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Australian Society of Exploration Geophysicists

PREVIEW

PREVIEW

ADVERTISERS INDEX

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Editor's desk

This issue of *Preview* is full of goodies. Duan Uys, a fan of InSAR, has taken time out from his Master's project to write a user friendly introduction to the technology: 'InSAR: an introduction'. If you are curious about InSAR, but you missed out on the presentations given by the 2015 EAGE Visiting Lecturer Alessandro Ferretti, this article is for you.

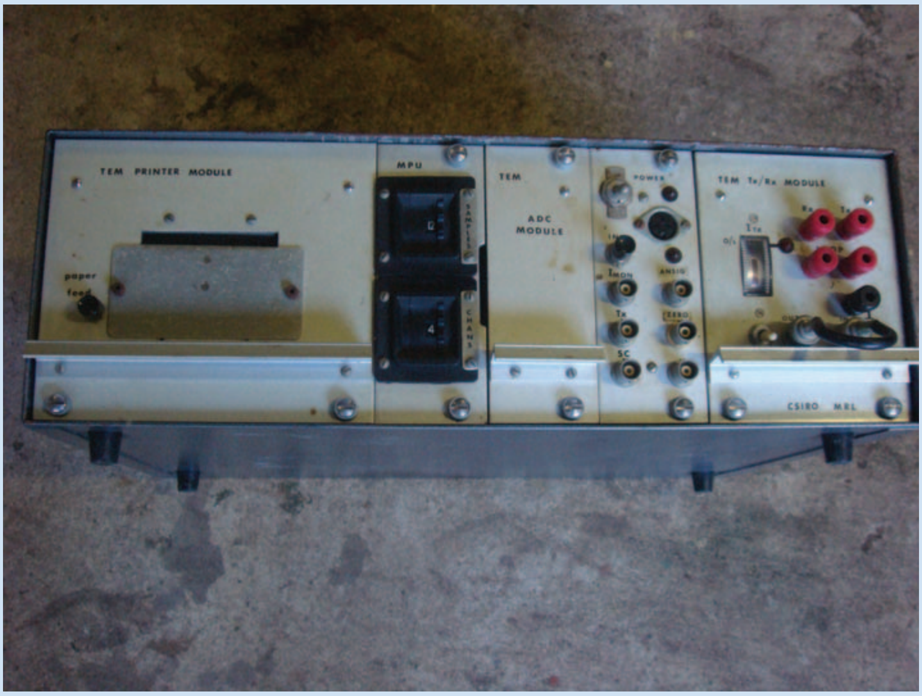
Steve Hobbs, who has just finished his PhD project, is passionate about building robots for space exploration and has written a guide to the Australian Marsobot project: 'The Marsobot project: tools for the geophysical exploration of space'. If you are a fan of Dr Who (you know who you are) or otherwise fond of gadgets then this one is for you!

In addition, but wait there is more, we have our usual news and commentary. David Denham reviews the last Federal Budget (*Canberra observed*) and Ken Witherly (*Minerals geophysics*) compares the Canadian and (developing) Australian government programmes supporting minerals exploration. Michael Asten (*Education matters*) reports on the successful applicants for ASEG Research Foundation grants. One of the successful applicants, who graces the cover of this issue, would seem to be following in the footsteps of the great Lew Richardson (see last issue) – all he needs is a decent tie. Michael also reports on the Teacher Earth Science Education Programme and gets a little bit Churchillian on us (hint: take a look at the caption for the TESEP photo montage).

Mike Hatch (*Environmental geophysics*) taunts us with the possibility of using geophysics as an excuse to visit archaeological sites on beautiful Greek islands (someone also needs to give Ian Moffat a tie). Dave Annetts (*Webwaves*), our newish Webmaster, warns us that the Web Committee is about to launch the new ASEG website and tries to soften us up by quoting Heraclitus (more Greeks). He also invites us to send in photographs taken during fieldwork, and images of data, for use on the new website. The best photos/data images will win a prize, but he doesn't say what the prizes are (my bet is that the winners will get an ASEG tie). Mick Micenko (*Seismic window*) considers how best to survive the current downturn and Guy Holmes (*Data trends*) has a grumble about the performance of data tapes.

As this issue of *Preview* is the first issue post the 2016 ASEG AGM we also introduce the new President (*President's piece*) and the new 2016–2017 ASEG Federal Executive (*Meet your new Federal Executive*). When I reviewed those pieces I was struck by the fact that three of the four Directors elected at the AGM were women, including the President, President Elect and Secretary. In addition, six of the 12 members of the new look Federal Executive are women. I think this must be some kind of record for the ASEG, if not for geoscientific societies worldwide, and should stand the ASEG in good stead come time to report to Australian Securities and Investment Commission!

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



This photo is of the original, sole prototype of the SIROTEM series of TEM equipment held in the ASEG historic instrument collection. Developed from 1972 in the Mineral Physics division of the CSIRO, it led to the design of three ever-improved models of SIROTEM in the next 30 years. It was the first geophysical instrument in Australia to incorporate a microprocessor that, originally utilising the software instruction set of the PDP-8 computer, enabled digital manipulation of data in the field. The available memory was then about 6 kilobytes. The total weight of the instrument was 8 kg and it was easily carried by one person. The modules shown are, from right to left; Tx-Rx (transmitter-receiver), Power, ADC (analogue-to-digital), MPU (microprocessor unit), and Printer for recording the transient response.

ASEG news

Introducing the new ASEG President

Katherine McKenna

It is an honour to put together my first President's piece for *Preview*. I would like to start by welcoming the new members of the Federal Executive. They are Andrea Rutley (President Elect) and Lisa Vella (Vice President). I am sure that the experience of both these geophysicists will help ASEG to achieve its goals for the year, and the years to come.

While welcoming the two new members, we must also recognise the service of the two members that are leaving. Barry Drummond has served as Secretary of the ASEG since 2012. He has been a valuable member of the team and instrumental in getting the FedEx to formulate business plans for the future development and success of the ASEG, in the creation of special interest groups such as Young Professional and Near Surface groups, and in making sure each and every member of the FedEx has read the constitution! Barry worked tirelessly throughout his terms as Secretary and his services, humour and enthusiasm will be missed.

Theo Aravanis has served as Treasurer of the ASEG since 2014. After the success of the Melbourne conference in 2013 he was sought out and convinced that his services and skills were needed. Theo has been responsible for a marked improvement in the accounts, and accountability throughout the ASEG. The transition from CASEM to TAS as managers of the ASEG's business was, under Theo's direction and from a financial point of view, very smooth and resulted in much improvement. Theo's term as Treasurer also saw improvements in accounting standards, a better understanding of what and where money is being spent, a monthly update on exactly how the budget was progressing with respect to states and committees, and the most colourful graphs and charts – which highlighted every aspect of his reports. Rest assured that during Theo's reign as Treasurer no Member's money was spent or approved to be spent unless it could be fully justified as being beneficial to the Society and the Members. Theo's dogged and tenacious manner, sense of fair play and hint of enjoyment will be missed.

This year is a conference year and I am looking forward to the ASEG-PESA-AIG 25th International Geophysical Conference and Exhibition in Adelaide this August. While 2016 is definitely a challenging year for our industry, it does give us the opportunity to take time for further education and get an update on new ideas and technologies. There seems to be a real international flavour to the conference this year with papers and posters from Australia together with Indonesia, Papua New Guinea, China, Canada, USA, Iran, Brazil, South Africa, UAE, Singapore, Mexico, Denmark, New Zealand, Malaysia, India, and South Korea.

The conference, I have always felt, gives geophysicists a great sense of community. My first ASEG conference was something I will always remember. It was during the Pilot Strike in 1989 and was held in Melbourne. I was sent as a graduate geophysicist to represent Lachlan Resources by Bob Richardson, who directed me 'to learn'. People came from all over Australia with stories about how they travelled to Melbourne without using domestic flights. There were people that travelled by bus from Perth, international air flights from the capital cities, and Air Force flights from different bases around Australia. The conference opened my eyes to different ideas, great case studies and an array of research. It also taught me about the stamina required for a conference week, as it is not only about learning and presentations but also about meeting and catching up with people in the industry. This often made for three very long days with little sleep. Since 1989 I have only missed one conference (Tasmania), due to a work commitment, as I have never lost the enthusiasm for them and acknowledge the value gained.

This year the FedEx has set some high goals. At the recent strategy day a new Communications and Promotions Committee was formed, and will be chaired by Andrea Rutley. This Committee will have responsibility for formulating a marketing plan, promoting the Society to geophysicists and other earth science professions, improving communication with Members, and tackling and managing social media applications. The formation of the Committee was, in part, an outcome of the membership survey that was completed last year. One of the things that was highlighted in the survey was poor communication with Members about existing ASEG services, opportunities and benefits. I look forward to the progress of this Committee and hope to 'tweet' a response or two along the way.

Another ambitious goal this year will be the release of a new ASEG website. There have been a lot of patches over the last few years and, with the advent of a new membership database, it was recognised that a new website was very much needed. David Annetts, Chair of the Web Committee, and his team have been working hard over many months, getting the design and concepts together. The new website will happen this year, stay tuned for when.

I look forward to meeting up with as many Members as possible over the next 12 months. Let us hope that at the end of 12 months the memories of this challenging time in our industry will be just that, 'a memory'.

aut viam inveniet aut faciet
(She will find a way or make one)

Katherine McKenna
ASEG President
president@aseg.org.au

Welcome to new Members

The ASEG extends a warm welcome to 39 new Members approved by the Federal Executive at its April and May meetings (see table).

First name	Last name	Organisation	State	Country	Membership type
Faryal	Abbas	University of Adelaide	SA	Australia	Student
Kristoffer	Andersen	Aarhus University		Denmark	Active
David	Barker	University of Adelaide	SA	Australia	Student
Emma	Brigden	University of Adelaide	SA	Australia	Student
Jefferson	Bustamante	University of Western Australia	WA	Australia	Student
William	Cook	University of Adelaide	SA	Australia	Student
Mackenzie	Duggan	University of Adelaide	SA	Australia	Student
Shane	Evans	Moombarriga Geoscience	WA	Australia	Active
Amanda	Folkers	Cheveron	WA	Australia	Active
Chris	Folkes	Geoscience Australia	ACT	Australia	Active
Nicole	Gardner	Queensland University of Technology	QLD	Australia	Student
Ausama	Giwelli	CSIRO	WA	Australia	Active
Teresa	Grand-Paris	International Geophysical Technology		Spain	Active
Denys	Grombacher	Aarhus University		Denmark	Active
Mathew	Iannella	University of Adelaide	SA	Australia	Student
Barranco	Ishtar	Chevron	WA	Australia	Active
India	Karalus	Santos	SA	Australia	Active
Camilla	Leyton	BHP Billiton		Chile	Active
Cassandra	Lintvelt	University of Adelaide	SA	Australia	Student
Cameron	MacPhail	University of Adelaide	SA	Australia	Student
Racheal	Mahlknecht	University of Adelaide	SA	Australia	Student
Anna	Manka	University of Adelaide	SA	Australia	Student
Dev-orson	Mbara	University of Adelaide	SA	Australia	Student
Niall	Mitchell	University of Adelaide	SA	Australia	Student
Dara	Mullins	University of Western Australia	WA	Australia	Student
James	Nankvell	University of Adelaide	SA	Australia	Student
Golden	Nhunhama	Discrete Geophysical Services	VIC	Australia	Active
Angus	Nixon	University of Adelaide	SA	Australia	Student
Annabel	Payne	Macquarie University	NSW	Australia	Student
Bailey	Payten	University of Sydney	NSW	Australia	Student
Christopher	Semeniuk	Curtin University	WA	Australia	Student
Rachael	Sharp	University of Adelaide	SA	Australia	Student
Zoe	Smit	Shlumberger	SA	Australia	Active
Alketas	Sprydon	University of Adelaide	SA	Australia	Student
Alastar	Stark	University of Adelaide	SA	Australia	Student
Joanna	Tobin	University of Sydney	NSW	Australia	Student
Duan	Uys	Macquarie University	NSW	Australia	Student
Larry	Wellspring	Synterra Technologies Ltd		Canada	Associate
Simon	Wetherley	CGG Multi-Physics	WA	Australia	Active

Young professionals update

Millicent Crowe

My first ASEG Conference was in Melbourne in 2013. I saw people excitedly chatting with friends and former colleagues. I saw people comparing freebies from a range of different booths. There were geophysical companies and techniques I'd never heard of. I wondered, how did everyone know each other? I was overwhelmed by the size of the conference and number of geophysicists. I wanted to be a part of it, I wanted to talk to new people, to 'network', but I didn't know where to start. It was very daunting coming into a new environment where everyone appears to know each other. The next conference in Perth I hosted a Young Professionals Breakfast and learnt that this feeling is very common amongst the younger Members of the society. We enjoyed chatting to one another and imagined how we would have enjoyed the conference more if we had known each other from Day 1. We decided that we needed to find a way to meet one another before the conference starts. At this year's conference we are creating an environment for other young professionals to meet one another and this starts with our networking workshop, a speed-dating, networking, afternoon tea.

This is where I should introduce myself, I am Millicent Crowe, a young geophysicist at Geoscience Australia. With the endorsement of the Federal Executive, I have started the ASEG Young Professionals Group. Our aim is to facilitate networking and development opportunities of young geophysicists. We are running two workshops at the ASEG-PESA-AIG Conference; a two-hour networking workshop before the welcome drinks on Sunday (Workshop 19) and a one-day professional development course on Thursday (Workshop 20). These will be run by young professionals, for young professionals, and will take a fun interactive twist on the traditional workshop. They have input from other groups such as AIG Graduates and the Young Petroleum Professionals. The workshop details can be found on the Conference website under workshops.

During the conference, we are using different ways to build and integrate the young professional network. Keep an eye out for some distinguishing stickers on the conference name tags (think brightly coloured metallic unicorns) and if you see someone with one, think back to when you were a wee geophysicist and say hello. Drop into our Conference booth, a relaxed informal environment where you can meet other young professionals and learn what we are doing. We are always on the lookout for new ideas. If you have any scathingly brilliant ideas (or ideas in general) on the development of the ASEG Young Professionals I would love to hear from you.

I need your help to build the network. If you are a young professional, come along to one of our events, like our Facebook page or get in touch. If you are a mentor of young professionals, encourage them to check out the workshops and get involved.

It's not what you know it's who you know. We are here to help with the who.

Millicent Crowe
President, ASEG Young Professionals Specialist Group
Millicent.crowe@ga.gov.au

conference activities

networking

Workshop 19

Sunday 21 August

Join us as we learn some tools to effectively network and build our networks in a fun and informal way.

3.30 – 5.30pm
Hungry Hippo Café
Cost is FREE

conference booth

VISIT US!

22 – 24 August

Hang out at our booth and learn more about what we can do for you. Keep a lookout for stickers on nametags to identify other young professionals.

career development

Workshop 20

Thursday 25 August

One day professional development workshop with tools and tips to ***land that job***!

9.30 am– 4.30 pm
Aquinas College
Cost is FREE

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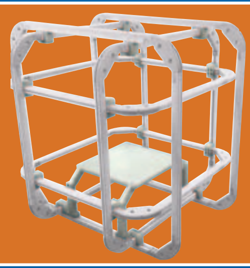

MS2/MS3 Magnetic Susceptibility Equipment

- Resolution to $2x10^{-6}$ SI
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- Field survey equipment

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Meet your new 2016–2017 Federal Executive

Directors

President

Katherine McKenna (2013 – present)
president@aseg.org.au

The President of the ASEG is one of the four Directors of the Society as recognised by Australian Securities and Investment Commission (ASIC), and has legal obligations to ASIC under the Corporations Act 2001 for the proper running of the Society. The President oversees the general running of the ASEG Federal Executive (FedEx), chairs FedEx meetings, General Meetings and the ASEG council meeting held at the ASEG conference. In addition, the President represents the Society at the ASEG annual conference and at international meetings. A candidate for President is expected to serve for a minimum of 3 years; the first as President Elect learning the ropes, then a year as President and finally a year as Past President acting as a mentor to the President and President Elect. There is no requirement to resign after 3 years if one still has energy and enthusiasm for the job and the support of the FedEx. The 3-year term allows the President to take on projects and see them through to completion, therefore it is not uncommon for the Past President to be running with projects they started, or which were started during their term as President. Both the President Elect and President are Directors of the Society and responsible to the Members as well as ASIC.

Katherine is also the Chair of the Membership Committee. The Membership Committee is responsible for membership matters, which include admission, renewal, promotion and dismissal. They assist the Secretariat in maintaining the membership database and any enquiries that arise. The Membership Chair advises the FedEx of new member applications and membership upgrades and assists the Secretariat in preparing renewal procedures and forms.

This is Katherine's second stint on the FedEx, having served in 2001. You might not know, but Katherine is a keen long distance cycling enthusiast.

President Elect

Andrea Rutley (2016 – present)
presidentelect@aseg.org.au

The President Elect's role is to support the President and act on their behalf when required, and also to work with the standing committees when the opportunity arises. The President Elect has 12 months to become familiar with the issues facing the Society so they will be able to implement plans the following year. Andrea is also Chair of the newly formed Promotions Committee. This is Andrea's second stint on the FedEx, having previously served from 2008 to 2011.

Treasurer

Danny Burns (2015 – present)
treasurer@aseg.org.au

The Federal Treasurer is elected at the Annual General Meeting as a Director of the Society. This role requires the Treasurer to be responsible for all of the Society's accounts and finances (federal and state) and to be accountable to the relevant regulations under ASIC. The Treasurer is also the Chair of the Finance Committee, which advises the FedEx on longer term financial matters. Danny says 'The oil industry is never dull', and he expects that his term on the FedEx won't be dull either!

Secretary

Marina Costelloe (2015 – present)
fedsec@aseg.org.au

The ASEG has a professional Secretariat that undertakes many of the traditional roles of an Honorary Secretary. This has allowed the ASEG's Secretary to focus on improvement of old policies, and the development of new policies that describe how the Federal Executive puts into practice the Society's Constitution. The Secretary organises FedEx events such as the Annual General Meeting and meetings of Council. They also maintain the Society's Strategic Plan. The Secretary is elected each year and is a Director of the ASEG. You might not know, but Marina is a huge Dr Who fan.

Non-Directors

Immediate Past President

Phil Schmidt (2009 – present)
pastpresident@aseg.org.au

The position of Immediate Past President is filled by the President of the previous year. The role of Immediate Past President is to provide continuity in the activities of the ASEG FedEx. The Immediate Past President is expected to advise the current President about the status of standing projects and issues, past resolutions and contacts in foreign societies. They advise the Directors from their experience. Phil has had a tree change, he now owns 3000 guava trees!

Publications Committee Co-Chairs

Greg Street

Lisa Vella

Greg Street (2013 – present) and Lisa Vella (2016 – present)
publications@aseg.org.au

The Publications Committee Chair's role is to coordinate the Publication Committee's efforts to deliver the Society's publications on time and on budget. This requires dealing with the publisher (currently CSIRO Publishing) to address changing Society needs, new technologies and interfacing between the publisher and the Committee. The Publications Committee comprises the Chair, the Publications Officer and the Editors-in-Chief of *Exploration Geophysics* and *Preview*. What you might not know about Lisa Vella is that she suspects she is the only person in the mining industry who does not drink beer – ever. But she does like wine. And Greg? What we don't know about Greg isn't worth knowing. Both Greg and Lisa are serving their second terms on the FedEx having done time between 1988 and 1991 and 2002 and 2006 respectively.

AGC Representative

Kim Frankcombe (2011 – present)
kfankcombe@iinet.net.au

The Australian Geoscience Council (AGC) is a body representing the Geoscience Learned Societies. As well as the ASEG it includes the AIG, AusIMM, PESA, GSA, IAH, AGIA and AAG. Representation and voting power is determined by each society's size. Its main role is in lobbying and focusing geoscience agendas for the benefit of its members. Following the very successful IGC conference in Brisbane, the AGC now also has funds to apply to education as well as other worthwhile projects that may benefit Australian geoscientists in general. Kim is also the Federal Executive representative on the Conference Advisory Committee and Technical Standards Committee and, apparently, he has somehow missed out on a call up for the Wallabies…..

Continuing Education Committee Chair

Wendy Watkins (2013 – present)
continuingeducation@aseg.org.au

The Continuing Education Committee aims to help meet the needs for the ongoing education of Members and to help to promote geophysics as a career. This is achieved by arranging for visiting lecturers from overseas societies to present at State

Branch meetings, and by providing 1-day courses e.g. SEG Distinguished Instructor Short Courses, EAEG Education Tours and the ASEG OZSTEP courses. The aim is to deliver one minerals and one petroleum course per year. In the future more educational material will be presented online and the Society is developing a strategy to facilitate this.

State Branch Representative

Tania Dhu (2013 – present)
branchrep@aseg.org.au

State Branches hold a key role in delivering services to local Members. The State Branch Representative liaises between the Branches and the FedEx, communicating relevant issues between the Federal and Branch levels of the Society. Tania is also responsible for liaison with Specialist and Working Groups.

Web Committee Chair (Webmaster)

David Annetts (2015 – present)
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The Webmaster works with Web Committee, designers and the Secretariat to design, maintain and keep the web page up to date. They work on strategies to allow for continuous improvement of the web functionality, its services to Members and in helping promote the Society to the greater community.

International Affairs Committee Chair

Koya Suto (1992 – present!)
vicepresident@aseg.org.au

ASEG has 10 associated societies: SEG, EAGE, SEG Japan, Korean SEG, Engineering and Environmental Geophysical Society (EEGS), SAGA (South Africa), SPE India, Chinese SEG, SBGf (Brazil) and Mongolian SEG. The responsibility of the International Affairs Committee includes communicating with these societies on conferences and other activities, and organising meetings with them. As the President often represents ASEG at meetings with the associate societies, the Chair of the International Affairs Committee reports directly to the President. Koya also represents the Society on the Board of the ASEG Research Foundation, assists Wendy with education and acts as the corporate memory for the FedEx.

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 two monthly meetings, which were held in April and May. Anyone who would like to see the minutes of these meetings should add their name to the mailing list maintained by the Secretariat. FedEx also holds planning meetings twice a year. A report on the last planning meeting, which was held in Perth in April, is included in this brief.

Society finances

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

Year to date income: $96 313.70
Year to date expenditure: $48 215.08
Net assets: $1 286 013.75

Membership

At the end of May, the Society had 988 Members; 80% renewal to date compared to 73% renewal at the same time last year. Corporate membership issues were discussed at the April and May monthly meetings as well as at the April planning meeting. Current Corporate Members are: Instrument GDD, Total Scan and Survey, Archimedes Financial Planning, Velseis, Terrex Seismic. We also welcomed in new active, associate and student Members. Whilst on the subject of membership – thank you to Katherine McKenna and Koya Suto for preparing the 2016 Yearbook – we appreciate your hard work.

Education

The SEG Distinguished Lecturer James Gaiser, who is presenting on 3C Seismic and VSP, will visit South Australia on 21 August and the ACT on 26 August – just after the Adelaide conference. SEG Honorary Lecturer How-Wei Chen, who is presenting on boundaries among near-surface, energy resource exploration, earthquake and technetronic studies, will be touring the Branches in May and June; SA (16 May); WA (15 June); VIC (20 June); ACT (21 June); NSW (22 June); and QLD (23 June). Professor Steven Constable will also be visiting later in 2016, details will be made available as they come to hand. Other exciting workshops and lectures are on the horizon.

The April planning meeting

The FedEx meets face to face twice a year to plan future directions and strategies for the Society. Representatives of the local Branch where these meetings are held and the Honorary Editors are also invited to attend. The April planning meeting was held in Perth, the day after the AGM. The main reason for the meeting was to address the strategic plan and other issues arising from the monthly phone hook-up meetings pertaining to the running of the Society. The FedEx thanks Kathlene Oliver and Katherine McKenna for organising the day and for making all the volunteers feel very welcome in the West.

The ASEG's strategic plan encompasses aspirational goals that include: implementing strategies to help address the issue of geophysics education; strengthening our Membership Base; and becoming more proactive in geoscience debates. We know that we have a healthy ASEG when: our Branches have comprehensive programs of technical meetings and vibrant social programmes that ensure that their Members engage enthusiastically with the Society; our conferences are well supported by a broad cross section of the geophysics community, including those overseas; our scientific publications have a growing (and measureable) Impact Factor; the Society remains financially viable; the Society identifies and helps to implement new ways of delivering geophysics education to a broader base; the Society attracts and retains new Members from a broader base of companies, universities and government agencies; and the Society becomes a preferred source of advice on matters affecting our industry.

At the start of the meeting new FedEx Members were appointed – and outgoing Members were thanked sincerely for all of their hard work and dedication. This was followed by an overview of the work The Association Specialists (TAS) undertakes for the ASEG, particularly as the secretariat. This overview was presented by Ben Williams and was well received. I'd like to thank Ben for his help in keeping the ASEG operating.

The Publications Committee were next up and publications matters were discussed in detail, as publications are one of the important avenues to achieving the Society's goals. Working on joint publications with other societies, with an initial focus on the South African Geophysical Association (SAGA) and

ASEG news

Himpunan Ahli Geofisika Indonesia (HAGI), will significantly assist in achieving our goal of maintaining our status as a learned association. Koya Suto spends much of his time and effort facilitating joint publications – thank you Koya. Lisa Worrall, our wonderful *Preview* editor, spoke about her work with CSIRO Publishing and their collaborative management of the *Preview* production process – thank you Lisa for your hard work.

The Education Committee presentation by Wendy Watkins highlighted the amazing range of speakers and workshops on offer both in the past 6 months and for the next 6 months. Wendy spoke about getting in specialised workshop presenters for the Australian Lecturers Expanded Advancement Program – OzLEAP. OzLEAP will provide training, in a workshop lasting 3–5 days, which will ensure that attendees are proficient and work-ready in a specialised area of geophysics. OzLEAP will do this by offering intense face-to-face teaching and practical, hands-on experience. A key distinguishing component of OzLEAP will be the requirement for participants to work on problems that reinforce key, practical understandings or skills. If any Society Member has suggestions about OzLEAP topics or presenters please contact us. The Education Committee really want to be providing courses that potential employers are interested in. Wendy, on behalf of those who attend ASEG courses, thank you.

Greg Street presented a policy paper on supporting education in the Asia region. After considerable discussion Greg was given approval to proceed with a small pilot program in Myanmar that the Society will co-sponsor. Greg had been approached by Professor Day Wa Aung, Head of Geology at the University of Yangon, about setting up a mineral geophysics course at the University of Yangon. The pilot project outcomes will feed into finalising and updating a decision making process and updated policy on education in countries in our region. I'm looking forward to seeing how the pilot goes and what we can learn from it – I'm sure Greg will have photos and news on his return.

Succession planning was also an item on the agenda for the planning meeting. As FedEx is run by volunteers we are always looking for new volunteers who are willing and motivated to help in so many of the Society's interesting and dynamic activities. If you are interested in volunteering on the FedEx or any of the sub committees please contact me.

Progress was made on establishing a Communication and Promotion Committee. The newly formed committee will be chaired by Andrea Rutley (who is also the ASEG President-Elect). Other Members are Katherine McKenna (ASEG President) and Lisa Worrall (*Preview* Editor). A proposal for a communication strategy and promotion plan to include intra society promotion and external promotion is being prepared. The development of this plan is a FedEx priority so stay tuned for details.

All in all 27 action items arose from the daylong meeting, most of these items will be actioned before this edition of *Preview* goes to print.

New By Law

On 21 April 2016, at the AGM in Perth, a By Law was passed to handle complaints against Members.

On rare occasions the Federal Executive of the Australian Society of Exploration Geophysicists (the Society) receives complaints from and about Members. The Constitution of the Society makes no provision for how complaints should be handled by and the sanctions that are available to the Federal Executive, although in the extreme it does allow for the expulsion of Members.

This By Law establishes a process for handling complaints against a Member of the Society that will ensure;

i. Fairness for the Member against whom the complaint has been made and for the Member(s) or non-Member(s) making the complaint, and
ii. consistency through time in all cases of where complaints are made.

For a complaint (or complaints) to be considered using the process set out in this By Law, the complaint must: be in writing and delivered in either a physical (hard copy) or electronic form to a Member of the Federal Executive; and, it must clearly state the name of the person(s) making the complaint, and, it must not only contain a statement that a complaint is being made but explain the nature of the complaint and provide evidence to support the complaint. All other Members of the Federal Executive will be informed of the complaint, except that if the complaint involves in some way a Member of the Federal Executive, that Member will be excluded from all procedures that consider the complaint. The existence of the complaint, its nature, and the identity of the Accused and the Complainant will be held in strict confidence by the Federal Executive except to the extent that those Members involved in implementing the complaint handling process set out in this By Law need to know.

Potential Sanctions that are available include but need not be restricted to:

i. Case dismissed – No Sanctions.
ii. Partially substantiated but considered minor – written caution.
iii. Guilty but not considered too serious – written apology to be published in *Preview* (anonymously or with people named and if appropriate a written apology to the person aggrieved.
iv. Guilty of an offence but in the opinion of the investigation committee the offence was unintended, and/or the offender is remorseful and/or unlikely to re-offend – suspension of membership for a period to be determined by the Federal Executive.
v. Guilty of an offence and in the opinion of the investigation committee the offence was intended, and/or the offender is exhibiting no evidence of remorse and/or of changing their ways – permanent revocation of membership to the Society.

Expulsion from the Society is reserved for the most grievous offences and the Constitution of the Society sets out some conditions and time lines that must be considered by the Federal Executive and investigation committee when implementing the procedure. The Constitution establishes that the following constitute grounds for expulsion:

i. Bringing the Society into disrepute, or
ii. Failure to observe or be bound by
    - the Society's Constitution, or
    - the Objects of the Society, including its
    - Code of Ethics, or
    - Code of Professional Conduct.

I would like to stress again, it is very rare for the Society to receive a complaint about a Member. For more details please don't hesitate to contact me.

Marina Costelloe
Honorary Secretary
fedsec@aseg.org.au

ASEG Branch news

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.

Interested Members and other parties should also keep an eye on the seminar program of the University of Tasmania's School of Earth Sciences, which regularly delivers presentations of geophysical as well as general earth science interest. Contact **Mark Duffett** taspresident@aseg.org.au for further details.

Mark Duffett
(Tasmanian Branch President)

Victoria

The ASEG Victorian Branch met in the Kelvin Club on 27 April. **Peter Betts,** from Monash University, presented a very interesting technical talk titled 'Structural Geophysics, Geological Principles Applied to Geophysical Data' and, as the title indicates, he emphasized the importance of integrating the two disciplines for the best possible interpretation when making maps.

The next meeting of the Victorian Branch will be held on 20 June at the Kelvin Club (6–8 pm). The Shell sponsored, 2016 Pacific South Honorary lecturer **Dr How-Wei Chen**, from the Institute of Geophysics, National Central University Taiwan, Republic of China, will be visiting Melbourne and he will give a talk titled 'Crossing boundaries among near-surface, energy-resource exploration, earthquake, and tectonic studies'.

Dorte Ambirk
(Victorian Branch Secretary)

Western Australia

The WA Branch was very active over the last quarter, hosting three technical presentations, the Federal Executive AGM, and a workshop. The Branch is also honoured to be hosting travelling experts as part of our technical program. The first of our technical events was a workshop facilitated by one of those travelling experts, **Dr Serge A. Shapiro**. It was entitled 'Rock physics and geomechanics of fluid-induced seismicity: hydraulic fracturing, stimulation of geothermal systems and hazard assessment'. The workshop, which was held on 15 March, was well attended by a mix of industry, consulting and contracting geophysicists.

Following the workshop, the WA Branch were lucky enough to secure the SEG Distinguished Lecturer (DL) **Joe Dellinger** to present at our 18 March technical evening. After a distinguished career, Joe was awarded life membership in SEG in 2001 for his service in transforming the association's digital presence. In addition, and in honour of his efforts as a scientist, the asteroid '78392 Dellinger' was named after him. Joe presented on 'Forensic data processing – revealing your data's hidden stories', covering three concepts: (1) what is your source really doing?; (2) what does background noise in the data look like?; and (3) can we do anything useful with that background noise? Joe's goal was to start us on our journey to becoming data connoisseurs instead of being merely indiscriminate consumers. The presentation was very well received by the audience who were a mix of industry, academic, government, consulting and contracting people.

In line with the long-standing ASEG tradition the WA Branch were invited to host the ASEG AGM as the home state of the incoming President, **Katherine McKenna**. After the formalities of the AGM were completed, a technical presentation was given by **Mark Baigent** on 'Horizon mapping and fault detection using Airborne Gravity Gradiometer and magnetic data – Canning Basin Study' and, given the large audience, a vigorous debate ensued.

In May Branch Members had the opportunity to learn about the new NRG XCite TDEM airborne system. **Keith Fisk** provided an overview of the system and its development, and case studies showing the system in action. The talk was very well attended with lots of positive feedback on the venue (The Brown Fox). Members enjoyed attending the technical session in a pub environment, which worked well for networking.

The Branch has a packed agenda of technical programs for the coming quarter, including hosting the SEG Honorary Lecturer **Dr How-Wei Chen** in June. Dr Chen will present 'Crossing boundaries among near surface, energy resource, exploration, earthquake and tectonic studies' – a diverse talk which we believe will be of interest to a large portion of our Members. An up-to-date calendar of events is provided in this edition of *Preview* for your reference.

Prue Leeming
(WA Branch Preview *correspondent)*

Australian Capital Territory

As alluded to in the last edition of *Preview*, the ACT Branch held its AGM on Thursday 24 March and duly elected the Branch Committee for 2016. It gives me great pleasure to introduce the new office bearers:

President: **Ned Stolz**
Secretary: **James Goodwin**
Assistant Secretary: **Adam Kroll**

Our long serving (suffering?) Treasurer, **Ross Costelloe** was elected to mind the books for another year and the meeting also welcomed new Committee Member; **Neil Symington**, and welcomed back existing Committee Members; **Ray Tracey**, **Phil Wynne**, **Bill Jones**, **Marina Costelloe** and **Millicent Crowe**. Ned Stolz thanked the outgoing office bearers for their in efforts in delivering an active and stimulating program of speakers and events, and said that he hoped he would be able to maintain the high standard that had been set.

Prior to the AGM the meeting was treated to a presentation from **James Goodwin** about the various ground geophysics methods being trialled by Geoscience Australia to estimate cover thickness at proposed drill sites in the Southern Thompson Uncover Project. James' talk led to a lively discussion among the audience about how results from ground methods such as refraction seismic would compare with mapping from AEM inversions. **Ian Roach**'s talk at the upcoming ASEG conference in Adelaide may shed more light on this one (spoiler alert!).

Another item of note from the AGM was the outgoing Secretary's report, presented

ASEG news

Malcolm Gamlen, Bill Jones, Andrew Lewis and Peter Milligan enjoy catching-up after the AGM.

by Millie Crowe, which showed that ASEG membership in the Nation's Capital continues to grow. This is due in no small part to the efforts of the previous year's office bearers. On behalf of the Branch, I'd like to extend my sincere thanks to Marina, Millie and Ross for making 2015 such a memorable one for local geophysics.

James Goodwin presenting his paper to the ACT Branch on comparing geophysical methods for estimating cover depth.

As a stop press from the recent Federal Budget, Geoscience Australia was allocated $100 million over four years for precompetitive geoscience programs in northern Australia and South Australia. This should generate fantastic new data and innovative geophysics as feed-stock for ACT Branch and ASEG conference presentations in the years ahead.

Ned Stolz
(ACT Branch President)

New South Wales

In March **Katie Silversides**, from the University of Sydney, spoke about automated recognition of stratigraphic marker shales from geophysical logs in BIF hosted iron ore deposits. Katie outlined that in the Hamersley Ranges of Western Australia highly consistent marker shales are used to identify the stratigraphic location of the banded iron formation (BIF) or BIF hosted ore. Katie detailed how these marker shales produce distinctive signatures in the natural gamma downhole logs, but not in the other geophysical logs currently collected. Katie noted that the information from the natural gamma logs is currently processed by slow manual interpretation. Katie outlined her research into alternative methods of automatically identifying stratigraphically important marker shales from the natural gamma logs. Katie showed a comparison between existing interpretations and the new automated approach and where the process could be improved. Katie's talk was enjoyed by all with much discussion ensuing.

In April **James Austin**, from the CSIRO, gave a talk entitled 'Iron, Sulphur, Redox and Remanence: Petrophysical variability and geophysical insights into the Cloncurry District mineral system'. James spoke about examining the petrophysics, mineralogy, plus structural and chemical controls of approximately 20 deposits/prospects, including: iron oxide copper-gold (IOCG), iron sulphide copper-gold (ISCG), sedex, structurally controlled hydrothermal, and skarn styles of mineralisation in the region and how that will assist future exploration, under cover, on the fringes of the Mount Isa Inlier. James detailed the results from a couple of deposits and outlined his ideas about ore formation in the region. Many questions were asked during and after his presentation.

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

Mark Lackie
(NSW Branch President)

Queensland

April's Branch meeting was a great success, drawing a record crowd to hear our very own Branch Treasurer Mr **Henk van Paridon** present his talk 'Coal Seismic is Not Easy'.

The next meeting was scheduled for 31 May. **Alan Meulenbroek** presented his talk 'Inversion of Seismic Refraction Amplitudes for Near-Surface Velocity Control'. This talk summarised the work he has completed for his thesis (of the same title), while obtaining his Master's Degree from the University of Queensland this year.

The Qld Branch will also host SEG HL **How-Wei Chen** in June. He will give a talk titled 'Crossing boundaries among near-surface, energy-resource exploration, earthquake, and tectonic studies' on Thursday June 23.

An invitation to attend Queensland's Branch meetings is extended to all ASEG members and interested parties. Details of upcoming events will be posted to the ASEG website.

Megan Nightingale
(QLD Branch Secretary)

South Australia & Northern Territory

Since the last edition of *Preview* the SA/NT Branch has enjoyed two fantastic events. These events included our second technical evening for the year and the Annual Student Pizza Night.

Our April Technical Evening was again held at the Coopers Alehouse, where we were joined by **Henk van Paridon** who gave an excellent presentation titled 'Coal seismic is not easy'. The talk looked at the whole process from acquisition, processing and interpretation of seismic data in the context of targeting coal seams, while canvassing some of the reasons and remedies for the loss of coal seam reflectors in what appear to be good data zones. It was a very thought provoking talk and there was much discussion into the night, not just in the context of coal seams, but how the learnings can be applied in situations where any strong reflectors can affect signal going deeper into a sequence. We thank Henk for his efforts.

Our Annual Student Pizza Night was very well attended by students from first year to third year, as well as students completing their honours, masters and PhDs. They came along to hear about the very interesting and incredibly diverse careers of **Reg Nelson** and **Dave Cockshell**, two of South Australia's industry greats. Their stories and advice were well received, with most students in attendance staying after the presentations to chat and ask questions for the next hour at least. The SA/NT Branch thanks both Reg and Dave for volunteering their time, and going above and beyond to chat to students for such a long time after their presentations. It really is a great opportunity for students to get an understanding of the vast array of jobs on offer in our industry and the variety of locations they can work in. Hopefully, this resulted in a totally different perspective on what it means to be an exploration geophysicist, one that they might not fully appreciate when they are sitting in a lecture theatre learning about Fourier transform or Monte Carlo simulations.

Our technical meetings are made possible by our very generous group of sponsors, which in 2016 includes Beach Energy, Minotaur Exploration, Borehole Wireline and Zonge. We will be in touch with other previous sponsors hoping they will return in again this year. 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.

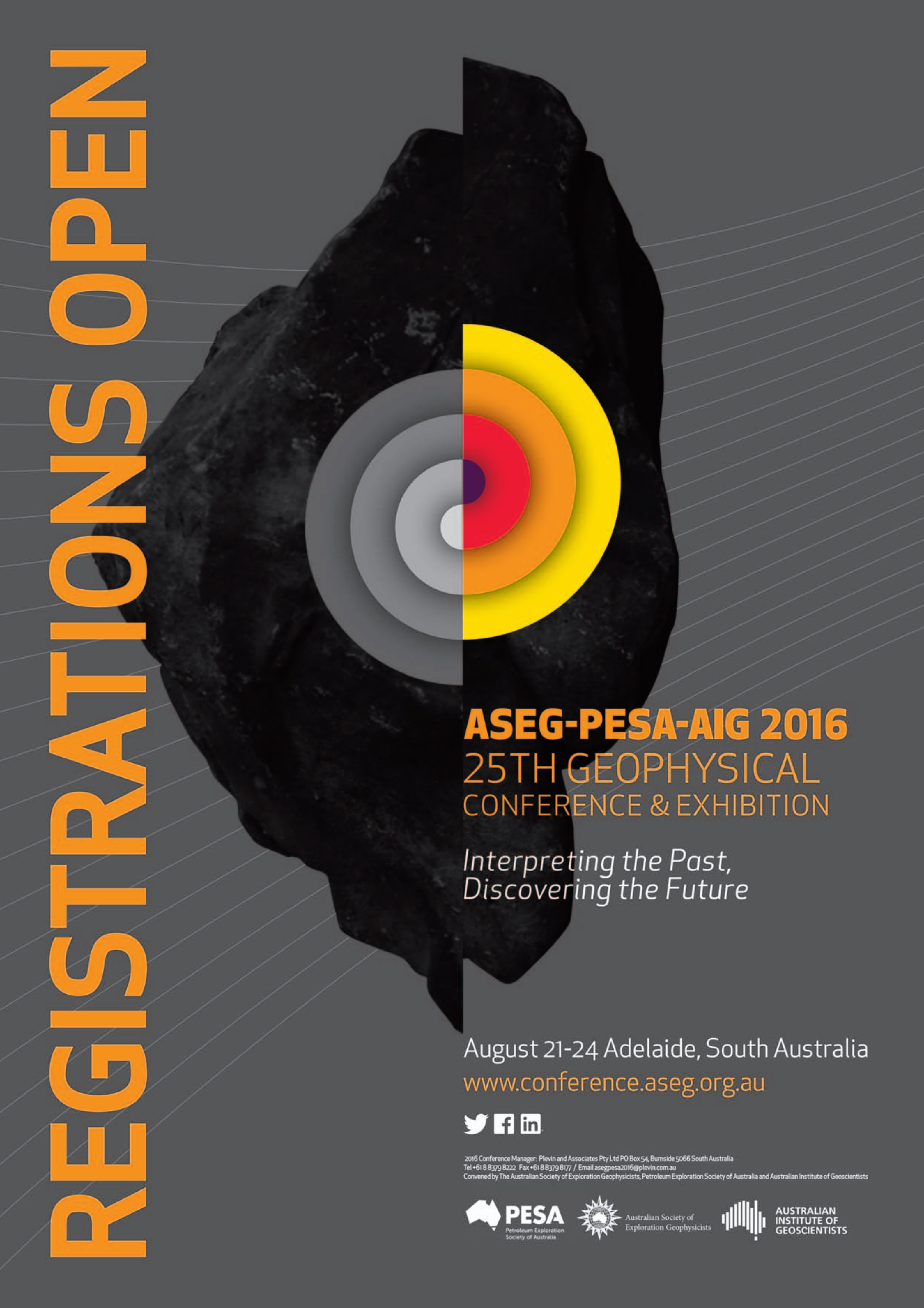
Josh Sage
(SA/NT Branch President)

ASEG news

ASEG calendar: technical meetings, courses and events

Date	Branch	Event	Presenter	Time	Venue
2016					
16 Jun	SA	Crossing boundaries among near-surface, energy resource exploration, earthquake and tectonic studies	Professor How-Wei Chen	1730	Coopers Alehouse, 316 Pulteney Street, Adelaide
20 Jun	VIC	Crossing boundaries among near-surface, energy resource exploration, earthquake and tectonic studies	Professor How-Wei Chen	1800	The Kelvin Club, Melbourne
21 Jun	ACT	Crossing boundaries among near-surface, energy resource exploration, earthquake and tectonic studies	Professor How-Wei Chen	1600	Scrivener Room, Geoscience Australia, Symonston, ACT
23 Jun	QLD	Crossing boundaries among near-surface, energy resource exploration, earthquake and tectonic studies	Professor How-Wei Chen	1730	Cinema, XXXX Brewery, Corner of Black Street and Paten Street Milton
13 Jul	WA	Tech Night	Brett Harris, CU	1730–1900	TBA
10 Aug	WA	Tech Night: Minerals	Jeremy Cook, Evolution Gold Minerals	1730–1900	TBA
21 Aug	SA	SEG DISC: 3C Seismic and VSP: Converted Waves and Vector Wavefield Applications	James Gaiser	0830–1700	TBA
25 Aug	ACT	SEG DISC: 3C Seismic and VSP: Converted Waves and Vector Wavefield Applications	James Gaiser	0830–1700	TBA
28 Aug	WA	SEG DISC: 3C Seismic and VSP: Converted Waves and Vector Wavefield Applications	James Gaiser	0830–1700	City West Reception Centre, 45 Plaistowe Mews, West Perth
12 Oct	WA	Tech Night: Tina zinc deposit case study	Darren Hunt, Teck	1730–1900	TBA

TBA, to be advised (please contact your state Branch Secretary for more information).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ASEG-PESA-AIG 2016
25TH GEOPHYSICAL
CONFERENCE & EXHIBITION
Interpreting the Past,
Discovering the Future
August 21-24 Adelaide, South Australia
www.conference.aseg.org.au
2016 Conference Manager: Plevin and Associates Pty Ltd PO Box 54, Burnside 5066 South Australia
Tel +61 8 8379 8222 Fax +61 8 8379 8177 / Email asegpesa2016@plevin.com.au
Convened by The Australian Society of Exploration Geophysicists, Petroleum Exploration Society of Australia and Australian Institute of Geoscientists
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Australian Society of Exploration Geophysicists
AUSTRALIAN INSTITUTE OF GEOSCIENTISTS

ASEG-PESA-AIG 2016: update from the Conference Organising Committee

ASEG-PESA-AIG 2016
25TH GEOPHYSICAL
CONFERENCE & EXHIBITION

Interpreting the Past, Discovering the Future

It's full speed ahead for ASEG-PESA-AIG 2016! As this is the last edition of *Preview* before the conference edition it's fitting to take the opportunity to thank some people.

The programme committee has done an amazing job constructing a first-rate programme for the conference. Not only have they had the challenge of squeezing over 200 talks into 3 days, but they've grouped the mineral talks into the Uncover themes. This wasn't a simple process and it means that there will be more variety in each of the Uncover streams. The programme is still being tweaked so be sure to use the pocket programme at the conference for the most up-to-date information. Well done Stephan Thiel, Mike Hatch and Simon Brealey. Also, thank you to all those members of the geophysical community in Adelaide and further afield who have contributed their time and expertise by reviewing papers and volunteering to chair sessions during the Conference.

Most of the workshops look like they'll be going ahead, and a thank you to our workshop coordinator Tim Keeping for orchestrating them. Regrettably a couple of workshops have been cancelled. If you haven't booked for workshops as yet please do so at your earliest convenience in order to avoid disappointment.

Also a big shout out to Claudia Fintina and Zoe Smit who have acted as our relentless sponsorship officers. It has been a tough sponsorship drive but (at the time of writing) we have a Silver sponsor (BP), Five Bronze Sponsors (Austhai Geophysical, Beach Energy, CSIRO, Velseis, Santos), as well as sponsorship from First Quantum Minerals Ltd (Best Paper Awards Sponsor), and Wireline Logging (Lanyard sponsor). If you'd like to be involved there are still plenty of opportunities available.

The Exhibition Halls are nearly full, and thank you Rod Lovibond for being in charge of this exercise at such a difficult time in the commodity cycle. At the time

The ASEG-PESA-AIG 2016 Conference Organisers.

of writing nearly 80 booths are planned to grace Halls F and H of the Adelaide Convention Centre.

We're still putting the finishing touches on the dinner at the Adelaide Oval. Kelly Keates has done an amazing job researching entertainment and the running sheet for the night is coming together nicely.

The Student Day will be the Wednesday of the conference. SA/NT Branch President Josh Sage has put together an exciting programme and 50 high school students and 10 teachers will have the opportunity to learn a little about what we do in the geophysics world. Josh has also been instrumental in organising the EAGE GeoQuiz night. If you're a student make sure you register for this event – you could win a trip to Paris to attend the 79th EAGE conference!

Thank you Erin Shirley for keeping on top of the publicity for the conference. As well as the national publications we've had regular advertisements internationally in *The Leading Edge*, through email user groups, and through social media.

The diligent finance team (Adam Davey, Luke Gardiner and Philip Heath) have been meticulously keeping tabs on the financial viability of the conference, in a particularly tough climate.

Thank you also to the general committee members who have attended meetings, offered ideas, helped on subcommittees, and kept us going. These include Doug Roberts, Phil McBride, Terry Crabb, Duncan Cogswell, Alex Ross, Matthew Musolino, Sandy Menpes, Wayne Spilsbury, David Rowe, and Adrian Brewer.

Finally thank you to our Professional Conference Organisers Phil and Irene Plevin (and associates) for their work in making this conference happen. We couldn't have done it without them.

Cheers and see you in August!

Philip Heath and Luke Gardiner

Philip Heath
Co-chair Minerals
philip.heath@sa.gov.au

Luke Gardiner
Co-chair Petroleum
luke.gardiner@beachenergy.com.au

2016 Ludger Mintrop Award for Derecke Palmer

Derecke Palmer

The European Association of Geoscientists and Engineers (EAGE) has chosen Dr Derecke Palmer to receive the Ludger Mintrop Award for the best paper published in *Near Surface Geophysics* in 2016. The paper is entitled 'Is accuracy more important than precision in near surface refraction seismology?'.

The award was presented to Derecke Palmer by EAGE President Mohammed Alfaraj and Vice-President Chris Ward during the Opening Session of the 78th EAGE Conference and Exhibition held in Vienna in May 2016.

Frank Arnott Award update

In the April 2015 issue of *Preview* (PV 175) a first announcement was made concerning a geoscience challenge entitled the Frank Arnott Award. As the challenge has been open for 12 months, the organising committee has deemed it appropriate to provide an update.

The contest was established to promote innovation in exploration geoscience, specifically in the areas of data integration and visualisation and is named after Frank Arnott (1951–2009), an exceptional visionary who developed innovative approaches to bringing together multidisciplinary data sets that underpin exploration decision making. The Frank Arnott Award is designed to be an open **challenge** that focuses on collaborative innovation in **data integration** and **visualisation**.

As collaboration in data integration is a key theme, team entries are preferred with the participants bringing a **mix of geophysics, geology and geochemistry** expertise. The teams are able to choose from five regional **high quality datasets** that include Dawson Plateau (Yukon, Canada) and Quesnel Trough (BC, Canada), Kevitsa (Finland), Broken Hill (NSW) and Gawler Craton (SA). Teams are welcome (in fact encouraged) to find and utilise supplementary information to contribute to their final submission and will be assessed accordingly.

The minerals exploration industry uses a limited range of tools and familiarity with computer applications provides new graduates with an edge when it comes to rating for employment opportunities. The primary software developers in our industry such as Geosoft, Pitney Bowes, and Mira Geoscience have indicated that they will provide educational licenses for use by teams that are participating in the Frank Arnott Award.

By working in teams, participants will hone teamwork skills, valued by employers in the industry. Learning to understand and values each other's skills and also learn their own limitations is an important part of the collaboration. The FAA provides an opportunity for individuals and teams to expand their network of industry contacts which will serve them well throughout their career.

Teams are encouraged to deliver their submissions (pre or post the FAA deadline) at local (branch) industry society meetings e.g. ASEG. Superior communication skills are required in the modern work environment and delivering talks to friendly society gatherings will refine their presentation planning capability and deliver confidence for subsequent interviews or oral presentations to peers.

A highly experienced team of judges has been chosen from a cross-section of industry to assess submissions. The judges will take note of the high achievers across the spectrum of contributions and the top teams will be encouraged to deliver oral presentations and publish their results in the prestigious Exploration 2017 Decennial Conference (October in Toronto, Canada (www.exploration17.com). This conference takes place every 10 years and is focused on a retrospective of the previous 10 years and gives a select group the opportunity to deliver their view of developments likely to play out in the next decade. As such, the winners of the Frank Arnott Award will be well placed to deliver their presentations.

The Frank Arnott Award presents students and young professionals an opportunity to stand out from the crowd, particularly those with an eye on future employment prospects with academia and industry. Entries are open until 31 December 2016 and the conditions of entry are provided at www.frankarnottaward.com. To date, 120 individuals from across the globe have registered.

For further information, explore www.frankarnottaward.com or contact the FAA organising committee:

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Maria Nicolaidis, Geosoft, Inc.
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Theo Aravanis, Rio Tinto Exploration
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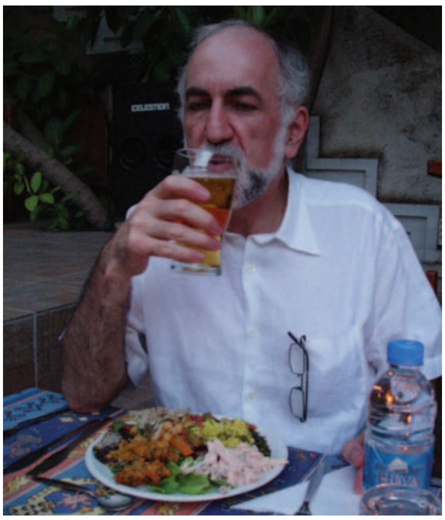
tim.dobush@geosoft.com



GA: update on geophysical survey progress from the Geological Surveys of Western Australia, South Australia, Northern Territory, Queensland and Victoria (information current on 16 May 2016)

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
Coompana	GSSA	GA	GPX Surveys	7 Feb 2015	255 265	400 m 80 m E–W	85 910	8 Nov 2015	Dec 2015 for magnetic and elevation data	173: Dec 2014 p. 24	The radiometric data are expected to be released in Jun 2016
Menindee	GA	GA	TBA	May 2016	10 300	100 m 50 m NE–SW	941	Jun 2016	Jun 2016	This issue	The proposed survey covers parts of the Menindee, Nartooka and Lake Tandou Standard 1:100k map sheets

TBA, to be advised.

Table 2. Gravity surveys

Survey name	Client	Project management	Contractor	Start survey	No. of stations	Station spacing (km)	Area (km^2)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Stavely	GSV	GA	TBA	Survey Quotation Request in preparation	Approx. 8000 in 9 separate areas	500 m regular grid in 8 areas and 500 m station interval along one traverse	TBA	TBA	TBA	The proposed survey covers parts of the Horsham, Hamilton, Ballarat and Colac Standard 1:250 000 map sheets	TBA
Wiluna	GSWA	GA	TBA	TBA	Approx 17 000 in 2 separate areas	2500 m regular grid	103 000	TBA	TBA	The proposed survey covers parts of the Bullen, Trainor, Nabberu, Wiluna, Sir Samuel, Madley, Herbert, Robert Standard 1:250 000 map sheets. The Quotation Request was released on 27 Jan and closed on 23 Feb. The Contract was expected to be formally executed before the end of May	TBA
Daly Basin	NTGS	GA	TBA	Before the end of Jun 2016	2537	Regular grid of 4, 2 and 1 km	35 730	TBA	TBA	This issue	The proposed survey covers parts of the Cape Scott, Pine Creek, Port Keats, Fergusson River and Katherine Standard 1:250k map sheet areas. The Quotation Request was released on 13 May and closed on 27 May

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 – PACE Area	GSSA	GA	CGG Aviation	TBA	8489	2 km; E–W lines	16 371	TBA	TBA	179: Dec 2015 p. 23	The proposed survey covers parts of the Mann, Woodroffe, Birksgate and Lindsay Standard 1:250 000 map sheets
Musgraves – CSIRO Area	GSSA	GA	SkyTEM Australia	TBA	7182	2 km; E–W lines	14 320	TBA	TBA	179: Dec 2015 p. 23	The proposed survey covers parts of the Woodroffe, Alberga, Lindsay and Everard Standard 1:250 000 map sheets
West Kimberley and Ord-Bonaparte	WA Government: Departments of Water, Agriculture and Food	GA	SkyTEM Australia	26 Sep 2015	7837	Various + traverses	TBA	3 Nov 2015	TBA	178: Oct 2015 pp. 30–31	The release date for the survey data is to be decided by the WA Government Department of Water
Isa Region	GSQ	GA	Geotech Airborne	Winter 2016. Centred on Cloncurry	TBA	TBA	TBA	TBA	TBA	This issue	The survey covers the Dobbyn, Cloncurry, Julia Creek, Duchess, McKinlay, Boulia and Mackunda Standard 1:250 000 map sheets. The survey is expected to mobilise in Jun 2016
Thomson Extension	GA	GA	TBA	May 2016	2415	5 km, E-W lines	TBA	Jun 2016	Jun 2016	This issue	The survey covers the Toompine, Eulo, Yantabulla, Enngonia, White Cliffs and Louth Standard 1:250 000 map sheets. The survey was expected to mobilise on 23 May 2016

TBA, to be advised.

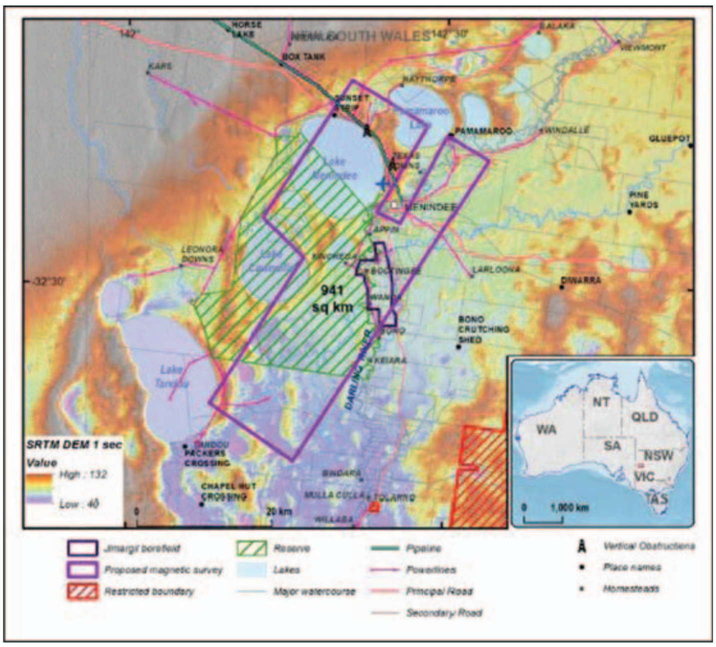


Figure 1. *Area of the Menindee magnetic and radiometric survey.*

Figure 2. *Area of the Daly Basin gravity survey.*

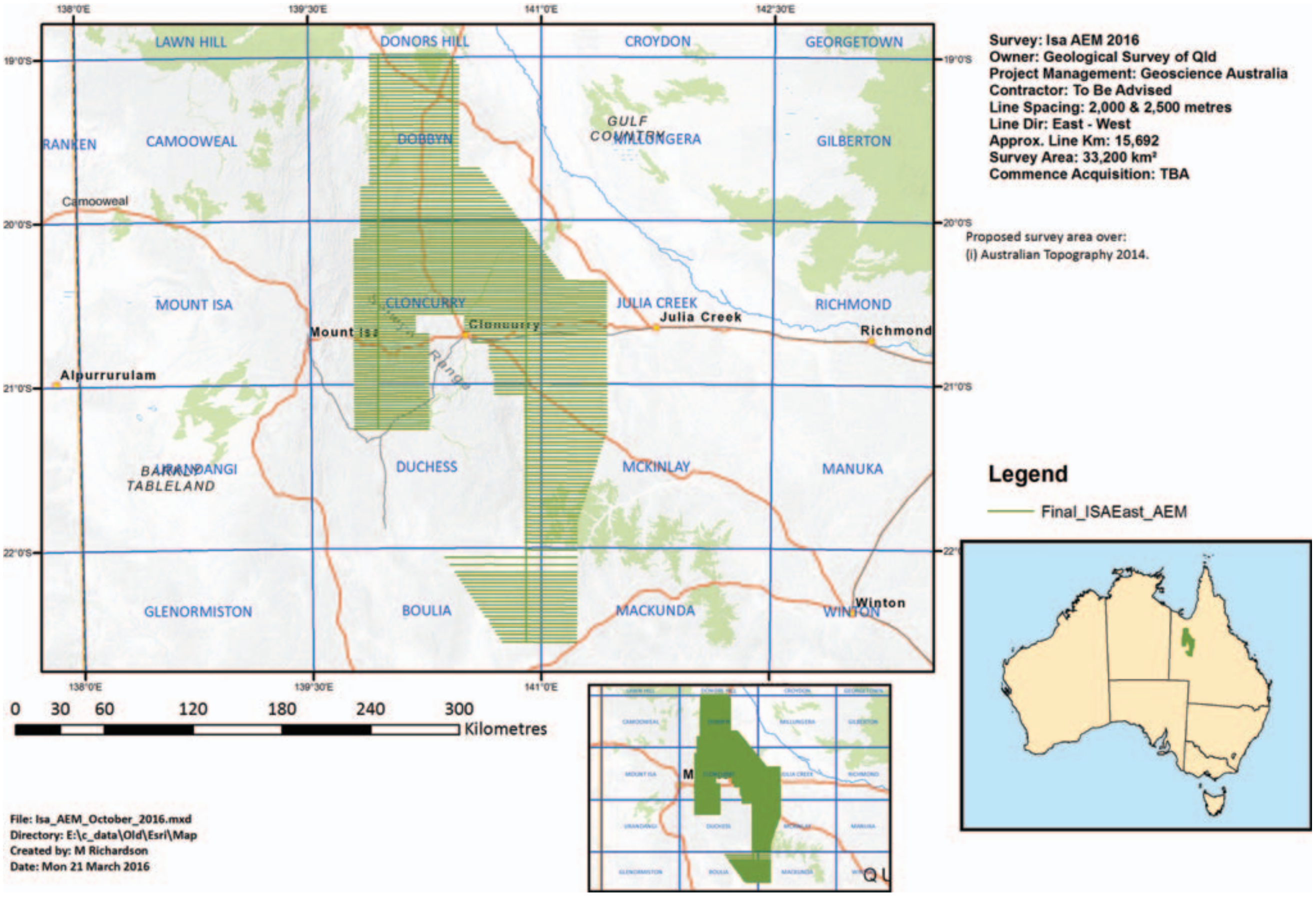


Figure 3. *Area of the proposed Isa Region AEM survey.*

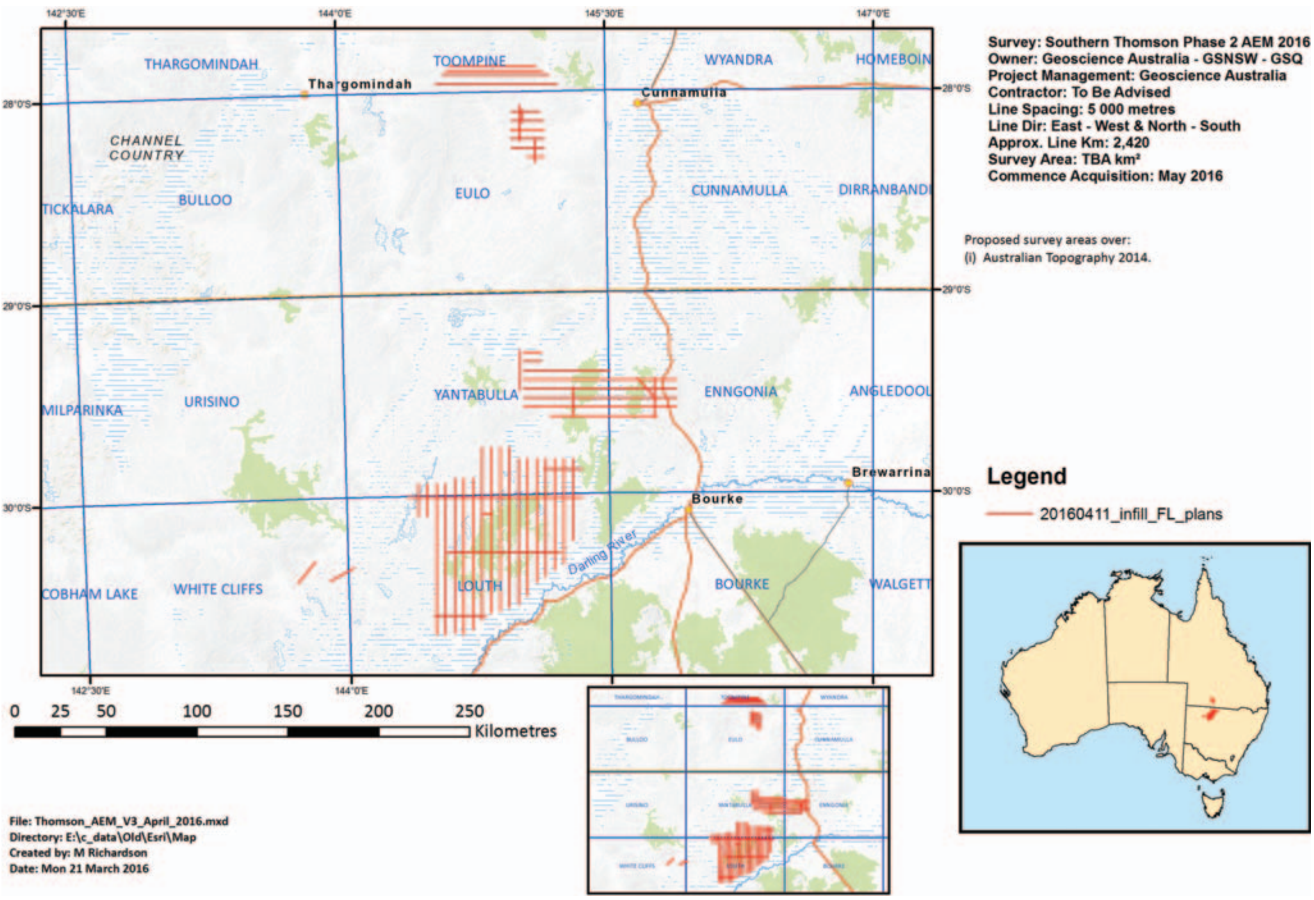


Figure 4. *Area of the proposed Southern Thomson AEM survey.*

GSWA: Southwest Yilgarn 2015 gravity survey, Western Australia

The Geological Survey of Western Australia (GSWA) Southwest Yilgarn 2015 gravity survey was the fifth stage in the National Collaboration Project Agreement CMCG4003A PA5 between the Department of Mines and Petroleum (DMP) and Geoscience Australia (GA) – WA Reconnaissance Gravity Surveys 2013–20, with this fifth-stage project funded by Western Australia's Exploration Incentive Scheme. The objective of the project was to complete 'Generation 2' regional reconnaissance gravity coverage of Western Australia at a spatial wavelength resolution of 5 km or less. At the time the program commenced, approximately 60% of the area of Western Australia – about 1.5 million square kilometres – remained to be covered to the required standard.

The Southwest Yilgarn survey, covering an area of 175 000 km^2, added a total of 23 736 new gravity stations to the national gravity database (Figure 1). Acquisition by Atlas Geophysics Pty Ltd using light-vehicle (LV) borne techniques occurred between June and December 2015 with project management conducted by GA. Observations were made at a nominal spacing of 2 km along public roads and tracks with location and elevation control using Global Navigation Satellite Systems (GNSS) technology. Data from the survey were released in February 2016.

A complete data package with point-located data, georeferenced grids, survey operations report and images of the new data merged with existing data (Figure 2) has been compiled. It is available via the GeoVIEW.WA interactive map application on the DMP website (www.dmp.wa.gov.au/geoview; GSWA survey registration number 1020).

Located survey data are also accessible via the national Geophysics Archive Data Delivery System (www.ga.gov.au/gadds; GA Project number P201561).

For further information contact: David.Howard@dmp.wa.gov.au or John.Brett@dmp.wa.gov.au.

John Brett
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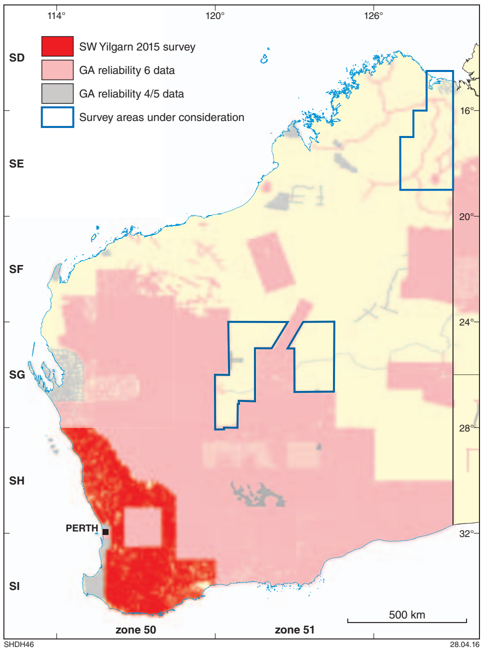

Figure 1. *Second-generation gravity coverage of Western Australia as at April 2016.*

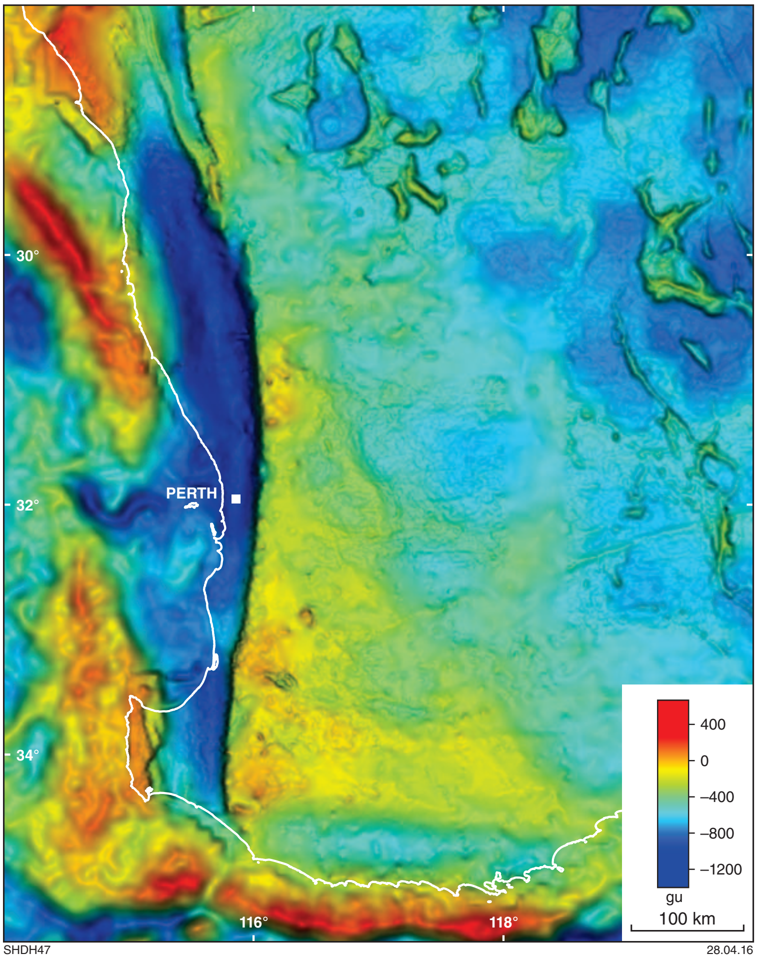

Figure 2. *Gravity anomaly compilation of the southwest of Western Australia including new data from the Southwest Yilgarn 2015 survey (Spherical Cap Bouguer Anomaly onshore, Free-air offshore).*

GSSA: new gravity stations on SARIG

Prior to May 2016, 747 public domain gravity surveys were downloadable directly through SARIG. The GSSA have identified 594 more surveys bringing the total to 1341 gravity surveys downloadable through SARIG. These surveys date from 1937 to the present; however, the bulk of the newly released data were acquired in the last couple of decades.

The total number of gravity survey points downloadable through SARIG is now 699 255 stations, compared to 495 269 prior to the update. That's a total of 203 986 new stations; roughly 41% increase.

The GSSA geophysicists have searched through open file envelopes to locate the additional surveys. Many of the surveys were already attached to open file envelopes and simply needed to be added to the online GIS. Many were already on the system, and simply needed their confidentiality status updated.

There are two ways to download gravity data through SARIG. Simply right-clicking on the layer 'Gravity – Stations (visible 500K)' in the Map Layers area will allow you to download the entire dataset. However, if you're after a specific area, choose the 'Geophysical Data' option under Databases (top left hand side of the screen), and draw a box around your area of interest. Then simply follow the prompts.

If you're aware of any gravity surveys in South Australia that aren't being shown on SARIG please don't hesitate to contact customer services (resources.customerservices@sa.gov.au) and ask to speak to the Geophysics team.

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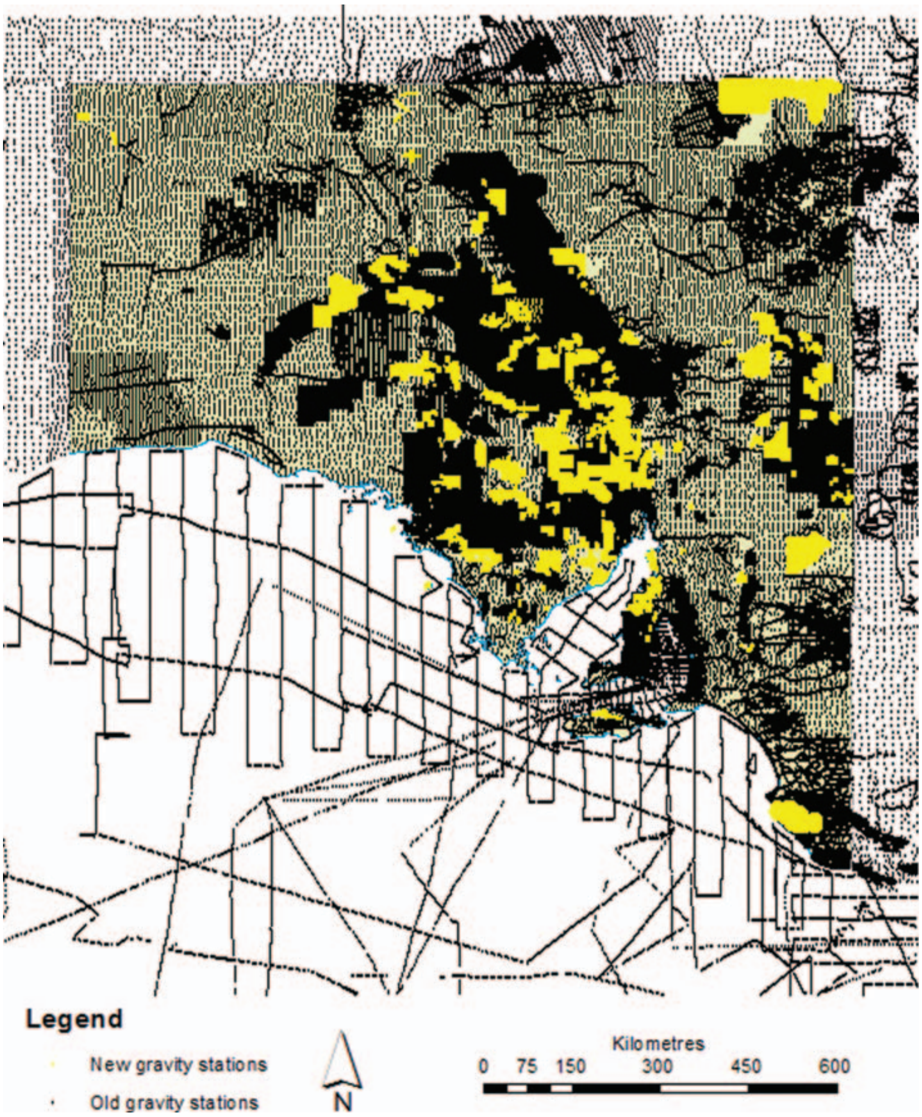

Figure 1. *South Australian gravity stations May 2016.*

Canberra observed

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A smoke and mirrors budget

The 2016 Budget was overshadowed by the double dissolution shenanigans and will be followed by two months of electioneering, when we will have to endure MPs and Senators fighting for their jobs instead of working in the Parliament for the benefit of the country.

And, if anyone thought there would be any debates of any substance about policy, they would be disappointed. As I write Turnbull is only talking about jobs and growth; nothing about the environment, foreign policy, terrorism, or even where the jobs will be – unless it's building submarines in South Australia. Meanwhile, Bill Shorten seems to be only talking about health and education and how he's going raise taxes to pay for them. All very very boring.

Now back to the smoke and mirrors budget. And it is smoke and mirrors because what is given in one hand is taken away with the other – and you aren't meant to see the hand that's doing the taking.

Let me give some examples:

1. **Innovation**: In December 2015 the Government announced a plan to invest $1.1 billion over four years 'to incentivise innovation and entrepreneurship, reward risk taking'. If funding for this appears anywhere in the budget, then it must be well hidden – there does not appear to be any new money for this activity. It's all coming from somewhere in the 2015 forward estimates.
2. **The Great Barrier Reef**: There will be a $171.0 million boost to protect the Great Barrier Reef and a $70 million additional injection to the Reef Trust. However, $101 million of this has been taken from the National Landcare Programme.
3. **Antarctic research**: The Government has signed a contract for Australia's new icebreaker, amounting to a $1.912 billion investment, but the custom-built ship will not arrive in Australia until the mid-2020s. The ship will cost $529 million and the $1.38 billion remainder will be spent on operations and maintenance over its 30 year lifespan. So, very little of this money will be spent in the next financial year – it's all a commitment for future governments to deal with in the next 30 years. At the same time as this investment is being made CSIRO has announced that it will be ceasing all work in Antarctica. Quite bizarre.

I think it's time Science Minister Christopher Pyne intervened in the management of CSIRO because these cuts and the reported sacking of 74 jobs in its Oceans and Atmosphere Division is contrary to the Government's commitment to boost Antarctic research. He cannot keep on saying that CSIRO is an independent authority, because it's governing Act requires the organisation to:

'Carry out scientific research for any of the following purposes:

(i) assisting Australian industry;
(ii) furthering the interests of the Australian community;
(iii) contributing to the achievement of Australian national objectives or the performance of the national and **international responsibilities of the Commonwealth;**
(iv) **any other purpose determined by the Minister**.'

It is clear that CSIRO's actions will affect Australia's international responsibilities and that the Minister can intervene when the organisation loses its way. His silence is deafening and it says a lot about the current Government's commitment to our international obligations and long term strategic research.

4. **Geoscience Australia**: The Government will provide $100.5 million in additional funding to Geoscience Australia over four years from 2016–17. This will fund the 'Exploring for the Future' programme, which will produce the next generation of pre-competitive geoscience data, with a focus on targeted areas of northern Australia and parts of South Australia. It will improve Australia's long term exploration prospects and address declining onshore greenfield exploration activities. The smoke and mirrors are evident because, as can be seen in the table below, the funding increases by only $6 million from the current financial year to the next, not the expected $25 million.

Science agency funding

A summary of the budget outcomes for the main science agencies is given below and some of the relevant numbers are show in the table.

Institute of Marine Science (AIMS)

Funding will continue in line with last year's budget.

Australian Nuclear Science and Technology Organisation (ANSTO)

The Government will redirect funding of $39.4 million over three years from 2016-17 to allow for the reprocessing of spent fuel from ANSTO's Open Pool Australian Lightwater Reactor in France rather than in the United States of America as previously planned. The processed fuel will eventually be returned to Australia for storage at the National Radioactive Waste Management Facility, which is expected to be operational from 2020.

Australian Research Council (ARC)

Funding for the ARC has continued to fall from $913 million in 2013–14 to $751 million in 2016–17. Fortunately, the forward estimates indicate that the bottom of the trough has been reached and funding for research grants is expected to grow, albeit it at a slightly reduced rate than forecast in last year's budget, to reach $774 million by 2018–19. However, the damage may have already been done and bright innovative students may have been put off undertaking research at Australian Universities.

Science agency funding						
Agency	**Government appropriation in $m and (average staff numbers)[A]**					
Financial year	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**	**2018/19**
AIMS	33	39	40 (208)	42 (207)	42	45
ANSTO	314	314	336 (1257)	338 (1257)	349	356
ARC	913	904	821 (128)	751 (136)	767	774
BOM	357	357	367 (1581)	368 (1602)	320	320
Antarctic Division		171	158	141?	141?	141?
Geoscience Australia	187	180	121 (584)	140 (590)	151	147
CSIRO	753	717	750 (5056)	787 (5058)	797	832
NHMRC	878	949	934 (185)	927 (179)	929	942
ABS		396	489 (2871)	601 (2830)	410	396
CRCs	145	150	141	150	160	156
DSTG			464	438	435	420

[A]The average annual staff numbers are in brackets. The Government funding is for running costs (not capital equipment) provided by the Australian Government. The budget documents are so complicated some adjustments may be necessary, but the numbers in the table can be used to represent trends.

Bureau of Meteorology

Additional investment will be made in a new supercomputer for the Bureau of Meteorology, following the hacking incident last year. The amount of investment is currently commercial in confidence. No additional funds have been identified to replace the functions formerly carried out by CSIRO on modelling the atmosphere and the oceans.

Antarctic Division

The Government will provide $55.0 million over 10 years from 2016–17 to undertake scoping studies and commence delivery of enhanced infrastructure capabilities in the Australian Antarctic Territory. Provision for this funding had been provided in the forward estimates.

It will also provide $83.1 million over four years from 2016–17 and further funding of $413.1 million over 29 years from 2020–21 with $10.3 million per annum ongoing from 2049–50, to support Australia's presence in Antarctica. How these measures will impact on the funding for the new ice-breaker is not made clear and the Division is not listed as an Agency in the portfolio budget Statements.

Geoscience Australia (GA)

Geoscience Australia has been provided with $100 million over the next four years to produce an integrated resources prospectus for key targeted regions in northern Australia and parts of South Australia. These areas have been selected based on gaps in data and knowledge for minerals, energy and groundwater resources. However, the increase in funding for 2016–17 is only $6 million, presumably because other projects have been completed.

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

There were no major changes relating to CSIRO in the budget papers. According to the forward estimates appropriation from the Government is expected to grow more quickly than outlined in the 2015–16 Budget and should reach $832 million in 2018. So, why the organisation had to attack its environmental programmes is inexplicable.

National Health and Medical Research Council (NHMRC)

Funding for the NHMRC has mostly been maintained, with a $6 million reduction over last year to $927 million. It is now significantly larger than the ARC, which has now declined to $751 million. In 2013 the ARC appropriation was $25 million larger than the NHMRC. How times have changed.

And then there is the **Medical Research Future Fund**. This was projected to reach $20 billion by 2020–21 (one year later than estimated in the 2015 Budget). Forecast disbursements for this fund have been significantly reduced. The current numbers are: 2016–17 – $61 million; 2017–18 – $122 million; 2018–19 – $215 million and 2019–20 – $386 million. Whether so much of the nation's research funding should be allocated to medical research is a question that should be considered by the Chief Scientist.

Australian Bureau of Statistics (ABS)

There are no changes to the forward estimates from the 2015–16 Budget and funding for the 2016 census has been maintained. Remember; when Mr Abbott became Prime Minister there was push to abolish the census.

Cooperative Research Centres (CRC) Programme

Savings of $20 million from the CRC programme over two years from 2015–16 will be made to extend funding for the Australian Astronomical Observatory and partially to fund a communications and compliance campaign for the new country of origin labelling framework. The majority of these savings relate to unspent funds arising from the delay in the CRC programme in 2015–16 rather than any cuts to the CRC programme. The Government will also provide $12.6 million in 2019–20 for the operating costs of the Australian Astronomical Observatory from the CRC programme.

Defence Science Technology Group (DSTG)

Reductions in funding to DSTG (previously DSTO) were announced in last year's budget and these will still go ahead, but not at the same level as previously forecast. Funding will be about $21 million lower in 2019–20 compared to 2016–17. As you can see in the table the numbers do not make happy reading.

And I almost forgot, there is $374 million allocated for decisions made but not yet announced. Code for an election war chest? Watch this space!

Education matters

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'Exploring for the Future' brings opportunities to universities

University geoscience programs can expect to be indirect beneficiaries of the 'Exploring for the Future' special allocation to Geoscience Australia, announced in the Commonwealth Budget on 3 May. Provision of $100 million over four years (in addition to the GA standard budget) was announced by Minister for Resources Energy and Northern Australia Josh Frydenburg, with funds to be directed to minerals, energy and groundwater potential in northern Australia and South Australia. The stated intention is to deliver a program of data acquisition and analysis that will allow Australia to identify new greenfield exploration sites for future development, and it is an outcome of the UNCOVER seminars, workshops and conversations that have been held nationally since the Australian Academy of Sciences initiated discussions on this challenge four years ago.

Geoscience Australia has a strong tradition of collaborating with universities in the past across a wide range of research topics, and in being an employer of choice for many of our top graduate students. We can look forward to many more such opportunities as details of this program are released.

Chris Pigram, CEO of GA, welcomed the budget outcome saying 'The program will be wide ranging and hence offers the opportunity to build on our extensive record of collaboration. We welcome collaboration to assist us to tackle the many challenges that will arise as we attempt to understand the geological evolution of northern Australia, and the resource endowment that has accrued.'

Chris Pigram
CEO Geoscience Australia

Research Foundation announces $103K in grants for graduate student projects

Phil Harman
Research Foundation Chair

On behalf of the ASEG Research Foundation I would like to acknowledge and thank the ASEG Federal Executive for their recent donation on behalf of the ASEG, of $100 000 to help support the research grants for 2016.

This year we received 17 excellent applications, 8 for petroleum, 7 for minerals and 2 for engineering. Of these 8 were chosen for support, 3 in petroleum, 4 in minerals and 1 in engineering, some at a slightly reduced level to what was requested.

At the Foundation our policy is that we only commit support with funds that we already hold so that we can be sure that we are able to deliver on what we promise. The trend now is that more proposals are coming at the PhD level so we need to look beyond the current year in retained funds. This makes the support of the ASEG even more critical to the future of the Foundation, which is now well past a total of $1 million invested since its formation in the 90s.

Thanks also to the Members, both private and corporate that have donated to the Foundation this year. Their individual contributions not only give us great moral support but also add considerably to what the Foundation is able to achieve financially … just a few thousand dollars is an extra Honours scholarship.

Just to remind everyone, the Research Foundation was established to help students with the additional cost of essential field and laboratory work needed to carry out their research. The Foundation qualifies as a registered charity and hence all donations are tax deductible.

Once again thanks to Doug Roberts our Secretary for coordinating the granting of this year's awards and to Peter Priest our Treasurer. Also thanks to Koya Suto for liaising with the Federal Executive on our behalf.

With the ASEG Conference in August fast approaching, let's all keep the Research Foundation and its essential role uppermost in our minds and use the occasion to commit to supporting this essential function of the ASEG.

Successful projects

Harrison Jones (Macquarie University). Supervisor Mark Lackie, industry monitor Mike Smith: *Geophysical Study of a Silurian Base Metal Occurrence west of Numeralla in New South Wales.*

This research will be based on a geographic area near Cooma, NSW with the following objectives:

- Investigate how the detailed geophysics relates to the geology of the area at the local and the prospect scale;

- Determine petrophysical measurements for basement units; and
- Ascertain the usefulness of different geophysical techniques in highlighting features of base metal deposits in the Numeralla area.

The Palaeozoic terrain of NSW is generally well mineralised and is host to many large copper, gold, lead, zinc, silver deposits; some of which are extremely important to the economy of the state. The mineral potential of the Silurian belt of metavolcanics and metasediments in the southern Monaro is, however, still to be determined.

Historically the Silurian belt has had base metal producing mines, and characterisation of mineralisation in the region may well aid exploration programs. This study will employ a variety of geophysical methods, including magnetic, gravity, electrical and electro-magnetic techniques. These will be employed over known surface indicators of base metal and precious metal mineralisation to determine the applicability of these respective methods to exploration and to assess the size and extent of possible sub-surface mineralisation in the target area. Areas of particular interest include the Rosebank Mine and surrounds, where gossan and rock chip samples have given significant gold indicators as well as strongly anomalous silver, lead, zinc, copper, barium, bismuth, arsenic and molybdenum. In addition, to the east of the Rosebank Mine dump, two previous drill holes will be investigated based on pyritic black shale extractions as a comparison with the mineralised site.

Harrison graduated from Macquarie University in 2015 with a Bachelor of Science double majoring in Geology and Geophysics. He is currently continuing his studies undertaking a Bachelor of Philosophy/Masters of Research (BPhil/MRes) again at Macquarie University. His professional vision is to expand his knowledge of the mineral and energy resources industry and to strive towards a successful career utilising geophysics and geology. Harrison's other personal interests include sports (mainly basketball), outdoor activities generally, reading, travelling and meeting new people.

Zubair Ahmed (Curtin University). Supervisor Maxim Lebedev: *Rock Characterization using Physical Methods on Powders.*

Continuous monitoring of the petrophysical properties of subsurface rocks that are being penetrated during drilling is important to the drillers at the rig site. Core samples can provide these properties but they are costly to acquire and time consuming to measure and analyse. Moreover, cores can be missing or broken. To overcome these drawbacks it is proposed to develop a new concept that relies on the drill cuttings that come up during drilling. Ultrasonic measurement on these rock powders with successive pressure levels can give the effective dynamic elastic moduli of the powder pack. These dynamic moduli can be inverted to get the elastic moduli of the constituent grains of the rock. The same procedure will be applied to core pulps and solid cores to compare the results.

Zubair Ahmed's PhD project is sponsored by DET CRC. His research interest lies in studying elastic waves to identify and analyse mechanical properties of the rocks and minerals that have significant influence on economically potential deposits. Prior to starting his doctoral study, he completed a Master of Science in Applied Geophysics from Chiang Mai University, Thailand and Bachelor of Science in Geology from University of Dhaka, Bangladesh. He has been working in the oil and gas industry as a geophysicist for more than five years. His expertise includes seismic data acquisition line designing, field data quality control and seismic data interpretation.

Xuiyan Ren (RMIT). Supervisor Jim Macnae, industry monitor Jovan Silic: *3D Time domain EM modelling and inversion with finite volume method.*

First, we aim to implement the OcTree method to speed up forward modelling. Next we aim to implement the methodology defined by supervisor Macnae in providing good starting models for 3D inversions. Testing and reporting of the inversion results on Australia airborne EM data will advance interpretation methodology. The outcome will lie in improved capability to automatically fit geologically sensible 3D models to AEM data.

A joint project with Jilin University, China permits PhD student Ren to spend one year of her PhD at RMIT University, subject to receipt of a Chinese Government award, the results of which are imminent. Ren has already coded in China a forward modelling algorithm using the staggered grid finite volume method. Xiuyan is fascinated by geophysics and has received seven individual scholarships and 11 other awards and prizes for excellence in her undergraduate and graduate studies to date. She has already co-authored six refereed publications. Her supervisor in China is Professor Chang Chun Yin, familiar to many mining geophysicists from his time with Fugro Airborne Surveys in Canada.

Afzal Iqbal (University of Western Australia). Supervisor Julien Bourget, industry monitor David Moffat: *Tectono-*

stratigraphic evolution and petroleum prospectivity of the Roebuck Basin: insights from a 3D Seismic megasurvey.

This project is focussed on describing and mapping the basin scale regional structural framework and the impact of tectonic events on the depositional system and tectono-stratigraphic architecture of Roebuck Basin by using state-of-the-art methodologies. High resolution, three-dimensional structural and stratigraphic mapping at basin-scale will have significant impact in evaluating the petroleum prospectivity and in targeting new deeper prospects in the largely underexplored Roebuck Basin, only recently established as a promising oil and gas province.

Afzal Iqbal graduated from University of The Punjab – Pakistan in 2001 with a BSc – applied geology (1999) and MSc (2001) in petroleum geology. After working five years with Landmark Resources at various locations in Middle East and Pakistan, he joined Chevron International in mid-2006. Afzal held various positions in geoscience disciplines at Chevron International in the Middle East and Australia till the end of 2015. He has now joined the Centre for Energy Geoscience at UWA where his PhD research focuses on the tectono-stratigraphic evolution of the Roebuck and Canning basins, offshore Western Australia.

Roman Beloborodov (Curtin University). Supervisor Maxim Lebedev, industry monitor Marina Pervukhina. *Correlation of geomechanical and petrophysical properties of shale rocks – Extrapolation of laboratory core measurements on the borehole using well-log data.*

This project aims to develop an algorithm for the extrapolation of the laboratory measured geomechanical core properties

and anisotropy parameters to the whole length of the shale intervals in the borehole. The complexity of shale mineralogy, in-situ conditions and, finally, scaling effects make this task challenging.

Comprehensive laboratory investigation of synthetic and natural shale rocks along with the numerical modeling are required to understand the correlation between petrophysical and geomechanical properties of these rocks. State-of-the-art data mining and artificial neural network techniques are to be implemented for the analysis of wireline logs and linking them with the data acquired in the laboratory.

This approach will allow upscaling core properties on a borehole, and predicting of the geomechanical properties and anisotropy parameters of shales using the wireline logs. Outcomes of this study will make the exploration techniques more informative to cope efficiently with the common safety drilling issues, to choose the suitable methods of hydrocarbon extraction, and to ensure the operative tying of seismic surveys to well-log data.

Roman has graduated from Lomonosov Moscow State University (MSU) with a BSc in Hydrogeology and Engineering Geology, and a MSc in Soil Science and Artificial Lithogenesis. As a research fellow at MSU he was involved in multidisciplinary fieldwork on geothermal fields of Kamchatka Peninsula studying properties of geothermal clay rocks with geomechanical, chemical and physical methods. This work formed the basis for his MS thesis. For three years Roman worked in industry as an engineer-geologist, with a variety of duties from field and laboratory data acquisition and processing to supervision and quality control of engineering-geological surveys. As an intern at CSIRO (Perth), Roman was involved in a commercial project on shales characterisation by conducting the physical and numerical modeling of shale rock properties. When he isn't working hard in the laboratory, he spends time with his family, goes for cycle rides, learns new languages and improves his programming skills.

Hamish Stein (University of Melbourne). Supervisor Stephen Gallagher, industry monitor Jarrod Dunne: *Geological and rock-physical considerations for building shallow elastic property models in deep-marine settings (NW Shelf, Australia).*

Modern geophysical imaging projects lack geological context and often undervalue or ignore proper rock physical constraints, especially when building complex high velocity models of the shallow overburden. Geophysical models have developed highly sophisticated migration algorithms, which have advanced ahead of our ability to provide accurate velocity models. As a result current methods tend to approximate velocity data, especially in the shallow overburden, and use methods that are not tied to or driven by, readily available geological and rock-physical knowledge.

The recent International Ocean Drilling Program (Expedition 356) campaign on the NW Shelf of Australia, has collected abundant information over the shallow Neogene strata in the form of logs, core, pressures, temperatures, etc. Analysis will initially focus specifically on the relationship between sonic velocity, vertical effective stress and lithology. When integrated with the regional seismic data and geological understanding (sequence stratigraphy, tectonics) it may be possible to build a predictive model for elastic parameters in the Neogene for the entire north-western margin of Australia.

Born and raised in Perth, Hamish moved to Melbourne in 2010 in order to undertake a Bachelor of Commerce at the University of Melbourne. Majoring in Economics and Management, Hamish graduated in 2013, and moved to London where he spent time gaining experience in the finance industry, interning first at Hannam & Partners and then at Ophir Energy in the M&A departments. In 2015 Hamish returned to Melbourne to undertake a Graduate Diploma in Geology, before transitioning into the two-year MSc. program in 2016. Hamish was inspired to study geology following his time working in London with a largely resource sector focus, he hopes to develop a strong technical background through his studies to compliment his commercial experience. Outside of his studies Hamish is a keen hockey player, currently playing in the Victorian Premier League with the University of Melbourne Hockey club.

Lee Tasker (University of Western Australia). Supervisor Jeffrey Shragge, industry monitor Mads Toft: *4D Monitoring of Civil Infrastructure using Multichannel 3D Ground Penetrating Radar.*

The aim of this project is to develop a 4D-monitoring tool using multichannel 3D GPR technology to scan and image infrastructure over calendar time to enhance and improve the ability to accurately identify, interpret and monitor structural defects: (1) cracking and/or voiding present within infrastructure; and (2) volumetric changes of regions experiencing structural deformation. As a result of this research geophysicists will be able to provide Civil and Asset Management Engineers with a more accurate infrastructure-monitoring tool and geophysical data to better understand the material behaviour of their infrastructure over calendar time. These near-surface geophysical tools will prove most useful in the planning and prioritising of long-term maintenance of an infrastructure, saving time, money and improving the overall safety management of the infrastructure.

Lee Tasker is a PhD student at the University of Western Australia (UWA) and a Geophysics Consultant with Draig Geoscience. He specialises in near-surface geophysics, with a focus on geophysical solutions to engineering problems. Lee has a Master of Physics (MPhys) from Cardiff University, UK and a Graduate Diploma in Science (GradDipSci) in Geophysics from Victoria University of Wellington (VUW), NZ. With over eight years of professional geophysical consulting experience, he has worked both nationally and internationally on projects in the engineering geophysics, environmental, heritage and exploration fields in Australia, Mongolia, New Zealand, Pakistan and Papua New Guinea. Lee also serves as the Western Australian Members' representative on the ASEG Near-Surface Geophysics Group. He received an ASEG WA Student Award in December 2015.

2015 Annual Report on TESEP (Teacher Earth Science Education Programme)

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Thanks to the significant Principal level funding by PESA, Platinum level funding from the Minerals Council Australia, ASEG, and ExxonMobil, Gold level funding from the AIG, DSD (SA) and Silver level funding from the AusIMM and ANU (RSES), 2015 has been another rewarding year for TESEP presenters as well as recipient teachers. Continued, overwhelmingly, positive feedback from teachers has reinforced the TESEP team's keen determination for delivery of a quality teaching programme to secondary teachers at as many east-central Australian locations as possible.

Making a difference in the classroom – is there still a need?

1. After eight years of intensive TESEP workshop (& fieldtrip) delivery with:
   - 1836 teacher attendances at 144 workshops in 30 locations, and
   - 559 teacher attendances at 40 field/site visits.

Have we made a difference to Earth & Environmental Science teaching in the classroom?

Teacher feedback says YES.

*The multiplier effect of each TESEP teacher influencing 2 to 5 other teachers' results in close to **600 000** students being impacted by TESEP EES teaching resources.*

2. How does TESEP sit along with other earth science (e.g. Earth Science WA), Science Technology Engineering and Mathematics (STEM) and science by action programs?

Teacher feedback indicates that there is still a need for teacher PD training as delivered by TESEP in all eastern/central states and territories. Classroom-based training of teachers and students, as done by Earth Science WA (ESWA), is outside of the funding capabilities of TESEP. We will continue to teach the teachers via our mainstay: workshops, hands-on exercises, field/site visits and webinars.

3. In the current waning cycle in mining/energy resources industries is there still a need for TESEP?

***YES** we do still need to plan for replacement of the current aging earth science (and science) professional knowledge-base.*

New TESEP teacher attendees:

1. Many teachers are still only just joining the TESEP teacher network, after hearing a Science Teachers Conference TESEP 'taster talk'. In 2015, 155 teacher participants, attended TESEP conference taster talks (TESEP conference attendance was funded through an Australian Geoscience Council special fund). In the past 8 years there has been a TESEP booth, and taster talks have been run, at 28 science teacher (and geological) conferences.
2. Teacher feedback has resoundingly indicated that teachers, who have participated in TESEP professional development (PD) workshops, are more confidently and knowledgeably teaching Earth and Environmental Science at secondary school level.
3. TESEP teacher participants indicate that they are passing on their knowledge and TESEP materials to at least 1 to 3 other teachers at their school.
4. Some new TESEP participants are trainee teachers wanting to expand the depth and breadth of their Science teaching skill-set.

TESEP special projects:

1. Field/site visits – To give teachers that 'light-bulb moment', fieldtrips to key field exposures and site visits to university, geological survey and corporate laboratories, as well as site visits to museums, mine sites and international conference career presentations and industry exhibition halls have been added to the TESEP teaching experience. In 2015, a total of 57 teachers took part in field/site experience and 30 exceptional Science teachers of merit were invited from 5 states to travel to Victoria for an industry-led 3-day field excursion (Cape Liptrap & Gippsland field sites) and AAPG ICE/ASEG-PESA international conference. Articles on this field experience were distributed to partner society newsletters in September 2015.
2. Virtual Fieldtrip – using software developed by TESEP partner, University of Tasmania's Dr Michael Roach, field exposures can be brought to the students in classrooms. Key field world-class field exposures can be rotated and investigated at semi-regional to macro scale and structural/stratigraphic relationships can be investigated from the school classroom. Virtual petrography of rock and minerals as well as details of strata, fossils and sedimentary structures can be analysed. Hobart-area field exposures are being trialed by TESEP in 2016 as a demonstration of this application.
3. Standardised Rock and Mineral Kits – plans to link these to the virtual field locations and have teaching exercises developed as a new tenth PD of 'The Challenging Earth' series of 9.
4. Case studies supplement (currently over 30 freely downloadable case studies from across Australia and across the Earth Science spectrum have been developed to supplement the Year 11–12 EES Textbook (developed by ESWA).
5. Plate Tectonics, as an overarching theme, has been used to promote TESEP nationally using a classroom A2-sized gloss-finish poster, drafted and designed by AusIMM's Alison Potter for TESEP. Copies of this poster are now hanging in many classrooms across the country, as a colourful visual display, to enquiring young minds, of the inter-relationship between Earth's natural and physical resources and our use of the planet.
6. New fieldtrip guides for teachers and students have been developed for the Mt Gambier region, SA and for Cape Liptrap region, Vic.
7. Demonstration of the Exploration Seismograph exercise (funded by ASEG) (using donated geophones, standard teacher laptop and TESEP DVD film) at Labtech & Science Teacher conferences and PD venues.
8. Collaboration with new and existing partners – museums, universities, societies, corporates – to develop new and interesting teaching materials.

National Science Curriculum roll-out continues:

2014 through to 2017 are critical years for the new national Science curriculum roll-out. 2015 has seen the continuation of Year 8 (Rocks, Minerals & Mining – PD1) and Year 9 (PD9 Plate Tectonics) rolled out in all states and territories. In the 2015–2017 period, Year 10 and elective years 11 and 12 will include groundwater, climate-change and energy/resources of TESEP PD themes. Earth and Environmental Science is now a significant part of junior, middle and senior Science and many teachers now teaching EES, (many only with biology, geography, environmental science and mathematics backgrounds), are challenged to learn and then teach their students on the themes of Earth and Environmental Science in the new curriculum.

That is why continued funding of TESEP presenters and developers to enable enthusiastic teachers to gain new knowledge using this teaching resource material, is so important. Slower times in the energy/resources industry have seen a drop-off of several corporates and some universities and government funding for TESEP.

2015–2016 has seen ongoing collaboration with:

- Australian Science Teachers Association (ASTA), who administer TESEP, and assist in web portal facilitation for webinars, standardisation for national-ready classroom material and accreditation of PDs, and provide national and state-based conferences for TESEP to present materials for teachers and network with teachers, as well as newsletter networks.
- Scienceworks/Planetarium and Museum Victoria (Melbourne), Australian Museum (Sydney), QMEA (PDs across Qld), VSSEC Space Centre (Strathmore, Vic) have provided venues and teaching materials that complement TESEP PD presentations and allow teachers guided access to exhibitions to which they may take students in future classroom excursions.
- Earth Science WA (ESWA), Earth Ed (Vic) and Geoscience Pathways Program (SA) share materials, presenters and fieldtrip developers.
- Geoscience Pathways website webmaster funding (shared by PESA & ASEG) – this site is used to upload TESEP PD material for teachers to have free download access.
- Minerals Council Australia (Vic) re addition of more mine site tours to TESEP PDs.

TESEP team thank all partners for their support to TESEP in 2015 and look forward to ongoing collaboration in this national EES teacher education program. Inquiries: Jill Stevens (Chair) cp@tesep.org.au or Greg McNamara (Executive Officer) eo@tesep.org.au.

TESEP teaches geoscience on the beaches and at the cliffs; in the classroom and on the playgrounds. The programme will continue.

Environmental geophysics

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Welcome readers to this month's column on geophysics applied to the environment. In this issue we are looking at a subject that is somewhat 'out of the box' – geophysics applied to archaeology. I have asked Ian Moffat, from the Department of Archaeology at Flinders University, to tell us about some of the technologies that he has used over the past few years as a practicing geophysical archaeologist (archaeological geophysicist?). As was the case with last month's contributor, I am envious of the projects that he is working on and would love to be participating in them. Ian has just been awarded an ARC DECRA fellowship to investigate the climate during a period of rapid human development in the Pleistocene. He will be using geophysical and geochemical techniques to establish new climate records for Indonesia and South Africa so that the influence of the environment on the evolution of human behaviour can be assessed.

In this piece Ian will describe for us a few of the interesting developments in geophysical archaeology. Here is Ian's story:

Geophysics applied to archaeology

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Archaeologists are often thought of as trowel toting, hat wearing and (as Hollywood would have us believe) whip wielding adventurers who have to meticulously dig through the soil to study the past. While this stereotype remains somewhat accurate, it may be that the next generation of archaeologists will look more at home in Silicon Valley, as new technologies are rapidly changing archaeological best practice. These exciting new approaches promise to transform the way that archaeological sites are investigated, and thereby help in the effective management and interpretation of cultural heritage. In the field of archaeological geophysics the recent widespread availability of multi-sensor geophysical methods, and the development of techniques that make easy-to-interpret structure maps from motion photogrammetry software, is transforming the discipline from 'archaeological prospection' to a true 'geophysical archaeology'.

Geophysical techniques have been used by archaeologists since the 1950s to locate and map features in the subsurface. Common techniques have included ground penetrating radar, magnetometry, resistivity and electromagnetic induction. Among the most important recent instrument improvements is the development of multi-sensor platforms, particularly multi-sensor magnetic gradiometer systems (shown in Figure 1), which have up to 16 fluxgate sensors positioned on a survey cart. These sensors take advantage of cm accurate positioning systems (e.g. differential GPS) to provide high density data coverage, using real time navigation, thereby providing spatially accurate geophysical results and avoiding the need to lay out survey grids. This approach allows wide swaths of a site to be covered rapidly, at a very high data density on each pass. An additional advantage to this approach is that because each sensor remains at a constant orientation and distance from the other sensors the data quality is dramatically improved. Recent fieldwork at the Greek classical cities of Elis and Mantinea in the Peloponnese highlights the ability of this technique to provide insights into organisation of urban space on a

Figure 1. *The author in the field with a multi-sensor gradiometer at the classical Greek site of Elis.*

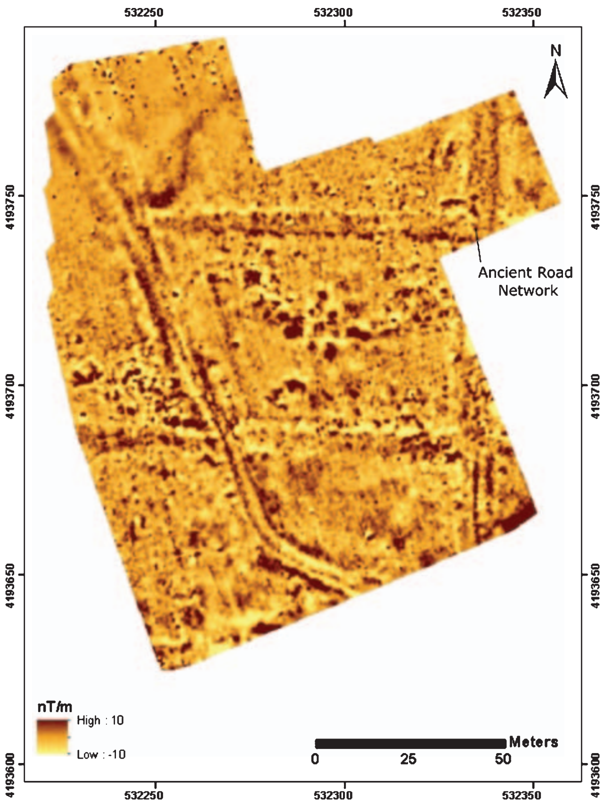

Figure 2. *Some of the results from Elis, using the Sensys MX V3 multi-sensor magnetic gradiometer (from Moffat et al., 2015).*

Figure 3. *The now-submerged archaeological site of Agioi Theodoroi in Crete recorded with kite mounted photogrammetry.*

landscape scale, despite these former cities being largely covered by farmland today (Moffat et al., 2015). Figure 2 shows some of the Elis results using a high-precision magnetic gradiometer, which show an extensive, largely orthogonal, road network that extends far beyond previous archaeological investigations.

Another technology having a transformative impact on archaeological research is the creation of high resolution aerial photographs using advanced photogrammetry software. This approach blends multiple photographs from any camera, by the automatic detection of a 'cloud' of common points. This is used to create a 3D model of a site that can then be positioned using information from, for example, a differential GPS. The camera can be ground-based, mounted on an aerial platform such as a drone or a kite, or even used underwater. The most common product is a very high resolution georectified orthophoto that can be used to map archaeological features directly, or as a base map for geophysical data. This high resolution visual information is critical to effective archaeological geophysics as the targets of these surveys are generally geographically small and geophysically subtle, and the closely spaced survey lines (swaths) are often not nicely orthogonal, but run in more complex spatial patterns, depending on ground obstacles, etc. By accurately placing geophysical data within the context of the survey area it is possible to understand how geophysically located features are related to the archaeological site and to allow interpreters to consider any interference from surface features.

The use of this technology to create a high resolution orthophoto is shown in Figure 3 from the now submerged Minoan-aged site of Agioi Theodoroi in Crete. Photographs were taken from a camera mounted on a kite and were used to record submerged features and as a base map to overlay marine ERT data (Simyrdanis et al., 2015). The orthophotos prepared for this project also precisely documented the site's condition, including the topography in very high detail, in a way that would have been impossible with conventional survey methods.

In summary, the use of multi-sensor geophysics and structure from motion photogrammetry provides the opportunity to approach archaeological investigation in exciting new ways. These techniques build on the existing benefits of rapid non-invasive site coverage provided by conventional geophysics and add increased resolution, additional survey speed, enhanced coverage and detailed 3D site recording, allowing the archaeological record to be examined in ways that it has never been examined before. The quality of the data is such that it is possible to develop informed hypotheses about human behaviour without excavation, transforming the role of geophysics from focusing on finding archaeological sites to making nuanced interpretations that would not be possible with invasive survey techniques. These new tools should form a part of every archaeological geophysicists' tool kit, and are potentially useful for other geophysicists who require high resolution surveys.

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Minerals geophysics

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Back to the future

If Dr Emmett Brown, the temporal star of Spielberg's hit film of the 80s *Back to the Future* was a geologist and landed in the present day, he'd be able to observe major programmes in Australia and Canada intended to help the exploration industry confront what many regard as a crisis in discovery performance. Although both programmes appear at a distance to be passingly similar, a closer examination shows there are marked differences. Will either of these programmes be successful? Unless Brown gives us the keys to the Deloraine we can only guess. The following is brief summary of what the Australian and Canadian groups are up to, and some thoughts as to how things may unfold.

Background

The minerals exploration industry (MEI) is a complex business ostensibly directed to the discovery of new mineral resources. While government and academia provide an important supporting role to the MEI, the primary players are mining companies (Majors) who support their own internal exploration efforts, consortia of mining companies that support independent exploration groups to explore (historically called Syndicates) and small exploration-focused companies that are either supported on the stock exchange or, in a limited number of cases, by private equity funding (together here termed Juniors).

In the past 20 years Majors and Juniors have done most of the exploration work. The percentage of the total exploration spend that Majors have contributed has varied over time, due to changes in corporate leadership and commodity cycles. Overall, in terms of emphasis, the Majors have shifted to spending more on brownfields (near mine) programmes, leaving the Juniors spending more on greenfields programmes.

Starting in around 2003, the amount of funds spent on exploration rose dramatically as shown in the attached graph (Figure 1) produced by MinEx Consulting (Keenan and Schodde, 2016). What distinguishes this spike, as compared with two others in the mid-80s and 90s, is the absolute funds expended on exploration and the declining percentage of funds spent on drilling. Most importantly, in the decade 2005-2015 something over US$100B was spent, but the numbers and quality of new deposits that can be attributed to this expenditure appears to have declined.

The reasons for this decline (in part mitigated by as-yet unreported discoveries shown in light blue) have been attributed to a number of factors including:

- Maturation of exploration settings
- Increase in non-discovery costs such as administration and salaries
- Increase in exploration fees and taxes
- Increase in cost of drilling and a decrease in amount of drilling as part of the total exploration spend.

While not referenced in most discussions about exploration performance, factors that should be working in favour of enabling more discoveries include:

- Better geophysical and geochemical technologies
- Better data modelling and GIS technology
- More precompetitive data sets in many jurisdictions
- Better trained and experienced geoscientists.

In the late 2000s industry and government groups in Australia and Canada were sufficiently concerned about the lack of discoveries that they began a process to upgrade exploration efforts in their respective countries. The Canadian initiative, designated 'Footprints', was arguably simpler in scope and relied on more traditional approaches to geoscience R&D. The five-year programme kicked off in 2013 and is scheduled to be completed in 2018 – only two years away. The Australian programme has the umbrella designation 'Uncover' and the first proposals for actual work are now being prepared for consideration by sponsors. An intellectually allied endeavour, which is not formally part of the Uncover initiative, is the DETCRC. This CRC has been going since 2010 and is focused on delivering major innovations to industry in the form of

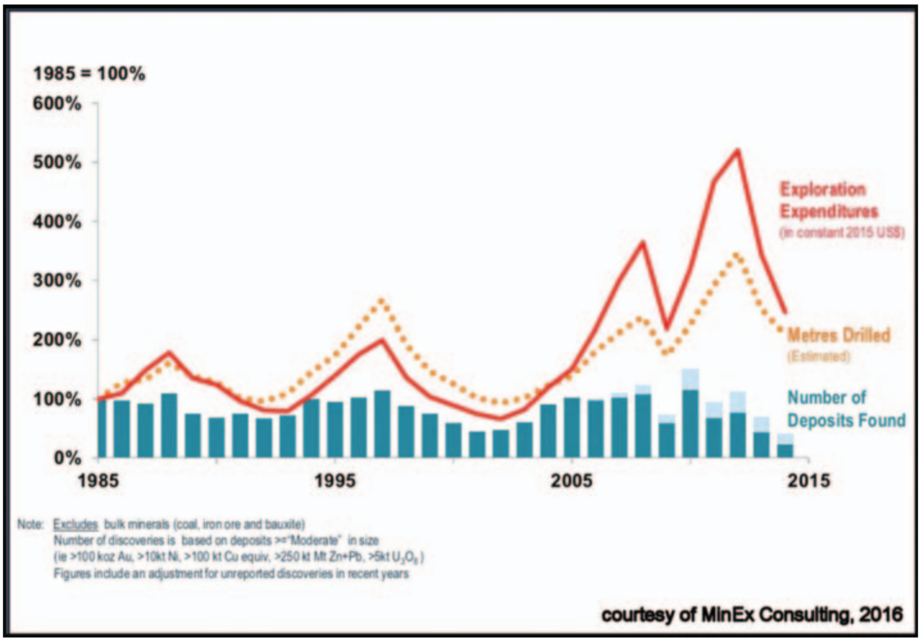

Figure 1. *Plot of global exploration expenditures, drilling and discoveries 1985–2015. Source: MinEx Consulting 2016.*

new drilling, sampling and analysis techniques. A short summary of the two national programmes is provided below.

Footprints

The primary focus of the Footprints programme is a detailed multi-parameter assessment of three deposits in Canada viz; the Canadian Malartic gold deposit in Quebec, the McArthur-Millennium unconformity uranium deposits in Saskatchewan, and the Highland Valley Cu-Mo deposit in British Columbia.

The high level objectives of the programme are to:

- Develop comprehensive and robust models of the footprints of large-scale ore-forming systems at three integrated study sites, combining geological, mineralogical, geochemical, and physical rock properties from the local to the camp scale
- Develop novel methods for integrating and interrogating multiple data sets that will enhance the exploration process and, at the same time, answer fundamental questions about the origins of large-scale ore-forming systems
- Identify the best combinations of geological, geophysical, petrophysical, mineralogical, and geochemical tools to detect the footprints of major ore-forming systems.

The industry group CMIC (Canadian Mining Innovation Council) is the overall sponsoring agency for the Footprints programme and a high-level outline of the scientific programme is shown in Figure 2 (Lesher and Hannington, 2015). A total of 24 universities were to be involved, with over 100 researchers and students engaged in various projects. The Canadian government's NSERC group (National Science and Engineering Research Council) provided $5.1M. In addition, thirty commercial sponsors (including 15 mining companies) were involved and collectively provided $7.8M in cash and in-kind.

Much of the geological, geochemical and geophysical work to be undertaken could be deemed traditional or state-of-the-art. This was almost a requirement so as to allow the programme to advance in a timely fashion. The 'newness' of the effort focused on the processing of the data sets and then bringing these results together in what are considered to be innovative ways. This stage of the programme is planned to be a joint effort between the researchers and the deposit holders.

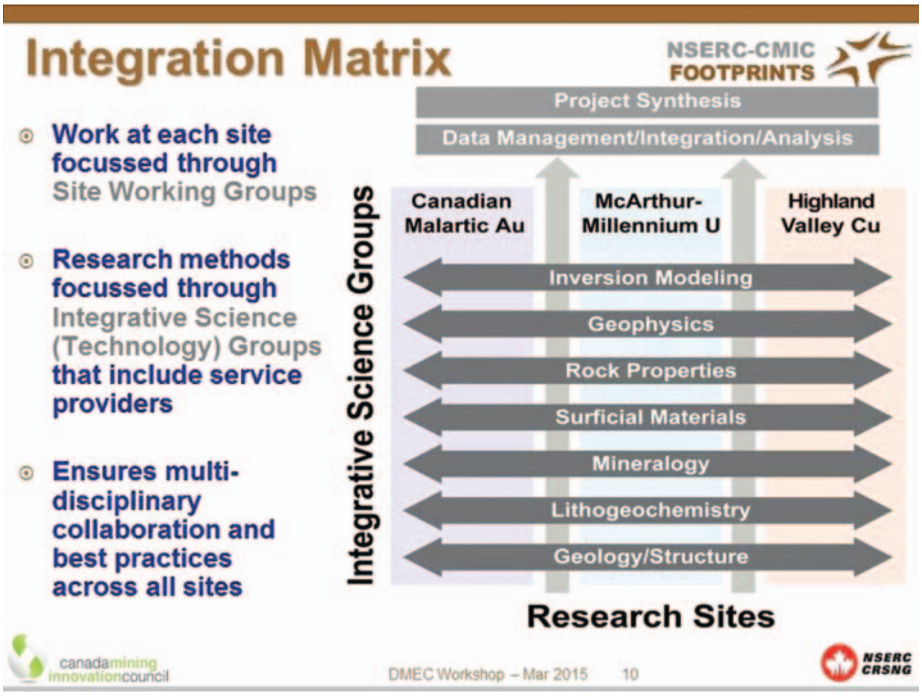

Figure 2. *CMIC Footprints science programme for study areas. Source: Lesher and Hannington, 2015.*

Uncover

The Uncover programme does not focus on specific deposits, as is the case with the Footprints programme. The programme recognises the value of the minerals system approach (Wyborn et al., 1994) and will consider how basic mineral prospectivity is defined and design search approaches best suited to the problem.

A national consensus building exercise was carried out in 2010 with the theme 'Searching the Deep Earth; The Future of Australian Resource Discovery and Utilisation' (https://www.science.org.au/news-and-events/events/future-australian-resource-discovery-and-utilisation). The final proceedings of this meeting were released in 2012. In this document the beginnings of a road map emerged, with following key topics identified:

- Characterising Australia's cover
- Investigating Australia's lithospheric architecture
- Resolving the 4D geodynamic and metallogenic evolution of Australia
- Characterising and detecting the distal footprints of ore deposits.

After a series of additional planning meetings AMIRA released the 'Roadmap for Exploration Undercover' in mid-2015. This roadmap identified a series of priority topics, the most important of which are listed below:

- Type, age and depth of cover; compilation and production of 3D geological and palaeosurface maps and layers
- Depth-to-basement and cover-characteristics; imaging from new targeted airborne National (20 km) EM surveys
- Compilation and integration of models and data to build 3D architecture and composition of the Australian lithosphere (mantle-crust-surface) from current data and knowledge
- Acceleration and completion of the national AusLamp long period MT (55 km spaced) programme
- Better understanding and definitions of mineral systems across scales for different model/deposit types and commodities
- Characterisation and mapping of whole mineral system footprints, proximal to distal, through compilation of geological, geochemical and geophysical data.

AMIRA is about to release a follow-up proposal, which will define specific projects for support by industry. Earlier this month, the Australian Commonwealth Government announced the start of a new initiative called 'Exploring for the Future', which will be allocated $100 million over the next four years to be managed by Geoscience Australia. This initiative will hopefully give further momentum to the Uncover programme and allow it to continue to grow.

Commentary

While the Footprints and Uncover programmes both use 'national good' rhetoric, this rhetoric is used to muster favour with the local politicians as, in reality, useful knowledge about any topic passes around the world in a blindingly fast manner. In addition, almost all major explorers tread on a global stage and expect to employ 'best practice' wherever they work, regardless of the point of origin of such practice.

The Footprints programme is providing major support to the academic geoscience community in Canada and it is expected that the Uncover programme will do the same in Australia. This in itself is an outcome of value for the world of applied geoscience, especially as the industrial sector has been battling with large debts, low commodity prices and angry investors for the past three years.

While both programmes have/will generate a great deal of science and formal academic assessments of large amounts of geoscience data, I am not confident that the larger problem of improving exploration performance will be addressed by either. If the task of exploration were purely science driven then one would expect the prodigious amount of new data and ideas generated over the last decade to have made an impact on exploration performance. However, as has been observed on many occasions, exploration could be better described as an art. If this is the case then the scientific effort to improve the quality of data and data acquisition techniques (paint, brushes and canvas) will not make a substantial difference to final outcome (the quality of the painting).

On the geophysical front discussions about exploration performance are generally focused on improving technology and, sometimes, on reducing the cost of data acquisition (e.g. the current discussion around drone systems). Discussions about the process of exploration that engage the geological community at large currently seem to be suggesting that to be successful in the future the practice of the past must be emulated (e.g. Sillitoe, 1995; Meussig, 2014). This 'back to the future' approach would seem unlikely to yield, by itself, the sort of improvement in the exploration process the industry requires. But, if this advice is a call to remember the 'art of exploration' and to examine how this art was successfully practiced, then such invocations could be of real value. In this regard the interested reader is directed to a piece by John Masters, a petroleum geologist (Masters, 1991). As the conductor of an orchestra that included many geoscientific 'instruments' Masters was able to bring art and science together to create a discovery culture that was incredibly successful.

At the 1997 ASEG conference a workshop was held to mark the close of the CRC AMET. As part of this event a panel was set up to examine the question of future trends and directions for mining geophysics. Prof Gordon West was given the lead talk, with which he 'boldly' jumped 25 years into the future. He started, however, by stating how he felt geologists and geophysicists should interact in order to effectively deal with the challenges of minerals exploration.

> *But there is one vital field for mining geophysics that may easily get lost in the rush for higher tech geophysical systems. It is understanding the relationship between the geological characteristics of earth materials and the physical properties that can be remotely sensed. This can only be improved by organized, systematic feed-back from geologists who can measure the geological effectiveness (or ineffectiveness) of geophysical products to geophysicists who design the geophysical methods and surveys and (hopefully) understand the physics involved.* (West, 1997)

The current efforts to advance the science of geophysics and allied fields via major R&D programmes in Canada and Australia show that industry, government, and academia care seriously about mining and that they believe that success in exploration is a key component for the long term health of the industry. Success in exploration, however, has never been simply about the quality of the technology being used, the amount of data being acquired, or the models produced, but how these components can be blended in creative ways. In this regard the past carries important lessons for the future.

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Seismic window

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Boom and bust, doom and gloom

While rummaging in my garage recently I unearthed a folder of old invoices that led to me ponder the boom and bust cycle of the industry. This is something that I have come to live with over the years as the industry responds to fluctuations in commodity prices, but are mass layoffs an overreaction?

Many of my colleagues are currently taking a break from oil and gas exploration. Some have retired early or are working in honorary positions while others are wondering how they are going to feed the kids and pay the rent. This situation has been brought about as companies shed staff because of the collapse in oil prices from over $100 to less than $30 (Figure 1). It is not a new thing – it is the fourth time in my career that the industry has contracted and jobs have been hard to find (Figure 2).

Figure 1 shows the oil price in both actual and 2012 dollars since I graduated. As you can see the current price is not far off the long term trend in price (in 2012 $ terms) whereas the extreme high values from 1978–84 and 2006–14 are the anomalies. The relatively low but stable prices of the 1980s–90s have been the norm. In these normal times the industry did quite well and made significant technology improvements. These times were good for everyone but eventually staff numbers increased to levels that became unsustainable when prices dropped.

Another interesting observation is the dotted line titled 'rate' (you will notice I have not put any values on the vertical axis to avoid potential issues regarding price fixing). This line shows the change in the remuneration I have received over the same period and is based on the contents of the dusty folder I found in my garage. It seems remuneration has been only weakly dependent on the oil price. Why? One reason for this lack of dependence may be that I have tried to keep up with change and gain more experience, which has been valued even in tough times.

Figure 2 shows a curve of day rate divided by price per barrel and shows how staff costs have varied over time, with each jump in the curve resulting in periods of reduced employment and opportunity. One heartening aspect is that the good times have returned, and lasted longer each time, so the next boom should probably see me through to retirement. Importantly, it may take another twenty years, but the really good times will return. In the meantime enjoy the average times – they are pretty good as well. We all manage our careers in our own ways but for me I put my almost continuous employment down to staying up to date with technology and shmoozing… and being prepared to move.

Things may be looking up! As I submit this article oil prices have improved to over $50 per barrel and Saudi Arabia is talking about diversifying its economy away from oil. Time will tell I guess.

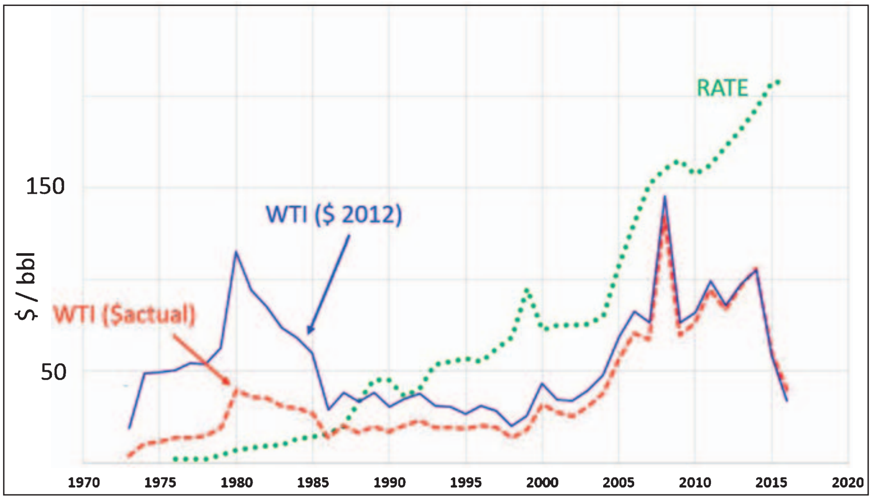


Figure 1. *Oil price since 1979 in real terms and 2012 dollars plotted along with estimated consulting rate since my graduation in 1975.*

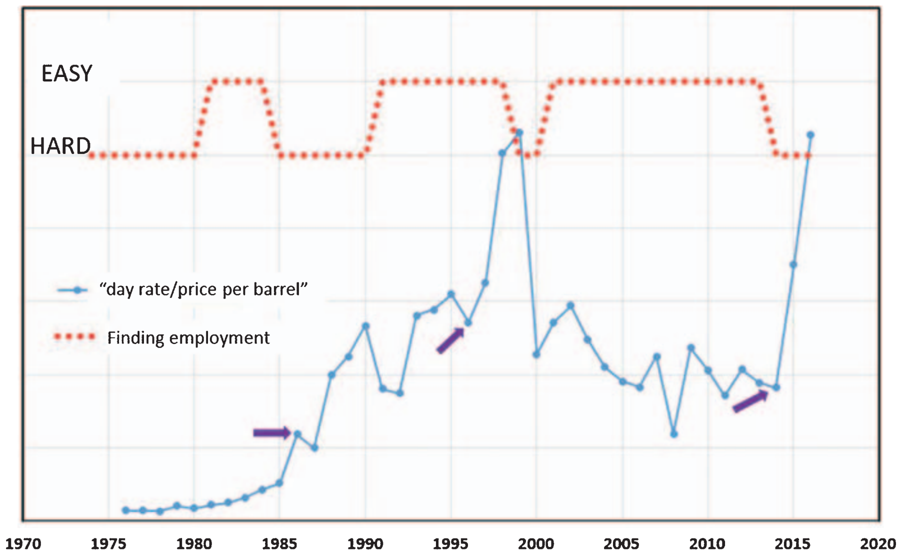
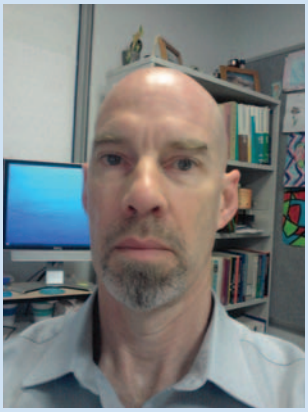


Figure 2. *Are we too expensive – day rate/price of oil (blue) since 1975. Each large increase in the rate relative to the price per barrel results in reduced employment opportunity (red curve).*

Webwaves



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A new website for the ASEG

The quote 'The only thing that is constant is change' has been attributed to Heraclitus. Examples of its veracity are seen in many aspects of life. In exploration geophysics, Fountain (1998) has documented what is now nearly 70 years of evolution of airborne electromagnetic prospecting systems from McPhar's Avro Anson-based frequency-domain system in 1948, to modern systems exemplified by Tempest and SkyTEM systems. Green (1998) drew an analogy between the evolution of AEM systems and the development of Precambrian life fossilised in the Burgess Shale.

The worldwide web was made available to the public in the mid-1990s, and has gone through a similarly rapid evolution. The wayback machine (http://archive.org/web/) can be used to see changes on the ASEG's website over the years. From the earliest example in 1999, major changes in layout and content have been seen in 2000, 2006, 2013 and 2014. It is easy to see, especially in comparison to websites of similar societies, that the ASEG has attempted to stay current and relevant.

And so it is that the time has come to update the website again. Its current incarnation is the result of efforts of previous webmasters, and, for the most part, it works well. The Web Committee think that it can be made to work better than it does at the moment, and have started the process of redesign. Part of this is structural, relating to pages and how they are served to users, but a significant component is visual. The Web Committee could use stock images for the redesigned site. However, since the direction of the Society is very much determined by its Members, we thought that it would be more interesting to ask ASEG Members for their input: photographs taken during fieldwork, insightful data presentations or the like. If you or your employer has copyright on the image, and can give the ASEG permission to use the image as a backdrop on the web page, we would welcome any submission. More formally:

Entries for the inaugural ASEG photo competition are now open!

Have you been anywhere spectacular in your fieldwork?

Have you produced a particularly colourful, insightful plot during data analysis?

The ASEG are seeking photographs taken during fieldwork and images of data to use on the website. Entries must be submitted before the Adelaide conference (21–24 August 2016), and 1st, 2nd and 3rd prizes will be chosen by votes from conference attendees. Entrants are required to be current Members of the ASEG, and entries must be suitable for public display.

If you qualify, and have a suitable image, please send it to webmaster@aseg.org.au together with a small caption describing the submission. All suitable entries will be used as stock photography appearing on the ASEG website. Images will be displayed with: "Image \copyright <author> and used with permission"

References

Fountain, D., 1998, Airborne electromagnetic systems – 50 years of development: *Exploration Geophysics*, 29, 1–11.

Green, A., Morrison, F., and Smith, B., 1998, Summaries, discussion and future trends: *Exploration Geophysics*, 29, 263–271.

Data trends

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The capacity of speed

Unbelievable … the amount of data that we can store on a single piece of recording media (disk, tape, thumb drive, etc.) just seems to keep getting larger. Will it ever end?

For many years, data recording technology in the oil and gas sector has been dominated by IBM. Starting with the development of the 9 track tape in the 1960s, followed by the closed cartridge technology called 3480 in 1984, IBM has been the leader in the seismic recording industry for as long as I have been alive.

The 3480 was the first of a long line of closed cartridge recording media that still has direct descendants in the market place today. Not too many companies can claim to have invented a device in 1984 and can still show that a current modern version of what is essentially the same thing is still being developed and used commercially over 30 years later. The first telephone looks nothing like my current one, the phonograph looks nothing like my Spotify account, etc. But with this media type (unless you know a lot about it), you would be hard pressed to tell the difference between the one created in 1984 and the one being used today in 2016 (from a visual point of view anyway).

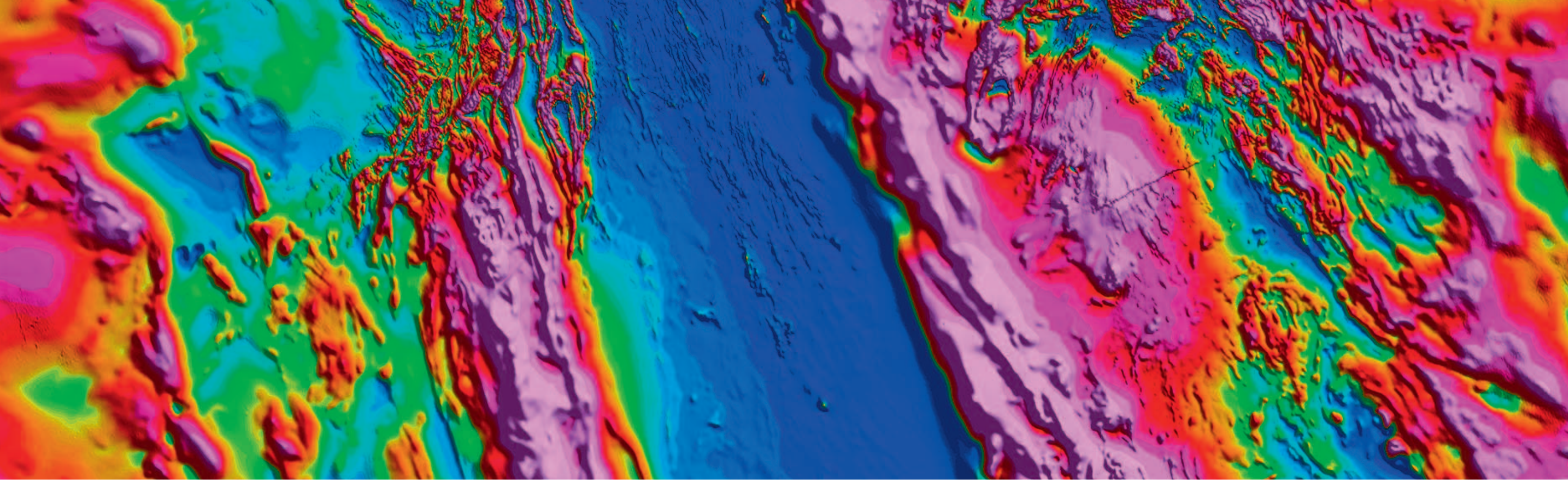
What has changed, however, is the storage capacity of the media as it has moved from one generation to the next. In fact, this IBM technology has had about 10 generational releases and has increased in capacity some 5000 times since it was invented while, amazingly, it has not really changed in size. The 3480 in 1984 could store 200 MB; however, its latest descendant, the 3592E08, can now hold 1 250 000 MB (10 TB). This increase in capacity was achieved by increasing the number of tracks written to the tape, while at the same time increasing the density of the bytes being packed into each of these new these tracks.

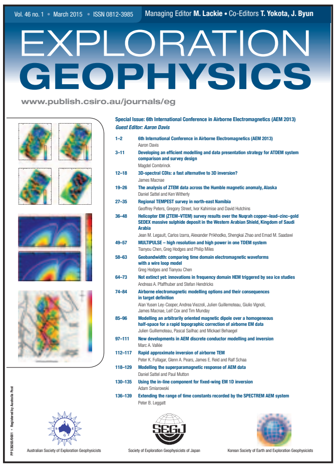
Whilst this capacity change is quite incredible, there is one significant feature of the media that is not so incredible, and almost all recording technologies suffer from the same shortcoming. That shortcoming is the speed at which you can read the data from the tape. Between the 3480 and the 3592E08, speed has only increased from 3 MB/s to 300 MB/s (a 100 times increase), while at the same time capacity has increased 5000 times. Maybe I should be grateful with the capacity increase and ignore the performance issues? No – not me! I like to complain too much to let this one slip by.

So, as an analogy, we are saying that 130 years ago the first car was invented that had a petrol tank that held about 7 litres of petrol and could drive at 16 km/h. And, through evolution, we have essentially created a car with a petrol tank that holds 35 000 litres of petrol but can only go at 160 km/h. Picture a Honda Civic with a petrol tank the size of a semi-trailer tanker. You won't go very fast, but the upside is that you will be able to drive around the world about 75 times before you need a refill! I mean, what is the point?

3480 tapes could be read in less than 3 minutes, but it takes more than 20 hours to read the 3592E08. If I wanted to look at some data in 1980 I only had to wait for 3 or 4 minutes. Now I have to wait hours. Are we really better off just because the tapes hold more?

This photo shows one type of hand-held differential spectrometers from the ASEG historic equipment collection. Unlike scintillometers, which measure total radiation above a particular energy level in the gamma radiation spectrum, differential spectrometers measure the energy within bands, or windows. In geophysical applications windows are chosen that signify the three standard elements traditionally measured in airborne radiation surveys, namely uranium, potassium, thorium and also the total count. All spectrometers consist of electronic analysers and detectors. The detectors for geophysical use are usually crystals that react to gamma rays impinging on them by scintillating. These scintillations are measured by photo-multiplier tubes. The crystal detectors vary in size from just a cubic centimetre or two for hand held units such as one illustrated, increasing to many tens of litres used in aircraft where the distance from the source is greater.





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InSAR: an introduction

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Synthetic aperture radar (SAR) is a mature technology that has given birth to Interferometry SAR (InSAR). Comparing phase differences between two or more SAR images separated either by time or space makes it is possible to look at the world in three-dimensions. InSAR has many practical and academic applications ranging from measuring surface deformation to monitoring geomorphic processes. Using InSAR, for example, scientists have been able to precisely measure the after-effects of earthquakes, and to map glacial flow and ocean currents. In the industrial sector InSAR has been already been applied to the monitoring of mine sites and landslides – and has potential value in any area wherever natural displacement hazards exist.

InSAR data can be processed using commercial or open-source programs. GMTSAR, ROI PAC, and NEST-Snap are among the more powerful open-source packages that are readily available to the public. In most circles InSAR is still considered a new technology but it shows considerable promise as a powerful tool for mapping and monitoring earth surface processes; servicing both academic and industry interests.

History of development

In all sciences, there is an elegant dance between engineering and discovery. SAR (Synthetic Aperture Radar) was invented for a purpose. In the 1940s it was a military reconnaissance tool. In the 1950s it answered the need for an all-weather, 24-hour aerial remote surveillance device (Engineering and Technology History, 2015). Radar had been a popular method for obtaining aerial images of the ground because it was not weather or time dependent; relying on the electromagnetic radiation wavelength of microwave and radio proportions. However, because of physical limitations, radar antennas needed to be the size of a football field to obtain a suitable resolution for practical purposes. This caused a problem for many organisations needing high quality imagery. SAR methods use normal aperture radars across spatial distance to emulate a large radar antenna. Carl Wiley of Goodyear Aircraft Company (known later as Lockheed Martin) achieved fame as the father and inventor of SAR methods (Lasswell, 2005). Over the decades since it was first invented SAR has become the most used technique for obtaining radar imagery, servicing countless organisations stretching over many diverse sectors.

SAR gave birth to InSAR (Interferometry SAR). InSAR uses repeat-pass techniques to obtain two SAR images of a region over different times. An interferometry diagram is created to compare the phase differences (UNSW, 2004). The InSAR concept was developed not long after the invention of SAR. However, the computer power required to process InSAR data was not readily available back in the 1950-60s. InSAR data processing did not become practical until the early 1990s (GSI, 2004).

SEASAT, the first satellite platform with a SAR sensor on board, was launched in 1978 (Ferretti, 2013). RADARSAT-1, a well-known and popular satellite, was launched in 1995 (Canadian Space Agency, 2014) and operated at 5.3GHz, in the C-band wavelength (Canadian Space Agency, 2015). Over the next few years, more satellites equipped with the instruments for InSAR methods were launched and the data became more readily available. The combination of data availability and computer power allowed InSAR methods to develop.

Theory

An understanding of SAR is a necessary precursor to an understanding of InSAR. In conventional methods the purpose of SAR imagery is to measure the distance to a target of interest (Hensley and Rosen, 2001). The drawback to traditional SAR is that it views a three-dimensional world in planimetric view as shown in Figure 1. The main platforms used for SAR imagery are mounted on satellites and space shuttles and, because of their orbital paths around the Earth, the information recorded in a SAR image is plotted on a two-dimensional graph with the range, cross-track, as one axis and the azimuth, along-track, as

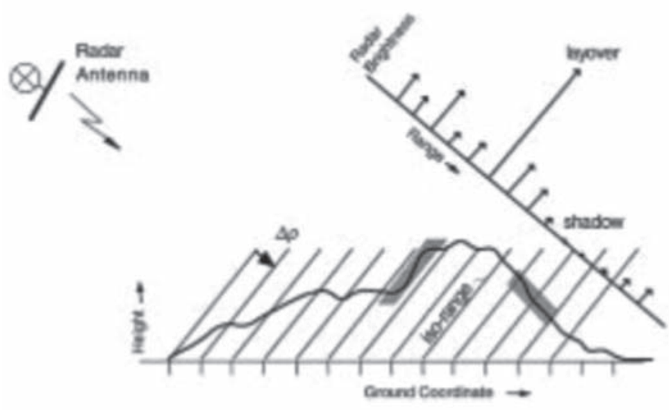

Figure 1. *Conventional SAR image forces a 3-D terrain to collapse into a 2-D profile. The brightness recorded indicates the amplitude of the return signal. The profile above is spatially distributed according to the distance to the radar defined by: $\Delta\rho = c/2\Delta f\_BW$ – where c is the speed of light and Δf_BW is the range bandwidth of the radar. Figure from Hensley and Rosen, 2001.*

the other. As SAR operates mostly in a two-dimensional environment, plane and amplitude variations limit interpretation. InSAR adds a third dimension (either time or space). Currently InSAR is mostly applied to (1) topographic mapping and (2) surface deformation monitoring (Hensley and Rosen, 2001). This review will focus on the latter application, which has the potential to be particularly advantageous in industry sectors.

InSAR works around the concept of using phase delay information for each radar pulse pixel. When an EM (Electromagnetic) wave transmits from a radar, the corresponding backscatter return signal always has an associated phase delay given by the signal as a function of time:

$$S_r(t) = Acos[2\pi f_o(t-\tau)] \ (1.1)$$

Where $\tau = 2x/c$; the time it takes for the signal to travel to target and back; pulse delay; c is the speed of an electromagnetic wave in the appropriate medium. EM waves, being thought of transitional waves, display a sinusoidal form, and using $\lambda = \frac{c}{f_o}$ we can rearrange equation 1.1:

$$S(t) = Acos[2\pi f_o t - \phi] \ (1.2)$$

Where $\phi = -\frac{4\pi}{\lambda}x$; known as the phase delay. This is the fundamental concept that gives InSAR its power. The phase delay may include a noise contribution, but for simplicity it is usually ignored (Ulaby and Long, 2014). InSAR methods are based on combining radar return signals from two different SAR images separated in space (topography) or time (surface deformation). When monitoring surface deformation the phase delay is compared between two SAR images at different times.

Modulo-2π

The concept of Modulo-2π is important to grasp, because it allows us to understand something, but not everything, about what is going on (Ferretti, 2013). Because of EM wave properties, the sensor-to-target is better expressed as a number of wavelengths, plus a segment equal to a fraction of λ. To better clarify this thought, suppose a radar antenna is operating in the X-band with a wavelength of about 3 cm. The point of interest is 30 m away. In this case, the sensor-target distance is exactly 1000 wavelengths, $1000\lambda = \frac{30m}{0.03m}$. Considering a two-way path for the signal, the total distance would be equal to 2000 wavelengths. Now consider moving the same target 0.50 cm towards the radar, corresponding to surface inflation, the signal would not have to travel as far. In fact, it would take only 999 wavelengths plus 0.83λ, corresponding to a total 1999 full wavelengths plus 0.66λ for two-way travel. We needed one-third less of a wavelength to complete the sensor-target distance the second time around. As a consequence, in this example, the return signal for the second run would correspond to a phase value of $\phi = -\frac{\pi}{3}$.

Although this method is very effective at measuring deformation, if inflation or deflation equals half of a wavelength this wouldn't correspond to any phase shift. This is because moving the point 1.5 cm away/toward the distance travelled by the radar pulse would equal $2 \times 30.015 = 60m + 3cm$, and this would correspond to a full complete wavelength (Ferretti, 2013). Also known as the *effective wavelength* - $\lambda/_2$, any shift that coincides with multiples of the effective wavelength will not result in a phase change. Without prior information all that would be known is that a phase shift has occurred of $\phi = \pi$, but it would not be certain whether the shift is towards or away from the sensor. A good analogy would be waking in a dark room with a clock on the wall. The clock indicates that is 12 o' clock, but without prior knowledge and other information it wouldn't be clear whether it is midday or midnight.

Surface deformation

Studies of surface deformation using InSAR are more complex than studies of topography. Surface deformation studies also include motion, such as the movements of glaciers, ocean currents, and sand dunes. These studies can be an important investment in certain industries where valuable property could be affected by geomorphic processes. Surface deformation is calculated using along-track interferometry. This is because by altering the imaging geometry to an along-track path InSAR measures surface motion rather than topography (Ulaby and Long, 2014). To create time separated InSAR images an equation must to be derived to account for the complexity of satellite systems. Originally, before satellites became a major source of InSAR data, aeroplanes were used. Two SAR sensors would be mounted on the side of an aeroplane, one at the nose and the other at the tail as shown in Figure 2. This allowed two SAR images to be taken in the same spatial area, but at different times. If no cross-track displacement has occurred any return response due to topographic signal would, in theory, be null. A response, therefore, must be due to surface deformation/motion.

Figure 3 shows an example situation whereby an object of interest recedes from the aeroplane mounted with SAR sensors. At t_1, A_1 captures a SAR image with a distance to target of R_1. After a time, $t = B/_u$, sensor A_2 is in the same position as the former sensor with a distance shown by:

$$R_2 = R_1 \pm \frac{B}{u} v_r \ sin\theta \ (1.3)$$

Where v_r is the radial velocity that corresponds to the velocity that the object of interest recedes or advances relative to the sensor position; θ coincides with the incidence angle. Putting this into terms of interferometric phase this conforms too:

$$\Delta\phi = \phi_1 - \phi_2 = -\frac{4\pi}{\lambda}(R_1 - R_2) \ (1.4)$$

$$\Delta\phi = \pm\frac{4\pi}{\lambda u} B v_r sin\theta \ (1.5)$$

By studying this equation, the interferometric phase is directly proportional to the radial velocity (Ulaby and Long, 2014). Equation 1.5 can be rearranged to solve for radial velocity:

$$\pm v_r = \frac{\lambda u}{4\pi B \ sin\theta} \phi_{int} \ (1.6)$$

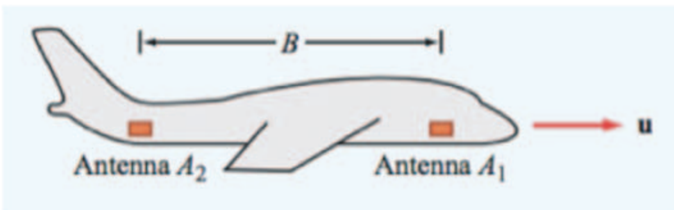

Figure 2. *Time separated SAR setup on an aeroplane. With a linear velocity of u and coupled with a baseline of B. A SAR image would be taken from A_1 after a time t=B/u has passed another SAR image would be taken at A_2. This would allow two different SAR images taken in same spatial area at different times. If topographic responses are assumed to be null (no cross-track displacement has occurred), any responses must be due to surface deformation/motion. Assuming backscatter amplitudes at both times are the same, ϕ_s1=ϕ_s2. Figure from Ulaby and Long, 2014.*

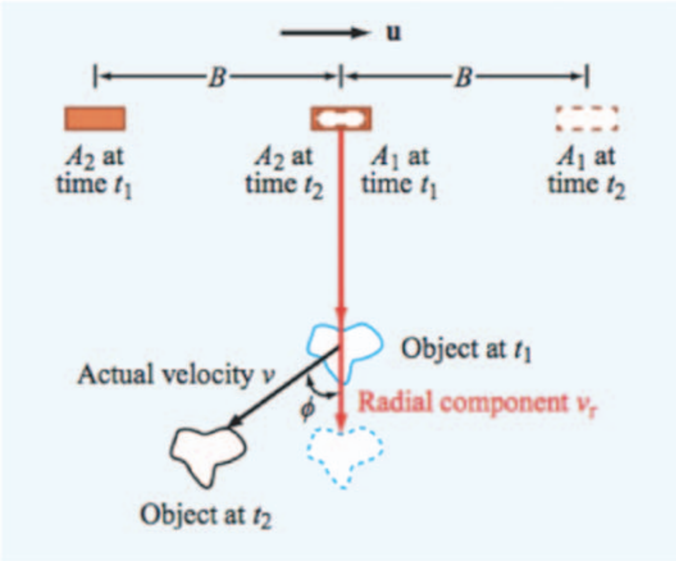

Figure 3. *Shows an object receding from the satellite during t_1 and t_2 taken by A_1 and A_2 respectively. The useful information is the radial velocity, v_r that will provide how fast the object is moving relative to the satellite. Figure from Ulaby and Long, 2014.*

The above equation (1.6) is a great method of measuring the velocity of an object that tends to be constantly moving, such as ocean currents (Ulaby and Long, 2014).

Surface deformation studies tend to use the exactly same concepts and techniques to measure phase differences. The only modification would be, conventionally, that satellites are used instead of aeroplanes, and the time difference between two non-spatial SAR images could be days or weeks contrasted to the milliseconds on a fixed aeroplane. This allows for the study and measurement of surface deformation that takes place over a considerable period of time. Such examples could include: glacial travel, volcanic deflation, and tectonic plate movement (Figure 4).

However, studies can also be conducted on areas that experienced sudden deformation, such as in earthquakes, tsunamis, and landslides. Using ERS-1 SAR images over

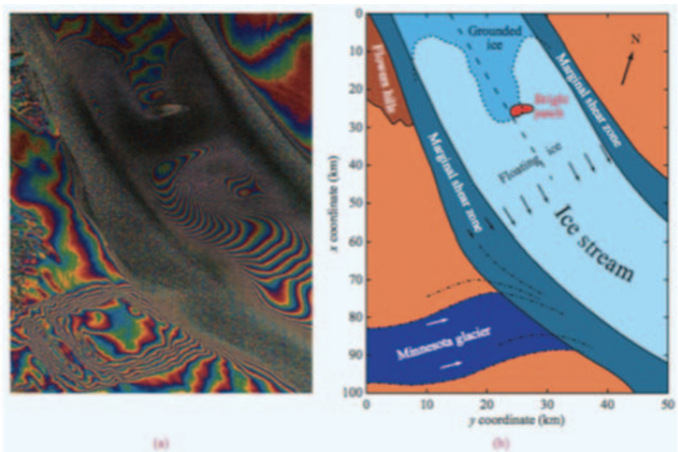

Figure 4. *InSAR diagram of the Rutford ice stream in Antarctica. The map on the left is essentially the fringe pattern that represents the surface deformation due to flowing ice. The closer the fringes are to each other the more deformation has occurred. To produce this diagram, the images were taken 6 days apart with the ERS-1 Satellite. Figure from Ulaby and Long, 2014.*

Antartica, Goldstein et al. (1988) demonstrated that the flow velocity of an ice stream could be measured with a precision of about $3 \times 10^{-8} \frac{m}{s}$ (Goldstein, 1993). As demonstrated in Eq. (1.6), the ratio $B/_u$ represents the time delay Δt between the two SAR images. Plugging these numbers into the equation gives us:

$$\pm v_r = \frac{\lambda}{4\pi \, sin\theta \, \Delta t} \phi_{int} \; (1.7)$$

If two observations are 15 days apart and within the X-band range; $\theta = 45^{\circ}$ $\phi_{int} = 0.05$ radians; accuracy of satellite. Eq. (1.7) leads to:

$$v_r = \frac{0.03}{4\pi \cdot 15 \, days} \cdot 0.05$$

$$v_r = \frac{0.03}{4\pi \cdot 0.707 \cdot 15 \, days} \cdot 0.05$$

$$v_r = 1.1 \times 10^{-5} \frac{m}{day} = 0.41 \frac{cm}{year}$$

The measurement is comparable to the velocity of tectonic motion. This data shows that InSAR has the ability to measure surface deformation even for processes that are extremely slow. This same idea can be applied to tectonic episodes; the majority of tectonic movement isn't as fluid as that of glacial flow, but occurs in sudden incidents we can use Eq. (1.7) to be able to measure directly the topographic change in elevation. Consider an earthquake that strikes without notice. As shown in Figure 5, using the two different phase delay information, it is possible to straightforwardly quantify the difference in elevation due to the earthquake. Breaking apart Eq. (1.4):

$$\phi(t_1) = -\frac{4\pi}{\lambda} R_1 + \phi_{s1} \; (1.8)$$

$$\phi(t_2) = -\frac{4\pi}{\lambda} (R_1 - \Delta R) + \phi_{s2} \; (1.9)$$

Eq. (1.8) and (1.9) corresponds to image 1 and 2 from Figure 5 respectively. Assuming the backscatter of both SAR images are equivalent $\phi_{s1} = \phi_{s2}$, it can be shown that directly measuring the interferometry phase can result in a direct quantity that parallels the topographic elevation change. From Eq. (1.4), (1.8), and (1.9) it is revealed that the measurement can be comprised by two factors (1) changes in the surface scatters causing $\phi_{s1} \neq \phi_{s2}$, and (2) deviation in the satellite orbit between the two observations permitting topographic responses to be leaked into the data (Ulaby and Long, 2014). A technique known as stacking is most commonly used on satellite interferometry to remove data that could potentially pose a threat to quality data. This idea is simple enough that instead of a two-pass track, the SAR detector forces an n^{th} –pass to obtain more SAR images that are essentially 'stacked' upon one another. This method is useful in the sense that is reduces statistical errors, but it only yields a single average deformation measurement (Ulaby and Long, 2014). It is almost impossible to be able to retrieve time history measurements from a multi stacked (added) interferometry diagram; this is also known as time-series InSAR applications.

Unwrapping phase

The methods used to recover phase delays in each individual pixel are important, because they allow for the extraction of phase difference. The biggest problem that faces scientists, who

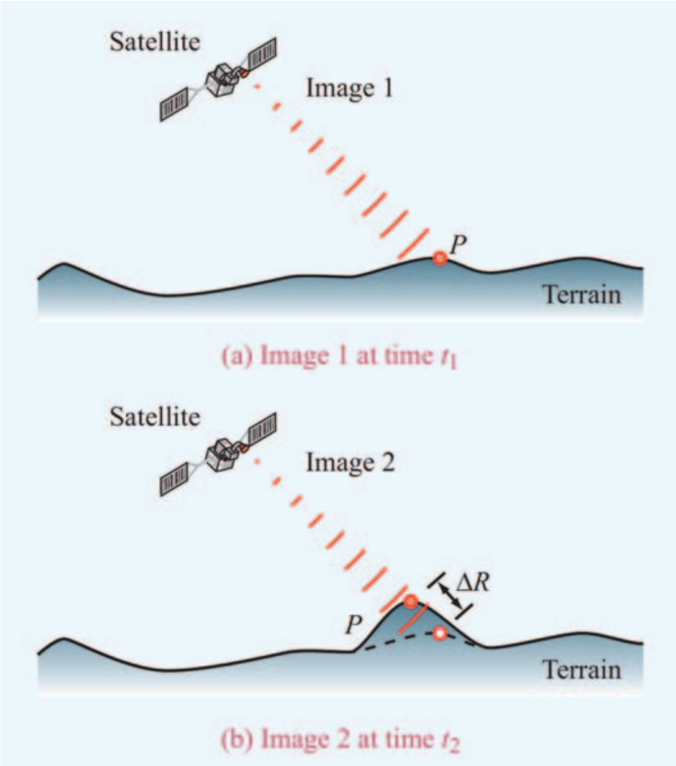

Figure 5. *Image 1 shows the first SAR image of a satellite with its own unique phase delay + phase backscatter. Image 2 is taken after a sudden tectonic event happens that brings the ground closer to the SAR detector. This results in a unique phase delay, assuming, for simplicity, that both backscatter responses are identical. Figure from Ulaby and Long, 2014.*

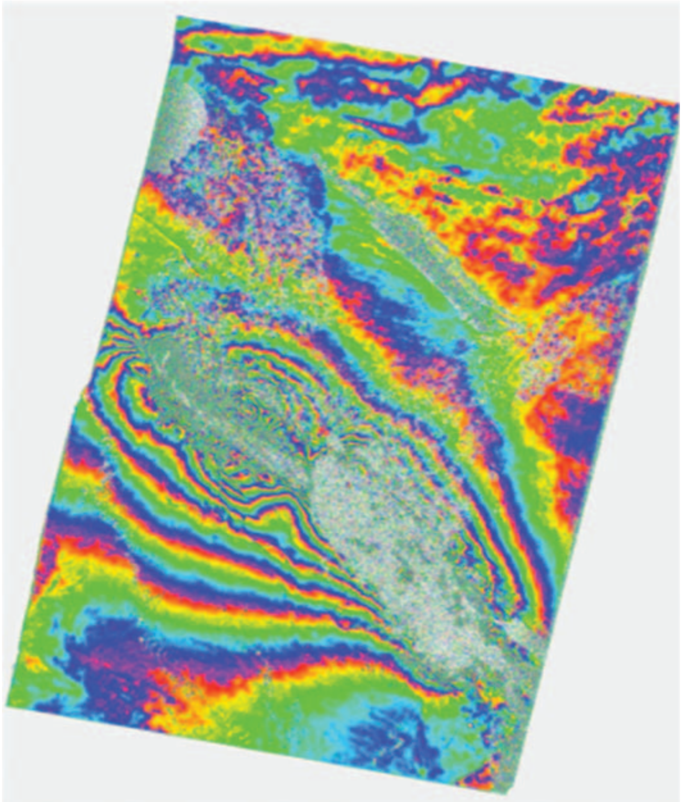

Figure 6. *An InSAR image of Baja California processed using GMTSAR. The image shows a close fringe pattern towards its centre, which indicates the extent of surface deformation resulting from the earthquake. Figure from GMTSAR, 2010.*

are interested in a particular value that corresponds to an elevation change, comes back to the previous topic of Modulo-2π. The data is very limited if the information just displays a phase difference. This is because the information shows an interferometric phase has taken place, but not how many integer wavelengths it took to obtain said phase. Therefore, it is almost impossible to obtain any practical elevation difference unless a process known as unwrapping is used, which has both great advantages and disadvantages.

Interferometry records data in complex format – Euler's Identity,

$$e^{j\theta} = cos\theta + jsin\theta \ (1.10)$$

It cycles between π and π; due to the nature of electromagnetic waves. The signal that is true, and resembles the true amount of wavelengths to target, is hidden or wrapped to the values that are the remainder after dividing the full value by 2π. Phase unwrapping is the process of reversing and attempting to reconstruct the true, unwrapped signal from the wrapped interferogram (Nee, 2012). To obtain such results many techniques and algorithms have been invented over the years, and attempts are constantly being made to make the process more precise and accurate. That development process is, however, beyond the scope of this review. Snaphu is the most popular unwrapping algorithm that has been incorporated in much of the free-source InSAR processing packages such as GMTSAR and ROI PAC (Chen and Zebker, 2003).

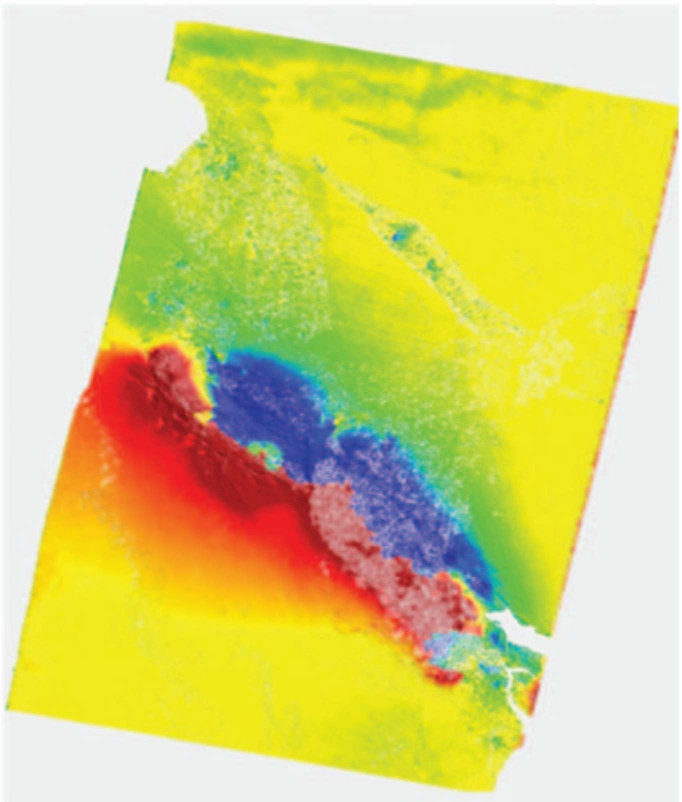

Figure 7. *An unwrapped image over Baja California, which is much easier to interpret than the complex interferogram shown in Figure 6. The red colour indicates the area has moved closer to the SAR sensor. In contrast, the blue colour indicates areas that have moved farther away. Figure from GMTSAR, 2010.*

Academic applications

InSAR has been in the academic world since its inception, and many papers have been written about its applications. The most

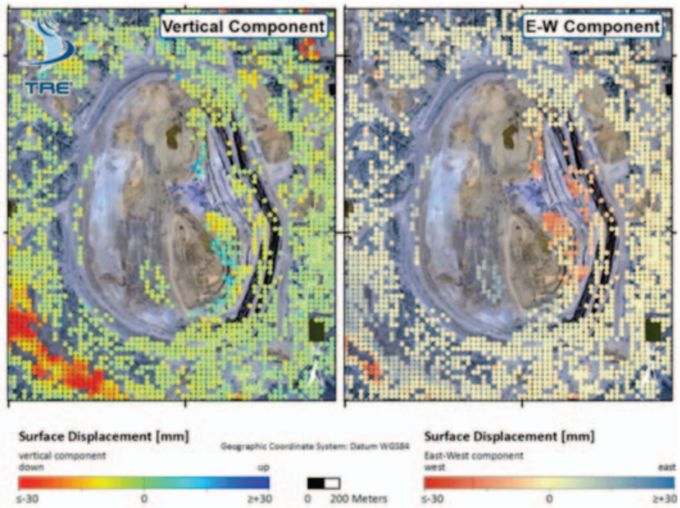

Figure 8. *Images showing an open-pit diamond mine in South Africa. The image on the left shows points that correlate to vertical displacement on the pit-slopes. As can be seen, the area on the bottom left of the image is highly active in terms of vertical displacement. The image on the right shows the same open-pit mine, but with points correlating to shear displacement. This data demonstrates the practical significance of InSAR. Figure from Colombo and MacDonald, 2015.*

notable scientists to use InSAR are: Zebker, Chen, Hensley, Rosen, and Ferretti. An important case study, conducted by Rosen in 1994, demonstrated the measurement of surface deformation due to volcanic inflation in Hawaii. The results were compared to GPS data to verify that InSAR has similar accuracy potential. Many disciplines of InSAR exist, but the end goal of any discipline is to compare two or more SAR image phase delays. The only prominent difference lies in the different techniques used to account for the various factors that can affect what the target of interest would be. In the Hawaiian case, a process known as Differential Interferometry (DinSAR) was used to measure the centimetre scale deformation of an active caldera over a period of six months (Rosen et al., 1996). Differential InSAR is the most common process whereby a SAR image, known as a master, is taken at a certain time interval. After a period of time has passed, another SAR image, a slave, is taken of the same area. In theory, it is easy to calculate the interferometry between two SAR images, assuming that no spatial distance has taken place. However, in the real world, a satellite does not exactly retrace its steps perfectly, and because of this even the slightest shift from the original position can cause the data to be ruined by the addition of topographic phase response. This problem can be resolved by introducing a DEM (Digital Elevation Model) of the area. The DEM allows any response due to topography to be 'zeroed' out, but it is only as accurate to the level of resolution provided by the DEM.

The study of volcanic inflation/deflation is common, as is the study of sudden surface deformation such as that created by earthquakes. Using InSAR a group of scientists followed a swarm of earthquakes that occurred in western United States of America in the Columbian River Flood Basalts (Wicks et al., 2011). Figure 6 shows an interferometry image of an area over Baja California taken by ENVISAT. The image shows a close fringe pattern towards its centre, which indicates the extent of surface deformation resulting from the earthquake. It can be tough when interpreting the data to know how the elevation has changed and by how much, and this is where unwrapping becomes useful. Figure 7 shows the same image, but this time it has been unwrapped using Snaphu, allowing for easier interpretation. Unwrapping is only as accurate as algorithms that govern it, but is accurate enough for most practical purposes.

Industry applications

InSAR has yet to make a real impact in industry. One of the world's leading researchers and engineers, and the EAGE Visiting Lecturer in Australia in 2015, Alessandro Ferretti, has repeatedly demonstrated just how useful InSAR could be from a business standpoint. According to Ferretti, InSAR data can be used for fault characterization and calibration of geo-mechanical models in the oil and gas sector, for monitoring landslides, volcanoes, faults, and areas prone to sinkholes and subsidence, for understanding terrain compaction phenomena induced by tunnelling works, and even for monitoring the stability of individual buildings (Ferretti et al., 2015).

In Australia the mining industry could use InSAR to monitor the stability of mine sites. In the past it was almost impossible to remotely monitor mine sites due to the long revisiting time frame of available satellites. However, that is not a problem with modern satellites[1] (Colombo and MacDonald, 2015). Colombo and MacDonald studied an open-pit diamond mine in South Africa. The stability of the pit walls was of particular concern as it was feared a landslide would damage valuable assets. As shown in Figure 8, points on the open-pit showed vertical and shear displacements. The data identified areas at risk of failure and highlights the value of InSAR in mine site assessment and monitoring; potentially saving assets and the lives of mine workers.

Processing

Many commercial products exist that support InSAR data processing. However, there are also a number of open-source packages that are available online. The most common and powerful suites obtainable are: GMTSAR, ROI PAC, and NEST-Snap (Alaska Satellite Facility, 1991). The first named is a command-line utility that is built off the famous GMT (Generic Mapping Tools) that was created by Paul Wessel and others at the University of Hawaii (Wessel, 2013). Many routes can be taken to process InSAR data. GMTSAR processes and procedures are only given as an example.

GMTSAR processing

GMTSAR[2] takes raw data from the major satellites[3] that provide high-quality SAR imagery and processes the data in six steps: (1) Assuming data is downloaded in raw format, known as Level 0 data (L0), from their respective platforms GMTSAR first processes the raw data to a format that is compatible to the inner workings of the platform. (2) The second stage is governed by a series of GMT shell scripts and compiled C files that align and focus the satellite data. This is needed in order for the two, or more, SAR images to be precisely aligned with one another so each master cell's phase delay can be compared with the slave(s). After alignment and focusing has been completed the data set has evolved to Level 1 data (L1). GMTSAR then produces a DEM of the area of interest to compare with L1 data. (3) The DEM, which is a gridded file, is used to eliminate any

[1] COSMO-SkyMed Satellite: 8-day revisit period for example.
[2] http://topex.ucsd.edu/gmtsar/.
[3] ALOS-1, ALOS-2, Envisat, ERS, COSMOS-Sky, Radarsat, Sentinel-1A, and TerraSAR-X.

topographic phase response from the master file, allowing for (4) an interferogram to be created using any filters that may have been provided; this results in an image as shown in Figure 6. Depending on whether unwrapping is required, (5) GMTSAR will use its built-in unwrapper, Snaphu, to produce the unwrapped version of the interferogram, as in Figure 7. Finally (6), GMTSAR finishes up by converting all calculated data into readable formats. This includes image and Google Earth[4] files that can easily be reproduced and shared. GMTSAR and other freely available processing software are powerful resources for potential users of InSAR. Enjoy!

Mathematical proofs

$$1.1\ S(t) = A\cos[2\pi f_o(t-\tau)]$$

$$\Rightarrow S(t) = A\cos\left[2\pi f_o\left(t-\frac{2x}{c}\right)\right]$$

$$\Rightarrow S(t) = A\cos\left[2\pi f_o t - \frac{4\pi x}{c} f_o\right]$$

$$\Rightarrow S(t) = A\cos\left[2\pi f_o t - \frac{4\pi x}{c}\cdot\frac{c}{\lambda}\right]$$

$$\Rightarrow S(t) = A\cos\left[2\pi f_o t - \frac{4\pi}{\lambda} x\right]$$

$$1.2\ S(t) = A\cos[2\pi f_o t - \phi]$$

$$1.3\ R_2 = R_1 \pm \frac{B}{u} v_r \sin\theta$$

$$1.4\ \phi_{int} = -\frac{4\pi}{\lambda}(R_1 - R_2)$$

$$\Rightarrow \phi_{int} = -\frac{4\pi}{\lambda}\left(R_1 - R_1 \mp \frac{B}{u} v_r \sin\theta\right)$$

$$\Rightarrow \phi_{int} = -\frac{4\pi}{\lambda}\left(\mp \frac{B}{u} v_r \sin\theta\right)$$

$$1.5\ \phi_{int} = \pm\frac{4\pi}{\lambda u} B v_r \sin\theta$$

$$1.6\ \pm v_r = \frac{\lambda u}{4\pi B \sin\theta}\ \phi_{int}$$

$$\Rightarrow \pm v_r = \frac{\lambda}{4\pi \sin\theta}\cdot\frac{u}{B}\ \phi_{int}$$

$$\Rightarrow \pm v_r = \frac{\lambda}{4\pi \sin\theta}\cdot\frac{1}{\Delta t}\ \phi_{int}$$

$$1.7\ \pm v_r = \frac{\lambda}{4\pi \sin\theta\, \Delta t}\ \phi_{int}$$

$$1.8\ \phi(t_1) = -\frac{4\pi}{\lambda} R_1 + \phi_{s1}$$

$$1.9\ \phi(t_2) = -\frac{4\pi}{\lambda}(R_1 - \Delta R) + \phi_{s2}$$

$$1.10\ e^{j\theta} = \cos\theta + j\sin\theta$$

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Duan Uys is currently a Masters student at Macquarie University in Sydney, Australia. His research is focused on the application of InSAR to monitoring slope stability, particularly in areas where slope failure could result in loss of life. He believes that InSAR is currently underrated as a monitoring tool by the scientific community and is hoping that his work will change perceptions in that regard.

The Marsobot project: tools for the geophysical exploration of space

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Background

The role that geophysics is playing in the scientific exploration of extra-terrestrial bodies is as important as the role that geophysics has played in the exploration of the Earth. As described in the article that Jon Clarke wrote for *Preview* last year (Clarke, 2015), for nearly six decades robotic and manned missions from many nations have measured the geophysical properties of many bodies in our solar system. The exploration of Mars has been a particular focus of many of these missions. In fact, more spacecraft have visited (flown past, orbited, landed on, or crashed into) the Red Planet than any other body in our solar system (Barlow, 2008). The reason for such attention is that Mars more closely resembles the Earth than any other world in the known universe, as well as being close enough to be sampled directly by surface missions. Although Mars is half the diameter of Earth, it shares many of the geological features observed on our own world; such as volcanoes, rift valleys, ice caps, sedimentary successions, and sand dunes (Soderblom and Bell, 2008). There is also abundant evidence of past and present fluvial activity in the form of erosional and depositional channels and associated sediments, raising the possibility that life may once have existed on Mars (Newsom et al., 2001).

The bulk of the missions sent to Mars have been 'all-rounders', and have included a mix of sensors. Although active sensors have been carried on many of these missions, the MOLA instrument on Mars Global Surveyor (MGS) is an example, the bulk of the sensors have been passive and remote sensing in nature (Barlow, 2008). Part of the reason for this is that the construction and operation of passive instruments tends to be simpler than for those that need to directly interact with the environment, such as a penetrometer or soil conductivity measuring device. Despite this, geophysical experiments have returned much useful data from Mars, such as measurements of a fossilised magnetic field, gravity (Acuña et al., 1998), and regolith physical properties (Zent et al., 2010).

Wheeled landers

The extreme nature of outer space adds an order of magnitude to the difficulties in engineering required to construct and operate a reliable mission, and instrument or spacecraft failure can be catastrophic. This leads to conservative design, where established engineering methods, rigorously tested, are often favoured over innovation (Mishkin, 2003). Earth hardware has also been employed in the analogous sense in order to characterise and test potential robotic designs intended for space explorations. Examples for Mars include the rocky series of Microrovers; 2–10 kg class of vehicles that were developed in conjunction with the Sojourner Mars rover (Hayati et al., 1997), and the FIDO vehicle designed to trial concepts employed in MER (Anderson et al., 2006).

Recent advances in electronics and mobile robotics make it possible for small teams to build small autonomous or remotely controlled space vehicles that save on payload weight, launch and landing costs. This is the goal of the Marsobot project; a Mars Society Australia led joint project with University of New South Wales that aims to develop open source hardware and operational techniques that can be used to build and fly the next generation of Mars rovers (Hobbs et al., 2014). The Marsobot project aims to develop affordable small rover platforms suitable for undertaking specific scientific exploration in terrestrial environments analogous to Mars. In order to achieve this goal open source electronics are being used, including the Arduino and Raspberry Pi. The use of these popular microcontrollers fosters greater collaboration between a large community of programmers and electronic enthusiasts. Commercial-off-the-shelf (COTS) hardware is also being used for the Marsobot project, though one of the goals of the Marsobot project is to design and test custom built, low cost sensors. With the successful arrival of India's orbital mission to Mars, as well as the private company SpaceX Red Dragon capsule (with the goal of launching to the Red Planet as soon 2018 and advertised delivery of payloads to a Mars transfer orbit among its services) it is clear that NASA and even major governmental agencies no longer have exclusive rights to space exploration. This evolving business and technical climate allows smaller operators, such as universities or even start-up ventures, the potential for access to space. The Marsobot project is designed to exploit this new environment and will contribute to our understanding of operating planetary missions.

'The Marsobot project aims to develop affordable small rover platforms suitable for undertaking specific scientific exploration in terrestrial environments analogous to Mars'

Marsobot rover description

The Marsobot project currently incorporates three operational rovers of differing scales, in order to gather information regarding the operation of machines of various sizes and weights. The largest rover, the Miner, is an eight wheeled skid steered machine fitted and designed to trial astronaut assistance tasks, and also regolith extraction and processing. Little Blue, a four wheeled skid-steered rover was built to approximate the size of Sojourner, a microrover deployed to Mars in 1997 (Figure 1). Both of these rovers participated in standardised US

National Institute of Standards and Technology (DHS-NIST-ASTM) tests over the period 5–12 July, 2014 (Hobbs et al., 2014; Clarke et al., 2014). The tests were conducted in controlled conditions and were designed to provide useful engineering data on the rovers' range and mobility, as well as highlight potential flaws and limitations in design (Clarke et al., 2014). An additional rover was included in the New Zealand Spaceward Bound trip to the hot springs in Rotorua, New Zealand in 2015 (Figure 2). This rover tested a multispectral camera and non-contact thermometer for use in identifying and characterising extreme forms of life within acid and alkaline hot spring areas thought to be analogous to early Mars environments (Barns et al., 1996).

The A4 rover, so named as it is designed to fit onto an A4 sheet of paper, is the most recent addition to the Marsobot project (Figure 3). It is intended to test and characterise mobility and the collection of scientific data for a nanorover class vehicle in three Mars analogue environments in Australia and India. The A4 rover will trial a skid-steer, rocker bogie suspension system on environments expected to be observed on Mars such as ice-rich sediment, sands and loose stones. Results from these experiments will provide valuable data for rovers in this class. These data will be used to refine mobility and locomotion designs for the A4 Rover and contribute to the design of a space qualified rover.

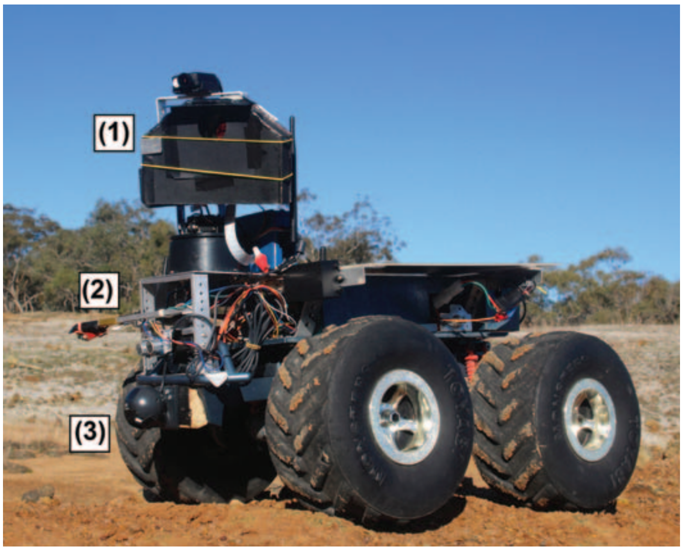

Figure 1. *The Little Blue rover has been trialled in engineering tests in the Northern Flinders ranges. The rover is equipped with remote sensing and geophysical instruments for sampling the environment around it. Labelled instruments are: (1) multispectral camera; (2) non-contact IR sensor on a swing arm; and (3) macroscopic camera for close-up regolith investigation.*

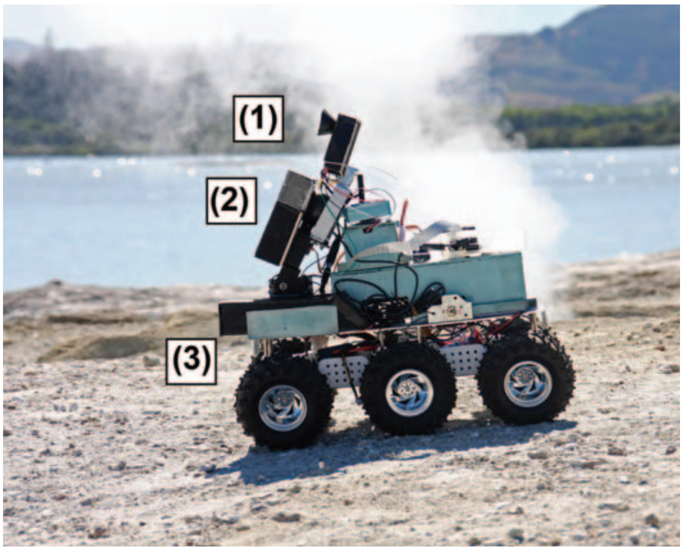

Figure 2. *Junior is a small robot that used to explore the hot springs environment in Rotorua, New Zealand, to look for extreme forms of life. Instruments on the rover include (1) non-contact IR sensor; (2) multispectral camera; and (3) spectrometer.*

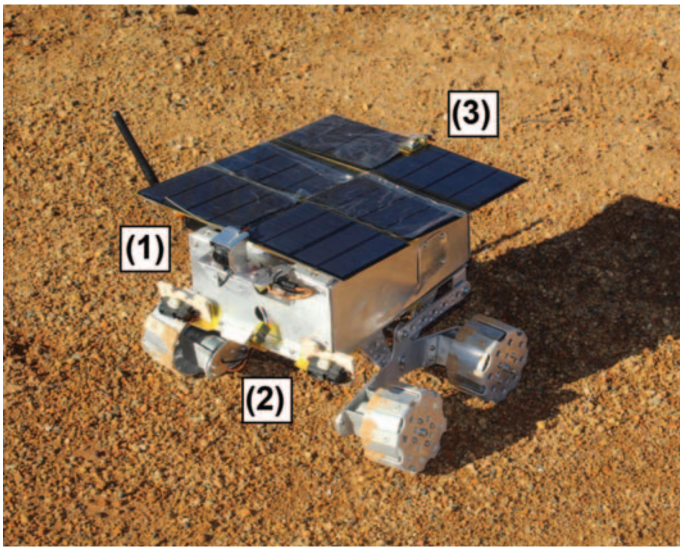

Figure 3. *The A4 rover was designed to test and characterise skid-steer mobility and geophysical data collection for a nanorover class vehicle in Mars analogue environments on Earth. This rover carries (1) a visible light camera; (2) non-contact IR sensor; and (3) ultraviolet sensor.*

Rover sensor design

All of these rovers are fitted with a variety of instruments capable of gathering remotely sensed and geophysical data on the rover's surroundings. As an example, both Little Blue and the A4 Rover are equipped with multispectral cameras and non-contact IR sensors that have been tested in field trials conducted in 2015 and 2016. The combined use of these sensors will allow data to be acquired on the chemical composition, albedo and thermal inertia of local rock and regolith materials. Larger objects retain heat better than smaller objects so thermal inertia is a useful tool for inferring particle size where physical measurements are impossible. Measurements for thermal inertia have been conducted by MGS and Mars Odyssey (Christensen et al., 2004; Christensen, 2006), and have been used for diverse applications such as inferring dune composition (Hobbs et al., 2010), and the host regolith of Martian crater gullies (Hobbs et al., 2013). Initial trials of the non-contact IR sensor and multispectral camera within a custom built 'Mars Yard' have shown that thermal inertia data can be acquired using this method.

Geophysical data have also been obtained indirectly through engineering testing and operations. An example of this includes determination of Martian regolith consistency and strength as derived from the physical examination of rover wheel tracks. The depth to which a vehicle of a known weight sinks into a planetary surface allows for estimation of the load bearing ability of the host regolith (Lindemann, 2005). This data is usually supplemented by other engineering data such as motor current consumption from which regolith engineering properties can be inferred. For example, more energy is required to drive a rover forward on loosely consolidated, sandy material than is required for firmer surfaces that are more able to support a vehicle's weight. Similarly, surface obstacles such as rocks require more power for the rover to negotiate than smooth terrain (Zhou et al., 2014). These data can yield quantitative materials property data (Sullivan et al., 2011). Utilising engineering data in this way maximises the benefit from a planetary mission operation as dedicated instruments do not have to be added to the mission payload, thus saving space and weight. Additional data on regolith type and erosion rates can be gathered by imaging vehicle tracks over different time periods. An example occurred during the Opportunity traverse into and out of Victoria Crater in Meridiani Planum. The rover entered and exited the crater using similar routes, enabling the vehicle tracks to be imaged over both time periods. As there was a six month period between the two sets of tracks, the rate of erosion could be inferred (Barlow, 2008).

Engineering testing has been an important component of the Marsobot project. Gathering geophysical data from these operations requires the behaviour and characteristics of each rover to be precisely understood. Results from the 2014 NIST trials (Hobbs et al., 2014) have been consolidated with a new series of testing designed to gather data on rover wheel performance and motor power consumption over various surfaces and differing slopes. A version of the MER testing conducted by NASA JPL has been used, where custom made ramps can be filled with different types of material and set at various slopes (Figure 4). So far the A4 Rover has been trialled on slopes ranging from 0-20 degrees, and driven over loosely consolidated surfaces, pebbles and sand. Motor currents, wheel sinkage and slippage were all recorded in order to determine the response of the rover under controlled conditions.

Results from these tests were supplemented by conducting field trials of the A4 rover at the Kiangara abandoned mine site, 30 km from Yass, New South Wales. The site had been used to mine gold and heavy metals at the turn of the previous century and residual contamination has left it largely bereft of vegetation. This feature, as well as its diverse geology, has enabled the site to be used as a Martian analogue. The A4 rover was driven over differing surfaces and slopes at this site using similar metrics to the laboratory style ramp tests. Results from the field tests will be compared with those conducted under controlled conditions in order to determine how well the geophysical properties of the driving surface can be inferred.

Figure 4. *An important part of developing open source instruments is calibration. To this end a custom Mars yard and calibration target has been built to characterise instrument performance.*

Future directions

Research and development in the Marsobot project is ongoing. A second field trip to Arkaroola is planned, where Little Blue and the A4 rover will be driven to gather a range of geophysical, engineering and remote sensing data. Arkaroola offers a diversity of analogous terrain, including radioactive hot springs that host extremophile life forms, basaltic slopes and alluvial fans. An additional field trip to the high mountain passes near Ladakh in northwest India is planned, where Little Blue will be trialled on arid, glacial environments. These expeditions, along with additional development, will provide valuable contributions to our understanding of the geophysical properties of the environment around us.

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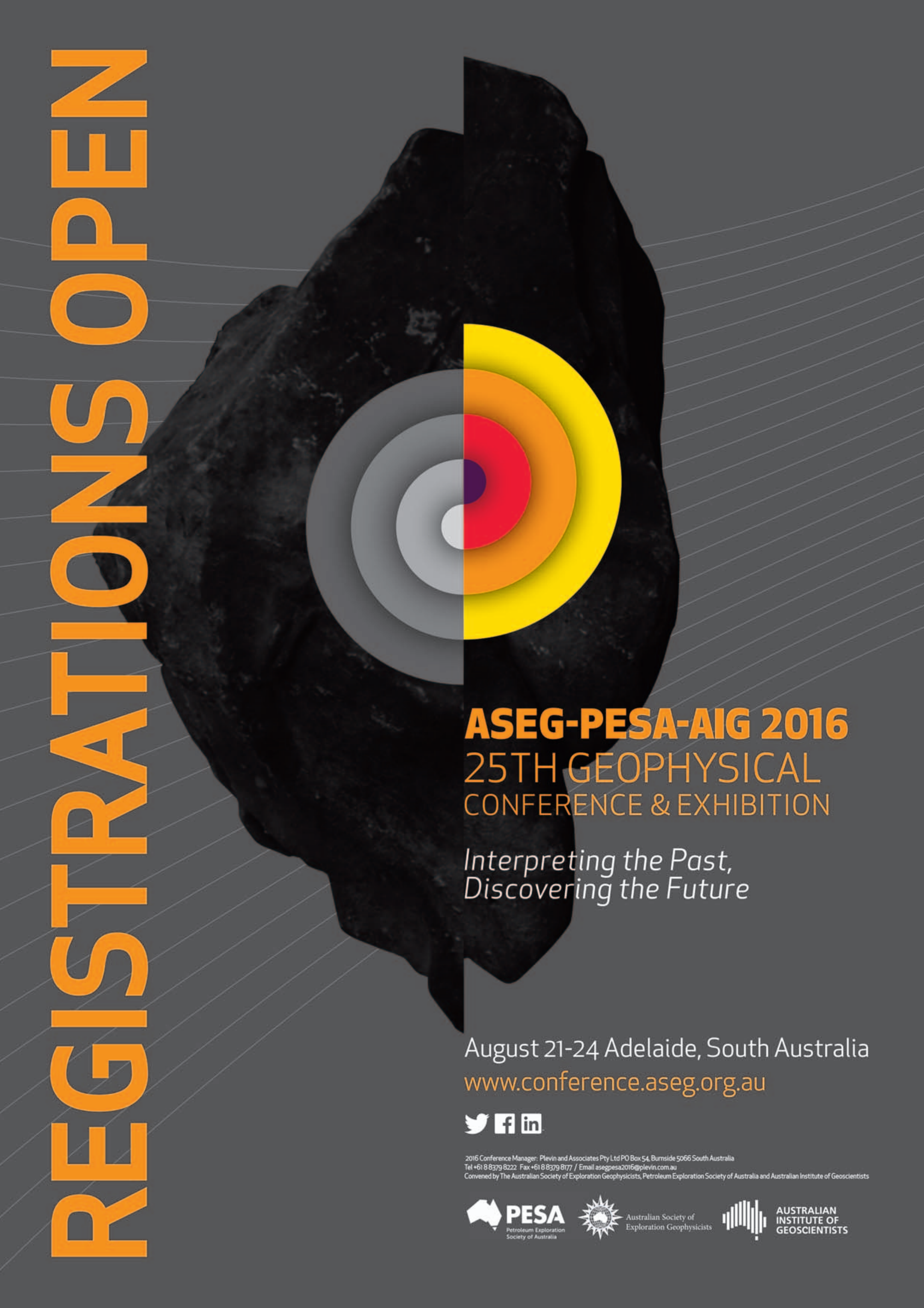
Steven Hobbs has just completed a PhD at the University of New South Wales that compares the development of terrestrial gullies in peri-glacial, temperate and semi-arid settings with the development of Martian gullies in Noachis Terra. He is extending the scope of this research using robotic applications of remote sensing, and raw material extraction through the use of ground-based systems.

This photo shows some of the magnetic susceptibility meters held in the ASEG historic instrument collection. Magnetic susceptibility indicates the amount of magnetism that a rock can have and, of the minerals involved, magnetite produces the highest readings. These meters are designed to instantly display measurements made on outcrops and drill core. Anomalous readings can indicate the source of airborne and ground magnetic anomalies and assist in planning magnetic surveys. They also have application in environmental studies. As the meters are designed to be small (due to the use of microprocessor electronics) and therefore easily portable, they are also popular with geologists and many thousand have been used throughout the world. There have been at least 10 different manufacturers, including some in Australia, and many different models have been produced.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11–14	7th International Geosciences Student Conference	Katowice	Poland
August	**2016**		
21–24	ASEG-PESA-AIG 2016: 25th Geophysical Conference and Exhibition http://www.conference.aseg.org.au/	Adelaide	Australia
27 Aug– 4 Sep	35th International Geological Congress http://www.35igc.org/	Cape Town	South Africa
September	**2016**		
4–8	EAGE Near Surface Geoscience Conference and Exhibition https://www.eage.org/event/?eventid=1419	Barcelona	Spain
5–9	5th International Conference on Geo Technical and Geophysical Site Characterisation http://www.isc5.com.au	Gold Coast	Australia
11–14	AAPG/SEG International Conference and Exhibition	Cancun	Mexico
26–28	SPE Annual Meeting	Dubai	UAE
October	**2016**		
3–5	Multi-physics integration for Geological Modeling (Potential Fields)	Dubai	UAE
15–20	Vietnam Association of Geophysicists International Scientific Conference 2016	Hanoi	Vietnam
16–21	SEG International Exhibition and 86th Annual Meeting http://www.seg.org	Dallas	USA
December	**2016**		
12–16	AGU Fall Conference	San Francisco	USA
June	**2017**		
12–15	79th EAGE Conference and Exhibition 2017 http://www.eage.org/	Paris	France
July	**2017**		
17–19 (TBC)	3rd Near-Surface Geophysics Asia-Pacific Conference (website TBA)	Cairns	Australia
September	**2017**		
12–14	Offshore Site Investigation and Geotechnics Committee (Society for Underwater Technologies) 8th International Conference http://www.sut.org/specialist-interest-group/osig-offshore-site-investigation-and-geotechnics/	London	UK
24–27	SEG International Exhibition and 87th Annual Meeting http://www.seg.org	Houston	USA
October	**2017**		
15–18	AAPG/SEG International Conference and Exhibition http://www.aapg.org/events/conferences/ice/announcement/articleid/5666/aapg-seg-2017-international-conference-exhibition	London	UK
21–25	Exploration '17 http://www.exploration17.com/	Toronto	Canada

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