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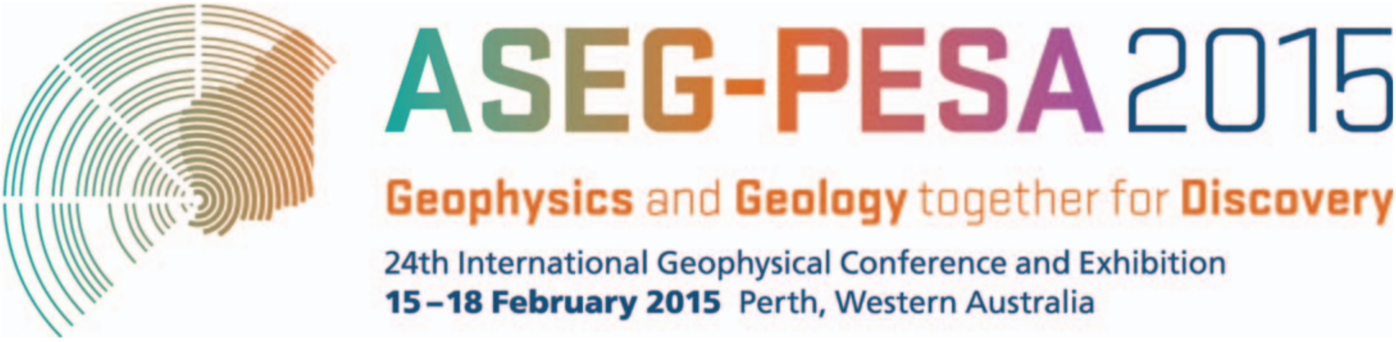
News

Multi-level air gun source technology

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



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 out 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 in^3. 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

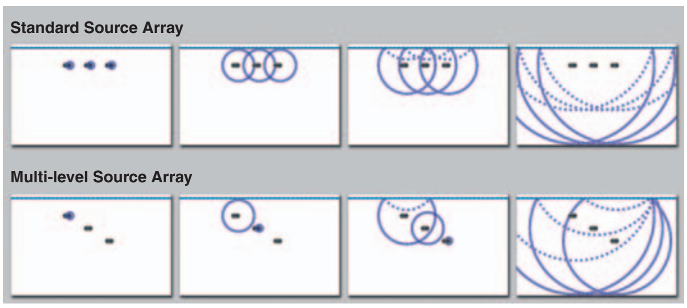


Fig. 1. *A conventional source array (upper) fires all guns simultaneously, generating a constructive down-going wave (solid) and ghost (dashed). The sequential firing of the multi-level source (lower) builds a constructive down-going wave, but not a constructive ghost. Note however, the constructive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

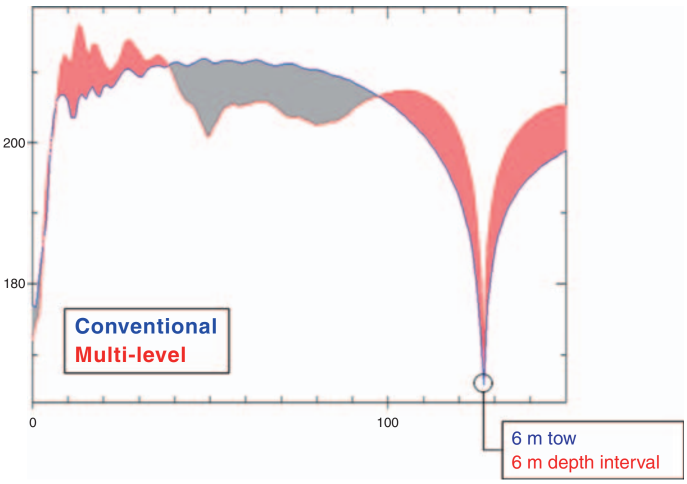


Fig. 2. *Superimposed conventional and multilevel source spectrum (red vs blue, respectively) for a prototype test in 2008.*

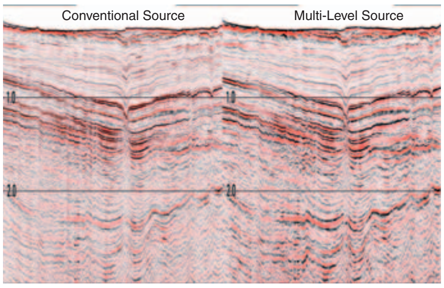


Fig. 3. *Raw pre-stack time migrated comparison of the test line in a 0–3 s time window. Both panels include receiver-side deghosting via dual-sensor wavefield separation, the difference is therefore related to the source arrays (conventional source on the left and MLS on the right). Note the improved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

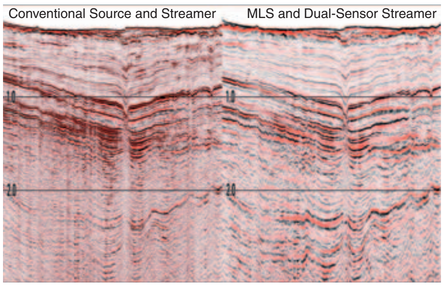


Fig. 4. *Raw pre-stack time migrated comparison of the test line in the target time window of 1–3 s. When the effects of both the source-side and receiver-side ghost are present on conventional data (left) the target events are very weak, incoherent and impossible to interpret. In contrast, the MLS and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

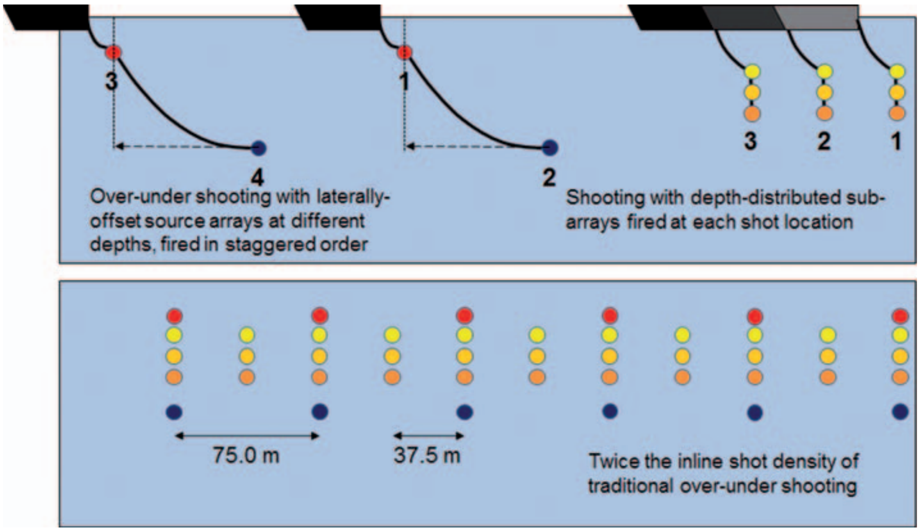


Fig. 5. *With over-under source firing a conventional source array at shallow depth is fired first in a given location (Events 1 and 3). A second conventional source array towed deep is deployed at twice the nominal shot interval behind the shallow source array. When the deep source array is towed into 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 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 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 in^3 array (three sub-arrays), a conventional 6180 in^3 array (six sub-arrays), and the 6180 in^3 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 in^3. Larger air guns have increasingly unstable bubble behaviour when towed, prohibiting accurate low frequency amplitude and phase modelling or measurement, thereby corrupting source designature 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

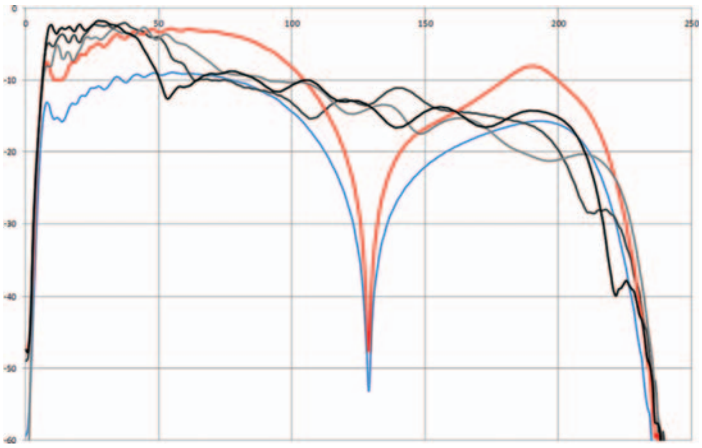


Fig. 6. *Superimposed amplitude spectra for a 3090 in³ array consisting of three sub-arrays at 6 m depth (blue), a 6180 in³ array consisting of six sub-arrays at 6 m depth (red) and the 6180 in³ array configured in MLS mode with sub-arrays at three different depth configurations: (11 m, 14 m, 17 m (black 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.

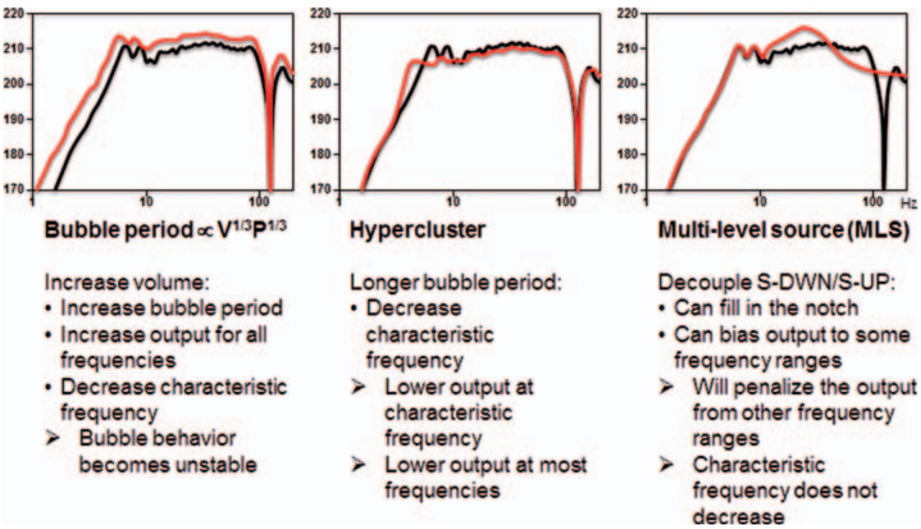


Fig. 7. *Schematic comparison of the main published methods to modify air gun array output. The only established approach to increasing ultra-low frequency output below about 8 Hz relies on increasing bubble oscillation period, either by using large air gun volume (established) or by decreasing air gun 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 Expended 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, Z011.

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
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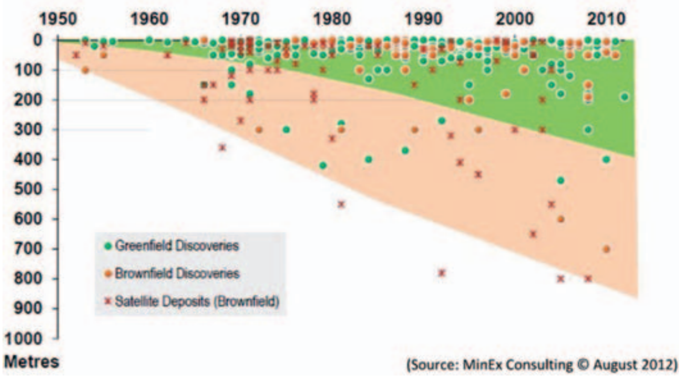
Graham Ascough
Mithril Resources, Adelaide SA

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.

	1950-59	1960-69	1970-79	1980-89	1990-99	2000-12
Greenfield	5	35	45	52	27	64
Brownfield (including satellite deposits)	46	86	66	77	114	185



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

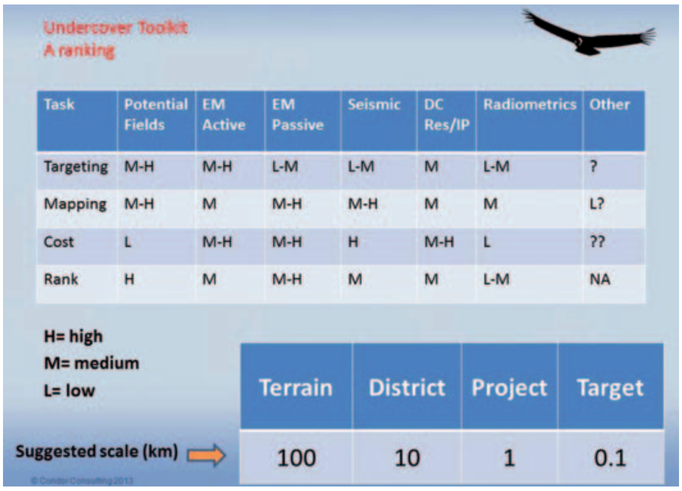
The geophysical tool kit to map the upper 3 km

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.



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

Terrain	District	Project	Target
100	10	1	0.1

Witherly; toolkit score card for exploring undercover.

Exploring undercover: building and testing geological models

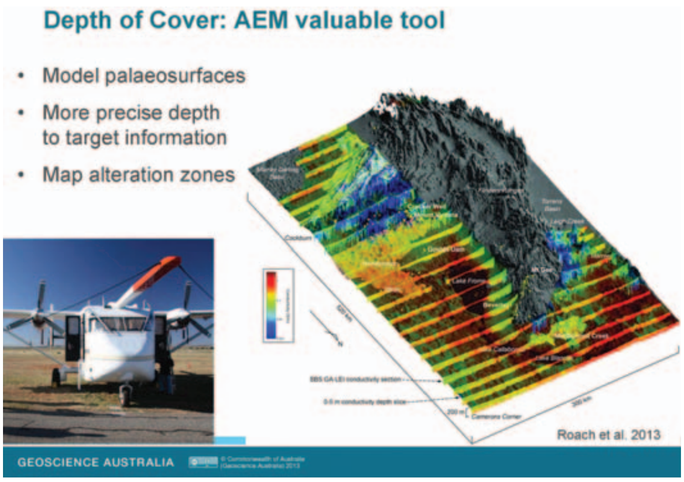
Andy Barnicoat
Geoscience Australia (GA), Canberra

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.

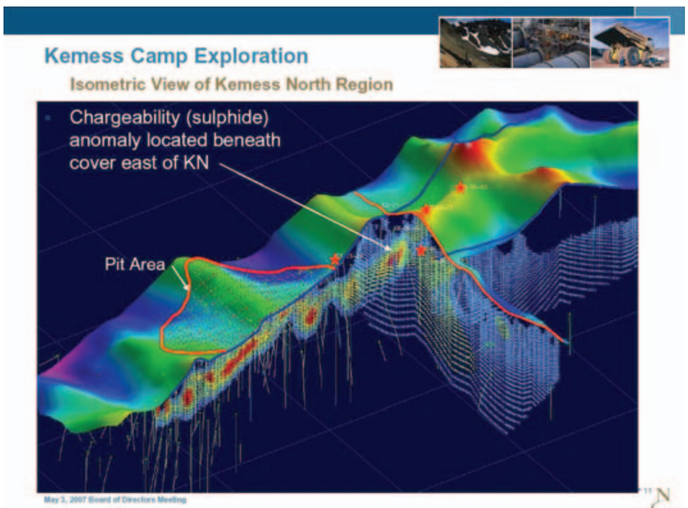


Barnicoat; from Roach et al. *2013; example of using AEM to map cover sequence.*

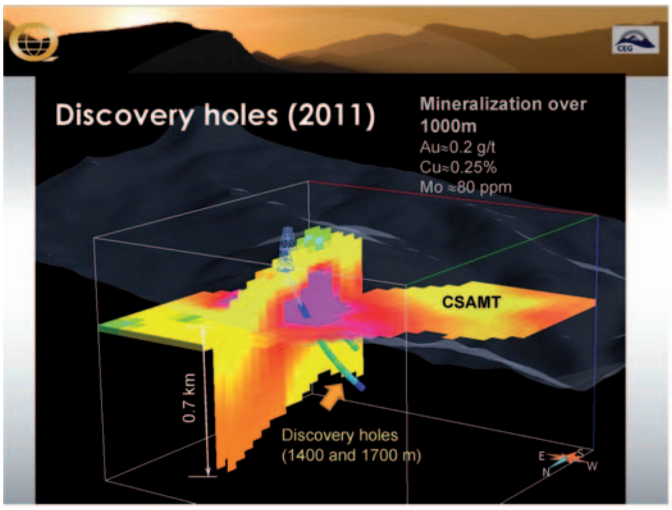
Porphyry exploration in the Americas: 2-D synthetic and field resistivity data modelling

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.



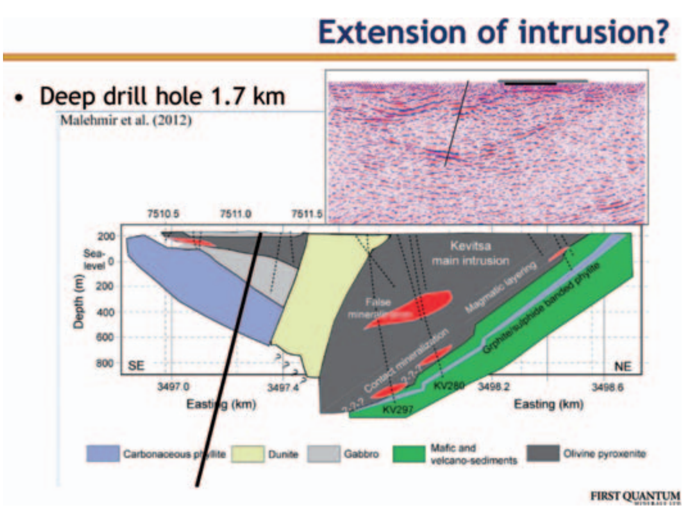
Rudd; geophysics and discovery holes on Santa Cecelia deposit (Chile).

the depth of investigation the client required. When the survey was completed, new targets at depths of approximately 1 km were revealed. At Santa Cecelia, 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.

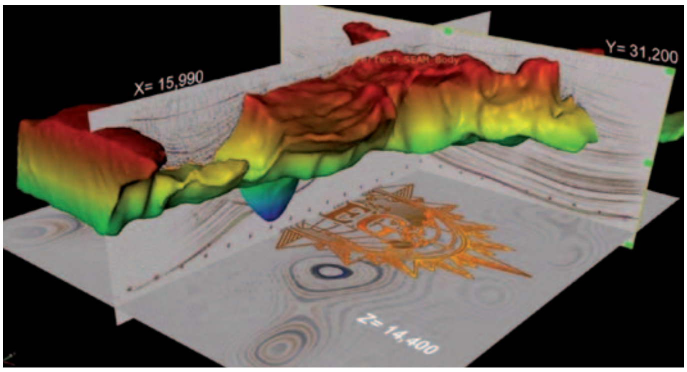
SEAM: the challenge of modelling seismic exploration at full scale

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 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.

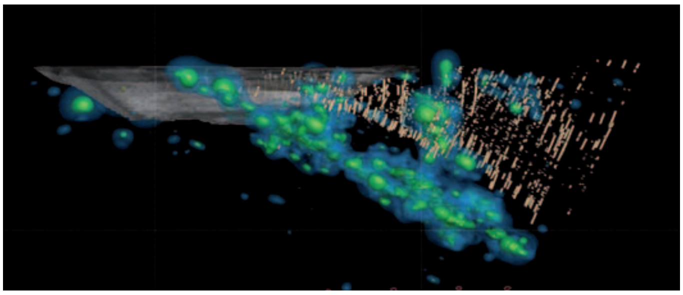


Li; SEAM sub-salt model from Gulf of Mexico.

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

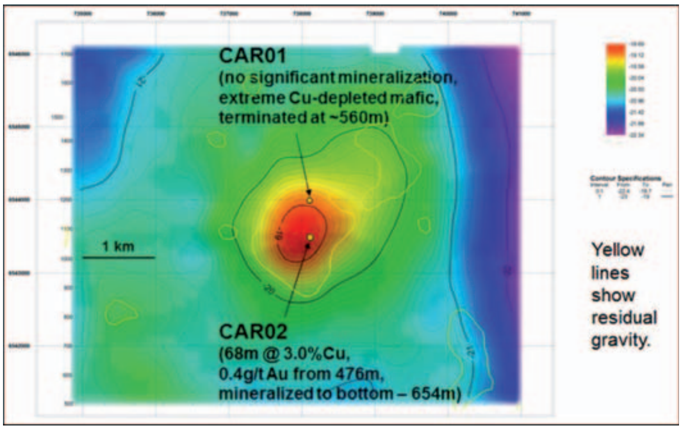
John McGaughey
MIRA, Canada

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).

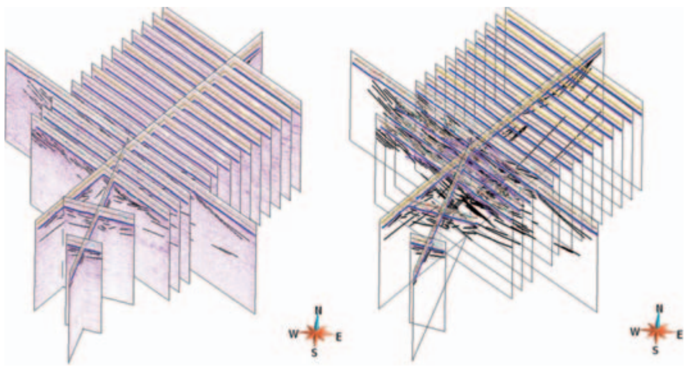


Vella; discovery holes and geophysics at Carrapateena deposit (Australia).

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

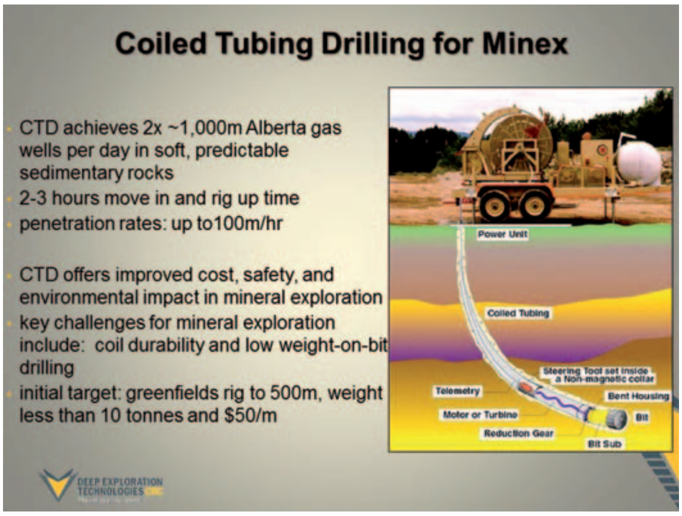
Ted first laid out the challenges explorers and governments face in keeping a strong and successful minerals industry present in Australia. He outlined how the South Australian (SA) government looks at a combination of pre-competitive R&D (including providing state-of-the-art geoscience data sets) as 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.

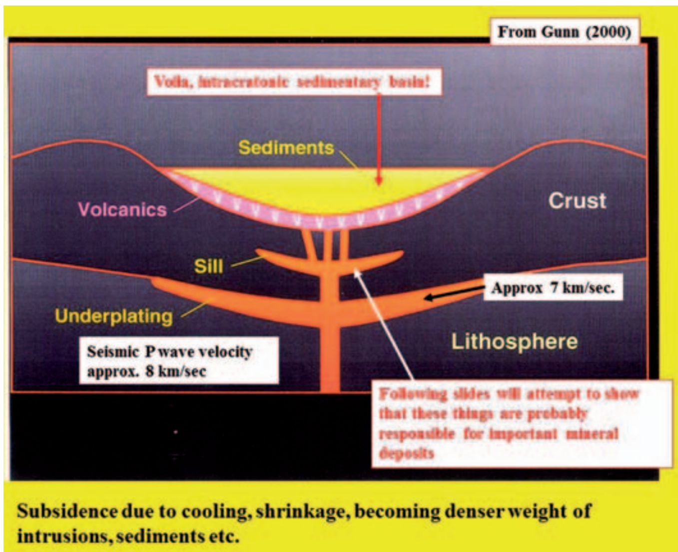


Hillis; concept of Coil Tube Drilling system for minerals.

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.

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.

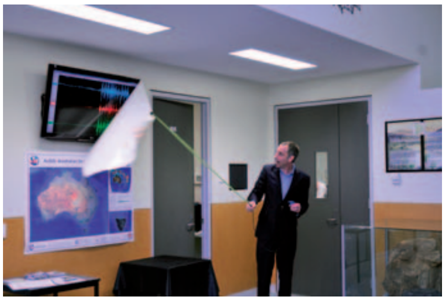
Teacher Earth Science Education Programme (TESEP): news highlights Oct–Nov 2013

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

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 km^2 (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.

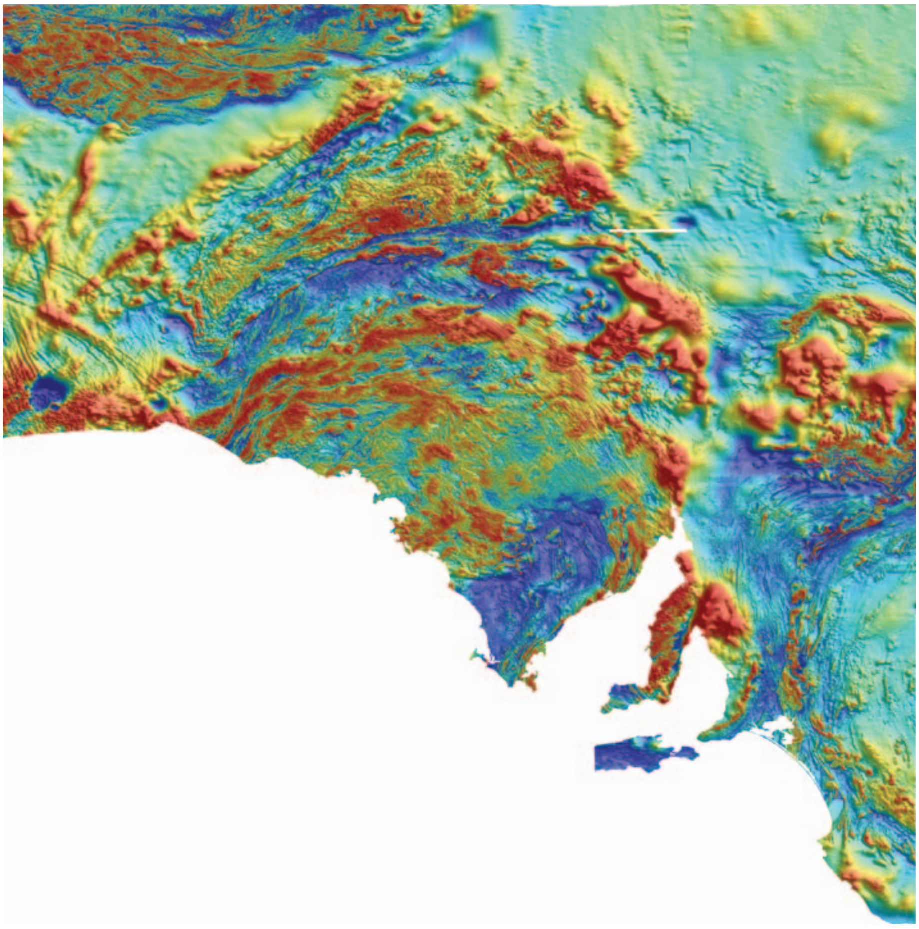


Fig. 1. *The magnetic grid of South Australia is viewable and downloadable through SARIG (https://sarig.pir.sa.gov.au/Map: Map Layers menu → Data tab → Geophysical State Images → Magnetics → TMI).*

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, Tieyon and Agnes Creek 1:100 K 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