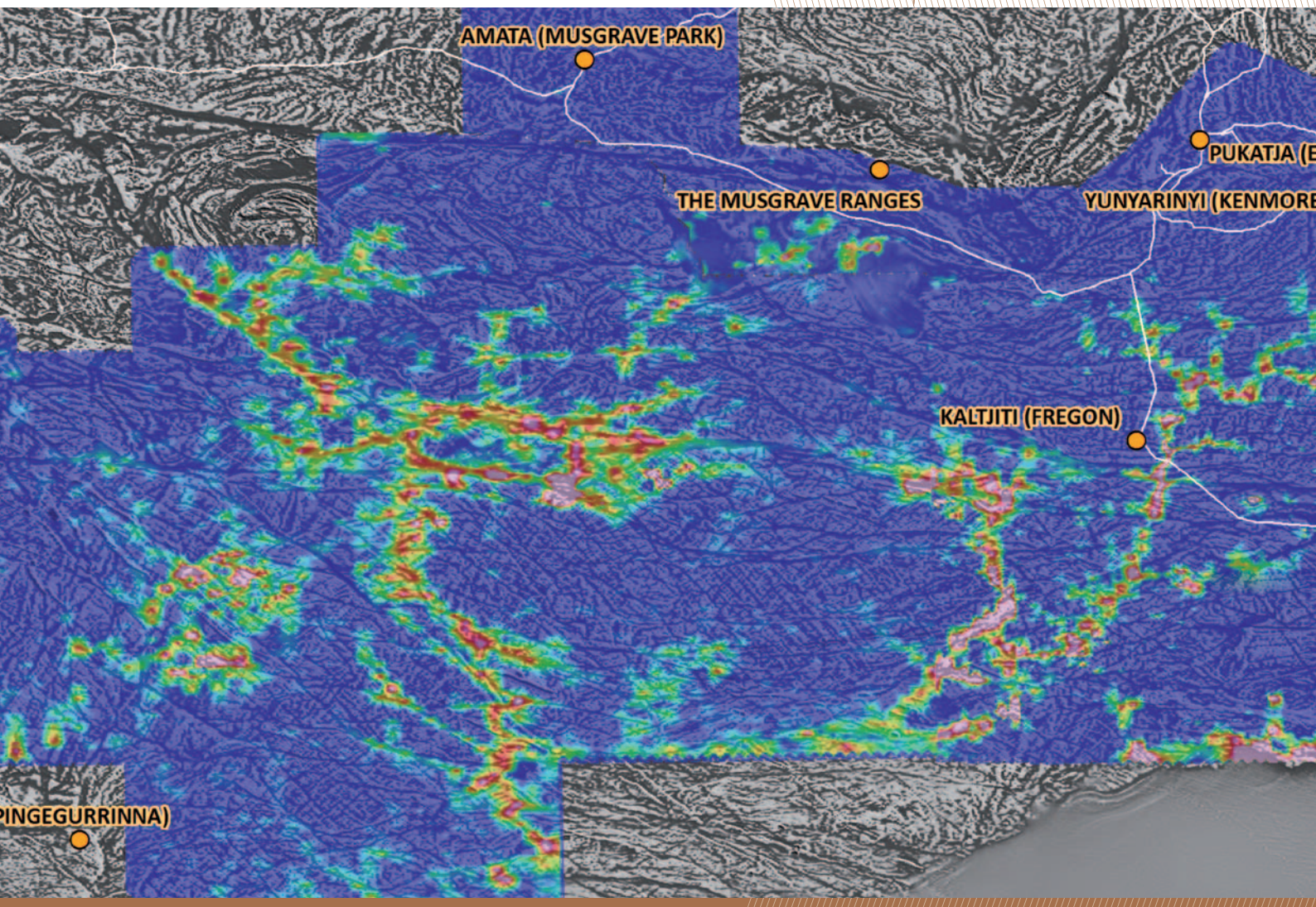
Australian Society of Exploration Geophysicists

OCTOBER 2017 • ISSUE 190
ABN 71 000 876 040 ISSN 1443-2471

PREVIEW



NEWS AND COMMENTARY

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ASEG CORPORATE PLUS MEMBER

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2017 ASEG CORPORATE PLUS MEMBER

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FRONT COVER

A portion of the *PACE* Copper Musgraves AEM survey data recently released by the Geological Survey of South Australia. For more information see *Geophysics in the Surveys* in this issue of *Preview*.

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

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Editor's desk

This issue of *Preview* features the second part of Roger Henderson's article on the state of exploration geophysics in Australia prior to the IGES, 1928–30. Part One prompted a number of readers to start a conversation with Roger about the history of exploration geophysics, and new information is being brought to light. Roger shares the outcome of one of these conversations in a *Letter to the Editor*.

This issue also features a consideration of the impact of sampling on precision by Stefan Elieff. This piece was prompted by recent airborne gravity surveying in WA. Not only GSWA but Geoscience Australia and most of the other state surveys are pouring money into airborne geophysical data acquisition, and the results would be astonishing to pioneers of exploration geophysics operating in Australia less than 100 years ago. Our cover features an AEM survey over the Musgraves funded by GSSA. The palaeochannels in this vast, largely unexplored area have been revealed with astonishing clarity.

As always, our regular commentators do not disappoint. David Denham (*Canberra observed*) shares some good news about the recovery of minerals and petroleum exploration and the support being offered by the Federal Government to Junior Explorers (did someone say 'flow-through shares'?). Michael Asten (*Education matters*) highlights networking opportunities for students and reminds all students completing their theses in 2017 to send a summary of their work to *Preview* for publication in the December issue. Mike Hatch (*Environmental geophysics*) had some good feedback on his article about drones in the last issue, and convinced one of his correspondents, Andrew Foley, to share his story about using drones to acquire high resolution magnetic data over Lake Lefroy in WA. Terry Harvey (*Mineral geophysics*) has taken time out from his wanderings in deepest darkest Africa to remind us about the dangers of lies, dammed lies and colour stretches, and Mick Micenko (*Seismic window*) takes a good hard look at faults.

The results of the 2017 ASEG Membership survey also appear in this issue. The ASEG has over 1000 Members and more than 400 completed the survey – a response rate of around 40%. FedEx included a number of specific questions about *Preview*. It would seem that most respondents (312 or 78%) are pretty happy with *Preview* as it is; however, some respondents (77 or 19%) felt that some improvements could be made. Well, there is always room for improvement, and we are carefully reviewing all suggestions. Most of these relate to improving our coverage of news, particularly company news. So, if you have your finger on the pulse of companies in the minerals and/or energy sectors, and are willing to report to *Preview* readers on a regular or semi-regular basis, I would like to hear from you! I would also like to hear from the Member who suggested a comic strip – we have the space if you have the talent!

Lisa Worrall
Preview *Editor*
previeweditor@aseg.org.au

Letter to the Editor

Dear Lisa

In my article in the last issue of *Preview* (189, pp. 42–49) I considered what might be the earliest applied geophysics survey in Australia. I quoted Thyer, who suggested it might have been by Dodwell with his magnetometer measurements in the Musgrave Ranges in 1915.

However, Doug Morrison, whom I should always consult beforehand in future (!), has made me aware of a relatively recent paper (Vernon, 2010) that describes surveys for mineralisation in parts of Australia from as early as 1903. These used an instrument called 'Electric Ore-Finder', which was invented by Leo Daft and Alfred Williams in England in 1900 and from its description appears to be the equipotential method (perhaps first ever use of this method).

According to Vernon, the 'Electric Ore-Finder' was brought to Kalgoorlie in August 1903 by Ernest Lidgey, an Australian mining geologist, and used on various parts of the goldfield before being taken in 1904 to Ballarat, Vic., Cobar, NSW (where the rights to use it in Australia were acquired by Cobar Corporation) and later Kapunda and Moonta in SA.

While I have not verified this claim, if true it would certainly be the earliest survey known to me. Unfortunately Vernon says that no documentation of survey results has been found from any of the surveys. Should this then be regarded as the first in Australia even if there are no results available?

It is intriguing that Thyer, and any of the other authors of Australian geophysics history known to me – such as Day or Doyle, did not refer to the use of 'Electric Ore-Finder' in Australia. Was it because it never achieved any success, at least any that was worth documenting? Or were the results kept confidential to the users? Certainly Vernon reports that the last known survey in Australia in 1907 in Moonta, SA 'was apparently a failure, as no identified veins were proved underground'. A strong possibility is that by using AC input, and not DC input as preferred by Conrad Schlumberger, Daft and Williams' results were affected by coupling.

Incidentally, Doug Morrison claims from his studies of Dodwell's exploits (see Morrison, 2005) that he had planned, at least, to observe more than just regional magnetics in the Musgrave Ranges.

Regards

Roger Henderson
rogah@tpg.com.au

References

Morrison, D., 2005, George Dodwell and some geophysical co-operation: *Preview*, **117**, 17–20.

Vernon, R. W., 2010, Alfred Williams and Leo Daft. Pioneers in geophysical prospection for minerals: *Proceedings of the International Commission on the History of Geological Sciences (INHIGEO) Annual Conference*, Madrid, Spain, July 2010.

President's piece

Andrea Rutley

As geophysicists we are accustomed to the cyclical nature of the commodity business. Those of us who have been around for a few years, or many years, would have lost count of the number of these cycles that we have seen. Whilst globalisation brings many advantages, it also brings us challenges, as our industry becomes vulnerable to a wider range of external forces; many of which are very difficult to predict. Marketing departments in our resource companies are continually working with clients to optimise products, and are frequently working with a crystal ball to determine the next global commodity challenge.

How do we stay ahead of the cycles, remain relevant and technically valued? We should be able to look to our professional societies to assist us and the ASEG recognises that it can play a key role. We need to remain focussed on working with our Members to provide the best information about the most relevant technical advancements. To remind everyone, the ASEG has four key aims:

- 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.

Our recent Member survey supplied a fantastic amount of detailed feedback on how our Members believe we are performing as a technical society; in relation to these aims, as well as what we need to do to improve our service to our Members and to the broader public. This edition of *Preview* contains graphical representations of the results and allows you to draw some of your own conclusions. There will be actions generated as a result of the survey and many of the suggestions will be worked on in a way that will ensure that ASEG remains relevant to our Members.

If I could highlight a few of the conclusions from the survey, it would be that:
Members are very keen to see an increase in communication between ASEG and the broader public. This topic was the focus of discussion at a recent Brisbane PESA Symposium, after Bruce Holland from Norwood Resources (https://thenorwoodresource.org.au) gave a presentation. Norwood Resources is a group that is dedicated to sharing oil and gas industry facts with the public in such a manner that the community is made aware of the facts behind the industry, rather than just the information provided by various lobby/interest groups. Our Members feel that there is a need for the ASEG to be able to act in a similar way and, as part of the work on the results from the survey, we will look at how we can best achieve this.

Members also expressed the sentiment, via the survey, that the ASEG should provide greater support for its retired or currently unemployed/self-employed Members, particularly in relation to reduced rates for conferences and workshops. It is timely to remind all Members that the ASEG will consider all hardship cases for membership dues, and other aspects of ASEG activity, on a case by case basis, and all conversations are held in the strictest of confidence. For any questions or discussion in relation to this, please email membership@aseg.org.au.

The ASEG is also aware that it has a responsibility to its Members to assist, where possible, in the search for employment, and has an 'Employment' section on the website where, governed by the Job Advertising Policy, Members can advertise vacant positions and job seekers can send a message to ASEG to show they are actively looking for employment (https://www.aseg.org.au/employment/job-seeker). Take some time to have a look around the website and re-familiarise yourself with the options.

Some positive feedback from the survey is that many of our Members are keen to act as mentors for the recently graduated geophysicists. This is fantastic, as it is our younger Members that must become actively involved in the running of the ASEG to ensure its relevance and ongoing survival. Perhaps it is our younger and thirstier Members who also suggested beer can holders! That will be an easy action to implement and clearly a crowd pleaser.

Finally, thanks to everyone for taking to the time to share their thoughts via the survey and we look forward to sharing with you all how we are going to act upon your feedback.

Andrea Rutley
ASEG President
president@aseg.org.au

Welcome to new Members

The ASEG extends a warm welcome to nine new Members approved by the Federal Executive at its August and September meetings (see table).

First name	Last name	Organisation	State	Country	Membership type
Iain	Campbell	Department of the Premier and Cabinet (Government of South Australia)	SA	Australia	Active
Oliver	Capaldo	The University of Adelaide	SA	Australia	Student
Arnold	Getz	Retired	NSW	Australia	Associate
Tenyears	Gumede	Knowledge Factory		Zimbabwe	Active
Kade	Hancock	The University of Newcastle	NSW	Australia	Student
Marcus	Haynes	Australian National University	ACT	Australia	Student
Joseph	Ma	National University of Singapore		Singapore	Student
Jason	Storey		WA	Australia	Active
Ahmed	Tahir	Ministry of Energy and Minerals	Maroodi Jeex	Somalia	Associate

ASEG Federal Executive 2017–18

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Email: president@aseg.org.au

Marina Costelloe: President Elect
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Megan Nightingale: Secretary
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Email: fedsec@aseg.org.au

Danny Burns: Treasurer (Finance Committee Chair)
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Email: treasurer@aseg.org.au

Katherine McKenna: Past President (Membership Committee, International Affairs Committee, ASEG RF)
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Emma Brand (Education Committee Chair)
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Conference Advisory Committee Chair:
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Email: cac@aseg.org.au

Honours and Awards Committee Chair:
Andrew Mutton
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Research Foundation Chair: Philip Harman
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Email: research-foundation@aseg.org.au

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Executive brief

The Federal Executive of the ASEG (FedEx) is the governing body of the ASEG. It meets once a month, via teleconference, to see to the administration of the Society. This brief reports on the last monthly meeting, which was held in August.

Society finances

The Society's financial position at the end of July 2017:

Year to date income $207 256

Year to date expenditure $253 904

Net assets $1 030 192

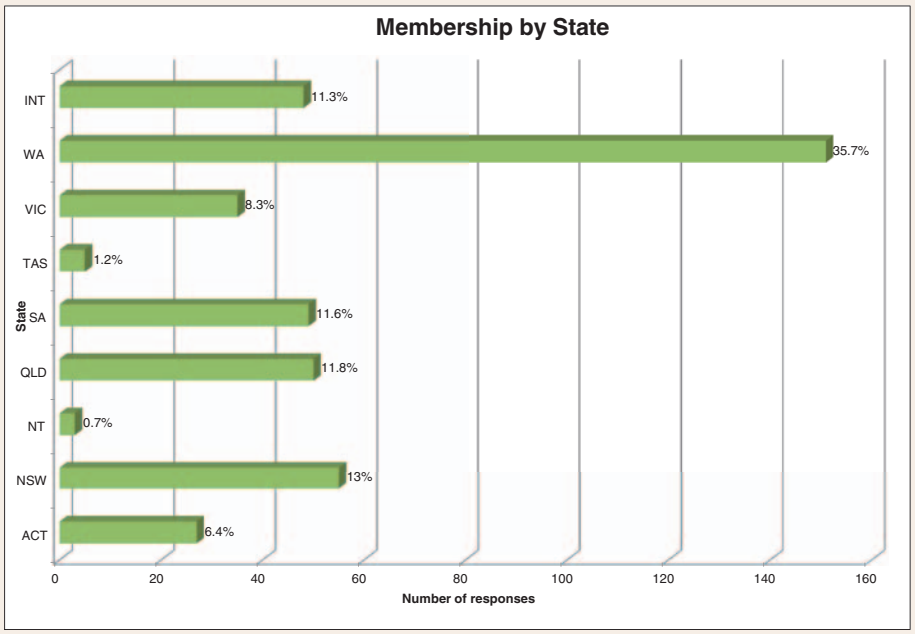
2017 Membership survey results

The 2017 Membership survey was a great opportunity to have your say, and over 400 Members did just that. Please find below some of the major results and findings. Thank you to everyone who contributed to the survey as your feedback is invaluable. Particular thanks go to those Members who have nominated to contribute to the Society by joining a committee, being a mentor or volunteering to present at branch events.

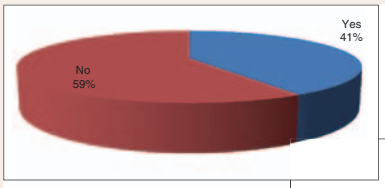
Your local state branch will be given more details about these survey results and may decide to run a more focused and much shorter survey to gauge their Member's interests. We invite you to contact your local branch president if you have any concerns, comments or ideas after reading the 2017 Membership Survey Results.

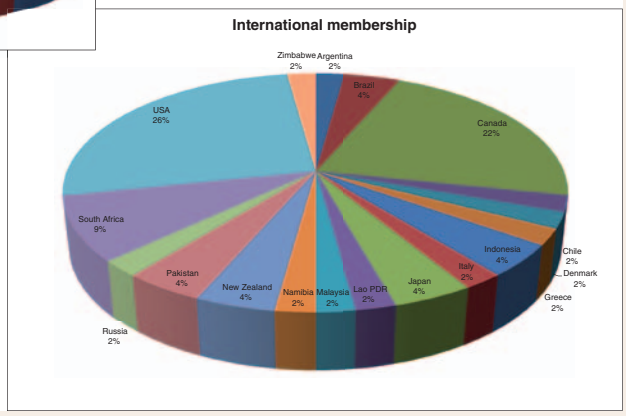
Stay tuned to *Preview* to find out more about how the ASEG are responding to your suggestions and improving the ASEG for all Members.

Question 1: In which state/country is your membership held?



Question 2: Does the new ASEG policy of lower membership fees in developing countries encourage you to keep your membership?

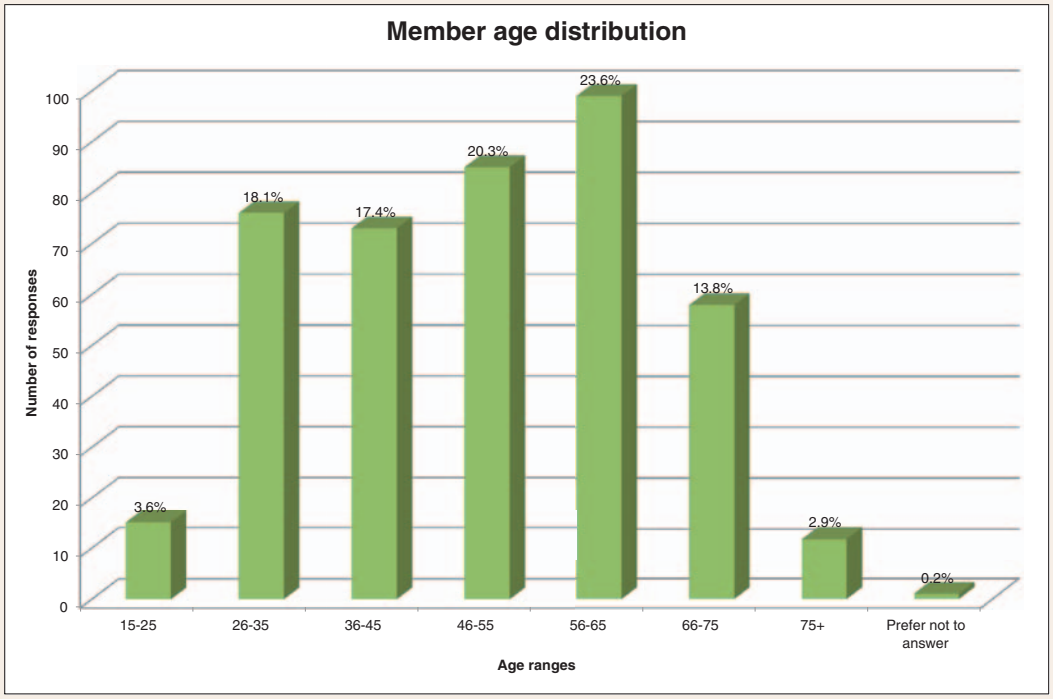




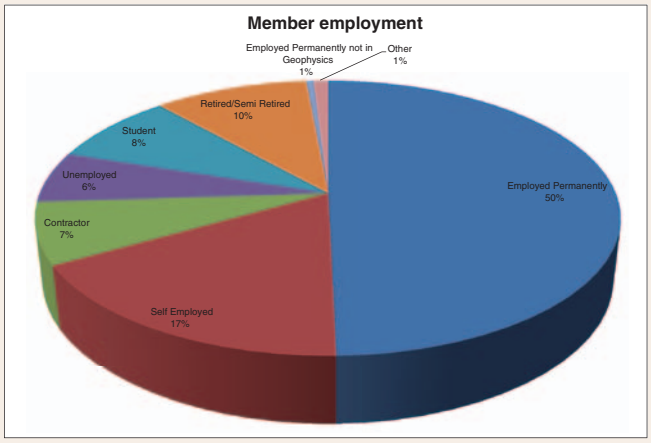
Question 3: What is your gender?

- 346 (86%) male
- 65 (15%) female
- 8 (2%) other/prefer not to answer

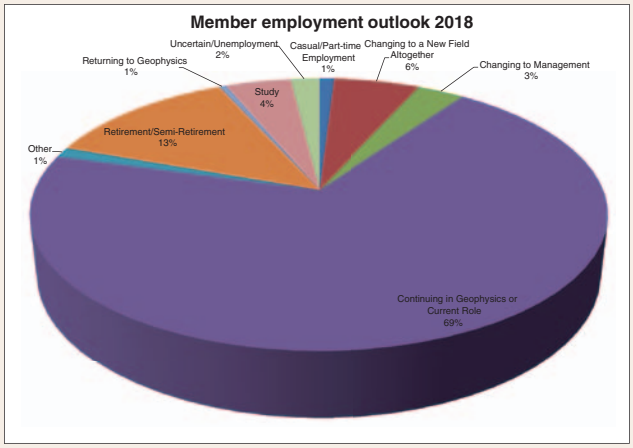
Question 4: Please let us know your age.



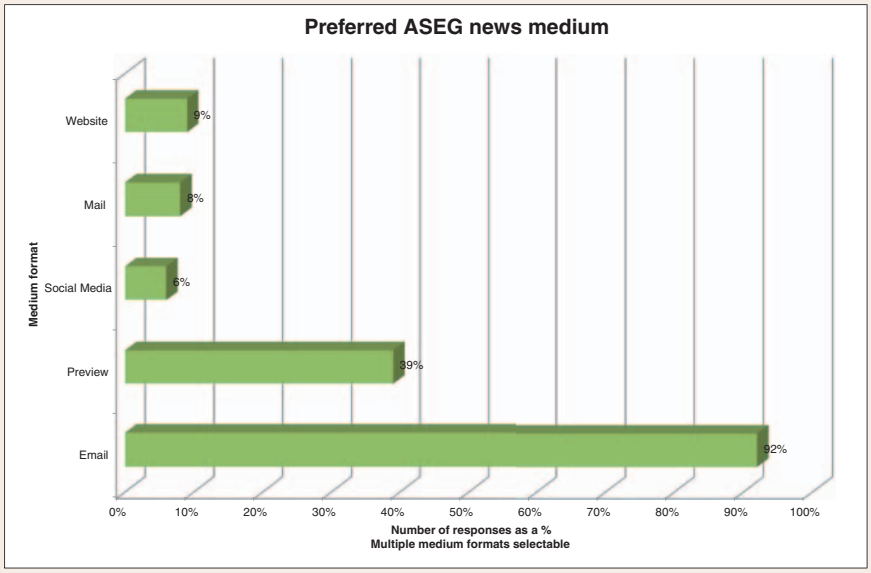
Question 5: Employment, are you…



Question 6: Employment, how do you see the next 12 months?



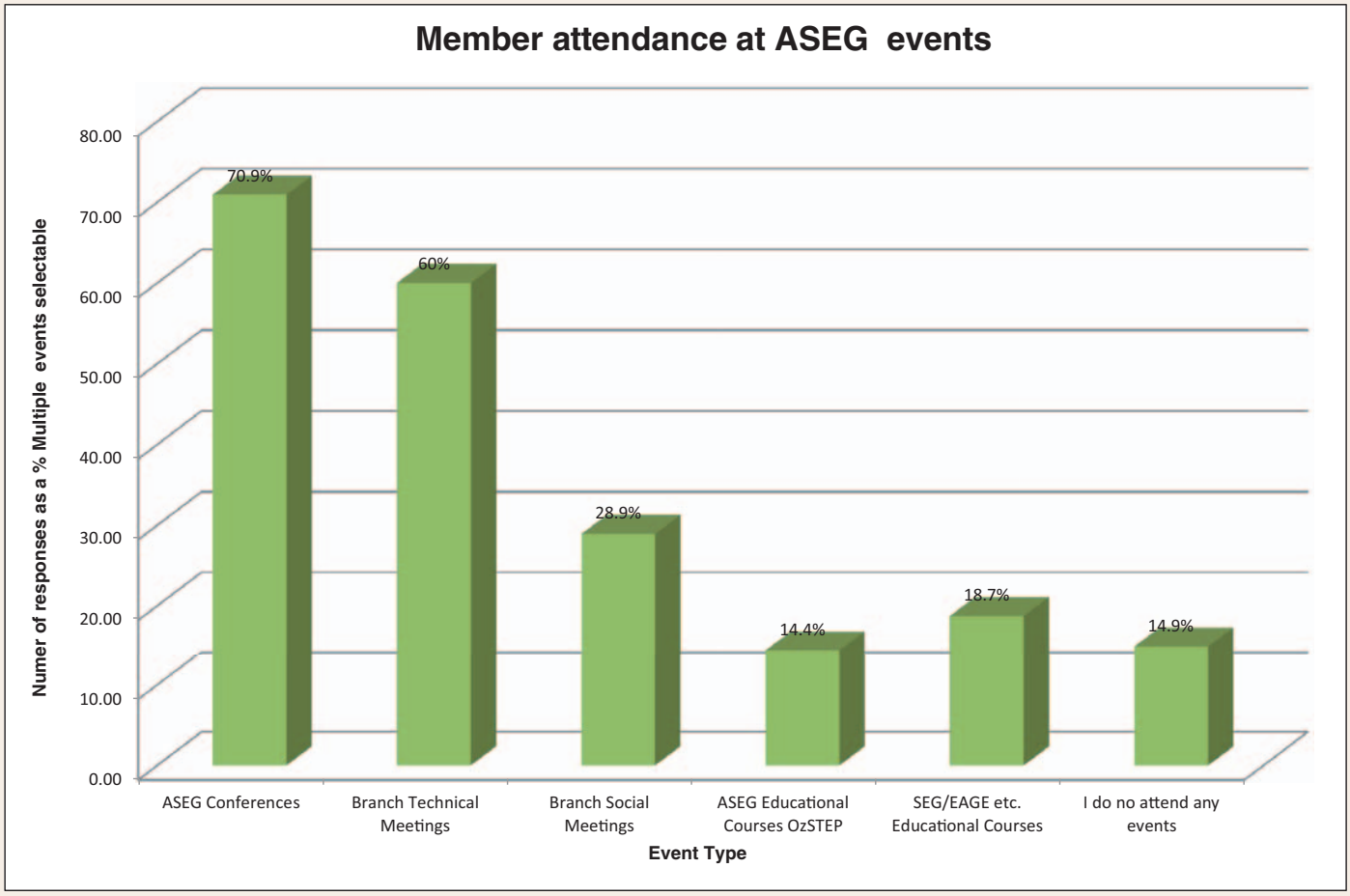
Question 7: How do you prefer to receive news from the ASEG?



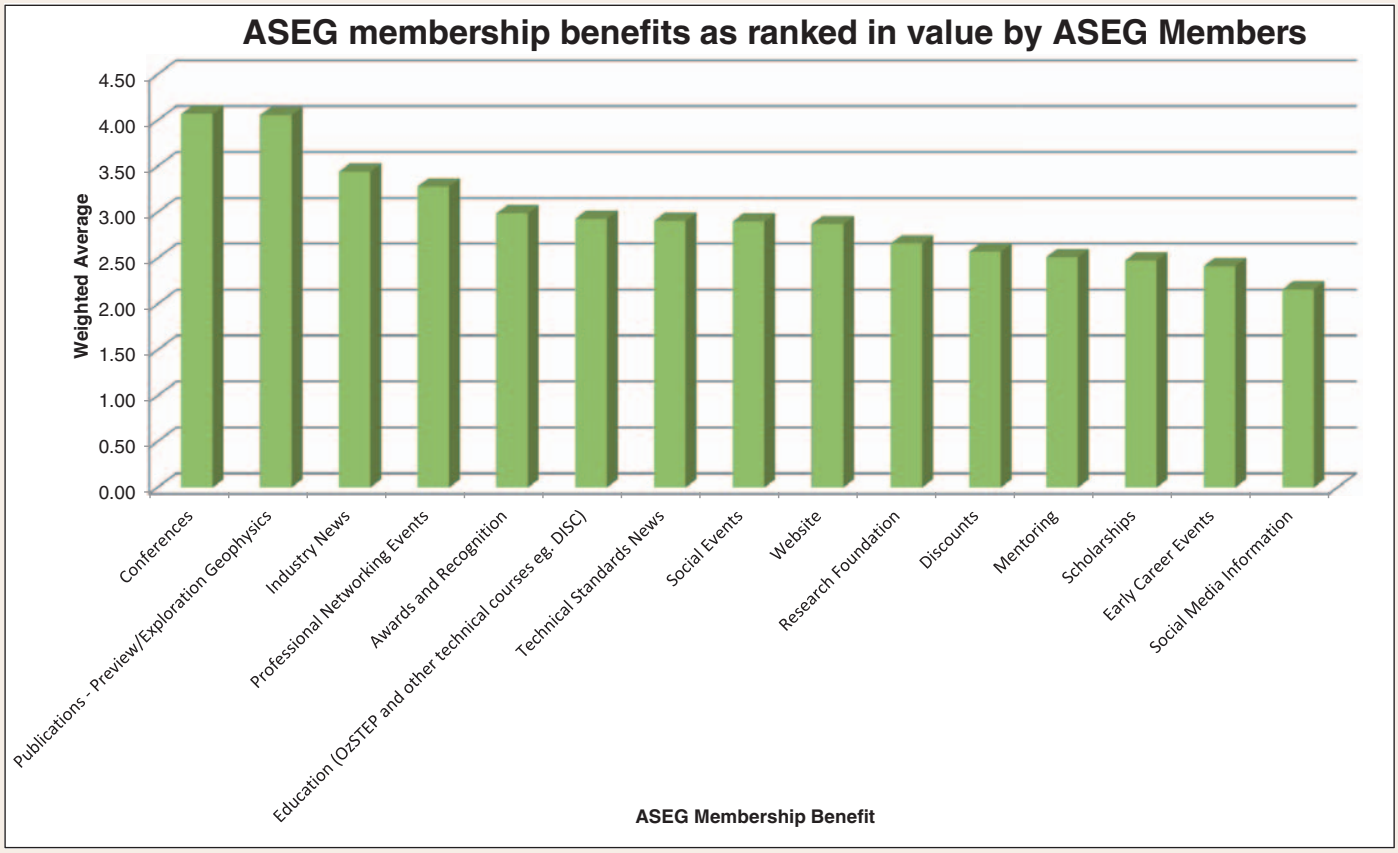
Question 8: Other societies distribute regular email news to Members, bundling all their activities in one email newsletter. Would you like the ASEG to do this as well?

- 323 (80%) Yes responses
- 79 (20%) No responses

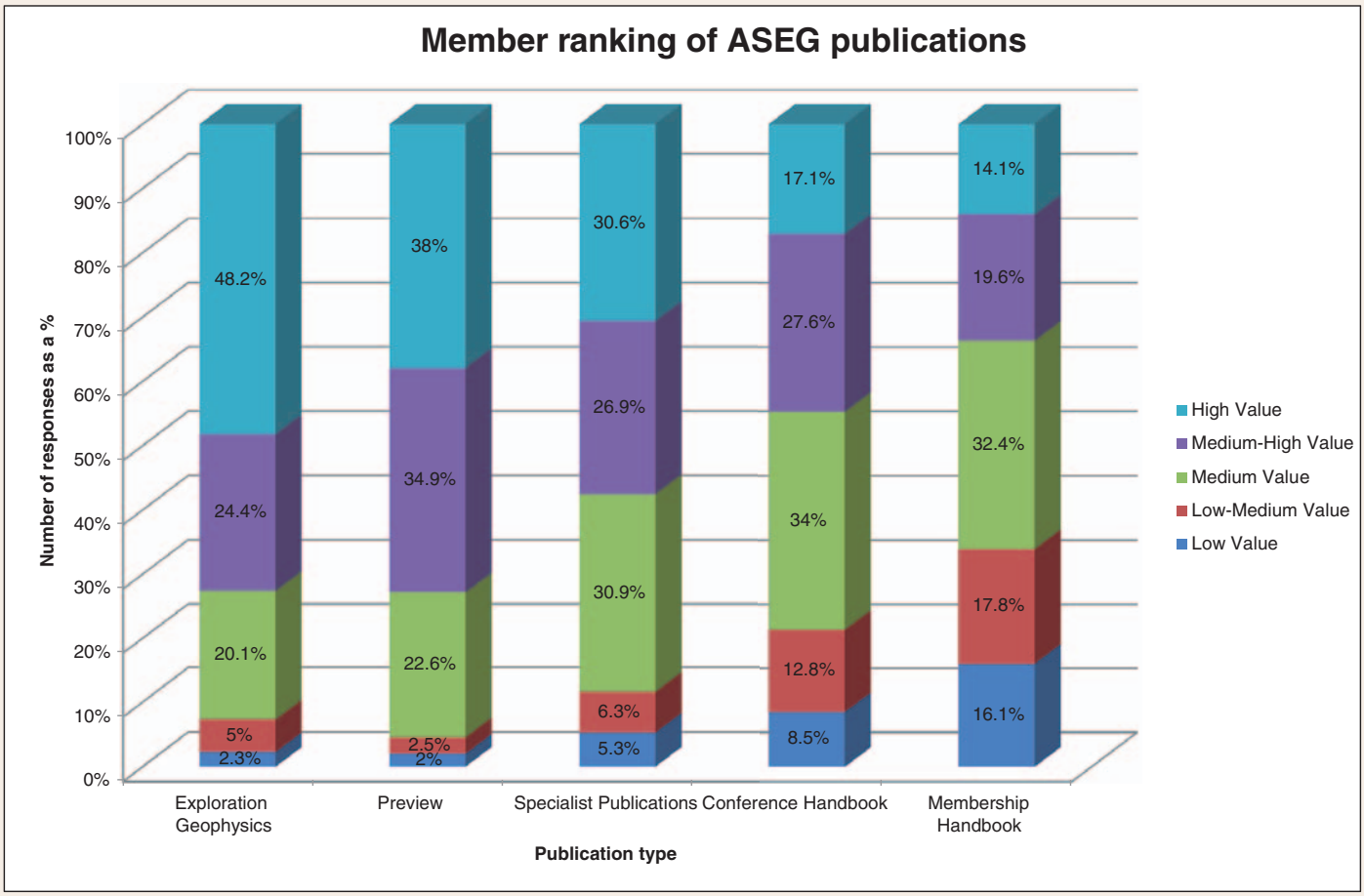
Question 9: Do you attend any of the following ASEG events?



Question 10: Please indicate the value of the following ASEG membership benefits based on you and your career.

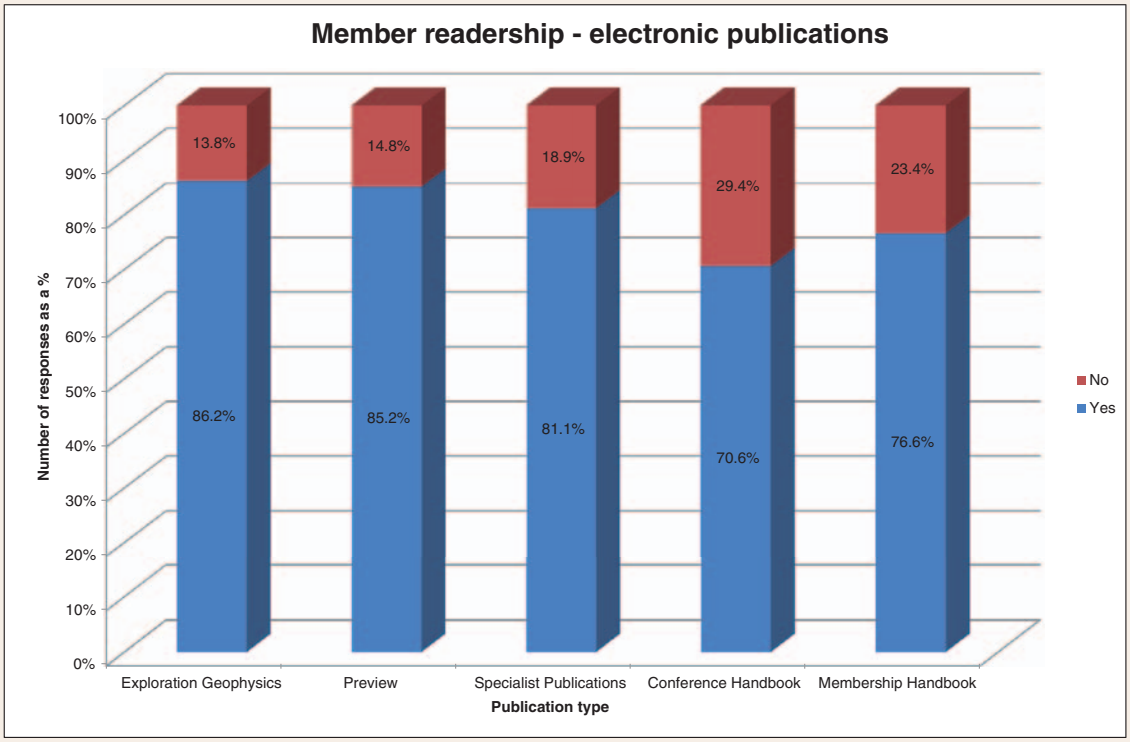


Question 11: Please rank the following ASEG publications.



Question 12: Would you continue to read these publications if they were only available electronically?

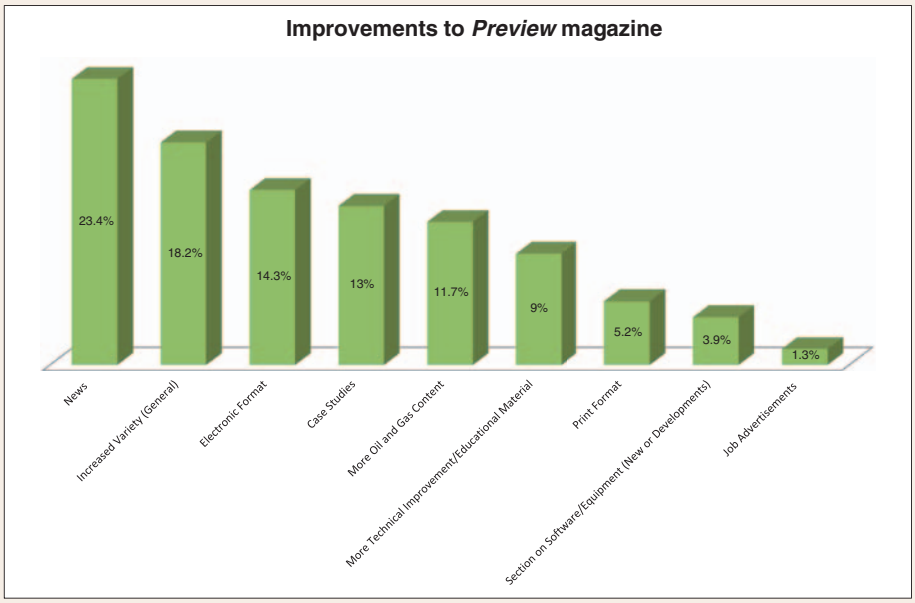
- Some Members have said that this impact could be reduced if an app was tailor made for *Preview*.
- Most comments indicate that our Members are comfortable with using, or are already using, a digital format to read articles in *Exploration Geophysics*; they use it as a research tool and are generally looking for specific topics/articles.



Question 13: Are there any improvements you would like to see in the Preview *magazine?*

- 312 (78%) No responses
- 77 (19%) Yes responses
- 4 (1%) Don't receive it
- 5 (1%) Don't read it

Question 13: Are there any improvements you would like to see in the Preview *magazine? Detailed comments from the 77 'Yes' respondents.*



Question 13: Are there any improvements you would like to see in the Preview *magazine? Detailed comments from the 77 'Yes' respondents.*

News

- Company news
- Oil/mineral discoveries
- University news
- Social news e.g. retirement of prominent geophysicists

Increased variety

- Themed issues
- Interpretation features
- Near-surface geophysics
- IP
- Rock properties
- TDEM
- Climate change/topical issues
- Global research
- Student papers
- Geophysicist features
- Company histories
- Equipment history
- Tips from older members on how to survive the boom and bust of our industry
- A comic strip

Electronic format

- See improvement through turning the publication electronic e.g. links to references
- Would like and use a phone app to read

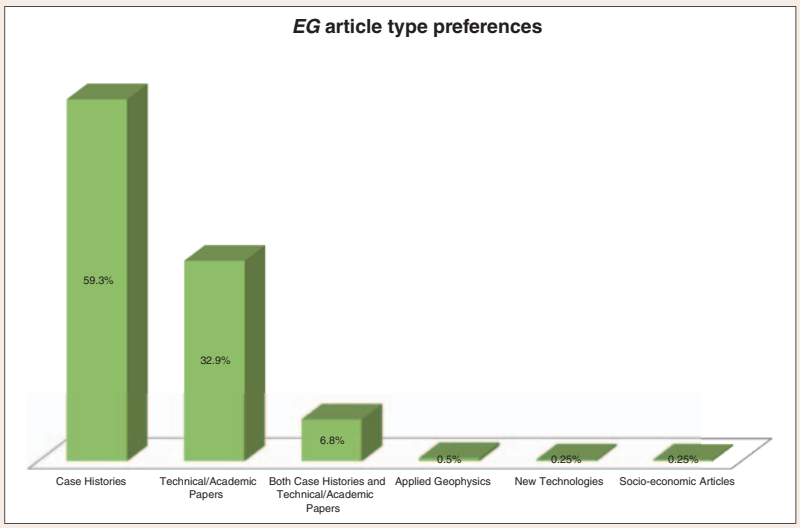
Print format

- Could make *Preview* smaller
- Better formatting for readability
- Snippets on the front cover
- Print on nicer paper (like *PESA* Magazine)

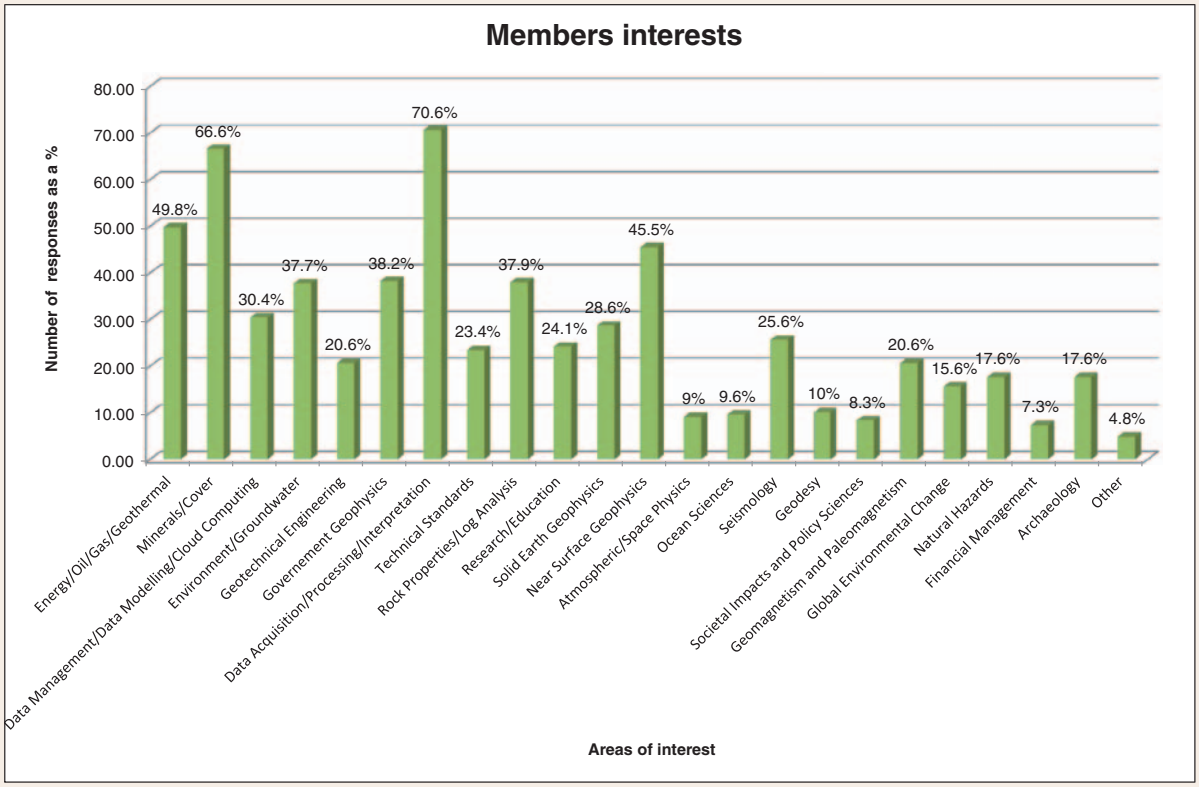
Question 14: Do you routinely read articles in Exploration Geophysics*?*

- 244 (62%) Yes responses
- 154 (39%) No responses

Question 15: Do you prefer?



Question 16: What are your areas of interest (select all that apply)?



Question 17: Do you identify as an early career geophysicist?

- 70 positive ('Yes') responses
- 57 emails/comments registered
- 34 NEW members to the Young Professional mailing list.

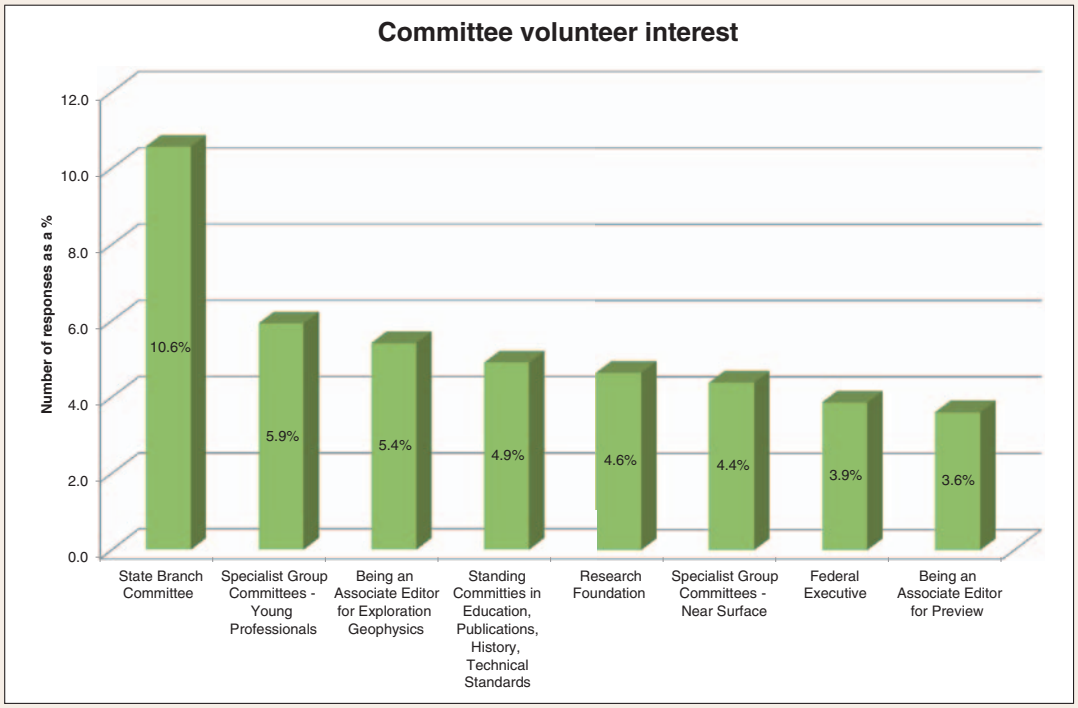
Question 18: Do you identify as a mentor?

- 84 positive ('Yes') responses
- 69 emails/comments registered

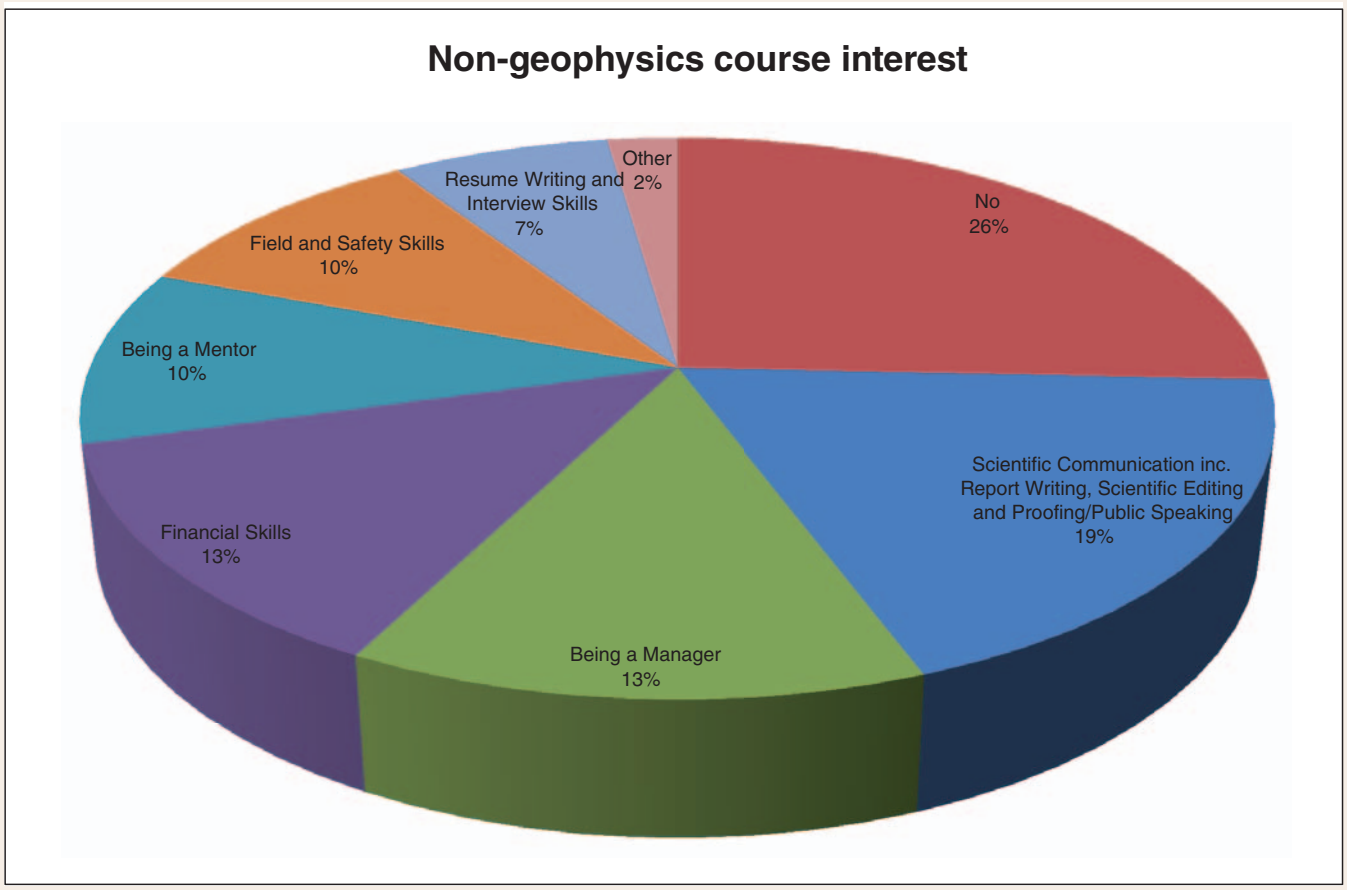
Thank you to the 50 people who nominated themselves as mentors.

Question 19: Are you interested in helping to direct the future of the ASEG by joining a Society committee?

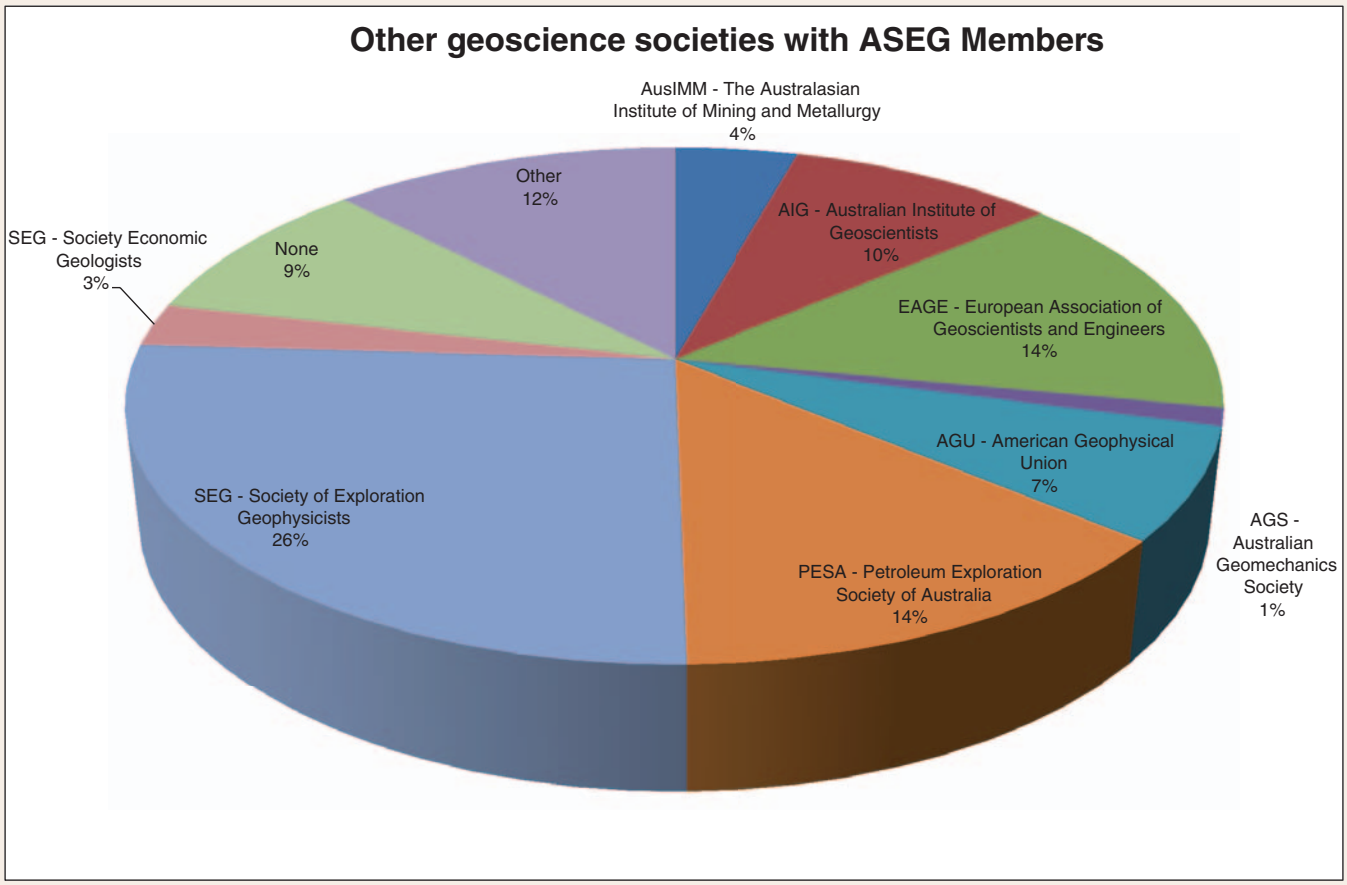
- 87 positive responses
- 37 emails registered



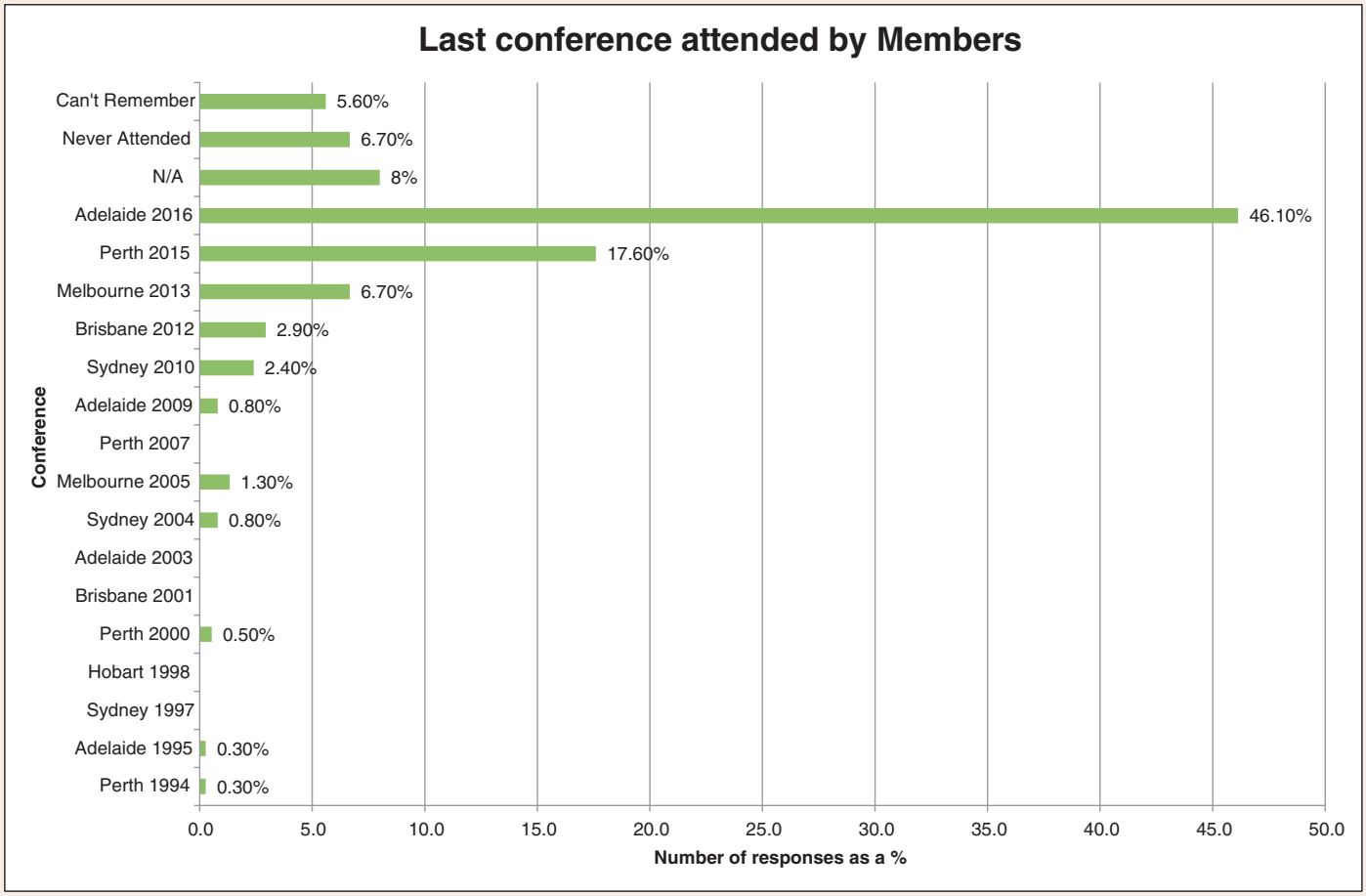
Question 20: Are there other non-geophysics related skills that you would like to develop and have access to courses through the ASEG?



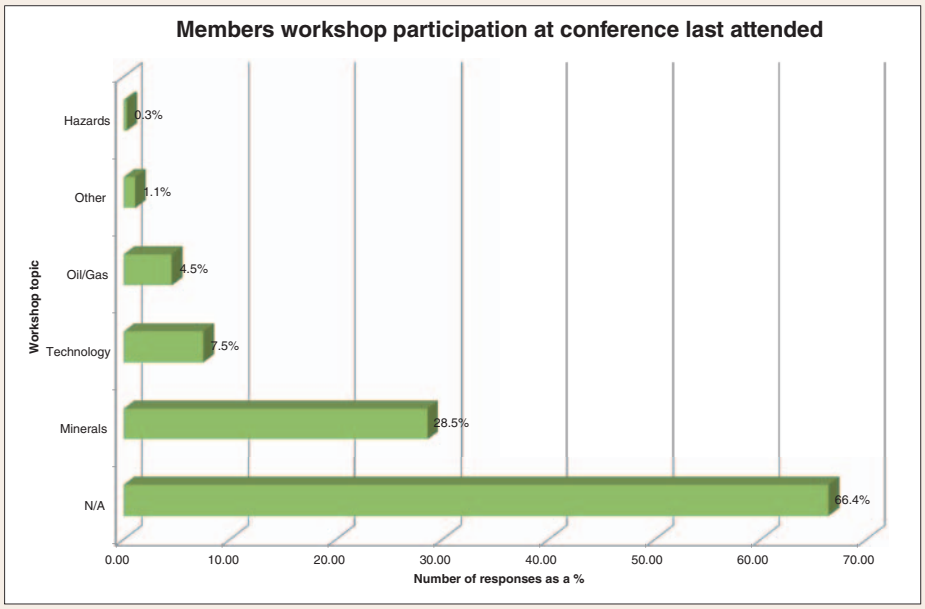
Question 21: Please select the other geoscience societies you belong to.



Question 22: What is the most recent ASEG conference you attended?



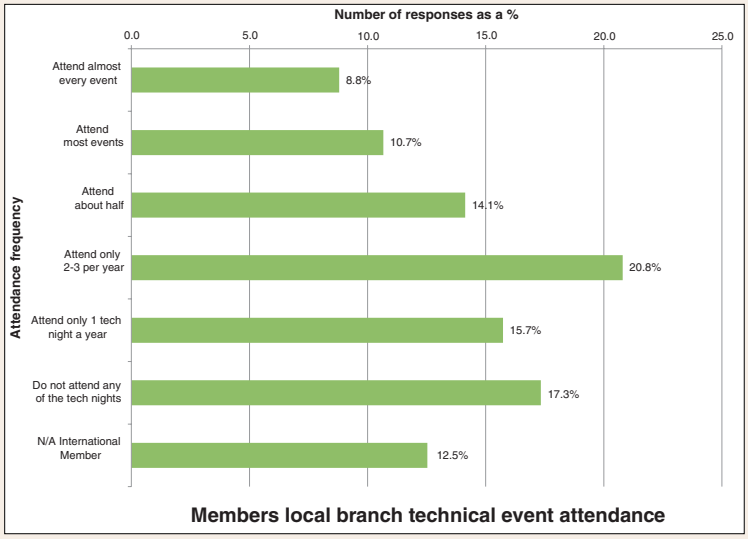
Question 23: Did you participate in any workshops at that conference?



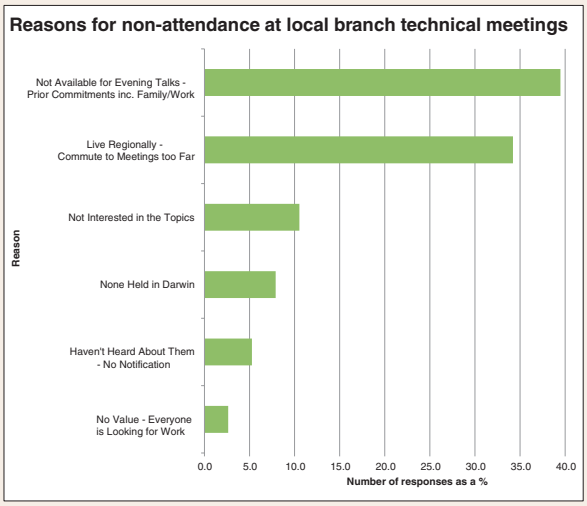
Question 24: If the ASEG were to arrange independent child care facilities at conferences and technical events would you be interested?

- 29 (8%) Yes responses
- 127 (34%) No responses
- 214 (58%) NA responses

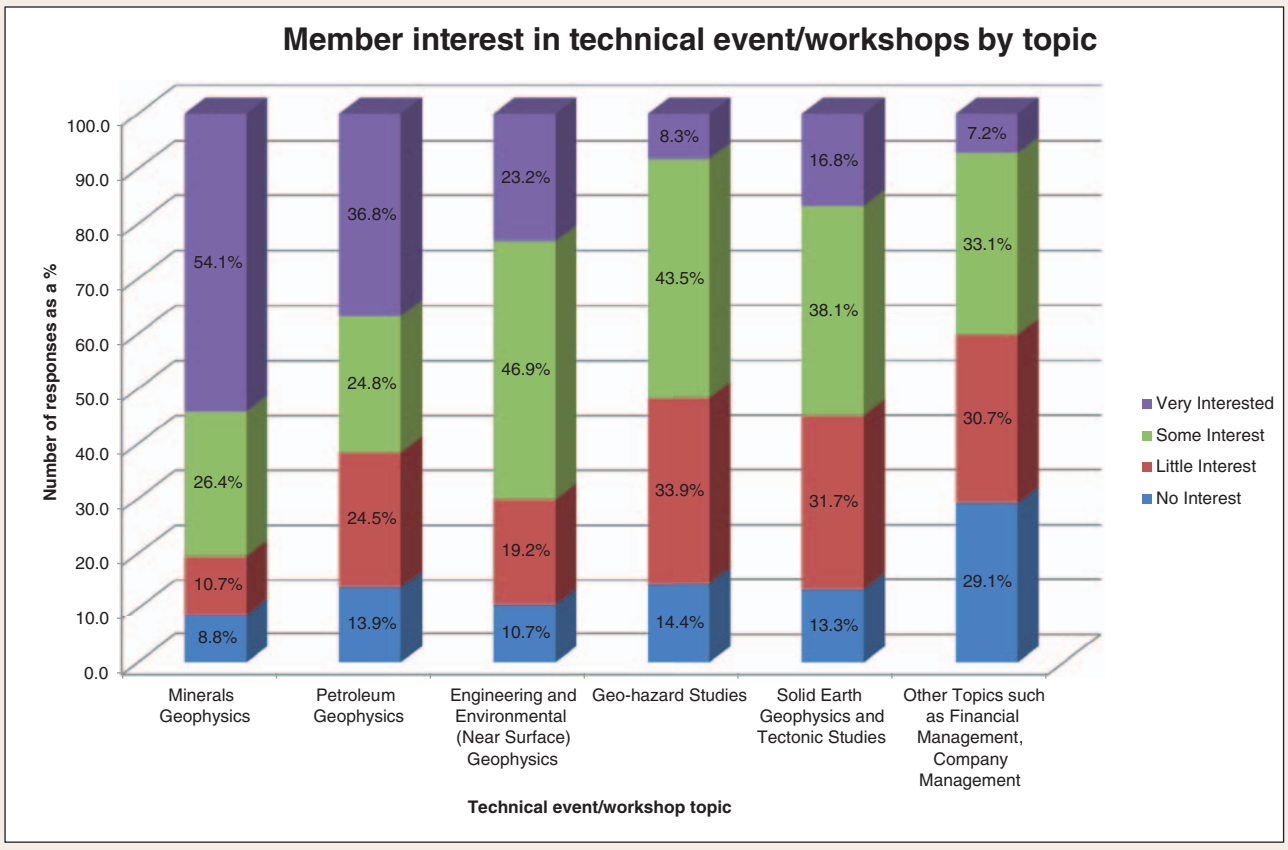
Question 25: How often do you attend local ASEG Branch technical events?



Question 25: How often do you attend local ASEG Branch technical events? Detail:



Question 26: Please indicate your level of interest in the following topics for technical events/workshops?



Question 27: Would you be willing to present at your local or interstate Branch?

- Thank you to the 17 people who nominated themselves to speak at their local branch. Your local branch president will be contacting you shortly.

Summary of survey results generated by Megan Nightingale and Marina Costelloe.

Megan Nightingale
Secretary
fedsec@aseg.org.au

News from the ASEG Young Professionals Network

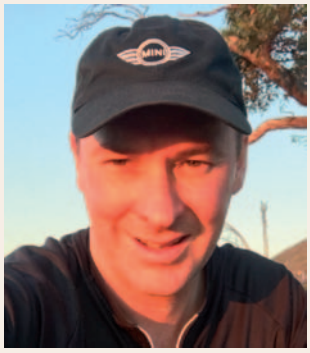
Although the weather may be freezing in some parts of Australia, things are slowly hotting up for the ASEG YP SIG. If you like what you see, then it's never too late to join this group to ensure front row access to some great events that may help to kickstart your career.

First up is an event being held on 17 October for Melbourne-based YPs who are Members of either ASEG or PESA. We are kickstarting a mentoring programme where we shall attempt to effectively 'match-make' volunteer mentors with YPs looking to have some long-term career guidance and support. An informal networking event is planned to roll-out the initiative, to make introductions to mentors where possible and to discuss the training needs for YPs. We've also arranged for Peter Stickland, who is the MD of Melbana Energy and a Board Member of APPEA, to provide an overview on the state of the petroleum industry, which should help set expectations for those keen on entering that sector.

Second, in conjunction with the Education Committee, we've been busy identifying a range of training opportunities in the form of workshops, lectures and short courses. Wearing our YP SIG hats, we've focussed on what might be referred to as 'soft skill' training, with a view to building a portfolio of training opportunities that might be offered at conferences or rolled out through the states. Please don't hesitate to email ypadmin@aseg.org.au with any ideas or requests on that front.

In this vein, registration has opened for a 1-day workshop focussing on presentation skills to be held prior to the AEGC conference (to register visit the ASEG/Events website, or follow the link: https://www.aseg.org.au/presentation-skills-workshop). The workshop is open to anyone attending the conference (with discounts applying for Members) but it is envisaged that it may appeal most to YPs who are not 'set in their way' when it comes to presenting. I've been working closely with the workshop leader, Doug Knight (www.Doug-Knight.com), to adapt his workshop to address typical geoscience presentations. Without giving too much away, one of Doug's goals is to help participants to feel comfortable in their own communication style and to get their message across to an audience in an interesting and memorable way. I can guarantee it will be a fun day watching a bunch of geoscientists attempt to break the traditional presentation mould!

Finally, Megan Nightingale has been busy trying to arrange sponsorship and a suitable meeting place for YPs at the AEGC conference (held in February in Sydney). We'll be joining forces with the AIG and PESA and we hope to arrange a social evening for YPs, so keep some calendar space free for that if you're planning on attending the conference.



Jarrod Dunne
ASEG Young Professionals Network
ypadmin@aseg.org

ASEG Branch news

Victoria

It has certainly been a busy couple of months for the Victorian branch. We got underway in July with a last-minute replacement speaker for our technical night. With open arms we gratefully welcomed **Bala Kunjan** from CUE Energy, who offered a refreshing overview of the probabilistic nature of exploration prediction inherent in the oil and gas business. His synopsis duly titled 'The challenges with exploration chance of success predictions and suggestions to manage them' captured the essence of the risks, costs and rewards aspects of exploration expectation and their outcomes. We thank Bala for his insightful contributions and wish him all the best during September as he presents at the PESGB and various chapters of the SPE in Europe.

August was certainly our busiest month as we kicked it off with another technical meeting at the Kelvin Club. Associate Professor **Steven Micklethwaite** from Monash University delivered a captivating perspective on the application of Unmanned Aerial Vehicles ('UAVs), or simply 'drones', for use in geological innovation. His presentation, 'Making Supergeos: Drones and A.I. for Earth Sciences and Industry' portrayed the rapidly growing disruptive technology drones are providing to the resources sector for accelerating multi-scale recording of vast amounts of optical and geophysical data that could deliver results within minutes of acquisition. Steven's address has certainly piqued our interest in drone technology and the future applications it could bring to the resources industry. Thank you, Steven!

We ended August with the annual Winter Social gathering hosted together with our sister PESA branch at Henry and The Fox. The turnout was excellent despite the event being held outdoors on a cold Melbourne winter's night. Light discussions on the state of our industry and the incredible opportunities before us could be overheard amongst attendees. Thank you to everyone who joined us for a tipple or two.

It has been months in the making, so it brings us immense pleasure to announce the launch of the joint ASEG-PESA Victoria Young Professionals Mentoring Programme! The programme is designed to help young professionals in obtaining local support in their career development from experienced members. The programme will be launched at a special event to be held on Tuesday 17 October at Melbourne University. Keep an eye out for updates!

Finally, we had the pleasure of welcoming **Tom Whiting** as our September technical meeting speaker. Tom is a celebrated exponent of applying new exploration technologies in our industry and has had tremendous success during his illustrious career. We are also in the throes of securing our October technical meeting speaker so stay tuned!

Seda Rouxel
vicpresident@aseg.org.au

Western Australia

The WA Branch continues to be very active with Tech Night presentations. In August the Branch hosted **Ben Jupp**, SRK Consulting, who presented a case study on the use of geophysics at the Mt Magnet gold camp. In September **Bee Jik Lim**, Area Geophysicist WesternGeco, presented 'Marine Seismic Acquisition: Environmental Impact Benefits from New Design Marine Source'. Both talks were well attended and received by Members.

The WA Branch is pleased to welcome the following companies as sponsors for the 2017–2018 financial year: Globe Claritas (Platinum), Resource Potentials (Gold), Western Geco, NRG Australia, First Quantum Minerals (Australia) Pty Ltd, Southern Geoscience, GPX Surveys, HiSeis, NGI, Geosoft, CGG (Silver), Atlas Geophysics, ExploreGeo, and a personal Bronze sponsorship in memory of Marion Rose. The Branch could not put together a wide range of technical activities without the support of our sponsors, and we look forward to a long standing partnership with these companies.

The WA Branch has awarded two student awards this year, with the successful applicants being **Alexander Costall** and **Sean Standen**. These applicants were selected based on the quality of their application, academic performance and relevance of study, and level of active engagement in the university, geophysical and general community. Congratulations to both Alexander and Sean who win $2000 each. Also thank you to the selection committee (**Brett Adams**, **Lianping Zhang**, and **Emanuelle Frery**) for their efforts in reviewing the applications, and thanks also to **Prue Leeming** for coordinating the Award Programme.

Our technical programme has presenters lined up through the end of the year with the following presenters:

- October – **Bill Peters** (Southern Geoscience) presenting on geophysics for nickel-copper exploration; and
- November – Student presentations from UWA and Curtin University.

The schedule is subject to change due to speaker availability. Please check the website for up-to-date information. We are excited about the programme of events planned for 2017 and look forward to catching up with our fellow Members.

We will be hosting the Branch AGM and Christmas Party in December. It is planned to have an informal BBQ function at Kings Park (subject to availability of gazebo). All of the statutory positions (President, Secretary and Treasurer) are open for nomination and anyone interested in joining the ASEG WA Branch committee as a member or in one of these statutory roles are encouraged to lodge a nomination form ahead of the AGM. Further information will be circulated to Members shortly.

Kathlene Oliver
wapresident@aseg.org.au

Australian Capital Territory

In August the ACT Branch enjoyed a guest speaker presentation from the 2017 SEG Honorary Lecturer – **Koya Suto,** entitled 'A Hitchhiker's Guide to Geophysics'. Koya's presentation guided us around the fascinating world of geophysics and provided us with a number of interesting analogies and metaphors to help describe complex geophysical concepts. The presentation also provided to the Branch with a fantastic resource for teaching and promoting geophysics to a non-specialist audience.

In September the ACT Branch was delighted to host a Gold Medal Award ceremony for **Richard Lane**. The ASEG Gold Medal has only been awarded

ACT Branch members with 2017 SEG Honorary Lecturer Koya Suto.

a handful of times throughout the ASEG's history and is awarded for exceptional and highly distinguished contributions to the science and practice of geophysics, resulting in wide recognition within the geoscientific community. Congratulations Richard for receiving such a prestigious award!

Two students, **Marcus Haynes** and **Taimoor Sohail**, are congratulated for receiving Student Scholarship Awards from the ACT Branch. The Branch looks forward to learning more about 'Australian Shallow Crustal Temperature and Heat Flow' from Marcus and 'A Turbulence-Resolving Model of Southern Ocean Circulation' from Taimoor in their presentations to the Branch in November.

James Goodwin
actpresident@aseg.org.au

New South Wales

In July, we held our annual dinner. It was held in a restaurant in the city; we ate lots of steak and fish, drank lots of reds and whites, and discussed lots of geophysical and non-geophysical topics. We had a good turnout and a great time was had by all.

In August, **Alan Oertel** from the CSIRO spoke about 'Non-linear IP effects in sulphides. Can this effect be used to determine the mineralogy of conductive targets?'. Alan went through the background theory to the topic and then showed results from the many laboratory experiments and finally showed the 'hot off the presses' results from the just completed field trials. Many questions and much discussion followed Alan's presentation.

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

Queensland

Since the last issue the Queensland Branch hosted the **Doug Oldenburg** SEG DISC course, which set out to promote fundamental understanding about principles of electromagnetics and how the different surveys make use of these principles to tackle a broad spectrum of problems using EM geophysics.

The Annual ASEG/PESA Trivia night was held at the stock exchange on 8 August. There was a great industry turnout with the Energetics team winning by a narrow margin, taking the last year's crown from Velseis team.

September's Branch meeting saw Geological Survey of Queensland Geophysicist **Janelle Simpson** present

a well-received and interactive presentation on interpreting geology from magnetotelluric data.

In early October the Qld branch of the ASEG will coordinate an overnight, student field trip to a 2D seismic survey near Chinchilla in October. It will be a fantastic opportunity for a small group of students to get some hands-on experience on the operational side of seismic.

An invitation to attend Queensland Branch meeting is extended to all ASEG Members and interested parties. Details of all upcoming Queensland events can be found on the Qld Events tab on the ASEG website.

Mark Kneipp
qldsecretary@aseg.org.au

South Australia & Northern Territory

Since the last SA/NT Branch update the SA membership has only enjoyed one technical evening. In July we were joined by Dr **Mike Hatch**, who was representing Vista Clara Inc., Zonge Australia and the University of Adelaide with his talk 'NMR Geophysics Applied to Groundwater and Environmental Investigations: Show me the Water!' Mike gave a very interesting review of some of the work he has been doing over the previous months comparing in-wellbore nuclear magnetic resonance responses to changes in water tables, both by natural seasonal variation and through human use of water resources, to the ground-based non-invasive GMR system. We thank Mike for spending the time to present on these powerful tools which can be employed in the search for and monitoring of groundwater resources, with numerous examples from both Australia and the US.

In August we were also very happy to host Prof **Doug Oldenburg** and **Lindsey Heagy** halfway through the Australian leg of their tour presenting his 2017 DISC, 'Electromagnetics Fundamentals and Applications'. The first day, the formal part of the course, was very well received and we had a great turnout of participants both from the SA/NT Branch and from interstate. The second day saw a much more informal group discussion led by Doug dealing with specific local issues and case studies, again this was very well received and many of the participants relayed to me that this was a very valuable session, which added a great deal to the previous day's lectures. Many thanks to Doug and Lindsey for coming to Adelaide to present and to the Hotel Richmond and the University of Adelaide for the use of their facilities.

Our technical meetings are made possible by our very generous group of sponsors, including the Department of the Premier and Cabinet, Beach Energy, Minotaur Exploration, 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 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 joshua.sage@beachenergy.com.au or on 8338 2833.

Josh Sage
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 programme at the University of Tasmania/CODES, which routinely includes presentations of a geophysical and computational nature as well as on a broad range of earth sciences topics.

Please contact the ASEG Tasmania Branch President **Mark Duffett** with any queries.

Mark Duffett
taspresident@aseg.org.au

ASEG national calendar: technical meetings, courses and events

Date		Branch	Event	Presenter	Time	Venue
	Oct	QLD	Student field trip	Various	TBA	Chinchilla
11	Oct	WA	Tech night	Bill Peters	1730–1900	TBA
17	Oct	VIC	Launch of the ASEG-PESA Victoria Young Professionals Mentoring Programme	Peter Stickland	TBA	The University of Melbourne, Melbourne
18	Oct	NSW	Tech night	TBA	1730–1900	99 on York, 99 York Street, Sydney
18	Oct	VIC	Tech night	TBA	1800–2000	The Kelvin Club, 14–30 Melbourne Place, Melbourne
08	Nov	WA	Student presentations	Various	TBA	TBA
09	Nov	VIC	Victorian Universities Earth and Environmental Student Conference	Various	TBA	The University of Melbourne, Melbourne
	Nov	ACT	Student presentations	Various	TBA	Geoscience Australia, Symonston, Canberra
15	Nov	NSW	Tech night	TBA	1730–1900	99 on York, 99 York Street, Sydney
13	Dec	NSW	Tech night	TBA	1730–1900	99 on York, 99 York Street, Sydney
	Dec	WA	AGM & Christmas party	TBA	TBA	Kings Park, Perth

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

Final call to nominate a colleague for an ASEG Honour or Award for 2018

NOMINATIONS CLOSING 13 DECEMBER 2017

The ASEG acknowledges the outstanding contributions of its individual Members both to the profession of geophysics and to the ASEG, through the presentation of the Society's Honours and Awards across a range of categories. The next Awards are scheduled to be presented in conjunction with AEGC 2018, to be held from 18–21 February 2018 in Sydney.

All ASEG Members, as well as State and Federal executives, are invited to nominate those they consider deserving of these awards. The available awards are:

- **ASEG Gold Medal** – For exceptional and highly significant distinguished contributions to the science and practice of geophysics, resulting in wide recognition within the geoscientific community.
- **Honorary Membership** – For distinguished contributions by a Member to the profession of exploration geophysics and to the ASEG over many years.
- **Grahame Sands Award** – For innovation in applied geophysics through a significant practical development in the field of instrumentation, data acquisition, interpretation or theory.
- **Lindsay Ingall Memorial Award** – For the promotion of geophysics to the wider community.
- **Early Achievement Award** – For significant contributions to the profession by a Member under 36 years of age through publications in *Exploration Geophysics* or similar reputable journals, or overall contributions to geophysics, ASEG Branch activities, Committees, or events.
- **ASEG Service Awards** – For distinguished service by a Member to the ASEG.

ASEG Members are eligible for all award categories. Non-members also are eligible for the Lindsay Ingall and Grahame Sands awards. Under exceptional circumstances, the other awards may be offered to a non-member of the ASEG who has given appropriate service to the ASEG or to the profession of geoscience, and who has been duly nominated by the Federal Executive.

Nomination procedure

Any Member of the Society may submit nominations for an award. These nominations are to be supported by a seconder, and in the case of the Lindsay Ingall Memorial Award by at least four geoscientists who are Members of an Australian geoscience body (e.g. ASEG, GSA, AusIMM, AIG, PESA, or similar).

The awards carry considerable prestige within the ASEG and the geoscience profession. Therefore, appropriate documentation is required to support each nomination. Nominations must be specific to a particular award and all aspects of the defined criteria should be addressed.

Further details of the award categories, lists of previous awardees and citations for recent awards, award criteria, nomination guidelines and nomination forms can be found on the ASEG website at: https://www.aseg.org.au/about-aseg/honours-awards.

Further information can be obtained by contacting the Chair of the Honours and Awards Committee. All correspondence and nominations will be treated confidentially.

Nominations including digital copies of all relevant supporting documentation are to be emailed to:

Andrew Mutton
ASEG Honours and Awards Committee Chair
awards@aseg.org.au

Nominations close Wednesday 13 December 2017.

Update from the AEGC 2018 Conference Organising Committee

At the time of writing there are only five months until the conference and still a lot to do. Extended abstracts are being reviewed, booths are still being sold, workshops have been finalised, and sponsors are being sought.

Early bird registration is now open (http://www.aegc2018.com.au/). It will close on 31 October 2017, so get in quickly! Please note that if your paper is accepted as part of the conference you will have until 31 October to register for the conference to ensure your place in the conference programme.

We are proud to announce that our Platinum sponsor is Australia Minerals, our Sapphire Sponsor is CSIRO, our Gold Sponsor is Oil Search and our Opal Sponsor is Geoscience Australia. Our Silver Sponsors are Bridgeport Energy, Geosoft, Horizon Oil, Kinetic and Velseis. Wireline Services Group will be our lanyard sponsor, while GBG Australia will sponsor one of our morning teas and First Quantum Minerals are sponsoring the best paper and poster awards. There are still sponsorship opportunities available if your company is looking for exciting promotion opportunities. Again, please do not hesitate to contact us if you are interested and would like further information.

Our team of paper reviewers are ploughing through around 300 extended abstract submissions. By the time of this publication the programme will be near completion. We are very impressed with the quality of the abstracts and are very happy with the programme. Our thanks to all who submitted an abstract, this is an exciting programme. We have eight concurrent streams; three covering the Energy stream, three and half covering the Mineral Geoscience stream, and one and half covering the Near Surface and Groundwater stream. In the Energy stream we cover a diverse range of topics from Basin Symposia (WA, CA and EA), through to Non-Conventional, PNG and New Technologies in Seismics. The Mineral Geoscience theme covers such topics as geophysics and geology case histories, airborne geophysics, magnetics and EM theory, and Industrial and Strategic. The Near Surface and Groundwater theme has such topics as innovation, case studies and what is new in groundwater investigations.

Peter Botten, the Managing Director of Oil Search, will be giving the plenary address. Keynote speakers are listed below and the conference website contains photos and a short biography of most of them.

The exhibition hall is filling up fast, please visit the website to see who has already secured a spot. If your company would like a booth please get in contact with us ASAP. The prospectus is available for download on the conference website: (http://www.aegc2018.com.au/). The Conference Organising Committee has endeavoured to contact as many companies as possible - if your company hasn't been contacted please let us know ASAP!

Please stay tuned to the website for any updates to this programme. We are also constructing an exciting Schools programme. Local high schools will be invited to participate in an information day to learn about the geophysical industries, and be given the opportunity to visit the trade exhibition. We have finalised a couple of excursions to visit some key geological sites in the region.

Mark Lackie
Co-Chair Minerals
mark.lackie@mq.edu.au

Max Williamson
Co-Chair Petroleum

Table 1. Confirmed Keynote speakers

Speaker	Affiliation
Peter Baillie	CGG
Katarina David	University of New South Wales
Natasha Hendrick	Santos
Kevin Hill	Oilsearch
Jim Macnae	RMIT
Graham Heinson	University of Adelaide
Richard Flook	Private Consultant in Industrial Minerals
Ryan Noble	CSIRO
John McGaughey	MIRA Geoscience
Richard Hillis	Deep Exploration Technologies CRC
Kevin Ruming	Geological Survey of NSW
Ross Large	University of Tasmania
Steve McIntosh	RioTinto
Mike McWilliams	CSIRO
Richard Blewitt	Geoscience Australia

SAVE THE DATE!

AEGC2018

FIRST AUSTRALASIAN EXPLORATION GEOSCIENCE CONFERENCE

18-21 FEBRUARY 2018 | SYDNEY AUSTRALIA

EXPLORATION • INNOVATION • INTEGRATION

On behalf of the Conference Organising Committee, we would like to invite you to attend the First Australasian Exploration Geoscience Conference in Sydney, to be held from February 18-21 2018. The event will be jointly hosted by ASEG, PESA and AIG. The theme of the meeting is Exploration, Innovation and Integration.

The Conference will also incorporate the Eastern Australia Basins Symposium normally managed by PESA and the rolling 18 months Conference of ASEG and will be home to the highest quality technical program and Exhibition that members will have grown accustomed to from our three organisations.

Discover Sydney, Australia's famous harbour city and capital of New South Wales. Plan your Sydney visit with beautiful sundrenched beaches and much more.

See you in Sydney in 2018!

Max Williamson and Mark Lackie (Co-Chairs)

Hosted by

Australian Society of Exploration Geophysicists

AUSTRALIAN INSTITUTE OF GEOSCIENTISTS
Supporting Geoscientists

PESA
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AEGC2018
AUSTRALASIAN EXPLORATION GEOSCIENCE CONFERENCE
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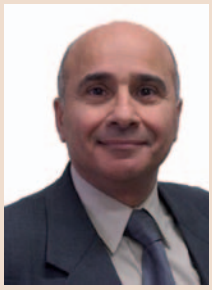
Australia's mining industry has a plan to address the challenges of exploring in areas of cover



Adele Seymon and Joe Cucuzza
AMIRA International
adele.seymon@amirainternational.com
joe.cucuzza@amirainternational.com

We are all aware of the downturn of the minerals industry and its effect on the Australian economy, but some may not be aware of, or fully appreciate the implications of, the structural decline that is associated with the fact that we are not replacing the reserves we are currently mining. It is not only that average head grades are decreasing and the remaining ore is becoming more complex and thus more energy and water intensive to process, more importantly we are simply not finding enough high quality ore.

More than 200 exploration personnel contribute to a Roadmap via AMIRA

The reason for this is not because companies are spending less on greenfield exploration, although there is that, the underlying reason is simply that in the more mature areas of the world most, if not all, of the world class deposits that were either at or near the surface have been found. The focus of exploration has largely been in these areas; however, in Australia this only represents about 30% of the landmass. There is an incredible opportunity if we can manage to reduce the uncertainty and risk in exploring in areas of cover. This is where the Australian Mineral Industries Research Association (AMIRA) International Roadmap for Under Cover Exploration: Unlocking Australia's Hidden Potential comes in.

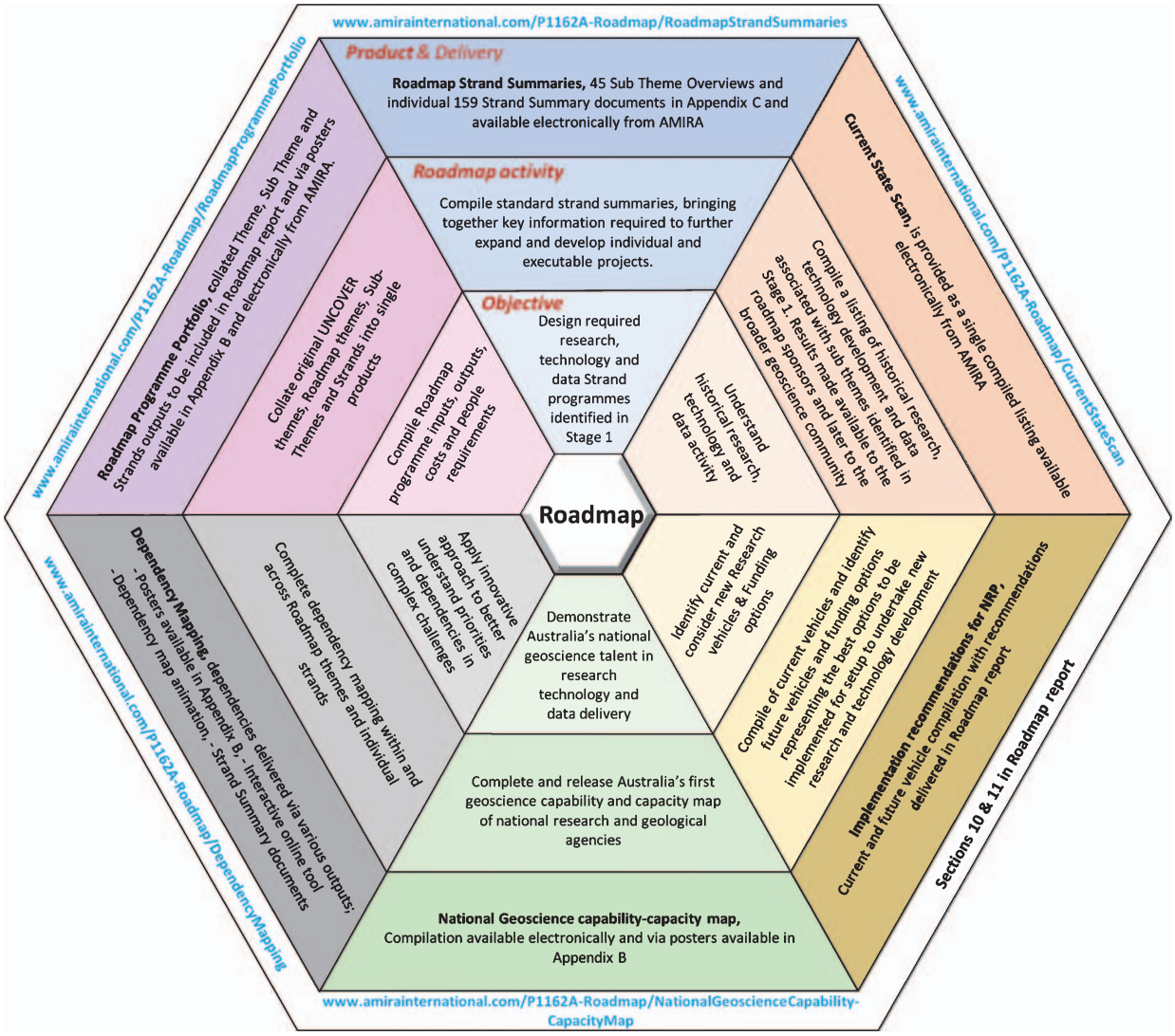


Figure 1. *AMIRA International Roadmap for Under Cover Exploration: Unlocking Australia's Hidden Potential.*

The Roadmap builds on the UNCOVER Initiative, and provides a badly needed blueprint not only on what needs to be done but also on how it can be achieved.

The Roadmap (Figure 1) is the result of an unprecedented collaboration over the last three years facilitated and managed by AMIRA International. A total of 53 organisations contributed financial support but more importantly 203 personnel representing exploration and mining companies (majors, mid-tier and juniors), METS suppliers, the research community and industry peak bodies contributed to the construction of the Roadmap. This is one of many industry Roadmaps that AMIRA International has developed over the years.

As the Roadmap outlines, to lower the uncertainty and risk associated with exploration in areas of cover, new data, new knowledge, new tools, new approaches and new skills will be required. The potential prize is huge – perhaps the next Olympic Dam, Mount Isa, Broken Hill or Kalgoorlie's Golden Mile, hidden under cover and waiting to be discovered. Such a discovery would provide a huge fillip to job creation, regional infrastructure, not to mention future mineral exports, and to exports of technology and services. We must also not forget that in developing solutions to the challenges outlined by the Roadmap, we will be enhancing Australia's research capability and training the next generation of industry leaders, operators and researchers.

The AusIMM has reported that the mining industry directly employs some 240 800 people and, with the METS sector, contributes some $236 billion per annum to Australia's economy. We will not be able to grow this, let alone maintain it, unless we start finding new world class deposits. Considering the length of the lead times to discovery and then to production, well we had better start pretty soon.

History tells us that it can take up to 10 years to make an economic discovery and up to 15–20 years to put it into production – statistics that are likely to get worse in areas of cover. In order to avoid the so called 'production cliff' in non-bulk mineral reserves in the near future we need to speed up discovery and of course accelerate the development time. As Richard Schodde has reported, half of the current mines in Australia are likely to stop producing in the next 15 years, and furthermore two thirds of current reserves, at least for gold, will have been depleted.

Half of the current mines in Australia are likely to stop producing in the next 15 years

The exploration tool kit and business models that have been successfully used, and indeed improved upon, since the advent of modern exploration in the 1950s in Australia are not going to be adequate to overcome the challenges of exploring under cover. Success requires change, doing things differently, and critically embracing a new collaborative paradigm by all sectors of industry, governments and the research community.

With real collaboration and co-investment from the various stakeholders along with a planned and unified approach to the implementation of the Roadmap, it is possible to boost Australia's economic mineral inventory.

The Roadmap calls for an investment in excess of AU$900m over 15 years in addition to the continued funding of incentives and programmes currently in place by the Australian Federal, States and Territory agencies. This funding is for new research, enhancing existing technologies, including geophysical, as well as developing new ones, and also to accelerate existing pre-competitive data acquisition programmes. Geophysics is going to play an even greater role in exploration under cover, as will better integration of data and knowledge aimed at improving our understanding of mineral systems which will enable improved prediction and detection of economic ore systems at a range of scales.

The Roadmap calls for an investment in excess of AU$900m over 15 years in addition to existing incentives and programmes

The Roadmap identifies some 'low hanging fruit', i.e. activities the results of which will provide impact in the short term:

- Understanding the type, ages and depth of cover leading to the production of 3D geology and palaeosurface maps and layers,
- Characterising and mapping major mineral system 'foot-print' signatures through compilation of geological, geochemical and geophysical data, and
- Improving the understanding of mineral systems across scales for different deposit types and commodities.

The next 12 months is going to be important; we need to bring together an Implementation Task Force, a representative group of senior personnel from key stakeholders, who will be tasked to make some decisions on the way forward presented in the Roadmap. Agreement on the funding model, and the nature of entity required to execute the R&D programmes are going to be key outcomes. The latter, which we have called the Australian Centre for under cover Exploration (ACE), will require a new collaborative model, one that is laser-focussed on developing the solutions in the most optimal and timely way. This means bringing together the best brains trust to address each of the research and technology development challenges, perhaps via a DARPA style operating model. AMIRA International stands ready to hep to make this happen.

We encourage all geoscientists to get behind this; we all should contribute anyway we can by lobbying, by encouraging our leaders whether in our companies, or in governments, to support this endeavour so that consensus can be reached and we can start the important work the Roadmap describes and truly UNCOVERING Australia.

To register for a copy of the AMIRA International Roadmap please visit www.amirainternational.com or go to AMIRA International Roadmap.

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 8 September 2017)

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 (km^2)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Murloocoppie	GSSA	GA	MAGSPEC Airborne Surveys	11 Feb 2017	109 560	200 m 60 m E–W	19 540	25 May 2017	Final magnetic and elevation data QA/QC in progress	183: Aug 2016 p. 34	TBA
Warrina	GSSA	GA	MAGSPEC Airborne Surveys	11 Feb 2017	135 628	200 m 60 m E–W	24 140	25 May 2017	Final magnetic and elevation data QA/QC in progress	183: Aug 2016 p. 34	TBA
Andamooka	GSSA	GA	Sander Geophysics	23 Feb 2017	81 396	200 m 60 m E–W	14 560	The survey flying was completed on 6 Jun 2017	Final elevation data QA/QC in progress	183: Aug 2016 p. 34	TBA
Barton	GSSA	GA	Thomson Aviation	22 Jan 2017	111 758	200 m 60 m E–W	20 560	11 May 2017	Raw data QA/QC in progress	183: Aug 2016 p. 34	TBA
Fowler	GSSA	GA	Thomson Aviation	18 Feb 2017	95 009	200 m 60 m E–W	17 360	2 Jun 2017	Raw data QA/QC in progress	183: Aug 2016 p. 34	TBA
Torrens	GSSA	GA	Sander Geophysics	4 Mar 2017	79 990	200 m 60 m E–W	14 800	15 Jun 2017	Final elevation data QA/QC in progress	183: Aug 2016 p. 34	TBA
Coonabarabran	GSNSW	GA	UTS Geophysics	17 May 2017	50 827	250 m 60 m E–W	11 000	TBA	Final magnetic and elevation data QA/QC in progress	184: Oct 2016 p. 23	TBA
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	National Collaborative Framework Agreement between GA and MRT has been executed. The survey has been deferred to occur between Oct 2017 and Mar 2018
Isa Region	GSQ	GA	GPX	3 Jul 2017	120 062	100 m 50 m E–W	11 000	55.5%	TBA	188: Jun 2017 p. 21	TBA
Tallaringa N (1A)	GSSA	GA	TBA	Est. late Sep 2017	97 762	200 m 60 m E–W	17 320	TBA	TBA	Figure 1	TBA
Tallaringa S (1B)	GSSA	GA	TBA	Est. late Sep 2017	145 042	200 m 60 m E–W	26 010	TBA	TBA	Figure 1	TBA
Coober Pedy (8A)	GSSA	GA	TBA	Est. late Sep 2017	90 627	200 m 60 m N–S	16 140	TBA	TBA	Figure 1	TBA
Billa Kalina (8B)	GSSA	GA	TBA	Est. late Sep 2017	90 625	200 m 60 m N–S	16 140	TBA	TBA	Figure 1	TBA
Childara (9A)	GSSA	GA	TBA	Est. late Sep 2017	135 021	200 m 60 m N–S	23 910	TBA	TBA	Figure 1	TBA
Lake Eyre (10)	GSSA	GA	TBA	Est. late Sep 2017	91 800	200 m 60 m E–W	16 180	TBA	TBA	Figure 1	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	TBA	64.4%	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	TBA
Kidson Sub-basin	GSWA	GA	CGG Aviation (Australia)	14 Jul 2017	72 933	2500 m line spacing	155 000	TBA	20%	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
South Nicholson	GA	GA	Atlas Geophysics	30 Jul 2017	2724	4 km spacing	43 330	28 Jul 2017	1 Sep 2017	The survey area covers parts of the Mount Drummond, Ranken and Avon Downs standard 1:250 k map sheet areas	12–14 Sep 2017

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
Musgraves – CSIRO Area	GSSA	GA	SkyTEM Australia	15 Sep 2016	7182	2 km; E–W lines	14 320	The survey completed flying on 13 Oct 2016	8 Mar 2017	179: Dec 2015 p. 23	22 Aug 2017
Isa Region	GSQ	GA	Geotech Airborne	8 Aug 2016	15 692	2 km; E–W	33 200	The survey completed flying on 4 Nov 2016	12 Apr 2017	182: Jun 2016 p. 23	The East Isa data were released on 11 Apr 2017. The Lawn Hill Extension data were released on 20 May 2017
AusAEM (Year 1)	GA	GA	CGG	TBA	59 349	20 km with areas of infill	TBA	TBA	16.9%	186: Feb 2017 p. 18	TBA
Surat-Galilee Basins QLD	GA	GA	SkyTEM Australia	2 Jul 2017	4627	Variable	Traverses	23 Jul 2017	21 Aug 2017	188: Jun 2017 p. 21	TBA
Stuart Corridor, NT	GA	GA	SkyTEM Australia	6 Jul 2017	9832	Variable	Traverses	12 Aug 2017	21 Aug 2017	188: Jun 2017 p. 22	TBA
Olympic Domain	GSSA	GA	TBA	TBA	3181	1.5 & 3 km E–W	33 200	TBA	TBA	Figure 2	TBA
Fowler Domain	GSSA	GA	TBA	TBA	3057	5 km NW–SE	15 000	TBA	TBA	Figure 3	TBA

TBA, to be advised.

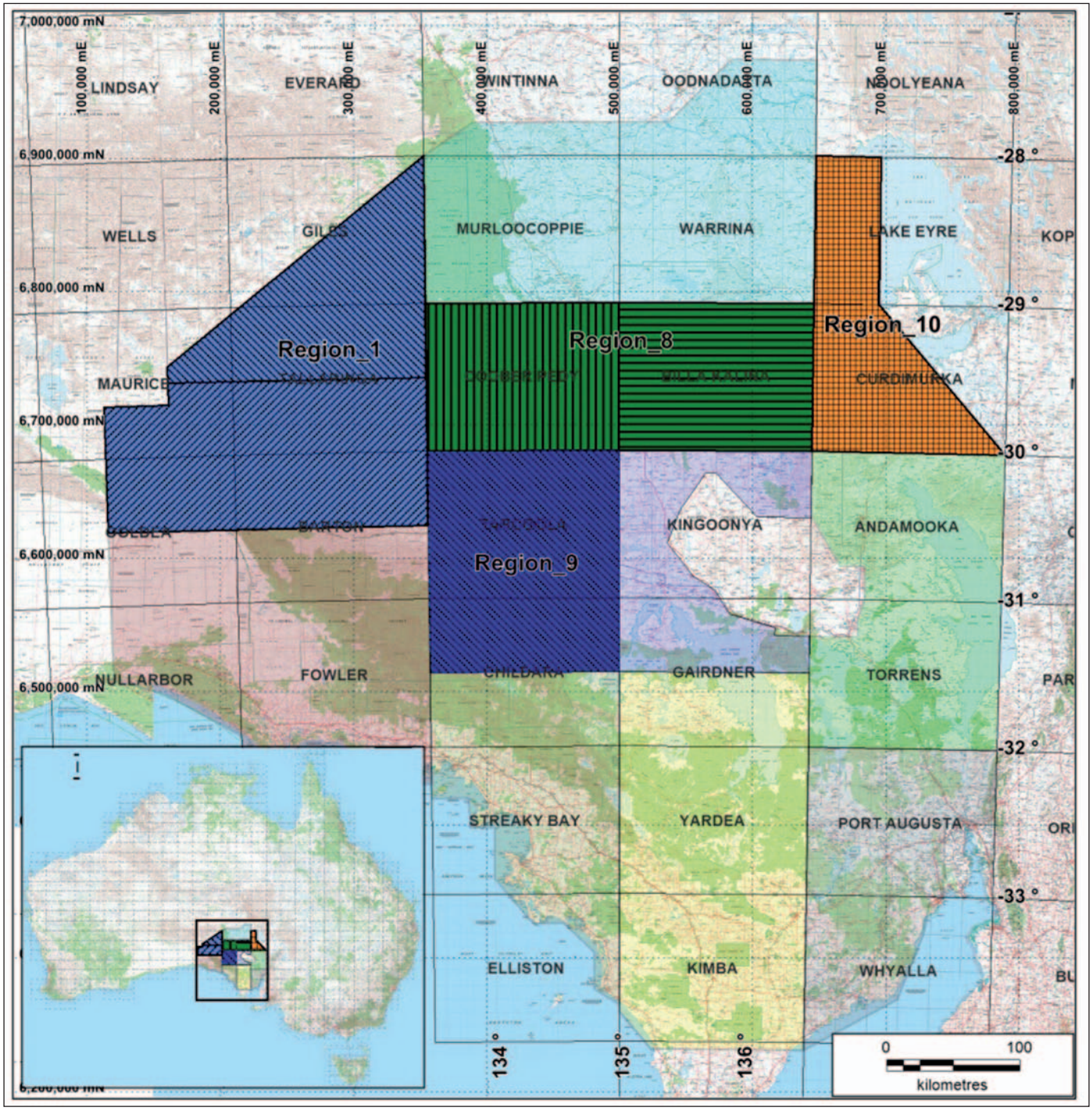


Figure 1. *Location of the Tallaringa N (1A), Tallaringa S (1B), Coober Pedy (8A), Billa Kalina (8B), Childara (9A) and Lake Eyre (10) airborne magnetic and radiometric surveys.*

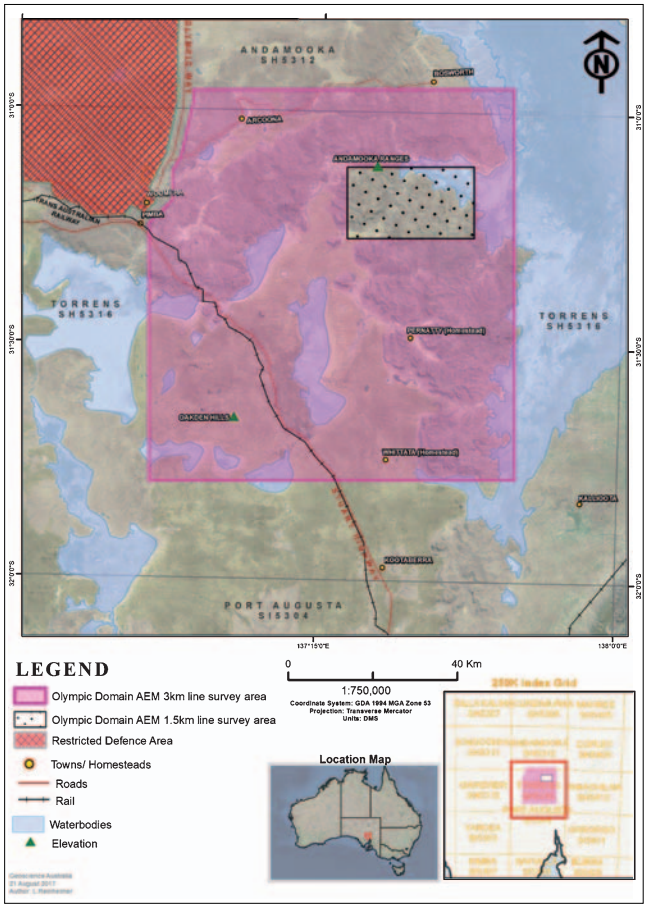


Figure 2. *Location of the Olympic Dam AEM survey, South Australia.*

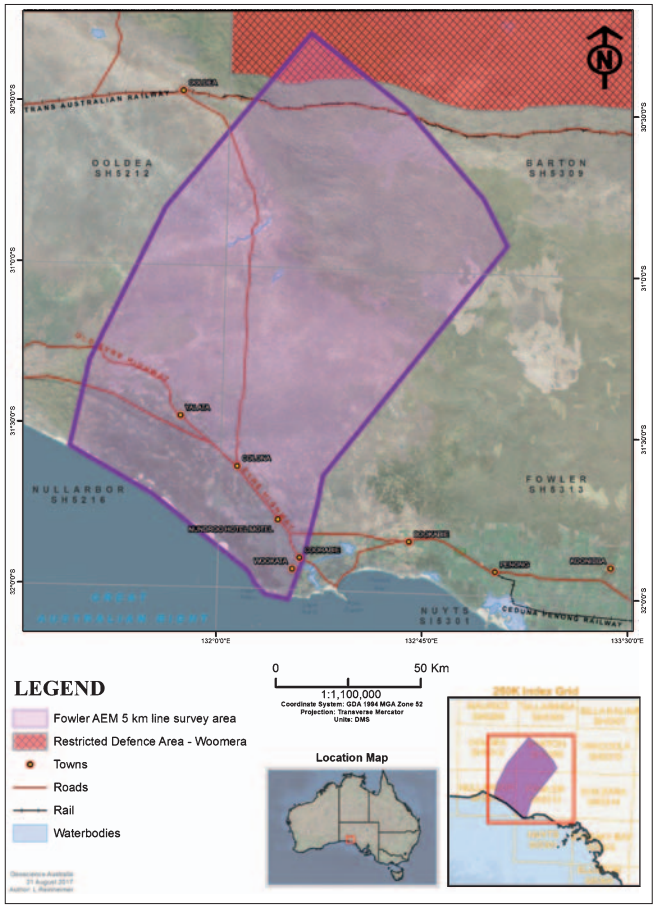


Figure 3. *Location of the Fowler AEM survey, South Australia.*

Geological Survey of South Australia: The Musgrave Ranges AEM surveys

Two AEM surveys conducted in the Musgrave Ranges in South Australia in late 2016 are now available for download via SARIG (https://map.sarig.sa.gov.au/). The surveys were funded by the Government of South Australia, through the Plan for Accelerated Exploration (PACE) Initiative and through the Goyder Institute of Water Research. Geoscience Australia managed the survey as part of a National Collaborative Framework project agreement with SA.

The first survey – a High Moment TEMPEST survey – was flown between 18 August and 17 September 2016 by CGG Aviation (Australia) Pty Ltd. This survey – on the west side of the total survey area – comprises 8595 line kilometres of data. The survey lines were oriented 177–357 degrees and the line spacing was 2 km. The nominal terrain clearance was 120 m.

The second survey – a SkyTEM survey – was flown between 9 September and 13 October 2016 by SkyTEM (Australia) Pty Ltd. This survey – to the north and east of the total survey area – is comprised of 8800 line kilometres of data. The survey lines were oriented N-S and the line spacing was 2 km, 500 m and 250 m. The nominal terrain clearance was 45 m.

These AEM surveys reveal new insight into the geology under the Musgrave Province. The data from both surveys have been merged together into a single seamless image and the figure here shows some of the exciting results from the surveys. The left portion shows some results of the CGG TEMPEST survey and the right side shows some SkyTEM survey data. The data are showing the conductivity of the earth at a depth between 80–110 m. The results clearly show features that correspond to underground water networks; palaeochannels.

Complete data and reports can be downloaded via SARIG (https://map.sarig.sa.gov.au/).

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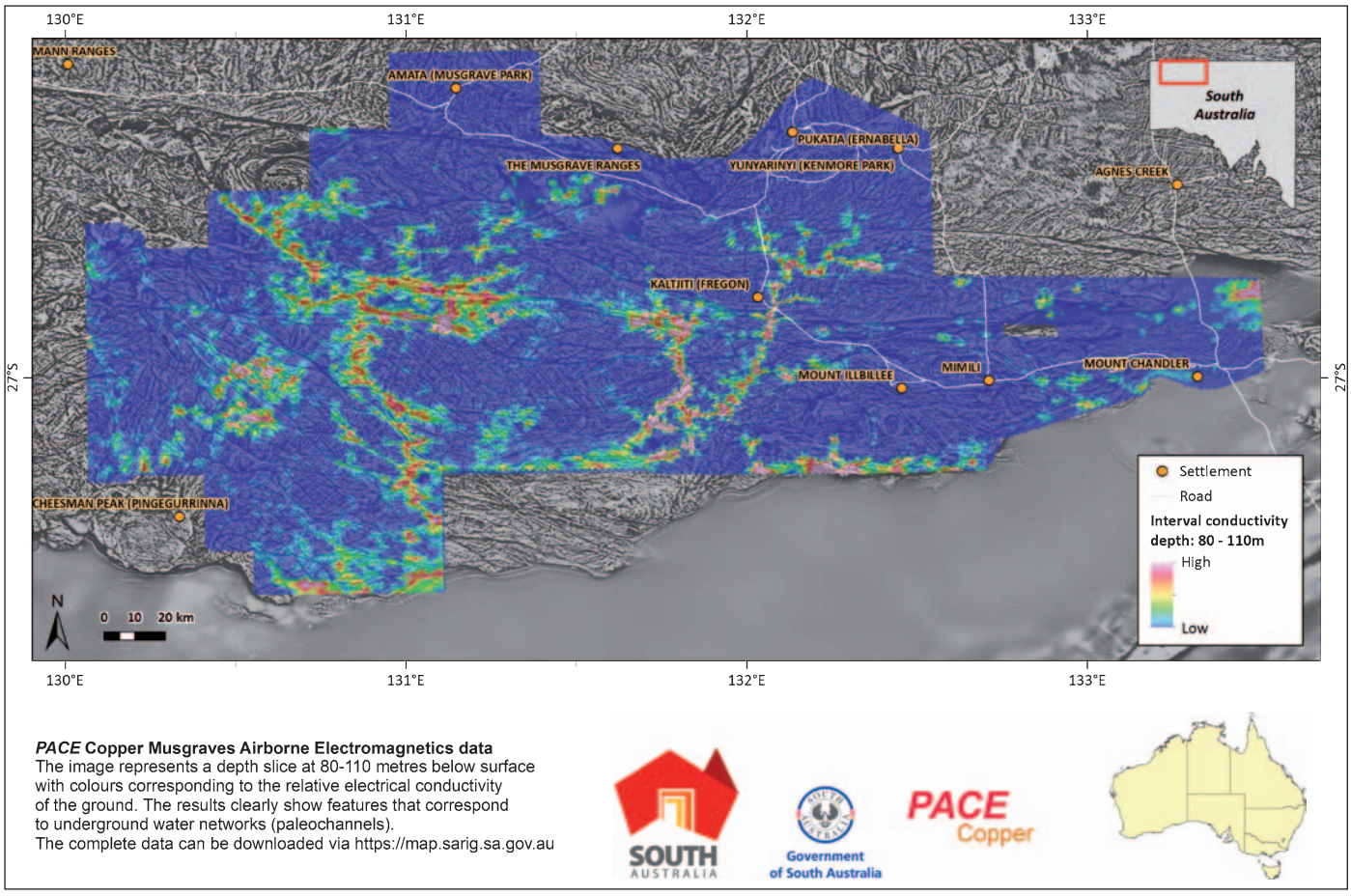

Figure 1. *The AEM data clearly show features that correspond to underground water networks, including palaeochannels.*

Geological Survey of New South Wales
Coonabarabran airborne geophysical survey complete!

Acquisition of the Coonabarabran airborne magnetic and radioelement survey is complete (Figure 1). Acquisition commenced May 10 and finished July 30. The aircraft flew east–west traverses every 250 m at an altitude of 60 m.

The survey area includes Warrumbungle National Park where Geological Survey New South Wales has been mapping geology in collaboration with National Parks and Wildlife Service. The park's distinctive landforms and rocks are due to hot spot volcanism; the park encompasses a volcano that was active 13–17 Ma. The centre of the volcano was previously mapped as Jurassic Pilliga Sandstone and Purlewaugh Formation. However, geological mapping with the aid of preliminary geophysical data indicate volcanic deposits (lavas and volcaniclastic rocks) within the central valley area, which are more consistent with a central volcanic vent area than Jurassic basement deposits. The geophysical data particularly helped the mapping team to define the various mafic and felsic lava flows around the volcano, and differentiate volcaniclastic rocks from the coherent lavas and intrusions, and also from Jurassic sedimentary rocks (Figures 1 and 2).

This survey was funded by the GSNSW New Frontiers initiative, with project management by Geoscience Australia. The survey data were acquired and processed by UTS Geophysics Pty Ltd. The data will be available for free through Geoscience Australia's Geophysical Archive Data Delivery System (GADDS). It will also be available via the NSW Government geophysical-data package; a portable hard drive that contains all geophysical data acquired by the NSW Government can be purchased (for $110 plus postage).

GADDS

https://www.google.com.au/search?q=gadds&rlz=1C1GGRV_enAU751AU751&oq=gadds&aqs=chrome..69i57j69i60j0l4.1535j0j8&sourceid=chrome&ie=UTF-8

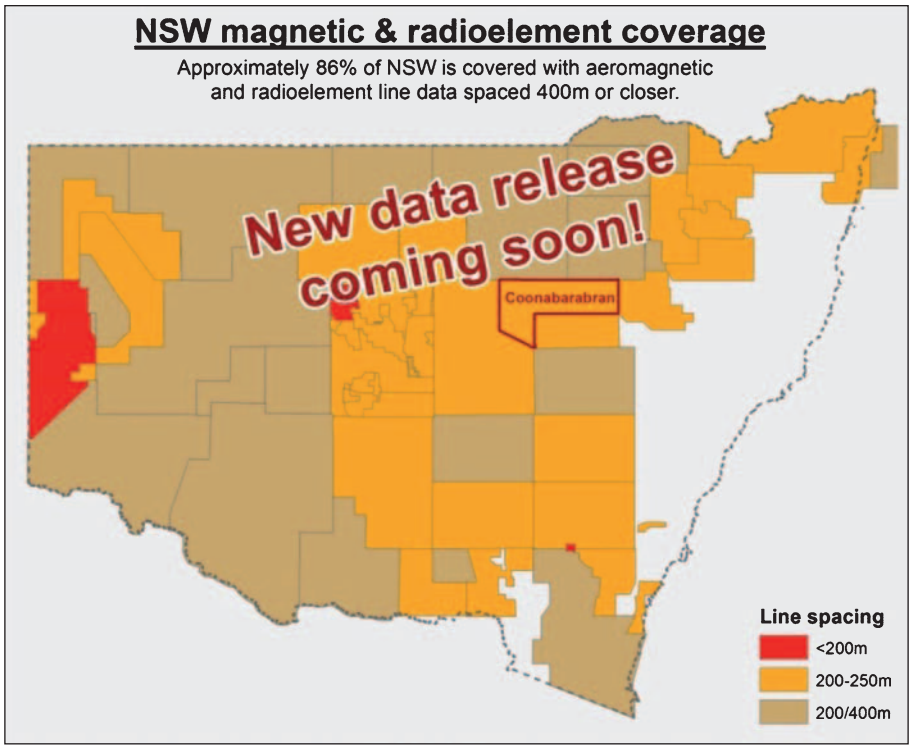

Figure 1. *Map of NSW government funded airborne magnetic & radioelement surveys.*

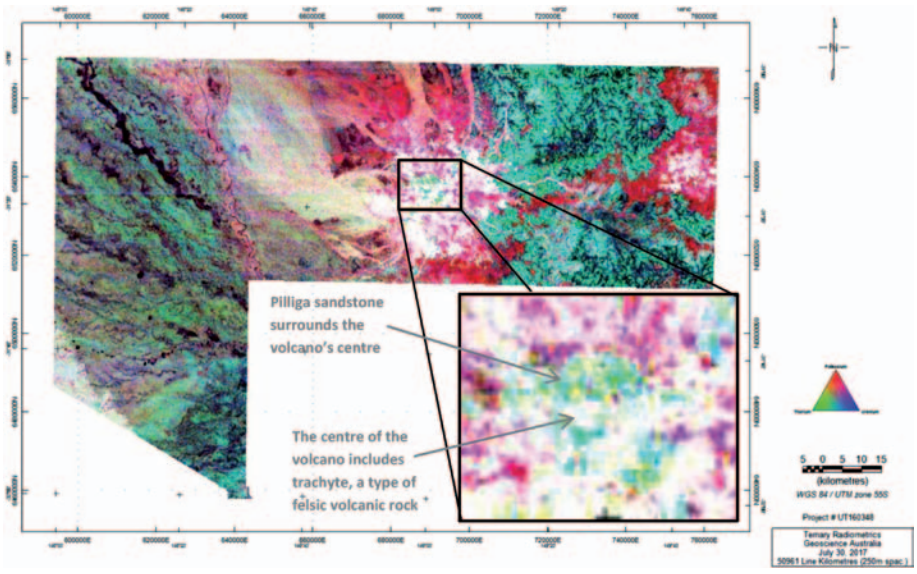

Figure 2. *Preliminary ternary radioelement image from the Coonabarabran Project. In a ternary radioelement image red, green and blue respectively represent the naturally radioactive occurring elements K, Th & U. The zoom insert shows the radioelement signature of the central volcanic vent.*

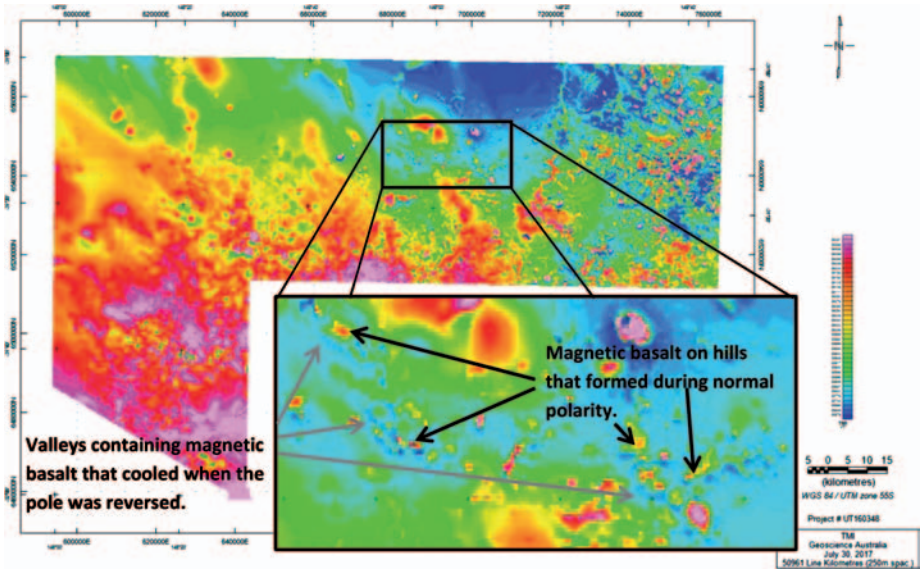

Figure 3. *Preliminary image of Total Magnetic Intensity data from the Coonabarabran Project, zoom insert showing anomalies from magnetic basalts.*

NSW Government geophysics-data package

http://www.resourcesandenergy.nsw.gov.au/miners-and-explorers/geoscience-information/products-and-data/geophysical-images-and-data

Final processing of the data is complete; the data will be made publicly available on 23 November at a meeting of the Sydney Mineral Exploration Discussion Group. To be notified about the Coonabarabran airborne magnetic, radioelement and elevation data public release please email geophysics.products@industry.nsw.gov.au.

For more information about the survey and the use of the data visit:

http://www.resourcesandenergy.nsw.gov.au/miners-and-explorers/geoscience-information/projects/coonabarabran-project

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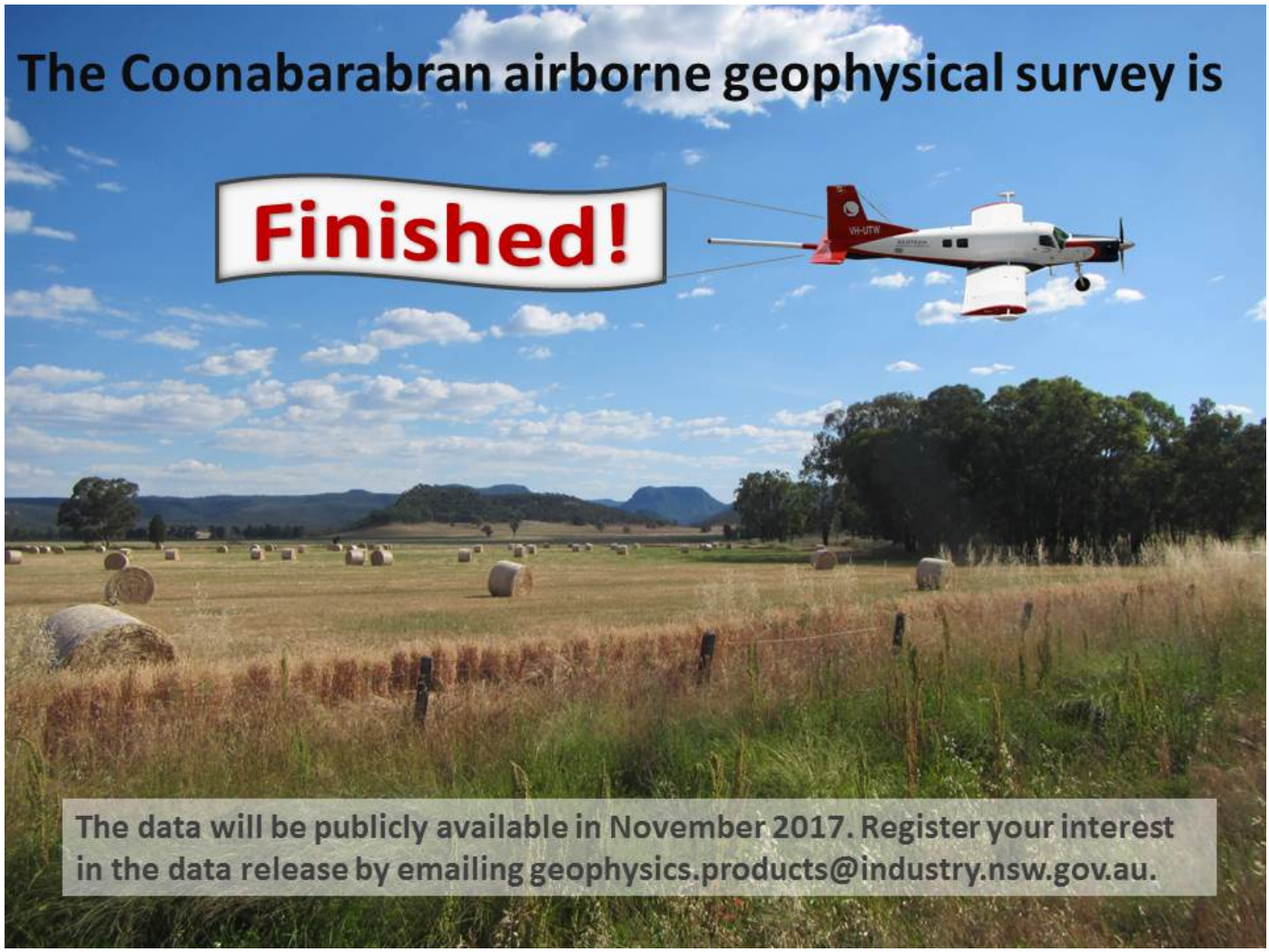

Stratigraphic drilling samples basement in the Southern Thomson Orogen Project

Seven drill holes have successfully sampled basement rocks of the Thomson Orogen, beneath the Eromanga Basin, in the Bourke – Hungerford area of remote northwest NSW. The drilling program is part of the cross-border collaborative Southern Thomson Project between GSNSW, the Geological Survey of Queensland and Geoscience Australia. The project sits within the national Uncover Initiative, which aims to reverse the decline in Australia's known mineral reserves by providing new information to explorers about undercover regions.

The rocks of the Thomson Orogen are potentially prospective for copper, lead–zinc, gold and other useful metals, however very little is known about them because they lie underneath younger sedimentary rocks of the Eromanga Basin. The Southern Thomson Project initially acquired and analysed airborne and ground-based geophysical surveys and undertook surface geochemical sampling, field mapping and satellite image analysis to define areas of interest within this vast region (300 km by 300 km).

A program of drill holes tested distinctive basement signatures in the aeromagnetic data (locations in Figure 1) using a combination of rotary mud drilling through cover sequences and diamond drilling of underlying basement rocks to provide around 50 m of representative core samples from each site (examples Figure 2). Wireline geophysical logs were run in the holes prior to casing. Preliminary drilling details to date are summarised in Table 1.

All cores will be comprehensively sampled for mineralogy, geochemistry and geochronological analysis as well as being scanned by the Hylogger™. Final

Table 1. Preliminary drilling results

Site ID (ref. Figure 1)	Total depth (m)	Basement lithology
GSNSW Milcarpa 1	290.9 m	Rhyodacite
GSNSW Euroli 1	153.7 m	Metasedimentary schist
GSNSW Tongo 1	312.8 m	Granodiorite
GSNSW Laurelvale 1	386.8 m	Siliciclastic turbidite
GSNSW Janina 1	222.2 m	Granite
GSNSW Congarrara 1	119.6 m	TBC
GSNSW Congarrara 1	TBC	TBC

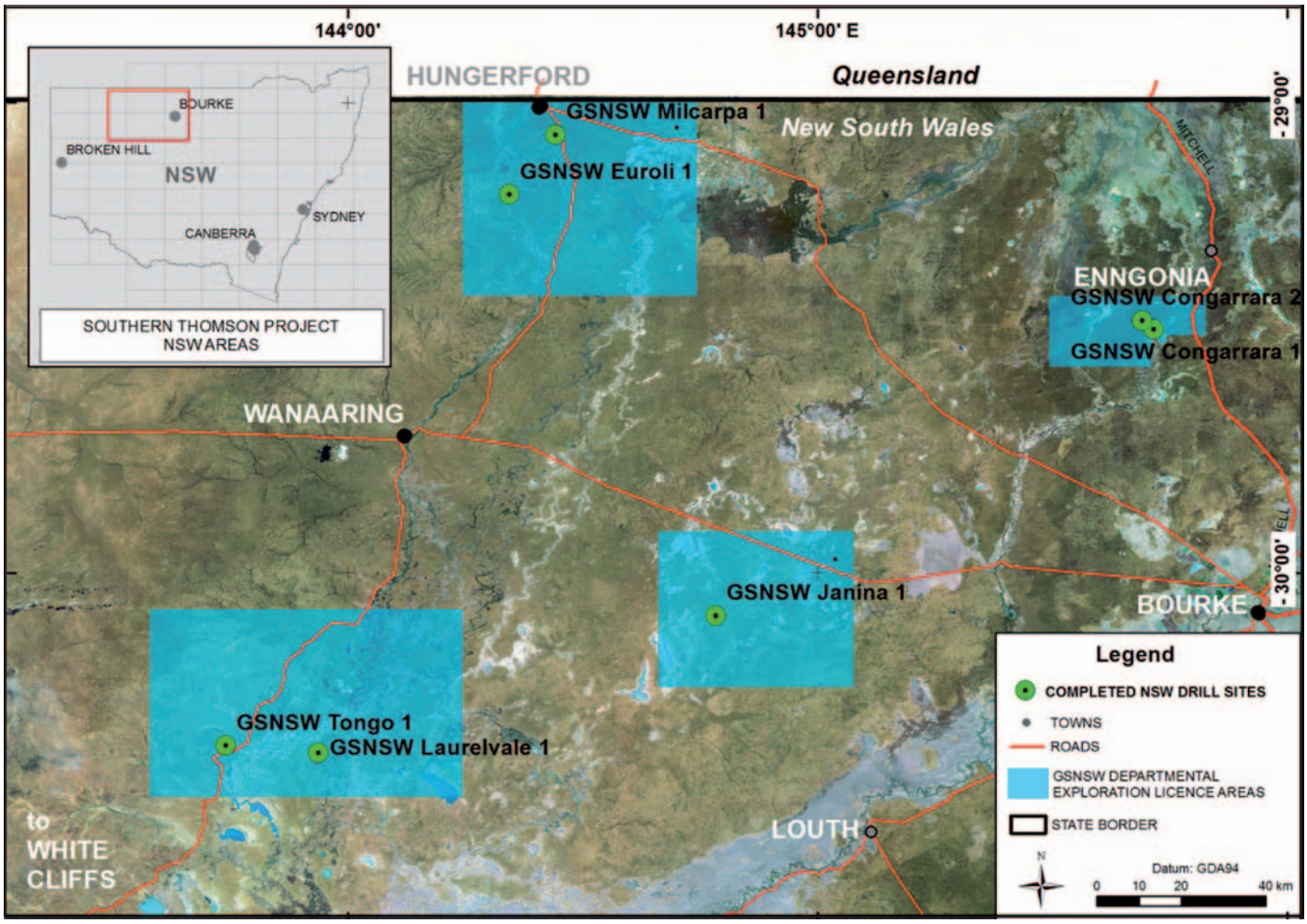

Figure 1. *Location of drill sites in the Bourke – Hungerford region.*

Figure 2. *Rhyodacite core from GSNSW Milcarpa 1 (top), metasedimentary schist from GSNSW Euroli 1 (centre) and granodiorite from GSNSW Tongo 1 (below).*

results will be made publicly available through the GSNSW website and presented at Southern Thomson Project workshops.

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Canberra observed

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Minerals and petroleum exploration activity recovering – minerals get a helping hand from government

Gold and base metals drive minerals revival

Investment in mineral exploration continues to increase, according to the Mineral and Petroleum Exploration data for the June quarter of 2017, released on 4 September 2017 by the Australian Bureau of Statistics (http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6401.0Jun%202017?OpenDocument#Time).

The trend-estimate for mineral exploration expenditure increased by 6.6% ($26.4m) to $428.5m in the June quarter 2017. The actual expenditure rose 31.8% ($107.3m) to $444.9m. Of the $449m total, Western Australia accounted for 65% ($291m), followed by Queensland with $57.6m, and New South Wales with $45.3m. This is the highest quarterly figure since September 2014 and, although well below the record of $1062m in June 2012, the numbers show a consistent increase since the $295m figure for the March 2016 quarter (see Figure 1). Notice how the petroleum numbers now are almost the same as the minerals numbers, which was also the case in 2005.

The two main drivers for the increase in minerals investment have been gold and all the selected base metals (copper, silver, lead, zinc, nickel and cobalt). Gold exploration reached $193m in the June quarter. This is the highest it has been since the September quarter of 2012 and 23% higher that the June 2016 quarter. The gold price has hovered around US$1300/oz during the past five years (see Figure 2), so gold explorers are no doubt relying on it being in the $1100–US$1400/oz range for the next few years. However, as you can see in Figure 2, although the gold price has been in this range it can be quite volatile and is still a lot lower than the peak of US$1896 it reached in 2012.

All the main base metals are now in demand with exploration expenditure on

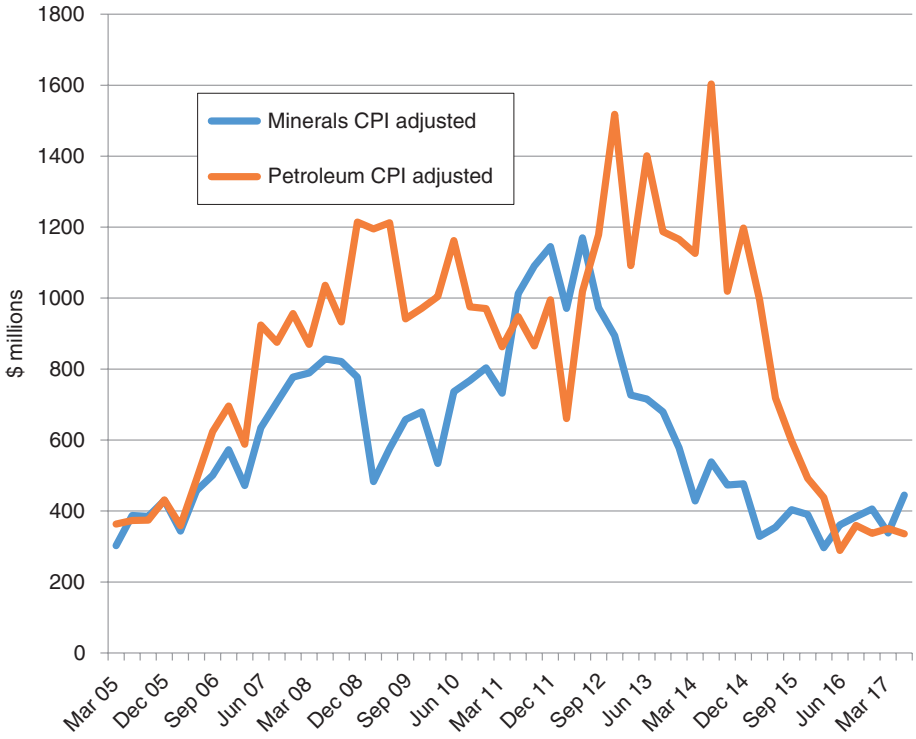

Figure 1. *Quarterly petroleum and mineral exploration investment 2005–2017. Notice how the level of investment for minerals and petroleum exploration are now similar, and the same as they were in 2005. All data have been normalised to June 2017 A$, using the CPI. The raw data were supplied courtesy of the Australian Bureau of Statistics. See: http://www.abs.gov.au/ausstats/abs@.nsf/mf/8412.*

Figure 2. *Gold price in US$/oz from 2000–2017 from the website: http://www.lbma.org.uk/pricing-and-statistics-mobile.*

them rising from $54.8m to $94.8m from the June quarter in 2016.

All the other indicators were positive with the number of metres drilled rising from 1795 km in the June quarter of 2016 to 2299 km in the June 2017 quarter. Furthermore, the increases were in both existing deposits – up from 1376 km to 1616 km, and in areas of new deposits – up from 418 km to 683 km. And, exploration on areas of new deposits rose 32.1% ($33.0m) and expenditure on areas of existing deposits rose 31.6% ($74.1m). But that is not all!

Australian Government commits $100 million to encourage mineral exploration

As well as the encouraging numbers for the minerals exploration, there is also a helping hand from the Australian Government. On 2 September 2017, the Government announced that:

> *"It will commit $100 million to secure additional private investment in vital greenfield mineral exploration to drive the next wave of mineral discoveries crucial to the resources sector and the Australian economy."*
>
> *"It will provide tax incentives for junior exploration companies to encourage investment and risk taking which are needed to underpin the future strength of our resources sector and the Australian economy."*

To quote from the Prime Minister's media release:

> *"These tax incentives will encourage 'junior explorers' to take risks and to have a go at discovering the next large-scale mineral deposit."*
>
> *"We want to turnaround the greenfields minerals exploration expenditure that have declined by almost 70 per cent over the past five years.*
>
> *Under the new $100 million Junior Mineral Exploration Tax Credit scheme, Australian resident investors of junior explorer companies will receive a tax credit where the exploration company chooses to give up a portion of their losses relating to their greenfields exploration expenditure in an income year.*
>
> *The ability to immediately distribute tax credits to investors will make investing in a 'junior explorer' more immediately attractive and encourage investment in small exploration companies undertaking greenfields mineral exploration in Australia."*

The devil might be in the detail, but:

> *"only newly issued shares relating to capital raising for investment in new greenfields exploration activity will be eligible for these tax credits.*
>
> *This will help maximise the incentive for additional investment in minerals exploration.*
>
> *Tax credits of up to $100 million over four years will be made available from this financial year on a first-in first served basis consistent with arrangements to be administered by the Australian Taxation Office."*

The media release did not define Junior Explorers, but it is a very welcome step in the right direction.

When I was President of the Australian Geoscience Council in the late 1990s we tried to persuade the government that such a scheme would be a good investment. It's good to see it happening, even if it did take 20 years!

Petroleum exploration investment also rises – but only just

According to the Australian Bureau of Statistics the trend-estimate for total petroleum exploration expenditure rose 0.9% ($3.0m) to $345.8m in the June quarter 2017. Exploration expenditure on production leases rose 35.1% ($14.5m) and exploration expenditure on all other areas fell 3.6% (–$10.8m). The seasonally adjusted estimate for total petroleum exploration expenditure rose 4.7% ($16.1m) to $355.6m in the June quarter. Exploration expenditure on production leases rose 53.1% ($22.2m) and exploration expenditure on all other areas fell 2.0% (–$6.0m). Western Australia remains the premier petroleum state for exploration and it accounted for $108m of the $336m. However, as can be seen in Figure 3, it is difficult to see any increase in investment levels that are now back to where they were in 2005. With the oil price remaining close to US$50/barrel it is also difficult to see Australia as an attractive offshore exploration area.

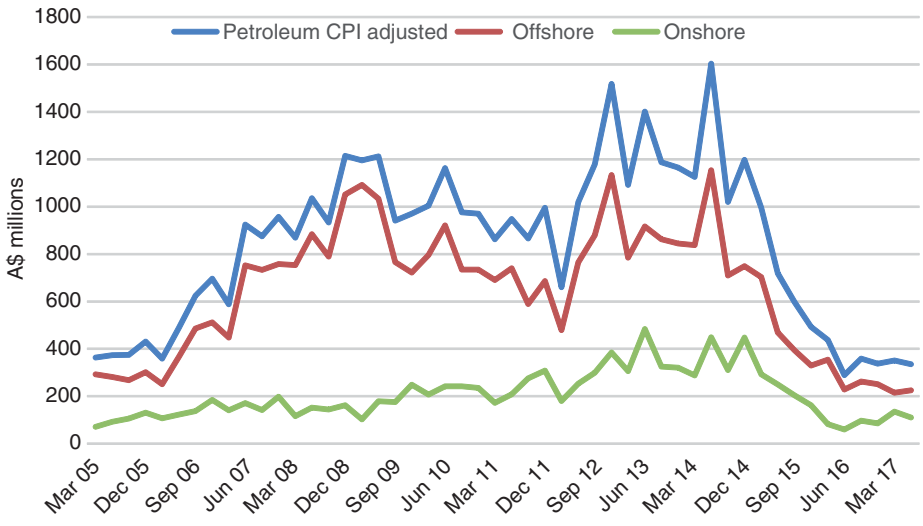

Figure 3. *Onshore and Offshore petroleum exploration investment 2005–2017. All data have been normalised to June 2017 A$, using the CPI. The raw data were supplied courtesy of the Australian Bureau of Statistics. See: http://www.abs.gov.au/ausstats/abs@.nsf/mf/8412.*

Education matters

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Final term in universities – and it is full of opportunities

Opportunities for graduating students abound. No, I am not talking jobs this time around, but opportunities to network in our industry and show-case your own work.

In Melbourne the VUEESC conference (Victorian Universities Earth and Environmental Science Conference) is coming up soon and would be great to advertise your work by giving a paper. There is more information at http://earthsci.unimelb.edu.au/events/details?event=9318.

The conference is a one-day event providing opportunity for students (honours, masters and PhD) to show-case their work and network with a cross-section of industry and academic people. Presentations include research in the fields of Geology, Atmospheric Science, Environmental Science, Agricultural Science and Environmental Engineering.

Jarrod Dunne, geophysical specialist at Karoon Gas Australia Ltd and one industry person in Melbourne who takes a keen interest in these events, is encouraging fellow professionals to attend, and rates past conferences as a very well organised events with a wide range of geoscience presentations refreshingly presented.

Submissions of papers and posters to the VUEESC close at 5 pm on 20 October. This is only one of many such occasions sponsored by the ASEG and other geoscientific societies around the country. Check with your local branch for details of future dates. Also be sure to take the opportunity to present a paper at your local branch Student Night usually held in November or December.

The future of mineral exploration in Australia

I wrote in the last issue about the optimistic assessment by the World Bank on the future of the mineral industry in a future sustainable low-carbon industrial world ('Clean Energy Transition Will Increase Demand for Minerals – World Bank', *Preview* August 2017). Complementing that global viewpoint we have the new release of a Road Map for mineral exploration in Australia, using new technologies to search under regolith cover. See the article by AMIRA's Adele Seymon and Joe Cucuzza in this issue of *Preview* ('Australia's mining industry has a plan'); it has been a huge project using input from 208 people over the past two years, and, if a career in mineral exploration figures in your ideas or job interviews, you can't miss the opportunity to be informed by this study.

Call for summaries of student theses completed in 2017 for the December issue of *Preview*

As you complete your thesis and plan your future, ensure you provide a summary of your thesis to *Preview* before leaving campus (previeweditor@aseg.org.au). The December issues of *Preview* are a marvellous opportunity for first publication of student work and remember, everyone in industry reads this material and it is your chance to catch the eye of some future employer who really needs some of your newly developed expertise!

Careers event in WA: 'You can't beat a career in geoscience'

ASEG's WA branch, together with four other geoscience societies, hosted a Careers in Geoscience day on August 22. University students from Curtin and UWA had the opportunity to meet with representatives from the resources industry and academia for the annual event; a total of 40 students, and representatives from 14 organisations, spanning petroleum exploration, mining, service providers, consulting, and professional associations convened at the Technology Park Function Centre in Bentley to discuss geoscientific careers over drinks and canapes.

The event highlighted the range of career opportunities available for budding geoscience students after they finish their studies. It was organised through a collaboration of the Australian Institute of Geoscientists (AIG), the Geological Society of Australia (GSA), Earth Science Western Australia (ESWA), the Australian Society of Exploration Geophysicists (ASEG), and the International Association of Hydrologists Australia (IAH). Careers in Geoscience was generously sponsored by several exhibitors, including CSA Global, CGG, Curtin University, Evolution Mining, Newmont Australia, PGS Australia, Reflex, Southern Geoscience Consultants and UWA. The Petroleum Exploration Society of Australia (PESA) also exhibited and ConocoPhillips Australia contributed to catering for the event.

Drew Bellamy from Westernex Raytrac presented the keynote address on his career in geoscience and entrepreneurship. He suggested that the three critical components for a successful career in geoscience are networking, curiosity, and resilience; fitting, given the Careers in Geoscience event facilitated these three components.

John Grigson, a third-year student from UWA, attended the event as he believed it would be a 'good opportunity to meet other members of the geoscience community and work on developing a

network of contacts, discuss geological topics of interest in a more social setting, and ideally learn something new from my interactions', adding that he 'achieved all these things on the night and thoroughly enjoyed the experience'.

It wasn't just the students who gained from the night. Ned Howard from Evolution Mining commented that 'Attending the Careers in Geoscience event gave us the opportunity to interact and connect with engaged students who want to be part of the industry, and these are exactly the people we want working for us at Evolution'. And Kathlene Oliver, General Manager at the Department of Mines, Industry Regulation and Safety, said that events like Careers in Geoscience are an invaluable tool for generating interest in studying fields of geoscience, creating the future expertise needed to grow the resource sector. This event gives students a chance to learn about geoscience careers from industry people, consultants and academics.

The event showcased part of what makes a career in geoscience so rewarding: passionate people getting together to share ideas and experiences. The success of the event was made possible by the sponsors, organising committee, and of course the students. You clearly can't beat a career in geoscience!

Thanks to Al Harvey, one of the organising committee for Careers in Geoscience, for this overview and photo.

Students entering the 'guess the age of the zircon' competition at the GSA booth.

Environmental geophysics

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Welcome readers to this issue's column on geophysics applied to the environment. I was very pleased when I got interest from readers on last issue's subject – equipment miniaturisation for use on UAVs. Andrew Foley, Group Chief Geophysicist at Gold Fields, wrote to me about work that his group is doing along these lines to collect high-resolution magnetics data over some of their ground, which is pretty challenging. Here is Andrew's story.

Ultra-high-resolution magnetic data acquisition over Lake Lefroy, WA

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Starting in 2012, Gold Fields designed and built a high-resolution dry lake-capable magnetic acquisition platform called SKIMPI (Sled Kart Instrument for Magnetic Prospectivity Imaging). The system was designed to rapidly acquire ultra-high-resolution magnetic data across the Lake Lefroy salt lake system, which covers approximately 40% of the St Ives tenement package (Figure 1).

High-resolution aeromagnetic data (40 to 50 m line spacing) already existed across the area and, in some cases, high-resolution ground magnetics (20 m and 40 m line spacing) was also available. However, it was felt that significant upgrades in our geological understanding, particularly with respect to structural mapping, could be achieved by acquiring ultra-detailed data, and so, a prototype lake platform and magnetometer system, SKIMPI, was built by Gold Fields and Technical Images Pty Ltd.

The SKIMPI system collects data at 25 Hz on 7.5 m spaced lines, and to date has completed acquisition across approximately 250 km^2 of Lake Lefroy. The system handled most conditions that the lake could dish up, from hardpan, glass smooth salt crust, through thick mud, to deep windblown water and waves. That said, inaccessible areas still exist, e.g. in particularly muddy inflow channels, drill-disturbed areas, and causeway 'dams'. In addition to this, the salt lake environment and style of driving required for straight-line data acquisition system was brutal on the towing vehicles,

Figure 1. *The SKIMPI system being towed across Lake Lefroy, WA.*

which ranged from Teryx, Max and Argo ATVs (in increasing terrain capability).

So, the logical next step was to go to the air, taking advantage of our experience miniaturising the system onto the SKIMPI platform, as well as the hard-, firm- and softwares that we had developed. The first phase of this project has now been completed with the development and deployment of the TRAMPE (Tethered Rotary Airborne Platform for Exploration) UAS (Unmanned Aerial System) system (Figure 2).

TRAMPE is a towed bird configuration flying at a Mean Terrain Clearance (MTC) of 5 m for the magnetometer, again sampled at 25 Hz at an average speed of 25 kph along 10 m spaced lines. Flight control is fully autonomous with pilot intervention only during take-off and landing; mostly as a precautionary procedure in order to face the bird into the wind on take-off and to protect the bird structure and sensor during landing. Broadcast differential GPS information is collected during acquisition. Final data processing utilises a post-processed DGPS workflow, along with standard, and specialised in-house potential-fields processing workflows.

Figure 2. *The TRAMPE system in action.*

Unfortunately, due to the need to maximise data collection (and the fact that the two acquisition systems are so similar), a full comparison/overfly of SKIMPI and TRAMPE data sets has not yet been undertaken – apart from merging overlaps. An example of a merged data set is shown in Figure 3. The top image shows the UAV-based TRAMPE data only. This data set has been reduced to pole (RTP). The second image shows the

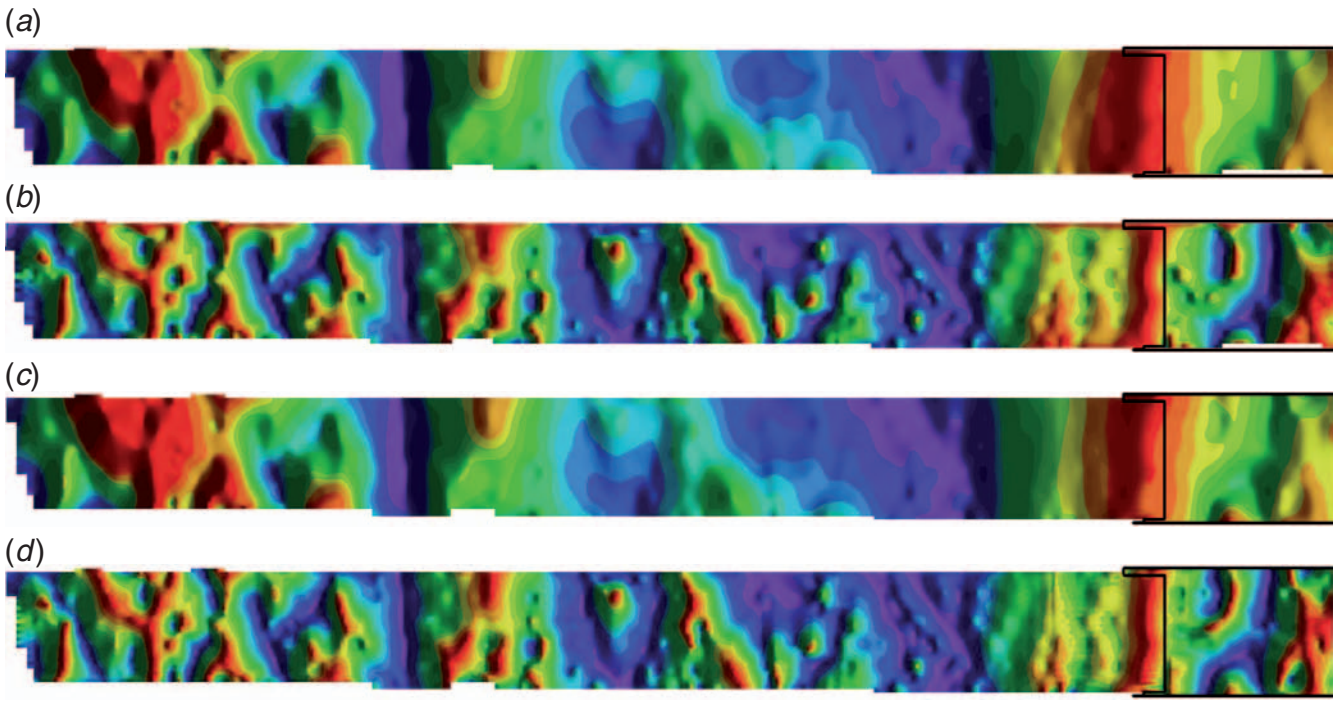

Figure 3. *Comparison of UAV-based TRAMPE data and ground-based SKIMPI data, highlighting the compatibility of the two data sets. (a) TRAMPE RTP data (overlap area with SKIMPI highlighted in black on right). (b) TRAMPE RTP data with TDR enhancement. (c) Merged SKIMPI and TRAMPE RTP data. (d) Merged SKIMPI and TRAMPE with TDR enhancement.*

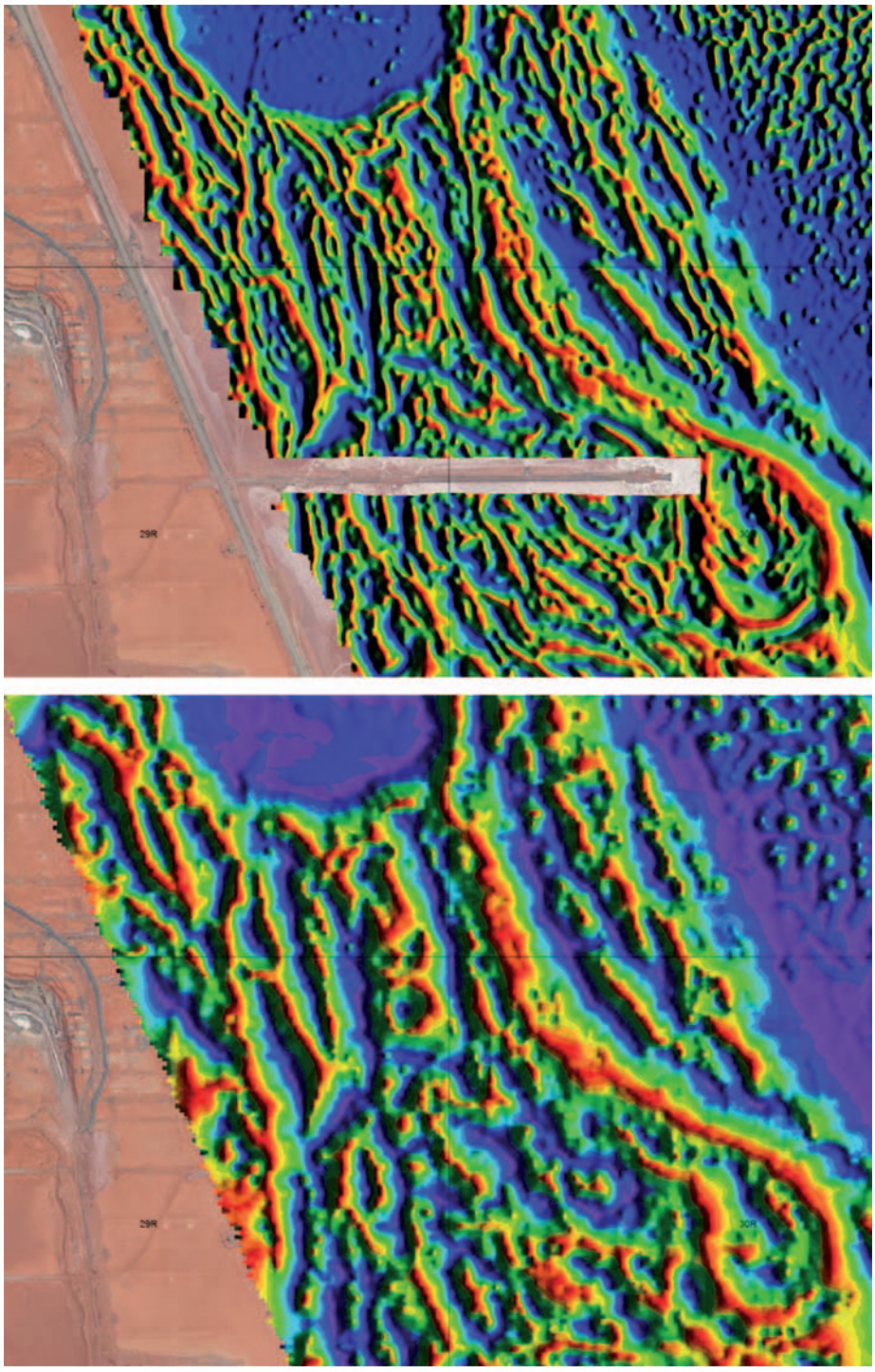

Figure 4. *Comparison of SKIMPI data (top) and high resolution ground mag data (bottom) collected at 20 m line spacing. Both data sets are RTP and then TDR filtered.*

same TRAMPE data, this time processed with additional tilt derivative filtering (TDR). The third image shows the merged SKIMPI and TRAMPE RTP data sets, and the bottom plot shows the merged data sets with TDR filtering. For all plots the overlap area is highlighted with the black polygon on the right side of the figure. Comparison of Figure 3*b* and 3*d* shows that the two data sets are very compatible.

To further illustrate the value of collecting high resolution data, whether ground-based SKIMPI data or UAV-based TRAMPE data, Figure 4 shows a comparison of SKIMPI data (top figure) and conventional high-resolution data (bottom figure – collected on foot).

With the deployment of TRAMPE Mk I now complete, further refinement of the system is underway. These include improvements with respect to the drape and avoidance systems, as well as the development of a stinger mounted magnetic sensor. All of which, if successful, will result in a lower flying height and closer line spacing!

Biography

Andrew Foley graduated in 1988 with an Honours degree in Geophysics and Exploration Geophysics. He joined Normandy Mining in 1991 through 2001, based in Adelaide, Perth and Townsville. In 2001 after the Newmont – Normandy – Franco Nevada merger, Andrew relocated with Newmont to Denver. In 2007 he joined Gold Fields International as Chief Geophysicist based in Denver, and remained through 2014, during which time he completed a Grad Dip in GIS and Data Modelling, 2012. After a major restructuring of the Exploration Group, Andrew relocated to Perth in 2014 as Group Chief Geophysicist.

Minerals geophysics

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Colour me red

In modern times, spectacular developments in geophysical processing, interpretation and presentation technology have changed the role of geophysicists. Geophysical data presentations used to be quite basic – typically contours and sections of the survey results themselves, perhaps with some simple modelling. Because of this, and the arcane knowledge needed to understand the processes involved, only geophysicists interpreted geophysical data. Not anymore! Now we have a powerful array of processing and interpretation tools – think constrained 3D inversions for example - and a wide spectrum of presentation options to draw upon. Thanks to these, geophysical survey data are now much more clearly related to the geological environment they seek to investigate. Geophysical survey results are no longer the province of a select few, but are accessible and usable by all geo-scientists.

In particular, in the matter of image presentation, the range of options available to us is impressive. We can now image results (often inversions or purpose-built algorithm products) to emphasise (or de-emphasise) pattern elements, strike directions, anomaly styles and magnitudes, etc.

As a simple and basic example, I'd like to focus on colour tables, and more particularly on colour stretches. The potential for problems was first brought home to me after poring over a regional magnetics image with an exploration manager, identifying magnetic anomalies of interest in a general targeting exercise. However, on reprocessing that part of the image covering our area of interest, most of our targeted magnetic anomalies diminished alarmingly – casualties of the colour stretch. Now I insist on fully descriptive titles and colour bars for all images!

The impact that colour stretches can have is well-illustrated in the following example. We were surveying an area looking for extensions to known structurally controlled mineralisation. The survey results as delivered by the

contractor were quite spectacular (see Figure 1); the known mineralisation, on the bottom margin of the map, had responded well, and there were strong indications for similar mineralisation within prominent structural trends through the area. However, the colour stretch used was histogram equal area, the default option in many imaging packages because it requires no operator intervention and produces attractive maps. By way of contrast, the image produced using a simple linear colour stretch was equally spectacular (see Figure 2), but for all the wrong reasons. The mineralisation-related response remained, but all other responses in the survey area were seen to be nowhere near the required magnitude. All our new 'mineralisation' had vanished! As a simple compromise, I settled for a clipped range linear image (see Figure 3) which emphasised the absence of other significant responses, but did retain the structural information, albeit, unfortunately, un-mineralised. The message here is that, by their very nature,

Histogram equal area colour stretches will always deliver a significant proportion of apparently anomalous responses – regardless of the actual response magnitudes

histogram equal area colour stretches will always deliver a significant proportion of apparently anomalous responses (i.e. coloured red), no matter what the actual response magnitudes are.

So, along with these powerful new visualisation tools, come new responsibilities for the geophysicist. At the touch of a button we have the means to strongly influence how the results are visualised. And, perhaps worryingly, modern software now gives other geoscientists the ability to apply their own colour stretches to 'our' data. So, some education may be in order.

Finally, I have to confess that occasionally I've let this new-found power go to my head. I once created a soft fluffy pastel colour stretch (think English rose pink through to powder puff blue and you'll get the general idea) for a particularly macho geologist in our team – he was not impressed! Such is the power of modern computer processing.

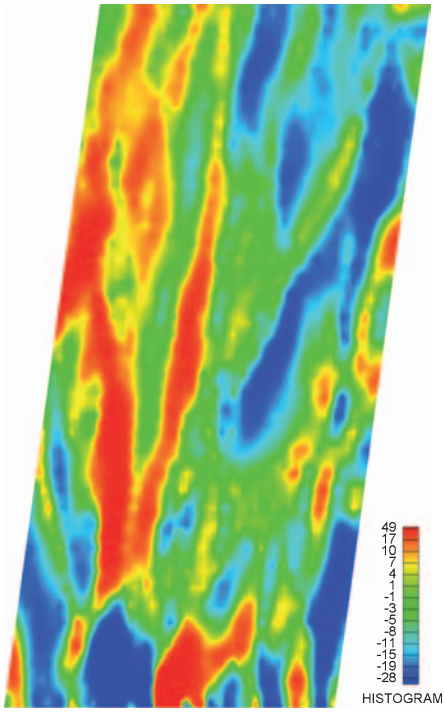

Figure 1. *Histogram equal area colour stretch.*

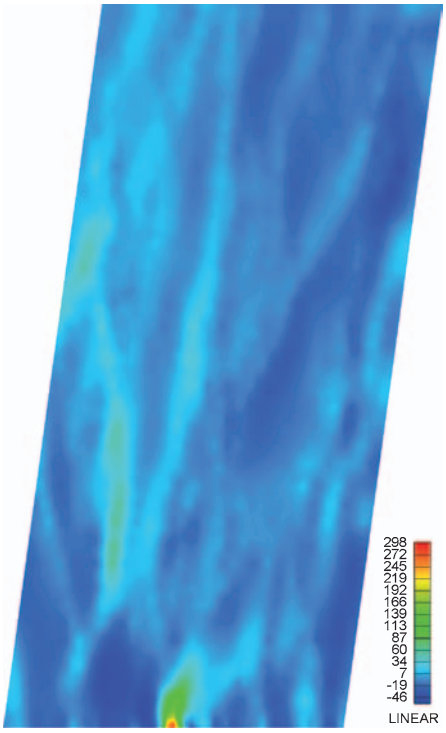

Figure 2. *Linear colour stretch.*

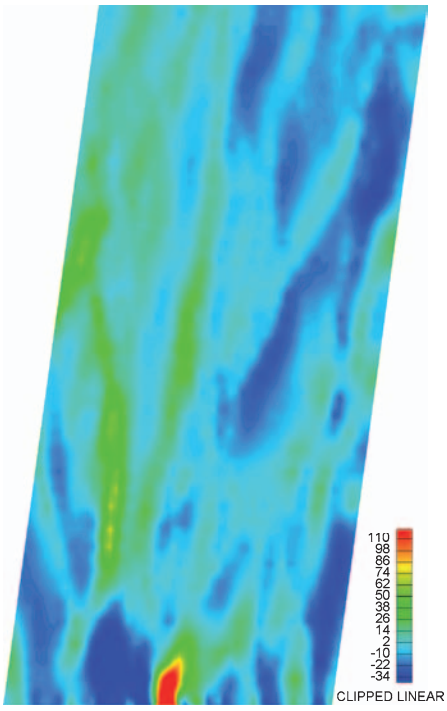

Figure 3. *Clipped linear colour stretch.*

Seismic window

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Faults

How far will a fracture propagate during hydraulic stimulation? I was investigating this topic following the Western Australian Government's moratorium on 'fracking' when I came across some notes on fault deformation (I will provide the answer later). Around the same time a colleague decided to go back to university and to begin researching the structural evolution of the Carnarvon Basin. These two events led me to my *Atlas of Analogue Modelling of Extensional Fault Systems* for a quick brush up on extensional tectonics. This Atlas was produced by the National Centre for Petroleum Geology and Geophysics at Adelaide University and documented several sand box models of different structural settings found on the NW shelf. With its sand box modelling of the Mermaid Fault this book would be a good place for my colleague to start his research.

Early in my career, when I began interpreting seismic, I had access to several useful atlases that contained example seismic sections from various structural and stratigraphic settings. I still have eight of these books. They are large format; maybe 60 × 30 cm and a few centimetres thick, covering topics such as Australian and New Zealand basins, Seismic Stratigraphy, Rocky Mountain Region, Modern Convergent Structures, three volumes of Structural Styles, and, my favourite, the 'Fault Atlas'. They are a useful reference but use more shelf space than I would like. Today we have the internet.

This got me thinking about the importance of having a good fault interpretation as a foundation for prospect mapping. I'm not a structural geologist, but I think I know most of the rules; such as individual faults are not very long, and even long ones are actually several short faults that have amalgamated. There is an empirical relationship between fault throw and fault length with outcrop and mine studies suggesting the length is 50 to 100 times the throw. Using this ratio would suggest the fault shown in Figure 1 should be 5–10 km long because its displacement is about 100 m. But it appears to extend for over 25 km. A closer examination of the similarity attribute (Figure 2) reveals several shorter segments about 6 km long (B and C), which are linked by faulted relays. Further to the west, there are some examples of relay ramps. As an interpreter is it better to pick each fault segment separately, or pick the entire length as a single fault? In my experience both have problems but generally it is better to pick each separate segment.

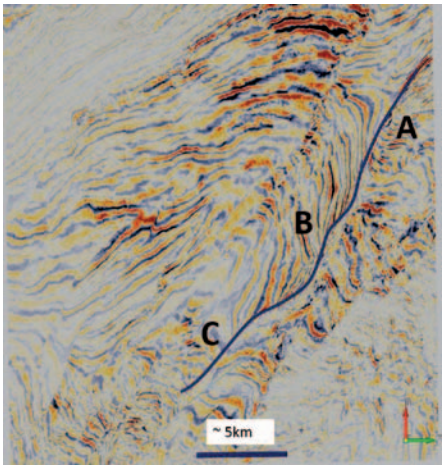


Figure 1. *Seismic timeslice at 1800 ms. Several faults can be identified with Fault ABC appearing to be over 25 km long. On closer examination it consists of a number of linked faults (A, B and C) each about 6 km long and connected by relay faults which form kinks along the fault trace.*

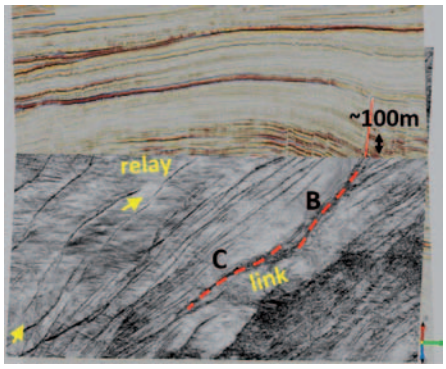


Figure 2. *Vertical seismic with similarity attribute on 1800 ms timeslice. Similarity helps to identify the 6–8 km long segments of the red fault which is consistent with the 100 m throw. The relay ramps have failed and faults link the segments. Yellow arrows indicate relay ramps that have not yet failed.*

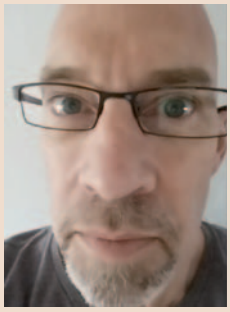
Back to hydraulic stimulation. Researchers at Durham University have built a database of the results of thousands of fracture stimulation projects around the world. The longest vertical fracture created is 588 m, and statistically the chance of a vertical fracture exceeding 350 m is only 1%. This puts a safety buffer of more than a thousand metres between deep reservoirs and shallow aquifers. Another interesting snippet of information – a 1 m displacement along a fault results in/from a magnitude 6 earthquake so a 100 m fault requires either a huge earthquake or dozens of smaller ones.

For those who really want to get into the details of fault modelling, structural restoration and validating geometries I suggest taking a look at Structure Solver (www.structuresolver.com). The website for this neat piece of software has several examples of different fault regimes and a large gallery of informative videos.

Reference

ATLAS: 3D Analogue Modelling of Extensional Fault Systems plus Field Applications, NCPGG Adelaide University, 1995.

Webwaves



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One year on, how is the new ASEG website being used?

In mid-August, some users may have been affected by an issue accessing *Exploration Geophysics* (EG). Unfortunately, the access issues were coincident with a new edition of EG. Although the causes of these issues remain unclear, it did give the site's developers (SpringDigital) an opportunity to rethink authentication methods. Their revised method is much simpler and less prone to errors than the initial method.

The remainder of this issue of *Webwaves* focuses on the website, which was launched in August 2016 during the 2016 ASEG conference, and is now officially one year old.

Over the year from August 2016 to August 2017 the site has had a total of 11 994 visitors, with over 80% from return visitors. This averages to 56 visitors per day. Figure 1 plots site visits over the first year. Red and green arrows indicate adjusted publication dates of EG and *Preview* (PV) respectively. Because it is difficult to determine publication dates exactly EG was adjusted to the end of the appropriate month, while PV was adjusted to the middle. There is some correlation between spikes in site visits and publication of either EG or PV.

It is interesting to see where visitors come from. Figure 2 shows the number of worldwide visitors. Visits from Australia, USA and Canada dominate as might be expected. The site is also visited by large numbers from Brazil, South-East Asia, China and Russia. The site has been visited by most countries in South America and South Africa. Figure 3 shows site visits by city. Again dominated by Australian cities, it is interesting to note that the site had more visits from Kuala Lumpur than Darwin. It is also perhaps noteworthy to see the presence of Indian, Brazilian and Japanese cities.

So what do visitors do when they visit the site? Figure 4 shows the 25 most visited pages over the year (omitting the home page). There is strong interest in publications (EG and PV), conferences, the contractor database, the two pages dedicated to jobs, the online equipment museum and workshop proceedings. The presence of the page '/cms' on the list is indicative of the level of site maintenance, including updates. The 2016 Wine offer shows strong interest as well. The eighth entry in the list suggests that site users are proactive in bringing issues to the attention of the ASEG.

It is also useful to examine pages lying outside the top 25. Perhaps because it was the first workshop placed on the site, the 2016 Near Surface Passive Seismics workshop proceedings ranked 35th.

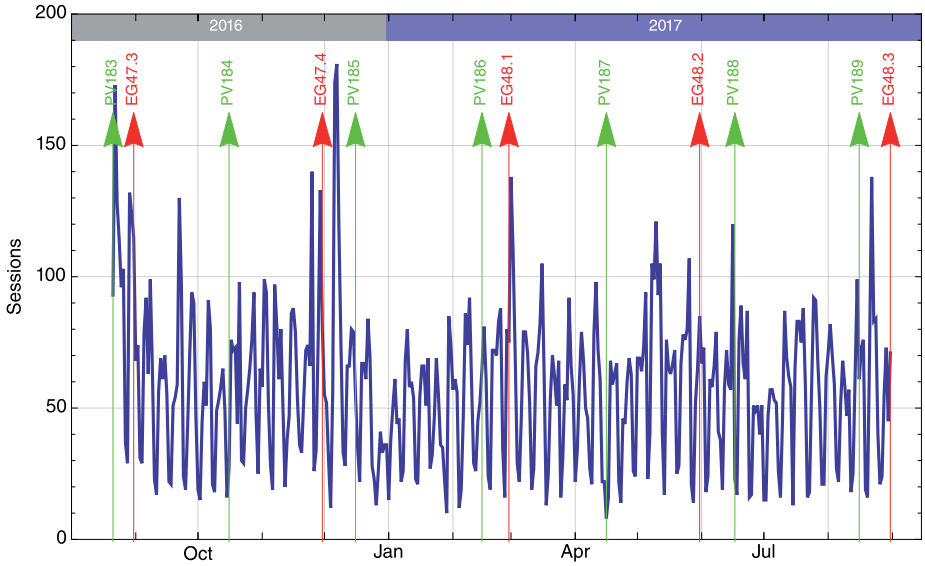

Figure 1. *Visits to the new ASEG website during the first year of operation.*

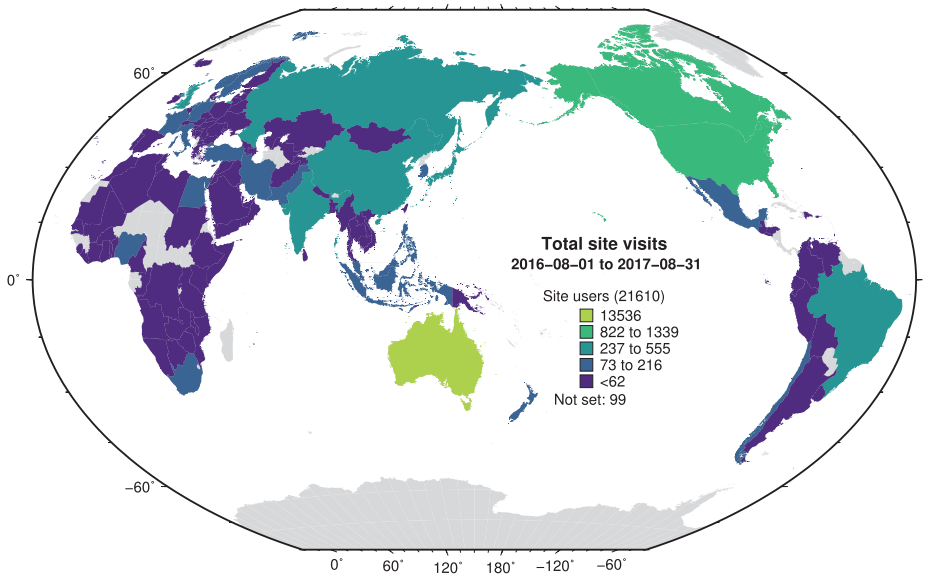

Figure 2. *Visits to the new ASEG website by country during the first year of operation.*

Other workshops of note were the 2012 Practical AEM workshop (112th) and the 2016 IP Processing and QC workshop (250th). Website pages associated with each branch are also accessed regularly. Most accessed was WA (27th), then NSW (43rd) and Queensland (59th). There was also a reasonable level of interest in equipment manuals with the most interest in manuals associated with electromagnetic instruments.

With the one-year anniversary completed, it is natural to look to the future. The next 12 months are likely to see (in no particular order) the contractor's database updated for easier searching, cosmetic changes to the Geophysical Test Ranges, and the 2017 Wine Offer. Interest in workshop proceedings suggests that making proceedings of workshops from the 2018 AEGC conference available would also be greatly appreciated by Members.

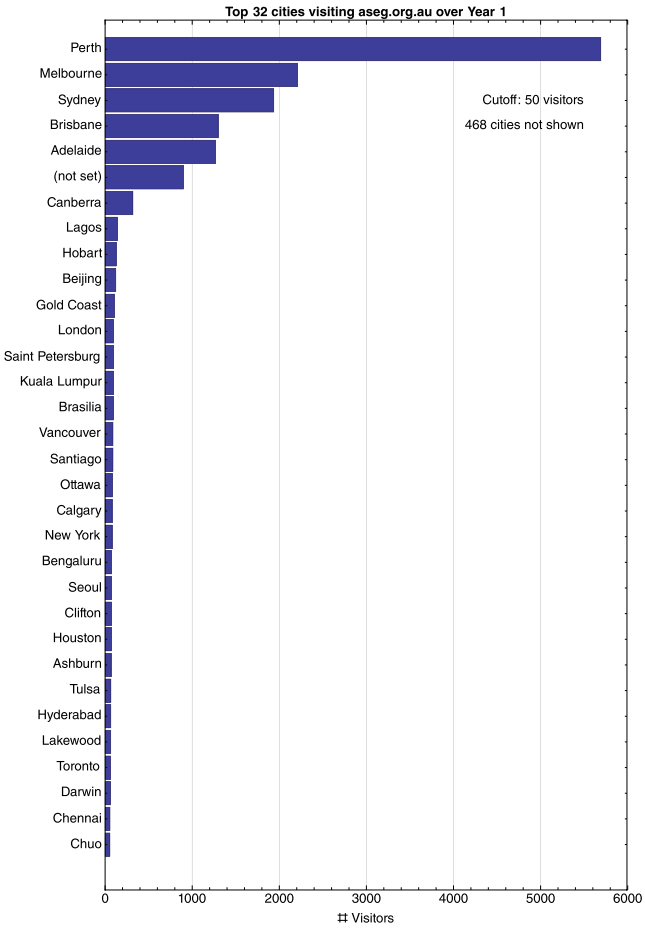

Figure 3. *Visits to the new ASEG website by city during the first year of operation.*

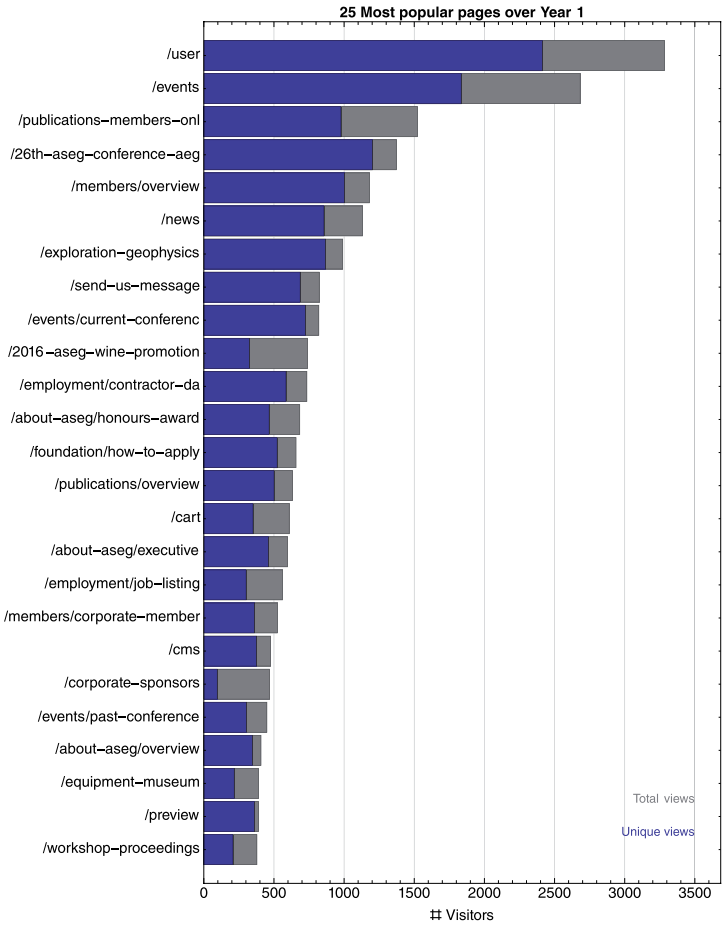

Figure 4. *Most popular webpages during the new ASEG website's first year of operation.*

Book reviews

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A call for volunteers

A few years ago now I drifted into the role of Associate Editor for Book reviews for *Preview*. It all started with a flourish. I contacted all the major publishing houses I could think of and offered to arrange reviews of their new geophysics books. Since then, however, I've only arranged a handful of book reviews in *Preview*, far less than the initial burst of enthusiasm had promised.

Soliciting book reviews requires little bursts of effort to organise a reviewer, sometimes persistent follow up, but generally once I've gotten my act together, it's been a trouble-free process of sending finalised reviews to our *Preview* Editor, Lisa Worrall, for publication. Whether I'm lazy or simply distracted, following up on potential book reviews hasn't always been undertaken diligently. The hardest part has been deciding who to approach for a review. But perhaps matching books to reviewers would work better if tackled in a different way? If, that is, book reviews are still relevant in this day and age.

I have wondered how often we all look at books relevant to our profession these days. I know my daughter – powering through her first year of high school – has a beautiful (but very dense) maths text book to refer to. I've never actually seen it in her hands though; it apparently gets used in class sometimes, but beyond that it stays in her locker and she accesses the online version on her BYOD (Bring Your Own Device). She has a Japanese textbook too, but alas, no science textbook (?!). Most of her assignments appear to make reference to various websites, so I do hope that her training in the pitfalls of internet information is effective.

Do you still use textbooks? Do you still value reading a book review in *Preview*? I have a few favourite textbooks that get opened occasionally. I even still have one on quantum physics that has a well-bound, bright blue (hard) cover, is not too heavy and not too light and, quite frankly, feels accurate and reliable. I've kept it despite never really grasping its contents.

Perhaps you've spotted a new book that you'd love to add to your shelf (if you still have the luxury of a bookcase in your workplace)? Or maybe you're curious to see what all the fuss is about a good, solid textbook? Publishers generally provide a gratis copy of books that are reviewed, although these days it is often a login to access the eBook. But don't let that deter you! If you do spot a book of interest, I'd be happy to contact the publisher to enquire about a copy for review.

While you ponder whether you know of a new book that you'd like to review, here are a couple that have come into my inbox in the last year or so, but clearly didn't get much further:

- *Guidelines for Mine Waste Dump and Stockpile Design*, edited by Mark Hawley and John Cunning, published April 2017 by CSIRO Publishing (almost got a reviewer for this one)
- *The Geology of Australia* (3rd edition) by Robert Henderson and David Johnson, published September 2016 by Cambridge University Press.

Please get in touch if either of these books are of interest to you, or if you can suggest someone who could undertake a review, or even if you'd like to express an opinion about the evolution of information sources in our profession.

The level of knowledge about exploration geophysical methods in Australia prior to the Imperial Geophysical Experimental Survey (IGES), 1928–30. Part 2

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Introduction

In Part 1, published in *Preview*, **189**, pp. 42–49, nine sources of knowledge about exploration geophysics in Australia before the IGES were identified and examined individually and generally. In Part 2 details about the knowledge of the particular methods revealed by the sources are discussed. As in Part 1, descriptions of instrumentation are not included as the instruments, in any case, are mostly obsolete.

Sources available before IGES

The nine sources available to the author, which describe exploration geophysical methods available in Australia before 1929, are, in chronological order and abbreviated form:

[1] Andrews, March 1925.*
[2] *Western Argus* newspaper, December 1925.
[3] Krahmann, 1926 *(Andrews' copy dated '1928').
[4] Elbof Geophysical Co Ltd, 1927 *(Andrews' copy not dated).
[5] Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research, November 1927 *(Andrews' initials on cover).
[6] Gepp et al., June 1927.
[7] Mason, December 1927 *(Andrews' copy dated 21 05 28).
[8] Barton, February 1928 *(Andrews' copy dated 21 05 28).
[9] Andrews, 1928.*

*Denotes copies originally held by E. C. Andrews and now retained by the author.

The content of these sources is considered by individual geophysical method.

Methods

Magnetic method

The magnetic method was not discussed in Andrews (1925), the *Western Argus* (1925) or Barton (1928). The Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research (1927), hereafter referred to as the "Sub-Committee", states that the magnetic method was an exception to the belief that "employment of geophysical methods is comparatively recent" because it was used in *"the middle of the 19th century in searching for deposits of iron ore"*, particularly in Sweden. After initially being used only on magnetic ores, "Magnetic methods …are now applicable to the differentiation of igneous and sedimentary rocks and to the survey of salt deposits".

Krahmann's (1926), chapter on magnetic intensity commences with "Magnetic investigations were first carried out in Skandinavia [sic] on the enormous magnetite deposits found there…", unfortunately with no dates. He goes on to say, "Only recently, in the last year or two [i.e., 1924 or 5]…theoretical principles have been much improved". Four examples of case studies, in Germany, with intensity contour plots ("isodynamic lines") are shown, one acquired in 1922 and interpreted by C. A. Heiland[1]. One of the examples given in Krahmann, 1926 (Figure 1) shows "pronounced magnetic anomalies in the Tertiary sedimentary and basaltic area". Three of Krahmann's (1926) examples are also used by the Sub-Committee (1927), and two by Gepp et al. (1927).

In the chapter on "Magnetic Surveys" in Elbof Geophysical Co Ltd (1927), hereafter referred to as Elbof (1927), magnetic susceptibilities are listed and then five German examples are given (all different from those of Krahmann, 1926); three on iron ore deposits, one on a salt ridge indicated by a magnetic low, and another to map the depth and thickness of oil bearing chalk. Gepp et al. (1927) has four pages, on "Magnetic" (sic). The techniques and equipment are referenced to Heiland (1926) and also to Krahmann (1926), the latter suggesting that Gepp et al. (1927) may have seen a copy of Krahmann (1926).

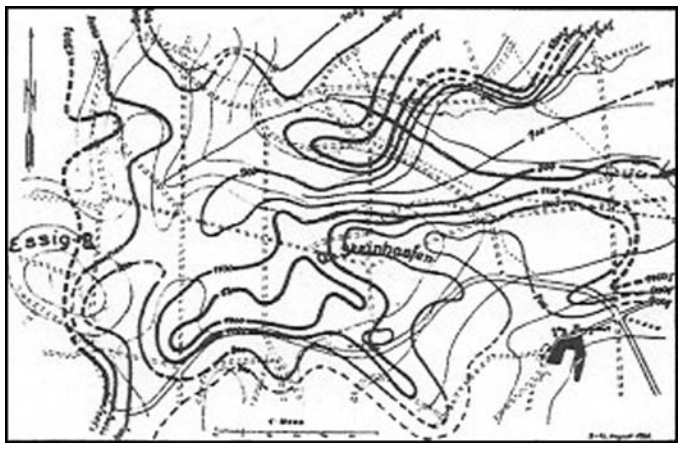

Figure 1. *"Isodynamic lines" of vertical magnetic intensity over basalt near Cassel, Germany, surveyed by Krahmann in 1925 (from Krahmann, 1926, Fig. 31).*

[1]Heiland, who was later to become Professor of Geophysics at Colorado School of Mines, authored many papers and a seminal textbook; *Geophysical Exploration* (Heiland, 1940).

The Sub-Committee (1927) further states "Magnetics are also used *in combination* with gravity as it takes ….less than one-tenth of the time required… of the latter". Also, magnetics are being used "in combination with the gravimetric method by the leading Oil Companies" and in combination with electrical methods "in the Southern Lapland mining districts". A general conclusion is that the magnetic method is quick and well able to complement the results of other methods.

Only one small magnetic survey was conducted in Australia before the IGES; see Part 1.

Gravity method

This method was not applied in Australia before the IGES. It was discussed by all sources except Andrews (1925) and the *Western Argus* (1925).

While the Eötvös torsion balance was first tested in the field in 1891 (Szabo, 1998), it was not used for prospecting until some years later. Broughton Edge and Laby (1931, p. 136) offer an example of what may be one of the *earliest applied geophysics uses* as, "Schweydar, in 1917, carried out the first torsion balance survey in Germany over a salt dome…". It is noted by the Sub-Committee (1927), somewhat pointedly, that "the original idea" of the torsion balance is based on "experiments … by the English physicist, Cavendish" in 1797.

Krahmann (1926) concludes that the torsion balance instrument "*is at once, the most difficult, the slowest and the most sensitive of all geophysical instruments*". "The most important limitation…is the necessity of flat, or at least almost level country". Krahmann (1926) notes that the "mathematical elimination" of high ground that disturbs results "can of course only be carried out very approximately". Mason (1927) claims, however, that "the effect of near-by surface irregularities [is] computed and corrections made therefore". Andrews (1928) claims that correction for topography "requires a considerable knowledge of mathematical principles".

Regarding interpretation, the Sub-Committee (1927) claim that "the approximate thickness and the depth of the deposit can be calculated", although "cumbrous". "Recent theoretical developments have however, tended to facilitate the interpretation…and it is now claimed…*it is possible to calculate the effect to be expected from any known body of whatever form"*[2]. Gepp et al. (1927) in their section on "Gravitometric" (sic) quote entirely from other sources (in particular, Shaw and Lancaster-Jones, 1925) and add nothing to the more interpretational aspects described above. Mason (1927) has concerns for the method's use in *mining environments* where topography and structural complexity will be prominent, thus, "… the success of the Eötvös balance in such districts as the oil fields of Texas cannot be duplicated in most mining regions". This caution is repeated by Andrews (1928).

Regarding petroleum exploration, Krahmann (1926) acknowledges, "especially good results have been obtained … [on] salt domes in the northern states of America, also large faults in Mexico…such as are of importance in connection with oil deposits". The Sub-Committee (1927) also refer to the use of the torsion balance method in Texas, USA, where in 1925 alone, five new salt domes likely to be associated with oil deposits were found. Only six were discovered without the use of geophysical methods in the previous 20 years.

Generally, the Sub-Committee (1927) state; "The instrument has not hitherto, however, been used in considerable numbers by *British concerns*". One instance, at an iron-ore mine in Cumberland in 1925, was described with satisfactory results. Also, they report that the method was used in Northern Sweden to determine if the electrical indications were due to ores or graphitic slates (by their different densities).

The most recent and authoritative source for this method is Barton (1928), the subject being the Eötvös torsion balance only. There was no indication from any of the other sources, apart from E C Andrews, who held a copy, that they had read this paper. Barton (1928) quotes numerous examples of its use in the USA, including over salt domes in Texas, on faults and a granite ridge, and he proposes its use in *mapping geology*. The gradients over the Nash Dome, discovered in 1924 and generally quoted as *the first discovery of an oilfield by any geophysical method,* are illustrated in Figure 2. The use of the torsion balance in mining is dealt with in only five short sentences, including: that the "Colorado School of Mines and the U S Bureau of Mines are cooperating in some experiments … in mining problems in Colorado".

Unfortunately the torsion balance had a limited future. The early 1930s saw the rise of the spring gravity meters, which were a lot easier to use.

Electrical methods

These methods, of one type or another, were referred to by all sources except Barton (1928), whose only subject was gravity. The report in the *Western Argus* (1925) epitomises the commonly expressed belief in the value of the electrical methods: "In prospecting for ore bodies, the methods…have

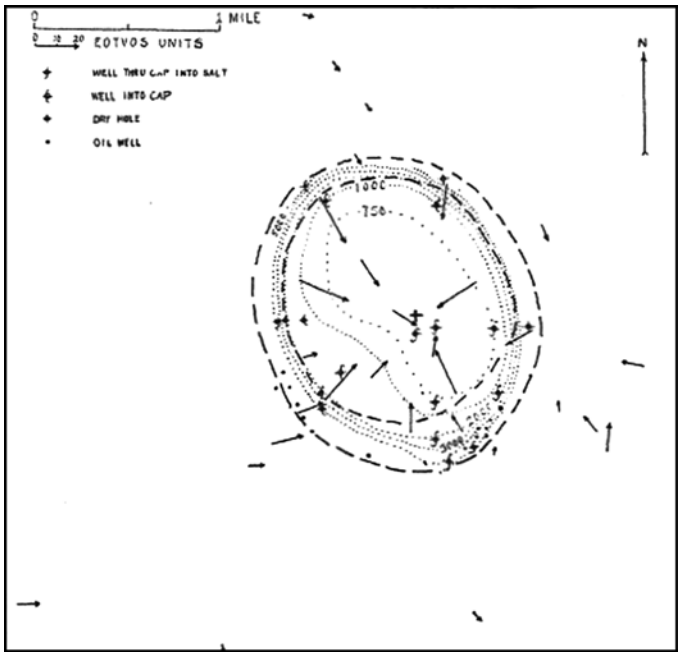

Figure 2. *Eötvös gravity gradients (the arrows representing intensity and direction) over the Nash Dome, Gulf Coast, Texas. The dashed lines show the interpreted limits of the dome at two depth levels, the outer at 4–5000 feet deep (from Barton, 1928, Figure 9).*

[2]No support is given to this bold statement by references, but they could be referring to such work of Shaw and Lancaster-Jones (1922) and (1925); two Englishmen based at the Science Museum, London.

proved most successful". They have also "been subject to the most energetic …work, especially in Sweden".

The electrical methods described by the sources were the 'Equipotential method' (with contact or non-contact receivers) available since the early 1900s, the 'Inductive method' (with or without a grounded source) since 1921, and the 'Self-Potential' method practiced as early as 1830. The 'resistivity sounding method' was mentioned only by Elbof (1927). See more on this below.

(a) Equipotential method

All sources, except Barton (1928), described the use of the equipotential method. Current passed into the ground through point sources develops a field of which the equipotential lines can be mapped using 'search' electrodes or coils. Figure 2 in Part 1 illustrates the basis of this method. Distortions in the normal pattern are attributed to the presence of anomalous conductivity.

Andrews (1925) in his informal paper titled "Electrical Prospecting" only described the equipotential method and with AC current, "preferred by most experimenters" (although "Schlumberger was inclined to favour the application of direct current"), point source current electrodes and two "search" electrodes with an intervening "telephone". Later, Andrews (1928) called this method the "Surface Potential Method" (as did Mason, 1927) with two variations, 'the Schlumberger method', with point sources, and the 'Lundberg method' when line sources are used. Figure 3 is a schematic of the method's use with line electrodes and illustrates how equipotentials may be disturbed by anomalous conductivity. Andrews (1928) also noted the potential of this method to *map structure.*

As an example of "the striking results which may be obtained by means of electrical prospecting", Andrews (1925) refers to "the discovery of the Kristine Berg [sic] Ore Deposits in Northern Sweden" and references Yearbook No. 16, 1922 of the Geological Survey of Sweden (without any author(s)). Krahmann (1926) also refers to this same Yearbook with the reference as "Lundberg-Nathorst" (1922). Gepp et al. (1927) also refer to the Kristineberg deposit and their figure 9 illustrates a particularly good result of the use of the method in this field.

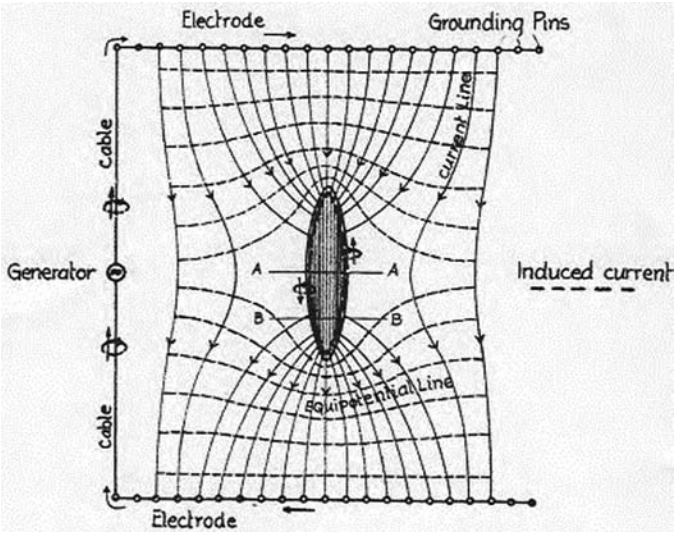

Figure 3. *The distortion of the equipotential field by anomalous conductivity when using line (Lundberg type) source electrodes (from Lundberg, 1929, Figure 3a).*

Another variant of the equipotential method is that which Krahmann (1926) calls the 'Elbof' technique using grounded AC current input, and non-contact, 'search coil' receivers. Figure 4 shows the Elbof type of receiver apparatus. He believed the Swedish methods, of using contact receiver 'sondes', limited their ground penetration and therefore rendered them not so useful for oil exploration, which is "the main field of utility of the 'Elbof' method". Following a detailed description of all elements of the method, Krahmann (1926) gives four case studies acquired by Elbof Geophysical Co., including one at a copper mine in California, USA, surveyed in 1924. Elbof (1927) provides six

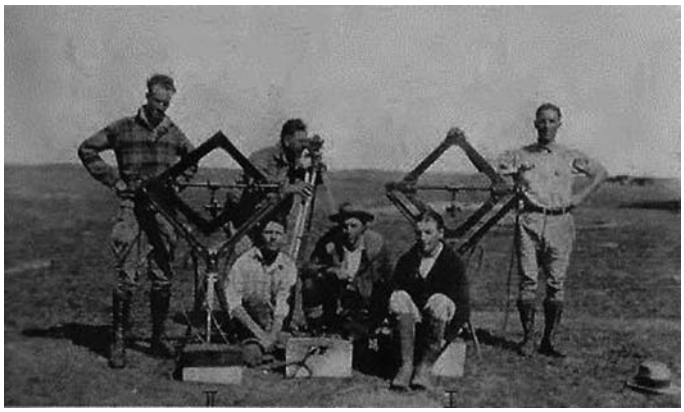

Figure 4. *The non-contact receiving apparatus used by Elbof (from Elbof, 1927, p. 9).*

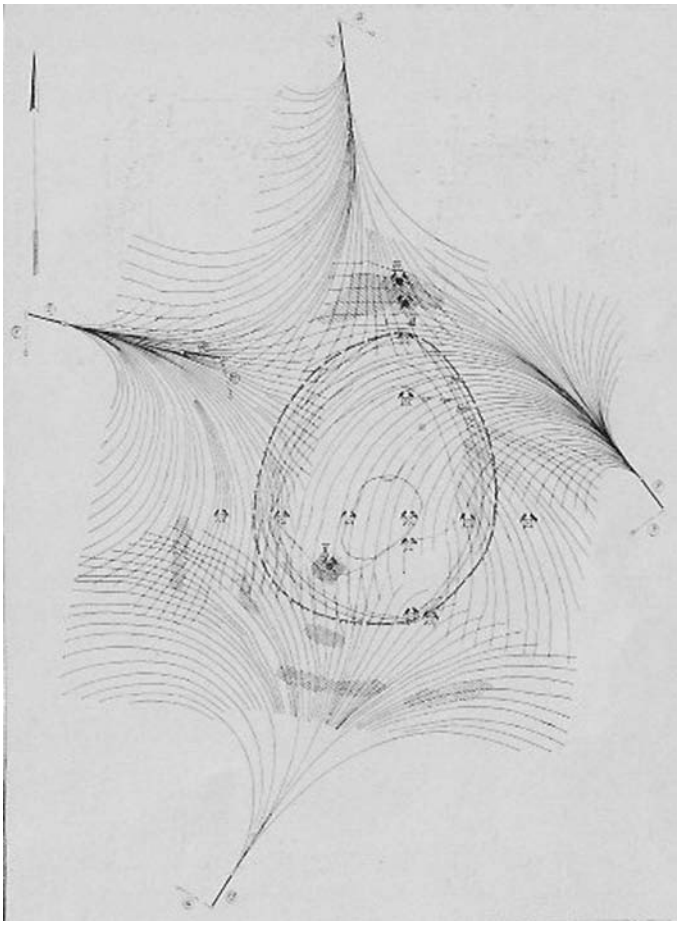

Figure 5. *The "Elbof"-type equipotential method showing four of the 14 current dipoles used over a salt dome in U.S. A. (outlined) with areas of divergence 'hachured' (from Elbof, 1927 p. 15).*

case histories illustrating the use of the Elbof style equipotential method with good diagrams, including diagrams of metalliferous deposits in Quebec, Canada and Germany and oil and gas deposits in Texas and Germany. Figure 5 shows deviations over a salt dome (outlined) in the USA resulting from fourteen separate current dipoles (only four are shown for clarity.)

As well as the distortions in the equipotential fields giving the size, shape and strike of the target body or bodies, for Elbof (1927), the depth to sub-horizontal bodies is separately given "by the 'sounding method' originated by Schlumberger". This is the one exception in all the sources where depth sounding is mentioned, and in this case using the Schlumberger array.

Eblof (1927) also refers to employing "particular apparatus" for work underground. Mason (1927) refers to surveying underground as an application for methods in general.

The equipotential method was used by the IGES, but soon after that its value was superseded by the resistivity method's ability to obtain more quantitative conductivity and depth information.

(b) Electromagnetic method

This method is described in all sources except Andrews (1925) and Barton (1928).

The *Western Argus* (1925) acknowledges the source of their information on the electromagnetic method as a paper by Hans Lunberg (sic), (possibly Lundberg and Nathorst, 1922) and report that "the main development occurred in 1921 when Karl Sundberg, a Swedish mining engineer, began to experiment with a number of their methods". They had been used "with good results since 1922 in prospecting in Sweden and Norway" and in particular, in the "Skelleftea district" of Sweden[3].

Krahmann (1926) at the end of his chapter on the electromagnetic method, states "Finally a new electro-magnetic method, the 'Sundberg' method from Sweden has recently appeared…. replacing the Lundberg-Nathorst method". He indicates that it uses induced transmission by insulated cable and an induction coil receiver.

Mason (1927) also describes a truly electromagnetic method distinguished by non-contact loop transmitters using AC, and the measurement of the secondary magnetic field using coil receivers. He credits H R Conklin with its development[4]. Andrews (1928) has "The Inductive Method" as a separate section with a similar description to Mason (1927), employing a vertical "triangular" source coil (several meters high) and an "induction coil" receiver.

(c) Self-potential method

This method is described in Krahmann (1926), Gepp et al. (1927), Mason (1927) and Andrews (1928).

Figure 4 in Part 1 illustrates the principle of this method; that of observing natural potentials due to some oxidizing ore bodies. This method is generally reported as being first demonstrated by R W Fox in 1830 in mines in Cornwall (Fox, 1830). Morrison (2004) includes one of Fox's many results. In 1882, Carl Barus, a physicist with the U.S. Geological Survey, greatly improved the viability of the method using non-polarising electrodes.

Krahmann (1926) deals briefly with "electric self-potentials" and expresses reservations about their use in prospecting, rather than their use "concerning the origin of ore-deposits". He gives Kelly, 1922 as one of his references. Gepp et al. (1927) call this method, strangely, "the Schlumberger method" and rely for its description on a long extract "from a paper by Sherwin H. [should be 'F'] Kelly…" and references Kelly, 1926[5]. Mason (1927) describes the self-potential method as expounded by "Mr Kelly", shows the result over a nickel body at Sudbury, and compares it favourably with results obtained earlier by S F Kelly on the same target (Kelly, 1922). He also states, "The best early work …was done by Carl Barus in 1822 at the Comstock Lode". Ninety years after Fox worked underground, directly on ore, Kelly was the main exponent of the practical surface method.

Capacitive coupling

The *Western Argus*, 1925, no doubt from Lundberg as its source, describes three different ways of causing current to flow, namely; inductively, galvanically and capacitively. Gepp et al., 1927 also mention capacitive coupling, in this case, via a "wire antennae suspended over and insulated from the ground".

It is intriguing to see capacitive coupling referred to as early as 1925, as there is no reference to its use at that time by Lundberg, or others. The author's earliest knowledge of capacitive coupling being employed is in Russia in 1978 (see Timofeev et al., 1994).

(d) Resistivity method

As we see from a) above, the only source to mention the resistivity method was Elbof (1927) to obtain the additional dimension of the depth to a body revealed by an equipotential field. Not even Mason (1927), the most advanced source in other ways, referred to it and consequently neither did Andrews (1928), who followed Mason (1927) closely. However, we know from Part 1 that Rooney and Gish (1927) carried out resistivity surveys in Western Australia from 1923. Henderson (2013, p. 43) reminds us that the four-electrode method to obtain resistivity was developed even earlier by Frank Wenner in 1915.

It would seem that a big leap was made from the scant knowledge of this method in the sources to that of the IGES Report (Broughton Edge and Laby, 1931), which devotes a special section to the "Resistivity Methods", separate from other electrical methods[6].

In summary, all these electrical methods were being used in Europe and the USA before the IGES (in the case of self-potential from 1830 and electromagnetic methods from 1917).

[3]The famous Boliden mine, described in detail by Gepp et al. (1927) is in this Skelleftea district and Kristineberg (as named by Andrews, 1925 and Gepp et al., 1927) is also close by.

[4]Conklin was with the U S Bureau of Standards at the time. Actually, Van Nostrand and Cook (1966) claim that Conklin developed the method from 1917 and that Sundberg's method from 1922, was based on Conklin's work.

[5]This naming of it as the Schlumberger method may relate to the Mason (1927) statement, "About 1913 Prof. C. Schlumberger, of Paris, revived interest in the self-potential work …which contributed much to the knowledge of this method".

[6]The technique to measure resistivity by Gish and Rooney, based on the four-electrode method after Wenner, with improvements, became well known as the "Gish – Rooney" method.

They were not being used in Australia, except for the use in Western Australia of the resistivity method by Americans, Rooney and Gish (1927) and an equipotential survey at Broken Hill in 1927 (Day, 1966–1967).

Acoustic methods

Krahmann (1926), the Sub-Committee (1927), Mason (1927) and Andrews (1928) only very briefly referred to acoustic methods. Gepp et al. (1927) dealt more extensively with these methods, thought to have a poor future by the others.

Mason (1927), for the purposes of geophysics, defines acoustic methods as "broadly speaking the study of echoes reflected by orebodies (sic) from incident sound waves". Note his bias to hard-rock applications. The media for such waves can be air, water or earth, and they are in the audible range.

Krahmann (1926), in a one-page chapter on 'Seismic' methods in general, appears unenthusiastic about acoustic waves "…work has been proceeding… but the results do not appear to have reached beyond the experimental stage. Further, "…there is no information published or otherwise available, concerning any practical results achieved by the method".

Gepp et al. (1927) in a short chapter on 'Sound Vibration', where they make no distinction between 'acoustic' and 'seismic' methods, describe as one of "two important methods"; the "Fessenden Method"[7]. This method consists of generating sound waves in water using oscillators and microphones and relies on "putting down shafts" to detect anomalous transmissions between four shafts filled with water. Figure 6 is Figure 1 from Gepp et al. (1927) and illustrates the method[8]. Gepp et al. reference Heiland (1926) for this method and give no indication of its use. The method may have been too hard to arrange and little use was made of it subsequently. Mason (1927) states, "The acoustic method…early proved rather disappointing". This method was referred to by the IGES report (Broughton Edge and Laby, 1931, pg. 195) in only one sentence "Fessenden attempted practical exploration in America in 1913, … he used the sonic sounder and a sonic receiver".

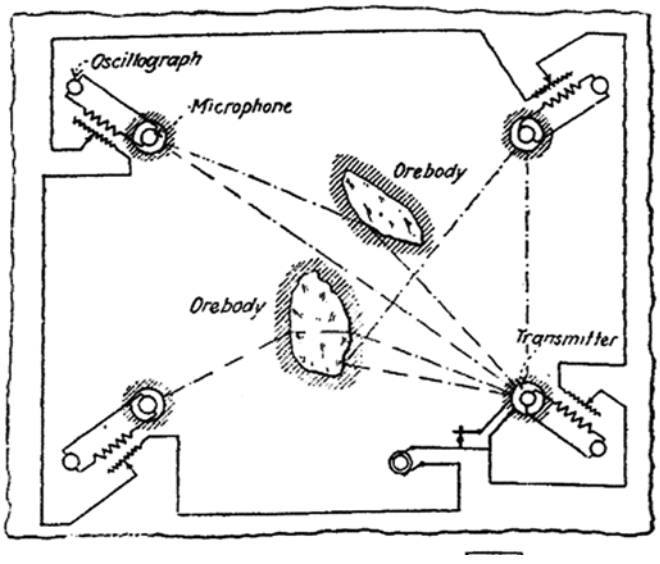

Figure 6. *A plan view of the Fessenden acoustic method showing the four shafts, oscillators, microphones and oscillographs used (from Gepp et al., 1927, Figure 1).*

The Sub-Committee (1927) make the surprising statement; "Sonic sounding" or "echo" methods…..have, we believe, been tried to a very limited extent *in Australia*", but so far no results of the experiments have come under our notice". The author is not aware of any such experiments. Nor is it clear whether the Sub-Committee is referring to the Fessenden method that Gepp et al. (1927) highlighted.

The acoustic method was not used by IGES, and the author does not believe that it has been used in Australia subsequent to the IGES.

Seismic method

This method was referred to by Krahmann (1926), the Sub-Committee (1927), Gepp et al. (1927), Mason (1927) and Andrews (1928). As simplified by Gepp et al. (1927), this method generates "artificial earthquakes" detected by "a very sensitive seismometer".

Krahmann (1926), in one page on the seismic method, notes the physical basis which "has led Dr Mintrop of the firm 'Seismos' of Hannover to a practical method of investigation".

Seismos G. m. b. H. of Hannover was the company of Dr Mintrop, a pioneer of seismic prospecting who, according to Lawyer et al., (2001), "filed in 1919, for a German patent entitled, "Method for Determination of Rock Structures'. He … set up….Seismos Limited in 1921". According to Barton (1929), Mintrop started experimenting with early seismographs during WWI. "By 1921, he had demonstrated the potential of the method…" and "In …1923 Mintrop's method was introduced in Mexico by the Royal Dutch Shell". Also, "The discovery of several salt domes late in 1924 by a troop (sic) of Mintrop's "Seismos" company… gave great impetus to the method".

Krahmann (1926) also discusses the use of 'distance-time curves' to determine "the thickness of covering layers" and the detection of concealed structures is explained; for which "there is already a substantial amount of research material for the calculation of these factors". The Sub-Committee (1927) conceded only that "….the thickness of the upper layer can be determined as well as the speed of….the layer below". They also indicate that in conjunction with electrical methods; "Seismic methods were used in the Skellefte district [of Northern Sweden] in the winter of 1923 for determining the depth of overburden…" with close accuracy compared to drilling. For Gepp et al. (1927), "Mintrop's Method" (sic) is the other one of their "two important methods" and their description is attributed to "Heiland, 1926". They also refer to its use in Sweden.

As none of the sources have any illustrations of the seismic method in operation (admittedly, at a time when photos were not readily produced, as now), Figure 7a–c reproduced from Rieber (1929), illustrate the level of practice at the time.

[7]One of the SEG Awards is the Reginald Fessenden Award; "for a specific technical contribution to exploration geophysics" and it has so far been awarded to two ASEG Members, Derecke Palmer in 1995 and Keeva Vozoff in 2009.
[8]This diagram is from Figure 1 of Fessenden's 1917, USA patent #1,240,328 (Lawyer et al., 2001).

Figure 7. *(a) "Receptor (geophone] being lowered into place" (from Reiber, 1929, Figure 3). (b) "A typical field party" (from Reiber, 1929, Figure 4). (c) "Dynamite truck firing a charge" (from Reiber, 1929, Figure 2).*

The seismic method was not used in Australia before the IGES. Part of the reason for this lack of use was the recognition that such methods were not as suited to the detection and delineation of ore-bodies, so much as they are for mapping relatively flat lying strata - especially that containing oil and gas fields. Mason (1927) states, "the difficulties in [the seismic methods] are of a serious nature". "In the neighbourhood of most orebodies the rock conditions are complicated by fracture zones, by faults or folds and, in general, by many irregularities". Andrews (1928) made this same observation (about the "irregularities") in what was by far the shortest description of the various methods dedicated to the "sonic and seismic methods" in his report.

The influence of IGES on the seismic method in Australia

The seismic method is a second instance (along with the resistivity method) of the rapid development of a method in Australia due to the instigation of the IGES. The big gap in knowledge between what was known of the seismic method in Australia before the IGES, and that subsequently published in the IGES report, is exemplified in the introduction to the report (Broughton Edge and Laby, 1931); "During these early preparations in London the testing of seismic methods by [IGES] was thought to be impracticable, since neither experienced operators nor the necessary equipment could be secured". However, "following on their war experiences of seismic methods, the late Professor J. A. Pollock, F.R.S. (one of designers of the first gravity meter, see Henderson, 2015) and Major E. H. Booth of Sydney University had, for some years, been carrying out experiments…very similar to that now being employed in geophysical investigations."(Broughton Edge and Laby, 1931, p. 3). Consequently, Major Booth consented to act as a consultant to the IGES for the seismic method.

Radiometric method

The author can find no reference to the use of the radiometric method in Australia before the IGES, nor was it used as part of the IGES. The only two sources that discuss this method, namely Krahmann (1926) and Elbof (1927), indicate that the method was in its infancy.

Krahmann (1926), in his Chapter VII "Geothermic and radio-activity surveys", which is only one page long, describes the measurement of radioactive gas emanations from soil at a depth of one meter, and "the radioactivity of bore-hole samples", which "I regard as more promising". Elbof (1927) in Chapter V "Geo-thermic and Radio-activity Investigations", claims the method enables faults and fissures to be located. Figure 8 is a radioactivity profile, across a faulted trough in Thuringia, Germany from Elbof (1927). No date is given. The faulted edges of the trough are clearly indicated by anomalous radioactivity[9].

This method has become, since the late 1940s, very important in the direct detection of uranium and in mapping geology and, in that respect, is very complementary to magnetic and gravity methods. Just as with regional magnetics, entire continents are now being mapped with radiometrics.

Geothermal method

Krahmann (1926) acknowledges anomalous temperature gradients with depth "in the vicinity of salt ridges, many

[9]The Geiger-Muller tube, which made the measurement of radioactivity so much more practical in the field, was not invented until 1928. Thyer (1979) reports that probably the first use of a 'Geiger counter' ("built in in the Physics Department of Adelaide University") was *by himself*, at Mt Painter, South Australia, in 1944.

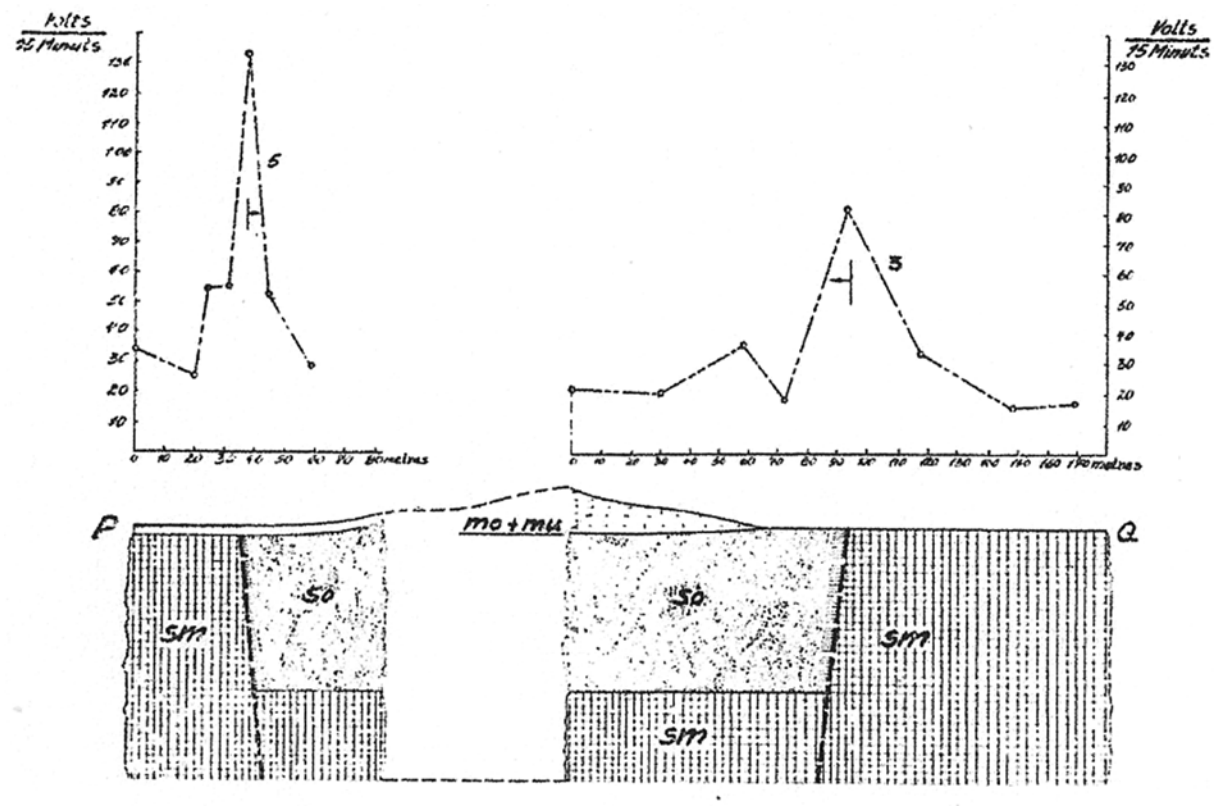

Figure 8. *A 'radio-activity' profile over faults in Thuringia, Germany of Volts/time (from Elbof, 1927, p. 41).*

petroleum deposits, coal seams of certain types and certain oxidisible ores….". However, he believed the science was "not yet clear enough to enable" its use for "geological purposes". In addition to repeating these anomalous situations, Elbof (1927) add the anomalous gradient due to radioactive minerals. The Sub-Committee (1927) only states, "[Thermal methods] have as yet no direct application to prospecting for minerals".

Geothermics was also not practiced before or during the IGES, in contrast to its use in the deep mines of Witwatersrand, South Africa from 1911 (de Beer, 2011). However, much more recently, "hot rocks" have become very popular in Australia as a source of geothermal energy.

The secrecy of companies

Krahmann (1926) and the Sub-Committee (1927) referred to what they regarded as the unhelpful secrecy surrounding the practices of some private companies.

Krahmann (1926, Ch. I, p.6) decried the lack of information on geophysical methods in general, and claimed that a "great obstacle is the fact that the parties for whom investigations are carried out nearly always require *secrecy* in regard to the results". The Sub-Committee (1927)] states that, contrary to the case of the gravity method of which "Full details….have been published in the scientific press…", "No comparable scientific publications have been issued in regard to the other geophysical methods. In particular, the electrical method has throughout been treated by the companies employing it as a *jealously-guarded secret trade process*". In this case I assume they are referring to companies like Elbof. With regard to seismic methods, "They have suffered hitherto from control by private interests and lack of publication of the methods used and the results obtained". For example, "very little is known, of the methods by the Seismos Gesellschaft in Germany"[10].

E H Booth, consultant to the IGES for seismic methods, made a similar claim as to the prior knowledge of seismic methods in his Presidential address to the Royal Society of NSW (Booth, 1938); "Up to this, [the time of the IGES] although certain scientific papers were available, the procedure and theoretical methods of interpretation,…were mysterious (sic) as they were applied by private companies which preferred to keep their methods *secret*".

To some extent this secrecy could be a result of companies not wanting their rivals to know about their proprietary techniques.

Exploration geophysics in South Africa before the time of the IGES

Johan de Beer in his comprehensive paper on early exploration geophysics in southern Africa (de Beer, 2011) reveals how magnetic, gravity, electrical, seismic and geothermal methods were all used in that region from the mid-1920s, some by geophysicists we know about from the 'sources'. The earliest use of mining geophysics in southern Africa was said, by de Beer, to be a geothermal survey reported in 1911; as indicated in 'Geothermal Method' earlier.

[10]Broughton Edge and Laby (1931) suggests that a major aim of the IGES was to address this paucity of information, particularly with electrical methods. With regard to seismic, "This branch …was entirely in the hands of certain geophysical companies".

The first practical electrical surveys started in 1925 "by the Electrical Prospecting Company from Stockholm". Electrical methods were suggested for the gold reefs of the Witswatersrand, in 1926 by "Conrad and Marcel Schlumberger of France, and Karl Sundberg and Helmer Hedström of Sweden"… "In 1925 and 1926, the British geophysicist Arthur Broughton-Edge (sic) conducted experimental geoelectrical surveys in the Northern Rhodesian (now Zambian) Copper Belt"[11]. In 1929, "self-potential and mise-à-la masse surveys" were conducted[12]. Refraction seismic surveys were conducted in 1927–8 and magnetic surveys were "carried out on an ad hoc basis" before the 1930s. Gravity surveys were not reported until later. In 1930, Rudolf Krahmann (See 'Krahmann in Australia (and South Africa, briefly)' in Part 1) arrived in South Africa and became famous for his magnetometer surveys, which resulted in more than twelve gold mines.

Why was there such poor knowledge in Australia before 1928 about exploration geophysical methods being practiced in Europe and north America?

Was the remoteness of Australia a factor? The distance to Australia from Europe and north America is of the order of 20 000 km and transport by ship, as experienced by E C Andrews in March, 1928, took two months. Regular air services were not available until later and, even so, were very expensive. The first radiotelegraph linking Australia to Europe started operation in April 1927, and the first radiotelephone in April 1930.

Apparently this remoteness was not as much a factor in South Africa, where geophysics was more advanced than in Australia before the IGES (see preceding section). Were connections better through the continent of Africa, at least for the British?

The well-known phrase "tyranny of distance" may be appropriate in this case. In the preface to his book of that title, Geoffrey Blainey (1968) states; "…most parts of Australia are at least 12,000 miles from western Europe, the source of most of their people, equipment, institutions and ideas". All this is very true of the science of geophysical exploration in the mid-1920s. Certainly there was no local development and manufacture of geophysical equipment at this time, or indeed for several decades later; E C Andrews was only just urging for the introduction of geophysical prospecting in institutions in 1928 (Henderson, 2013) and very few new ideas could be nourished when formal lectures on the subject did not start until 1949.

Edgar Booth, in his Presidential address to the Royal Society of NSW (Booth, 1938), acknowledged the value of the IGES to Australian geophysics, nevertheless, he alluded to the "temporary collapse of the economic system (the Depression) in the last year of the survey…". Had it not been for this, Booth was sure that the impetus of the IGES "would undoubtedly have resulted in the establishment of maintained training centres in our universities". Why then did this take nearly 20 years?

Another more technical reason for the late introduction of exploration geophysics to Australia could be the lack of outcrop, particularly when compared to countries like Sweden that had rich outcropping ore-bodies such as Boliden (referred to in detail by Gepp et al., 1927). Also, thick, conductive regolith was difficult to penetrate with electrical methods; the primary methods used for metalliferous targets.

Whilst Australians had a poor knowledge of exploration geophysical techniques prior to 1928, the IGES prompted a rapid expansion of interest and activity. Australian exploration geophysicists are now renowned throughout the world and have been responsible for notable advances in geophysical instrumentation.

[11]Here de Beer (2011) makes the surprising statement that "Broughton-Edge is regarded as the father of exploration geophysics in Australia", which can only be through his association with the IGES. The author is not aware of this claim being widely recognised.

[12]The method of Mise-à -la-masse, which involves inserting current into a conductor resulting in electrical potentials around it, was not mentioned in any of the Australian 'sources' nor was it employed by the IGES.

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An illustration of the impact of sampling on precision

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Summary

The R.J. Smith airborne gravity test range at Kauring is used to illustrate the impact sampling has on precision in the context of airborne and ground gravity surveys.

Procedure and results

In sampling theory, measuring a signal at an interval of ***D/2*** is the minimum required to reproduce signals of wavelength ***D***. However, sampling at the minimum interval ***D/2*** is not necessarily sufficient to reproduce a signal of wavelength ***D*** with *precision*. Even if the individual measurements are perfect, the reconstructed signal at wavelength ***D*** can be imprecise when shorter wavelengths bias the longer wavelengths. The magnitude of the error depends on the magnitude of the shorter wavelength signals that are present at each measurement point. For geophysical surveys, a precise measurement point can be an imprecise representation of the surrounding area due to the near-station effects of inhomogeneity.

The ground data from the AG area of the R.J. Smith airborne gravity test range (Daishsat Geodetic Surveyors, 2009) can be used to illustrate this. The free air gravity using all the ground stations with 500 m spacing is shown at left in Figure 1. At right, a 5000 m full-wavelength filter has been applied to the grid to create a 5 km full-wavelength 'regional' gravity field grid.

The ground data are then sub-sampled into five data sets of 2500 m spaced ground stations, offset from each other 500 m in the X and Y directions. The same 5000 m full-wavelength filter is applied to each. This is shown in Figure 2.

Each of these 2500 m spaced regional ground surveys reproduce the long wavelengths of the gravity field well, but there are differences in the shorter wavelengths approaching the 5000 m filter limit. The shorter wavelength signals at the measurement points are biasing the longer wavelengths.

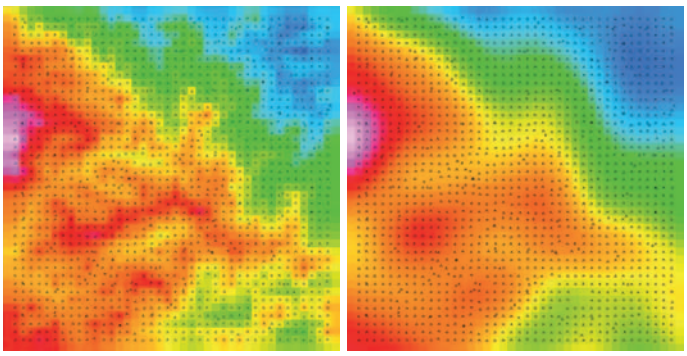

Figure 1. *Free air gravity from ground data stations at R.J. Smith airborne gravity test range.*

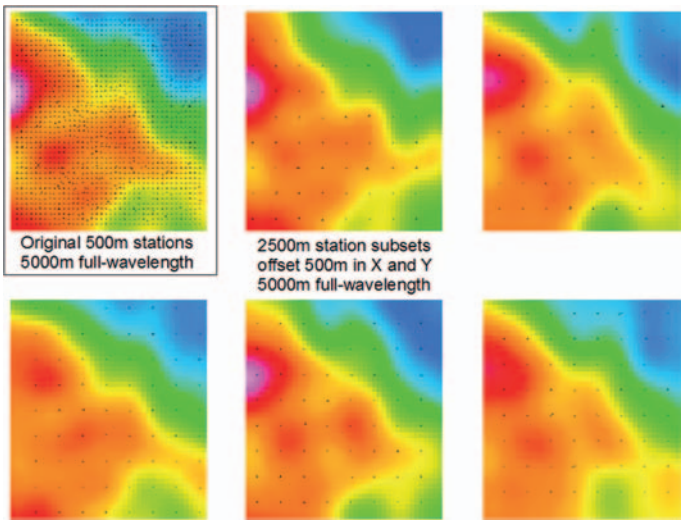

Figure 2. *2500 m station subsets each offset 500 m in X and Y.*

If sampling is increased by having lines of data, precision is improved. This is illustrated in Figure 3 using the ground data. The original 500 m sampling in the Y direction is kept to create lines with 2500 m spacing in the X direction, analogous to flight lines for an airborne survey. The same 5000 m grid filter is once again applied.

While there are still differences between each subset, the increased sampling using these north-south 'lines' visually reproduces the 5000 m wavelengths more consistently.

Quantitatively, the full 500 m spaced ground survey used in conjunction with the 5000 m full-wavelength filter can be considered to be a well-sampled regional 5000 m wavelength 'ground truth'. The standard deviations of the differences between this 5000 m filtered 'ground truth' (highlighted grid on the top left of the preceding two figures) and the collection of more sparsely sampled subsets (the other grids in those figures) are given in the following table (Table 1) in the blue columns.

Table 1. Standard deviations of the differences between the complete and sub-sampled grids

Free air 2500 m points	Free air 2500 m lines	Bouguer 2500 m points	Bouguer 2500 m lines
1.2 mGal	0.7 mGal	0.5 mGal	0.3 mGal

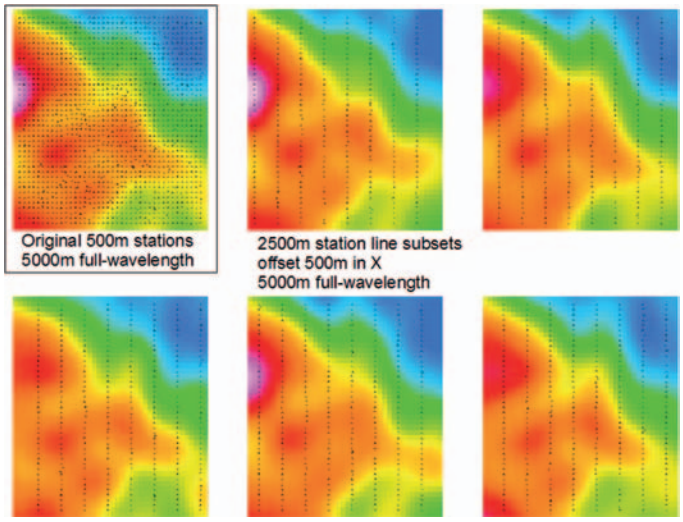

Figure 3. *2500 m station line subsets each offset 500 m in x-direction.*

Even though the individual points making up the subsets have perfect precision in this example, the subsets as a whole do not precisely reproduce the well-sampled 5000 m 'ground truth'. The lines of data, having sampled the area better, are able to reproduce the 'ground truth' with more precision than the grid of points. The differences are reduced when the procedure is repeated for Bouguer gravity (green columns) since the removal of topographic effects reduces the amount of biasing short wavelength signal.

Discussion

In the context of the East Kimberley airborne gravity survey (GSWA 2016, 2017), an AG system with a full-wavelength along line resolution of 5 km and a line spacing of 2.5 km is not truly equivalent to ground gravity stations on a regular 2.5 km grid of observations. The additional sampling along the line direction improves precision of an AG system relative to a regular 2.5 km grid of observation points.

Obviously other considerations come into play, and the noise present in the AG survey lines may offset this intrinsic sampling advantage. This will depend on the specific circumstances of the survey: it is a function of measurement spacing (ground observations and AG line spacing), resolution, the noise present in the AG data, and the nature of the gravity signal itself.

For East Kimberley, results from airborne and ground data appear to be broadly comparable for the survey parameters used. This makes sense if we combine the sampling precision estimated here using Kauring with the estimated instrument measurement precision.

AIRGrav 5000 m full-wavelength profiles have an estimated 0.5 mGal precision. Adding the 0.3 mGal sampling precision estimated above for 2.5 km spaced Bouguer profiles, the combined precision is $\sqrt{(0.5^2 + 0.3^2)} = 0.6$ mGal. Similarly, for 0.02 mGal ground point precision, and adding the 0.5 mGal sampling precision estimated above for a 2.5 km spaced ground measurement grid, the combined precision is $\sqrt{(0.02^2 + 0.5^2)} = 0.5$ mGal. A small additional noise reduction in the AIRGrav grid results from across line reduction of noise because the 2500 m line spacing is within the roll-off of the 5000 m grid filter.

In any case, the 0.02 mGal precision of individual ground measurements should not be viewed as equivalent to the precision of the regional gravity field representation that can be created from those measurements.

Summary

Converting a database of individual ground points into a continuous profile or grid of the gravity field is a necessary step for users who want to work with and interpret the data. The precision of this representation of the gravity field can be significantly less than the precision of the individual measurement points because of sampling.

A profile that samples the gravity field continuously, and which has a low pass filter applied, is not the same as discrete ground points spaced at 1/2 the filter length. The additional along-line sampling and averaging improves the relative precision of the profile.

In the Kauring example, the individual ground points assumed to have perfect precision produced 5 km full-wavelength regional free air and Bouguer grids with 1.2 and 0.5 mGal precision respectively. Using lines of data improved the precision to 0.7 and 0.3 mGal. Including this sampling precision with the instrument measurement precision produces a comparable overall whole-of-survey precision of approximately 0.5 mGal for both the AIRGrav (Sander Geophysics, 2012) and ground data sets.

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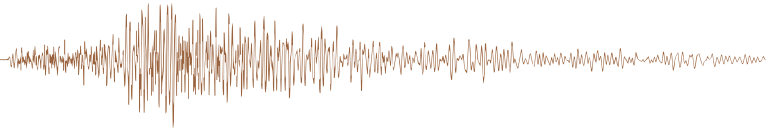
Biography

Stefan Elieff is a physicist based in Ottawa at Sander Geophysics, specialising in data from the AIRGrav airborne gravity meter. He has a Master of Science in Astronomy from Saint Mary's University in Halifax, Nova Scotia, Canada.



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9–12	International Conference on Engineering Geophysics (ICEG) http://seg.org/Events/ICEG2017	Al Ain	UAE
8–14	Earth Science Week http://www.earthsciweek.org/about-esw	–	–
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21–25	Exploration '17 http://www.exploration17.com/	Toronto	Canada
22–25	Geological Society of America (GSA) Annual Meeting 2017 http://www.geosociety.org/meetings/2017/	Seattle	USA
24–26	OTC Brazil http://www.otcbrasil.org/	Rio de Janeiro	Brazil
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December	**2017**		
4–6	Full Waveform Inversion: What are we getting? http://seg.org/Events/FWI2017	Manama	Bahrain
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18–21	Australasian Exploration Geoscience Conference http://www.aegc2018.com.au/	Sydney	Australia
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May	**2018**		
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June	**2018**		
11–14	80th EAGE Conference & Exhibition 2018 http://www.eage.org/	Copenhagen	Denmark
	The 8th International Conference on Environmental and Engineering Geophysics (ICEEG)	Beijing	China
September	**2018**		
23–25	SPE Annual Meeting	Dallas	USA
October	**2018**		
14–18	AGC Convention http://www.agc.org.au	Adelaide	Australia
14–19	SEG Annual Meeting	Anaheim	USA

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Preview is published bimonthly in February, April, June, August, October and December. The deadline for submission of material to the Editor is usually the second Friday of the month prior to the issue date. The deadline for the December 2017 issue is 10 November 2017. For the advertising copy deadline please contact Doug Walters on (03) 9545 8505 or doug.walters@csiro.au.

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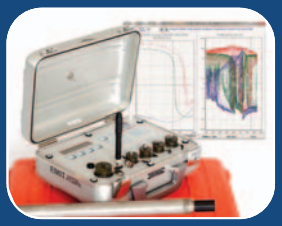

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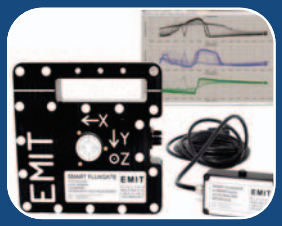

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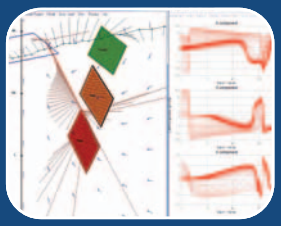

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