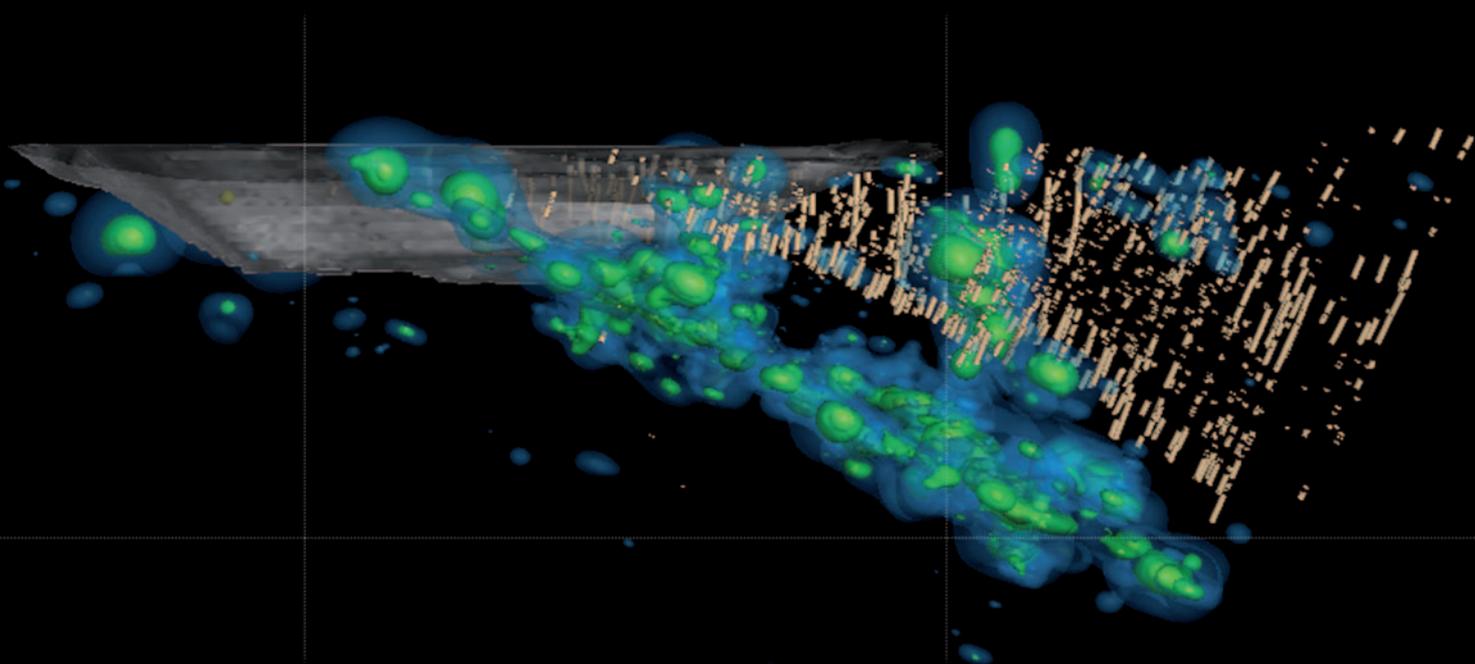


P PREVIEW

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS



NEWS AND COMMENTARY

2014 Tour: SEG Pacific HL S. Chandola
23rd IGC: undercover workshop recap
24th IGC: conference themes
GGSSA: overview and update
23rd IGC: a student perspective

FEATURE ARTICLE

Impact structures in the Eastern Yilgarn





Downhole EM, MMR and IP Surveys

Surface EM and MMR Surveys

Surface IP Surveys including 3D

Geophysical Consulting

Instrument Repair



VORTEX GEOPHYSICS

www.vortexgeophysics.com.au

4/133 Kelvin Rd, Maddington, Western Australia 6109
PO Box 3215, Lesmurdie, Western Australia 6076

Phone: (08) 9291 7733 Fax: (08) 9459 3953
Email: sales@vortexgeophysics.com.au

ADVERTISERS INDEX

Aerosystems	IBC
Alpha Geoscience	2, 37
Archimedes Financial Planning	37
Baigent Geosciences Pty Ltd	37
Borehole Wireline	37
CGG	3
Daishsat	IBC
EMIT	OBC
Fairfield Nodal	19
Flagstaff GeoConsultants	37
GBG Australia	37
Geophysical Software Solutions Pty Ltd	37
Geosensor	37
GPX Surveys	20
Groundwater Imaging	38
MagneticEarth	38
Minty Geophysics	38
Mira Geoscience	38
ModernMag	38
Monex	8
NSW Government	39
Petrosys	9
Systems Exploration (NSW) Pty Ltd	38
Tensor Research	38
Thomson Aviation	6
Vortex Geophysics	IFC
Zonge	18

2013 ASEG CORPORATE MEMBERS CORPORATE PLUS MEMBERS

BHP Billiton Limited
Elliott Geophysics International Pty Ltd
Outer-Rim Exploration Services Pty Ltd
Vale Exploration Pty Ltd
Velseis Pty Ltd

CORPORATE MEMBERS

Aeroquest Airborne
Alpha Geoscience Pty Ltd
Archimedes Financial Planning
Beach Energy Limited
CGGVeritas Services (Australia) Pty Ltd
Chevron Australia Pty Ltd
Eni Australia Limited
Fugro Airborne Surveys Pty Ltd
Geokinetics (Australasia) Pty Ltd
Geopublishing Ltd
Geoscience Australia
Geosensor Pty Ltd
Geosoft Australia Pty Ltd
Geotech Ltd
Gold and Copper Resources
Instrumentation GDD Inc.
Newmont Australia Pty Limited
Origin Energy Resources Ltd
Papuan Oil Search Limited
Petrosys Pty Ltd
PGS Australia Pty Ltd
Quantec Geoscience Pty Ltd
Rio Tinto Exploration Pty Ltd
Santos Limited
SGI Search Group Inc.
Seismic Asia Pacific Pty Ltd
Southern Geoscience Consultants Pty Ltd
Terrex Seismic
Thomson Aviation Pty Ltd
WesternGeco
Woodside Energy Ltd
Zonge Engineering

CONTENTS

Editor's Desk	2
ASEG News	
President's Piece	4
Executive Brief	5
People	6
Branch News	7
News	
Conferences and Events	10
Industry	20
Education	21
Geophysics in the Surveys	23
Feature Papers	
Meteorite impacts to gold and nickel deposits	25
Data Trends	33
Petroleum	34
Business Directory	37
Calendar of Events	40

FRONT COVER



Geochem dataset from the Ranger deposit (see article p. 13; image courtesy of James Cleverley, CSIRO).

NEWS AND COMMENTARY
2013 ASEG Meeting, 11 December
2013 ASEG Conference, 12-13 December
2013 ASEG, 14-15 December
2013 ASEG, 16-17 December
2013 ASEG, 18-19 December

FEATURE ARTICLES
Impact Structures in the Kimberley Pilgrims

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

Editor

John A. Theodoridis
Tel: 0427 103 398
Email: previeweditor@aseg.org.au

Associate Editors

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

Canberra Observed: David Denham
Email: denham@webone.com.au

Data Trends: Guy Holmes
Email: guy.holmes@spectrumdata.com.au

Minerals and Environment: Greg Street
Email: gstreet@intergeo.com.au

Petroleum: Mick Micenko
Email: micenko@bigpond.com

ASEG Head Office & Secretariat

Ron Adams
Centre for Association Management
Tel: (08) 9427 0838
Email: secretary@aseg.org.au
Website: <http://www.aseg.org.au>

Publisher

CSIRO PUBLISHING

Production Editor

Helen Pavlatos
Tel: (03) 9662 7613
Email: helen.pavlatos@csiro.au

Advertising

Doug Walters
Tel: (03) 9662 7606
Email: doug.walters@csiro.au



John A. Theodoridis

After an exhausting ASEG calendar, it is with much relief, sprinkled with a pinch of sentimentality, that we reach the final issue of *Preview* for 2013: festive season social drinks are well deserved by all.

In this issue, Ken Witherly and Graham Ascough provide us with summaries of the *Exploration Undercover* workshop components held on 15 August as part of the ASEG-PESA 2013 – 23rd IGC (Melbourne). Research within this area is motivated by the need to go beyond traditional near surface exploration strategies, given their ineffectiveness in the detection and delineation of mineralisations at depth or undercover. As both Witherly and Ascough remind us, industry is of the realisation that these problematic targets are likely to form the basis of deposits of substantial worth within the near future.

In the lead up to the ASEG-PESA 2015 – 24th IGC (Perth), Andrew Long (Co-Chair Petroleum) will be visiting themes, via a series of articles, anticipated to be prominent within the petroleum stream. He commences this series, and our ‘together for discovery’ in geophysics and geology, with an article entitled ‘Multi-level air gun source technology’.

In continuation of its professional development (PD) workshop *Challenging Earth Series*, designed for teachers and allied professionals alike, TESEP is launching an educational DVD for ‘PD9: plate tectonics’ on 4 December in Adelaide this year. To augment the DVD, geophones supplied by industry will be distributed to teachers nationwide as demonstration aids. Opportunities exist to support this programme, as additional functioning geophones are still required: please contact TESEP for more information.

Suppose a colleague approached you and spoke of their experience at a recent conference – though interested, you might anticipate more of the same. So imagine your astonishment as they

expounded in passionate enthusiastic tone the significance of the event within their career, and how it enabled them to broaden their aspect and focus their research, with renewed vigour and efficacy, providing direction to achieve the high standards demanded by industry to permit engagement in a prosperous career. Perhaps even, they may share their newly acquired wisdom of the importance of thoroughness and rigour in research despite its apparent triviality. Or how networking and presentations proved intellectually enriching, and workshops to acquire practical skills in data acquisition invaluable. Admittedly, one may be taken aback by such fervour, but still harbour perplexed curiosity and an unsettling sense of missed opportunity. Paraphrased from student accounts of the Melbourne 23rd IGC, these comments do

leave one wondering, that perhaps it is the well-established within the industry that missed out on their very own eureka moment – a humbling thought, no doubt!

We end by expressing our condolences for the recent passing of Dr Kenneth L. Zonge, founder of Zonge Engineering. His obituary, demonstrating our respect, shall be placed in the next issue of *Preview*.

Errata

The article ‘2013 Careers in Geoscience: a big hit!’ featured in the Education section of *Preview*, issue 166, p. 30, is authored by the co-organiser of the event Jo Watkins (Executive Officer, Secondary Education), and not Anne Tomlinson (WA Branch President) as printed.

downhole geophysical logging



- ✓ Full range of downhole probes
- ✓ Coal, Minerals, Uranium and groundwater applications
- ✓ Winches to 1,850 metres
- ✓ available for purchase or rental

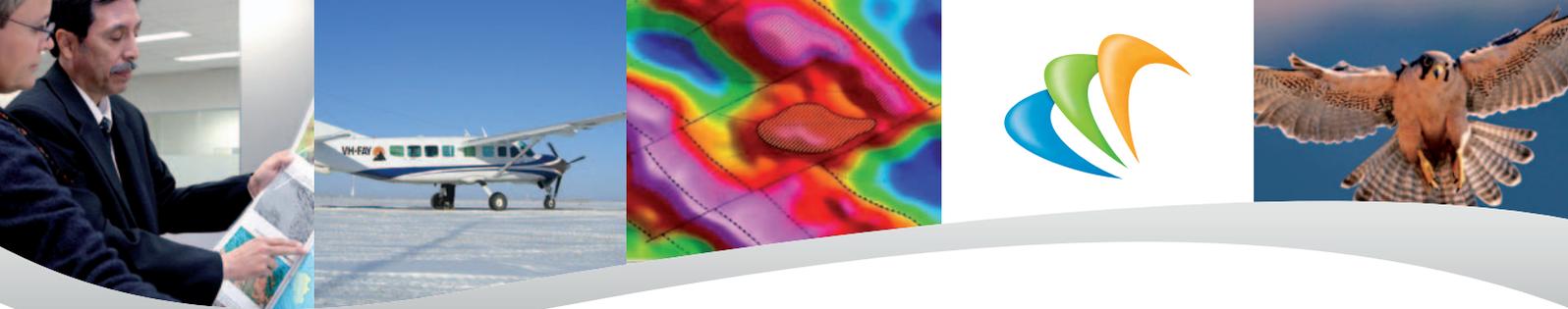


Find out today how the range of logging systems can suit your project needs. For product and technical enquiries please contact

Alpha GeoScience
Viewing the Earth

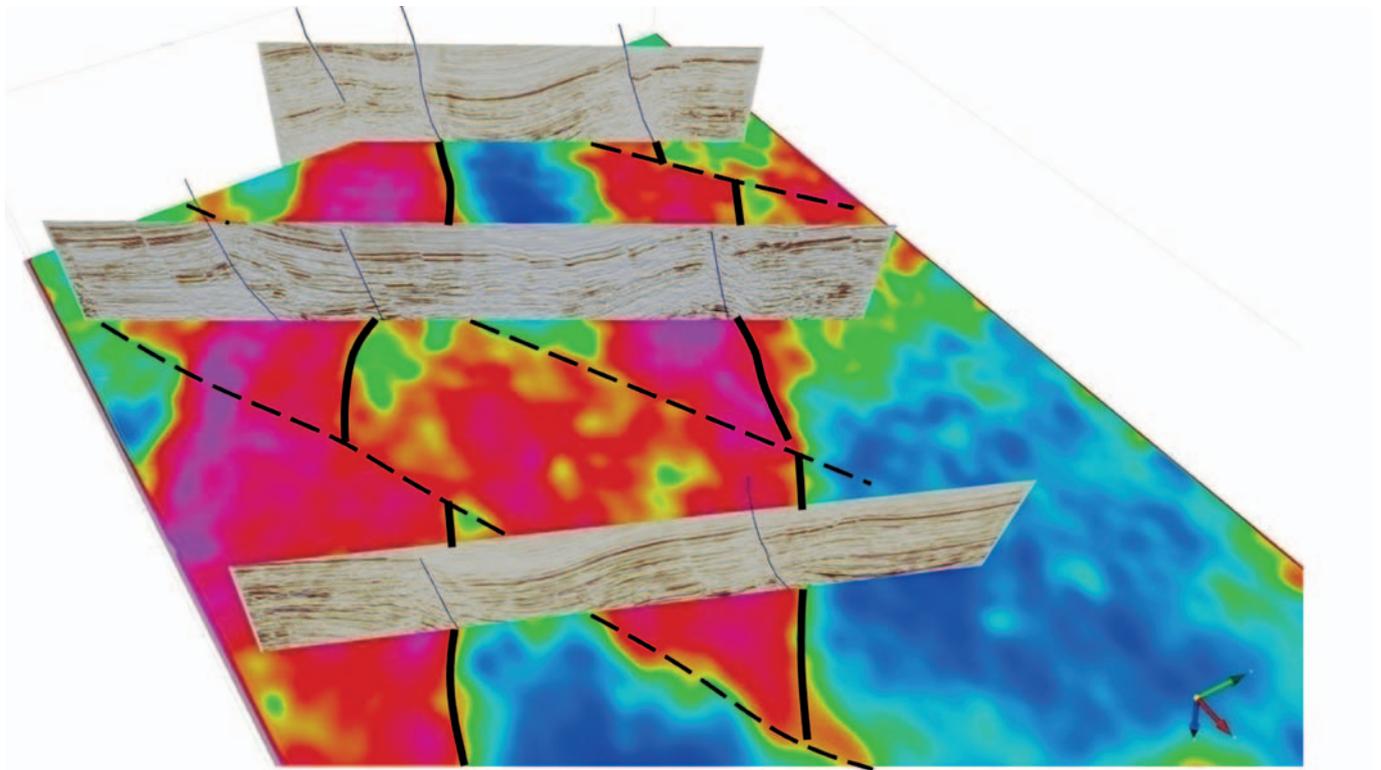
www.alpha-geo.com

Phone: +61 2 9584 7500 | E-mail: info@alpha-geo.com



FALCON

World-beating Airborne Gravity Gradiometry
Adding an extra dimension to 2D seismic



FALCON AGG enabling confident correlation of structure between seismic lines. Image courtesy of Buru Energy.

Two **FALCON**® systems now flying in Australia.
Five systems operating globally.

cgg.com/airborne

What is unexpected

I came to Australia in the middle of the 1970s. In my home country, Japan, it was a time of economic growth through to the early 1990s. In this 20-year period, GDP per capita of Japan in terms of US dollars increased by nearly 10 times! This figure is rather inflated as the exchange rate between the Japanese Yen and US dollar tripled during this time, so actual growth in terms of the local currency is about three times. It is still a remarkable growth. For comparison, Australia's growth during the same period was about 1.4 times – this, I totally missed.

During this period, economic analysts and researchers in culture and politics studied the background economic success of Japan. This inspired the publication of books such as *Japan as Number One* (Ezra Vogel, 1979) and *The Enigma of Japanese Power: People and Politics in a Stateless Nation* (Karel van Wolferen, 1990). About that time, I read an interview article in a current affairs magazine that my mother had sent me every month. The person interviewed was a top businessman of either Sony or Honda – I forget which company. Back then, as now, these companies were known to be the most innovative and quickly growing in Japan. One particular phrase within the interview impacted me the most: 'If something could not be done, listing the reasons why it cannot be done is one thing and thinking how to make it possible is another'.

In life, we often hear 'excuses': 'I didn't have time', 'I didn't know that', 'I wasn't told', 'It was someone else's job', 'It was beyond our expectation', and so on. The 'beyond expectation' excuse is interesting and is often heard when a natural disaster

hits: one such example pertains to the size of an earthquake, tsunami, hurricane, typhoon and volcanic eruption. We heard this excuse for the scale of the tsunami that hit the Fukushima Nuclear Reactor. Perhaps the engineers were not clever enough to expect the unexpected. But is this excuse permissible for a technical person? This question always hits me in many aspects of life.

Although, the 'unexpected' is not always bad. The ASEG had a good year with an 'unexpectedly' large surplus from the Melbourne conference – thanks to all those involved. Due to our strong financial position, your Federal Executive decided to keep the membership fee at the same level as last year. In addition, you can save further with the early bird rate if you pay the subscription before the end of the year.

The first OzSTEP proved a success in every state branch around the country. Thanks to the lecturers, Dennis Cooke and Mike Asten, and Wendy Watkins for organising the courses. Preparations for next year are underway with dates to be announced in the near future.

Along with the ASEG's five-year strategic plan, we will form Specialist Groups. These are groups of members with common interests, and will communicate to members via newsletters, single-subject workshops and symposia. We hope these groups will grow strong as technical forums of the ASEG. Please contact Tania Dhu (nt-rep@aseg.org.au) to submit either suggestions or requests to form a group.

I attended the SEG Annual Meeting in Houston in September. As Houston

holds SEG's largest membership base, the conference turnout was very big with about 10000 delegates. After the difficulty of the big change of the executive structure a few years ago, the SEG now seems to be running smoothly, and the Council meeting didn't have serious issues beyond house-keeping amendments to the By-Laws. The ASEG and SEG had an executive meeting, which I attended with our past presidents Mike Asten and Dennis Cooke. We thanked the SEG for their help in publishing our e-Book on *Aeromagnetic Interpretation* (Isles and Rankin, 2013) and for inclusion of *Exploration Geophysics* in the SEG digital library. We also gave assurances to continue subsidising the SEG's Distinguished Lecturers, Honorary Lecturers and DISC to bring more locations than their budget allows.

On behalf of the ASEG Federal Executives, I wish you all a Merry Christmas, a Happy New Year and a safe holiday season.



Koya Suto
ASEG – President
president@aseg.org.au



Koya at the ASEG booth at the SEG Annual Meeting.



After the SEG-ASEG Executive Meeting: (front L-R) Chris Liner, Mike Asten, David Monk, Koya Suto, Don Steeples and Dennis Cooke; (back L-R) Terry Todd, Rhonda Jacobs, Steve Davis, Ted Bakamijian and Tom Smith.

ASEG Federal Executive 2013–14

President, International Affairs Committee – Chair:
Koya Suto
Tel: (07) 3876 3848
Email: president@aseg.org.au

President Elect: Greg Street
Tel: (08) 9388 2839
Email: presidentelect@aseg.org.au

Vice President, Publications Committee – Chair:
Phil Schmidt
Tel: 0410 456 495
Email: publications@aseg.org.au

Vice President, Education Committee – Chair:
Mark Tingay
Tel: (08) 8303 3080
Email: education@aseg.org.au

Immediate Past President: Kim Frankcombe
Tel: (08) 6201 7719
Email: pastpresident@aseg.org.au

Past President: Michael Asten
Tel: 0412 348 682
Email: michael.asten@sci.monash.edu.au

Secretary: Barry Drummond
Tel: (02) 6254 7680
Email: fedsec@aseg.org.au

Treasurer: Reece Foster
(Finance Committee – Chair)
Tel: (08) 9378 8000
Email: treasurer@aseg.org.au

Committee Members

State Branch Representative: Philip Heath
Tel: (08) 8463 3087
Email: Branchrep@aseg.org.au

Web Committee – Webmaster: Carina Kemp
Tel: 0412 514 075
Email: webmaster@aseg.org.au

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

Continuing Education: Wendy Watkins
Tel: (02) 9921 2010
Email: continuingeducation@aseg.org.au

Chair people for Standing Committees (not on FedEx)

Research Foundation – Chair: Philip Harman
Tel: (03) 9909 7655
Email: research-foundation@aseg.org.au

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

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

Conference Advisory Committee – Chair:
Michael Hatch
Tel: 0417 306 382
Email: CAC@aseg.org.au

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

Technical Standards Committee – Chair:
David Robson
Tel: (02) 4931 6717
Email: technical-standards@aseg.org.au

ASEG BRANCHES

Australian Capital Territory

President: Carina Kemp
Tel: (02) 6249 9228
Email: actpresident@aseg.org.au

Secretary: Millie Crowe
Tel: (02) 6249 9846
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) 8907 7900
Email: nswsecretary@aseg.org.au

Queensland

President: Fiona Duncan
Tel: (07) 3024 7502
Email: qldpresident@aseg.org.au

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

South Australia & Northern Territory

President: Erin Shirley
Tel: (08) 8338 2833
Email: Sa-ntpresident@aseg.org.au

Secretary: Joshua Sage
Tel: 0438 705 941
Email: Sa-ntsecretary@aseg.org.au

NT Representative: Tania Dhu
Tel: (08) 8999 5214
Email: Nt-rep@aseg.org.au

Tasmania

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

Victoria

President: Asbjorn Norlund Christensen
Tel: (03) 9885 1378
Email: vicpresident@aseg.org.au

Secretary: John Theodoridis
Tel: 0427 103 398
Email: vicsecretary@aseg.org.au

Western Australia

President: Anne Tomlinson
Tel: (08) 6254 5000
Email: wapresident@aseg.org.au

Secretary: CASM (Ron Adams)
Tel: (08) 9427 0838
Email: wasecretary@aseg.org.au

The ASEG Secretariat

Centre for Association Management (CASM)
36 Brisbane Street, Perth, WA 6000
Tel: Ron Adams (08) 9427 0800
Fax: (08) 9427 0801
Email: aseg@casm.com.au

New members

The ASEG extends a warm welcome to the seven new individual members approved by the Federal Executive on 31 October 2013 (see table).

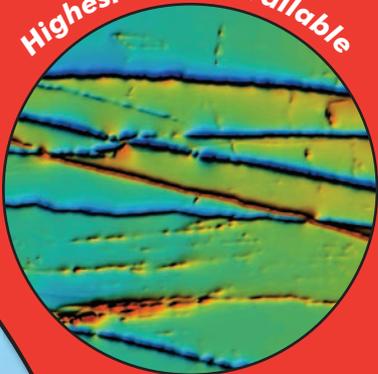
Name	Organisation	Country	Member Grade
Alexandra Bennet	Beach Energy	Australia	Active
Okan Evans	-	Australia	Student
Julie Ellen Fun	-	Australia	Student
Rie Kamei	CPG	Australia	Active
Sonny Hock Beng Lim	Beach Energy	Australia	Active
Ian Moffat	Archaemetry Pty Ltd	Australia	Active (upgrade)
Christopher Semeniuk	Schlumberger	Australia	Active

THOMSON AVIATION

Airborne Geophysical Survey



Highest Detail Available





Contact:
Paul Rogerson

P. +61 2 6964 9487
M. +61 427 681 484
E. paul@thomsonaviation.com.au
W. thomsonaviation.com.au

- High Quality Airborne Gravity, Magnetic & Radiometric Survey
- Fixed wing & Helicopter platforms
- Worldwide
- Utilising latest available equipment




Full member of



Australian Capital Territory

The ACT Branch has been quiet the past few months. We have been preparing for our OzSTEP courses to be run in late November. They are proving to be very popular and we hope we can accommodate all interested participants.

We had a very interesting technical meeting in October: Jingbo Wang of Geoscience Australia presented some of her previous PhD research and ideas for future research in the area of using seismic monitoring for fracking in the coal seam gas and geothermal industries. The talk created some debate in the audience and we all agreed that there was potential for geophysical applications to assist more in this contentious area.

Carina Kemp

New South Wales

In September, ASEG President Koya Suto gave a talk on the 'Multichannel analysis of surface wave technique', discussing applications and showing many examples of its use.

In October, we held our student night and the following students spoke. All talks were well presented and much discussion followed over beers and wine:

- Gareth Davies: 'Rapid 2D and 3D modelling of coastal groundwater salinity using integrated geophysical techniques' (UNSW).
- Morgan Evans: 'Kick-starting the thermal conductivity database for geothermal exploration' (Macquarie University).
- Amy I'Anson: 'Coal seam gas in the Galilee Basin, Queensland' (Sydney University).
- Cameron Perks: 'Describing the Dimboola structural subzone basement-rocks beneath EL5291' (Macquarie University).
- Nicky Wright: 'Revised reconstructions of the Late Cretaceous to recent history of the Pacific basin' (Sydney University).

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to be in town at that time. Meetings are 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

Queensland

The Brisbane Branch recently enjoyed a visit by SEG HL Valentina Socco. We have been lucky enough to secure a number of visits from SEG presenters this year and hope to continue this in 2014. To finish the year we are looking forward to Randal Taylor and Stewart Fletcher presenting their conference presentations to the Qld Branch on 5 December.

The Brisbane Branch is always on the lookout for presenters at present to fill our Technical programme. We would like to invite anybody willing to present to please contact the Queensland ASEG Branch president, Fiona Duncan (qldpresident@aseg.org.au), and extend this invitation to those passing through Brisbane.

Fiona Duncan

South Australia/Northern Territory

In September, the SA/NT Branch hosted the annual Industry Night. This year focussed on unconventional resources and the speakers were from Beach Energy, Santos, Petrofrontier and DMITRE. This was a very successful evening and had our largest audience turnout for the year. In October, Dr Dennis Cooke presented his OzSTEP short course 'Interpreting seismic amplitudes'. This was also highly successful with participants from industry, academia and students.

Our final events for this year include the SEG lecture to be presented by Valentina Socco, titled 'Surface wave analysis for near-surface characterisation: introduction, theme and variations'. Also coming up

this month, the annual Student Night will be held on 26 November, the speaker will include the SA scholarship winners, Joshua Sage and Dennis Conway, and other high-achieving students.

Everyone is invited to our upcoming events and for further details please check out the ASEG website www.aseg.org.au or contact sa-ntpresident@aseg.org.au. Also, if you have a presentation that you would be interested in giving to the SA Branch in 2014 please feel free to contact us.

The ASEG wine offer has closed for this year and orders should be delivered just in time for Christmas. Also a special thanks to the SA/NT committee for all your help and I have really enjoyed being the president this year.

Wishing everyone a very happy holiday season.

Erin Shirley

Victoria

On Wednesday 30 October 2013 the ASEG Victoria Branch hosted the ASEG OzSTEP one-day courses, 'Interpreting seismic amplitudes' by Dennis Cooke and 'Introduction to geophysics for explorationists' by Michael Asten at the Crowne Plaza Hotel in Melbourne's CBD. The courses were very well received by the participants. Regrettably we did not have as many participants to the courses as we would have liked. The low participation rate is perhaps a result of the glut of geophysical courses having been offered in Melbourne over the past three months: 20 alone during August at



2013 SEG HL – Valentina Socco presents at a Queensland Branch technical meeting.

the ASEG-PESA 2013 conference, and perhaps also an indication of the current state of the minerals exploration industry.

Nevertheless, a large anomaly of geophysicists turned up on the evening of Wednesday 30 October 2013 for the 'Annual ASEG Victoria Branch Student Night'. Five representatives of the next generation of exploration geophysicists from Melbourne University, Monash University and RMIT showcased their Honours and PhD projects: Joseph Hamad from RMIT first presented 'Compact EM transmitter coil design', Thomas Carmichael from Monash University followed with 'Using variography of structural measurements to characterise folding events', then Janenie Mohgan, University of Melbourne, discussed 'The potential of ground penetrating radar in bauxite exploration', after which Wang Liang from RMIT introduced 'Characterising laboratory EM noise' and finally Sheree Armistead, Monash University, talked us through 'Geophysical applications for IOCG exploration over the Benagerie Ridge Magnetic Complex, Curnamona Province, South Australia'. The four

judges, Paul St John, Seda Rouxel, Matt Zengerer and Craig Smith, had some difficulties selecting the winner in a field of strong performers. However, after due consideration first prize went to Sheree Armistead with Wang Liang and Janenie Mohgan each receiving runner-up prizes. A big 'thank you' goes out to all the students, who each did a tremendous job, and who all had put a lot of effort into their presentations.

On Wednesday 13 November 2013 at the Kelvin Club Theo Aravanis from Rio Tinto Exploration will be presenting an introduction to the work of the Ground Geophysical Survey Safety Association (GGSSA).

On Wednesday 11 December 2013 it will again be time for our Annual ASEG-PESA-SPE Societies Christmas Lunch at the Victoria Hotel. This year Steve Henzell (SPE President) will be speaking about the history of oil in Victoria.

After that it will be time to put the geophysical pursuits aside for a while and focus on family and friends over the holidays. First meeting in the New Year will be the joint ASEG-PESA-SPE

Summer Social Function to be held in early February. Entry will be free for paid-up members. On behalf of the ASEG Victoria Branch I wish you all the best for 2014.

Asbjorn Norlund Christensen

Western Australia

Please refer to the ASEG national calendar below and the ASEG website for upcoming meetings and events. To ensure that you never miss out, do sign-up to the WA mailing list at <http://cepurl.com/nleOD> or follow the QR link below to receive notifications and online registration details for WA news and events.



Anne Tomlinson



**Monex
GeoScope**
*Designers and manufacturers
of the terraTEM range of products*

Ground TEM Solutions

Whatever your TEM needs, Monex GeoScope can deliver a fully integrated system, reliable in all environments and terrains.

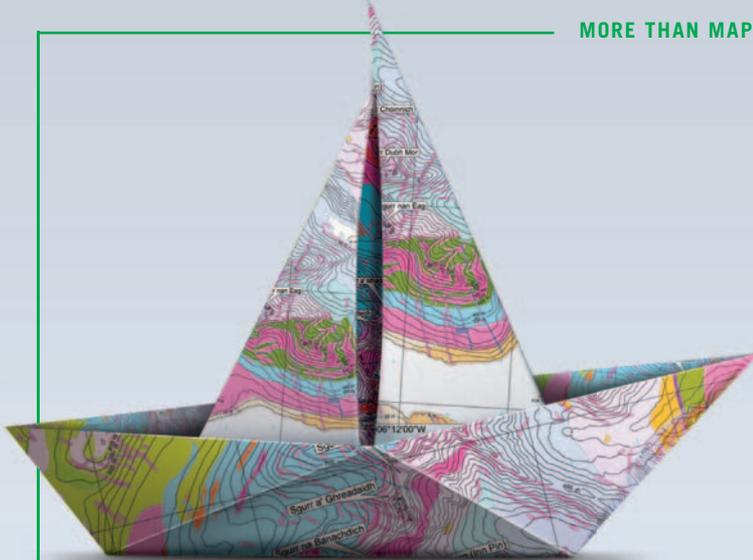
<p>terraTEM</p>  <ul style="list-style-type: none"> • 500kHz receiver • 3 simultaneous channels • Receiver and transmitter contained in one unit • 15A, 24V transmitter (48V optional) • Inbuilt data reduction and software processing package 	<p>terraTX-50</p>  <ul style="list-style-type: none"> • 250V maximum input voltage • 50A maximum output current • Fast turnoff • User selectable ramp • In-built GPS or Crystal Synch available • Touchscreen interface 	<p>Sensors</p>  <ul style="list-style-type: none"> • TRC induction sensor available in different bandwidths • Induction and B-field downhole tools • Surface B-field sensor, auto Earth field nulling and rotation correction
---	--	---

Monex GeoScope Pty Ltd
P: +61 (0)3 9762 7862 E: info@monexgeoscope.com.au W: www.monexgeoscope.com.au

ASEG national calendar: technical meetings, courses and events

Date	Event	Presenter	Time	Venue
2014				
12 Feb	'Looking for granitoid and graphite to find copper in Zambia'	Chris Wijns, First Quantum Minerals	1730–1900	City West, West Perth
9 Apr	'New logging and sensing technologies for mineral exploration'	Brett Harris, Curtin University	1730–1900	City West, West Perth
9 Jul	'Frequency-domain full waveform inversion: applications to marine and land seismic experiment'	Rie Kamei, UWA	1730–1900	City West, West Perth
13 Aug	Humanitarian geophysics	Jeff Shragge, UWA	1730–1900	City West, West Perth
13 Nov	Honours and Masters Students Research Presentations	Various	1730–1930	City West, West Perth
10 Dec	AGM and Christmas Party		1730–2030	TBA
2014 SEG Pacific South Honorary Lecturer: 'Marine Seismic Acquisition: Expanding the possibilities!' Presented by Sandeep K. Chandola, PETRONAS, Carigali, Kuala Lumpur, Malaysia. (http://www.seg.org/education/lectures-courses/honorary-lecturers/2014)				
Date	State Branch	–	Time	Venue
12 Mar	WA: Perth		1730–1900	City West, West Perth
13 Mar	SA: Adelaide		TBA	TBA
14 Mar	VIC: Melbourne		1800	The Kelvin Club
17 Mar	ACT: Canberra		TBA	TBA
18 Mar	QLD: Brisbane		TBA	TBA
19 Mar	NSW: Sydney		TBA	TBA
14 Apr	TAS: Hobart		TBA	TBA

TBA, to be advised.



MORE THAN MAPPING

CAN YOUR SOFTWARE WITHSTAND A FLOOD OF INFORMATION?

As the most dynamic data aggregator in the industry, Petrosys keeps your workflow moving.

SOFTWARE SERVICES CONNECTIVITY DATA MANAGEMENT

Only Petrosys' powerful suite of software effortlessly navigates the overflow of data from multiple sources and disciplines. Our industry-leading dynamic data aggregation, integration and surface modeling capabilities enable you to identify, refine and resolve issues more quickly. Dedicated technical support and service offer expert solutions when needed. And with our clear, logical interface, even getting started is smooth sailing. Start achieving exploration and production targets at a lower cost and in a shorter time frame with Petrosys. To learn more go to www.petrosys.com.au/transcend.



Multi-level air gun source technology

Themes for the ASEG-PESA 2015, 24th IGC, Perth, WA



ASEG-PESA 2015

Geophysics and Geology together for Discovery

24th International Geophysical Conference and Exhibition
15 – 18 February 2015 Perth, Western Australia

Over the next year I will visit themes likely to be high profile in the technical petroleum streams for the ASEG-PESA 2015 conference due to be held in Perth, Western Australia, in February 2015 (www.conference.aseg.org.au). In recent years the so-called ‘broadband’ towed streamer seismic theme has been particularly high-profile, with most attention on methods to address the receiver-side ghost effects. Ultimately, however, to recover more low and high frequency amplitude information from the earth than currently achieved, we must turn our attention to the injection of a larger bandwidth source wavefield into the earth. The multilevel source (MLS) approach was revived by PGS in 2008, and has become an increasingly common source platform applied by several service companies since.

I review the strengths and pitfalls of the MLS approach. We expect that the source side of seismic acquisition will be a particularly high-profile topic at the ASEG-PESA 2015 conference.

Sequential firing of sub-arrays at different depths

A conventional airgun array used for towed streamer seismic surveys is made of several sub-arrays each containing a number of guns, or clusters of guns. All guns are at the same depth (typically between 5 m and 10 m) and fire at the same time. This provides constructive down-going energy, but also constructive up-going energy (the upper part of Figure 1). The MLS concept puts air guns, clusters or sub-arrays at different depths and fires them sequentially so that only the down-going waves build up constructively (Cambois *et al.* 2009). The up-going wave (source ghost) does not build constructively and the ghost effects are consequently reduced.

Figure 2 shows the amplitude spectra from a prototype MLS array tested in a ‘no seismic’ zone affected by extensive carbonates in the overburden and poor/

discontinuous reflectivity at the target level on the NW Shelf of Australia. The conventional source used in the survey was made of four sub-arrays towed at 6 m depth, totalling 2980 in³. The MLS simply consisted of lowering two sub-arrays to 12 m depth and the remaining two sub-arrays to 18 m depth. The 6 m vertical separation corresponds to a 4 ms firing delay between the upper and lower arrays; the time taken to propagate sound 6 m through water.

The MLS amplitude spectrum is flatter than for a conventional source: more extended towards the high and low frequencies, but trimmed in the mid-frequency range. Note also that the array separation is in this case identical to the conventional source depth, which explains why both source signatures exhibit a notch at 125 Hz.

Figures 3 and 4 illustrate how the comparatively stronger low frequencies

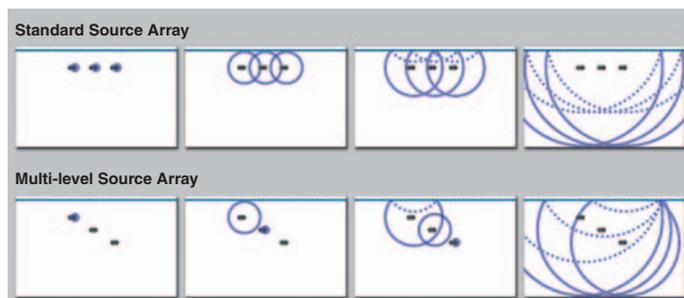


Fig. 1. A conventional source array (upper) fires all guns simultaneously, generating a constructive down-going wave (solid) and ghost (dashed). The sequential firing of the multi-level source (lower) builds a constructive down-going wave, but not a constructive ghost. Note however, the constructive energy on the upper-right corner of the last panel.

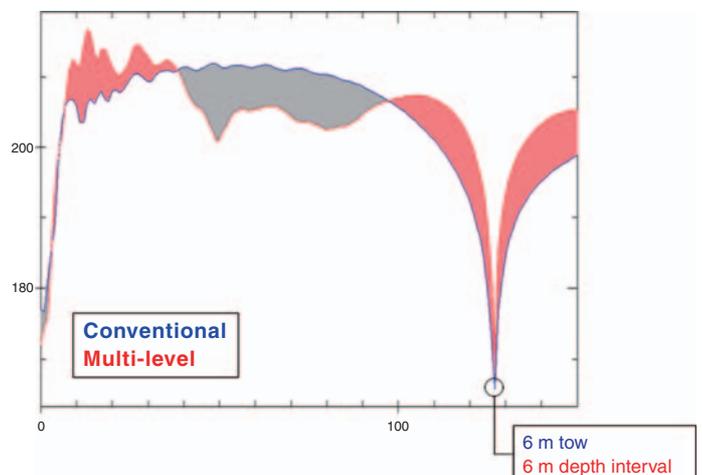


Fig. 2. Superimposed conventional and multilevel source spectrum (red vs blue, respectively) for a prototype test in 2008.

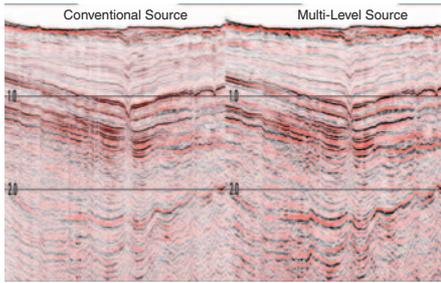


Fig. 3. Raw pre-stack time migrated comparison of the test line in a 0–3 s time window. Both panels include receiver-side deghosting via dual-sensor wavefield separation, the difference is therefore related to the source arrays (conventional source on the left and MLS on the right). Note the improved low frequency signal penetration on the right (compare with Figure 4).

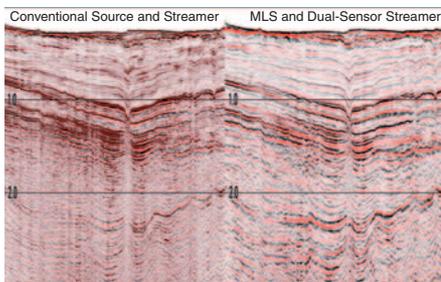


Fig. 4. Raw pre-stack time migrated comparison of the test line in the target time window of 1–3 s. When the effects of both the source-side and receiver-side ghost are present on conventional data (left) the target events are very weak, incoherent and impossible to interpret. In contrast, the MLS and dual-sensor streamer result (right) demonstrates a profound improvement in event strength, spatial coherency and interpretability (compare with Figure 3).

in the 10–40 Hz range assisted signal penetration through the carbonate overburden – an encouraging prototype test. In recent years since this test was published (based on a 30 year old idea), several large service companies have adopted commercial operations with MLS configurations. PGS simply refer to ‘Multi-Level Source’, CGG refer to ‘BroadSource’ and WesternGeco refer to ‘Delta Marine Broadband Seismic Source’.

Operational efficiency

Analogous to over-under streamer acquisition, over-under source firing is an old idea where sources are fired independently in roughly the same location, but using two different source array depths. However, the compromise is that the inline shot spacing is doubled in comparison to conventional shooting (Figure 5). This means the trace spacing

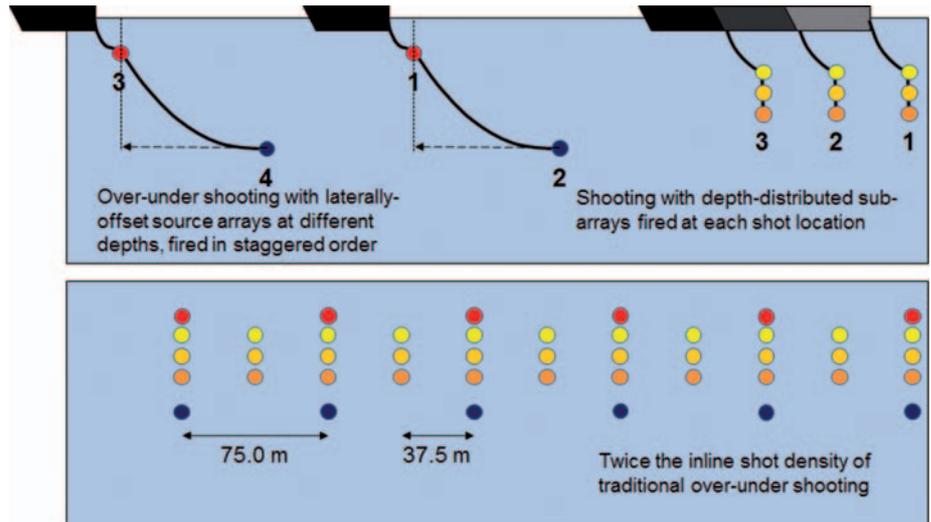


Fig. 5. With over-under source firing a conventional source array at shallow depth is fired first in a given location (Events 1 and 3). A second conventional source array towed deep is deployed at twice the nominal shot interval behind the shallow source array. When the deep source array is towed into the same shot location as the first shot it is fired (Events 2 and 4). The two source arrays (shallow and deep) are thus fired at the equivalent shot location (hopefully with a small radius of error), can be considered as independent shot events, and can be combined in processing to reduce or remove the effects of the source-side ghost. However, the operational compromise is that the inline over-under shot spacing is twice that for conventional source array firing. In contrast, MLS shot firing does not compromise inline shot spacing.

in the common midpoint, offset and receiver domains is doubled, and fold is halved. In comparison, MLS shooting can be considered as firing all (depth-distributed) sub-arrays in the same location, and thus no compromise is made to inline shot spacing.

Biasing the source amplitudes into different frequency ranges

Figure 6 compares modelled amplitude spectra for a conventional 3090 in³ array (three sub-arrays), a conventional 6180 in³ array (six sub-arrays), and the 6180 in³ array configured into a MLS configuration with three sub-array depths (two sub-arrays at each depth, 3 m vertical sub-array separation, 2 ms firing delay between each sub-array depth). Three different sets of MLS sub-array depths are modelled to illustrate how the amplitudes can be biased towards different frequency ranges. Note how a MLS array distributes amplitudes over a broader range of frequencies, so the amplitudes at various frequency ranges will be smaller than the equivalent amplitudes for a conventional source configuration. In other words, irrespective of the array configuration, there is roughly the same net energy available for injection into the earth. One related consideration is that signal-to-noise may also be compromised for certain frequency ranges in comparison to conventional source firing.

What about the ultra-low frequency output?

Figure 7 schematically illustrates the three fundamental approaches to configuring air gun arrays to modify the frequency-dependent output: increasing volume or pressure of the guns, or both; decreasing gun spacing to exploit interaction effects; or deploying sub-arrays of guns at two or more depths (either MLS or over-under). However, each approach has flaws regarding the ultra-low frequency output below about 7 Hz. The largest air gun volume typically used is 250 in³. Larger air guns have increasingly unstable bubble behaviour when towed, prohibiting accurate low frequency amplitude and phase modelling or measurement, thereby corrupting source signature during signal processing. So we are stuck with our existing gun volumes and pressures. The ‘hypercluster’ approach of Hopperstad *et al.* (2012) increases the overall bubble period of the array elements, thereby decreasing the characteristic frequency, the onset of significant amplitude in the frequency spectrum. In a prototype test the characteristic frequency decreased from about 9 Hz to about 5.5 Hz, but the amplitude was about 10 dB weaker. As described by Hegna and Parkes (2011), as gun depth is increased the hydrostatic pressure increases in the water column, the bubble period decreases and therefore

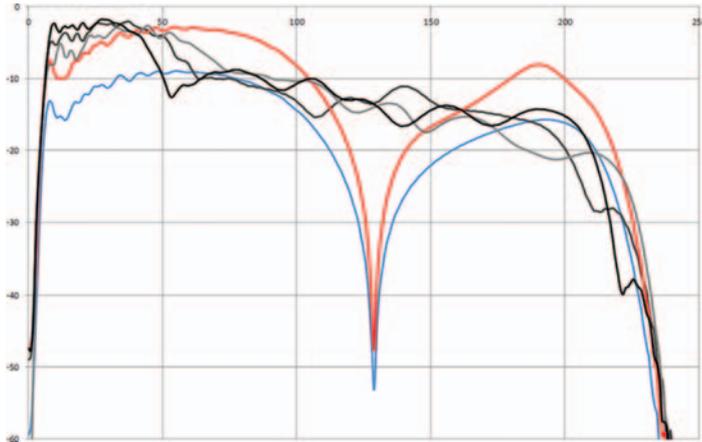


Fig. 6. Superimposed amplitude spectra for a 3090 in³ array consisting of three sub-arrays at 6 m depth (blue), a 6180 in³ array consisting of six sub-arrays at 6 m depth (red) and the 6180 in³ array configured in MLS mode with sub-arrays at three different depth configurations: (11 m, 14 m, 17 m (black line); 8 m, 11 m, 14 m (dark grey line); 5 m, 8 m, 11 m (light grey line). For each MLS sub-array depth, the sub-arrays are arranged in pairs at each depth, with the shallowest sub-arrays in the centre and the deepest sub-arrays on the outside. As the total energy output by a well-tuned source array is roughly proportional to the total array volume, the area (energy) under the red amplitude spectra (6180 in³ array at 6 m depth) is roughly twice the area (energy) under the blue amplitude spectra (3090 in³ array at 6 m depth). Likewise, the area (energy) under the red amplitude spectra (6180 in³ array at 6 m depth) is roughly equivalent to the area (energy) under the black amplitude spectra (6180 in³ array in MLS configuration). Note how the deep MLS configuration biases the radiated source energy towards a low frequency band at about 10–50 Hz in comparison to having all sub-arrays at 6 m depth. Overall, shallower MLS sub-array depths equate to a broader and flatter amplitude spectrum. The source ghost notch is completely filled in. Note also, that in all cases the ultra-low frequency amplitudes below about 8 Hz are not affected by changing the source configuration with constant (6180 in³) array volume. In fact, the deeper MLS sub-arrays generate less ultra-low frequency amplitudes because of reduced bubble period (below).

the characteristic frequency increases. In other words, we actually produce less ultra-low frequency amplitudes by towing deeper – in contrast to popular thinking. However, increasing array depth does move the source ghost bias towards

lower frequencies, for example, the 10–30 Hz range, as illustrated in Figure 6. Overall, the physics of air gun array behaviour makes ultra-low frequency output (0–7 Hz) very challenging in any scenario.

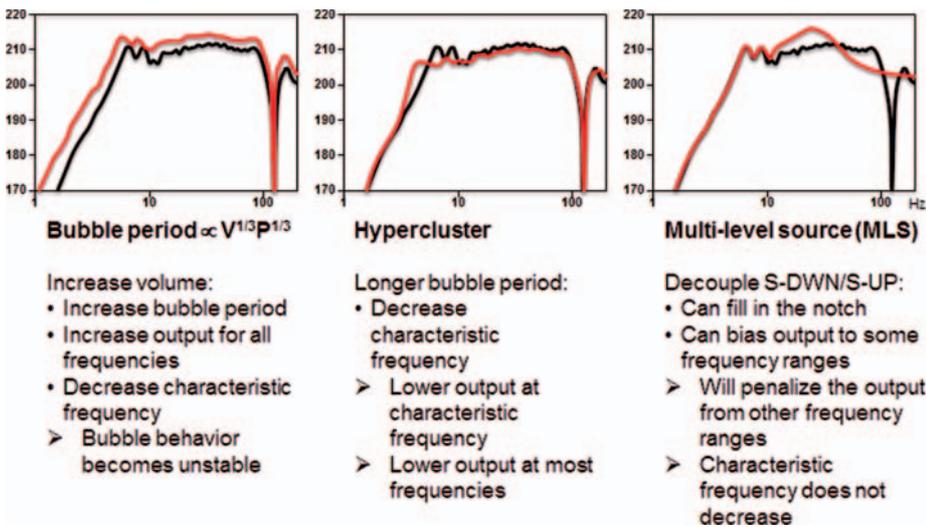


Fig. 7. Schematic comparison of the main published methods to modify air gun array output. The only established approach to increasing ultra-low frequency output below about 8 Hz relies on increasing bubble oscillation period, either by using large air gun volume (established) or by decreasing air gun spacing and exploiting the (prototype) frequency locking approach described by Hopperstad et al. (2012).

Summary

There exists no commercialised solution to significantly improve the ultra-low frequency (0–7 Hz) output of air gun arrays; for any source geometry or configuration, towing depth or firing scheme. Therefore, the ultra-low frequency component of the ‘broadband’ seismic story is constrained to removing the effects of the source-side and receiver-side ghosts (‘recovering’ more low frequencies from the earth, as opposed to ‘injecting’ more low frequencies into the earth). The multi-level source (MLS) approach is a robust way to fill in the source ghost notch and improve the range of frequencies injected into the earth – towards the high frequency side. While it is not a perfect source-side deghosting solution, survey design can be used to improve the range of frequencies being injected into the earth, thereby improving signal penetration in comparison to a conventional source array configuration. The ultra-low frequency output below 8–10 Hz will not be improved for any MLS array configuration. Operationally, there should be no compromise in inline shot spacing when using the MLS, but deploying, retrieving and servicing deep-towed air guns will be more difficult.

Andrew Long
Co-chair Petroleum
www.conference.aseg.org.au

References

Cambois, G., Long, A., Parkes, P., Lundsten, T., Mattsson, A., and Fromyr, E., 2009, Multi-level airgun array: a simple and effective way to enhance the low frequency content of marine seismic data. SEG Expanded Abstracts, 152–156.

Hegna, S., and Parkes, G., 2011, The low frequency output of marine air-gun arrays. SEG Expanded Abstract, 77–81.

Hopperstad, J. F., Laws, R., and Kragh, E. 2012, Hypercluster of airguns – more low frequencies for the same quantity of air. EAGE Extended Abstracts, 2011.

Summary of workshop held 15 August 2013 as part of the ASEG-PESA 23rd International Geophysical Conference and Exhibition

Workshop on Exploration Undercover; challenges and opportunities for industry, academia and government

Introduction

The minerals exploration industry over the past decade has come to realise that future significant mineral discoveries are most likely going to be found at depths or under cover material, that makes recognition of deposits, with the historically very successful boots and hammer type exploration approaches increasingly problematic. The term 'boots and hammer' in this context is defined as the geological recognition of outcropping or shallow mineralisation, and the use of simple 'bump finding' geophysical techniques, or the application of basic geochemical approaches, which were designed to detect shallow mineral systems.

Considerable efforts are being expended to define new exploration strategies and technologies in the two leading countries where most of the worlds' exploration technology is derived: Australia and Canada. These two countries also account for 28% of global exploration investment in 2012 conducted by publically traded companies according to the SNL-MEG, and so they would be major end users of any new exploration technologies as well.

Concurrent with the increased focus on exploration undercover is recognition of major changes in the commercial aspects of how companies search for new resources. Major producing companies have tended to pull back from supporting broad commodity and geographical programmes to much more focused efforts to support their current operations, most often in mature and politically safe settings. Intermediate producers appear to have greater risk tolerance regarding geography, but still shun *greenfield*-type exploration. This leaves *greenfield*-type settings, regarded by many as the best locations for new major discoveries, largely the focus of equity-funded junior companies that rely primarily on the vagaries of speculative investors to support their programmes. Whilst the markets made billions available for exploration over the past decade (Doggett 2013), few new major deposits have been located and the current funding drought has brought all but advanced exploration projects to a halt for the majority of juniors.

To help bring issues into sharper focus for the geophysical community, a workshop was organised as part of the recently held 23rd ASEG-PESA International Conference in Melbourne in early August. This workshop brought together senior representatives of state and federal geoscience groups, universities and industry to review the challenges and opportunities that are faced with 'going undercover'. While the primary focus was on undercover exploration in Australia, technology examples were drawn from the global community as well as oil and gas exploration.

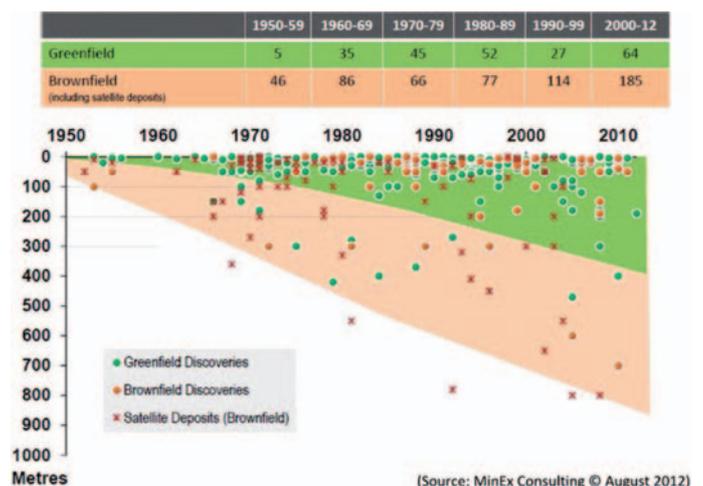
Ken Witherly
Condor Consulting Inc., Lakewood, CO, USA
ken@condorconsult.com

Graham Ascough
Mithril Resources, Adelaide SA

The economic need to explore undercover

Graham Ascough
Mithril Resources, Adelaide

Graham outlined that, over time, there has been a steady decline in the number and quality of near surface resources, meaning there is a greater requirement to find replacement deposits at depth. This task is arguably neither easy nor inexpensive and often takes longer to achieve, so major changes in how the discovery and development risk is managed are required. The commercial environment is challenging as well; while junior companies have seen significant increases in funding over the past decade, most investors are still reluctant to support long-term, high risk *greenfield*-type exploration. Graham cited an innovative approach whereby six juniors pooled their projects in a remote, but prospective part of South Australia into a new company and were then able to raise \$20m to support exploration that individually would not have been possible.



Ascough; from MinEx Discoveries; global greenfield-brownfield undercover; 1950-2010.

The geophysical tool kit to map the upper 3 km

Ken Witherly
Condor Consulting, USA

Ken reviewed the roster of geophysical techniques available to support undercover exploration. There were no surprises overall in this assessment as the industry has a comprehensive suite of:

- well understood applications covering potential fields, EM, electric and acoustic methods;
- a good service industry capable of supporting delivery of techniques to end users; and
- a wide range of readily available processing and analysis techniques to manipulate data.

Examples of techniques reaching several kilometres into the Earth were presented. However, as we go deeper overall the resulting images of what would be called targets at a shallow depth become inevitably ‘fuzzy’. Consequently, we have more chance of defining the likely environment that would host a deposit rather than the deposit per se. There appears to be no technological ‘silver bullet’ on the horizon to deal with this ambiguity of exploring at depth. The best means to manage this risk has been to have a group of explorers work as an interactive team on such problems, thereby allowing the overall risk to be defined and where possible, managed. While this style of exploration model was historically popular with major companies, it has proven difficult to translate to the junior exploration sector. A ‘score card’ of the various techniques available to explore at depth was presented.

Undercover Toolkit
A ranking

Task	Potential Fields	EM Active	EM Passive	Seismic	DC Res/IP	Radiometrics	Other
Targeting	M-H	M-H	L-M	L-M	M	L-M	?
Mapping	M-H	M	M-H	M-H	M	M	L?
Cost	L	M-H	M-H	H	M-H	L	??
Rank	H	M	M-H	M	M	L-M	NA

H= high
M= medium
L= low

	Terrain	District	Project	Target
Suggested scale (km)	100	10	1	0.1

Witherly; toolkit score card for exploring undercover.

Exploring undercover: building and testing geological models

Andy Barnicoat
Geoscience Australia (GA), Canberra

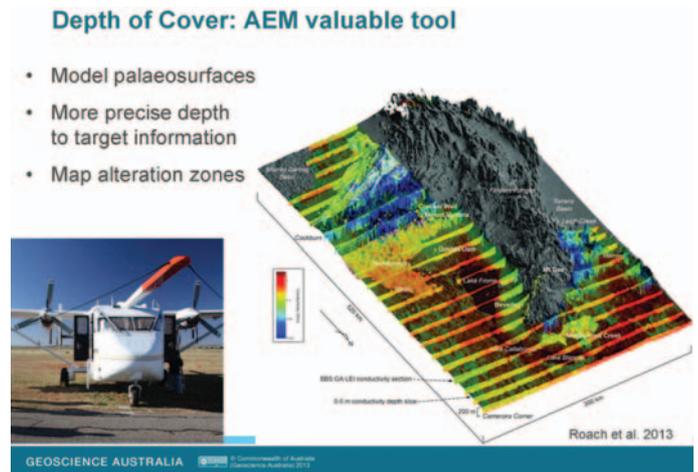
Andy started by pointing out that approximately 80% of Australia has some form of cover including extensive areas of relatively thin transported cover. Consequentially, almost all exploration and discoveries has focused to date on those remaining areas with easily accessible bedrock. To help coordinate Australia’s efforts to develop the technology and skills needed to explore effectively undercover, the Uncover Initiative was started several years ago. Four themes define rallying points for the efforts of research groups, government surveys, service providers and explorers:

1. character and depth of Australia’s cover;
2. investigating Australia’s lithospheric architecture;
3. 4-D geodynamic and metallogenic evolution of Australia; and
4. characterising and detecting the distal footprints.

Andy then provided examples of work on each of these themes that is being carried out. One major effort involving GA and CSIRO is to adapt airborne electromagnetic (AEM) technology to help in the remote mapping of the composition and thickness of cover material. This is a change from the traditional focus AEM has been used for which is to define generally confined bodies of high conductance (targets). With high-powered AEM

systems now available as well as rapid inversion software to produce 1-D, 2-D and 3-D conductivity outcomes, AEM can be used to help model palaeosurfaces, alteration zones and allow for the better design and interpretation of geochemical surveys.

One of the most exciting projects is focused on building continental scale 3-D models of the earth in 4-D and use to try and predict how ore systems came into being and deposit were then derived from these large scale crustal events.

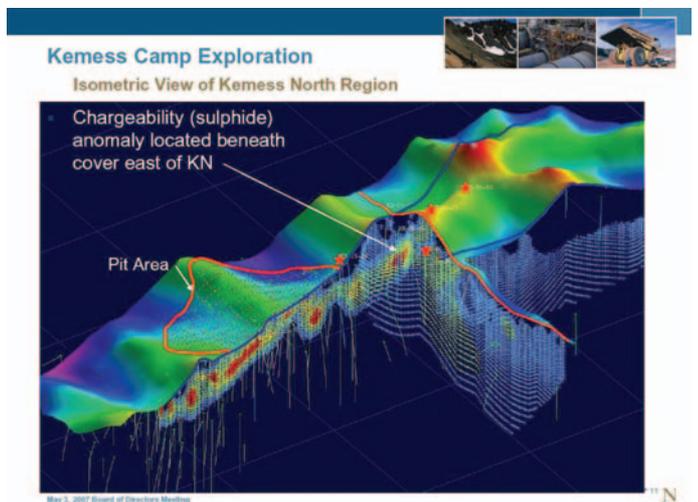


Barnicoat; from Roach et al. 2013; example of using AEM to map cover sequence.

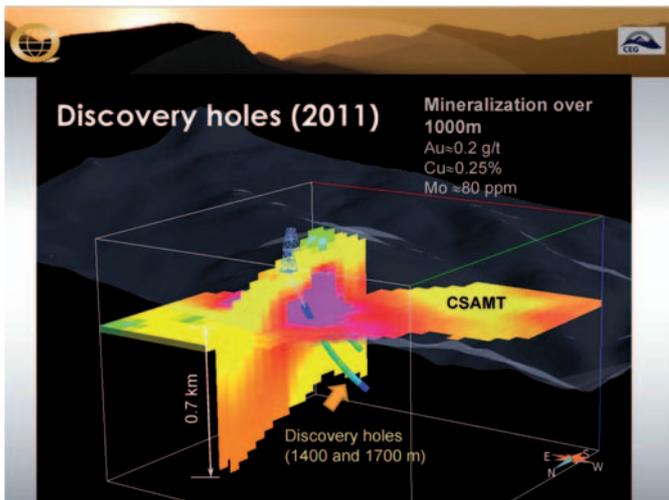
Porphyry exploration in the Americas: 2-D synthetic and field resistivity data modelling

Jonathan Rudd
Quantec Geosciences Ltd, Canada

Jonathan went through two case studies his company had worked on for clients; the Kemess North deposit in north central BC and the Santa Cecilia deposit in northern Chile. Both these are porphyry copper-gold systems. In the Kemess North study, Rudd showed that historic IP surveying as well as physical property data could be helpful in designing a modern survey, that was going to be expensive due to the terrain and



Rudd; Kemess deposit (Canada) 3-D IP section.



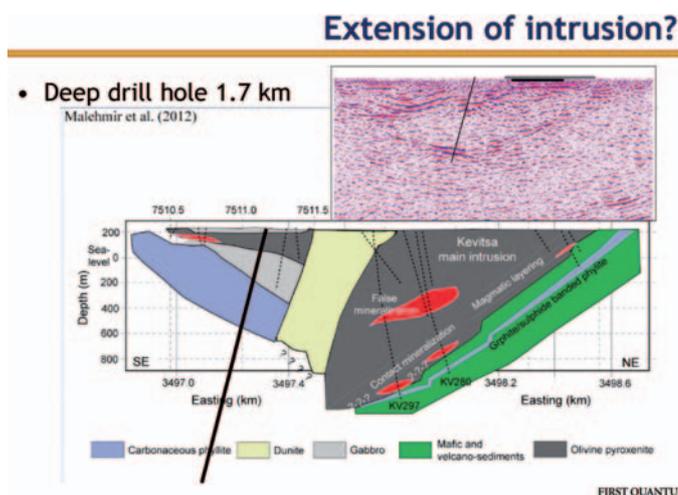
Rudd; geophysics and discovery holes on Santa Cecilia deposit (Chile).

the depth of investigation the client required. When the survey was completed, new targets at depths of approximately 1 km were revealed. At Santa Cecilia, understanding of the deposit, its geology, alteration and mineralisation built up over a 20-year period, culminated in the use of deep penetrating induced polarisation (IP) and magnetotellurics (MT) to define what is thought to be the overall system geometry. One of challenges with large systems was revealed in that, given their size (often several kilometres for the actual deposit), getting to background response using ground techniques can be challenging.

First Quantum's deep exploration: reasons and results

Chris Wijns
First Quantum, Perth

Chris started by giving his take on the importance of differentiating undercover from deep exploration and indicated that the challenges and opportunities were somewhat different. Areas that could be defined as undercover are arguably easier to explore, but likely need well-integrated use of technologies, especially geochemistry with geophysics. Deep exploration is seen as more the realm of conceptual geology and geophysics.



Wijns; seismic section and inferred geology at Kevitsa deposit (Finland).

Chris then outlined that his company preferred not to see itself as seeking deep resources as a priority, but did see the value in obtaining geological knowledge from depth so as to better understand deposits near surface. He then provided two examples of using deep exploration techniques: a Ni-Cu deposit in Finland; and, a Cu deposit in Zambia Copper Belt. In Finland, a seismic survey suggested a potential target area at a depth which would not otherwise been considered as 'attractive' to explore. However, deep drilling failed to define the presence of mineralisation at depth, but the geological results have allowed for what is believed to be a much better understanding of the ore system. In the Cu example, deep drilling was used to help better constrain the overall geometry of the mineralised system at depth.

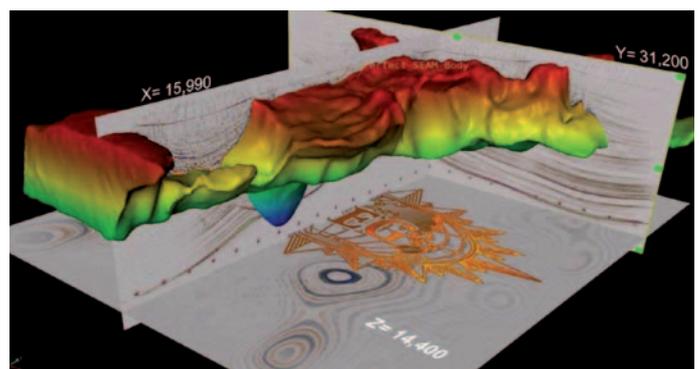
SEAM: the challenge of modelling seismic exploration at full scale

Yaoguo Li
Colorado School of Mines, USA

Yaoguo described the Society of Exploration Geophysicists (SEG) SEAM programme, a very successful research programme being run on behalf of a consortium of oil and gas producers and oil industry service companies. The programme builds computer models that replicate real-earth attributes with such accuracy that they can be used as an inexpensive means to:

- provide datasets to test algorithms for imaging and inversion, that is, datasets for models that represent realistic (complex) earth structures and physical parameters, where the true inversion result is known;
- better understand features and artefacts in real images;
- explore trade-offs in acquisition methodologies; and
- train next generation of seismic processing and imaging experts.

In the present context the SEAM approach could have value for the minerals industry to develop the capabilities to explore cost-effectively at great depths.



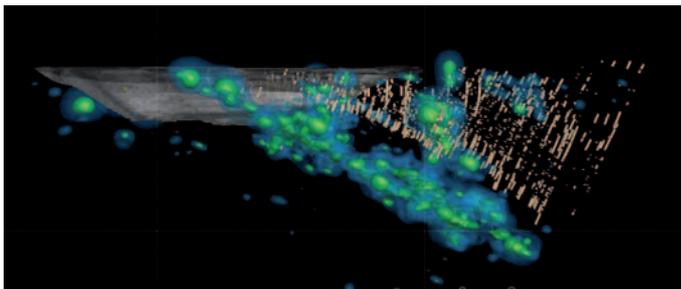
Li; SEAM sub-salt model from Gulf of Mexico.

Geochemical techniques for undercover exploration: the 'new geophysics'?

James Cleverley
CSIRO, Perth

James gave us a 'tour de force' of the state of the art of geochemistry as it relates to building capabilities around concepts that come out of mineral systems frame work. Understanding distal footprints of deposits becomes critical, but

also the need to much better understand the various settings that surround ore deposits at depth, as this ‘geo-setting’ can have an enormous influence on the geochemical outcomes. He examined new technology and how break through opportunities exist if applied in the right settings. Innovation is critical and he cited fields’ as diverse as oil and gas technology to planetary exploration as areas of study that offer opportunities that can be applied to the minerals exploration problem. He suggests that a closer merging of traditional geophysical approaches and geochemistry has much to offer industry as well. In closing he pointed out that exploration in general and geochemistry in particular has entered in the domain of Big Data and new approaches as to how we view and interpret information are required.



Cleverley; 3-D geochemistry at Ranger deposit (Australia).

Model building to support exploration undercover

John McGaughey
MIRA, Canada

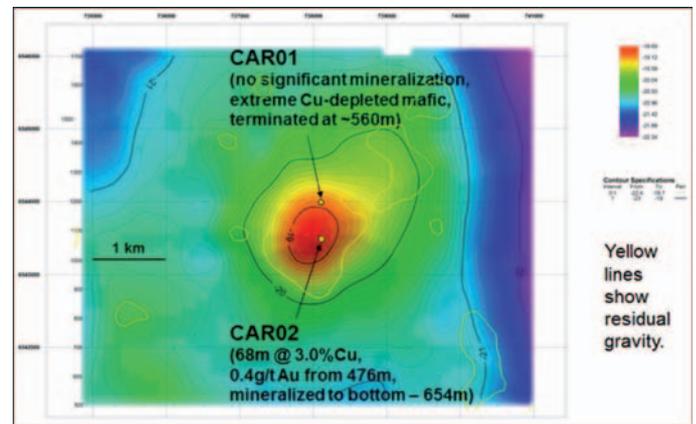
John outlined how model building to support exploration undercover has made significant progress with the addition of adding constraints during the inversion process. He provided a suite of examples that included several gravity data sets and a number of airborne EM data sets where constrained inversion had provided a superior outcome to traditional unconstrained approaches.

Carrapateena: discovery and early exploration

Lisa Vella
Southern Geoscience, Perth

Lisa’s presentation looked at the early stages of exploration for new IOCG style deposits that could be hosted in the Gawler Craton, home of the world-class Olympic Dam deposit. Starting in the late 1970s, explorers found encouraging alteration while testing aeromagnetic highs. However, as many have found, IOCG systems often have extensive alteration systems and to make an actual discovery of significance can take a considerable amount of patience, money and (often) serendipity. In 2005, using a variety of geophysical data sets but mainly Direct Current (DC) resistivity and gravity, two drill holes were designed to test the geophysical features: whilst the first hole failed to intersect mineralisation of interest, the second hole encountered 68 m @ 3% Cu + 0.4 g/T Au. This was a huge success for the property owner and the government of South Australia who were co-supporting the drilling programme. Lisa then reviewed the on-going exploration programme and research started on the deposit so as to try to better vector what

were thought to be other possible similar systems in the area. Deeper penetrating induced polarisation (IP) resistivity was used, along with the extensive use of 3-D modelling of the magnetic and gravity results. In the end, the geophysical signature was defined as a low order magnetic and gravity high that showed a DC conductivity response (but, nothing definitive with electromagnetics).

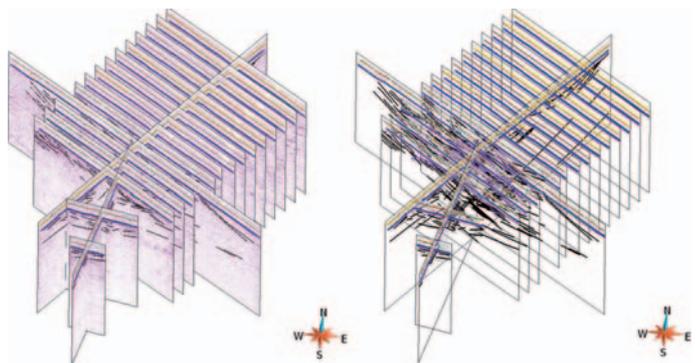


Vella; discovery holes and geophysics at Carrapateena deposit (Australia).

Carrapateena project

Charles Funk
Oz Minerals, Melbourne

Charles provided an update on the recent exploration and geotechnical work around the Carrapateena deposit. The challenges of defining a major complex ore body at depth were discussed and he noted that the main mineralised zone was not encountered until 30 holes after the discovery hole. The likely mining plan was discussed including the incredible machinery required to provide access to the deposit approximately 500 m below the ground surface. So as to better understand the geotechnical challenges with building such a deep underground mine, an extensive seismic survey was carried out over the deposit. Charles provided some information on two other IOCG systems in the vicinity; Khamsin and Fremantle Doctor. As well, he provided a set of comparison images showing the cover thickness and geophysical responses for Carrapateena and the Prominent Hill deposit located about 300 km to the NW.



Funk; section of 3-D seismic survey at Carrapateena deposit (Australia).

What role for government in pre-competitive R&D?

Ted Tyne
SADM, Adelaide

Ted first laid out the challenges explorers and governments face in keeping a strong and successful minerals industry present in Australia. He outlined how the South Australian (SA) government looks at a combination of pre-competitive R&D (including providing state-of-the-art geoscience data sets) as well as co-investment in high-risk drilling, much of it channelled through SA government's PACE programme. He also touched on various international initiatives whereby SADM is working with overseas groups under collaborative projects so as to enhance the understanding of important deposit models which could be present in SA. The Carrapateena discovery discussed earlier in the workshop was cited as one of successful outcomes of the PACE programme.



Tyne; acquiring gravity data in South Australia on Woomera test range (Australia).

How to exploit recent and current undercover initiatives?

Richard Hillis
DETCRC, Adelaide

Richard spoke about the major collaborative R&D project on-going in Australia - the Deep Exploration Technologies (DETCRC). The primary purpose of the DETCRC is to develop and facilitate the successful commercial implementation of new technology to assist explorers to work undercover. A major focus of the programme is to adapt oil field technology termed coil tube drilling to minerals exploration. A technology testing and development and training facility has been established at the Brukunga site north of Adelaide so as to provide a 'real world' setting for new techniques to be trialled. In addition to the improved drilling of holes, the DETCRC is working a range of in-hole measuring technologies, some operated in real time (whilst drilling) which will provide multi-parameter feed-back on geology, alteration, mineralisation and rock quality never-before available to explorers. Had Jules Verne written about minerals exploration, the DETCRC programme would have had a chapter in this book.

Coiled Tubing Drilling for Minex

- CTD achieves 2x ~1,000m Alberta gas wells per day in soft, predictable sedimentary rocks
- 2-3 hours move in and rig up time
- penetration rates: up to 100m/hr

- CTD offers improved cost, safety, and environmental impact in mineral exploration
- key challenges for mineral exploration include: coil durability and low weight-on-bit drilling
- initial target: greenfields rig to 500m, weight less than 10 tonnes and \$50/m

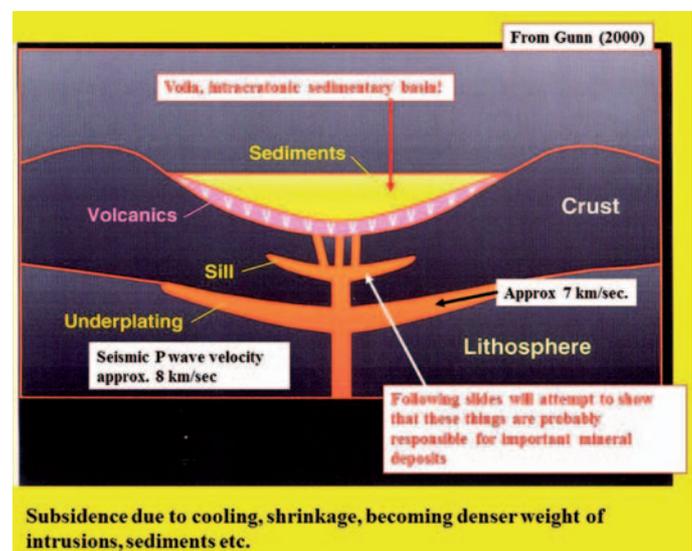
DEEP EXPLORATION TECHNOLOGIES

Hillis; concept of Coil Tube Drilling system for minerals.

Mapping igneous activity associated with mantle plumes and rifts to target mineral deposits

Peter Gunn
Bohuon Resources, Sydney

Peter provided what could be best termed a 'left-lateral leap' in how to think about exploration targeting, providing a range of examples of using often quite basic regional data sets to show how major mineral system events could have taken place. While most of Peter's examples had a minerals flavour, his dual career in having worked both in minerals as well as for a major international oil company showed through frequently as he is as comfortable with seismic data as he is potential fields and clearly sees them as complimentary when both are available. Mantle plumes are a favourite topic both given their size (geophysical foot print) and the sorts of major mineral deposits that can be associated with such events. He populated the talk with a number of examples from Australia and around the world that he has examined over his extensive career.



Gunn; geological and geophysical model of mantle plume.

The speakers are thanked for their excellent presentations. Portable Document Format (PDF) files of the talks (most speakers were able to release without any restriction) and the full oral presentations will soon be available on the ASEG web site. Thanks are also expressed to the workshop sponsors: the CSIRO National Flagship Minerals Down Under; and First Quantum Minerals.

References

- Doggett, M. 2013, The Challenge of Creating Value through Exploration; presentation at ProExplo 2013 Lima Peru May 2013.
- Roach, I. C. ed. 2012, The Frome airborne electromagnetic survey, South Australia: implications for energy, minerals and regional geology. Geoscience Australia Record 2012/40 – DMITRE Report Book 2012/00003, 296 pp.

Helping to target your resources

Next time you need a survey, call Zonge.

- use our **high powered** systems and latest technology for:
 - surface 2D and 3D IP/EM/NanoTEM/CSAMT/AMT/NMR
 - downhole IP/EM/MMR/NMR
- experienced, safe teams in any location
- efficient survey design
- quality data second to none
- highly responsive service

Call Zonge today +61 8 8371 0020

e zonge@zonge.com.au
w zonge.com.au

Electrical geophysical solutions

*Resource exploration, environmental
and geotechnical applications*



**ON ANY STRETCH OF LAND,
IN SHALLOW WATER OR DEEP,
CAPTURE THE SEISMIC YOU NEED
WITH LESS TROUBLE.**

A LOT LESS TROUBLE.



Dealing with piles of cable hinders any seismic acquisition, land or marine. That's why our true cable-free ZNodal® systems pay huge dividends in any environment.

Our lightweight, compact ZLand® system, now with the ability to add external sensors or available in a cable-free 3C version, lets crews work faster and much more safely, anywhere on earth.

Our ZMarine system, also completely self-contained, deploys easily and safely, even in congested areas, to water depths of 3000m, which makes it ideal for 4D reservoir monitoring.



fairfieldnodal.com

S Y S T E M S A C Q U I S I T I O N L I C E N S I N G P R O C E S S I N G I M A G I N G

Ground Geophysical Survey Safety Association (GGSSA)



The Ground Geophysical Survey Safety Association (GGSSA), formed in 2011, aims to develop Industry Guidelines for ground geophysical surveys. The formation of the Association responded to the NSW Government concerns around electrical ground surveys and the failure to adhere to NSW State Legislation and Australian Standards AS/NZ 3000 and AS3007, particularly around electrical protection, and isolation and insulation.

Since 2011, the foundation members (CGG, GPX Surveys, Rio Tinto, Search and Zonge Engineering) worked on a draft document covering guidelines for ground electrical surveys. Following submission to the industry for comments and suggestions, this document then underwent further updates. The current version of this document can be viewed at www.ggssa.org.

In September 2013, after the Melbourne ASEG conference, the association opened for active and associate membership: GGSSA has had membership applications from Australia and overseas. To date, GGSSA members are AngloGold Ashanti, Cira Pty Ltd, CGG, Discovery International Geophysics, EMIT, Fender Geophysics, Gap, Geoscience Australia, GPX Surveys, GDH, KEGS, Mackey Geophysics, NSW Department of Trade and Investment (Resources and Energy), RAMA Geoscience, Rio Tinto, Search Exploration Services, South Australian Department for Manufacturing, Innovation, Trade, Resources and Energy,

Southern Rock Geophysics and Zonge Engineering.

2013 has also seen the formation of a technical committee. The technical committee is made up of members of the association and will be reviewing the draft electrical surveys' guidelines along with looking into other issues that affect ground geophysical surveys.

The association has been giving presentations at ASEG state branch meetings and also at ASEG conferences. This month a presentation was given at the Victorian Branch by Theo Aravanis. Early 2014 will see a presentation at the WA state branch meeting.

Katherine McKenna, Managing Director, GPX Surveys

More information can be found on the web page www.ggssa.org.

If you are interested in joining GGSSA please email info@ggssa.org.

AEROMAGNETICS
GRAVITY
X-TEM HELI TDEM
CSAMT
AIRBORNE RADIOMETRICS
DOWNHOLE EM
INDUCED POLARISATION



www.gpxsurveys.com.au

GPX SURVEYS

Airborne & Ground Geophysics
Greg Reudavey or Katherine McKenna
4 Hehir Street, Belmont WA 6104
T +61 8 9477 5111 F +61 8 9477 5211
info@gpxsurveys.com.au

Africa | Australia | Asia | Middle East | Europe

Teacher Earth Science Education Programme (TESEP): news highlights Oct–Nov 2013

Australian Seismometers in Schools (AUSIS) programme

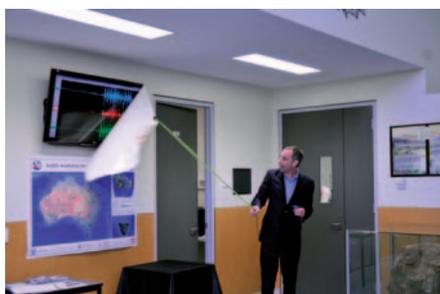
On Thursday 31 October 2013, Taroona High School in Hobart hosted the Tasmanian launch for the AUSIS programme.

Philip Sansom (TESEP Tasmanian coordinator) delivered a talk about the AUSIS programme (and yes he managed to drop TESEP into his talk!).



Nick McKim (The Tasmanian Minister of Education) launched the seismometer by removing an earthquake poster from the screen displaying an 'earthquake' produced by students jumping at the appropriate time. Overall a very

successful launch with lots of good publicity.



TESEP classroom remote sensing 1: exploration seismograph

Film (on DVD) to be launched by Len Altman and Greg McNamara on 4 December, Adelaide plate tectonics, PD9 Professional Development workshop. Geophones for the demonstration are being provided by industry. More old (functioning, single) geophones are needed as this DVD will be used by teachers nationally to demonstrate a seismic pulse (and what it measures) in schools. ASEG is gratefully acknowledged for its general funding that has contributed to this film.

TESEP presenter, Philip Sansom, demonstrated the use of the geophone in a geophysics exercise for teachers at a Melbourne workshop, December 2012 (exercise designed by Dr Michael Roach UTas). Using ASEG funding, TESEP has filmed this exercise for distribution to teachers, along with free geophones donated by industry (reproduced from *Preview* 162, p. 20).



For information, please contact TESEP directly: www.tesep.org.au.

Jill Stevens, TESEP Chairperson
cp@tesep.org.au

Greg McNamara, Executive Officer
eo@tesep.org.au



Subscribe now to our FREE email early alert or RSS feed
for the latest articles from *Exploration Geophysics*.

www.publish.csiro.au/earlyalert

NSW university students recount 23rd ASEG-PESA 2013 conference

The following recounts are from our NSW university students, who received a subsidy to attend the Melbourne conference.

Roger Henderson

‘The 23rd ASEG-PESA 2013 conference in Melbourne was really a big event in my scientific life. It changed the way I was thinking about my research and how the industrial world is working. It has really widening my gaze, showed how my research should be focused and where it should be oriented. It also showed me how to fulfil the standards that companies require for anyone to get a job. Thanks again for the generous support that I received from the NSW branch of the ASEG to attend the two days of field work on the structural geology and seismic stratigraphy of the West Gippsland Basin at the end of the conference which was an exciting journey to observe the structural, sedimentological and the stratigraphic relationships in the field, and to define the potential source and reservoir rocks of the basin.’

Omar Adil Mohammad, PhD candidate, School of Earth and Environmental Sciences, University of Wollongong

‘The presentations of particular interest to me at the conference in Melbourne were Tom Whiting’s presentation on the Blackthorne copper discovery in Zambia, and Dan Wood’s presentation on the Cadia discoveries.’

It was very interesting to hear about the history of the Cadia discoveries and the relatively small IP anomaly that led them to it. As I am currently analysing the

IP data for Gold and Copper Resources at Cadia, it has made me realise that no stone should go unturned, no matter how insignificant it may seem. Dan emphasised the need for deeper and much larger copper discoveries if supply is going to have any chance of meeting global demand, and because of this an integrated approach is needed with geology, geophysics and geochemistry all being of equal importance. It is imperative to develop models that encompass the entire ore system, instead of taking a more localised approach in looking for the ore alone.

The Lachlan Fold Belt where G&C are currently exploring has the potential to host a variety of ore systems, and so it was interesting to also learn about the IOCG discovery in Zambia.’

Emma Smith, Honours student at Macquarie University

‘Attendance at the conference in Melbourne was an enriching experience for me because a post-graduate research student is exposed to the latest equipment and its use, and recent research and development in geophysics.’

Some of the technical talks, that were my favourite, were on seismic techniques, particularly on acquisition and processing. One of the presentation I particularly found the most interesting, discussed the applicability of using mining machinery as a source for creating seismic topographic images, a technique which is usually very sensitive to background noise produced from drilling and blasting.

I attended a GPR workshop held at Rio Tinto, Bundoora. Applications of GPR

in shallow sub-surface investigation (utilities scanning, voids, etc.), and for deep mining exploration, especially, laterite and bauxite, were discussed with examples followed by a quick survey, using a low frequency antenna, to get hands on experience of data acquisition.

The postgraduate student reception sponsored by BP was very helpful in meeting other students and networking with them. All in all, I would say it was a very successful conference, with enriching oral and poster presentations and I am already looking forward to attend the next conference at Perth in Feb 2015 as an industry professional. I would like to thank the NSW Branch for giving this opportunity and awarding the grant.’

Rajat Taneja, Postgraduate student, Macquarie University

‘Having the opportunity to both attend and present a poster at ASEG-PESA 2013, and attend the Magnetic Remanence Workshop was a very beneficial experience. The quality and diversity of the presentations at both the workshop and conference sessions were excellent, with many directly relating to both my field of study and areas of interest. This was my first experience presenting my research at a conference, and found the process of author application, abstract writing and submission, and poster preparation a steep but rewarding learning curve. I received a lot of positive feedback on my research, as well as many useful suggestions on where to proceed with my work in the future.’

Mike Tetley, Honours student, University of Sydney

Update on Geophysical Survey Progress from the Geological Surveys of Western Australia, South Australia, Northern Territory and WA Department of Water (information current at 10 November 2013)

Tables 1–3 show the continuing acquisition of the airborne magnetic, radiometric, gravity and AEM data of the Australian continent respectively.

All surveys are being managed by Geoscience Australia (GA). 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	Contractor	Start flying	Line (km)	Spacing AGL Dir	Area (km ²)	End flying	Final data to GA	Locality diagram (Preview)	GADDS release
Marree	GSSA	UTS	29 Oct 12	130 473	400 m 80 m N–S	46 169	100% complete @ 10 May 13	24 Jul 13	Issue 160 (Oct 12) p. 16	Coincided with SA Exploration and Mining Conference 28 Nov 13
Browse Basin	GA	Thomson Aviation	21 Aug 13	189 361	800 m 80 m asl N–S	123 187	100% complete @ 7 Nov 13	TBA	Issue 164 (Jun 13) p. 19	TBA
Menzies North	GSWA	GPX Surveys	7 Aug 13	93 386	100 m 50 m N–S	8200	89.3% complete @ 10 Nov 13	TBA	Issue 165 (Aug 13) p. 11	TBA
Kalgoorlie East	GSWA	Thomson Aviation	5 Aug 13	122 000	100 m 50 m N–S	8200	41.2% complete @ 10 Nov 13	TBA	Issue 165 (Aug 13) p. 11	TBA
Widgiemooltha North	GSWA	UTS Geophysics	25 Jul 13	92 000	100 m 50 m N–S	8200	58.6% complete @ 10 Nov 13	TBA	Issue 165 (Aug 13) p. 11	TBA

TBA, to be advised.

Table 2. Gravity surveys

Survey name	Client	Contractor	Start survey	No. of stations	Station spacing (km)	Area (km ²)	End survey	Final data to GA	Locality diagram (Preview)	GADDS release
Esperance	GSWA	Atlas Geophysics	30 Jun 13	7850	2.5 km and 1 km along roads/tracks	TBA	3 Sep 13	Preliminary data to GA on 4 Sep 13	Issue 158 (Jun 12) p. 23	Final data released via GADDS on 24 Oct 13
Woomera Prohibited Area	DMITRE	Daishsat Pty Ltd	2 May 13	34 500	1 km/2 km regular grid	TBA	82% complete @ 4 Sep 13	TBA	Issue 163 (Apr 13) p. 17	Coincided with SA Exploration and Mining Conference 28 Nov 13
North Perth – Gingin Brook	WA Dept of Water	Atlas Geophysics	9 Apr 13	1230	1.5 km regular grid	TBA	100% complete @ 7 Jun 13	29 Jul 13	Issue 163 (Apr 13) p. 17	TBA
Southern Wiso Basin	NT	Atlas Geophysics	11 Jul 13	3856	4 km regular grid	61 700	100% complete @ 18 Aug 13	TBA	Issue 165 (Aug 13) p. 11	Final data released via GADDS on 31 Oct 13
Southern McArthur Basin	NT	Atlas Geophysics	15 Oct 13	6270	4 km regular grid with 2 km infill in 2 areas	74 380	83% complete @ 10 Nov 13	TBA	Issue 166 (Oct 13) p. 34	TBA
Goldfields, WA	WA	Atlas Geophysics	8 Nov 13	8100	2.5 km regular grid	TBA	TBA	TBA	Issue 166 (Oct 13) 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 (km ²)	End flying	Final data to GA	Locality diagram (Preview)	GADDS release
Swan/Scott Coastal Plain and Albany/Esperance	WA Dept of Water	GA	CGG Aviation (Australia)	25 Mar 13	8607	300/600 m	TBA	100% complete @ 15 May 13	Data resupplied 4 Nov 13	Issue 163 (Apr 13) p. 17	TBA
Capricorn Orogen	WA	GA	CGG Aviation (Australia)	19 Oct 13	29 697	5 km N–S	146 300	24% complete @ 12 Nov 13	TBA	Issue 166 (Oct 13) p. 34	TBA

TBA, to be advised.

News from the surveys: SA

The Geophysics and Prospectivity (GAP) Team in the Geological Survey of South Australia (GSSA) have been busy over the past few months working on a range of projects. This article gives a brief overview into some of these projects.

Much of the team's effort has been dedicated to capture and processing of geophysics in the Woomera Prohibited Area (WPA). The WPA is a military test and evaluation site of approximately 127 000 km² (approximately 13% of the State) in the north-west region of South Australia. It also covers over 30% of the Gawler Craton – some of the most prospective ground in South Australia (copper, gold, uranium and iron ore). Agreements have been reached to allow exploration in the area and the GSSA has funded a large-scale gravity survey covering a major portion of the WPA. DaishSat Geodetic Surveyors undertook

the survey between May and September 2013 and at the time of writing the data is undergoing final QA/QC, prior to an expected public release in December. The GSSA will be preparing new gravity imagery for the region, as well as updated magnetic grids.

The Marree magnetic and radiometric survey is now complete and at time of writing GSSA staff are preparing the data for an anticipated release in late November. This work combined with the WPA information will feed into updated state-wide imagery. Figure 1 shows the current magnetic grid of the state, available through SARIG (<https://sarig.pir.sa.gov.au/Map>).

Legislation through the South Australian Mining Act now includes a sunset clause. This allows previously confidential data to be released into the public domain after being held by Government for five

years. Details of released data can be found in issues of the *MESA journal* from September 2012 (http://www.minerals.dmitre.sa.gov.au/publications_and_information/mesa_journals). The next sunset clause data release will include AEM, magnetic, radiometric, gravity and MT survey data, all of which will be available through SARIG.

GSSA Geophysicists are also undertaking in-house gravity surveying in the far north of the state adjacent to the APY Lands, scheduled to be complete by the end of the 2013–2014 financial year. The survey is being conducted in parallel with the Musgrave geological mapping programme and covers parts of the Alcurra, Tiewon and Agnes Creek 1:100K map sheets.

The GSSA Geophysicists are also working on a series of case studies on IOCG prospectivity, integrating data from a range of sources, including petrophysics, geochemistry, spectral, gravity and magnetic inversions to characterise the alteration characteristics of IOCG systems at a range of scales.

As always, we are capturing and compiling petrophysical information from direct measurement of drillcore and company reporting. Collected information is uploaded onto our petrophysical database and released through SARIG. Petrophysical information can be found through the drillhole information on SARIG (Drillhole Advanced Search), in conjunction with spectral scanning, stratigraphy and lithology information.

For more information on current projects and data, SARIG now features a GSSA projects layer that can be found in the Map Layers widget, under the Geology drop-down.

Upcoming major geophysical surveys include a seismic and magnetotelluric survey, which will complete a traverse along the rail corridor between Haig in Western Australia to Tarcoola in South Australia. A magnetic/radiometric survey over the Coompana region in western South Australia is also planned for 2014.

Philip Heath (philip.heath@sa.gov.au), Tim Keeping, Tom Wise, Gary Reed, Laz Katona, George Gouthas, Jonathan Irvine and Miles Davies

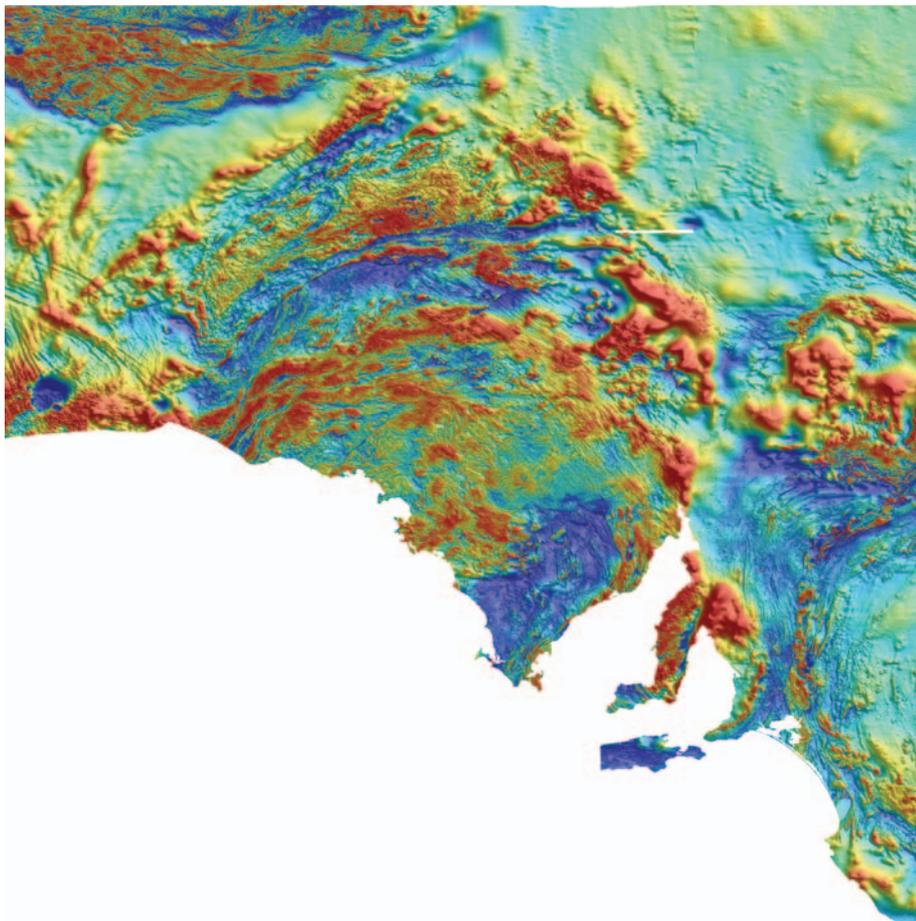


Fig. 1. The magnetic grid of South Australia is viewable and downloadable through SARIG (<https://sarig.pir.sa.gov.au/Map>: Map Layers menu → Data tab → Geophysical State Images → Magnetics → TMI).

Meteorite impacts to gold and nickel deposits (*continued*)

The discovery of *prima facies* evidence for impact structures in the Eastern Yilgarn, Western Australia



Robert (Bob) Bingley Watchorn

Bob Watchorn and Associates Pty Ltd
Email: bobwatchorn123@yahoo.com

A large circular feature was observed by the author in gravity data of the Yilgarn region of Western Australia in May 1999. The discovery in August 2013 of *prima facies* evidence on many of the documented rings associated with this structure confirmed it to be of impact origin. The rings of this impact structure (Watchorn Impact Structure) extend 560 km north–south and 480 km east–west diameter. From the impact structure's relationship with geological features the age of the impact is estimated at between 2.7–2.64 Ga. This is one of the largest and oldest impact structures worldwide. There are numerous other probable impact structures observable from Kalgoorlie right through to west of Wiluna.

In the Eastern Yilgarn there is an empirical correlation between the largest nickel, gold, copper, silver–lead–zinc and rare earth deposits and the rings of the impact structures. The age of the mineralisation is between 2.7 Ga and 2.62 Ga.

This observed relationship means a paradigm shift is needed for studying the genesis of mineralisation in the Yilgarn and the exploration methods required for success. This may apply to Archaean Cratons worldwide.

This paper is divided into three sections:

A. Examination of impact structures in the Yilgarn (previous issue: *Preview* 166, p. 35).

B. Exploration trip to verify the geology, mineralisation and morphology of the Watchorn Impact Structure (WIS) and to find *prima facies* evidence (this issue: *Preview* 167).

C. Q&A: areas for discussion and further study (next issue: *Preview* 168).

Due to space considerations, Section C shall be deferred until the next issue. In the interim, the author welcomes feedback from readers (Note: opportunity exists for select queries and replies to be published within section C). – Editor

B. Exploration trip to verify the geology, mineralisation and morphology of the Watchorn Impact Structure (WIS) and to find *prima facies* evidence

After discovering the WIS in 1999 an exploration reconnaissance trip was finally undertaken in 2013 to investigate some of the WIS rings that were observed on the gravity, seismic, DEM and most importantly, Landsat data. Notably:

- (1) The inner rings were best seen in the gravity data and consisted of two central circular rings of 50 km and 90 km diameter and an outside ring of 250 km diameter. Within these gravity rings and outside them to a diameter of 550 km were circular features observed on Landsat data.
- (2) These rings have the morphometric parameters of an impact crater formed by an object of 10–20 km diameter hitting the region just north west of Mertondale 50 km north of Leonora (Figure 1).

These rings were accessible between Menzies and Wiluna and the trip was planned to discover *prima facies* evidence of an impact origin for these specific WIS ring structures.

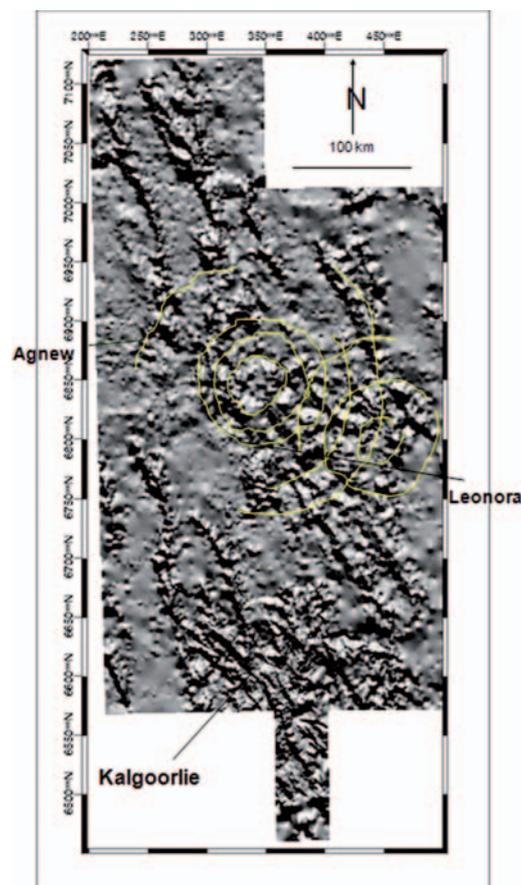


Fig. 1. Gravity image showing the deeper concentric features and the Watchorn Impact Structure overprinting relationship to the deep Eastern Yilgarn rift structures.

Prima facies evidence definition

On other planets and satellites morphometric dimensions are used as *prima facies* evidence as they are the only directly observable features. To differentiate impacts from the plethora of other circular features *prima facies* evidence of an impact structure on Earth is reserved to geological features that exhibit shock features. These include shatter cones, shock features in quartz and feldspar grains and rocks believed to be impact melt rocks (Grieve and Pilkington 1996).

Shatter cone. Shatter cones are shock waves preserved or captured in stone. Sudbury shatter cones surround the entire outer perimeter of the impact structure range in size from several centimeters to metres and have distinctive well-defined dominant characteristic deep grooves, converging striations and a narrow V-shape formation.

Shocked quartz. In the mineral quartz the passage of a strong shock wave can cause dislocation of the grain's crystal structure along preferred crystallographic orientations. Thin sections of quartz grains show different sets of planar deformation features (shock lamellae) when rotated.

Impact melt rocks. These rocks are remnants of the impact when rock instantly became fluidal, then cooled to become transformed into many varieties of melt rocks. This material occurs in many states and is associated with only the biggest impacts. **Impactites** are melt glass or melt rock found at the Sudbury impact structure. **Onaping breccias** are quite unusual in the sense that they are composed of small particles and fragments blasted skyward in the conical debris ejection that fell

back to earth forming a circular deposit of fallout material. An interesting feature is country rock fragments or quartz, rimmed by fluidal glass, showing well-developed flow lines. Large melt sheets or melt bodies exist around the Sudbury structure (Figure 2).

Targeting assumptions and methodology

It was noted that the WIS rings were more strongly developed in the greenstone corridors between the granites. Thus, the main area for the search for the *prima facies* evidence would be along these greenstone corridors, which so happen to be conveniently located amongst the mines and access roads.

Although the central rings were clearly seen on the Gravity and Landsat data the geology and aeromagnetic plans suggest that the area was intensively intruded by later shallower granites and that shock features may have been destroyed there.

The author had also noted that the largest mines, for all metals in the target area were located on or adjacent to the rings. The deposition structures of the gold mines examined reflected the direction of the ring associated with the mine. Thus, the geology of the rings and any mines associated with the rings would be documented to see if this megascopic observation was backed up by field evidence.

The position of the rings was plotted onto a detailed roadmap and an interpreted geology plan of the Yilgarn and the route was planned to visit as many of the sites as possible in three days (Figure 3).

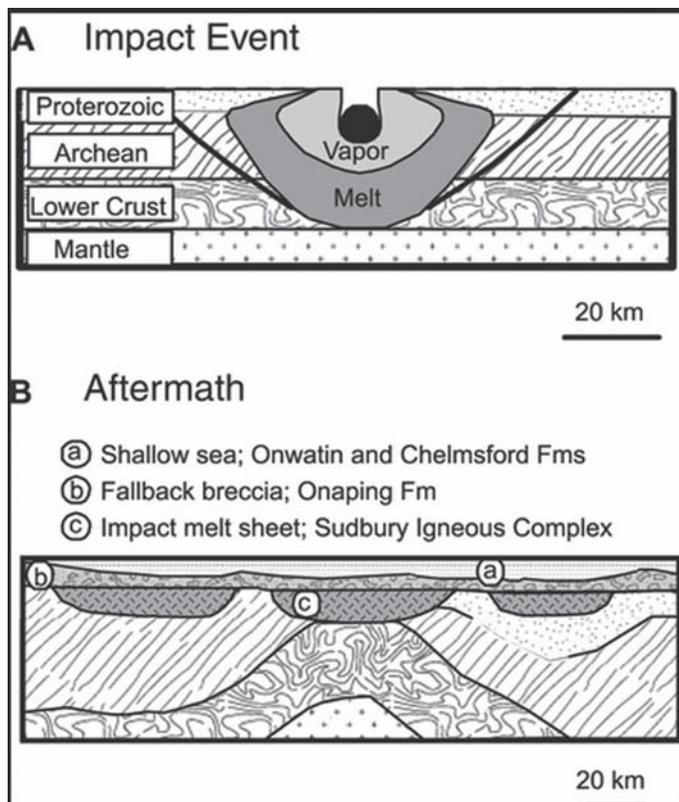


Fig. 2. Cross-section of the 250 km diameter Sudbury crater showing the dynamics of large crater formation and the major isostatic rebound of the mantle.

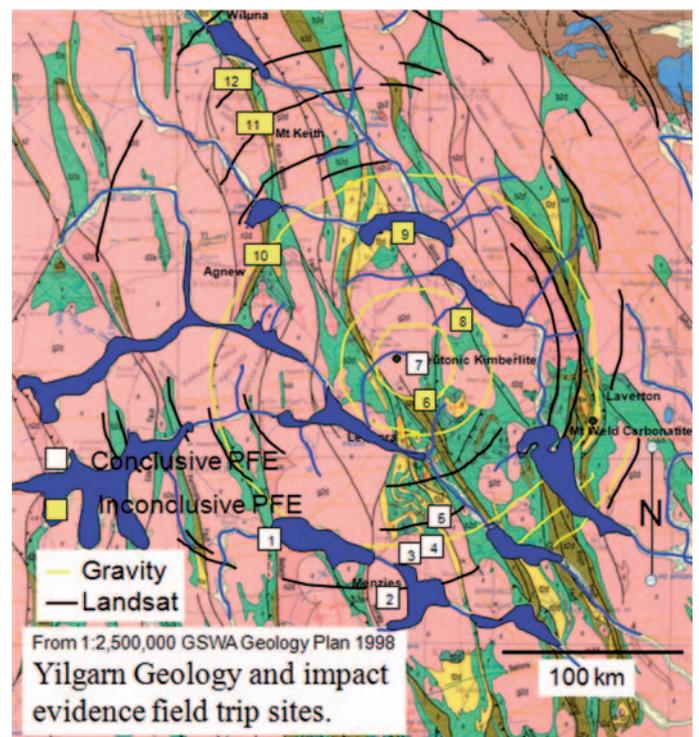


Fig. 3. Plan of field site locations 1–12 on a plan showing the Yilgarn Geology, Gravity and Landsat rings.

Field observations

The rings were examined at Sites 1–12 and observed on sites 1–5 as arcuate lines of hills with sheared, mylonitic basalt and granite with abundant quartz float trending along the rings.

Site 1: Agnew Outer Gravity Ring, Iron Statues Island, Lake Ballard. The island in the midst of the Lake Ballard Iron Statues is located on the Agnew ring and is shown on the Landsat as an intermittent dark arc that extends through Mount Ida to Agnew. The island is composed of fine grained spheroidal weathered basalt which has a steep south west dip and strike. There is a line of hills that is arcing parallel to the ring to the NW and, more importantly, to the SE towards Menzies. This ring links the Bardoc fault to the Ballard fault. Generally all other hills and features in this area are NS normal to the ring direction.

Site 2: Agnew Outer Gravity Ring, Lady Shenton Mine, Menzies. This mine also lies near the Agnew ring. The main strike of the orebody in the open pit is parallel to the direction of the not well defined ring at Menzies which is the intersection of the EW ring direction of and the NNW direction of the Bardoc fault.

Site 3: Outer Central Gravity Ring, Niagara. In a road cutting 1 km before Niagara Dam the lithology is comprised of flow banded pegmatite and granites dipping 70° N. The Niagara Mine is EW and is located in an EW line of hills, parallel to the banding in the granites. This banding is parallel to the Kookynie Ring.

Site 4: Landsat Ring, Kooyynie. The Kookynie mines are EW, parallel to the Kookynie Ring and dip 40° S. The country rock is basalt, no specimens of shock features observed.

Site 5: Mt Melita Landsat ring 25 km north of Kookynie. After following NS striking hills the next Mt Melita Landsat ring stood out as a line of EW hills composed of mafic intrusives. It became evident that the Landsat features were real on the ground and were comprised of lithologies that were trending EW with EW shearing contrary to the general NNW trend of the country. In general, the rings were also marked by more abundant quartz veins and float. There have not been any unusual or shock structures seen in the quartz or feldspar – yet. Mind you, we are not quite sure what to expect having never seen a shatter cone!

Site 6: Mertondale Inner Gravity Ring, 24 km NE of Leonora. On the Leonora–Mertondale road there was abundant quartz on flat ground at the site of the outer edge of the Mertondale inner gravity ring. Specimens of semi-annealed, shock textured quartz with the appearance of shatter cones were discovered. These were the first examples of what might be *prima facies* evidence seen on the site of a gravity ring. Eureka! These specimens were collected only 16 km from the centre of the Watchorn Impact Structure (WIS).

Specimen 6.3. This shatter cone appeared to have two shatter cones at approximately 30° to each other (Figure 4). This phenomenon was also seen at Sudbury in Canada where it was possible to find shatter cones associated with two impact events in one outcrop. The nose of the Sudbury shatter cones point toward the Sudbury structure, while the nose of the Wanapitei shatter cones point in the opposite direction.



Fig. 4. Site 6. Specimens 6.3 and 6.4 (inset) showing small shatter cones formed in two directions.



Fig. 5. Specimen 6.7. Welded (melt?) quartz rock with a matrix of ever decreasing sized rounded quartz grains with conchoidal fracture and with no shock texture (upper). It contains 2 mm clear unfractured quartz glass grains similar to spherules collected from Chicxulub crater, Mexico (inset).

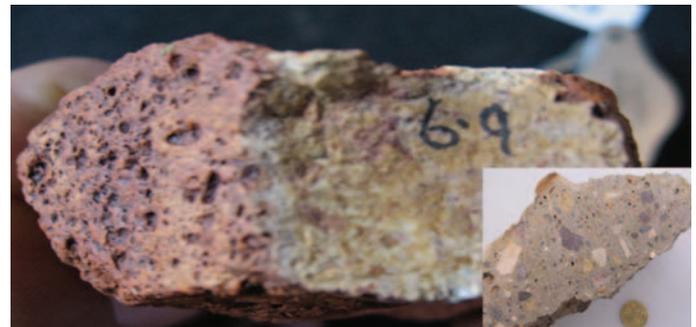


Fig. 6. Sample 6.9. Mertondale ring, Watchorn Impact Structure, Western Australia. Felsic rock composed of unsorted, welded, rounded and semi-lath shaped clasts. Matrix of fine, glassy felsic material. The specimen has conchoidal fractures and no deformation features. This suggests it is post or syn-impact and is similar to impact melt from Rochehouart Crater, France (inset).

This is *prima facies* evidence of the WIS, plus another impact in the North Eastern Yilgarn! Shattercones and welded rocks are shown in Figures 4–6.

Site 7: Centre of WIS, The Western Terraces. This is the central area of the WIS. Contorted granite was observed as we intersected the Western Terraces. This graded into massive coarse grained pegmatitic granite 1 km west at the campsite. There were no shock features, indeed no quartz noted. There were zones of granite that were strongly flow banded as is observed in the magnetics of the granite in this area – no samples taken.

Site 8: Leonora Outer Gravity Ring, 8.5 km north of Woolie Bore. The quartz here tended NNW parallel to the NE quadrant of the Leonora Outer Gravity Ring. The quartz was very strained in three directions, possibly once again suggesting more than one close impact (Figures 7 and 8). This area is close to the centre of the Mt Redcliffe Circular Magnetic Feature, which might be a later impact.

Site 9: Darlot Ring, Outer central Landsat Ring, East of the Darlot mine. Once again, there was a line of low hills trending EW in line with the Darlot mine. There were examples of shocked quartz and one specimen (Specimen 9.2) of a quartz shatter cone was found in the short time spent on site (Figure 9). This shatter cone also had two directions of striations – the second very weak.

Site 10: Agnew Outer Gravity ring north from Leinster turn off: definitive impact shock feature site. At this site the hills are striking at 50° – parallel to the 250 km diameter Agnew Gravity Ring. The basalt and dolerite stratigraphy is dipping at 50° N. There is an excellent 10 m thick outcrop of rounded shocked quartz. Some sections of this quartz show *in situ* shatter cone structures and striations (Figures 10 and 11).

A small vertical, 50° EW quartz vein was observed 100 m east with *in situ* shatter striations trending 140° towards the centre

of the WIS. The dolerite around the shatter cone quartz was also shatter rodded. The shatter zone area appeared localised. Specimens 10.1 and 10.4 are textbook shatter cones (Figures 12–14).

Site 11: Mt Keith Landsat Ring: west and opposite Mt Keith Mine. There is a broad EW quartz vein system on the Mt Keith ring west of the Mount Keith mine that trends towards the centre of the open pit (left of Figure 15 and left of Figure 16).

The Mt Keith ring can be seen on Landsat for many kilometres to the west. Shock striations in the massive quartz are NS and sub horizontal. The alteration associated with this quartz system

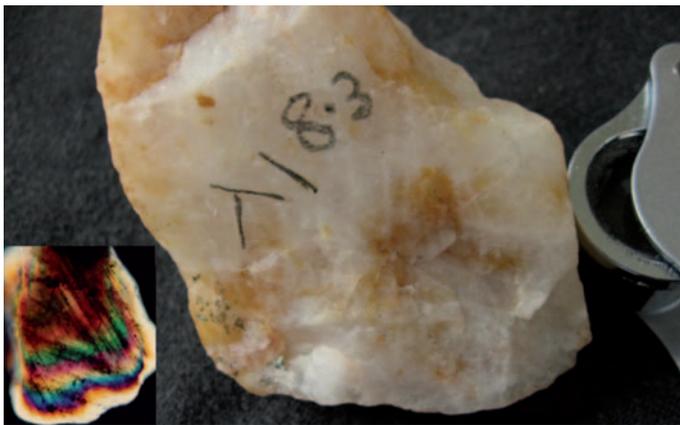


Fig. 7. Specimen 8.3. Fractured and semi-annealed quartz with three shock fracture directions possibly caused by more than one close impact? Sample from Chicxulub with two directions of Quartz Lamellae (inset).



Fig. 8. Specimen 8.4. Vitreous, slightly fractured quartz with fracture planes in two directions at A & B. Similar rock from Chicxulub Crater, Mexico (Inset).



Fig. 9. Specimen 9.2. Specimen of a small shatter cone showing two striation directions.



Fig. 10. Site 10. In situ striated shocked quartz (north to right).



Fig. 11. Site 10. Shatter cone rocks scattered on ground on Agnew ring.



Fig. 14. Specimen 10.4. Half of a 'knuckle' of a shatter cone. This sample is typical of many of the shatter cone pieces in that there seem to be an equal number of shatter cones in each direction parallel to each other. The combination of these two sets of cones makes up a parallel rod. This parallelism might be the result of the deep formation of the shatter cones (est. 5–10 km subsequent erosion).



Fig. 12. Site 10, Specimen 10.1. Textbook shatter cone showing deep striation grooves and aggregated rodded structure.

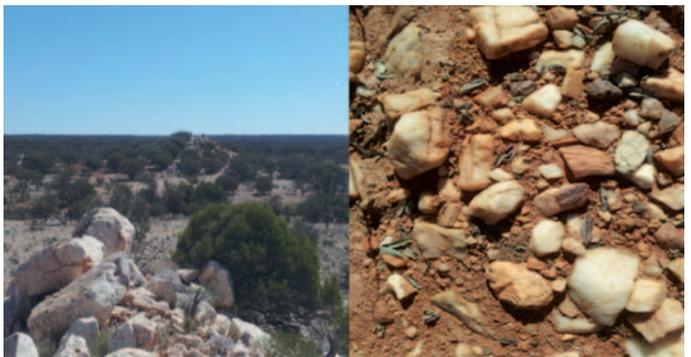


Fig. 15. Large EW quartz vein at Mt Keith looking west. (Left) This massive quartz vein system, west of the Wiluna road, trends to the centre of the Mount Keith mine. Striations in the massive quartz are NS and 5° N dip. (Right) Detritus of numerous shatter cone segments on ground west of Mt Keith.



Fig. 13. Specimen 10.1. A beautiful example of a single 'knuckle' of a shatter cone. Shatter cone is made up of numerous 'shatter cones' that can be observed all around the perimeter of end A (right) and in photo 9. At end B (left), there is what looks like a later, weaker shatter cone, normal to those at A. Shatter rods B overprint those at A, but with virtually no displacement. Is this evidence of a strong impact over-printed by a later, weaker impact?

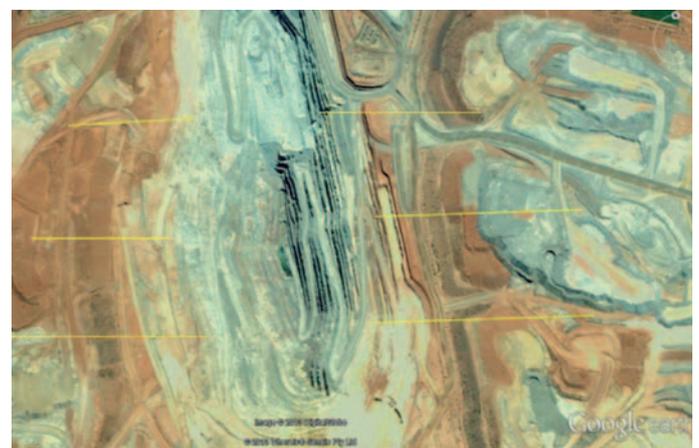


Fig. 16. Site 11. Mt Keith Open Pit Mine Site. Evidence of the Mt Keith Landsat ring in the Mt Keith open pit.

West of the Leonora-Wiluna highway *in situ* 500 mm long shatter cones in quartz and adjacent granite (Figure 17) were observed with the same striation direction and plunge as those in the large quartz vein. There are also specimens of shatter cone quartz and rodded feldspar granite (Figures 18–23).

Site 12: Honeymoon Well Landsat ring: tourist stopping point. This site is over 200 km NNW from the Western



Fig. 17. Site 11. *In situ* 500 mm long shatter cones in quartz and adjacent felsic granite west of Mount Keith Mine.



Fig. 18. Specimen 11.3. Intensely shocked and rodded felsic porphyry that is in line with the *in situ* quartz shatter cones. It is the intensely shocked medium grained felsic rock that occurs around the site.



Fig. 19. Site 11, specimen 11.1. Large annular specimen of shatter cone. Totally granular shattered quartz with deep, incised striations on both sides of the annulus. The diameter of the cone that this specimen is a section of would be about 2 m. Measurements of the amount of spreading indicate that the individual 'shatter cones' that make up the larger composite shatter cone would be about 1.5 m long. (Left) The striations seem to be burnt onto the shattered quartz.

Terraces which is the centre point of the WIS. The WIS appears to be symmetrical so it is over 400 km in diameter. There are one metre thick quartz veins located south of a granite breakaway that has 40° WNW dipping black mylonitic alteration



Fig. 20. Site 11, specimen 11.1. Shatter cone annulus in quartz. End section showing aggregates of circular rodded structures.



Fig. 21. Specimen 11.4. Shatter cone in quartz.



Fig. 22. Specimen 11.4. Shatter cone in quartz showing internal smooth sided tube between the rods. How are these formed in such a high shock environment?

and shearing. Both the quartz and the granite breakaway trend ENE parallel to the ring at a wide angle from the NS regional foliation. There is some rodded feldspar porphyry with NS rods with a sub horizontal plunge. There was some weakly shatter



Fig. 23. Site 11, specimen 11.7. Shatter cone 'knuckle' in iron-stained quartz.



Fig. 24. Site 12, specimen 12.1. Honeymoon Well shatter cone.

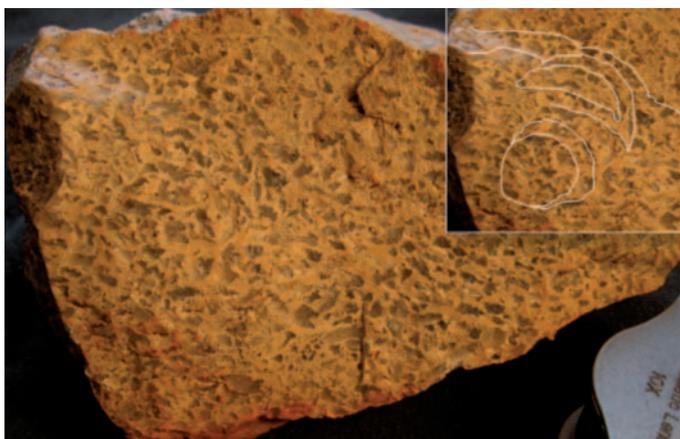


Fig. 25. Site 12, specimen 12.3. Post-impact glassy (spherules?) conchoidal quartz feldspar rock, completely undeformed. The surrounding granites show moderate deformation either from the impact or regional tectonics. Comprised of angular and rounded 1–3 mm laths of glassy quartz with a light cream coloured aphanitic, waxy, feldspar matrix. Is this an impact generated melt or welded rock? There are concentric rings of laths on the left side and at the bottom (inset). How would these form?

coned and strained quartz with a NS trend shown in Specimen 12.1 (Figure 24).

At Site 12, and at a few previous sites, there are strange, completely undeformed, quartz feldspar rocks (Specimen 12.3), which have a strange quartz/feldspar habit and might be an impact melt rock (Figure 25).

Conclusions of the *prima facies* evidence trip

The rings are real, verifiable geographical and geological features. They were identified from 5–8 km away as one approached them by road and were easily observed on the ground. The field geology and geographic features conformed to that expected from the gravity, DEM, magnetics and Landsat images.

Prima facie evidence of the WIS, discovered at multiple sites, consisted of shatter cones or shock-affected quartz and feldspar, plus welded or melt rocks: Sites 6 and 8 represent the central gravity rings; Site 9 represents a Landsat ring; Site 10 represents the 250 km diameter gravity ring; and Sites 11 and 12 represent the Outer Landsat Rings indicating that if the impact is symmetrical it has a diameter of greater than 500 km.

Two summary composite photos show the *prima facies* evidence from the WIS compared with similar *prima facies* evidence from recognised impact structures (Figures 26 and 27).



Fig. 26. Recognised *prima facies* evidence from recognised impact structures (left) and Watchorn Impact Structure (WIS), Australia (right). Top row: shatter cones from Cheigau crater, Bavaria (left) and Agnew ring, WIS, Western Australia (right). Middle row: impact Melt Rock, Dagamite Sweden (left). Radial quartz ground mass determines position of laths. Honeymoon Well ring WIS, Western Australia. Bottom row: impact melt or hot gas deposited clastic rocks with unsorted rounded and lath shaped quartz and other minerals. Rochehouart Crater France. Mertondale ring WIS Western Australia.



Fig. 27. Comparison of *prima facies* evidence from Chicxulub impact structure, Mexico (left) and Watchorn Impact Structure, Australia (right). Top row: melt or welded rocks containing quartz glass Spherulites. Note the similar quartz colours and conchoidal habit. Middle row: shocked glassy quartz with two sets of striations. Bottom row: shocked quartz lamellae (left) and quartz with three planes of striations (right).

The exploration trip confirmed, with the *prima facie* evidence located on the WIS rings, that at least one, but most likely two major impacts have occurred in the Leonora region (Figure 28).

There are at least eight other suspected impacts in the Eastern Yilgarn (Figure 1) that require field work in the light of the abundant *prima facies* evidence for the WIS.

The WIS rings also have an empirical megascopic and field correlation with the largest nickel, gold, copper, silver–lead–zinc and rare earth deposits. This is particularly evident in the

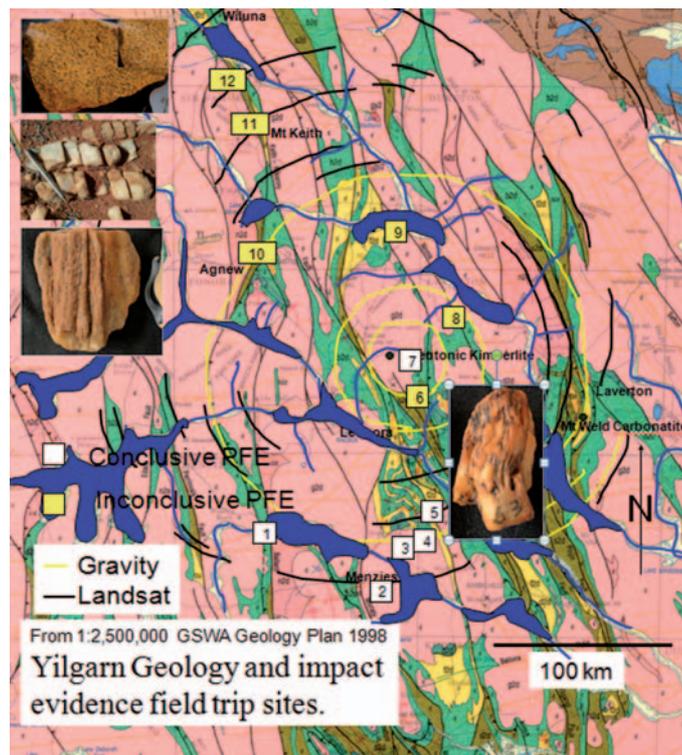


Fig. 28. Yilgarn Geology and WIS *prima facies* field evidence trip sites. Plan of field site locations on the Yilgarn Geology, Gravity and Landsat rings with the type specimens found at each location.

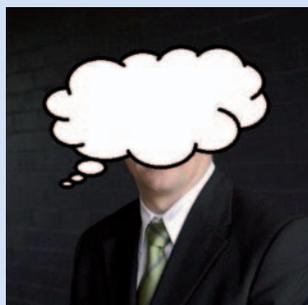
outer rims and the outer central concentric ring. This observed relationship means a paradigm shift is needed for studying the genesis of mineralisation in the Yilgarn and targeting requirements for exploration success. This might apply to the very similar Archaean Cratons worldwide and perhaps the same impact cratering mechanism has operated right up to the present?

This question will be the subject of the next paper.

Reference

Grieve, R. A. F., and Pilkington, M. (1996). The signature of terrestrial impacts. *AGSO Journal of Australian Geology & Geophysics* **16**, 399–420.

My head in the Cloud



Guy Holmes

Guy.Holmes@spectrumdata.com.au

Over the past 3 years, there has been a significant change in storage possibilities for data: it goes by the name the 'Cloud'.

Really up until a few months ago, Cloud technologies were not part of my vocabulary in terms of viable technology for exploration data storage, and this was typically due to the sheer size of the data with which we deal. How on earth would we get them into and out of the Cloud?

Recently, I attended a training course and have since been investigating the possibilities that the Cloud now offers. I can confidently say I am a serious convert. The offerings of companies like Amazon for instance that offer infinite storage and massive computing power at a fraction of the cost of owning the equipment and doing it yourself are simply too hard to pass up. Furthermore, since completing my training, I cannot stop thinking about the Cloud and its endless possibilities, especially where exploration data is concerned.

The most common rejection I get from users to using the Cloud is 'the Cloud is simply not fast enough for me to get access to the data, especially given the size of the files I use'. So let me address the issues of speed and size.

When a user talks about speed, they are usually doing comparative analysis: 'I can get access to data this fast right now, so how fast will it be if I move to the Cloud?'. Well, fair question, but let's not give too much credit to the user for asking, as typically the users forget a few important elements at play in this analysis. Using oil and gas data as an example:

- Newly collected data is usually accessed heavily within the first 3–6 months of acquisition and then 95% of the data is normally not accessed for many years at a time – or ever again. Therefore, you almost only ever need rapid access to data you are working on right now, not everything you have ever acquired. Additionally, the data you are working on right now probably won't have originated in the Cloud.
- Let's say you actually do need rapid access to that 95% of data you acquired 3 years ago, but usually don't need. How fast is it really going to be to get that data in the conventional way as compared to Cloud access? Well, in most cases the data from 3 years ago is on a tape in storage somewhere. You are looking at 36 hours minimum in the best circumstances to get this data by conventional means – probably more

like 72 hours. I can assure you the Cloud can manage to beat that timing on a routine basis without the need for intermediate tapes to be created, avoiding duplication costs and the need to interact with one of Australia's friendly courier drivers.

- Okay, so the Cloud is pretty fast, but the size of the files I need are massive and the Cloud can't handle moving that huge 3D we acquired back onto my network – sorry user, wrong again. Not only do Cloud providers offer direct connect access or import/export facilities to speed that process up, but more importantly I would question why you would download it at all when you can process the data in the Cloud without moving it using the almost infinite compute power available in the Cloud.

So, when will people start to migrate to the Cloud in the exploration industry? I believe the move in earnest has begun. People are asking questions and testing the capability much more routinely and it is only a matter of time (months not years) before someone integrates it into its forward planning.

I know what you are saying as you approach the end of this article... 'Guy finally wrote something that is serious relating to a "Data Trend"', and for this I must apologise.

Seismic window: where is the seismic line?



Michael Micenko
micenko@bigpond.com

Recently our data manager spent several months cleaning up a large seismic database that had numerous misties at line intersections. The misties were the result of incorrect positional data associated with the seismic lines and some protracted detective work was needed by him to correct the errors. This article describes some causes of the errors

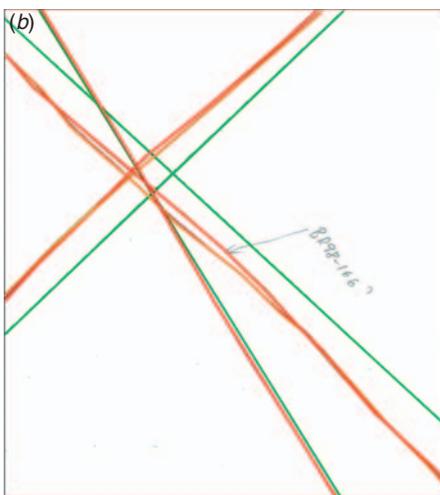
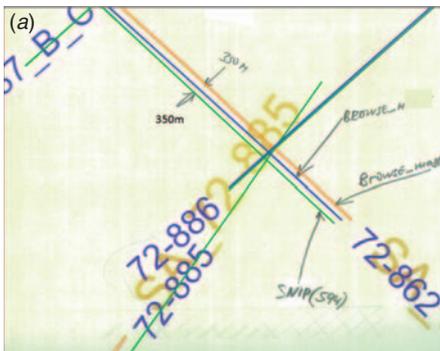


Fig. 1. (a,b) Typical examples showing a seismic line plotting in three different locations depending on the source of the coordinate information.

and is illustrated with sketches from his notes. The project database covers an area of the offshore Browse Basin and was populated with data from several sources: processing contractors, joint venture operators, study groups, acreage gazettal data packs, purchases, 'the Internet' and government agencies. It was found that where multiple versions of a seismic line were present they rarely plotted in the same place on a map (Figure 1).

The seismic trace data (or wiggles) are fine and the issue is locating the trace data in the correct position on the ground? Often the navigation data is poorly documented and it is still common for data from different sources to have different coordinates. Why is there a variety of locations for the same trace and how can the real location be determined?

In this project, incorrect coordinate data fell into two categories: an incorrect coordinate reference system (CRS); and deficiencies in the data. Most errors fall into the first category and to explain why, a brief history and explanation follows.

Up until the 1980s Australia used the Australian Geodetic Datum (AGD) and Australian Map Grid (AMG). AGD was based on a spheroid that gave a good match to the shape of the earth's surface in Australia, but was a poor match away from Australia. Unfortunately, the AGD spheroid was not geocentric (the centre of the spheroid was not the centre of the earth) and with the widespread use of satellite-based positioning there was a requirement for a geocentric spheroid.

During the 1990s Geocentric Datum of Australia (GDA) was introduced to replace AGD and was adopted by most companies from around 2000 onwards. GDA uses a geocentric spheroid and is very close to the World Geodetic System (WGS), which was commonly used by marine seismic contractors from the mid-1980s. So in the latter part of the past century seismic data was recorded using WGS while the official system for government reporting was AGD. The difference between AGD and GDA (or WGS) is ~200 m. Unfortunately, the difference was not fully appreciated and data was stored in whatever form was available (GDA, AGD, WGS) without full documentation. Sounds confusing – well many data-loading technicians also thought so and some (actually most) coordinate databases turned into a 'dog's

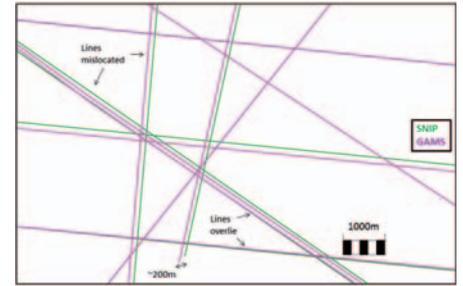


Fig. 2. Example showing a difference between SNIP (green) and GAMS (purple) line locations downloaded from the Geoscience Australia website in August 2013. Some lines match and others don't!

breakfast'. About this time the Shared Navigation Integration Project (SNIP) consortium began to sort things out and provided vetted sets of coordinates to subscribers. SNIP is being replaced with the Geoscience Australia Marine Surveys (GAMS) Project and data can be obtained from Geoscience Australia. GAMS has a disclaimer and is not guaranteed to be correct.

(The SNIP data was purchased by Geoscience Australia from Fugro Multi Client Services in 2007. The dataset includes 3156 onshore and offshore seismic navigation data from Australia and New Zealand for surveys acquired prior to 2003.)

So how do we find out which version of the navigation data is correct? My first step would be to check the locations against the SNIP or GAMS database. This works most of the time but sometimes there is an error in SNIP or GAMS (Figure 2). Next step is to try and get the original navigation information from the contractor or acquisition or processing reports. If these efforts still leave some doubt then the line locations from a number of sources can be compared and the most common positioning is selected.

Here are the top five reasons we found (Figure 3) for the wrong coordinate information being used, followed by examples:

1. Coordinates are believed to be GDA, but are actually AGD. Line is ~200 m SW of true position. The difference between GDA and AGD grid coordinates on a map is ~200 m so it is common for lines to be 200 m (or multiples of this) away from their true location. Even though GDA has

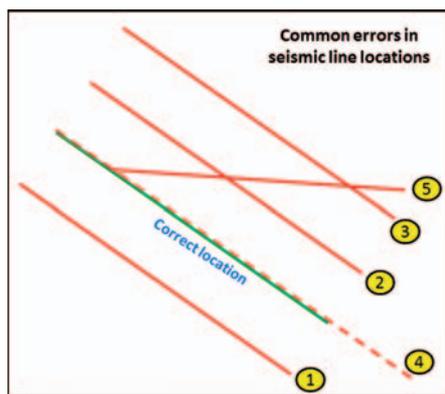


Fig. 3. Common types of seismic line location errors. Types 1, 2 and 3 are caused by errors in the CRS while Types 4 and 5 are because of lack of coordinate information or reading errors.

been in place for several years this error is still seen and the example in Figure 2 is a concern because not even the two common databases (SNIP and GAMS) have resolved this issue.

- Coordinates were believed to be AGD and were converted to GDA. Actually they were correct and no conversion was necessary. Line is 200 m NE of true position. This is common for old navigation WGS-based data stored in an AGD database. WGS is very close to GDA.

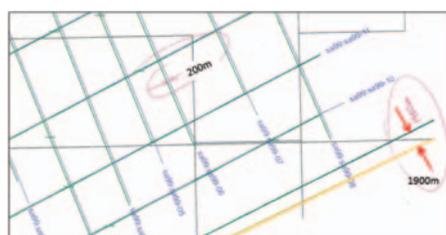


Fig. 4. Example of Type 1. Line locations from different sources. Coordinates for one dataset are in AGD while the other is in GDA. The difference between the two systems is ~200 m in this area. But the southernmost line has 1900 m between the two versions. This is an example of a Type 4 error. One version did not have the complete set of coordinate information so the line is plotted by extrapolation from the last two known points.

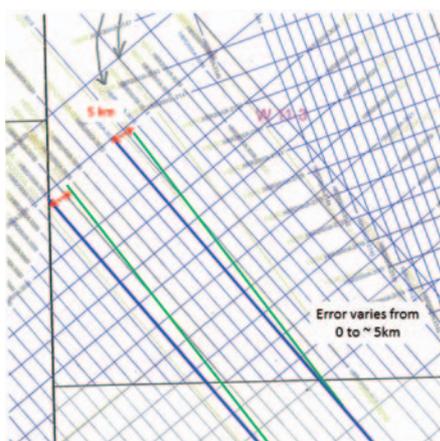


Fig. 5. Another example of Type 4 with several lines located up to 5 km from their correct position. Two examples are highlighted but there are several more in this small area.

- As above but corrected twice or coordinates in WGS were saved in an AGD database, which was then converted to GDA. Line is ~400 m NE of true position
- Extrapolation to areas of missing data. Common for lines recorded in parts where only coordinates for part A of the line were used and the extra shotpoints on Part B, C etc. were obtained by extrapolating from the last two shotpoints of part A. This is a very common error that can result in several kilometres of mislocation if the last two points deviate from the line (Figures 4 and 5). It is common because there are numerous lines recorded in parts for reasons such as whale activity or source malfunction. Each piece of the line is stored separately and often the ancillary data such as navigation files are lost or maybe no one remembers there is more than one part. This common error is usually easy to detect but correcting it requires the missing coordinate data.
- SEG-Y header read incorrectly. Even today there are many versions of SEG-Y and the seismic trace number is stored in many places in the trace

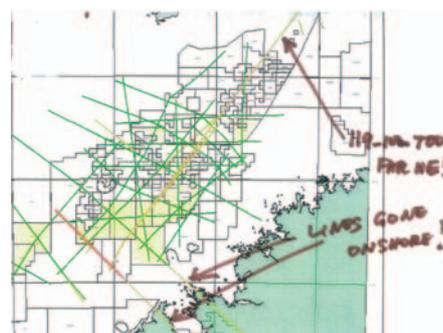


Fig. 6. Example of Type 5 where lines plot several kilometres onshore because the SEG-Y trace header was not read correctly.

headers. If the wrong byte position is read the trace numbering can be incorrect. This produces interesting results with lines being extended far beyond their actual location. The example in Figure 6 shows offshore line locations plotting onshore, which is obviously wrong.

These examples are all from offshore Western Australia, but don't think you are safe onshore. The problem exists everywhere and is not limited to 2-D seismic.

Why does an interpreter need to know about surveying issues?

Today our targets are much more subtle than in the past. Big undrilled anticlines are rare and our targets now are narrow horsts or stratigraphic features such as channel belts. In these cases an error of 2000 m to 5000 m, would result in a well missing the target completely. Even 200 m is important because a mislocated 3-D survey could have an interpreter trying to calibrate well results with the wrong seismic amplitudes. The answer is to make sure you really know the whereabouts of your seismic data.

Seismic window: unconformities are for superheroes

Looking back over the past year's articles it could be said that there is only one article on seismic interpretation, yet this column is nominally meant to address interpretation issues. There were articles on processing, acquisition, 'funny

methods' and navigation. I suggest this is a good representation of what interpreters (or *interpretators* as the Chief Geophysicist in my first industry job would say) actually do with their time. A good interpreter should know everything

about the data or at least as much as possible. This article will address the imbalance as it looks into the power of modern methods and the most difficult surface of all – the unconformity. In 1978 Nigel Anstey wrote, 'Strong continuous

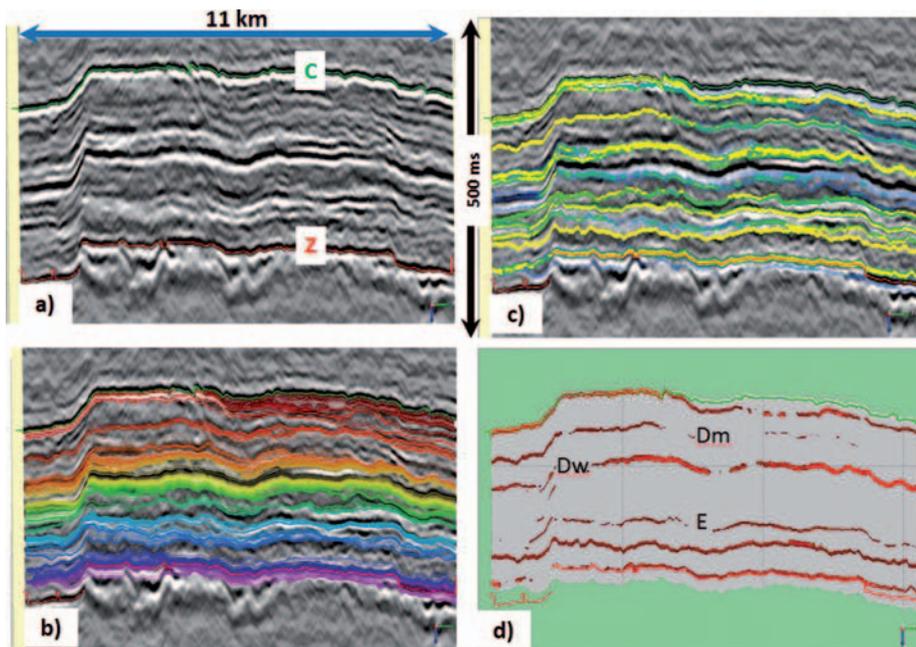


Fig. 1. Talgeberry example: (a) N-S seismic line across Talgeberry with bounding horizons 'C' horizon – green, and 'Z' horizon – red; (b) automatically tracked horizons – density of auto-picked horizons varies; (c) shows high (yellow) and moderate (blue) horizon density; and, (d) colour bar adjusted to highlight strongest unconformities in red (Dm, Murta; Dw, Westbourne; E, Birkhead).

reflectors are for kids. Unconformities are for men'. Today it may be more appropriate to replace the last word with 'superheroes'; alternatives like adults, mankind, people or that ugly word 'persons' just don't work so superheroes it is. Unconformities are difficult because they are usually not a single continuous reflector, but an event with varying strength and polarity – basic auto trackers hate them.

But, workstations can now automatically pick every reflection in a 3-D volume as demonstrated at the recent ASEG Conference in Melbourne in a talk by Jim Dirstein of Total Depth and Paul de Groot in his keynote address. Once a volume of surfaces is picked it can be used in many ways and one application is finding and mapping unconformities – I will present two examples to demonstrate: first, an example from the Talgeberry Field in SW Queensland and second, from the Exmouth sub-basin of Western Australia.

The Talgeberry example (Figure 1) summarises the technique that is based on the OpendTect horizon cube. In this case, horizons were tracked across the entire dataset from seed points spaced at 1 ms intervals on a selected trace (Figure 1b). The horizons converge or diverge based on the calculated dip of the seismic data.

Where there is a vertical change in dip resulting in a truncation, such as at an unconformity, the auto-tracked horizons tend to bunch up. The number of horizons within a short time window can be calculated (Figure 1c) and high values indicating there are many horizons within the window can identify an unconformity. By adjusting the colour bar (Figure 1d) the main unconformities are highlighted. It is quickly apparent that there are a number of possible unconformities between the 'C' and 'Z' horizons; one of which is close to the top Birkhead Fm discussed in a previous article. Other unconformities are identified in the Westbourne and Murta Formations that are associated with oil pools.

The seismic line (Figure 2) from the Exmouth sub-basin in the second example has a number of unconformities. The major unconformity at the top of the Barrow Group (arrows in Figure 2) is associated with hydrocarbon accumulations, but it is often difficult to pick the reflection from the unconformity. The horizon density volume in Figure 3 has identified the Top Barrow unconformity and almost exactly follows the hand-picked horizon that took several days to interpret across the area. Again, adjusting the colour bar and making the low values transparent further highlights the unconformities (Figure 4).

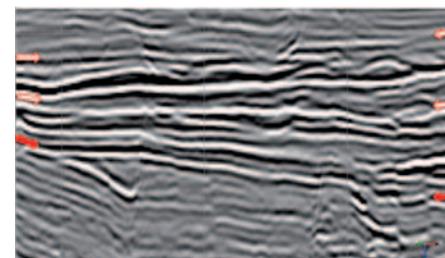


Fig. 2. Example of seismic from the offshore Exmouth sub-basin. This line has several unconformities with some indicated by arrows. The unconformity at the top of the Barrow Group is indicated with solid red arrows

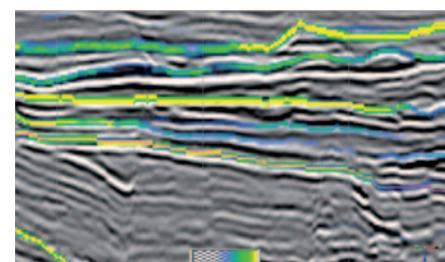


Fig. 3. At vertical changes in dip the auto-tracked horizons tend to bunch up. Here high values of horizon density, shown in yellow and green, indicate potential unconformities. Previous hand-picked unconformity surface is shown in purple.

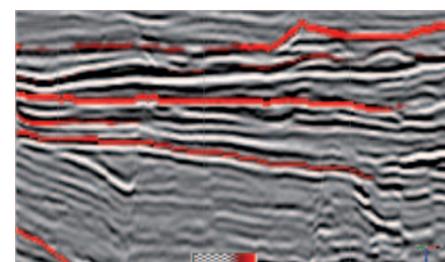


Fig. 4. Again, the colour bar can be adjusted to highlight the key unconformities in the area.

Modern workstations and software can now pick unconformities across large datasets and perhaps Anstey's quote can be rewritten 'strong continuous reflectors are for common autotrackers, but unconformities are easy for complex algorithms and workflows'.

Merry Christmas.

References

Anstey, N. A. 1978. Seismic exploration for sandstone reservoirs.
 De Groot, P. 2013, Global seismic interpretation techniques are coming of age. Keynote address, ASEG Conference and Exhibition.



Geophysical instruments,
contracting and
consulting services

www.alpha-geo.com

Alpha Geoscience Pty. Ltd.
Unit 1/43 Stanley Street,
Peakhurst NSW 2210, Australia

Ph: (02) 9584 7500
Fax: (02) 9584 7599
info@alpha-geo.com



ARCHIMEDES
FINANCIAL PLANNING

*"Using a scientifically principled approach
to improve financial buoyancy"*



Noll Moriarty, M.Sc(Hons), CFP®

*Specialising in detailed financial advice
required by discerning professionals*

Australian & International Clients

www.archimedesfinancial.com.au

3/1315 Gympie Rd, Aspley, QLD. Phone 1300 387 351 or (07) 3863 1846
Archimedes Financial Planning Pty Ltd: AFSL No. 437294 | ABN 68 094 727 152

Baigent Geosciences Pty Ltd

Geophysical Data Processing Services

- Magnetics and Radiometrics
- Fixed wing and Helicopter Data
- Full 256 channel radiometric processing
- NASVD, MNF or NASVD with clustering
- Gradiometer Enhancement processing
- Independent Data Quality control



7 Owsten Court
Banjup WA 6164
Ph: +61 8 9397 1691
Email: mark@bgs.net.au
URL: www.bgs.net.au

BOREHOLE WIRELINE

For Logging & Interpretation Service

Geophysical Borehole Logging

Acoustic / Optical BH Image Processing

Uranium • Coal • CBM • Iron Ore •
Geothermal • Groundwater • Geotechnical

Units operating throughout Australia.

(Vehicle based & Portable)

www.borehole-wireline.com.au

781 South Rd, (PO Box 21), Black Forest, SA. 5035. Tel/Fax: 08 8351 3255



Flagstaff GeoConsultants

Integrated geophysical, geological and exploration
consultancy services. World-wide experience.

Hugh Rutter
Michael Asten
Jovan Silic

Geof Fethers
Paul Hamlyn
Ross Caughey

Gary Hooper

Postman@flagstaff-geoconsultants.com.au
www.flagstaff-geoconsultants.com.au

Phone: 61 3 8420 6200
Fax: 61 3 8420 6299

Flagstaff GeoConsultants Pty Ltd (ABN 15 074 693 637)

A TOTAL EXPLORATION SERVICE



Land & Marine Engineering
Geophysics Consulting Services

Geophysics Equipment Rental

ADVANCED SUBSURFACE INVESTIGATIONS

Phone: +61 2 9890 2122 / +61 8 64361591
Fax: +61 2 9890 2922
E-mail: info@gbgoz.com.au
Web: www.gbgoz.com.au



Australian agent for sales & servicing GEM Systems

Geophysical Software Solutions Pty. Ltd.

ABN 53 347 822 476

Software services for the geosciences

Developers of...

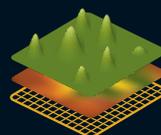
- Potent** – Versatile potential field modelling in a 3D environment
- PotentQ** – Rapid interpretation of magnetic and gravity anomalies
- EmQ** – Ultra-fast interactive EM modelling using moments

Richard Almond

Director

Tel: +61 (2) 6241 2407
Fax: +61 (2) 6241 2420
E-mail: ralmond@geoss.com.au
Web: www.geoss.com.au

PO Box 31, Gungahlin,
ACT 2912, Australia
18 Bungaree Crescent,
Ngunnawal, ACT 2913



GEO
SENSOR

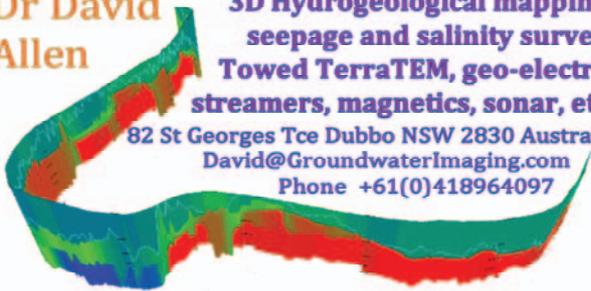
SALES & RENTALS

Ground & Airborne Instruments – Gravity, Magnetism, IP, Spectrometers & more.

P +61 (0)407 608 231 **W** www.geosensor.com.au

Garden City Office Park, Corporate House
Building 6, 2404 Logan Rd, Eight Mile Plains
Brisbane QLD Australia 4113

GROUNDWATER IMAGING
Dr David Allen 3D Hydrogeological mapping, seepage and salinity survey. Towed TerraTEM, geo-electric streamers, magnetics, sonar, etc.
 82 St Georges Tce Dubbo NSW 2830 Australia
 David@GroundwaterImaging.com
 Phone +61(0)418964097



www.GroundwaterImaging.com

MagneticEarth
 ABN 22 145 073 230



solutions for all magnetic exploration problems

phillip schmidt phd
 po box 1855
 macquarie centre nsw 2113
 email phil@magneticearth.com.au
 mobile 0410 456 495
 web www.magneticearth.com.au

 www.mintygeophysics.com

Specialising in the enhancement of airborne geophysical data

GAMMA_Plus™ - enhanced multichannel gamma-ray data processing
 GAMMA_Grid™ - equivalent-source gridding of gamma-ray data
 GAMMA_Target™ - automatic gamma anomaly detection and target generation

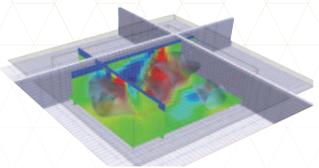
Dr Brian Minty
 Ph.D, M.Sc, B.Sc(Hons)

+61 (0)404083087
 Brian.Minty@mintygeophysics.com
 www.mintygeophysics.com

PO Box 3229
 Weston Creek ACT 2611
 Australia

 **Mira Geoscience** ...modelling the earth

- + Software, training, consulting
- + Integrated, quantitative, multi-disciplinary 3D earth modelling
- + Geophysical data interpretation, forward modelling and inversion
- + Drillhole targeting



www.MiraGeoscience.com info@mirageoscience.com

Want to use the best technology for your ground magnetic surveys?

If the signal from your deposit is there, our potassium vapour magnetometers will detect it the first time, saving you time and money.



coal · iron ore · mineral sands · diamonds · base metals · ground water

Ground mag surveys
 Magnetometer sales
modernmagnetic.com +61 0447 691 873



ROCK PROPERTIES

MASS - Density, Porosity (permeability also avail.)
 MAGNETIC - Susceptibility, Remanence; Aniso.
 ELECTRICAL - Resistivity, Anisotropy; IP effect [galvanic]
 ELECTROMAGNETIC - Conductivity, mag k [inductive]
 SEISMIC - P, S Wave Velocities, Anisotropy
 DIELECTRIC - Permittivity, Attenuation (by arrangement)
 THERMAL - Diffusivity, Conductivity (by arrangement)
 MECHANICAL - Rock Strength (by arrangement)

SYSTEMS EXPLORATION (NSW) PTY LTD
 Contact - Don Emerson Geophysical Consultant
 Phone: (02) 4579 1183 Fax: (02) 4579 1290
 (Box 6001, Dural Delivery Centre, NSW 2158)
 email: systemsnsw@gmail.com

 **Tensor Research**
 Geophysical Software Research and Services

Encom ModelVision - development, support, sales
 Encom QuickMag - sales
 Encom PA - sales
 Training, consulting research & software development

David A Pratt Mob +61 414 614 117 Tel +61 2 9404 8877
 david.pratt@tensor-research.com.au
 www.tensor-research.com.au

Gridded and image data sets

Geophysical data sets

— 1:250 000 Series DVDs

Image and gridded sets of geophysical data have been generated for each 1:250 000 scale sheet within NSW. All 58 sheets are complete and these suites of grids and images (with metadata) are available on DVD for each sheet.

The data imaged in GDA94, MGA, and NSW GDA94 Lambert for each 1:250 000 sheet includes:

Aeromagnetic data

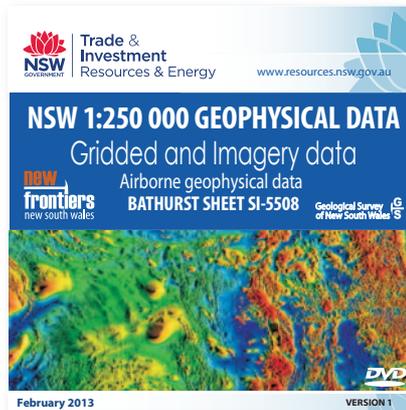
TMI, TMI RTP, 1VD TMI, 1VD TMI RTP, 2VD TMI, Greyscale TMI, Greyscale TMI RTP Tilt Filter, and TMI RTP Over TMI RTP Tilt Filter

Gravity data

Bouguer Gravity, Isostatic Bouguer Gravity, Greyscale Isostatic Bouguer Gravity Tilt Filter, and Isostatic Bouguer Gravity Over Isostatic Bouguer Gravity Tilt Filter

Radiometric data

Ternary K/U/Th

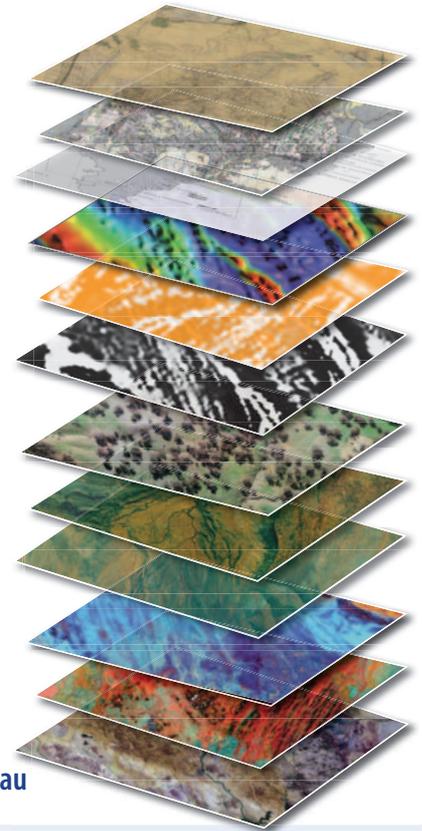


Additional

DEM, Landsat-7 Principal components 1, 2 & 3
The imagery for each sheet was compiled in the following formats:

- Gridded Data (.ers)
- ECWs
- Geo-rectified Tiffs (GeoTiffs), and
- Geo-rectified JPEGs

For further enquiries, please contact:
geophysics.products@industry.nsw.gov.au

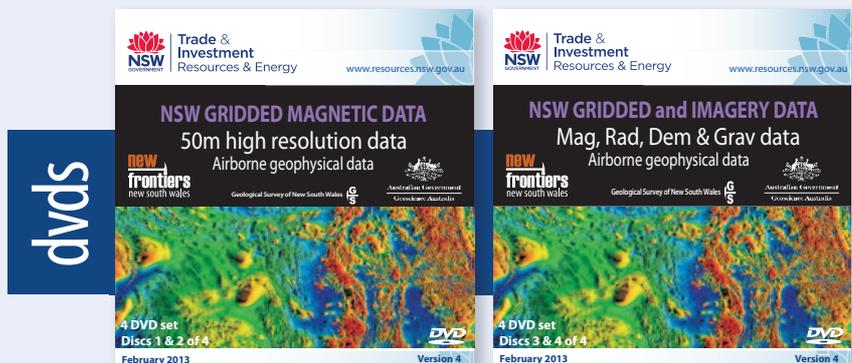


statewide data sets



Maps and data sets of statewide geophysical coverage are available as digital data (4 DVD set), and in hardcopy as flat posters or as folded maps at 1:1 500 000 scale.

Statewide data sets



Pricing

- Statewide grids and images for aeromagnetic, radiometric, gravity and SRTM (elevation) data are available as 4 DVD set \$110
- Hardcopy statewide images \$19.80 each

Available through shop.nsw.gov.au
or complete the order form on the back page

January			2014
19–22	The 7th International Petroleum Technology Conference (IPTC) http://www.iptcnet.org	Doha	Qatar
February			2014
25–27	SPE/EAGE European Unconventional Resources Conference and Exhibition http://www.eage.org/index.php?evp=1979	Vienna	Austria
March			2014
9–12	GEO 2014: 11th Middle East Geosciences Conference and Exhibition http://www.geo2014.com/	Manama	Kingdom of Bahrain
16–20	SAGEEP 2014 (The Symposium on the Application of Geophysics to Engineering and Environmental Problems) https://www.eegs.org/AnnualMeetingSAGEEP/SAGEEP2014.aspx	Boston, MA	USA
25–28	Offshore Technology Conference (OTC) Asia 2014 http://www.otcasia.org/2014/	Kuala Lumpur	Malaysia
April			2014
7–10	The 6th Saint Petersburg International Conference and Exhibition http://www.eage.org/index.php?evp=1979	Saint Petersburg	Russia
May			2014
28–30	130th SEGJ Conference http://www.segj.org	Tokyo	Japan
June			2014
16–19	76th EAGE Conference and Exhibition incorporating SPE EUROPEC 2014 http://www.eage.org	Amsterdam	The Netherlands
20–23	6th International Conference on Environmental and Engineering Geophysics (ICEEG2014) http://tdem.org/iceeg2014/	Xi'an	China
September			2014
15–17	EAGE Near Surface Geoscience 2014: 20th European Meeting of Environmental and Engineering Geophysics of the Near Surface Geoscience Division of the EAGE http://www.eage.org	Athens	Greece
28 Sep–2 Oct	2014 Canadian Geotechnical Conference <i>Conference website pending; please email cgs@cgs.ca for additional information or visit the CGS website (www.cgs.ca)</i>	Regina	Canada (Saskatchewan)
October			2014
26–31	SEG International Exhibition and 84th Annual Meeting http://www.seg.org	Denver, CO	USA
December			2014
10–12	International Petroleum Technology Conference (IPTC) http://www.iptcnet.org	Kuala Lumpur	Malaysia
February			2015
15–18	ASEG-PESA 2015: Geophysics and Geology together for Discover 24th International Geophysical Conference and Exhibition http://www.conference.aseg.org.au/	Perth	Australia
June			2015
1–4	77th Conference and Exhibition http://eage.org	Madrid	Spain
October			2015
18–23	SEG International Exhibition and 85th Annual Meeting http://www.seg.org	New Orleans, LA	USA

Preview is published for the Australian Society of Exploration Geophysicists. It contains news of advances in geophysical techniques, news and comments on the exploration industry, easy-to-read reviews and case histories, opinions of members, book reviews, and matters of general interest.

Advertising and editorial content in *Preview* does not necessarily represent the views of the ASEG or publisher unless expressly stated. No responsibility is accepted for the accuracy of any of the opinions or information or claims contained in *Preview* and readers should rely on their own enquiries in making decisions affecting their own

interests. Material published in *Preview* becomes the copyright of the ASEG.

Permission to reproduce text, photos and artwork must be obtained from the ASEG through the Editor. We reserve the right to edit all submissions. Reprints will not be provided, but authors can obtain, on request, a digital file of their article. Single copies of *Preview* can be purchased from the Publisher.

All editorial contributions should be submitted to the Editor by email at jthe1402@bigpond.net.au. For style considerations, please refer to the For Authors

section of the *Preview* website at: www.publish.csiro.au/journals/pv.

Preview is published bi-monthly in February, April, June, August, October and December. The deadline for submission of material to the Editor is usually before the 15th of the month prior to the issue date. The deadline for the February 2014 issue is 10 January 2014. For the advertising copy deadline please contact Doug Walters on (03) 9662 7606 or doug.walters@csiro.au.

GRAVITY

DAISHSAT is the leading provider of GPS positioned gravity surveys in Australia with the latest acquisition equipment and most experienced staff, resulting in the highest quality data for our clients. Contact David Daish for your next gravity survey.

Ground and helicopter borne gravity surveys

Precision GPS surveying

Image processing

Terrain corrections

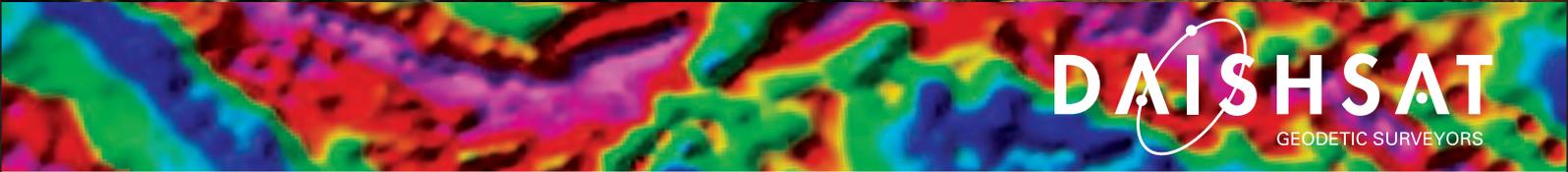
Operating Australia wide with support bases in Western and South Australia

Specially developed vehicles for safe efficient cross country surveying

T: 08 8531 0349 F: 08 8531 0684

E: info@daishsat.com

www.daishsat.com



DAISHSAT
GEODETTIC SURVEYORS



World first piston engine helicopter stinger installation for low cost, high quality airborne radiometric and magnetic data collection

Helicopter

- 30% the cost of existing helicopter platforms
- Close transect spacing
- Safe operations in rugged terrain
- Accurate terrain draping
- Remote site operations

Fixed wing

- High efficiency large area coverage
- Remote airstrip operations

Contact us for your next airborne survey
T 08 8532 5973 F 08 8531 0684
E info@aerosystems.com.au
www.aerosystems.com.au



AEROSYSTEMS

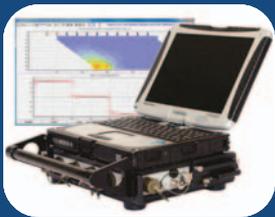


AEROSYSTEMS



Is it down there?

Find out.



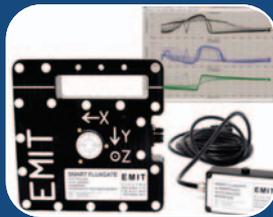
SMARTem24

16 channel, 24-bit electrical geophysics receiver system with GPS sync, time series recording and powerful signal processing



DigiAtlantis

Three-component digital borehole fluxgate magnetometer system for EM & MMR with simultaneous acquisition of all components



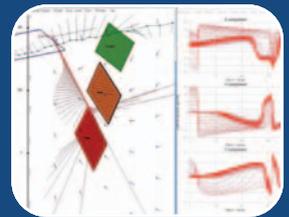
SMART Fluxgate

Rugged, low noise, calibrated, three-component fluxgate magnetometer with recording of Earth's magnetic field, digital tilt measurement and auto-nulling



SMARTx4

Intelligent and safe 3.6 kW transmitter for EM surveys, clean 40A square wave output, inbuilt GPS sync, current waveform recording, powered from any generator



Maxwell

Industry standard software for QC, processing, display, forward modelling and inversion of airborne, ground and borehole TEM & FEM data

EMIT

www.electromag.com.au

ELECTRO
MAGNETIC
IMAGING
TECHNOLOGY

6 / 9 The Avenue
Midland WA
AUSTRALIA 6056
+61 8 9250 8100
info@electromag.com.au

Advanced electrical
geophysics instrumentation
and software