Australian Society of
Exploration Geophysicists

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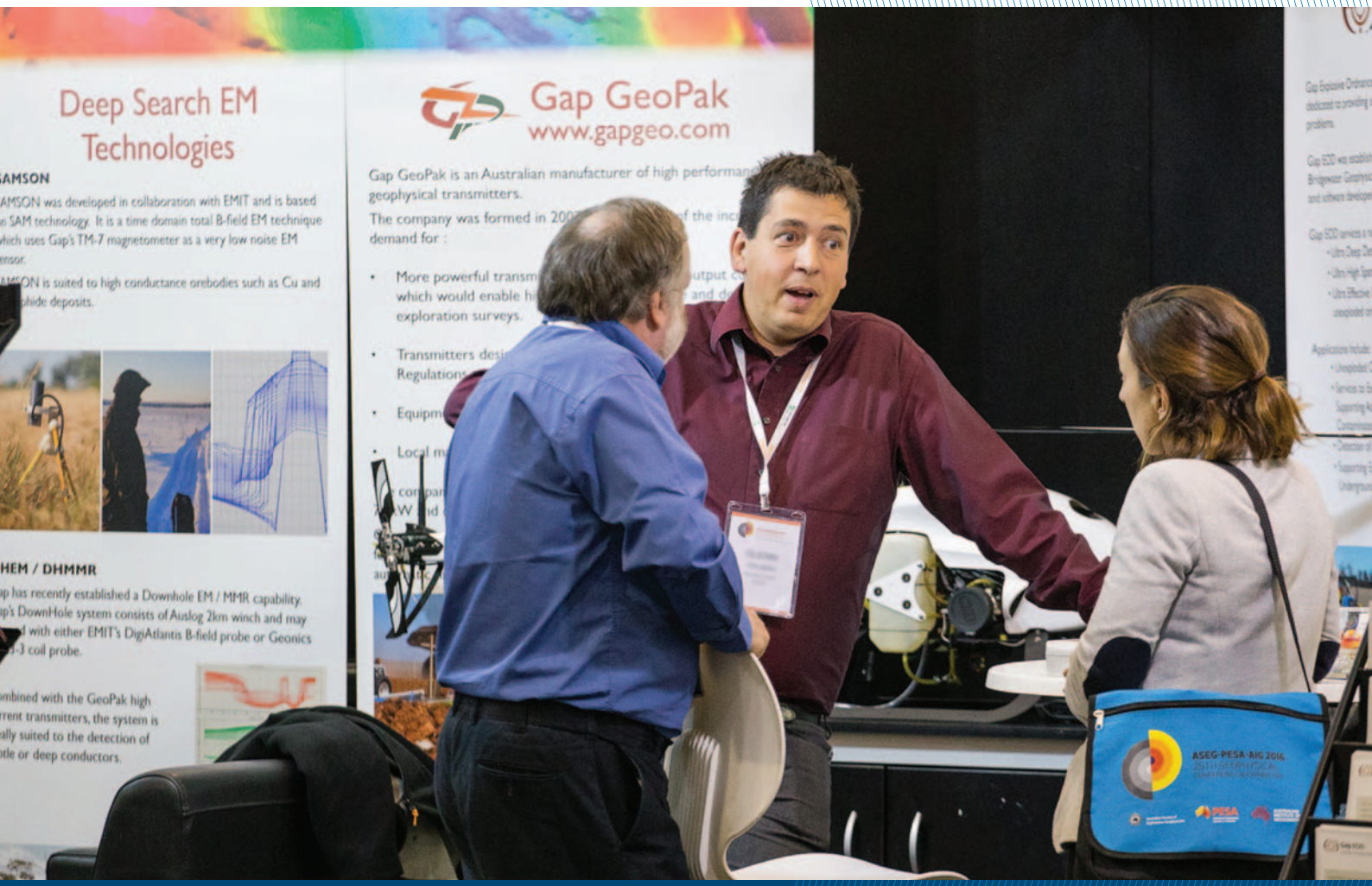
PREVIEW



NEWS AND COMMENTARY

FEATURES

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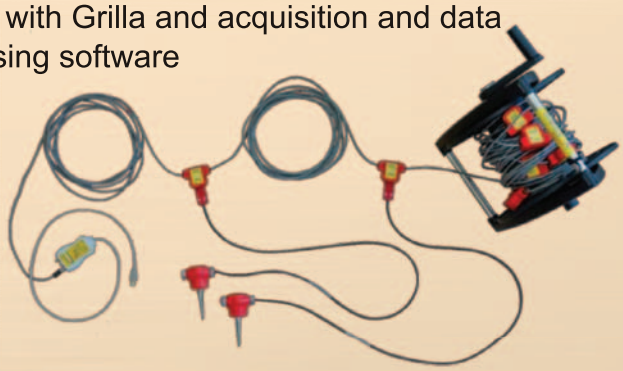

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2016 ASEG CORPORATE MEMBERS

Archimedes Financial Planning
Contact: Noll Moriarty
Tel: 1300 387 351
Email: Noll.Moriarty@ArchimedesFinancial.com.au

Instrumentation GDD Inc.
Contact: Pierre Gaucher
Tel: +1 418 877 4249
Email: pgaucher@gcc.ca

Terrex Seismic
Contact:
Tel: +61 8 9235 4600; +61 7 3621 0300
Email: info@terrexseismic.com

Total Scan and Survey
Contact:
Tel: +61 8 6188 7688
Email: admin@tssurvey.com.au

Velseis Pty Ltd
Contact:
Tel: +61 7 3376 5544
Email: info@velseis.com

FRONT COVER

Geophysicists in the Exhibition Hall at the ASEG-PESA-AIG 2016 Conference.

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CONTENTS

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

Associate Editors
Education: Michael Asten
Email: michael.asten@monash.edu

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

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

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

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

Geophysical Data Management and Analysis: Guy Holmes
Email: guy.holmes@katalystdm.com

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

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

Publisher
CSIRO Publishing

Production Editor
Helen Pavlatos
Tel: (03) 9545 8472
Email: helen.pavlatos@csiro.au

Advertising
Doug Walters
Tel: (03) 9545 8505
Email: doug.walters@csiro.au

Editor's desk

The organisers of the ASEG-PESA-AIG 2016 Conference and Exhibition in Adelaide did a fantastic job. The conference was well attended, given the downturn in the both the minerals and petroleum industries, and there was a good mix of presentations. The conference dinner, which was held in one of the Adelaide Oval grandstands with a superb view of the Adelaide Oval and cricketing memorabilia on display, was something to write – or text – home about. Some of the memorabilia were auctioned for charity (the ASEG RF) and I am still cheesed about missing out on the cricket ball autographed by the Earl of Twirl – just saying!

The presentations that seemed to excite the most interest at the conference were on passive seismic. This technique seems to have matured considerably in the last couple of years and is now demonstrably a rapid and cost effective means of mapping the thickness of regolith as well as elements within the regolith such as palaeochannels. Matt Owers and his colleagues, for example, gave a very interesting presentation entitled 'Passive seismic surveying for depth to base of palaeochannel mapping at Lake Wells, Western Australia'. There was also a lot of interest in presentations on 'big data', although the chat over coffee cups suggests that data processing algorithms have a long way to go, which makes Guy Holmes' commentary (*Data trends*) on versions of truth in this issue of *Preview* quite timely.

Generally speaking geophysicists on the minerals side of industry at the conference were cautiously optimistic about the future. Their optimism could be well founded as David Denham (*Canberra observed*) reports in this issue that the ABS statistics on mineral and petroleum exploration expenditure in the June quarter confirm that the expenditure on mineral exploration is recovering. Exploration on petroleum exploration, on the other hand, is still declining.

With one eye on the possibility that some money might be returning to mineral exploration we are publishing two highly practical guides to ensuring maximum return on investment in data acquisition programmes. One is a review of high productivity vibroseis techniques by Tim Dean at Curtin University, and the other is a comparison of magnetic susceptibility meters using samples from the Thompson Nickel Belt, Canada by Deng Deng and Richard Smith.

Last but not least, in this issue of *Preview* I have the pleasure of introducing a new Associate Editor for Minerals geophysics, Terry Harvey. We can all look forward to Terry's commentary on minerals geophysics in the coming months and years with almost as much pleasure as we can look forward to the next issue of *Preview* when we will be treated, once again, to a Don Emerson Christmas special – this time on Opal. I, for one, can hardly wait!

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

*This **Digital, Recording Vehicle-borne Magnetometer** from the ASEG virtual museum collection was generously donated by John Stanley, the inventor. It was built in 1978 at the Geophysical Research Institute at the University of New England and had a resolution of 0.1 nT @ 10 Hz. The rapid measurement rate capability of the caesium magnetic sensor demanded not just a method for automatically recording both the magnetic field measurement and the position at which each measurement was acquired, but it also demanded digital recording of this data and by 1978 this was becoming available. The data acquisition system was developed by Sonotek in Canada and could write magnetic measurement data triggered at programmable fixed distance increments along a traverse. Many thousands of survey km of magnetic data were acquired with this vehicle-borne system. With this system, magnetic data could be acquired at 1 m intervals while traversing at 40 kph.*

President's piece

Katherine McKenna

What a fantastic couple of months for the ASEG. The 25th International Geophysical Conference and Exhibition in Adelaide was brilliant. Congratulations go out to Phil Heath and Luke Gardiner and their entire organising committee for putting on such a great conference. In difficult times for our industry it was a true testament to their skills, hard work and persistence.

The conference had so many highlights. I started on Saturday night with the selection of wine for year's ASEG wine offering. On Sunday I attended the ASEG Council meeting and saw that just next door were there quite a few workshops underway, and they were all well attended. The exhibition, which was well populated with mineral and oil and gas exhibitors, was set up for the Icebreaker in the evening. At the opening ceremony the next day I heard a fascinating talk given by the main sponsor BP. It was really interesting to see how much money was being put into the state of South Australia in the name of exploration.

The oral and poster presentations during the conference were all well attended and covered a diversity of topics. I congratulate all those that gained awards for their presentations, especially student presenters – of which there were many.

FedEx Members had lunch with representatives of our sister societies on Monday. It was really interesting to have the opportunity to sit and discuss what is happening with different groups overseas and what is coming up in the future.

I also had an invitation to attend Professor David Boyd's 90th Celebration lunch on Tuesday. Not having been educated at Adelaide University I was a bit of an outsider. However, the stories by the presenters and talk given by Professor Boyd almost made me wish I had gone to Adelaide University. The 'just go out there and do it' attitude was intoxicating.

A very entertaining conference dinner at the Adelaide Oval on Tuesday night added to the conference atmosphere. There is no doubt that Adelaide has set a high standard for the next conference in Sydney!

After the conference in Adelaide I took leave and ventured on a bike tour from Spain to Italy covering Hannibal's trail. The crossing of the Alps has, from a geological point of view, been amazing. Along one ride I came across a geological park that marks a certified boundary between two ages of the Cretaceous period, being the Hauterivian and Valanginian. Whilst there, and taking a break from the cycling, three car loads of tourists stopped. Their interest demonstrates the potential of geotourism – if sites are presented well.

I look forward to seeing the report from the conference and hope everyone enjoyed the conference as much as I did!

homo minister et interpres naturae
(man, the servant and interpreter of nature)

Katherine McKenna
ASEG President
president@aseg.org.au

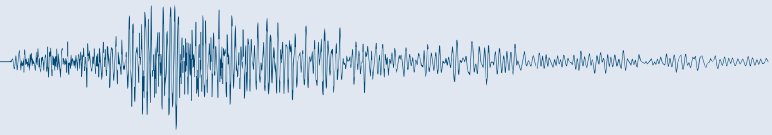
On Hannibal's trail.

At the ASEG booth with representatives of some of our sister societies and members of the ASEG publications team.

Welcome to new Members

The ASEG extends a warm welcome to 40 new Members approved by the Federal Executive at its July, August and September meetings (see table).

First name	Last name	Organisation	State	Country	Membership type
Htoo	Aung Khant	University of Yangon		Myanmar	Student
Saadullah	Baloch	University of Wollongong	NSW	Australia	Student
Michael	Barnes	Charles Stuart University	SA	Australia	Student
Sudip	Bhattacharya		NSW	Australia	Active
Bradley	Cave	University of Adelaide	SA	Australia	Student
Alexandra	Cotton	Curtin University	WA	Australia	Student
Jane	Cunneen	Curtin University	WA	Australia	Active
Cameron	Fink	Bridgeport Energy Limited	NSW	Australia	Active
Clive	Foss	CSIRO	NSW	Australia	Active
Alan	Gillespie	Planetary Geophysics Pty Ltd	QLD	Australia	Active
Neil	Godber	Mitre Geophysics	QLD	Australia	Active
Al	Harvey	Project Geoscientist	WA	Australia	Active
Amir	Hashempour Charlchi	University of Adelaide	SA	Australia	Student
Lucas	Heape	HPX Services Australia	QLD	Australia	Active
Timothy	Hill	Curtin University	WA	Australia	Student
Allen	Hundley	Geosonics Australia	NSW	Australia	Associate
Joanna	Joga	Conectel	QLD	Australia	Active
Dongwoo	Kim	Sejong University	Seoul	South Korea	Student
Bitnare	Kim	Sejong University	Seoul	South Korea	Student
David	Kulikowski	University of Adelaide	SA	Australia	Student
Simon	List	University of Adelaide	SA	Australia	Student
Cas	Lotter	Spectral Geophysics	Gaborone	Botswana	Active
Min	Lwin Tun	University of Yangon		Myanmar	Student
Mahyar	Madadi	Curtin University	WA	Australia	Associate
Brian	Main	GEDEX Inc	Ontario	Canada	Active
Daniel	Marsh	SRK Exploration Services Ltd	Cardiff	UK	Active
John	McMonagle	Velseis Pty Ltd	QLD	Australia	Active
Juthamard	Mhardsen	Austhai Geophical Consulting	BKK	Thailand	Associate
Klaus	Motschka	Geological Survey of Austria		Austria	Associate
Lachlan	Renfrey	Macquarie University	NSW	Australia	Student
Teerawat	Ruangsathianpong	Austhai Geophical Consulting	BKK	Thailand	Associate
Maxime	Salman	University of Waterloo	Ontario	Canada	Student
Sara	Sayyadi	Observatório Nacional/DPGG	RJ	Brazil	Student
Toke	Soltoft	Aarhus GeoSoftware		Denmark	Active
Seo Young	Song	Sejong University	Seoul	South Korea	Student
Kevin	Stephens	Exploration	WA	Australia	Active
Kyow	Tha Oo	University of Yangon		Myanmar	Student
Myat	Thandan Htwe	University of Yangon		Myanmar	Student
Chris	van Galder	CGG	WA	Australia	Active
Ye	Zaw	University of Yangon		Myanmar	Student



ASEG Federal Executive 2015–16

Katherine McKenna: President (Membership Committee Chair)
Tel: (08) 9477 5111
Email: president@aseg.org.au

Andrea Rutley: President Elect (Promotions Committee Chair)
Tel: (07) 3834 1836
Email: presidentelect@aseg.org.au

Marina Costelloe: Secretary
Tel: (02) 6249 9347
Email: fedsec@aseg.org.au

Danny Burns: Treasurer (Finance Committee Chair)
Tel: (08) 8338 2833
Email: treasurer@aseg.org.au

Phil Schmidt: Past President (Honours and Awards Committee)
Tel: 0410 456 495
Email: pastpresident@aseg.org.au

Koya Suto: (International Affairs Committee Chair, Research Foundation)
Tel: (07) 3876 3848
Email: vicepresident@aseg.org.au

Kim Frankcombe (AGC Representative, Conference Advisory Committee and Technical Standards Committee)
Tel: (08) 6201 7719
Email: kfrankcombe@iinet.net.au

Emma Brand (Education Committee Chair)
Tel: 0455 083 400
Email: continuingeducation@aseg.org.au

Tania Dhu (State Branch Representative, Specialist and Working Groups Liaison)
Tel: 0422 091 025
Email: branch-rep@aseg.org.au

David Annetts (Web Committee Chair)
Tel: (08) 6436 8517
Email: david.annetts@csiro.au

Lisa Vella: Vice President (Publications Committee Co-Chair)
Tel: (08) 6254 5000
Email: geofink@iinet.net.au

Greg Street (Publications Committee Co-Chair, History Committee)
Tel: (08) 9388 2839
Email: gstreet@iinet.net.au

Standing Committee Chairs

Finance Committee Chair: Danny Burns
Tel: (08) 8338 2833
Email: treasurer@aseg.org.au

Membership Committee Chair:
Katherine McKenna
Tel: (08) 9477 5111
Email: membership@aseg.org.au

State Branch Representative: Tania Dhu
Tel: 0422 091 025
Email: branch-rep@aseg.org.au

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

Honours and Awards Committee Chair:
Andrew Mutton
Tel: (07) 3278 5733
Email: awards@aseg.org.au

Publications Committee Co-Chairs:
Greg Street and Lisa Vella
Tel: –
Email: publications@aseg.org.au

Technical Standards Committee Chair:
Tim Keeping
Tel: (08) 8226 2376
Email: technical-standards@aseg.org.au

ASEG History Committee Chair:
Roger Henderson
Tel: 0408 284 580
Email: history@aseg.org.au

International Affairs Committee Chair:
Koya Suto
Tel: (07) 3876 3848
Email: vicepresident@aseg.org.au

Education Committee Chair: Emma Brand
Tel: 0455 083 400
Email: continuingeducation@aseg.org.au

Web Committee Chair: David Annetts
Tel: (08) 6436 8517
Email: david.annetts@csiro.au

Research Foundation Chair: Philip Harman
Tel: 0409 709 125
Email: research-foundation@aseg.org.au

Research Foundation – Donations: Peter Priest
Email: pwpriest@senet.com.au

Specialist Groups

Near Surface Geophysics Specialist Group
President: Greg Street
Tel: (08) 9388 2839
Email: gstreet@iinet.net.au

Early Career Geophysicists Specialist Group
President: Millie Crowe
Tel: (02) 6249 9846
Email: Millicent.Crowe@ga.gov.au

ASEG Branches

Australian Capital Territory

President: Ned Stolz
Tel: (02) 6144 4560
Email: actpresident@aseg.org.au

Secretary: James Goodwin and Adam Kroll
Tel: (02) 6249 9705; (02) 6283 4800
Email: actsecretary@aseg.org.au

New South Wales

President: Mark Lackie
Tel: (02) 9850 8377
Email: nswpresident@aseg.org.au

Secretary: Sherwyn Lye
Tel: (02) 8960 8417
Email: nswsecretary@aseg.org.au

Queensland

President: Fiona Duncan
Tel: (07) 3042 7502
Email: qldpresident@aseg.org.au

Secretary: Megan Nightingale
Tel: (07) 3839 3490
Email: qldsecretary@aseg.org.au

South Australia & Northern Territory

President: Joshua Sage
Tel: 0438 705 941
Email: sa-ntpresident@aseg.org.au

Secretary: Michael Dello
Tel: –
Email: sa-ntsecretary@aseg.org.au

NT Representative: Tania Dhu
Tel: 0422 091 025
Email: nt-rep@aseg.org.au

Tasmania

President: Mark Duffett
Tel: (03) 6165 4720
Email: taspresident@aseg.org.au

Secretary: Anya Reading
Tel: (03) 6226 2477
Email: tassecretary@aseg.org.au

Victoria

President: Seda Rouxel
Tel: 0452 541 575
Email: vicpresident@aseg.org.au

Secretary: Dorte Macrae
Tel: 0499 978 490
Email: vicsecretary@aseg.org.au

Western Australia

President: Kathlene Oliver
Tel: 0411 046 104
Email: wapresident@aseg.org.au

Secretary: David Farquhar-Smith
Tel: 0409 840 503
Email: wasecretary@aseg.org.au

The ASEG Secretariat

Ben Williams
The Association Specialists Pty Ltd (TAS)
PO Box 576, Crows Nest, NSW 1585
Tel: (02) 9431 8622
Fax: (02) 9431 8677
Email: secretary@aseg.org.au

Executive brief

The Federal Executive of the ASEG (FedEx) is the governing body of the ASEG. It meets once a month, via teleconference, to see to the administration of the Society. This brief reports on the last monthly meeting, which was held in September. Anyone who would like to see the minutes of the monthly meetings should add their name to the mailing list maintained by the Secretariat. FedEx also holds planning meetings twice a year.

Society finances

The Society's financial position at the end of August:

Year to date income $244 415.48
Year to date expenditure $388 087.09
Net assets $1 152 061.73

Membership

As of 5 August, the Society had 1075 Members. We hope to gain a few new Members from the recent successful conference in Adelaide.

New website

Congratulations to the Web Team for delivering a new website for our Members. If you have any additions, amendments, suggestions, information please don't hesitate to contact the Webmaster David Annetts.

Conference business meetings

During the very successful ASEG-PESA-AIG 2016 conference, a number of Committee meetings were held. If you are interested in getting involved on a Committee, or finding out about what's new, please contact the relevant Chair below.

If you are interested in a committee that is not listed please contact me, or the committee chair as noted on the ASEG website, and we will point you in the right direction.

ASEG Council meeting summary

On Sunday 21 August, in conjunction with the ASEG conference, an ASEG Council meeting was held. The agenda included reports from the President, Treasurer, State and Territory Branches, Young Professionals Committee, Education Committee, Web Committee, Communication Committee and the International Affairs Committee. I'd like to thank those who prepared and presented information at this meeting. A full report is available, please contact me if you are interested.

Summary from the Branch Presidents

Presented by Josh Sage, Seda Rouxel, Mark Lackie, Marina Costelloe, Koya Suto, Steve Kuhn and Tania Dhu.

The State and Territory Branches are very busy running technical evenings, education events and completing other Society functions. Finding volunteers to run events can be draining but the work is rewarding. Securing new Members and retaining existing Members is something all Branches work hard on; however, advertising the benefits of being a Member of the ASEG might need a bit of work (watch this space). Some states are using Event Bright for booking their technical meetings and this is working for the Committee as well as Members. Sponsorship for students is going really well, each state has a slightly different model on how to award sponsorship but at least 10 students from across Australia were supported to attend the conference from ASEG awards, which is terrific. Branches are also sponsoring student attendance at workshops (SEG/OzSTEP), another great initiative. The Branches are always on the lookout for excellent technical speakers so if you would like to nominate a speaker for an interstate talk please contact me.

Summary from the Finance Committee

Written by Danny Burns Treasurer and presented by Katherine McKenna, President.

Healthy balance sheet: At 1 January 2016 the ASEG had an audited total equity of AU$1 295 475. A chart showing the historical annual income and expenses from 2004 to 2016 indicates that both income and expenses rose steadily from 2004–2012 (allowing for expected income drops during non-conference years) and have been steady since 2012. However, in 2016 we estimate lower income (tough times) and increased expenditure.

Increasing expenditure: Over the last few years expenditure has outpaced income in education, publications, and meetings and events. This has largely been due to increased activity in these areas, particularly in regards to publications, where we have seen a significant increase in the number of pages published. While the ASEG has been working hard to raise the profile of our publications, the Publications Committee is currently reviewing our cost and fee structures. Education expenses are up due to our sponsorship of science teaching and the success of the OzSTEP courses, which we subsidise. It is also a healthy sign that the state Branch meetings and events are being well supported. In 2016 we also commissioned a new website, which is a 'one off' cost.

Decreasing income: The main decrease is in membership income. This is not unexpected during the tough times we currently find ourselves in so the FedEx is considering a drive to promote the Society and increase corporate membership.

Committee Meeting	Chair	Email
International affairs	Koya Suto	koya@terra-au.com
Publications Committee	Greg Street	gstreet@iinet.net.au
Technical standards Committee	Tim Keeping	tim.keeping@sa.gov.au
History Committee	Roger Henderson	rogah@tpg.com.au
Finance Committee	Danny Burns	treasurer@aseg.org.au
Exploration Geophysics joint publication partners	Koya Suto	koya@terra-au.com
Research Foundation Committee	Doug Roberts	dcrgeo@tpg.com.au
Young professionals	Millicent Crowe	millicent.crowe@ga.gov.au
Near surface geophysics	Greg Street	gstreet@iinet.net.au
Combined State Branches	Tania Dhu	tania.dhu@nt.gov.au
Membership	Katherine McKenna	president@aseg.org.au

ASEG news

Outlook: While our balance sheet is healthy current projections are for a ~$180k loss in 2016 and up to a ~$400k loss in 2017 (a non-conference year), leading to a decrease in total equity to around $700k at the end of 2017.
A number of areas of expenditure are being reviewed by the various committees to counter this decline in equity. It is anticipated that we will need to prioritise our activities and the levels of those activities.

Summary from the Education Committee

Presented by Emma Brand and Wendy Watkins.

Since the last Council meeting, a terrific selection of high quality courses have been run, including three OzSTEP courses. Bob Musgrave presented his course seven times, Brian Russell presented his course three times and David Lumley presented his course twice (due to low numbers the courses at some Branches were cancelled). There was also a short course presented by Serge Shapiro and run on similar lines to OzSTEP in the ACT and WA.

Emma provided an update on OzSTEP and is currently assessing two potential speakers. Courses will be confirmed later in the year. There is a decline in the number of SEG lecturers available, but it has been announced that Koya Suto will be an SEG Lecturer next year (Yay!).

Emma spoke about broadening the Education Committee's scope to provide not only excellent technical geophysical education but broader skills to help our Members be resilient in difficult times.

Summary from the Web Committee

Presented by David Annetts.

Dave Annetts gave some background to the recent website redevelopment and explained a part of the reason for upgrading the site was to utilise a new open source system. David said the new site should be easier for Members and Committees to use and change.

Summary from the Communications and Promotions Committee

Presented by Andrea Rutley.

It was agreed by FedEx, during a planning meeting held in Perth in April 2016, that there was a need for the ASEG to have a plan to promote the Society to other geoscientific societies and also to disseminate information to Branches and Members. An initial 'Purpose Document' to establish a sub-committee was prepared within the FedEx to act as a starting point for discussion. As a result, a sub-committee, called Communication and Promotions Committee was formed. The initial focus for the committee is to define:

1. Purpose
2. Responsibility
3. Approach

Currently the Committee is reviewing and refining the original purpose document to ensure clear and concise aims, and is revising the position description for the roles of Chair and Committee Members. Additionally, TAS was invited to submit a marketing and communication strategy to the Committee to outline how it could assist in achieving the Committee's aims. This is also with the Committee for review. The new Committee Members are Michael Lees, Megan Nightingale, Emma Brand and Andrea Rutley.

Summary from the International Affairs Committee

Presented by Koya Suto.

Currently the ASEG has agreements with 10 other societies, including: SEG, EAGE, SEGJ, KSEG, CGS, SPE India, SAGA, EEGS, GSM, SBGf. The ASEG has had a booth at six conferences in past 18 months. Katherine noted that through Koya's work HAGI were at the conference and had a booth for the first time. Koya also assists the Education, Publications, Conference Organising and Near Surface Committees.

We had a bit of fun with Facebook during the Council meeting. I posted a photo at the start of the meeting and less than 3 hours later the photo had been viewed by over 300 people, today nearly 600 people from around the world have viewed that post. If you have Facebook make sure you have 'liked' the Australian Society of Exploration Geophysics page.

Marina Costelloe
Honorary Secretary
fedsec@aseg.org.au

*This **Prototype Cesium Vapour Magnetometer Sensor** from the ASEG virtual museum collection was generously donated by John Stanley, the inventor. John Stanley was given the Grahame Sands Award for this invention in 1988. The initial tasks in the development of this sensor were undertaken as a joint honours degree project at UNE in 1969 by Jim Cull and John Stanley. The tasks were to manufacture a Cs spectral lamp and absorption cell. The Cs spectral light source required to perform optical pumping demanded a high degree of stability and this was achieved by Jim Cull, who successfully built a valve driven oscillator that met this purpose. In 1970 John continued the project to develop a self-oscillating magnetic sensor and digital magnetometer as research towards his PhD. In the prototype shown, the valve oscillator has been replaced by a transistorised one (RHS) and the feedback electronics (LHS) were built using discrete transistor components. In 2016 this lamp was still functioning.*

ASEG Technical Standards Committee

The ASEG Technical Standards Committee met at the 2016 ASEG-PESA-AIG conference. We were lucky to have Angela Manchester from Hexagon Geospatial attend to confirm that the ERMapper file formats are staying and that support for .alg will be in upcoming versions of ERDAS Imagine. She also pointed out that their current SDK allows free, unlimited size reading of ECW compressed files, and the emergence of 'patch' grid capability in their geospatial software, which could change the process of grid merge.

Most previous items were signed off, with a few exceptions. Those were to look at creating a map of known test ranges and calibration pads on the ASEG website and also to look at questionable clauses cited in some LiDAR survey contracts that would inhibit the data being submitted to government. These clauses are considered obsolete and clients should not feel trapped into paying to 'redistribute' their own data. The Committee is still looking at archiving and file encapsulation methods, with our GA colleagues investigating NASA's CDF system.

The main topics of discussion were the variety of gravity reduction equations in use, and using geophysics to characterise strata. Phil Heath pointed out a range of published gravity reduction equations that may appear similar but are not the same. This is on top of different terrain corrections that can result in different products. Murray Richardson stated that the calculations dependent on geodetic coordinates will very soon be complicated because the upcoming GDA2020 datum will be our first dynamic datum. It was agreed to wait until after GDA2020 is announced before developing a position.

On the use of geophysical characteristics for strata recorded in Geoscience Australia's official strata record, it was agreed that recording the grids and geophysical types used to map a strata would be useful. Recording any more information could be problematic because of the often relative nature of the grid data or because written descriptions duplicate values available in the grid. Useful petrophysical ranges are often specific to locations within the terrain and attempts to aggregate all can render a dataset vague.

Two points were raised in other business. First, David Allen cited that many EM surveys are performed for farmers for salinity. It does not appear that they are collected by any state or federal government departments and their quality may not be what the exploration community are used to. Second, drone use is expected to explode. Contractors must have a remote pilot license from CASA in order to operate a drone.

Please do not hesitate to contact the Committee with your questions, big or small.

Tim Keeping
ASEG Technical Standards Committee Chair
technical-standards@aseg.org.au

Exploration Geophysics achieves an impact factor >1

What is the importance of the 'Impact Factor'? Although calculated mathematically, the Impact Factor of a journal is more than just a number. By definition, it is a measure used to reflect the average number of citations from a journal as a ratio to the number of citable articles published within that journal over the course of one year. The reality is that many authors use Impact Factors to choose the journal in which to publish their articles as publication in a journal with a high Impact Factor can have a positive effect on their reputation as a researcher and, potentially, on their career. A journal is considered to be 'reputable' if it has an impact factor >1.

And so it is with considerable pride and equally considerable hard work, we can report that *Exploration Geophysics* has achieved an impact factor of 1.197 for 2015 (figures released mid-year 2016). For many years, in fact since 2010, *Exploration Geophysics* has been achieving results between 0.508 and 0.667, so for the latest jump to exceed 1.0 was a significant accomplishment.

Back in 2005, when Phil Schmidt took on the role of Chair of the Publications Committee, his first priority was to ensure that *Exploration Geophysics* was included in Impact Factor considerations. Impact Factors are assigned annually by Thomson Reuters. The next goal was to achieve an Impact Factor of >1. The hard work by the Publications Committee and the editors of *Exploration Geophysics* over time, particularly in recent years by Mark Lackie, have ensured that the articles presented within the journal are of a high quality and peer reviewed by respected members of the geophysics community.

Any journal with an Impact Factor of >1 can be considered to have 'arrived' on the international scene and the number of high-quality articles submitted to *Exploration Geophysics* continues to grow. Thanks to the hard working team for these efforts and we look forward to continuing to increase our Impact Factor.

Andrea Rutley (ASEG President Elect)
presidentelect@aseg.org.au

ASEG Branch news

Western Australia

The WA Branch continued with another busy few months with technical presentations from **Jeremy Cook**, Evolution Gold, SEG Honorary Lecturer **Dr How-Wei Chen**, and **Dr Stanislav Glubokovskikh**, Curtin University. The Branch also hosted a DISC workshop by **Dr James Gaiser** on 3C seismics.

In coming months the Branch is hosting SEG Distinguished Lecturer **Professor Steven Constable**, and an 'Introduction to GPR' workshop presented by **Dr Jan Francke**, **Darren Hunt**, Teck, and **Dr Allan Trench**, UWA. We have a busy few months planned in the run up to Christmas. We hope to see all our Members at these events, including our end of year windup and AGM planned for 25 November.

Kathlene Oliver
(WA Branch President)

Australian Capital Territory

The ACT Branch has not been idle during a particularly bleak Canberra winter this year, but have instead used the opportunity to brush up on their inversion and seismic theory by taking in three excellent Branch technical events.

The first was a presentation by our very own ACT Student Scholarship winner, **Rhys Hawkins**, which drew an excellent crowd of ASEG Members keen to escape the cold and warm up with a good red! Rhys is completing a PhD at the Australian National University under the supervision of **Professor Malcolm Sambridge** and presented a portion of his thesis work on a Monte-Carlo inversion approach called trans-dimensional trees. Unlike conventional inversions where the initial choice of a fixed model parameterization has dramatic effects on the resulting inferences and the estimated uncertainty, trans dimensional trees offer a way to sample over different model parameterizations to obtain both parsimonious results and more robust uncertainty estimates. Rhys gave examples from ambient noise seismic and airborne EM inversions.

Immediately following the Adelaide Conference and Exhibition the Branch hosted a DISC course on three component seismic theory presented by **Dr Jim Gaiser**. The one day course provided students with an overview of 3C seismic theory and practical application from fundamentals of PS-waves and VSPs, through to acquisition and processing including interpretation techniques.

Finally in September the Branch was fortunate again to host a 2016 SEG/AAPG Distinguished Lecture by **Professor Steven Constable** from Scripps Institution of Oceanography, University of California San Diego. Stephen has made a big contribution to a broad range of geophysical problems and is particularly associated with the development of marine electrical techniques. By popular poll the Branch invited Stephen to present his lecture about the ambiguities and pitfalls of inversion, 'Geophysical Inversion: Which Model Do You Want?'

The local Members will be hoping for some warmer weather in the remainder of the year!

Ned Stolz
(ACT Branch President)

New South Wales

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

In August, **Clive Foss** from the CSIRO presented a talk completed in conjunction with **Tania Dhu** (NT Geological Survey) entitled: 'Magnetic anomalies from non-magnetic holes'. Clive spoke about a case study that clearly establishes the need to consider contrasts rather than just absolute magnetization values in magnetic field interpretation. Clive outlined how these anomalies are due to holes in a magnetic sheet, producing a negative magnetization contrast with the surrounding material. Many questions were asked about contrast and remanence during and after his presentation, with discussion continuing into the evening.

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to be in town at the time. Meetings are generally held on the third Wednesday of each month from 5:30 pm at the 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

Prior to the ASEG-PESA-AIG Conference in Adelaide this August the Queensland Branch held two social events; The Zoeppritz Night Pub Crawl and The Annual ASEG/PESA Trivia Night.

Both events were a huge success. We'd like to give a special thank you to our Queensland Branch Treasurer **Mr Henk van Paridon**, who donned the Quizmaster hat and provided a fun-filled evening with very challenging questions.

The Queensland Branch hosted two Technical Meetings in September. **Nabeel Yassi** presented his talk 'Current trends in onshore seismic data acquisition; a case study on cable-free nodal systems' on 13 September. SEG Distinguished Lecturer **Steven Constable** presented his talk 'Mapping Gas Hydrate using Electromagnetic Methods' on 22 September.

At this point in time, no meetings have been organized for the remainder of the year. We are looking for speakers for the end of the year and for 2017. If you're interested in presenting to the Queensland Branch please contact qldsecretary@aseg.org.au.

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 under the Qld Events tab when they are available. Please keep an eye out for future meeting announcements.

Megan Nightingale
(Qld Branch Secretary)

South Australia & Northern Territory

Since my last update, the pace has certainly changed for many here at the SA/NT Branch in the lead up to the ASEG-PESA-AIG 25th International Geophysical Conference and Exhibition.

With the conference preparations in full swing we only held one local technical evening.

At our July technical evening we were joined by **Phil Heath** from the Department of State Development. With a great crowd to present to at the Coopers Alehouse, Phil spoke about some of his recent work, with a talk titled 'The perils and pitfalls of gravity processing.' The talk provided a very thorough overview of all of the issues and potential remedies when planning, collecting and processing gravity data with a lengthy discussion followed the presentation. Our thanks go to Phil for taking the time to come and present to our Branch.

August saw the much anticipated ASEG-PESA-AIG 25th International Geophysical Conference and Exhibition, which was held at the Adelaide Convention Centre. This was a fantastic event with very good representation from all sides of industry, government and academia from both petroleum and minerals fields as well as environmental monitoring. Many thanks must go to all the presenters, key note speakers, exhibitors, sponsors and delegates, as without any one of these groups our conferences would never be as successful as they have been over the years.

Also thanks and congratulations must go to Plevin & Associates and all of the members of the local Conference Organising Committee, especially Phil Heath and Luke Gardiner the conference co-chairs – without their tireless efforts over the past two years this conference would not have been the great event that it was.

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 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 will also be holding our annual Melbourne Cup Luncheon in early November; further details can be found on the ASEG website. Also please keep an eye out for the upcoming SA/NT Branch Wine Offer, advertisements will be included in *Preview* and on the ASEG website. We invite all Members, both SA/NT and interstate to attend, and of course any new Members or interested persons are also very welcome to join us. For any further information or event details, please check the ASEG website under SA/NT Branch events and please do not hesitate to get in touch at joshua.sage@beachenergy.com.au or on 8338 2833.

Josh Sage
(SA/NT Branch President)

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 Victoria Branch kept busy over the winter between talks and social events.

In July we had the pleasure of welcoming **Asbjorn N. Christensen** who gave a talk on 'Comparison of Satellite Altimeter-derived Gravity Data and Marine Gravity Data'. This talk was also presented the following month at the ASEG Adelaide conference.

August was the time of our traditional Winter Social event with our friends from PESA and SPE held at 'Henry and the Fox'. Despite the horrendous weather the venue was packed and the conversions lively!

We welcomed the spring by having **Gary Nicol** giving a talk on Seismic Acquisition planning. Using the Great Australian Bight BP survey example he emphasized the importance of creating permit specific seismic plan from pre-bidding to abandonment in order to decrease potential technical and commercial risks.

Our next meeting will be held on 26 September and we will welcome our Spring SEG lecturer from the US (University of California, San Diego), **Professor Steven Constable**, who will discuss about the choice of model in geophysical inversion.

Seda Rouxel
(Victorian Branch President)

ASEG national calendar: technical meetings, courses and events

Date	Branch	Event	Presenter	Time	Venue
2016					
12 Oct	WA	Tech night: Tina zinc deposit case study	Darren Hunt, Teck	1730–1900	TBA
19 Oct	NSW	Student night	Various	TBA	Rugby Club, Rugby Place, Off Pitt Street, Sydney
20 Oct	ACT	Tech talk: Geophysical Networks: Seismic, Geomagnetic and Infrasound Technologies	Marina Costelloe	1600-1800	Scrivener Room, Geoscience Australia, Symonston, Canberra
23 Oct	ACT	Morning tea		1030-1200	Adore Tea, Gold Creek, Canberra
Nov	Vic	Student night	Various	TBA	The Kelvin Club, 14-30 Melbourne Place, Melbourne
Nov	SA-NT	Student night	Various	TBA	Coopers Alehouse, Hurtle Square, Adelaide
Nov	Qld	Student night	Various	1730	XXXX Brewery, Corner of Black Street and Paten Street, Milton
16 Nov	NSW	Tech meeting	TBA	TBA	Rugby Club, Rugby Place, Off Pitt Street, Sydney
25 Nov	ACT	Christmas Party		TBA	TBA
25 Nov	WA	Christmas party and AGM	Various	TBA	TBA
1 Nov	SA-NT	Melbourne Cup Lunch	1200-1700	Ambassadors Hotel, Balcony Ballroom	107 King William Street, Adelaide
9 Nov	WA	Student Presentations	Various	TBA	TBA
10 Nov	ACT	Tech talk	Laurence Davies	1600-1800	Scrivener Room, Geoscience Australia, Symonston, Canberra
2 Dec	SA-NT	SAEMC (http://www.saexplorers.com.au/)	Various	0800-1700	Adelaide Convention Centre, Adelaide
14 Dec	NSW	Quiz night	TBA	TBA	Rugby Club, Rugby Place, Off Pitt Street, Sydney
14 Dec	Vic	Christmas lunch with PESA and SPE	TBA	TBA	TBA
15 Dec	ACT	Tech talks	Various	TBA	Sir Harold Raggatt Theatre, Geoscience Australia, Symonston, Canberra
2017					
Feb	SA-NT	AGM	TBA	1730	Coopers Alehouse, Hurtle Square, Adelaide
Feb	Qld	AGM	TBA	1730	XXXX Brewery, Corner of Black Street and Paten Street, Milton
15 Feb	NSW	AGM	TBA	TBA	Rugby Club, Rugby Place, Off Pitt Street, Sydney

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

The South Australian branches of **AIG**, **ASEG**, **AusIMM**, **GSA** *and* **SACOME,** *with principal supporters* **Department of State Development** *and* **Paydirt,** *invite you to the:*

SA EXPLORATION & MINING CONFERENCE

AUSTRALIA'S BEST VALUE MINING INDUSTRY CONFERENCE

13th South Australian Exploration and Mining Conference

Friday 2 December 2016, *Adelaide Convention Centre*

20 PRESENTATIONS	• New companies • Exploration projects • Feasibility studies • Mining operations
NETWORKING	• Five hours of networking in five sessions
COLLABORATIVE EVENT	• ***GSSA DISCOVERY DAY: Discover new data, new technology, new insights*** Thursday 1 December, ACC More Information: *www.minerals.statewidedevelopment.sa.gov.au/mineral_exploration*
WORKSHOPS	• AIG Roger Taylor – 2-day ***Ore Textures/Breccias Workshop,*** 30 Nov–1 Dec • AIG – 1-day ***Adelaide Hills Wine Tour,*** 3 Dec

Earlybird registration $160 before 1 Oct

- Registration 7.30 to 8.30 am
- Conference 8.30 am to 5.00 pm
- Drinks to follow 5.00 to 7.00 pm

REGISTRATION – $185
(all prices include GST)
- Students – $15
- *Includes coffee breaks, lunch and closing drinks*

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ISC'5: a unique melting pot for geotechnical and geophysical professionals

Were you aware of the following difference between exploration and engineering geophysicists? Conferences such as ASEG, SEG, EAGE etc. bring together exploration geophysicists and their mining or petroleum clients, while engineering geophysicists meet at SAGEEP, Near Surface Geoscience and the likes, where they mainly meet their peers and compare notes on methods but get little feedback on the user value of near surface geophysics. Every five years or so, engineering geophysicists and their geotechnical colleagues and clients get the chance to meet at the International Conference on Geotechnical and Geophysical site characterisation and it's my pleasure to report from this year's ISC'5 on the Gold Coast. Some 350 delegates from 47 countries, with 75% percent of delegates from overseas, made it a truly international conference.

With the predicted massive future infrastructure developments in the decades to come, the geotechnical industry may need some disruptive innovation. A new way of thinking that can best be stimulated when specialists from various disciplines learn each other's language and challenges and jointly find possible solutions. A cross-discipline-conference like this is fertile ground for that.

The technical program was well balanced between geophysical and geotechnical content, given that ISC primarily is a geotechnical conference. The geophysics talks involved the 'traditional' geotechnical methods, being seismic studies, and, increasingly, resistivity methods (DC and EM) and other geophysical or remote sensing themes (Figure 1). I shall try to report on talks I personally found memorable. NGI was represented with eight delegates (6 from Oslo and 2 from Perth) and I shall not mention any of our own talks as my personal favourites, even though they were pretty impressive. Many of the presentations should be available online at the time you are reading this, so see for yourself at isc5.com.au. As my geotechnical knowledge is rather superficial I won't comment too much on the geotechnical talks either. Here are simply some interesting aspects of the geophysical presentations:

Silvia Castellaro from Bologna University in Italy made a good case for the use of a more physics based approach to seismic soil classification. Current state of practice for seismic site effect assessment is Vs30, the apparent shear-wave velocity to 30 m depth, used as a proxy for the expected earthquake amplification factor. Both statistical and physical limitation of Vs30 have been reported and Castellaro proposed an alternative approach, based on the average shear wave velocity of the soil layer, the resonance frequency and the impedance contrast between soil and bedrock (VfZ). The beauty of the VfZ approach is that these parameters can be derived using the same measurements that are currently used for Vs30, namely H/V spectra and surface waves.

'The 'uber' of our industry may be geophysics, it can disrupt the way we plan our ground investigations leading to higher efficiency in terms of costs and time'

Natalie Campbell of Jacobs Australia and colleagues from Canterbury in NZ and Imperial College in the UK showcased results from a massive collection of shear wave velocity data (6500 measurements) from global lab and field sites stretching throughout the UK, US, Turkey, Canada, Taiwan, Romania and Italy. In addition to expected correlations between fracturing and weathering with Vs the data showed that estuarine, alluvial, aeolian and offshore sediments were on average characterised by an almost 40% lower velocity than colluvial, glacial and residual material. Differences in sorting and grading were stated as a possible explanation for this. Another interesting observation was a distinct difference in Vs based on field- or laboratory measurements. Great effort is taken when one takes sediment samples or rock cores and only the 'best' parts of the material are consequently tested in the lab. Velocities measured on samples (3000–4000 m/s) were found to be four times higher than the ones based on field tests (600–1400 m/s).

All in all, a good mix of method papers, case studies and especially integration with geotechnical soundings, lab data and soil physics models.

I'll end my summary with two quotes from the conference: (note that both quotes are presumably not fully correct, are based on my memory and have not been approved by the quoted individuals) Professor Carlos Santamarina (KAUST) concluded his excellent keynote with the remark that: 'Geophysics extends our senses, makes us see what we otherwise can't see' and Tim Thompson (Arup) said something along the lines of 'The 'uber' of our industry may be geophysics, it can disrupt the way we plan our ground investigations leading to higher efficiency in terms of costs and time'.

All in all a compulsory conference for engineering geophysicists to mutually learn and educate with our geotechnical colleagues and clients.

Andi A. Pfaffhuber, NGI Perth
app@ngi.no

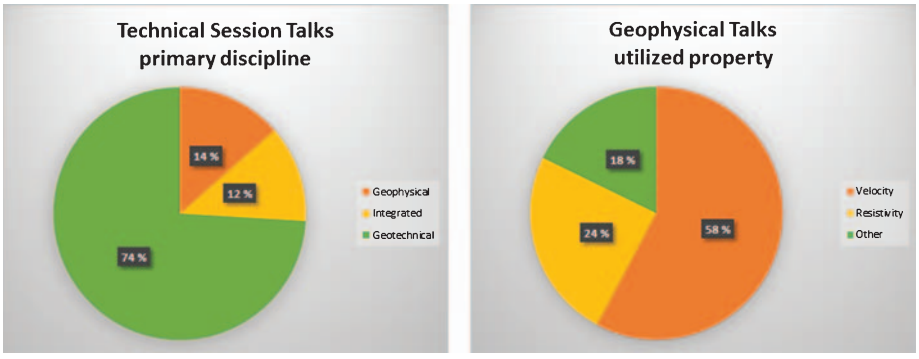


Figure 1. *ISC talks grouped by discipline and geophysical techniques.*

ASEG-PESA-AIG 2016

Reflections

The 25th Geophysical Conference and Exhibition was a landmark occasion on many levels. It was the 25th Conference and Exhibition, fittingly back in Adelaide where it all began. It was also the first ASEG conference held in the newly renovated Adelaide Convention Centre and the first conference involving the Australian Institute of Geoscientists; the first ASEG-PESA-AIG conference.

Here are some statistics from the conference:

- 712 delegates
- 87 exhibitors
- 10 conference sponsors
- 22 keynote presentations
- 133 regular oral
- presentations
- 43 posters
- 12 workshops
- 7 official social events.

Adelaide's August weather behaved itself and after a couple of days of workshops the conference began with opening drinks in the exhibition area on the Sunday afternoon. The great food and drink continued for three more days, including the conference dinner at the newly refurbished Adelaide Oval with stunning views of the Oval and North Adelaide.

The conference theme 'Interpreting the Past, Discovering the Future' was a nod to where we are now, not just as societies, but as geoscientists. Many of us find ourselves revisiting legacy data, reprocessing, and reinterpreting. Our conference logo was split into two halves: the greyscale past and colourful future. The wavefront pattern, the colour scales used, the layers of the circle representing layers of the Earth, the fault in the rock: all nods to the geophysical world.

Some highlights of the conference were:

- Professor David Blair's amazing keynote address on the discovery of gravity waves
- Dennis Conway and Victoria Seesaha winning the EAGE geoquiz night – enjoy your trip to Paris!
- Carmine Wainman winning the exhibitor passport prize
- Dr Ted Tyne's remarks on 25 ASEG conferences at the closing ceremony.

The Conference Organising Committee have received much praise for the conference, which has been greatly appreciated. We worked our hardest to deliver an enjoyable conference for all. The post-conference survey indicated that the vast majority of delegates and exhibitors were very pleased with how the event went. Thank you to everyone involved in organising this major conference and exhibition at a time which was economically very difficult.

We hand the baton to the NSW branch of the ASEG, and wish them all the best of luck for the Sydney Conference in early 2018. While the title of the next conference will change, registrants can be assured that all the aspects of the ASEG conference that they love will still be there, whether it be catching up with colleagues, clients and contractors, seeing the latest geophysical innovations in the exhibition hall or the technical geophysical presentations at the oral sessions.

On behalf of the 2016 Conference Organising Committee,
Philip Heath and Luke Gardiner (Co-chairs)

The 2016 Conference Organising Committee on stage during the closing plenary.

ASEG honours and awards

ASEG Gold Medal: Professor David Boyd

The ASEG Gold Medal is awarded from time to time for exceptional and highly distinguished contributions to the science and practice of geophysics by a member, resulting in wide recognition within the geoscientific community. Professor David Boyd was awarded the ASEG Gold Medal in 2016 for his outstanding achievements in his long professional career and in the education of generations of geophysicists, and for his successes in promoting the effective integration of aeromagnetics in geological mapping and exploration.

David entered Glasgow University in 1943 after a mildly disrupted secondary education during World War II. Alongside Natural Philosophy (Physics) he took geology, having been too late to join the Chemistry stream. This stroke of luck resulted in a double Honours in Natural Philosophy and Geology – a first for Glasgow University and the beginning of a most fruitful career trend.

After graduation in 1946, David became a Lecturer in the new science of geophysics and spent nine years teaching and conducting exploration field work in the UK, Iceland, and the Rift Valley in Uganda. He then spent two years with mining engineers, John Taylor and Sons working on many mines in the UK and also in Cyprus during the EOKA paramilitary uprising. Falling metal prices prompted a successful application for a geophysicist position at Hunting Geology and Geophysics in 1956. Thus began twelve very busy, productive and happy years working predominantly on large airborne magnetic projects worldwide. This work included extensive petroleum surveys for major oil companies in many parts of the world, including Australia. The integration of aeromagnetics with geology for mineral exploration was developed in Ghana, where excellent mapping existed, and refined in Uganda where David could work directly with geologists who were mapping in synchronisation with the airborne survey. The Hunting's era culminated in David's landmark paper at the Canadian Centennial Mineral and Ground Water Conference in Niagara in 1967; 'The contribution of airborne magnetic surveys to geological mapping', still a compelling read!

Eventually David decided to return to the more settled academic life. Fortunately for us he accepted a post as the new Chair of Geophysics in Eric Rudd's Department of Economic Geology at Adelaide University in 1969. His main focus was nurturing honours graduates who would be sought after by the mining industry. This has resulted in a 'breed' of geophysicists who have become leaders and achievers in the exploration industry. While best known for his passion for aeromagnetics and the accompanying emphasis on 'hard-rock' geology, many of his graduates have made their mark in the oil and gas industry, in seismic research, well logging and as founders and operators of successful exploration companies.

In the mining industry, David's students include company founders, ore-body discoverers as well as high profile researchers and company geophysicists. During his term as Professor, David attracted many interstate and international students to pursue post graduate research at Adelaide University. In particular his female PhD graduates from India, China and Poland have each made major contributions to worldwide geophysics. Another great contribution to the mining industry was the Australian Mineral Foundation course, Geophysics for Geologists, which David helped initiate and actively supported for many years. Over 600 geologists in Australia and overseas attended this course in the 1970s, 80s and 90s. This did much to bring the two disciplines together and had a significant impact on the Australian exploration culture.

David's research was predominantly through his students' projects, as shown in his publication list, but he has had a strong personal interest in the mafic dyke patterns in Australia. He was an advisor on many Government airborne survey programmes, including the South Australian Exploration Initiative which became a watershed in the application of aeromagnetic and radiometric surveys in Australia. He nurtured relationships with the airborne geophysical industries in Finland, India, China and Africa and was a frequent visitor to these countries, as guest lecturer and counsel.

Whilst Professor of Geophysics at Adelaide, he was appointed Dean of the Faculty of Science, then invited to chair the University's Education Committee. He also served as Acting Vice-Chancellor in 1982–83. He was elected President of the Geological Society of Australia (1986–87) during which time he agitated for a revival in geological mapping. Government mapping and aeromagnetic surveying flourished in Australia soon after this. Outside of geoscience, David was Chairman of the Animal Ethics Committee for the University of Adelaide Departments of Science, Medicine and Dentistry, and for the Waite Institute (1983–92), and was Chairman of the organising committees for ANZAAS congress in 1991 and 1997.

After retirement in 1992, David continued his involvement with geophysics students at Adelaide University and maintained his interest and enthusiasm for aeromagnetic applications. He continues today as advisor to Archimedes Consulting, a company created by one of his overseas PhD graduates, specialising in potential field applications for oil and gas exploration and deep crustal sensing.

David's hallmarks have been his enthusiasm and wisdom. His ability to inspire students to passionately pursue careers in geophysics and exploration has created a legacy that will be long-lived. He has not been the 'typical' geophysicist or geophysical professor but has forged a path that has brought geophysicists and geologists together in all manner of geoscientific endeavours. To his former students and professional associates, he remains a teacher, a mentor, a respected colleague and, most of all, a friend.

David was awarded Honorary Membership of the ASEG in 1997 for his outstanding contribution to the profession to that time, and it is only fitting that David's personal achievements, his positive influence on so many other members of the profession, and his distinguished career spanning 70 years, should now be recognised with the award of the ASEG Gold Medal.

Editor's note: for more information and images about Professor Boyd's career visit www.ageg.org.au/events.

Professor David Boyd speaking after receiving the ASEG Gold Medal.

Grahame Sands Memorial Award: Des Fitzgerald

The Grahame Sands award is based on an endowment made by Members of the ASEG and the geoscience profession in memory of the late Grahame Sands, who was tragically killed at the prime of his life in an aircraft crash in 1986, whilst developing and testing new equipment for geophysical survey aircraft. Because of Grahame's abilities to turn scientific theory into innovative application, the award is made for innovation in applied geophysics through a significant practical development of benefit to Australian exploration geophysics in the field of instrumentation, data acquisition, interpretation or theory.

The Grahame Sands Award for 2016 is presented to Dr Des Fitzgerald in recognition of Des' leadership and significant personal involvement in directing the development of the Intrepid Geophysical Processing System into an internationally renowned system for the processing of potential field and radiometric data.

Des graduated from the University of Melbourne in 1971 and completed his PhD in 1977. He founded Des Fitzgerald & Associates in 1978. Over the decades since that time, Des has been a great ambassador for Australian geophysics, the ASEG and his company. Des led the development of the Intrepid Geophysical Processing System, which began with an amalgamation of the successful BHP Pitts and BMR ARGUS geophysical processing systems, but under Des' leadership was developed into a world class, flexible, adaptable system to allow both GUI-based interactive and batch processing of potential field and radiometric data. The geophysics behind the software is very robust, due in no small part to Des' personal involvement in the writing and testing of the software.

As well as the Intrepid data processing system, Des has been instrumental in the development of the Jetstream data management and delivery system, which is at the core of the GADDS data delivery system used to deliver geophysical data collected by Geoscience Australia and state and territory surveys to the exploration industry. In addition, the Geomodeller software, initially developed by the BRGM (GeoFrance3D), was significantly enhanced under Des' leadership to invert geological field measurements to produce a geological model, in association with additional field geology observations. Combinations of implicit functions calculate the model from the interpreted geophysics and field geology observations. Testing and improving the 3D geology model is achieved via forward and potential field inversions.

The international success of the Des' software is testimony to the ability of the Australian geophysics industry to create solutions and a range of practical tools with universal application, making the software a major promoter of innovative Australian geophysics.

Des is generous with his time in helping students both from within Australia and overseas and with advice to practicing geophysicists and geologists. He shares his knowledge and experience in the geophysical community, regularly presenting at ASEG and other conferences, publishing numerous papers and encouraging his colleagues to publish their works. He has represented the ASEG at overseas conferences on a number of occasions. Des also chairs GeoJAG Australia, an association of companies and public sector organisations exporting a wide range of geoscience services. He was an early participant in setting up the Uncover initiative.

Des continues to bring new and innovative approaches to his software, in so doing helping Australian potential field and radiometric geophysics to flourish. He travels the world in search of new ideas and incorporates them into his software, thereby making the ideas available to Australian geophysicists. On this leading edge, Des has helped champion a 2.5D AEM solution for complete surveys, as well as a patented tensor gridding algorithm, as part of a comprehensive processing and interpretation system for vector and tensor observed gradients.

Through collaboration with government, university and company research organizations, Des has been able to bring new, innovative developments in geophysics to a much broader range of users through rapid development, enhancement and commercialization of new ideas.

Des is not only an excellent software engineer, he is also an outstanding geophysicist who has been able to turn scientific theory into innovative application, resulting in many internationally recognised products of practical benefit to Australian and international exploration geophysics. He is a worthy recipient of the ASEG Grahame Sands award.

Des Fitzgerald after receiving the Grahame Sands Memorial Award.

Shanti Rajagopalan Memorial Award: Camilla Sørensen

The Shanti Rajagopalan Memorial Award, inaugurated in 2013, is presented for the best paper published by a Student Member in *Exploration Geophysics* in the period prior to each ASEG Conference.

The award is named in memory of the late Dr Shanti Rajagopalan, who passed away in 2010. Shanti was one of the best known and respected members of the ASEG, and was well known within the geophysical profession for her outstanding contributions and service to the profession, and to the ASEG.

Shanti was a major contributor to the ASEG in many ways. She was Victorian branch President, and was actively involved in the organisation of ASEG conferences in Hobart and Melbourne. She was also Managing Editor of *Exploration Geophysics* in 2000 and 2001.

But it is most noteworthy in the context of this award that, in 1987, as a Student Member, Shanti received the inaugural Laric Hawkins Award for the most innovative use of a geophysical technique from a paper presented at the ASEG Conference. It is therefore very appropriate that an award to encourage technical excellence by our Student Members is named in honour of Shanti.

The winner and recipient of the Shanti Rajagopalan Memorial Award for 2016 is Camilla Sørensen, for her paper co-authored with Tim Munday and Graham Heinson entitled 'Integrated interpretation of overlapping AEM datasets achieved through standardisation'. The paper was published in *Exploration Geophysics*, **46**, 309–319.

Camilla has been completing a PhD at the University of Adelaide on Airborne Electromagnetic methods, specifically working on improving the conductivity-depth information that can be extracted from historical AEM datasets. She expects to complete her PhD during the latter half of 2016. She is currently working at CSIRO in Perth as a research scientist.

Camilla Sørensen receiving the Shanti Rajagopalan Memorial Award from ASEG President Katherine McKenna.

Honorary Membership of the ASEG: Doug Roberts

ASEG Honorary Membership has been conferred upon South Australian Branch Member Doug Roberts, in recognition of his distinguished career and outstanding contribution and leadership in geoscience spanning 40 years, and for his most valuable contributions to the ASEG over many years.

After graduating from Adelaide University with a BSc(Hons) in geology and geophysics in 1971, Doug worked initially as a geologist with Gold Copper Exploration Ltd in the Flinders Ranges and North Queensland, and as a demonstrator in geophysics at Adelaide University with Professor David Boyd. From 1974–1978, he worked as a geophysicist with the SA Department of Mines, prior to joining the SA Oil & Gas Company, leading to his long association with the SAGASCO/Boral/Origin Energy group from 1978 to 2000. He became Chief Geophysicist and subsequently Manager – Exploration Operations during this time.

He worked as a consultant geophysicist from 2000–2003 before joining Beach Energy as Operations co-ordinator and subsequently in 2012 was appointed Manager for Geophysics and Land Access.

During his career, he has contributed to the development of seismic acquisition and processing techniques suitable for a variety of Australian conditions, and he has worked to improve the quality and resolution of the resulting seismic data. At the same time Doug has pioneered various methods to minimise the environmental impact of seismic operations in remote areas of Australia (particularly the Cooper/Eromanga Basins), and in more densely populated rural areas of Australia (notably the South Australian and Victorian Otway Basin).

He has also endeavoured and succeeded in fostering very good working relationships with the Native Title groups associated with the exploration activities. He is a long-term member of the Petroleum Data Consultative Group, composed of representatives from Government, Industry and APPEA, and for many years a contributor to APPEA's Exploration Committee Data Working Group.

During his entire career Doug has been an active supporter and participant in many ASEG committees and activities, and has striven to promote the aims of the society. He has been a Member since 1973, and served on the SA Branch committee from 1975 to1990 including secretary for several years.

He has contributed directly to ASEG Conferences through his roles on the organizing committees for all seven ASEG conferences held in Adelaide since 1979, up to and including the 2016 conference. He is one of the white jacket brigade, those rare members who have attended all 25 ASEG conferences in Australia so far. Doug has also served on the ASEG Research Foundation Committee since 1990, and has undertaken the important role of secretary since 1995.

Doug was awarded an ASEG Service Certificate in 1998 in recognition of his significant contributions to the society at that time. It is very fitting that the ASEG now recognises Doug's continuing outstanding contributions to the ASEG, and to the geophysics profession, with the award of Honorary Membership of the ASEG.

Doug Roberts.

Honorary Membership of the ASEG: Mark Lackie

ASEG Honorary Membership has been awarded to Dr Mark Lackie, in recognition of his sustained and exceptional service to the ASEG over many years, and for his leadership in the education of geophysics at Macquarie University since 1994.

Mark graduated with a BSc(Hons) from Melbourne University in 1982, and completed his PhD on palaeomagnetism at Macquarie University in 1989. He was appointed as lecturer at Macquarie University in 1994 and has been there ever since.

Mark became a Member of the ASEG in 1981, and has been a consistent supporter and contributor to his State Branch since that time. Of note he has served as NSW Branch President since 2007 to the present, and he has made significant contributions to ASEG conferences, with his outstanding Co-Chairmanship of the Organising Committee of the 2010 ASEG-PESA International Conference and Exhibition, setting a benchmark for future conferences. In 2018, ASEG will again hold the convention in Sydney, and Mark has once again stepped forward to serve the society as co-chairman of the Organising Committee.

But it is Mark's ongoing efforts and contribution to ASEG Publications that have had a major impact on the Society. He took on the role of Managing Editor of *Exploration Geophysics* in 2009, a role that is pivotal to maintaining the Society's vital professional journal *Exploration Geophysics* on behalf of all Members of the Society. The Managing Editor is involved in developing journal strategy, scope, quality and direction, as well as overseeing the routine management of manuscripts, making editorial decisions on content of each publication, and liaising with Associate Editors and publisher. Through his diligence in this role, Mark has continued to develop and enhance the scientific quality and international reputation of the journal, as reflected in the 2016 Impact Factor figure for *Exploration Geophysics*, which showed a significant increase on the previous year.

The award also recognises Mark's leadership in the education of geophysics at Macquarie University from 1994. Mark is a Senior Lecturer and currently Director of Teaching in the Department of Earth and Planetary Sciences at

Macquarie University. His leadership in the education of numerous students in geophysics who have passed through Macquarie University from 1994 to 2016, and his valuable research activities no doubt have had a major influence on the future well-being of our industry.

Mark's research interests span a broad area of geophysics beginning with palaeomagnetism in his early career. More recently Mark's investigations have ranged from using magnetic and density measurements to validating the interpretation of potential field signatures of granitoids, and regional scale gravity modelling of basins. Mark has co-authored papers from diverse fields such as crustal architecture, geothermal gradients, seismic studies of the Amery Ice Shelf, Antarctica to the environmental control of magnetic properties of sediments near the Great Barrier Reef.

Mark maintains a high enthusiasm for student excursions, which is a disappearing attribute of some tertiary institutions. Mark has supervised a number of postgraduate students again with a strong focus on practical field studies. In addition to his teaching and research activities, he has been a strong supporter of ASEG grants to students to attend relevant courses and conferences.

For his outstanding contributions to the Society and his leadership in the education of geophysics, the ASEG is pleased to confer the award of Honorary Membership to Mark Lackie.

Mark Lackie thanking the ASEG for giving him Honorary Membership.

ASEG Service Certificate: Peter Milligan

Dr Peter Milligan has been awarded an ASEG Service Certificate for distinguished services to the ASEG over 28 years, in particular for his contributions to the ASEG through involvement in State Branch Committees, Conferences, Publications and Workshops.

Peter graduated from Flinders University of South Australia with a BSc(Hons) and DipEd in 1975, and in 1989 was awarded a PhD for his research in geomagnetism. Upon graduation in 1975, he taught science and maths in high schools before joining the Geomagnetism Section of Geoscience Australia (then the Bureau of Mineral Resources) in 1985. From 1986 to 1999 Peter worked with the Airborne Group, participating in airborne magnetic and radiometric surveys, and conducting research into the significance of micropulsations as a noise source in airborne magnetic data. Later research resulted in the production of a new Magnetic Anomaly Grid Database of Australia and the associated Magnetic Anomaly Maps of Australia. From 2007 to 2014 Peter helped establish the capability of Geoscience Australia to acquire regional magnetotelluric surveys across Australia. Peter retired from Geoscience Australia in 2014 as an Executive Level Senior Geophysicist.

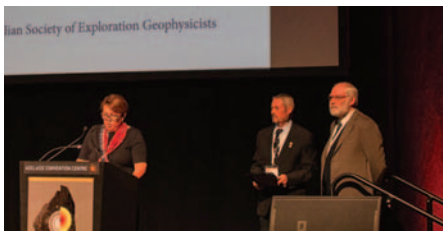
Peter has been a long-time contributor to the local ACT Branch of the ASEG. He has been a Branch Member since 1988, and a member of the Branch Committee for over 15 years, serving as Treasurer from 1996 to 2002.

Peter has also played an important role over many years in supporting the ASEG's goal of being a learned society, by virtue of his efforts in reviewing abstracts and geophysical papers for *Preview* and *Exploration Geophysics*.

Peter has attended and presented scientifically significant oral presentations, workshops and posters at ASEG conferences since 1985. In addition, he has represented the ASEG at many international conferences and meetings, and has assisted on conference organising committees including Melbourne in 2013.

Peter has represented the ASEG formally and informally through his scientific work. Since 2005, he has been on the Task Force of the World Digital Magnetic Anomaly Map and was a member of the Executive Committee. He has had an active role in implementing data acquisition and data quality standards worldwide, and contributing to new research in this area.

Peter continues to be an active member of the ACT Branch community. The ASEG recognises these achievements and significant contributions to the profession with this ASEG Service Certificate.



Peter Milligan (far right) listening to his citation being read by ASEG President Katherine McKenna.

ASEG Service Certificate: Kathlene Oliver

An ASEG Service Certificate has been awarded to Kathlene Oliver, the WA State Branch President, for her distinguished contributions over many years to local ASEG branch activities, both in Qld and WA.

Kathlene graduated from Macquarie University in 1994 with a BSc(Hons), majoring in Geophysics with Geology. She started her career in Environmental Geophysics acquiring, processing and interpreting geophysical datasets for the detection of environmental contamination and unexploded ordnance. Following this she worked in Petroleum Geophysics where she was involved in the acquisition and processing of 2D and 3D land and marine seismic datasets. She then moved into Mineral Geophysics working with Geophysical Technology Ltd, Geoforce, and Fugro Airborne Surveys before taking on the role of Managing Director of Fugro Ground Geophysics in 2009. She was a Founding Director of the Ground Geophysical Survey Safety Association Ltd in 2013, a not-for-profit association formed in response to particular concerns over safety on ground electrical surveys.

She subsequently completed an MBA at Murdoch University specialising in Economic and Environmental Sustainability, following which she joined the WA State Government in 2015 in her current regulatory role in the Department of Mines and Petroleum.

Kathlene joined the ASEG in 1995, and soon after became part of the local Branch Committee. She was Qld Branch Secretary from 1998–2002, and was involved in the Brisbane ASEG conference in 2001.

After moving to WA, Kathlene joined the local Committee and became State

Branch President in 2014. Since taking on this role she has organised and facilitated many excellent meetings presenting quality work in all aspects of geophysics, whilst providing networking opportunities to the Members. Throughout this, she has managed to create a very participating environment with healthy scientific debates.

Kathlene has brought a lot of energy and passion to the WA branch. Through her leadership she has championed the cause of diversity and inclusion, and has brought much vigour to the State Branch networking events. She is a worthy recipient of the ASEG Service Certificate for her past and ongoing contributions to the Society.

Kathlene Oliver.

ASEG Service Certificate: Wendy Watkins

An ASEG Service Certificate has been awarded to Wendy Watkins, for distinguished contributions to State Branch committees, conferences, and in particular for her significant contribution to the education activities of the ASEG as Chair of the ASEG Education Committee.

Wendy graduated from Flinders University in South Australia with a BSc (Hons) majoring in Geophysics. She joined ASEG in 1993 and whilst working as a geophysicist for Santos in Brisbane she was part of the Queensland State Branch Committee for several years, as well as the Conference Organizing Committee for the 2001 Brisbane Conference. After a few years out of geophysics, she returned to the profession in 2007, re-joining the oil industry with Velseis, Origin Energy and MBA Petroleum Consultants in Brisbane, and subsequently with AGL in Sydney.

Since 2013, Wendy has been an active member of the ASEG Federal Executive and Chair of the Education Committee. Her main task and contribution over this time has been to oversee all the training programmes for ASEG, including SEG's DISC and Distinguished Lecturer programmes, and EAGE's Education Tours.

When ASEG started its own OzSTEP programme, Wendy organised distinguished lecturer tours throughout the country in association with the State Branches. Her capable administration was appreciated by the Members attending the courses, and also by the State Branch organisers and the OzSTEP lecturers.

Her leadership and enthusiastic participation in these activities is a guiding example to all geophysicists, especially to those who may consider a career elsewhere when the industry experiences a hard time. The award of the ASEG Service Certificate is in recognition and appreciation of these valuable contributions to the Society.

Wendy Watkins receiving her award from ASEG President Katherine McKenna.

Early Achievement Award: Mojtaba Rajabi

The Early Achievement Award was inaugurated in 2007 in order to acknowledge significant contributions to the profession at an early stage in a person's career, by way of publications or professional work by an ASEG Member under 36 years of age.

The Early Achievement Award has been awarded this year to Mojtaba Rajabi of Adelaide University for his outstanding contributions through research and publication to our understanding of contemporary tectonic stress fields in Australia and the Earth.

Mojtaba Rajabi graduated as the top of his class in both his BSc (2006) and MSc (2009). After doing his compulsory military service, he undertook research work in Iran. In 2012, he was awarded a prestigious Adelaide Scholarship (International) to do his PhD at the University of Adelaide.

During his PhD he has also undertaken part-time work for Ikon Science (formerly JRS Petroleum Research), and completed significant extra research projects for the World Stress Map Project in Germany. Mojtaba will complete his PhD in 2016.

Mojtaba has already achieved an amazing reputation in petroleum geomechanics and geophysics over his short career. Before he has even completed his PhD, he has published 12 fully peer-reviewed papers including nine in journals such as *Tectonophysics*, *Journal of Geophysical Research*, *Computers & Geosciences* and *Basin Research*, and he has four more manuscripts submitted for review. He has authored or co-authored over 30 conference papers, including four extended abstracts published at ASEG and EAGE conferences.

His research has received 10 awards, including the prestigious Louis Cagniard Award for best poster presented at the 2015 EAGE international conference, and the Hugh Crocker Award from the Formation Evaluation Society of Australia. His research has also been widely read and utilised, with his publications being cited in over 60 other papers.

Furthermore, Mojtaba has made a remarkable contribution to our global knowledge of present-day stress, personally analysing over 1000 wells, which is more than any other person in the 30-year history of the World Stress Map Project. His work has revolutionised our understanding of contemporary stress in Australia, and his expertise in the field has been recognized by his numerous invitations to review papers for professional journals, and to give featured talks.

For his extraordinary contributions to the profession to date, Mojtaba is certainly a worthy recipient of the ASEG Early Achievement Award.

Mojtaba Rajabi.

Conference and exhibition awards, sponsored by First Quantum

Best Oral Paper: Minerals

Regis Neroni: Application of the airborne electromagnetic method for banded iron-formation mapping in the Hamersley Province, Western Australia

Best Oral Paper: Petroleum

Konstantin Galybin: Multi-azimuthal walkway VSP for full azimuth seismic calibration

Best Oral Paper: Near Surface/Engineering

Tim Munday: Uncovering the groundwater resource potential of Murchison Region in Western Australia through targeted application of airborne electromagnetics

Best Student Oral Paper: Minerals

Janelle Simpson: Interpreting the Eromanga and Georgina Basins from magnetotelluric data

Best Student Oral Paper: Petroleum

Stephanie Tyiasning: Uncovering seismic HTI anisotropy of the Cooper Basin

Best Student Oral Paper: Near Surface/Engineering

Roderick Lawrence: Finding bedrock in uncontrolled clayey fill – success with GPR profiling

Best Poster Paper: Minerals

Clive Foss, Tania Dhu: The bark without a dog – magnetic anomalies over holes in a volcanic sheet in the greater McArthur Basin, NT

Best Poster Paper: Petroleum

Irena Kivior, Stephen Markham, Leslie Mellon: Mapping sub-surface geology from magnetic data in the Hides area, Western Papuan Fold Belt, PNG

Best Poster Paper: Near Surface/Engineering

Marina Costelloe et al.: Geoscience Australia's geophysical network: critical infrastructure and observed and derived data for earth monitoring and community safety

Best Student Poster Paper: Minerals

Paul Soeffky, Graham Heinson, Stephan: Thiel The electrical resistivity of the Australian lower crust

Best Student Poster Oral Paper: Petroleum

Alexander Robson, Rosalind King, Simon Holford: Analysis of gravity-driven normal faults using a 3D seismic reflection dataset from the present-day shelf-edge break of the Otway Basin, Australia

Best Student Poster Oral Paper: Near Surface/Engineering

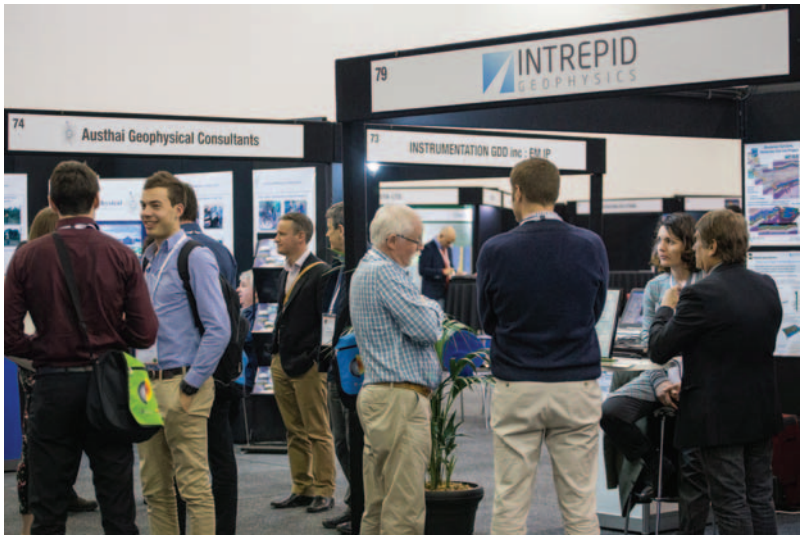
Joseph Rugari, Graham Heinson, Dennis Conway: Electrokinetic monitoring groundwater flow in fractured rock media

Best Exhibitior

Terrex Seismic

Laric Hawkins Award: For the most innovative use of a geophysical technique from a paper presented at the ASEG Conference

Alison Kirkby, Graham Heinson, Lars Krieger: Relating electrical resistivity to permeability using resistor networks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GA: update on geophysical survey progress from the Geological Surveys of Western Australia, South Australia, Northern Territory, Queensland and Victoria (information current on 9 September 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
Gawler – PACE area	GSSA	GA	TBA	TBA	1 800 000	200 m 60 m NS or EW	324 000	TBA	TBA	183: Aug 2016 p. 34	The Quotation Request for the first tranche of surveys is in the final stages of preparation
Coonabarabran	GSNSW	GA	TBA	TBA	~50 000	250 m 60 m EW	11 000	TBA	TBA	This issue (Figure 1)	The Quotation Request is in preparation by GA in collaboration with GSNSW

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	TBA	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	Atlas Geophysics	Late July 2016	Approx 17 000 in 2 separate areas	2500 m regular grid	103 000	TBA	TBA	This issue (Figure 2)	The current survey covers the Nabberu, Wiluna and Sir Samuel Standard 1:250 000 map sheet areas. The survey was 53% complete on 3 September
East Kimberley Airborne Gravity Survey	GSWA	GA	TBA	Sep–Oct 2016	38 000 line km	2500 m line spacing	82 690	TBA	TBA	This issue (Figure 3)	The proposed survey covers the Medusa Banks, Cambridge Gulf, Lissadell, Gordon Downs, Mount Ramsay and Lansdowne standard 1:250 000 map sheet areas
Daly Basin	NTGS	GA	Atlas Geophysics	13 Jul 2016	2537	Regular grid of 4, 2 and 1 km	35 730	6 Aug 2016	TBA	182: Jun 2016 p. 22	The proposed survey covers parts of the Cape Scott, Pine Creek, Port Keats, Fergusson River and Katherine Standard 1:250k map sheet areas
Coompana – PACE area	GSSA	GA	TBA	TBA	15 362	Regular grid of 2, 1 and 0.5 km	100 000	TBA	TBA	183: Aug 2016 p. 34	TBA

TBA, to be advised.

Table 3. AEM surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Musgraves – PACE Area	GSSA	GA	CGG Aviation	18 Aug 2016	8489	2 km; E–W lines	16 371	The survey was 45% complete to 8 Sep 2016	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	Mid Sep 2016	7182	2 km; E–W lines	14 320	The survey mobilised on 10 Sep 2016	TBA	179: Dec 2015 p. 23	The proposed survey covers parts of the Woodroffe, Alberga, Lindsay and Everard Standard 1:250 000 map sheets
Isa Region	GSQ	GA	Geotech Airborne	8 Aug 2016	15 692	2 km; E–W	33 200	The survey was 45% complete to 6 Sep 2016	TBA	182: Jun 2016 p. 23	The survey covers the Dobbyn, Cloncurry, Julia Creek, Duchess, McKinlay, Boulia and Mackunda Standard 1:250 000 map sheets

TBA, to be advised.

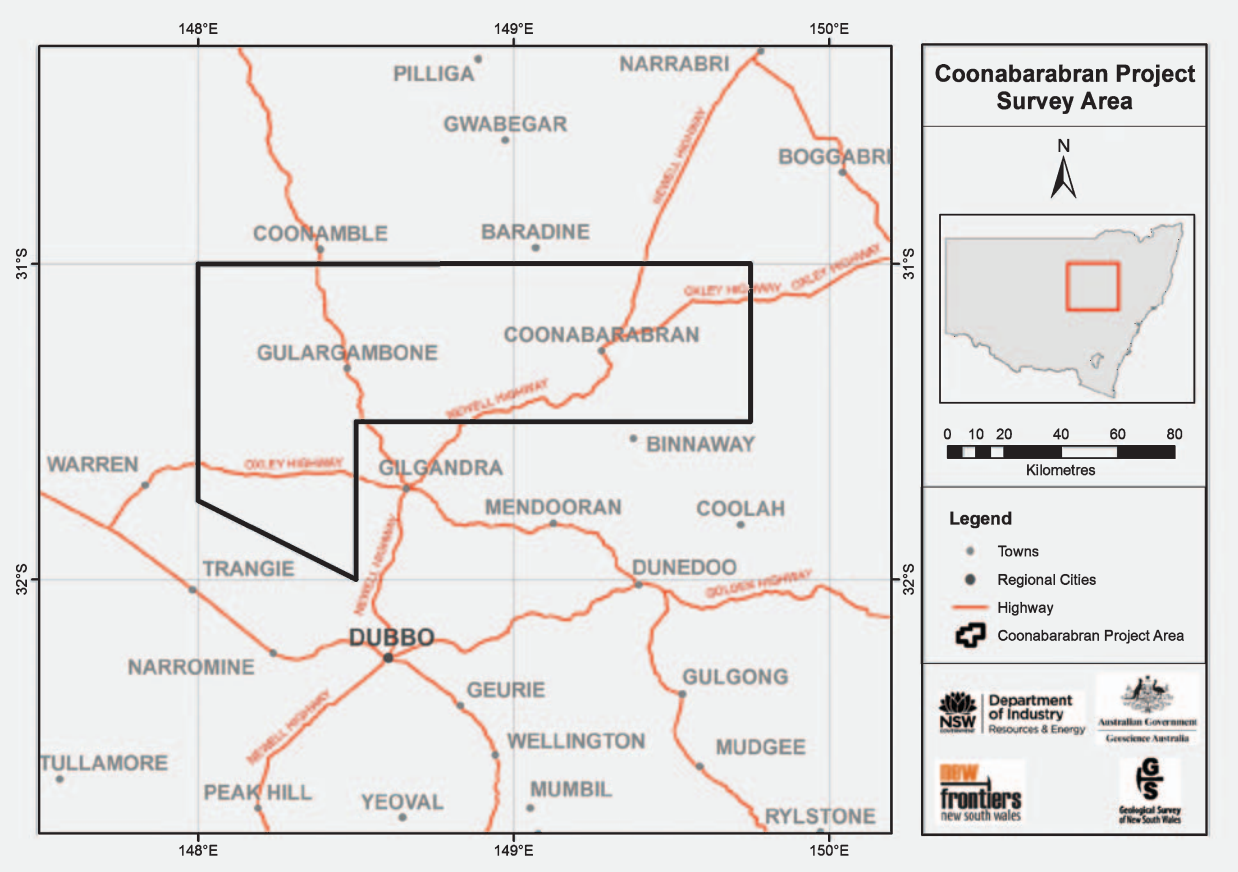


Figure 1. *Proposed Coonabarabran airborne magnetic-radiometric survey.*

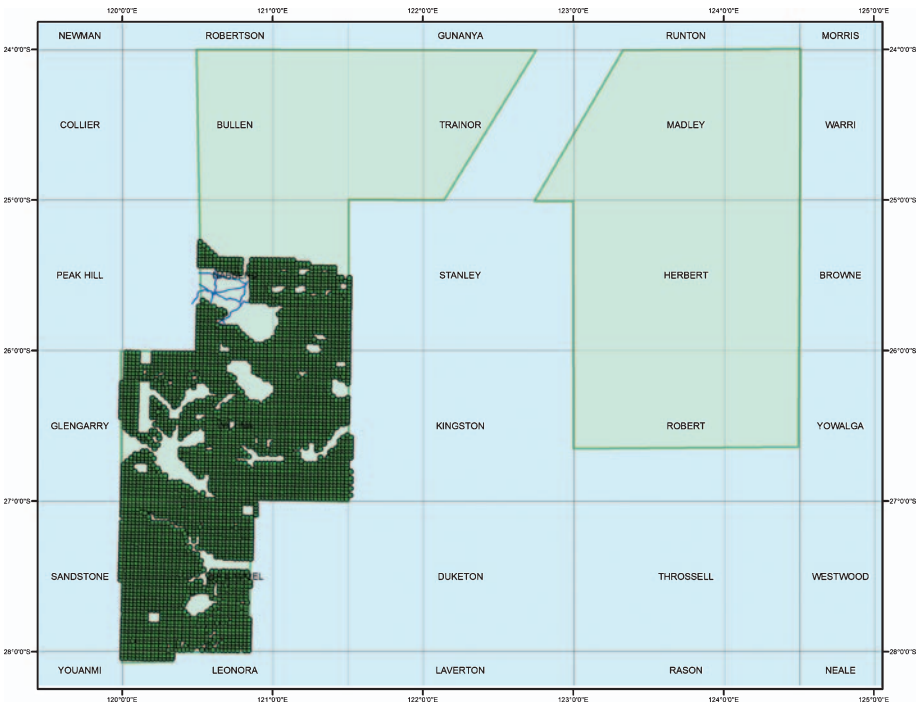


Figure 2. *Wiluna gravity survey.*

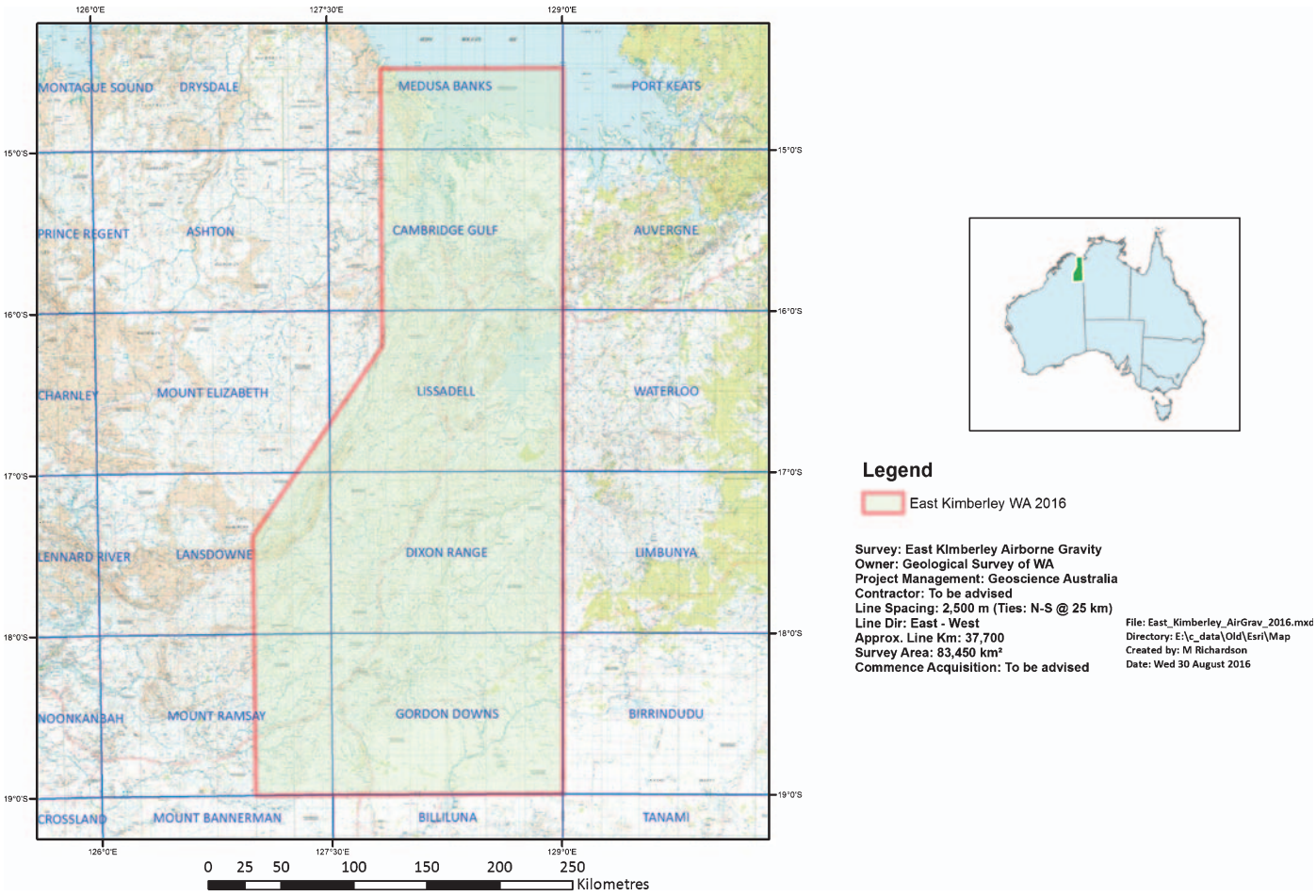


Figure 3. *Proposed east Kimberley airborne gravity survey.*

Mineral Resources Tasmania: new $1.4 million Geoscience Initiative Programme

In the most recent State Budget, a four-year, $1.4 million Geoscience Initiative Programme was assigned to Mineral Resources Tasmania, designed to improve Tasmania's capability to attract investment in mineral exploration and development. A portion of this funding will result in a significant addition to modern pre-competitive airborne geophysical survey coverage in Tasmania, which is substantially incomplete (see Figure 1). The new data is likely to retain the same 200 m line spacing and nominal 80 m terrain clearance that characterises almost all of Tasmania's extant regional surveys. Further details will appear in the next edition of *Preview*.

AusLAMP magnetotelluric data acquisition, co-sponsored by Mineral Resources Tasmania, is now being completed, with the final instrument deployments and retrievals currently under way. QC and processing of the data obtained through the AusLAMP array and the two traverses at approximately 2 km station spacing undertaken as part of Thomas Ostersen's MRT-sponsored PhD research at the University of Tasmania (described in the April 2016 issue of *Preview*) is now proceeding.

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

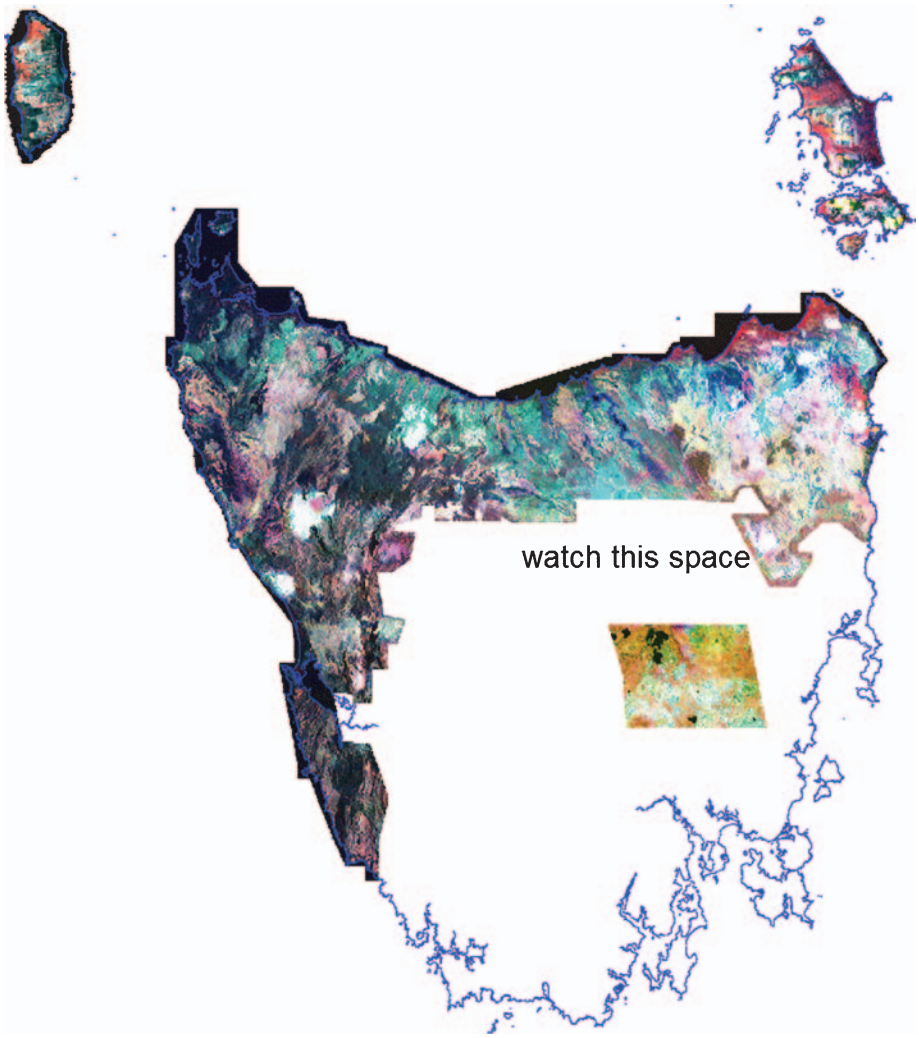


Figure 1. *Current radiometric survey data compilation for Tasmania.*

Geological Survey of South Australia: update on survey programmes

The Geological Survey of South Australia (GSSA) has had a busy couple of months. Much of their activity has been focused on the ASEG-PESA-AIG conference held in Adelaide in August 2016. Six presentations were delivered by GSSA staff, and a busy booth kept the 712 delegates informed of activities in SA.

We've been heavily involved with the design of the Gawler Craton Airborne Survey: re-flying the magnetics, radiometrics and DTM of the Gawler Province at 200 m line spacing. This survey will be undertaken in three phases, and will be the largest survey of this type ever conducted. As well as providing the exploration industry with world class exploration data the programme is expected to create jobs and support local businesses over the next few years.

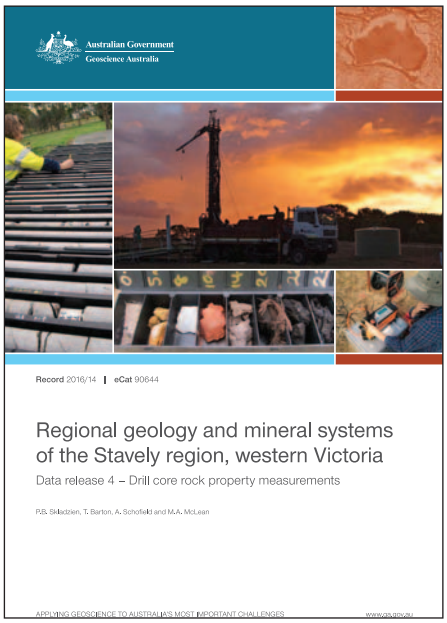
The GSSA has also been putting the finishing touches on a gravity programme in the far west of the state over the Coompana anomaly. This survey is designed as an aid to explorers and to help guide drilling activities in the region.

Prior to the drilling programme (and after the gravity survey) we are also planning a microgravity survey to delineate underground cavities that would pose a risk to the drilling in the area. This survey will be undertaken with a new CG5-HT gravity meter. The high-temperature instrument is especially suited to Australian conditions.

The next statewide gravity image is under construction and we are anticipating a release in late 2016. The new image is been constructed through a supervised variable density algorithm constructed by Laszlo Katona. For all the details please see the extended abstract in the ASEG-PESA-AIG conference proceedings.

Phillip Heath
Senior Geophysicist, Geological Survey of South Australia
Philip.Heath@sa.gov.au

Geological Survey of Victoria: Stavely Project update



A study of the regional geology and mineral systems of the Stavely region, western Victoria (the Stavely Project) continues to provide pre-competitive fundamental geoscience data to support the UNCOVER Initiative. Geoscience Australia and the Geological Survey of Victoria have collaborated to provide the fourth data release in a planned series of releases 'Regional geology and mineral systems of the Stavely region, western Victoria: Data release 4 – Drill core rock property measurements'. The report and accompanying data is now available from the Geoscience Australia website (http://www.ga.gov.au/metadata-gateway/metadata/record/90644).

This release provides the data and describes the methodology used to measure various rock properties (petrophysics) of the diamond core tails from thirteen of the fourteen Stavely Project stratigraphic drill holes. The scanning of core was undertaken by AuScope at their Australian Geophysical Observation System laboratory at Melbourne University. The data comprises measurements of density, magnetic susceptibility, P-wave velocity, resistivity and natural gamma for various rock types of the cover units and the Cambrian basement stratigraphy, and provides a valuable resource for constraining geophysical modelling, inversion and interpretation.

More information on the Stavely Project, including previous releases, can be accessed from Geoscience Australia's Stavely Project page (http://www.ga.gov.au/scientific-topics/minerals/unlocking-resource-potential/stavely-project) and from the Victorian Government (http://www.energyandresources.vic.gov.au/earth-resources/geology-of-victoria/gsv-projects/the-stavely-project).

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

Canberra observed

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

Minerals on road to recovery as petroleum plummets

In the August 2016 issue of *Preview*, I suggested that investment in minerals exploration was recovering. The June 2016 quarter data provided by the Australian Bureau of Statistics (ABS) confirms this observation. However, like all statistics there are several ways to look at the information.

The $354 million invested, Australia-wide, in the June quarter was $64 million more than in the March 2016 quarter and $10 million more than in the June 2015 quarter. However, the 'trend' estimate by the ABS still shows a drop of $7.1 million in the June 2016 quarter. The numbers are now very similar to those during 2005 (~$300 million, see *Preview*, August 2016, p. 35). The trend and seasonally adjusted ABS information are shown in Figure 1.

Gold is the dominant commodity. It accounts for $157 million of the $354 million, with iron ore ($77 million) and copper ($32 million) filling the second and third places. As you would expect, Western Australia is the leading state with a total investment of $228 million or a massive 64 percent of the Australian total. These numbers are a long way down from record $1148 million reached in the June 2012 quarter, but at least the future looks more positive than it did a year ago.

Petroleum

While mineral exploration may be recovering, petroleum is still declining rapidly. The actual quarterly expenditure fell to $283 million, the lowest it has been since June 2004 and well below the $1573 million invested in the June 2014 quarter. The trend estimate fell 19.4% (–$76.8 million) to $318.4 million and the seasonally adjusted estimate fell 30.8% to $295.3 million in the June quarter 2016. Whichever numbers you use the outcome is bad (see Figure 2). In trend terms, the onshore investment ($59.2 million) has not been as low since the December quarter 2003 and the offshore investment ($224.2 million) has not been as low since the June quarter 2006.

Western Australia is by far the most important state as far as petroleum is concerned, and although it experienced a fall of $127.9 million, or 38 percent, to $212.2 million, it still contributes 75 per cent of the total Australian investment. Unfortunately, with the oil price at less than US$50 a barrel, the re-bound could take a year or more to eventuate – unless Saudi Arabia starts cutting production.

Natural Gas Information 2016: a treasure trove of global information

Natural Gas Information 2016 is the latest edition of a publication on natural gas that has been produced annually since 1996 by the OECD/IEA team in France. It contains information on natural gas, in a global context, up to and including 2015, that relates to the production, storage, transport, reserves, price and many other parameters.

Natural gas is one of the success stories of the petroleum industry in the past 40 years. Figure 3 summarises the global production since 1973. This reached a record 3590 billion m^3 in 2015 and has more than doubled in the past 40 years.

Australia has been a standout performer, in 1973 its production was 4 billion m^3, and by 2015 it had grown to 66 billion m^3 with an annual production still increasing at more than 5 percent. On a global scale it is well short of the production rates from the USA (769 billion m^3) and Russia (638 billion m^3) but is nevertheless a very good record.

While global production increased in 2015 the prices fell dramatically and erratically. For European Union Members import prices by pipeline fell by an average of 27%, while in the United States they fell by 46%. The difference between the two prices was significant. In the US gas was about US$2.8/MBtu while in the EU it was close to US$7.0/MBtu, a significant difference. Prices for LNG showed a similar pattern with a drop of about 35% in Japan and Korea.

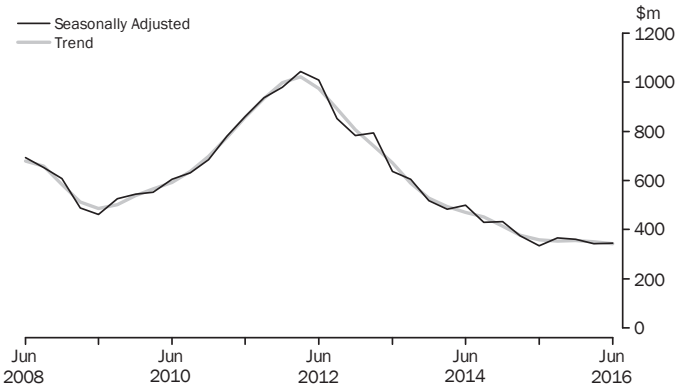


Figure 1. *Australian quarterly seasonally adjusted and trend data for mineral exploration investment for the period June 2008–June 2016 (courtesy Australian Bureau of Statistics).*

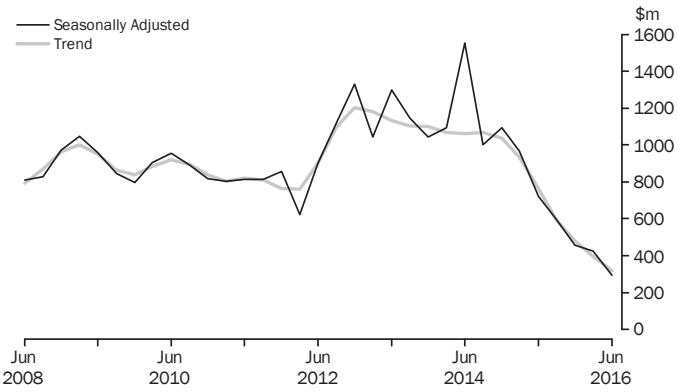


Figure 2. *Australian quarterly seasonally adjusted and trend data for petroleum exploration investment for the period June 2008–June 2016 (courtesy Australian Bureau of Statistics).*

The use of gas for power generation continued to increase (see Figure 4) apart from in 2014 when OECD usage dropped because of the very mild winter in the northern hemisphere. It will be interesting to see what the 2015 and 2016 data reveal as the globe continues to heat-up.

One of the many tables in the report relates to reserves. It turns out that at the end of 2014 global reserves were approximately 200 000 billion m^3 and Australia's is listed as 3700 billion m^3. These were unchanged from the end of 2013, presumably because when there are more than 50 years of proven reserves, there is not much point in frantically exploring for more.

Another table relates to storage capacity. This includes export terminal storage and geological storage. For Australia the working capacity is 6151 million m^3 and the peak daily output is 27 million m^3. Whether that is a good number or not I will leave to the strategic analysts.

What the report does not do is try to estimate the future demand for gas. For this information you have to read the International Energy Outlook (DOE/EIA-0484(2016) 1 May 2016) produced by the US Energy Information Administration. This publication is on the web at: www.eia.gov/forecasts/ieo.

Figure 5 indicates that the EIA estimates that consumption of natural gas worldwide will increase from 120 trillion cubic feet (Tcf) in 2012 to 203 Tcf in 2040. The assumptions are that by energy source, natural gas will account for the largest increase in world primary energy consumption. Because natural gas resources are abundant and its fuel efficiency is high it will remain a key fuel in the electric power sector and in other industrial sectors. Natural gas also burns cleaner than coal or petroleum products. As more governments begin to implement plans to reduce carbon dioxide (CO2) emissions, this may encourage the use of natural gas to displace more carbon-intensive coal and liquid fuels.

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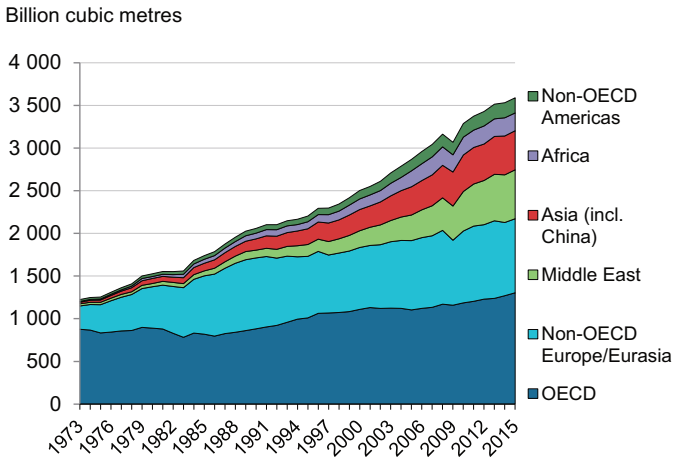

Figure 3. *Global natural gas production by region, courtesy of the International Energy Agency.*

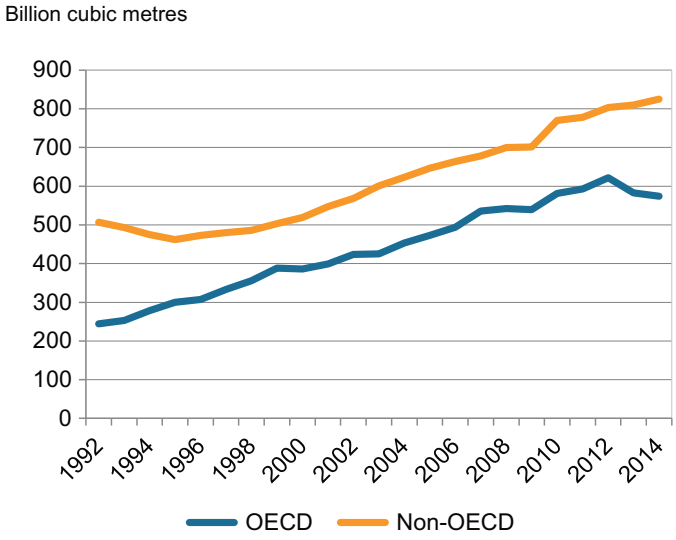

Figure 4. *Natural gas use for power generation 1992–2014, courtesy of the International Energy Agency.*

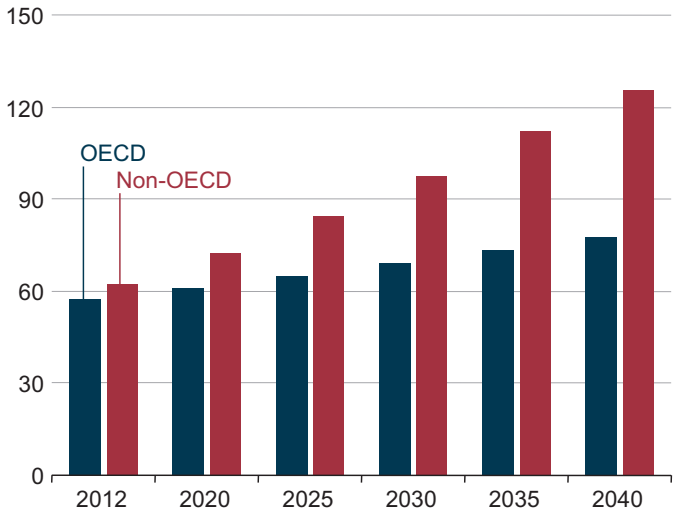

Figure 5. *World natural gas consumption, trillion cubic feet. Note: there are 0.0353 trillion cubic feet in one. Data courtesy of the U.S. Energy Information Administration.*

Education matters

Michael Asten
Associate Editor for Education
michael.asten@monash.edu

Australian Geoscience Council and Australian Academy of Science announce new round of travel grants

Another great opportunity arises for grad students and early career researchers, using proceeds of the very successful International Geological Congress held in Brisbane four years ago. Funds in the range $2000 to $5000 are available for conference or international travel for fieldwork or consultation with co-researchers. An online application form is available at http://www.agc.org.au/index.php/grants/154-igcfund. Applications close 31 October 2016.

Seven students receive awards at the 25th ASEG-PESA-AIG Conference

Congratulations to the students who received awards at our Adelaide Conference just concluded (see elsewhere in this issue of *Preview*). I was especially delighted to see University of Adelaide PhD student Alison Kirkby (with co-authors Professor Graham Heinson and Dr Lars Krieger) win the Laric Hawkins prize 'For the most innovative use of a geophysical technique from a paper presented at the ASEG Conference'. I am a great believer in the role of bright students making ground-breaking discoveries, and perhaps Alison's paper 'Relating electrical resistivity to permeability using resistor networks' will one day be seen in this category.

Alison Kirkby receives the Laric Hawkins prize from Dr Mike Hatch

It is not always easy for students to break new ground, and sometimes it is a thankless task if the innovation meets with resistance from peers or academia (see for example my column on Ted Irving of plate tectonics and palaeomagnetic fame, in *Preview* April 2015). An extreme example of such resistance 50 years ago is recorded by one of the central figures involved in the elucidation of sea-floor spreading via the palaeomagnetic 'stripes' recorded on the sea floor by magnetic reversals during the spreading process. Neil Opdyke told the story in *EOS* 1985, **66**(47), reprinted as Chapter 16 of 'History of Geophysics Volume 4' (2013). Opdyke painted a vivid picture of junior scientists leading the charge in believing new observational evidence, at a time when laboratory directors and associate directors vigorously – occasionally viciously – defended the (1966) *status quo* of 'immovable' continents.

Alison Kirkby has not faced any such opposition with her innovative look at resistivity methods and permeability (rather the reverse, according to Professor Heinson!) but she is to be congratulated none-the-less.

And may all our student geophysicists learn to be bold and innovative!

Environmental geophysics

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

The 2016 ASEG-PESA-AIG Conference: looking back

Welcome readers to this issue's column on geophysics applied to the environment. In the last issue I gave you a heads up in terms of what to expect at the ASEG-PESA-AIG Conference, which was held in Adelaide in August 2016. You will not be surprised to discover that in this issue I'll be reviewing the conference, from the standpoint of an environmental geophysicist.

Overall, I hope that most of you who attended found the conference interesting and enjoyable, and not as depressing as predicted given the state of the industry. I personally got a pretty positive vibe from the event (hmmm, how many of us would be in exploration if we weren't inherently optimistic?). Nevertheless, I am sincerely hoping that the economic conditions for the next conference will be better than they were in Adelaide. My thanks to all of the speakers and especially the keynotes. I think the programme got everyone thinking.

For 'new' technology on the shallow geophysics side of life I was pleased that the talks on passive seismic were as interesting as hoped (and it sounds as if the workshop was quite good as well). The passive seismic technique has been enthusiastically adopted by the minerals industry, being used mostly to remotely measure overburden thickness, as well as for palaeochannel mapping for uranium and iron ore applications. Although no explicit groundwater palaeochannel case studies were presented, it is logical to think that the method will be applied to these problems in the not so distant future.

Also, special mention for innovation on the groundwater side of environmental geophysics should be made of the development of the Australian Geoscience Data Cube (see Ken Lawrie's paper in the conference proceedings, as well as the Geoscience Australia website: http://www.ga.gov.au/about/projects/earth-observation-and-satellite-imagery/australian-geoscience-data-cube, and the NCI website: http://nci.org.au/virtual-laboratories/australian-geoscience-data-cube/, and finally: http://www.datacube.org.au/). This ongoing project was originally set up to enable viewing and analysis of almost 30 years of LANDSAT data on an entire nation-scaled basis (but useful down to the paddock scale), on an integrated platform (living on one of the ANU super-computers). It is now being expanded to include a number of other large scale data sets, making them also much easier to use and analyse.

Congratulations to all of the prize winners at the conference, especially those in environmental and engineering geophysics. Tim Munday and his group from CSIRO in Perth were recognised for their work on the use of AEM to characterise groundwater in the Murchison. Regis Neroni, winner of the best talk in minerals, used AEM data collected by his company's (Fortescue Metals Group) environmental arm for hydrological characterisation. The explorers in the company (of which Regis is one) realised that these data sets could be of use in exploration. This talk (to me) was a great example of getting everything you can out of every bit of data collected. I especially liked how they used some good processing 'tricks' to enhance features in the data that they were interested in.

See you at the next conference in Sydney!!

Minerals geophysics

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

Introducing our new Associate Editor for Minerals geophysics

During our recent ASEG Conference, your *Preview* Editor Lisa Worrall, with, I suspect, a word or two from Kim Frankcombe, suggested that the role of *Preview* Associate Editor: Minerals geophysics awaited, starting right now. Considering that mineral exploration geophysics has given, and continues to give me a stimulating and enjoyable working life, I was pleased to have the opportunity to contribute something in return.

Oh, and could I run off 450–500 words on my work experiences so far?

I completed a BSc degree in geology and physics at Adelaide University, graduating in 1966, then started with Mines Exploration, the exploration arm of Broken Hill South, as a geologist. They required an in-house geophysicist (they were big users of IP), so they sponsored me (accompanied by my wife) for two semesters at the Colorado School of Mines in 1967–68, doing every graduate and postgraduate geophysical course I could fit in. We returned home the long way – by ship to England, overland bus to Calcutta, flights to Perth, and finally train to Adelaide. I spent a total of nine years with Mines Exploration, exploring throughout Australasia mainly for base and precious metals, uranium and rock phosphate.

The industry was hit with a severe downturn in the mid-seventies (they had them back then too), and although Mines Exploration would have kept staff on, I felt I needed a break. For a while I worked as a contract ditch-digger for the local plumber (paid by the metre, so I got very fit), then exploration activity picked up and I took on consulting work in Australia. However, travel in the Middle East had whetted my appetite, and I secured a position with Riofinex as mineral exploration geophysicist in Saudi Arabia. This was an accompanied contract, with our son going to boarding school in Australia after the first year. The work spanned eight years (1978–86), targeting precious and base metals, and rock phosphate (again!).

With the end of the Saudi Arabian master contract, we returned to Australia, where I consulted principally for CRAE, focussing on IP, and Carpentaria Exploration (MIM), mainly around McArthur River. This, in turn, led to four years in South America working for Minera Mount Isa, based in Santiago, Chile (1994–98), where the main target was porphyry copper. We moved to Colorado for a brief stint, then another industry downturn saw us back in Australia.

In 2001 MIM offered me a fly-in fly-out geophysicist position in Mount Isa, working with the team exploring the Mt Isa Inlier for copper-gold deposits. MIM were subsequently taken over by Xstrata, which in turn merged with Glencore; current work includes a strong near-mine (Mt Isa and Ernest Henry) focus. The Isa team also provide input for zinc operations, including McArthur River Mine.

And what have all these experiences taught me? One thing is that learning never stops. So, universities and government agencies, geophysical contractors and consultants, instrument manufacturers, software developers, mining and exploration companies, I'd appreciate all the information, ideas and assistance you can give me to broaden awareness and distribute minerals geophysics knowledge via *Preview*. I look forward to your input!

Seismic window

Michael Micenko
Associate Editor for Petroleum
micenko@bigpond.com

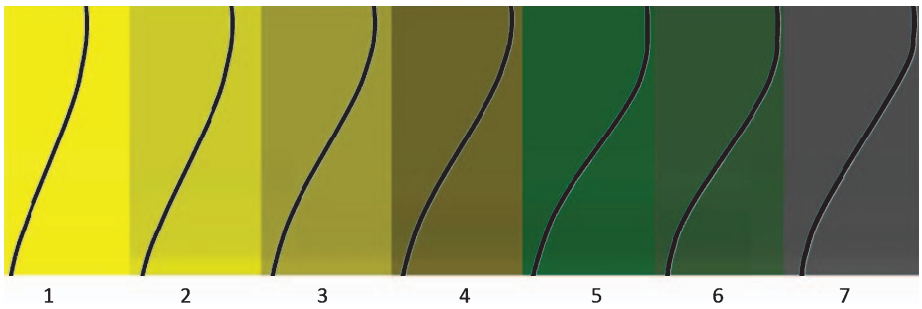

Figure 1. *Waveform classes from Cremasco et al. (2016). The use of a small window of half a wavelength results in amplitude being the only difference between classes.*

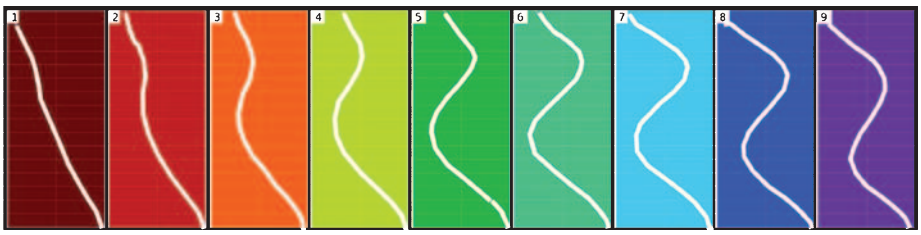

Figure 2. *Waveform classification from Lodwick and Grant-Wooley (2016). The main difference between classes is the peak-trough amplitude in the upper part of the analysis window.*

Waveform classification outshines amplitude

I can't remember if I was at the first ASEG Conference in Adelaide, I was definitely at the second, and last month I was lucky enough to attend the 25th and quite possibly last ASEG conference. The Australian geoscience community apparently can't support a variety of conferences so in future an amalgam of societies will present a joint conference that has been rebranded to AEGC (Australian Exploration Geoscience Conference).

There were a number of good petroleum papers presented at this year's conference, and two case studies that used waveform classification to map and determine thickness of reservoir sands caught my attention. I was interested in these papers because they are extensions of an idea I presented in 1988 and further discussed in a Seismic Window in 2013.

Briefly, waveform classification subdivides a seismic wavelet within a user specified window into a user specified number of clusters based on the waveform shape. An unconstrained classification maps how a waveform is changing across a survey without using *a priori* information. The technique uses a neural network to quantify changes in the waveform and assigns each location a discrete class which may be representative of a particular geology or facies. It is important to note that the software orders and numbers each class – there is no interpreter input to this process.

Paper 1 (Cremasco et al., 2016) identified a relationship between waveform class and the net reservoir thickness and used this to map sand filled channels across an area of interest. But why would a vaguely random number like waveform class be related to reservoir thickness? The answer lies in the number of samples used to classify the waveform. The window used in this case was only half a wavelength (Figure 1). And the sands were below tuning thickness. Wedge models show that below tuning thickness the wavelet shape does not change – the peak-trough separation remains constant – while destructive interference results in the amplitude decreasing almost linearly as the wedge thickness decreases. The waveform of each successive class is therefore only a slightly higher amplitude version of the previous class. The use of waveform classification in this case is possibly over kill and perhaps a simple peak-trough amplitude map would yield the same result and save some time.

Paper 2 (Lodwick and Grant-Wooley, 2016) also uses waveform classification, this time to produce a 'probability map', and states 'the map of waveform classification can be used in the surface calculator to generate a probability map of the lower non-reservoir thickness'. This is possibly an example of a Nintendo Geo pushing a button but not knowing exactly what happens. First, what is 'the surface calculator'? I think I know but I'm not sure.

Second, how does the waveform classification relate to probability? I don't believe it does. The lower non-reservoir is almost always present so it should have a probability close to 100% everywhere. Perhaps what the authors meant was the lower non-reservoir has a 50% chance of being at least a certain thickness. On further reading I found that 'the resulting probability map can be used to multiply the top porosity to MFS isochore and generate a lower non-reservoir thickness'. So now the map has morphed from probability to a measure of net-gross thickness. Once again the use of a small calculation window (up to one and a half wavelengths in this case) results in wave class being dominated by amplitude changes (Figure 2). When the waveforms of each class are overlain (Figure 3) the main difference is an increasing amplitude in the top part of the window. Once again it appears that a peak – trough amplitude map may yield a similar result.

These two papers have provided useful results for the development teams involved but I wonder if there is a proper understanding of the geophysics involved. I emailed the authors and judging by the responses I received I'm sure they are quite knowledgeable. Perhaps amplitude

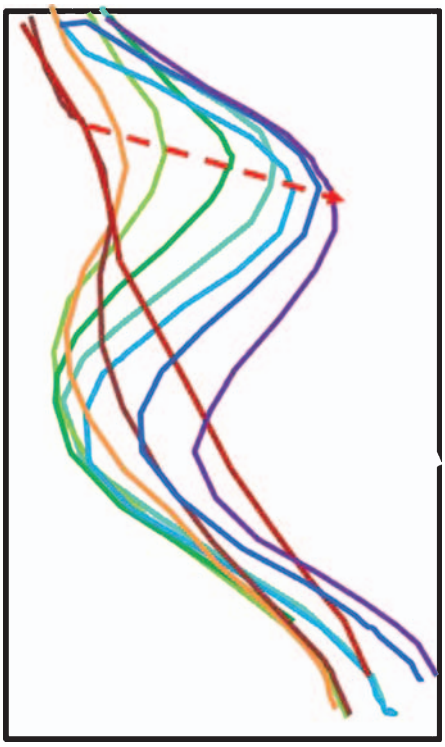

Figure 3. *Waveforms of Figure 2 overlain to highlight the main change between classes is amplitude. The amplitude increases from Class 1 (brown) to Class 9 (purple) with the peak shifting to later time.*

maps have become *passe* and conference attendees want to hear about more modern but complicated seismic attributes.

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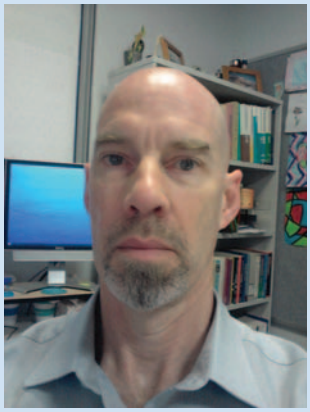
Webwaves



Dave Annetts
ASEG Webmaster
david.annetts@csiro.au

The new ASEG website has been launched

The new ASEG website was launched by the ASEG President, Katherine McKenna, in her opening address to the 25th International Geophysical Conference and Exhibition in Adelaide on 22 August 2016. We now have answers to the series of questions posed in this column in the last issue of *Preview*. Overall, Member feedback has been positive, and early statistics suggest strong access from desktop and mobile devices from around the world, mainly Australia, but also USA, Canada and the UK. In addition, a significant number of site users were from India, Japan, China and Indonesia. Strong use from mobile users is especially encouraging since one of the goals of the website redesign was to ease use for these users.

Recognising that the new website would make much greater use of images than previous versions of the site, the Web Committee organised a photo competition. The main purpose of this competition was to gather photos for use on the web. There were 23 competition entries from 11 Members. Member submissions are being used on the web in various ways, and we extend an invitation for submissions at any time. The winning photo was submitted by Andrew Long. Three entries took equal second place (Andrew Long, Malcolm Sambridge and Doug Morrison). The remaining votes were for photos by Adrian McCallum, Andi Pfaffhuber and Jeremy Lee. The website has more details. Hopefully the photo competition will return and provide Members the chance to share details of interesting datasets and the exciting locations that we visit as geoscientists.

The current website introduces some new features to the ASEG. In a sense extending the contractor's database, the website also offers the facility for companies to post job adverts, and for Members to post notice that they are looking for a position. Neither of these features attempts to supplant existing job services. Rather, they are offered as a facility to connect employers with job seekers. Forums are another feature of the current site. These were present in the old site, yet never quite gained traction. The Web Committee has attempted to incorporate feedback as to why this might have been the case. Amongst other purposes, forums may be used by Members to post questions and answers on a range of topics including geophysical methods and state-related matters.

Another feature worthy of mention is the Online Equipment Museum. The History Committee has acquired a number of older instruments from various sources, and is in the process of producing an online museum where instruments are described, ideally with manuals and examples of data. The online museum currently has one exhibit, a SIROTEM prototype, and others are sure to follow. Anyone interested in helping is urged to contact the History Committee (history@aseg.org.au)

As with any new endeavour, there were some teething problems with the launch of the new website. These problems, which were chiefly concerned with donations to the research fund and Member access to *Exploration Geophysics*, have now largely been resolved. We urge Members to test the new website and report any issues to webmaster@aseg.org.au.

*This **Caesium Magnetometer Sensor** is from the ASEG virtual museum collection and was generously donated by John Stanley, formerly a lecturer at the University of New England and an inventor. It was built in 1980 as one of hundreds produced by Scintrex of Toronto, Canada and measures the total field. By 1978, the US had declassified its military development of Caesium sensors and these could now be purchased from the developer, Varian Associates. Varian later licensed their product to Scintrex and later to Geometrics. The instrument exhibited here was produced by Scintrex under licence to Varian.*
A feature of this sensor is that the polarising filter was divided into two halves, one right circular polarising and the other left circular polarising. In doing this the small, equal and opposite heading effect associated with each polarisation were able to cancel each other. This was thus described as a compensated sensor.

Data trends

Guy Holmes
guy.holmes@katalystdm.com

My version of the truth

I was on a flight this week and, as usual, after wearing out my finger on the call bell seeking more red wine, I turned to the inflight entertainment to absorb as many documentaries as I could. It makes me feel better to say I watched documentaries rather than movies.

On this flight there was a great documentary on the Hubble Space Telescope, one on the great comedian, actor and director Mike Nichols, and a range of others. But the one that really caught my attention was called '(Dis) Honesty – the Truth about Lies' by the behavioural scientist Dan Ariely. This documentary looks at how and why people lie using data from various scientific behavioural studies carried out on a global scale.

It really got me thinking about data, how we create it and the ways we and others form opinions based on data. Can the same data tell more than one truth? Is anything ever categorical, or can two very different conclusions be drawn from the same data? If you can draw two different conclusions from the same data what factors play a role in directing people to one conclusion over another? Does the fact that we deviate from the hard data to tell our version of the story really constitute a lie?

Seismic data analysis is the perfect arena in which to look at how the same data can tell two (or in fact a lot more) different stories, and how each story can lead to very different conclusions. We all know geophysics is not a perfect science, and that an 'interpretation' is just that - someone's view of the data based on their opinion, experience and, of course, all other related data they have used in current and past projects. But the fact that two very experienced geoscientists can reach often widely different conclusions using the same data should be a concern for everyone. What can lead to this?

Here are some contributing factors:

1. Geoscientists are infamous for being protective about their data. Many geoscientists simply don't like to have their work criticised by anyone else, least of all by another geoscientist. This can lead to selective reasoning or the selective sharing of facts that one party knows will support their conclusion rather than detract from it.

2. Most of our software tools are designed to try and support the story we want to hear. Take this word processing software I am using to type this article right now. It certainly will highlight spelling mistakes or grammatical issues it detects in the sentences, but it offers no opinion on the quality or accuracy of my story. Essentially I can type whatever I want into this software and, as long as I don't make a spelling mistake or a grammatical error, it will happily allow my drivel to be published and form popular opinion (well probably not that popular).

Geoscience software can be very similar. Feed it a list of values and the software might check that the values are reasonable for the type of data you are analysing and ensure that there are no formatting errors in the data (letters where numbers should be etc.). It will then produce a result. However, what if that list you uploaded was a list of your last 300 top scores in Candy Crush instead of the gravity measurements over a prospect?

3. In the world of big oil, teams of people often work on individual parts of a larger science project. All of the various results are then brought together to create a 'final' result. Once that result is agreed upon it can become very difficult to challenge and, ultimately, it may become the *de facto* truth. Imagine eight or ten scientists working together to create a result, and two or three of them using a little creative license with their data to ensure they meet the team deadline for the drilling project. Just think about how that could change the trajectory of a result! Some of you don't have to then imagine drilling a duster and trying to reason with management as to how you arrived at your result to drill in the first place.

None of the above really constitutes lies, but the after effect of them often leads to having to find a more convenient truth about how we came to our conclusions. In essence, as per a quote from Chris Jami – 'Just because something isn't a lie, doesn't mean it isn't deceptive'. The irony about the geosciences is that we often reach a conclusion with the support of data, but not necessarily a conclusion that supports the data. After all, I'd be lying if I said geoscience was about the facts!

High productivity vibroseis techniques: a review

Tim Dean
Department of Exploration Geophysics,
Curtin University
Tim.Dean@curtin.edu.au

Overview

Since their introduction in the 1950s hydraulic vibrators have become the source of choice for large land seismic surveys (the vibroseis method), used whenever the terrain will allow.
A hydraulic vibrator (Figure 1) transmits energy into the ground via a baseplate held in place by the weight of the vehicle and decoupled from it by airbags. Above the baseplate a reaction-mass, typically between 3500 and 5000 kg, is hydraulically driven up and down, transmitting a signal into the earth.

The transmitted signal (the pilot sweep) typically varies monotonically, between frequencies of about 8 to 100 Hz, over a period of ~18 seconds. Figure 2 is a very simple synthetic example of vibroseis data. Figure 2a shows the pilot sweep, in this case with a limited bandwidth of 2 to 12 Hz over 4 seconds. Figure 2b shows the signal recorded (in blue) resulting from the reflectivity sequence (shown in red), each event is replaced with a copy of the pilot sweep with corresponding magnitude and polarity (i.e. the convolution of the pilot sweep and the reflectivity). Note that the record length is the sum of the pilot sweep length (4 s) and the length of the record we wish to obtain after correlation, the listen time (2 s). Figure 2c shows the data after we have correlated the recorded signal with the pilot sweep. Note that each reflectivity event has been replaced by the autocorrelation of the pilot sweep.

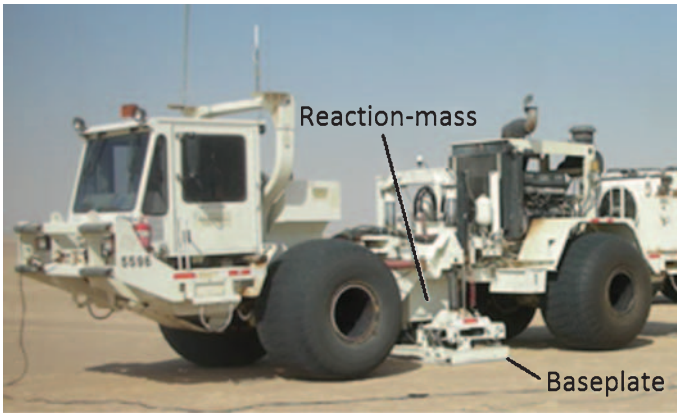


Figure 1. *A hydraulic vibrator in action. The baseplate is on the ground between the two axles. The reaction-mass is the large white steel cube directly above the baseplate.*

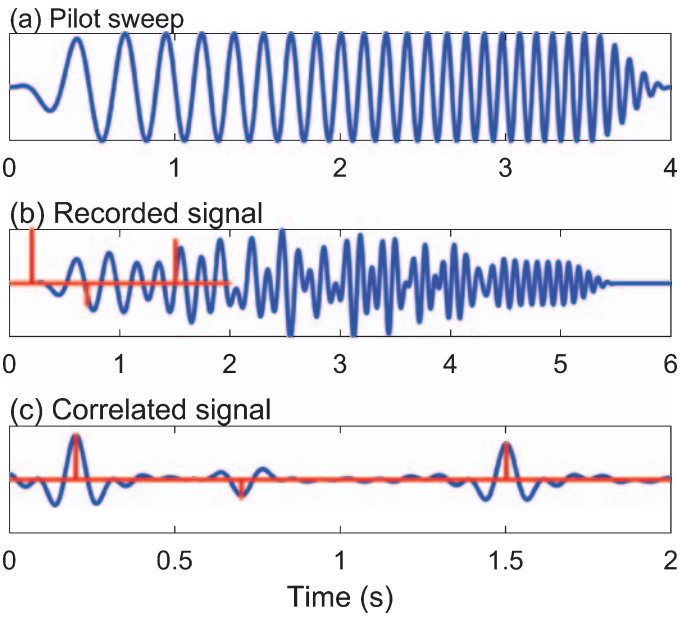


Figure 2. *A very simple example of extracting reflectivity from a synthetic vibroseis signal using correlation.*

Unfortunately, despite their undoubted value, the cost of land seismic surveys is high. So a number of methods, commonly referred to as *high-productivity techniques*, have been introduced to increase their efficiency and thus reduce their cost. In this article I describe the most commonly used high-productivity techniques. Excluding those that involve phase encoding since they require additional sweeps at each source point, and are therefore not considered to be high-productivity techniques. A description of phase encoding techniques is included in Bagaini (2010).

Standard acquisition and flip-flop

Originally, vibroseis crews utilised a single fleet of vibrators, typically comprising of between three and five units. The fleet of vibrators would sweep at a source point then move-up to the next point, sweep, move-up, etc. (Figure 3a). Although easy to manage, this is clearly an inefficient method as the recording system is idle for the majority of the time, in this case more than 60%.

An increase in the number of vibrators on crews enabled the formation of more than one fleet resulting in the introduction of the *flip-flop* method. In flip-flop acquisition fleets move-up between source points while other fleets are sweeping, reducing the dead time between records (Figure 3b). If sufficient fleets are available then we can achieve the theoretical 'maximum productivity' (Figure 3c). As shown below, other techniques can increase productivity even further, but flip-flop remains the most popular.

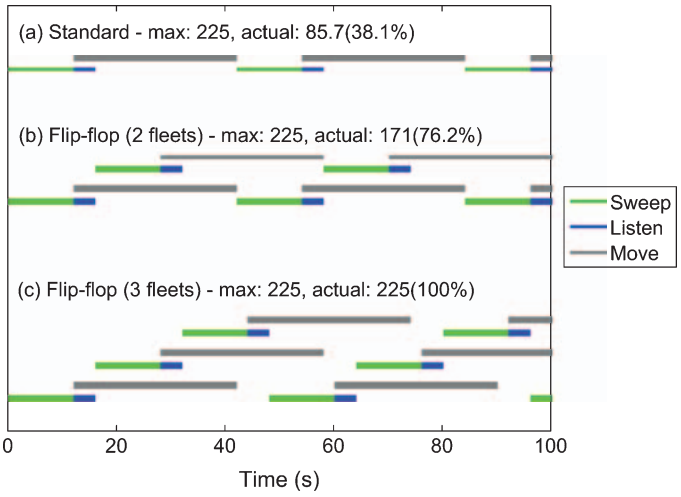


Figure 3. *Diagrammatic representations of different vibroseis acquisition techniques. The sweep length (green) is 12 s, listen time (blue) 4 s and move-up time (grey) 30 s. The values in the headings are the maximum and actual productivities in source points per hour.*

Slip-sweep

Rozemond (1996) was the first to recognise that, although the flip-flop method may appear efficient when viewed as a simple time series (Figure 4a), when viewed in the frequency-time domain there is actually considerable unused time (Figure 4b). The slip-sweep method involves overlapping the sweeps in time (Figure 4c) such that we fill more of the un-used space (Figure 4d). The *slip-time* is defined as the minimum time between the start of subsequent sweeps.

Theoretically, there should be no impact from the use of slip-sweep on data quality but unfortunately, as well as the pilot sweep that is considered signal, the vibrator also emits harmonics (Figure 5a). After correlation the fundamental is compressed to a Klauder wavelet with the harmonics appearing in *negative time* (i.e. before the event with which they are associated, Figure 5b). On real data this results in harmonics associated with the first-breaks (typically one of the strongest events) interfering with the weak events at the bottom of the previous record, if the slip-time is small enough.

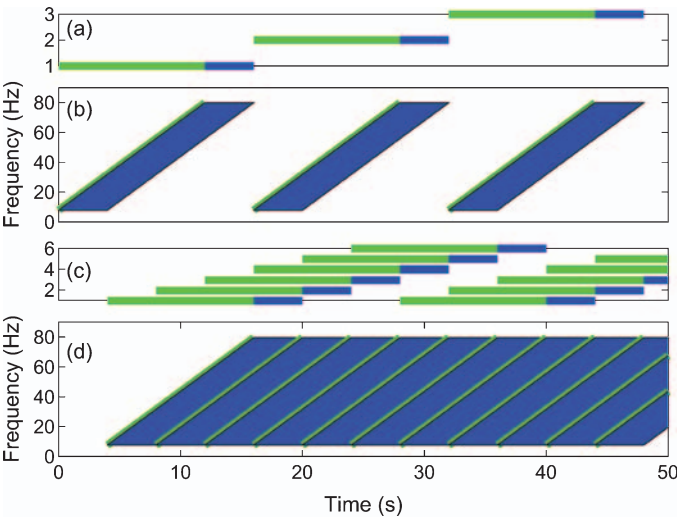


Figure 4. *Diagrammatic representation of the slip-sweep method.*

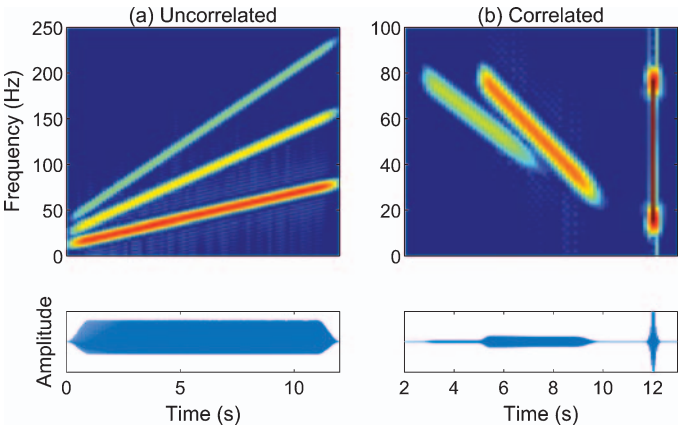


Figure 5. *Synthetic vibroseis traces showing the fundamental (the strongest component) and two harmonics with decreasing strength before (a) and after (b) correlation. The noise train shown before the fundamental in (b) would appear at the bottom of the previous record if the slip-time allowed.*

Obviously the interference can be controlled by limiting the slip-time. In practice slip-sweep acquisition can be divided into three categories depending on the slip-time chosen and the resulting level of interference (Dean et al., 2010). *Noise-free* acquisition occurs when the slip-time is such that the harmonics do not appear in the preceding record (Figure 6a), *non-aggressive* (Figure 6b), and *aggressive* (Figure 6c) slip-sweep is where the previous record is contaminated by the harmonics from a single and multiple shots respectively.

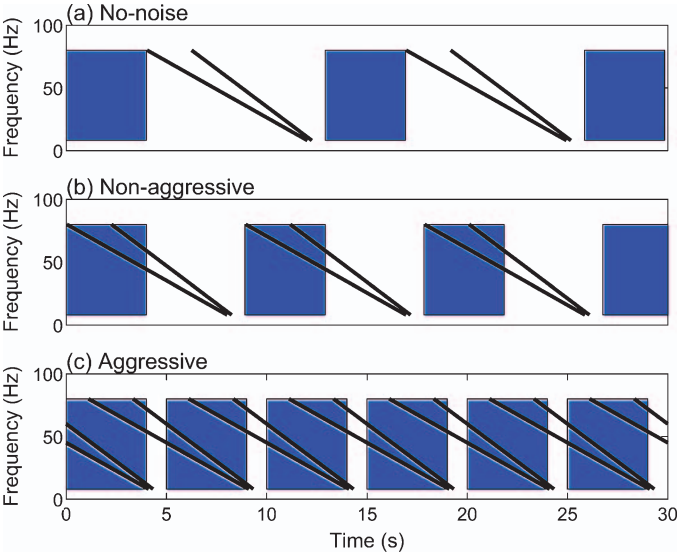


Figure 6. *Diagrammatic representation of the three different types of slip-sweep acquisition. The blue box indicates the region of the frequency-time domain occupied by a single record (after correlation). The black lines indicate the extent of the first two harmonics. The number of black lines overlapping the blue boxes is an indication of the level of interference noise.*

Figure 7 shows examples of the cross-harmonic noise resulting from the choice of slip-time along with an uncontaminated record. The noise-free record (Figure 7a) shows no sign of harmonic noise contamination (the noise seen is vehicle noise), while for the non-aggressive data (Figure 7b) the noise is noticeable but decreases up the record. The noise on the aggressive data (Figure 7c) is significant across the whole record. For limited amounts of cross-harmonic noise it often simply stacks out, if not, then various methodologies exist for removing noise, but clearly it is better not to record it in the first place.

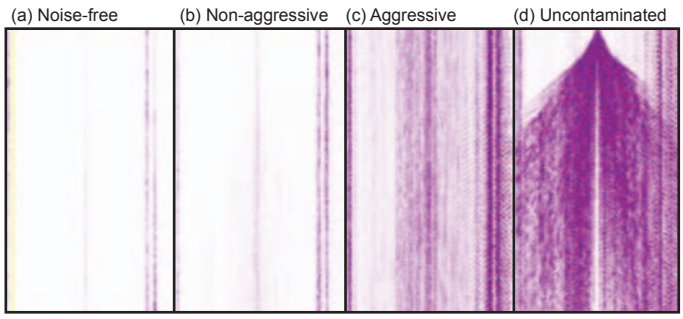


Figure 7. *Examples of observed cross-harmonic interference noise for the different types of slip-sweep acquisition. The record length is 4 s. Adapted from Dean et al., (2010).*

When introduced by Petroleum Development Oman in 1998, the slip-sweep method resulted in a doubling of productivity over the flip-flop method (Matheny et al., 2009). Nevertheless it has seen only limited adoption elsewhere. Within Oman it has since been replaced by a new, even more productive, technique described next.

Distance separated simultaneous sweeping

Beasley (2008) recognised that, if the receiver line was long enough, shots fired at either end of the line would interfere below the reflections of interest. This idea is the foundation of the *Distance Separated Simultaneous Sweeping* (DS^3) technique (Bouska 2010). The method (Figure 8) relies on the recording spread being large enough to allow the required separation between fleets, which depends on the location but is typically of the order of 10 km.

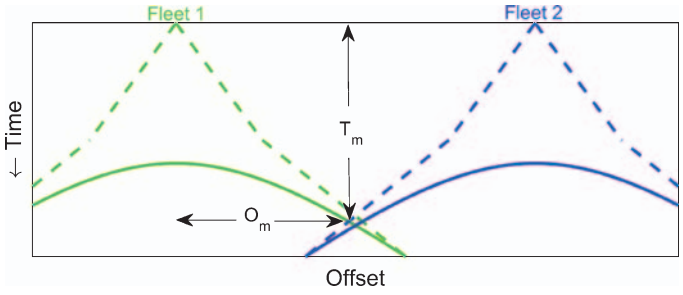


Figure 8. *Diagram of the DS^3 method. The two fleets 1 (green) and 2 (blue) sweep simultaneously, producing reflections of from the horizon of interest (solid lines) that intersect with the other's noise (dashed lines) only at times and offsets greater than Tm and Om respectively. Adapted from Bouska (2010).*

Bouska (2010) reported a peak productivity of 1,024 records/hour using 15 vibrators within an 18.5 × 11 km receiver patch, compared to about 1000 records/day for previous flip-flop surveys and 1700 records/day for slip-sweep. Stone and Bouska (2013) combined the DS^3 and slip-sweep methods, achieving productivities of up to 1060 records/hour using 24 vibrators within a 12.6 × 28 km receiver patch.

Independent simultaneous sweeping

Independent Simultaneous Sweeping (ISS also known as *blended acquisition*) was first introduced by Howe et al. (2008). The source points are divided into separate areas each with a fleet (usually containing a single vibrator) as shown in Figure 9. The fleets then acquire the source points independently, i.e. they sweep whenever they are ready irrespective of what the other fleets are doing, with the acquisition system continuously recording data.

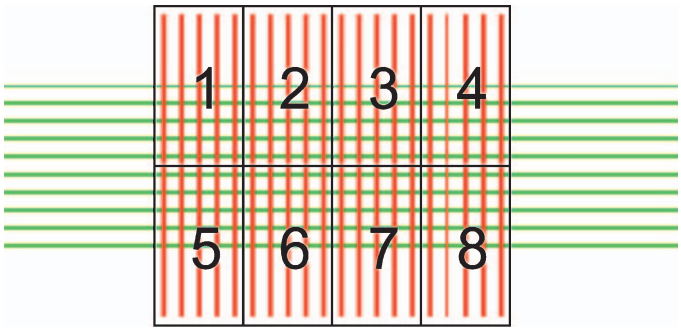


Figure 9. *Diagram showing the configuration for an ISS survey. The source lines (in red, receiver lines in green) have been divided between eight fleets which acquire their respective source points autonomously.*

Originally the fleets used sweeps with different lengths, or pseudorandom sweeps (Dean 2014), but later this approach was discarded in favour of every fleet using the same sweep, which simplified acquisition with no discernible effect on data quality (Abma et al., 2015). This technique requires the system to be recording data continuously, from which each record is then extracted. The effect of any interference between records that remains after extraction/deblending and noise removal is considered to be more than offset by improvements due to the increase in spatial sampling made possible by the efficiency (Abma et al., 2015).

In the first full ISS survey productivities of up to 1,200 source points per hour were achieved using 14 single-vibrator fleets (Howe et al., 2009). Using ISS Pecholcs et al. (2010) achieved productivities of over 45 000 source points per day using 18 single-vibrator fleets.

Managed spread and source

Managed Spread and Source (MSS) effectively encompasses all the previously detailed methods via a set of acquisition 'rules'. An example of such rules is shown in Figure 10. The left panel shows a shot record where the regions of signal (shown in blue)

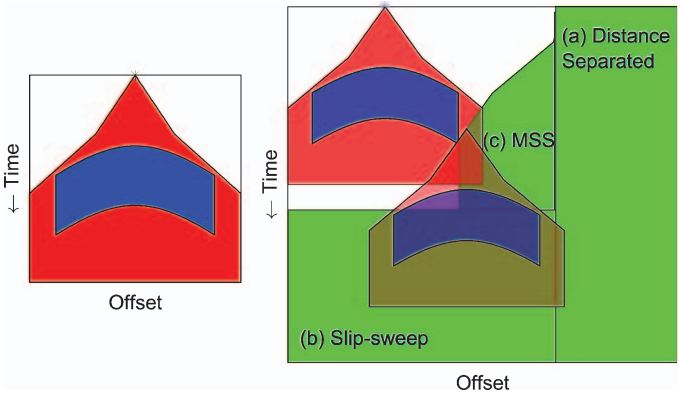


Figure 10. *Example of some simple MSS rules. The left panels shows a single record with areas of signal and noise shown in blue and red respectively. The right panel shows the areas of the offset/time domain within which a second fleet can start sweeping in green. A second record, on the boundary of the green zone, is also shown.*

and noise (shown in red) have been defined. The right hand panel shows the resulting rules that are applied during acquisition. The signal and noise regions in the offset/time domain for a shot are shown in blue and red as before. The green regions indicate areas of the domain within which another fleet can begin sweeping without its noise zone overlapping the signal zone of the previous shot and vice versa. The area labelled as 'a' indicates a region where interference is avoided by distance separation, the area labelled as 'b' indicates an area where interference is avoided by time separation, i.e. slip-sweep. The irregularly shaped region labelled 'c' is one that can only be defined using MSS rules, the impact of a second sweep starting on the boundary of this region is included to show how the noise region from the second shot does not impact the signal region of the first.

Figure 11 shows the resulting CMP stack for synthetic data generating using ISS and MSS simulations. The MSS result is significantly less noisy than the ISS result. Some noise does leak through around 2 s but this is due to the lack of offset limits (all offsets were included in the stack rather than just those within 2,000 m). Overall the MSS data would have taken 5% longer to acquire (productivity was enhanced by queue management as detailed in Dean (2012)).

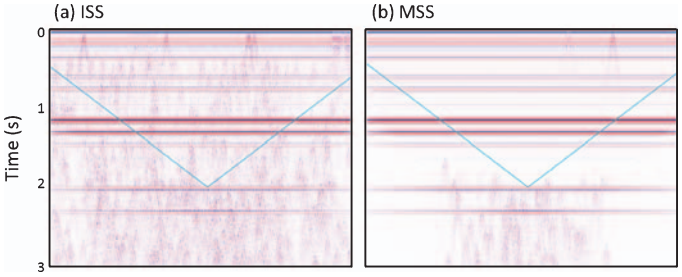


Figure 11. *Stacks of synthetic (a) ISS and (b) MSS data. The blue line indicates the fold. Image courtesy of WesternGeco.*

Discussion

Although this article is primarily concerned with vibroseis acquisition techniques, these techniques cannot be addressed in isolation, being both enabled by, and enabling, other technologies. Techniques involving large receiver spreads (ISS/DS^3/MSS) require large channel count systems, often incorporating point-receivers rather than arrays to reduce the total number of sensors that need to be deployed. Techniques where the sources act independently (ISS) require GPS timing plus an acquisition system capable of recording data continuously rather than creating discrete records. Even simpler techniques, such as slip-sweep, require the acquisition system to be able to record files with durations long enough to encompass multiple records. In-turn, high-productivity techniques have resulted in order-of-magnitude increases in productivity, enabling the acquisition of wide-azimuth surveys with dense source points and folds of more than 9,000 (Pecholcs et al., 2012).

To take full advantage of the adoption of these techniques, a change in mind-set with regards to survey planning is required. Most importantly, the additional source energy possible is better spent increasing the fold of the survey by increasing the number of source points, rather than increasing the amount of energy emitted at each source point (Bianchi et al., 2009; Matheny et al., 2009). So when comparing different acquisition plans, we may need to balance the loss in source energy at each point due to a reduction in the number of vibrators in each fleet (the SNR is proportional to the number of vibrators and the square root of the sweep length (Dean and Tulett 2014)) against the number of extra source points made possible. Even the productivity of more traditional surveys can be improved through the use of slip-sweep, often without any detrimental effect on data quality.

The acquisition method chosen is always a trade-off between productivity and interference. The less restrictions applied to when the vibrators can sweep results in the highest productivity, but unfortunately, also results in the most interference. Nevertheless, the resulting increase in source density may more than compensate for the individually noisy shot records. Perhaps the key point is that the choice of acquisition method needs to be part of the survey design process, and not merely an afterthought, so that such trade-offs can be properly evaluated.

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Tim Dean has an Honours degree in Geophysics from Curtin University and a PhD in Physics from the University of New South Wales. He spent more than 12 years working for WesternGeco and Schlumberger in a variety of roles including field operations, software development and research located in Saudi Arabia, England, Norway and Australia. His research areas include land seismic acquisition, vibroseis, VSPs, the seismoelectric method and DAS. He is currently a Research Fellow in the Department of Exploration Geophysics at Curtin University.

A comparison of magnetic susceptibility meters using samples from the Thompson Nickel Belt, Canada

Deng Ngang Deng and Richard S Smith
deng.deng@utoronto.ca
rssmith@laurentian.ca

Overview

Comparisons of field portable magnetic susceptibility (MS) meters have been carried out by a number of geophysicists. Bleeker (2012) compared the KT-10 and the SM-30. He concluded that the KT-10 was most suitable for his purposes, as the KT-10 has a mode that provides the average and standard deviation of multiple readings on an outcrop. Bleeker (2012) found that the MS readings were useful for studying dyke swarms and differentiating between different dyke swarms. Lee and Morris (2013) compared three instruments and found that the KT10 and SM-30 gave similar readings, with the Bartington MS2E giving readings that were about 9% greater.

This article builds on this previous work and summarises the results of a study carried out for an MSc project (Deng, 2014). Measurements were taken on 71 samples of drill core, recovered from the Thompson Nickel Belt in Canada, using six types of magnetic susceptibility meters, two of which were also capable of measuring conductivities greater than about 1 S/m. Some of the meters used were quite versatile in that they could measure in different modes, for example, they could take individual (more accurate) measurements, or continuous measurements as the meter is moved along a core box or over an outcrop. In this study, we were interested in accuracy and reproducibility, so we chose the more accurate mode. Table 1 shows the meters used, the mode selected, and some other specifications of the meters (N/A implies information not available). Note that the Bartington MS2C and MS2K are only sensors; they cannot be used without a MS3 meter.

Measurements

Seventy-one samples were chosen to cover a broad range of susceptibilities from very small values to values up to about 200 $\times 10^{-3}$ SI. On each sample a specific location was marked with a permanent marker to ensure that all the measurements were made at the same location. Nevertheless, different meters will sample different volumes of the rock depending on their coil size. Susceptibility meters generally show some variability due to instrument drift and geological variation. Lee and Morris (2013) recommend six readings per sample and Rainsford and Muir (2010) recommend up to ten measurements on an outcrop. In this study we took five measurements per sample as a reasonable compromise between collecting good data and spending too long on the data acquisition process.

The first test, of reproducibility or drift, was undertaken by taking repeat measurements on a number of different samples with different susceptibilities. As one example, we show the measurements taken over a man-made sample that can be purchased from Terraplus for calibrating their instrument (Figure 1). This sample was too large to be placed in the coils used with the MS2C, but was measured using all the other instruments. The factory-calibrated value for the sample is 36 x 10^{-3} SI, however most instruments give a value a few percent less than this, except the MS2K, which gave values about 10% greater. Values for the MS2K are relatively erratic, while the others are fairly reproducible, with the RT-1 showing a slight downward drift, the KT-10 and SM-30 showing a very slight upward drift and the GDD showing an increase in scatter in the later measurements. It took about 10 minutes for each instrument to acquire 35 measurements. These calibration measurements were repeated a number of times over two months and very similar values were obtained.

Drift experiments were also undertaken on strongly and weakly susceptible geological samples, with slightly different results being obtained. This indicates that the degree of drift might vary

Table 1. Meters used in this study, mode selected and other specifications

	Fugro RT-1	Terraplus KT-10 S/C	GDD MPP-EMS2+	Bartington MS2K	Bartington MS2C	ZH Instruments SM30
Physical quantities	MS	MS and conductivity	MS and conductivity	MS	MS	MS
Number of modes	2	3	4	2	2	6
Mode selected	Scan	Measure	Manual	Manual	Manual	Mode B
Sensing area (mm^2)	N/A	3318	N/A	491	4072	1964
Operating frequency (kHz)	0.75	10	N/A	0.93	0.565	8
Resolution	10^{-4}	10^{-6}	10^{-6}	10^{-6}	10^{-6}	10^{-7}
Comments					Designed for cylindrical core	

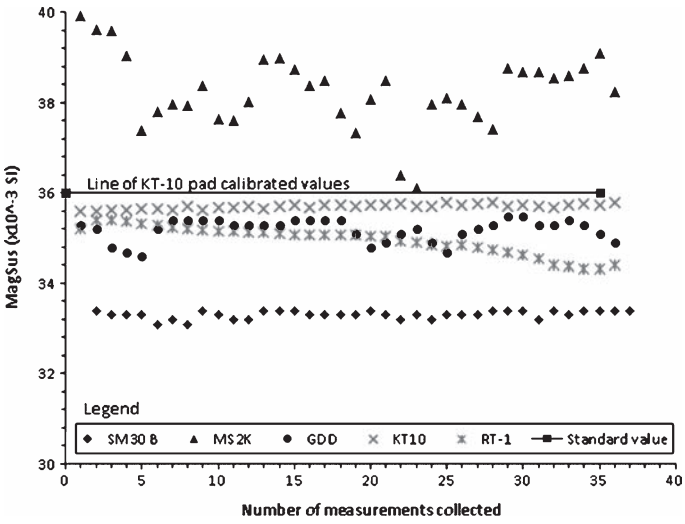

Figure 1. *Repeat measurements on a calibration sample with five instruments. The factory calibration value is 36 x 10-3 SI. Four of the instruments generally give a reading below this value, with each instrument showing different degrees of drift and scatter in the values.*

with the strength of the magnetic susceptibility, or it might be a function of the homogeneity of the sample. In general, the instruments with smaller coils seemed to show greater drift (GDD and MS2K). The results are summarised on rows 3 and 4 of Table 2.

Analysis

We compared the values measured by one instrument with the values measured by other instruments for all 71 samples. As an example, in Figure 2 we compare the KT-10 with the other five instruments. In this analysis we used the median of the five measurements taken by each meter on each sample. When we used the mean we found that the fit was poorer and the scatter greater. From this we concluded that for magnetic susceptibility values the median is a better way to estimate the central value of a distribution than the mean. Lee and Morris (2013) suggested a logarithmic average, but we did not test this option. Each plot in the correlation analysis shows a line of best fit. In a perfect world each instrument would give the same reading on the same sample, and the line of best fit would have a slope of one, an intercept of zero and an R^2=1. The slight differences in slope might be due to operating frequency, instrument design or the factory calibration of the instrument. Using curves similar to those on Figure 2, it should be possible to compare/convert the values measured with one instrument with/to those measured with another instrument.

When looking at all the plots we noticed that, in general, there was greater scatter in the bottom left quadrant compared to the top right quadrant. This suggested that measurements for smaller values are less reliable than measurements for larger values; however, it is not clear which of the two instruments is less reliable. In order to gauge the reliability of each instrument as a function of the measured value, we calculated the standard deviation σ of each measurement. When the standard deviation is divided by the mean m, this gives the co-efficient of variation CV = σ /m. If CV is less than 0.1 (10% error), then the reading is reliable, if it is greater, then the reading is unreliable.

In general, we found that for large MS, the CV was small, but for smaller values of MS, the CVs sometimes increased. We concluded that the instrument was not able to give reliable readings below a value where the CV was greater than 0.1. This was the lower limit of susceptibility that the instrument is capable of measuring. Figure 3 shows the plot of the $\log_{10}$ of the CV as a function of the $\log_{10}$ of the measured susceptibility (with the $x10^{-3}$ ignored). For large values of MS, the CV is small, but as the MS decreases there is trend towards increasing CV such that when the MS is less than 0.1×10^{-3} SI the readings are not reliable. Hence for the RT-1, we estimate the lower limit of sensitivity of the instrument as 0.1×10^{-3} SI. Similar plots have been interpreted for the other instruments and the lower limits of resolution of the instruments as interpreted from the CVs are shown on the first row of Table 2. In cases

Table 2. Summary of results and some features of the six magnetic susceptibility meters used in this study

	RT-1	KT-10	GDD	MS2K	MS2C	SM30
Lower limit of accuracy (SI) CV>0.1 or lower limit	0.1×10^{-3}	0.007×10^{-3}	0.15×10^{-3}	0.005×10^{-3}	0.02×10^{-3}	0.02×10^{-3}
Largest value measured (SI)	280×10^{-3}	186×10^{-3}	360×10^{-3}	230×10^{-3}	220×10^{-3}	200×10^{-3}
Example drift – strongly susc ($\times10^{-3}$ SI)	0.0014	0.0082	–0.0396	–0.0053	–0.0008	0.0058
Example drift – weakly susc ($\times10^{-3}$ SI)	–0.0004	0.00004	0.0011	0.0001	–0.00006	–0.0014
Portability in the field	✓	✓	✓	x	x	✓
Usability on large irregular sample size	✓	✓	✓	✓	x	✓
Usability on core of diameter >72 mm	✓	✓	✓	✓	x	✓
Usability on core of diameter ≤72 mm	✓	✓	✓	✓	✓	✓
Ability for the instrument to account for split core in software	x	x	✓	x	x	x
Mode used in this research	Scan	Measure	Manual	Manual	Manual	Basic mode B
Most Erratic mode	Step	Scanner	N/A	N/A	N/A	Scanning
Reading on diamagnetic sample (should be negative)	Zero	Positive	Zero	Negative	Negative	Small negative
Cost when purchased in 2011	AU$2850	CA$2150 or CA$4450 for S/C	CA$6300	US$2925 + 2520 (for MS3)	US$2925 + 2520 (for MS3)	US$1995

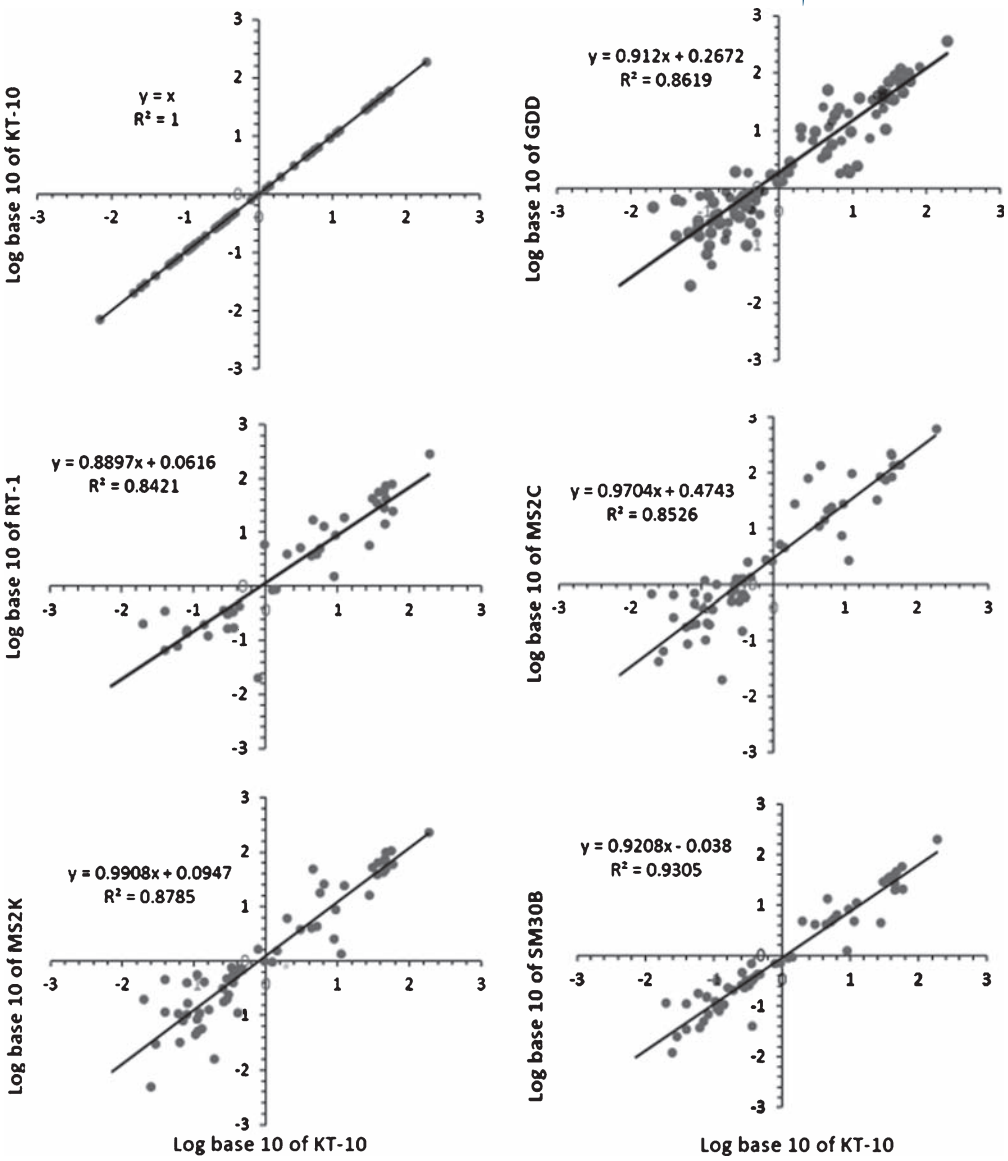

Figure 2. *Comparison of the susceptibilities measured on 71 samples using the KT-10 (horizontal axis) and the other five instruments (vertical axis). Ideally, the plot should be a straight line with slope one, intercept zero and R^2=1.*

when the CV was never larger than 0.1, we selected the lower limit of the instrument as the smallest value measured by the instrument.

The upper limit of an instrument is difficult to determine. Lee and Morris (2013) found that the linearity of the correlations plots (similar to those shown on Figure 2) broke down when one of the instruments was near its upper limit. However we did not see any sign of this in our study, so we conservatively estimated an upper limit as the largest susceptibility that we measured. There are no iron formations or highly susceptible rocks in the study area, so this will be a low value and we acknowledge that is not realistic. These values are also tabulated in the second row of Table 2.

A further feature that might be required of magnetic susceptibility meters is the ability to measure the susceptibility of diamagnetic materials that have small negative susceptibilities. Twenty measurements were taken with each instrument on a sample of quartzite (Figure 4). The RT-1 and GDD instruments gave readings of zero. The KT-10 gave erratic positive readings, the SM30 gave very small negative readings, and the MS2K and MS2C gave larger negative readings, with the latter being larger and more erratic.

Which instrument should I use for my project?

The most appropriate instrument to use on a particular project will depend on the purpose of the project. For example, if an instrument is to be used in a study of highly susceptible iron formations then accuracy at large values is required, and this study will not provide appropriate guidance. In other cases, the speed or ease of undertaking measurements might determine which instrument to use, or the ease with which the data can be downloaded from the instrument might be an important. These logistical factors are discussed in greater length by Deng (2014). In ideal circumstances measurements should be taken on fresh (unweathered) and flat sample surfaces. However, some instruments can correct for the diameter of the core, or have the correction factors built into the software of the instrument (Deng, 2014). The MS2C sensor assumes the core is cylindrical. Information in Table 2 will guide individuals interested in particular instrument features, i.e. lower limits of sensitivity,

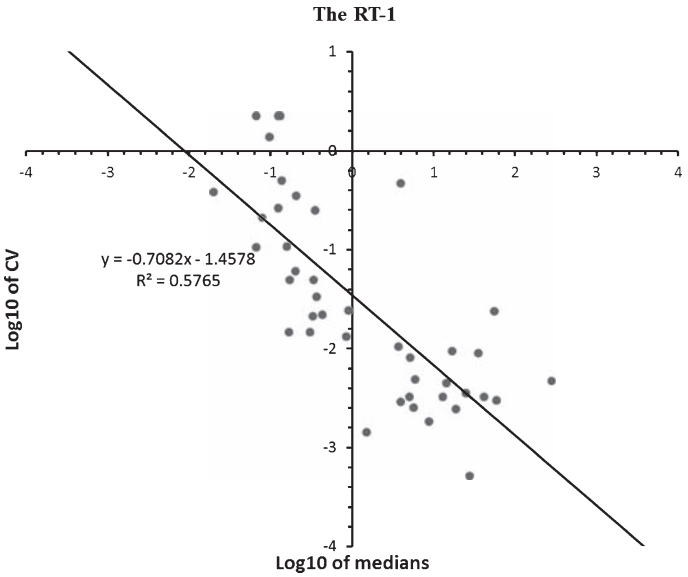

Figure 3. *The co-efficient of variation (standard deviation/mean) as a function of the measured magnetic susceptibility (log-log plot).*

drift rate, ability to handle cylindrical core, cost etc. In addition to the information on the table, we have the following observations about each instrument.

The **RT-1** Instrument is the easiest to use. It can take readings within a few seconds of being switched on and can download the readings via Bluetooth. This instrument gave poorer results for small and negative susceptibilities. The instrument has a scan mode for finding the most susceptible samples.

The Bartington Instruments' **MS3** sensor requires 20 to 45 minutes to set-up, but once set up measurements can be taken quickly and easily. It can be used with a variety of sensors for different types of samples. The **MS2C** is restricted to narrow cylindrical core, and the **MS2K** is designed for flat surfaces. The instruments and computers required to connect to the **MS3** require mains power, so they are not easy to use in the field, but could be used in a core shed. We found that the **MS2C** generally returns stable values.

The **GDD-EMS2+** requires 40 minutes to warm up after it is switched on. The instrument comes with a pocket computer that processes, logs and displays the data in a convenient manner. This instrument showed some temporal drift, but was stable over the two month period during which data were collected. The main advantage of this instrument is that it can simultaneously measure conductivity, provided that the conductivity is greater than 0.5 S/m. The GDD instrument can take continuous measurements and graph the results on the pocket computer.

The **KT-10** requires the sensor to be moved away from the samples for an in-air calibration. The buttons must also be pressed in a certain time frame or an error message will be displayed. This procedure requires some practice. The KT-10 showed minimal drift, but did not measure a negative susceptibility on our sample of diamagnetic quartz. Bleeker (2012) found the KT-10's scan mode more convenient than the SM-30. The S/C version of the KT-10 can also measure conductivity for values greater than 1 S/m. Since this study was undertaken, Terraplus has released a new model called KT-20, which also measures MS and conductivity. This new instrument has a resolution of 0.1 S/m for conductivity and may have different characteristics from the KT-10 we tested.

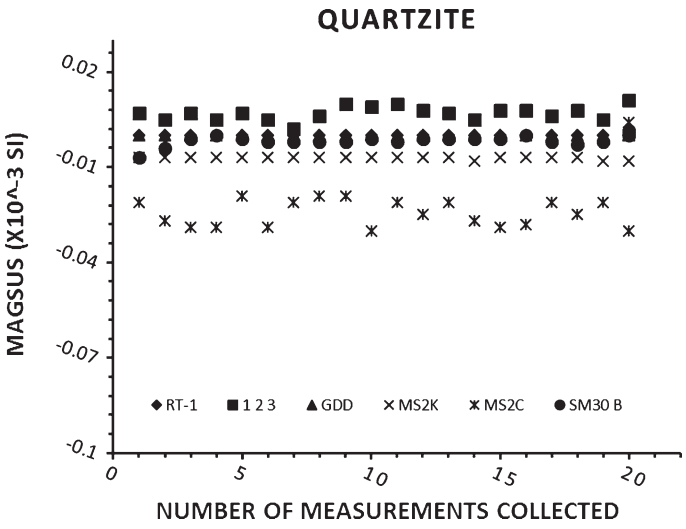

Figure 4. *Repeated measurements of the susceptibility on diamagnetic quartzite. The results should be small and negative. The GDD readings and RT-1 readings (the latter are obscured) are zero.*

The **SM-30** is a little complicated to operate, so the manual should be read carefully and the correct procedures followed to avoid mixing modes and overwriting measurements. Like the KT-10, the SM-30 showed minimal drift. One of its greatest advantages is that it is comparable in size to a large cigarette packet and can be carried in a pocket.

After having purchased an instrument the manufacturer should be contacted to ensure that the instrument includes the latest version of the appropriate software. We found this was necessary in one case and after the software was upgraded better results were obtained. Readings can be erratic; we found that it was a good idea to take at least five reading and to take the median of these as the measurement.

Acknowledgements

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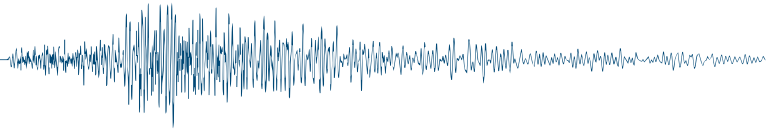

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12–15	79th EAGE Conference and Exhibition 2017 http://www.eage.org/	Paris	France
September	**2017**		
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24–27	SEG International Exhibition and 87th Annual Meeting http://www.seg.org	Houston	USA
October	**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
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Hand crafted in the Angove small batch winery, the berries were gently de-stemmed with a large proportion of whole berries included. A three day cold soak was followed by fermentation during which the juice is gently pumped over the skins to extract colour, flavour and tannin. The finished ferment was then basket pressed to ensure the gentle handling continues as the delicate flavours are coaxed from the grapes. Maturation in small oak for 12 months prior to barrel selection and assemblage preceded minimal fining and light filtration pre bottling.

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	Hugo Wines Sauvignon Blanc 2016	$135	
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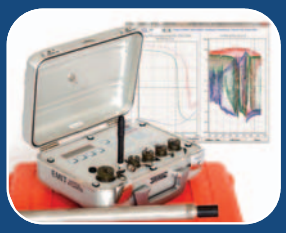

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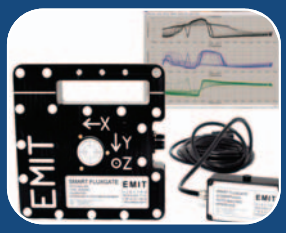

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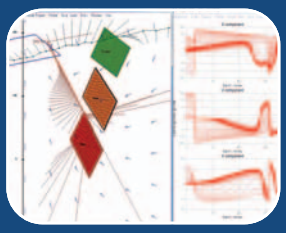

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