certain geophysical companies" (Broughton Edge and Laby, 1931, p. 3).

In general, "Broughton Edge joined T H Laby on a number of occasions in publicising the Survey [the IGES] and its likely benefits to groups whose influence and support were thought necessary to its success" (Butcher, 1984, p. 36).

On one occasion during the operation of the IGES, Broughton Edge met a delegation of local officials of Kadina, South Australia to explain why the IGES would not be surveying in their area. Perhaps to offer some hope for the future, it was reported that he "mentioned that a number of Australian university graduates that had been working with the [IGES] would continue with similar work if private enterprise should require it" (*The Kadina and Wallaroo Times*, 1929). Evidently, Broughton Edge thought the graduates in the IGES had learnt enough to be employable in the future.

I have not found a photo of Broughton Edge (other than one taken at his wedding in England in 1935 – see below). Granted, photos of geophysical surveys were not common at this time, but it is surprising that one was not thought appropriate, at least as a memento of his time in Australia.

Broughton Edge as a geophysicist – geophysical instrument developments

On ships' logs, Broughton Edge declared his occupation as 'geologist' (even on returning from Australia). No doubt the term 'geophysicist' was still new at this time, and not generally

[3]There is evidence of Broughton Edge having traveled in this area at this time. A search of ships' logs in the UK shows "Edge, Arthur, geologist", travelling from Lisbon, Portugal to London on the 'Desna' in May, 1922 and again on the 'Gelria' in July 1923.

[4]Cyprus was a British colony from 1925 and, therefore, a natural place for a British geologist to work.

[5]As to 'electricity generally', we learn below (see Broughton Edge as a geophysicist) that he developed and modified electrical equipment.

[6]We know from above that Broughton Edge did travel to London before coming to Australia, but apparently he did not consider his stay there, of only a few months, as 'permanent'. Note also the use of the hyphenated family name.

[7]Butcher (1984, p. 37) adds; "with the assistance of splendidly prepared slides which aroused great interest".

Photo of Muriel and Arthur B Broughton Edge at their wedding in 1935.

understood. Nevertheless, his appointment by the Sub-Committee (1927) was as a geophysicist. Some newspaper reports (see Appendix 1) have him, at least, as leader of a 'geophysical party'.

There are good reasons to describe Broughton Edge as a 'geophysicist' rather than a 'mining geologist'.

Firstly, the IGES report (*op cit*) has, in a footnote to page 50, that Broughton Edge, in 1925, devised a "three contact ratio arm bridge" for the A.C. Potential Ratio method and it "was first used in N. Rhodesia [now Zambia] during that year". For this, British Patent Application No. 19120/30 is held in his name (Broughton Edge, 1925). Figure 1 is a schematic of the principle of the A C potential ratio method showing the three ground contact electrodes, two 'ratio arms' and headphones to detect a balance in potential and phase. Figure 2 is a photo of the ratiometer in use with headphones (shown diagrammatically in Figure 1) and an amplifier[8].

Secondly, the IGES Report, in a footnote to page 237, states, "This instrument [referring to a potentiometer] and non-

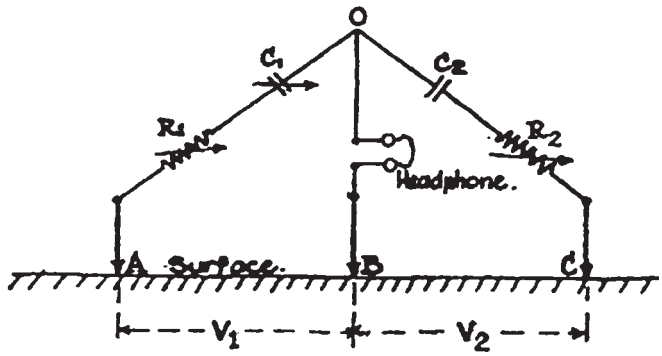

Figure 1. *A schematic of the principle of the A C potential ratio method, showing: three ground contact electrodes, A, B and C; two 'ratio arms', AO and CO and headphones in BO (from Broughton Edge and Laby, 1931, Fig. 31).*

[8]Can any reader identify the operator?

Figure 2. *A photo of the ratiometer in use with headphones and an amplifier on the operator's back (from Broughton Edge and Laby, 1931, Fig. 33).*

polarising electrodes… were designed originally by A Broughton Edge. Figure 3 is a diagram of the panel arrangement of the potentiometer (incorporating a galvanometer) for self-potential measurements. Figure 4 is a diagram of two types of non-polarizing electrodes with "Type A" designed by Conrad Schlumberger and "Type B" as modified by Broughton Edge to provide "increased stability and portability".

It is clear that Broughton Edge understood electrical methods and designed geophysical instruments; therefore, I contend that he should be called a geophysicist. He also co-authored a valuable compilation of current knowledge of most methods of exploration geophysics in the report of the IGES (Broughton Edge and Laby, 1931). His other publications and a patent are also the achievements of a geophysicist.

After Australia

The ship's log for the 'Alcantara' shows 'Arthur Edge, geologist', travelling from Lisbon to arrive in Southhampton on 5 June, 1931 and gives his 'Country of last permanent address' as Australia[9].

[9]Butcher (1984, p. 38) states that he "returned to the UK late in 1929". While it is possible that he left in that year, and may have visited Lisbon in transit, by giving Australia as his last permanent address he, presumably, didn't consider any other stop along the way as permanent.

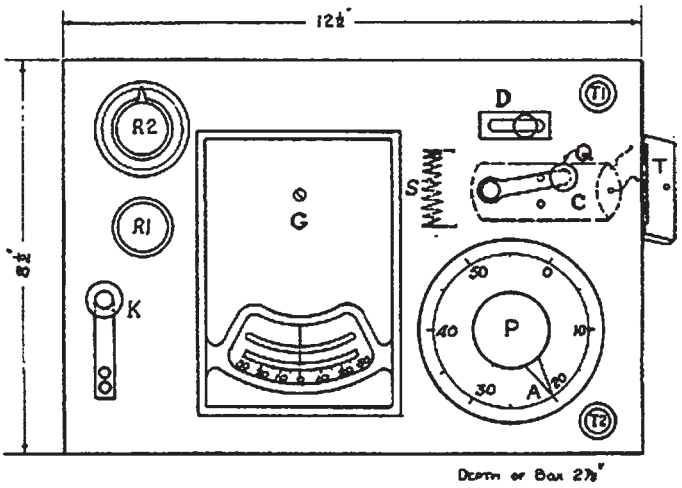

Figure 3. *A sketch of the panel arrangement of the potentiometer designed original by Broughton Edge, where G is a galvanometer and T1 and T2 are potential electrode sockets (from Broughton Edge and Laby, 1931, Fig. 179).*

Back in England, Broughton Edge (1932) presented a paper to the Royal Society of Arts on the general topic of geophysical methods (not just electrical methods as with his AIMM paper). In a preceding introduction to the author (by an unknown person), Broughton Edge is described as "one of the first British geologists *(sic)* to carry these methods into practice", a plausible claim. This continues with high praise for Broughton Edge including "when it was decided to send an expedition *(sic)* to Australia… there was no doubt that Mr. Broughton Edge was the man to lead it". His paper is described as "the first public opportunity…since the completion of the work [IGES] to testify to the smoothness and the skill with which the investigations were carried out".

In 1933, Broughton Edge was awarded the 'Lyell Medal' of the Geological Society of UK for his "significant contribution to the science by means of a substantial body of research". This was undoubtedly for his involvement in the IGES and the publication of its report.

The value of Broughton Edge to Australia

Broughton Edge was certainly the first British geologist to come to Australia with experience in exploration geophysics, at least in electrical methods. Although he was only in the country for two years, from 1928 to 1930, his leadership in the IGES provided training to a number of Australian graduates at that time. As we have seen, he believed those graduates would be capable of operating geophysical surveys by themselves and, indeed, some went on to conduct their own surveys. Later some of these graduates became section leaders in the Aerial Geological and Geophysical Survey of Northern Australia AGGSNA (1935–1940), and later in the Bureau of Mineral Resources (BMR). More on these subsequent exploits is given in Thyer (1979, pp. 246–9).

Also, Thyer (1979, p. 248) notes that "Three of the six geophysicists appointed [to the AGGSNA] had received their training with the IGES"[10]. In that sense, perhaps, Broughton Edge was a 'father' to these young trainees and, as such, the "father of exploration geophysics in Australia".

[10]These young geologists included, J M (Jack) Rayner, L A (Lew) Richardson, T F (Bob) Thyer, E L (Eric) Blazey, and N H (Norm) Fisher.

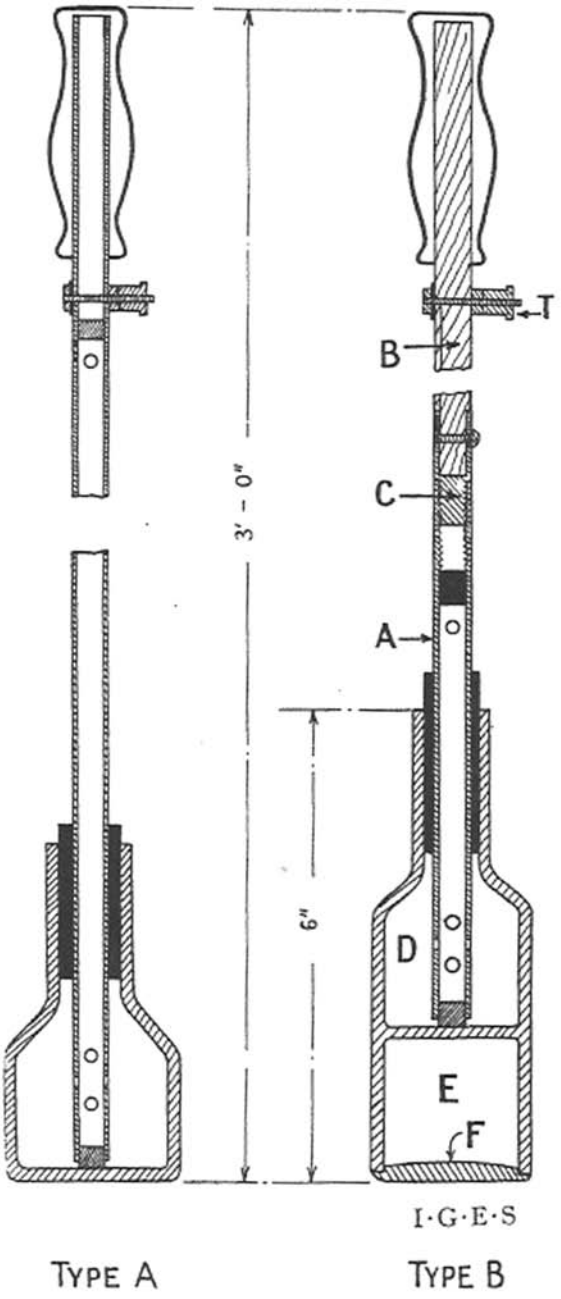

Figure 4. *Drawings of two types of non-polarising electrodes, Type A after C Schlumberger and Type B originally designed by Broughton Edge (from Broughton Edge and Laby, 1931, Fig. 180).*

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Appendix 1. Newspaper reports concerning Broughton Edge

The IGES had a high public profile from the time it was first mooted, gaining considerable exposure in newspapers. Not all reports are entirely reliable or original, but some reveal useful information. Those with reference to Broughton Edge are included here, with informative details underlined. See Appendix 2 for references given here.

The first mention found by the author of Broughton Edge in an Australian newspaper, is in the Murwillumbah *Tweed Daily* of August 8, 1927 (*Tweed Daily*, 1927). In 100 words, with a heading "Seeing Underground", it is reported that the then Prime Minister, Mr. Bruce, announced Australia's involvement in the IGES and that "Sir *(sic)* Broughton Edge, who is an expert in this form of scientific prospecting, would visit Australia next year to organize investigation by this means [the IGES] and also train Australian graduates".

On March 14, 1928, the Adelaide *Advertiser* newspaper in a short, 56 word article (*The Advertiser*, 1928), reported that "Mr Broughton Edge of the London *(sic)* School of Mines, will arrive in Australia shortly". "He will be assisted by several specially selected Australians".

After his arrival in Australia, the following newspaper reports allow us to follow Broughton Edge's progress through key cities in 1928.

On May 5, 1928, *The Sydney Morning Herald* has two separate items on page 18 referring to Broughton Edge (*The Sydney Morning Herald*, 1928). One item of 320 words under the heading "A hopeful experiment", reported that "Mr A. Broughton Edge" was the leader of the survey party and that he was at present in Australia.

Also on the same page, in a 150 word article headed "Geophysical Survey. Expert's arrival. Kalgoorlie" (*op cit*) it was reported that "Mr Broughton Edge, leader of the geophysical *(sic)* party arrived in Kalgoorlie yesterday [May 4], and left for Melbourne to-day, where he will confer with the Commonwealth authorities…". "Whilst in Kalgoorlie he spent most of his time inspecting the mines". That evening he was given a civic reception by the Mayor of Kalgoorlie who "expressed the hope that the Federal authorities would decide to commence …on the Golden Mile" (the gold mine at Kalgoorlie). Broughton Edge, it is reported, said "nothing would give him greater pleasure", but that "He could not say, however, what his programme would be until he consulted the Federal authorities". This was a suitably diplomatic reply at this early stage. As it transpired, the only IGES survey made in WA was in the Northampton mineral field, near Geraldton, 475 km north of Perth, using electrical methods.

The Kalgoorlie *Western Argus* of May 8, 1928, in an article giving much more space (1100 words) to the "civic reception" in Kalgoorlie, reported that the reception was in the presence of over 20 people including members of the WA Chamber of Mines and WA School of Mines (*Western Argus*, 1928). Mr Broughton Edge was introduced as "one of the world's leading authorities on the comparatively new science of geophysics". This was prior to his departure on the "trans-Australian train" (he later arrived in Adelaide on or before Monday May 7 and Melbourne on May 8).

On May 9, 1928, *The Argus* of Melbourne reports that Broughton Edge arrived in "Melbourne from Adelaide yesterday morning" (*Argus*, 1928). Its 490 word article largely repeats earlier reports but advises that "He had conferred with the Government geologists in Western Australia and South Australia and would consult the Government geologists in each of the other States before beginning operations". A piece of confirmatory information here is that Broughton Edge "arrived in the Commonwealth three weeks before …Mr S. H. Shaw, one of Mr Edges's assistants".

On May 28, 1928, the *Examiner* newspaper, of Launceston, in 127 words, reports that "Applications are now being invited in Australia for the appointment of physicists, geologists and surveyors". "…several members [of the party] are yet on the water between England and Australia. The first of these, Mr. J. C. Ferguson, a highly trained assistant who has spent some years

with Mr. Edge in Rhodesia, is on the Orvieto…" (*Examiner*, 1928).

On July 26, 1928, the *Brisbane Courier*, in 137 words, reported that Broughton Edge "conferred" with the [Queensland] Minister for Mines (Mr A J Jones) together with the Chief Geologist, Mr B Dunstan. Also, "He will attend a special meeting of the Queensland Oil Board" (*Brisbane Courier*, 1928).

Appendix 2. References for newspaper articles

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June	**2018**		
10–13	The 8th International Conference on Environmental and Engineering Geophysics (ICEEG)	Hangzhou	China
10–16	16th Castle Meeting – New Trends on Paleo, Rock and Environmental Magnetism http://castle2018.igf.edu.pl	Chęciny	Poland
11–14	80th EAGE Conference & Exhibition 2018 http://www.eage.org/	Copenhagen	Denmark
18–21	GPR 2018 https://www.gpr2018.hsr.ch/	Rapperswil	Switzerland
22–24	Global Symposium on Millimeter Waves (GSMM) 2018 http://www.gsmm2018.org	Boulder	USA
July	**2018**		
23–25	URTeC http://urtec.org/2018	Houston	USA
August	**2018**		
5–7	2018 SEG Reservoir geophysics workshop https://seg.org/Events/Events-Calendar/Reservoir-Geophysics-Workshop	Daqing Oilfield	China
27–29	EAGE/SEG Workshop on Marine Multi-Component Seismic https://events.eage.org/	Kuala Lumpur	Malaysia
September	**2018**		
2–7	36th General Assembly of the European Seismological Commission http://www.escmalta2018.eu	Valletta	Malta
3	The International Conference on Magmatism of the Earth and related Strategic Metal Deposits http://magmas-and-metals.ru/	Moscow	Russia
10–12	Near Surface Geoscience 2018 https://events.eage.org/	Porto	Portugal
23–25	SPE Annual Meeting http://www.atce.org	Dallas	USA
24–27	43rd HAGI Scientific Annual Meeting http://events.hagi.or.id/2018/	Semarang	Indonesia
October	**2018**		
1–3	Future Energy Africa 2018: Conference and Exhibition https://www.futureenergyafrica.com/	Capetown	South Africa
14–18	AGC Convention http://www.agc.org.au	Adelaide	Australia
14–19	SEG Annual Meeting https://seg.org/Annual-Meeting-2018	Anaheim	USA
November	**2018**		
4–7	2018 GSA Annual Meeting https://www.geosociety.org/GSA/Events/Annual_Meeting/GSA/Events/gsa2018.asp	Indianapolis	USA
4–7	AAPG International Conference & Exhibition 2018 http://capetown2018.iceevent.org/	Capetown	South Africa
12–14	13th SEGJ International Symposium http://www.segj.org/is/13th/	Tokyo	Japan
13–15	Fourth AAPG/EAGE/MGS Myanmar Oil & Gas Conference	Yangon	Myanmar
December	**2018**		
10–14	AGU Fall Conference	Washington, DC	USA
May	**2019**		
19–22	EM 2019 Xi'an	Xi'an	China
September	**2019**		
15–20	SEG International Exposition and 89th Annual Meeting	San Antonio	USA

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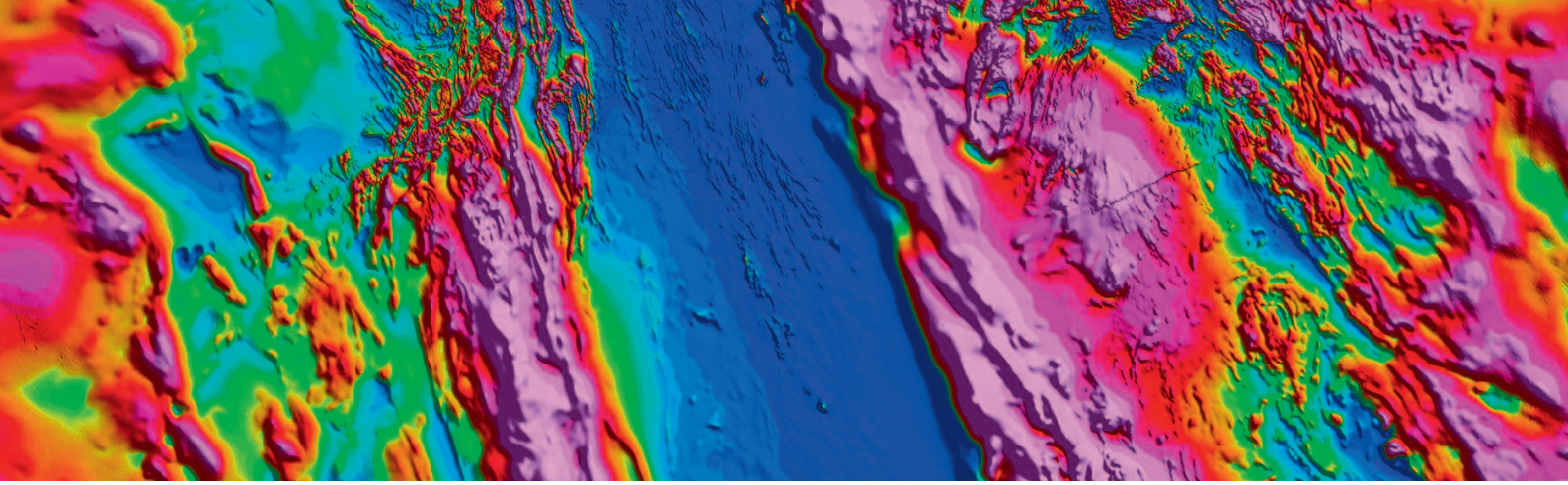

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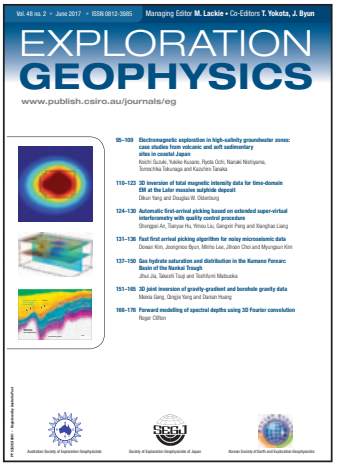

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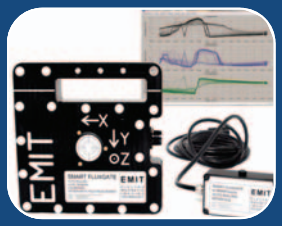

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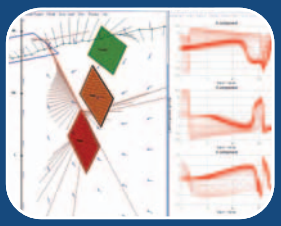

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