James Duncan Crone: 7 August 1929 – 4 March 2011

James Duncan Crone, pioneering Canadian mining geophysicist, explorationist and entrepreneur, passed away on Friday 4 March 2011, in Mississauga at the age of 81. Duncan, known and recognized in the mining and exploration community around the globe, was a very innovative, practical-minded geophysicist who made numerous important contributions to the advancement of mining geophysics and to mineral exploration discoveries during his long career.

In 1962, Duncan founded Crone Geophysics Ltd. where the Shootback EM method was further improved and put into production. Duncan's innovation and inventiveness led him to produce numerous practical and portable instruments such as the CEM (Shootback), the VEM (Vertical Loop), the RADEM (VLF receiver), I.P. Receivers, and backpackable I.P. transmitters. These were sold to a worldwide market.

Realizing that there was a growing need to look deeper into the earth, Duncan began to develop borehole and surface time-domain EM equipment, which he named Pulse EM. The original Crone surface Pulse EM system, developed in 1973, was first used in the Sultanate of Oman where, serendipitously, the first field test outlined three massive sulphide ore bodies. This was the first commercially available surface time-domain EM system, and it was an immediate success. He followed this in 1978 with the first commercial Borehole Pulse EM system. Today, borehole Pulse EM is an integral part of many mineral exploration programs, and has led to the discovery of many deep massive sulphide orebodies.

Duncan presented many papers and wrote numerous case histories in his very readable, straightforward style.

The easy-to-operate and highly reliable geophysical instruments for practical geophysical surveys developed by Duncan and his dedicated collaborators provided a great service to the exploration industry and are his legacy. He will be remembered by many colleagues, associates and friends who were inspired by his ideas, benefited from his innovations and encouragement, and enjoyed his humour, his down-to-earth nature and his generosity of spirit.

Duncan is survived by his devoted wife, step-daughter, five children from two prior marriages, fifteen grandchildren and sixteen great-grandchildren.

A detailed obituary and profile can be found at www.cronegeophysics.com/Home/JDuncanCroneObituary.pdf.

Len Collett: 19 September 1922 – 9 March 2011

Leonard Stanier Collett spent his pre-university years on a farm near Burford, Ontario, graduated from McMaster University with a degree in Physics and Chemistry, then completed his masters in Geophysics at the University of Toronto. After four years with Newmont Mining in Arizona, he joined the Geological Survey of Canada for a full and valued career in Ottawa.

The following is extracted from an article in *The Phoenix* in June 1995.

> *…His career [at the GSC], spanning more than 30 years, was many-faceted. The early days included research into near surface seismic sounding with George Hobson; in the early 1960s the electrical methods section was set up to research rock properties (Collett was one of the five original researchers measuring electrical properties of lunar rocks); radar sounding came in the '70s and finally, his role of 'scientific watchdog' through the 1980s with IRAP (Industrial Research Assistance Program) and the Unsolicited Proposal Program.*

Collett retired in 1987 at age 65 and then stayed on part-time for two and a half years as an IRAP representative. His greatest joy outside of his professional life was creating a haven of self-taught cabinet making on their farm near Hopetown, including the propagation of nut trees surrounded by a thriving grove of black walnut. As a humanitarian, Len was active in community affairs, supported the arts and cultural life of Ottawa, and was a strong advocate of scholarships for students of geo-sciences.

Len passed away peacefully at the Ottawa Civic Hospital on Wednesday, March 9, 2011 after a brief struggle with mesothelioma. He was predeceased by their son Ronald in 1973 and is survived by his devoted and loving wife, Genice (nee Mauney).

ASEG 2012 22nd ASEG International Conference and Exhibition News Update (05)

Our key focus at this time is the appointment of sponsors. So far the following companies have agreed to be sponsors at the conference: Anglo American Exploration (Australia) and Origin at the Gold level; Beach Energy, CGGVeritas, Carpentaria Exploration, Geosoft, Pitney Bowes Business Insight, Talisman Energy and Velseis at the Silver level; and Planetary Geophysics Pty Ltd at the Bronze level. Congratulations to them and we welcome them. There is still time in this financial year to get on board.

If you have not done so already, please visit our website (www.aseg2012.com.au) to register your expression of interest in presenting a paper. The closing date is 30 June 2011. Twelve keynote speakers have been invited to date and we are confident that most if not all of these will accept the invitation. Keep visiting the website for further updates.

Please contact Michelle Ianna at mianna@arinex.com.au for a poster for your office. Your assistance will help us to promote this event.

Co-Chairs: Wayne Mogg & Andrea Rutley
Technical: Binzhong Zhou
Sponsorship: Ron Palmer
Exhibition: John Donohue
Finance: Noll Moriarty
Workshops: Koya Suto
Publicity: Henk van Paridon
Students: Shaun Strong
Social: Janelle Kuter

Anyone able to help (we still urgently need people to help with papers) should contact Binzhong. You don't need to be in Brisbane.

Our conference theme of 'Unearthing new layers' recognises that change within our industry remains achievable, and as such we invite contributions from all geophysical and related disciplines, highlighting the application of geophysics in diverse industries from resource exploitation to environmental and engineering applications.

Henk van Paridon

A lacklustre Budget for Science and Innovation in 2011

Funding declines in real terms

The 2011/12 Federal Budget, tabled in May this year, was a rather boring steady as she goes document. There were no major surprises and no significant new initiatives.

Even the prime media release of Senator Kim Carr, the Minister for Innovation, Industry, Science and Research, which reported that the government will support CSIRO to the tune of '*a record $3 billion, through a new Quadrennial Funding Agreement to operate over four years from 2011'* did not effectively change the allocation for CSIRO.

A closer look at the numbers reveals that government funding for CSIRO in 2010/11 of $720 million will only rise, in the forward estimates, to $768 million by 2014/15 (see Table 1) – in other words an increase of about 1.7% per year. This is unlikely to keep pace with inflation. All that seems to have happened is that CSIRO have been locked in for four years to government funding that will decline in value over the four years covered by the agreement.

At the same time the cash received from external goods and services is budgeted to rise from $458 million to $548 million. This amounts to an increase of about 20% or 5% per year – so we may be back to the bad old days of cost recovery driving scientific programs. By 2014/15 the ratio of external earnings to government appropriation will have risen from 64 to 71% - quite a hike.

It was therefore rather strange for the Australian Academy of Science to *'welcome the Government's decision to protect science research funding in the 2011 Federal Budget but said it was disappointed there will be no increase in the research budget'*. The Academy release had a headline: *Steady science budget shows lack of inspiration* – for once the headline tells a better story than the text.

The '*Take home message'* from the Federation of Australian Scientific and Technological Societies (FASTS') media release hit all the nails on the heads.

> *The Federal Budget is quite unremarkable and takes a business as usual approach. The budget offers no vision to the science sector, nor does it recognise science and technology as drivers of economic growth and productivity. Australia continues to lag behind the OECD average on research expenditure (less than 2 per cent of GDP) leaving Australia ranked 13th amongst OECD countries.*

Table 1 shows the fate of the main government science and research agencies. As can be seen, the larger agencies such as CSIRO, the Australian Research Council, and the National Health and Medical Research Council are scheduled to obtain small increases, but the smaller agencies, such as The Australian Institute of Marine Science (AIMS), Geoscience Australia, The Australian National Nuclear Research and Development Organisation (ANSTO and the CRC Program do not fare well in the forward estimates.

Notice how the total funding for all the agencies only increases by 1.7% per year in the period 2010/11 to 2014/15 – hardly sustainable.

Table 1. Appropriation from Government for key science agencies

Agency	Appropriation from Australian Government in $ million								
Year	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
CSIRO	610	664	668	691	720	725	742	756	768
ARC (Value of grants)	575	577	603	676	718	817	886	898	899
NH & MRC	466	541	632	722	766	791	818	831	835
DSTO	341	365	352	390	447	434	441	424	448
CRC Program	189	212	183	197	173	166	155	146	136
BoM	214	235	245	254	252	261	266	266	269
ANSTO	142	153	164	153	166	158	160	158	158
Geoscience Australia	125	145	139	129	123	111	112	98	97
Antarctica	102	107	105	110	103	103	88	88	88
AIMS	24	27	28	28	31	31	32	32	33
Totals	2788	3026	3119	3350	3499	3597	3700	3697	3731

Government review of Geoscience Australia recognises the value of GA

However, a government review of Geoscience Australia released with the budget papers confirmed the value of the agency's work to the ongoing exploration of Australia's natural resources. The media release stated:

> *Geoscience Australia is Australia's national geological surveyor, offering valuable pre-competitive data for explorers. Its products and services inform the government on a wide range of policy challenges in managing Australia's natural environment.*
>
> *The Department of Finance and Deregulation looked at the future direction of Geoscience Australia.*
>
> *The Review recognised the significant value of Geoscience Australia to the nation's economy. This includes vital functions relating to Earth monitoring, remote satellite sensing, spatial data, ground water and natural disaster warnings and assessments.*
>
> *Major resources companies operate globally – capital is highly mobile and the work undertaken by Geoscience Australia helps attract that investment to Australia's shores, boosting jobs and exports.*
>
> *Geoscience Australia is a world leader in its field. The Review found that much of its work amounts to a national prospectus for some of Australia's most lucrative natural resources.*
>
> *The Review is an important mechanism to ensure that, as with all government funding, value for our public money is achieved.*

The Review found Geoscience Australia's activities complement those of other government agencies. It called for more structured policy oversight of some activities, in particular the spatial data functions.

Recent calculations show that Geoscience Australia's work under the Offshore Energy Security Program for the period June 2006 to June 2011 delivered a return on the Government's investment of $75 million of $625 million in committed frontier exploration expenditure in acreage awarded to date, with an additional $1 billion for secondary work programs.

And the agency is encouraged to advance a case to government to address the fall in funding indicated by the forward estimates in Table 1. The full report of the Review of Geoscience Australia is available at http://finance.gov.au/publications/strategic-reviews/geoscience.html.

Big picture indicates stable (stagnant?) situation

Table 2 (taken from numbers in the budget papers) and Figure 1 show the changes in government investment as a percentage of government expenditure and also as a percentage of GDP, during this century. As can be seen these percentages have remained relatively unchanged during this century.

As expected the government's investment in Science and Innovation has kept pace with the GDP, but according to FASTS, we should be aiming higher.

Eristicus

Table 2. Australian Government Investment in Science and Innovation

Financial year	Government investment $ billion	% of Gov. expenditure	% GDP	GDP $ billion
99/00	4.025	2.57	0.624	645
00/01	4.206	2.34	0.614	689
01/02	4.793	2.49	0.622	736
02/03	4.967	2.42	0.608	782
03/04	5.674	2.60	0.638	841
04/05	5.251	2.27	0.548	898
05/06	6.043	2.42	0.574	967
06/07	6.557	2.46	0.575	1047
07/08	6.548	2.34	0.541	1146
08/09	7.268	2.26	0.528	1206
09/10	8.372	2.75	0.651	1286
10/11	9.077	2.56	0.654	1388
11/12	9.384	2.56	0.635	1478

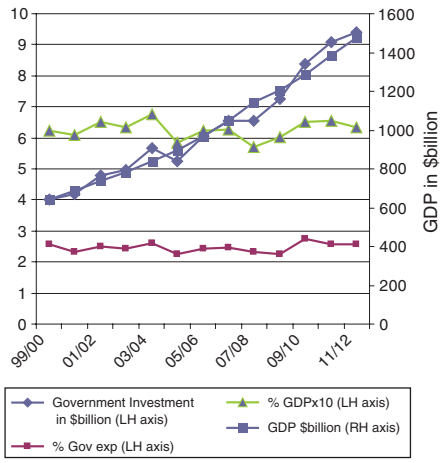

Fig. 1. *Changes in the Australian Government's investment in Science and Innovation this century. The left hand axis shows investment in $billion (blue): as a percentage of GDP x 10 (green); and as a percentage of government expenditure (red). The right hand axis shows the Australian GDP in $billion (purple).*

Professor Ian Chubb, Australia's new Chief Scientist

Prime Minister Julia Gillard and Minister for Innovation Senator Kim Carr have appointed Professor Ian Chubb AC as Australia's new Chief Scientist. Professor Chubb commenced his new role on 23 May 2011.

Professor Chubb has had a distinguished career in higher education and research and recently retired after a decade as vice-chancellor of the Australian National University. He is a neuroscientist by training, has co-authored some 70 full papers and co-edited one book all related to his research. He later took on leadership roles in university administration and sector advocacy bodies.

Professor Chubb has a Masters in Science, a DPhil from the University of Oxford and is an honorary doctor of science from Flinders University. He was made an Officer in the general division of the Order of Australia in the Queen's Birthday Honours in 1999, and was made a Companion of the Order in 2006 for service to higher education. He was made the ACT's Australian of the Year in 2011 for his contribution to higher education.

Professor Chubb's appointment has been largely welcomed by the Australian science community. Australian Academy of Science President Professor Suzanne Cory said, 'He is well known for his ability to put a powerfully reasoned case for research. We hope as Chief Scientist he will speak strongly for the entire Australian science community'. Similarly, FASTS President Dr. Cathy Foley said, 'Professor Chubb has a long track record of being a strong advocate for science and FASTS looks forward to his continued advocacy'.

Last year Professor Ian Chubb said, 'The world can't do without science, and if we denigrate it and belittle it and besmirch it by inappropriate behaviour we're in trouble'. We wish him well in selling this message to our politicians.

Professor Ian Chubb accepting his new appointment as Chief Scientist for Australia.

HELITEM™ flying in Australia

The Australian introduction of Fugro Airborne Surveys HELITEM™, the world's highest powered helicopter TEM system, is proving very successful with the system rapidly gaining acceptance by explorers.

A HELITEM system has been operating in Australia since October 2010. Surveys completed to date, totalling over 18 000 line km, have been located in WA, NT, QLD and NSW. Mineralisation types targeted include VMS, Cobar-style base metals, IOCG, Cu-Au, and Poly-metallic.

In response to high demand, a second system started operations in June 2011. This will improve system availability for explorers across Australia.

Worldwide, Fugro Airborne Surveys currently have eight HELITEM systems operating, with major surveys in Canada, India, Mexico, Brazil, Africa and elsewhere.

HELITEM is the product of R&D by Fugro Airborne Surveys over a number of years, and is produced in Toronto by Fugro. HELITEM was designed for mineral exploration applications with particular emphasis on deep conductor detection in conductive as well as resistive regimes, with increased conductor definition and interpretability.

To achieve these design goals, key features include:

- The transmitter features a moment of 2 million A.m², the highest powered helicopter TEM system available, a 25 Hz base frequency and a long off-time, providing deep conductor detection in conductive as well as resistive terrains;
- The receiver features three component X, Y and Z coils, for maximum interpretability of anomalies, in an unique Stable Suspension Receiver Cone mounting for low noise levels and increased sensitivity; and
- Complete on-time and off-time measurements at full sensitivity providing high sensitivity to both strong and weak conductors, and allowing the calculation of high quality B-field data.

In Australia, demonstration surveys have been flown at Forrestania and Nepean in Western Australia, with evaluation datasets available on request. For more information, please contact Craig Annison (CAnnison@fugroairborne.com.au).

HELITEM™ in the air, Forrestania, WA, February 2011 (photo courtesy of Fugro Airborne Surveys).

Geophysics in The Centre for Exploration Targeting, The University of Western Australia

Mike Dentith

Winthrop Professor, CET, UWA
Email: michael.dentith@uwa.edu.au

The Centre for Exploration Targeting (CET; www.cet.uwa.edu.au) was established in 2005 and is the latest in a series of successful mining-industry oriented research and teaching centres within the School of Earth and Environment (previously Department of Geology & Geophysics) at The University of Western Australia (UWA). Growth has been rapid since the inception of the CET with turnover in 2011 projected to exceed $5 000 000 with 30 research staff working in the centre.

The CET's goal is to work with industry to develop more efficient exploration methods and to share research with the community to encourage and cultivate future economic growth. One of the CET's key performance indicators is the commercialisation of its research outputs. The work of the CET is dominantly, but not exclusively, in applied science. However, in 2009, CET also produced a third of UWA publications in the top international journals *Nature* and *Science,* all from industry co-funded projects, demonstrating that astute research project design can satisfy both academic and industry priorities.

The current Director of the CET is Professor T. Campbell McCuaig. The CET has a Board (Chair Dr Jon Hronsky), which is responsible for the Centre's mission, objectives and strategic directions, including technical and financial performance and risk management. There is also an External Advisory Group (EAG), with overall responsibility for reviewing the Centre's research strategy, comprising personnel from the mineral exploration sector, CSIRO and the Geological Survey of WA. The current geophysical representatives are Lisa Vella of Teck Australia and Howard Golden of Kinross Gold. Barry Bourne (Barrick Gold) is a past geophysical representative.

As with all geophysics at UWA, the geophysical teaching and research in CET is fully integrated with the geology programmes and continues the successful practice of working closely with scientists with expertise in fields other than geophysics. As shown in Figure 1, the CET has five main 'themes': three are specific commodity oriented and two are cross-disciplinary. The 'Geophysics and Image Analysis' theme is jointly led by Professor Mike Dentith and Associate Professor Eun-Jung Holden. They lead a team of six researchers, which includes geophysicists, geologists and computer scientists.

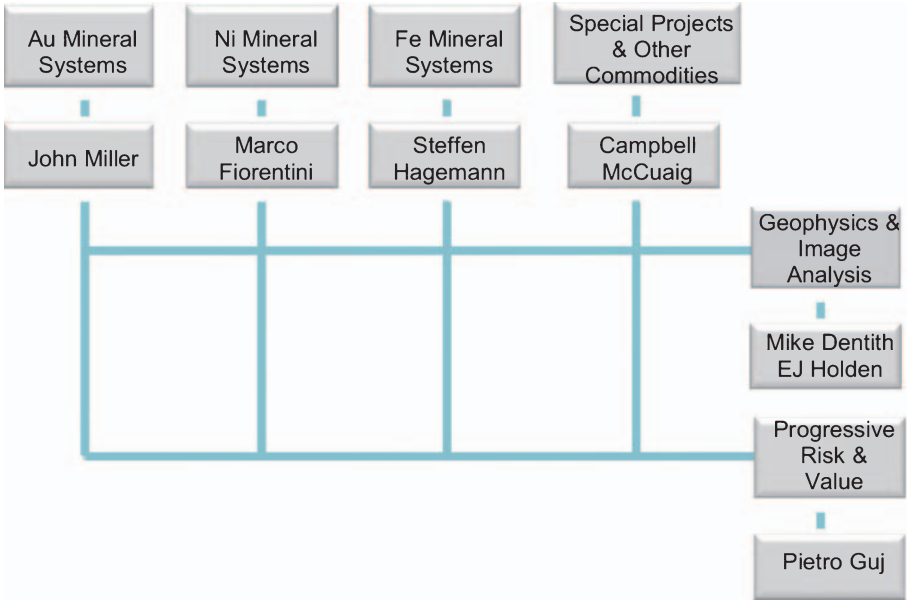

Fig. 1. *Organisation of research within the Centre for Exploration Targeting.*

- Professor Mike Dentith: applied geophysics
- Associate Professor Eun-Jung Holden: image analysis
- Dr Luis Gallardo: inverse modeling, near-surface geophysics
- Dr Alan Aitken: interpretation and modelling of potential field data, structural and tectonic analysis
- Dr Aurore Joly: geological interpretation of geophysical data, geoscientific model building
- Professor Peter Kovesi: image analysis
- Dr Daniel Wedge: image analysis, pattern recognition
- Dr Jason Wong: visualisation, game development.

Individuals in this research team have significantly different expertise but together, and incorporating other CET staff, represent cross-disciplinary capabilities and interrelated research interests allowing for a variety of research directions. Combined with the computational and seismic geophysics expertise concentrated in other research centres in UWA this represents a significant pool of geophysical expertise. The overall theme of the research in the CET is the geophysical characterisation of mineralised environments from drillhole to terrain scale (http://www.cet.uwa.edu.au/research/geophysics-image-analysis). Some current research areas are briefly described below.

Geophysical characteristics of deposit and camp-scale environments (Aitkin, Dentith, Holden, Kovesi, Wedge, Wong)

Research on the geophysical responses of individual deposits is a long standing activity at UWA (e.g. Guo and Dentith, 1997; Dentith, 2003). Current student research projects in this area include constrained inverse modelling of the Wallaby gold deposit, an investigation of the optimal application of downhole IP surveys at the Centenary gold deposit (both sponsored by Barrick Gold) and a study of controls on the electrical responses of massive sulphide deposits (with Teck Australia). Following some early attempts to apply computer vision derived methods to geophysical datasets (Dentith, 1995), image analysis applied to geophysical data became a major area of research with the appointment of

Dr Eun-Jung Holden, a computer scientist by training. Current research projects are focusing on characterizing camp-scale environments as a means of better utilising regional geophysical datasets (e.g. Holden et al., 2008).

A major area of recent research is the development of automated image analysis methods to identify potentially prospective areas in gridded geophysical datasets. Working with Archean lode-gold deposits, the initial emphasis was on mapping structures via lineaments in the data with particular use made of phase congruency and textural mapping. In April 2010, these algorithms were commercialised as the CET Grid Analysis Extension for the Oasis Montaj package which is marketed by Geosoft Inc. This product contains a suite of algorithms for texture analysis, and ridge/edge detection and their vectorisation.

Subsequent work concentrated on the analysis of the spatial distribution of lineaments (Figure 2). Given the lineament features that are automatically identified from the existing algorithms, 'heat maps' are generated which characterise the structural complexity in local neighbourhoods based on such parameters as lineament crossings and range of orientations. These tools are designed to highlight the areas of structural complexity where lode gold deposits are known to occur. These structural heat maps can be used either to aid manual prospectivity analysis or as an additional layer of information for GIS-based quantitative prospectivity analysis that combines multiple geoscientific datasets.

Another fruitful line of research has been on the automatic detection of anomalies with characteristics consistent with particular mineralized environments. A set of tools has been developed to aid in identifying the magnetic response of an idealised copper-gold porphyry system within magnetic datasets. Porphyry-style mineralisation is associated with comparatively widespread hydrothermal alteration with approximately concentric alteration zones surrounding a central intrusion. In some zones, magnetite is destroyed and in others, it may be created. The result is annular magnetic responses which may be positive or negative with respect to the surrounding areas. These algorithms allow the detection of circular anomalies that are associated with the central intrusion of the porphyry system and the boundaries of the features based on their magnetic contrast relative to the surrounding. This work was funded by Barrick Gold of Australia.

Interest is currently being assessed in the development an 'interpreters tool box' for gridded geophysical data, equivalent to those available to seismic interpreters. The intention is to allow semi-automated and simultaneous interpretations of mineral geophysical datasets to assist stratigraphic and structural analysis for exploration purposes.

Terrain-scale prospectivity analysis using geophysical datasets (Aitkin, Dentith, Gallardo, Joly, McCuaig)

A major ongoing project, in association with the Geological Survey of Western Australia (GSWA) and funded by the Western Australian Government's Exploration Incentives Scheme, involves assessing the mineral prospectivity of selected terrains in Western Australia. The intention is to achieve a step change in the exploration relevance of GSWA datasets; it has been recognized that a series of targeting products will help junior to mid-size exploration companies translate the GSWA's geoscientific datasets into actual ground acquisition and drill target decisions.

This project will consider eight terrains: with work in the Western Arunta Orogen and southern Yilgarn Craton largely complete, current emphasis is on the Musgraves Orogen. A typical work flow involves compilation of available data, regional scale interpretation of geological and geophysical data to create a 3D geological model and develop a 4D understanding of the study area. The resulting geological map and 4D history are used as a basis for GIS-based prospectivity analysis for delineating and ranking exploration targets. A mineral system approach is used to identify the critical processes involved in the deposit formation, as well as their respective exploration criteria and spatial proxies (or predictor maps). One of the key objectives is to develop a method for best-practice in terrane- to camp-scale exploration targeting that can be applied to different terranes and deposit types.

To complement the prospectivity studies, and in particular to provide 3D information, the acquisition and interpretation of magnetotelluric data has become a significant area of activity in CET. Working with personnel from Moombarriga Geoscience and the Universities of Adelaide and Manitoba, four surveys have been undertaken to date: Fraser mobile Belt (Balladonia-Kambalda); southern Yilgarn Craton (Hyden-Norseman), Musgraves Complex and eastern Capricorn (Sylvania to Marymia inliers).

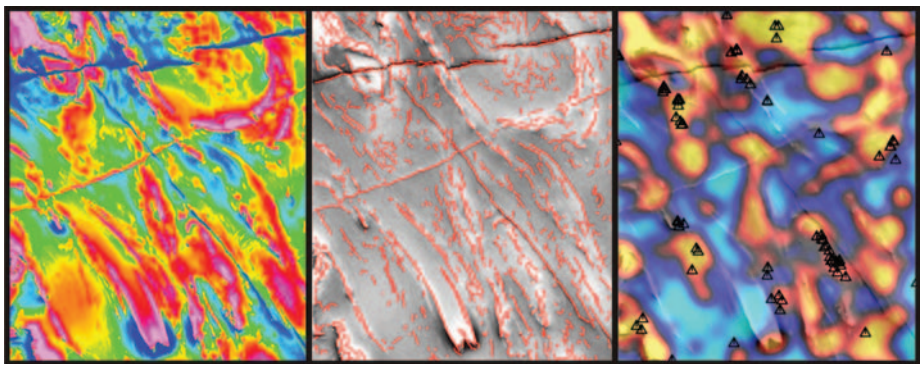

Fig. 2. *(Left) An RTP TMI aeromagnetic image from the Yilgarn Craton of Western Australia, the property of Fugro Airborne Surveys Pty Ltd (Group A – Menzies to Norseman 1986–1987 Non-exclusive Database); (Middle) Automated lineament detection result in red overlaid over the grayscale image of the RTP-TMI; (Right) The orientation entropy heat map, which uses the cold-hot colour map where blue indicates low and yellow indicates high values, overlaid on the grayscale RTP-TMI data. Locations of gold deposits greater than 1 t are shown by the black triangles.*

Geophysical interpreter-data interaction (Dentith, Holden, McCuaig)

Geophysical data interpretation is a highly subjective task and interpreters use various data visualisation methods for enhancement and display in this process. The ultimate goals of this research theme are twofold: one is to understand how current visualisation practices evolved and how they may affect an interpretation; and the second is ultimately to design and implement more effective visualisation and interpretation methods. As a first step toward these goals, work has concentrated on

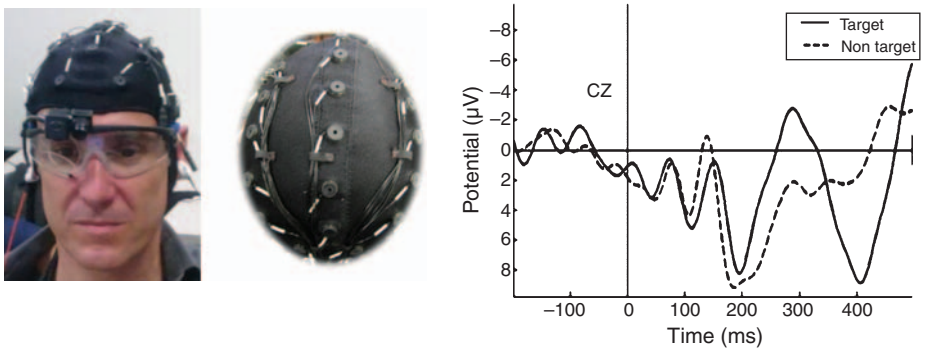

Fig. 3. *(Left) An interpreter wearing an eye tracker goggle and an EEG cap; (Middle) The top-down view of the EEG cap; (Right) Brain responses when viewing a target (a feature of interest) and a non-target. The positive deflection between 300 and 600 ms is the 'P300' response elicited by task relevant stimuli.*

understanding how interpreters interact with the data when conducting specific tasks during interpretation, and analysis of how these interactions differ when different visualisation methods are used. This is a collaborative project by a team of multidisciplinary researchers (electrical engineering, psychiatry, and computer science) at UWA and Curtin University.

The neurological and physiological responses of interpreters are monitored using an eye tracker system (ETS) that pursues their vision during data observation and an electroencephalograph (EEG) that captures brain responses of the interpreter as the interpretation proceeds (see Figure 3). Since 2010, a PhD study by Yathnanthan Sivarajah has been focusing on the detection of brain waves that are associated with the mental fitting of a geoscientific model to the patterns of variation within data being interpreted. On-going study combines this mental fitting process with the data observation patterns identified by the eye tracker, which will help us understand the variations in the mental fitting process associated with specific data patterns that are being observed.

Numerical geophysics (Gallardo)

Mathematical geophysics has a long history at UWA with early research guided by Dr Ron List from the Department of Mathematics. Research undertaken in the 1990s included some of the first applications of genetic algorithms to geophysical inverse problems (e.g. Boschetti et al., 1996) and wavelets in geophysical data processing (e.g. Ridsdil-Smith and Dentith, 1999).

More recently, mathematical geophysics has again become an active area of research following the appointment of Dr Luis Gallardo as Goodeve Lecturer in Geophysics. This position is funded by the UWA Geoscience Foundation and the Goodeve Foundation, a foundation created in memory of the ex-government and industry geophysicist Peter Goodeve. Dr Gallardo's particular speciality is developing methods for the simultaneous inversion of multiple datasets (Gallardo and Meju, 2011). Originally developed for shallow geophysical surveys (Gallardo and Meju, 2003; Gallardo, 2007), the methods are currently being used as part of collaborative projects with geologists working in mineralised granitoid-greenstone and Proterozoic orogenic terrains in Australia, Africa and South America. Work is also underway to extend the methods to 3D and to simultaneously model potential field and magnetotelluric data.

Figure 4 shows an example of inversion results from a granitoid-greenstone terrain near Leonora, in central Western Australia. Nineteen cross-cutting sections have been created showing subsurface variations in density and magnetisation. The physical property variations in the sections are found to:

(i) correlate with the different suites of granites and greenstone sequences exposed on the surface,

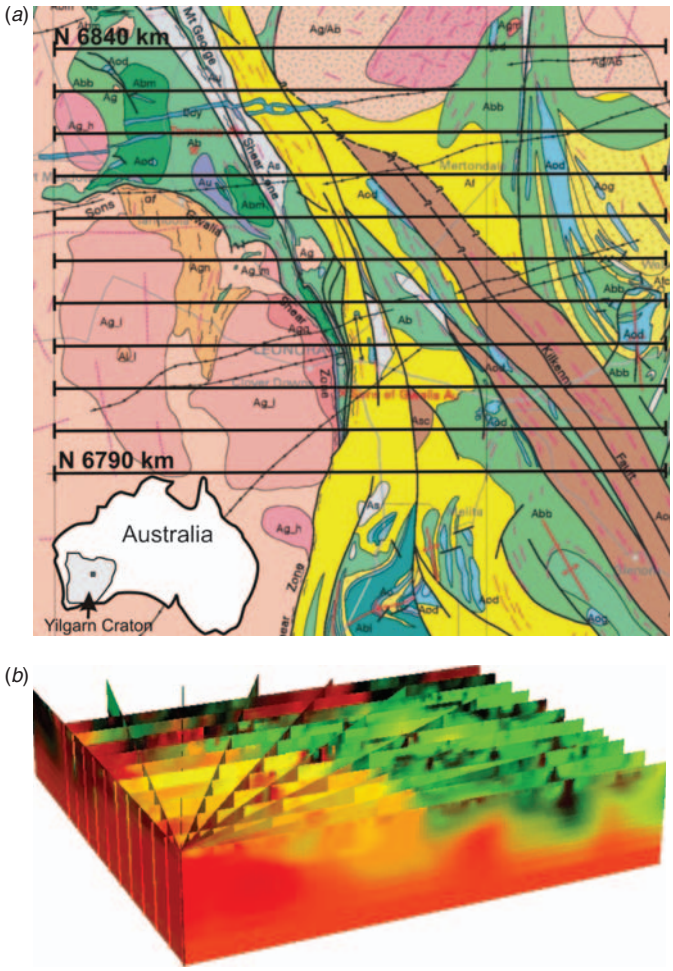

Fig. 4. *(a) Location map of Leonora district showing the location of East–West profiles for joint gravity and magnetic inversion. (b) Density-magnetisation images of the profiles in the studied area. Colours are associated with characteristic density-magnetism combinations and are directly correlated with different lithologies exposed at the surface and features on the NY1 seismic section.*

(ii) match the structures imaged by the NY1 seismic reflection data, and
(iii) coincide with the major tectonic structures mapped in the area.

The methodology has demonstrated its suitability for improved use of gravity and magnetic exploration in structurally complex cratonic areas.

Conclusion

The Centre for Exploration Targeting has assembled a group of geophysical researchers whose expertise ranges from numerical modeling and analysis through to geologically oriented data interpretation. Within UWA there is also significant geophysical expertise in sister research centres (Centre for Petroleum Geoscience and CO_2 Sequestration, Western Australia Geothermal Centre of Excellence). A close working relationship with these centres, a track record of delivering fundamental and applied research valued by industry, and close collaboration with personnel from other fields of geosciences and many other disciplines has allowed significant growth in geophysical research in CET and the host School. It is anticipated that geophysics will continue to develop in CET. One field where it is hoped to increase activity is in petrophysics: both database creation and understanding of the processes that affect rock physical properties.

References

Boschetti, F., Dentith, M.C., and List, R.D., 1996, Inversion of seismic refraction data using genetic algorithms: *Geophysics*, **61**, 1715–1727.

Dentith, M.C., 1995, Textural filtering of aeromagnetic data: *Exploration Geophysics*, **26**, 209–214.

Dentith, M.C. (editor), 2003, Geophysical Signatures of South Australian Mineral Deposits: Centre for Global Metallogeny Publication No. 31, Australian Society of Exploration Geophysicists Special Publication No. 12, 297 pp.

Gallardo, L.A., 2007, Multiple cross-gradient joint inversion for geospectral imaging: *Geophysical Research Letters*, **34**, L19301. doi:19310.11029/12007GL030409

Gallardo, L.A., and Meju, M.A., 2003, Characterization of heterogeneous near-surface materials by joint 2D inversion of dc resistivity and seismic data: *Geophysical Research Letters*, **30**, 1658. doi:1610.1029/2003GL017370

Gallardo, L.A., and Meju, M.A., 2011, Structure-coupled multiphysics imaging in geophysical sciences: *Reviews in Geophysics*, **49**, RG1003.

Guo, W.W., and Dentith, M.C., 1997, Geophysical signature of the Jinchuan Ni-Cu-PGE deposit, Gansu Province, China: *Exploration and Mining Geology*, **6**, 223–231.

Holden, E.J., Dentith, M., and Kovesi, P., 2008, Towards the automatic analysis of regional aeromagnetic data to identify regions prospective for gold deposits: *Computers & Geosciences*, **34**, 838–848.

Ridsdill-Smith, T., and Dentith, M.C., 1999, The wavelet transform in aeromagnetic data processing: *Geophysics*, **64**, 1003–1013.

WesternGeco and Schlumberger support Curtin University students

As part of WesternGeco and Schlumberger's commitment to helping educate the next generation of geoscientists, two students from Curtin University, Jason Valuri and Sean Herbert, along with their Curtin University supervisor, Dr Christian Dupuis, and WesternGeco co-supervisor, Dr Tim Dean, recently travelled to the United Arab Emirates to acquire data for their honours projects. Their work, which involves the evaluation of seismoelectric methods using vibratory sources in arid environments, was conducted as part of a larger study showcasing the use of WesternGeco's state-of-the-art acquisition technology for near-surface hydrogeological studies.

Fig. 3. *Members of the project team dwarfed by a tracked 80 000 lb Desert Explorer vibrator. From left: Sean Herbert (Curtin University), Rolf Herrmann (Schlumberger Water Services – Abu Dhabi), Tristan Hollande (WesternGeco – Oslo Technology Centre), Christian Dupuis (Curtin University), Jason Valuri (Curtin University), Tim Dean (WesternGeco – Perth GeoSolutions Development Centre) and Peter Nyhuus (WesternGeco – Oslo Technology Centre).*

The Shwaib test site is located on the western edge of the northern Oman mountains about 60 km north of Al Ain (Figure 1) and was originally developed as a prototype aquifer storage and recovery project by the Environment Agency-Abu Dhabi and Schlumberger Water Services (Black et al., 2008). In order to develop a better understanding of the aquifer, its recharge and storage capacity, Schlumberger Waters Services had previously acquired a number of geophysical surveys such as gravity, surface NMR, time-domain electromagnetics and well logging. The reprocessing of heritage 2D seismic data in the region highlighted the benefits that could be obtained using high-resolution seismic over the area. The availability of all the additional geophysical data also made it an excellent site to further the on-going seismoelectric research at Curtin University.

Fig. 1. *Location of the study area (adapted from Bradley et al., 2007).*

Fig. 2. *Burying the UniQ geophone accelerometers.*

The test involved all of the latest proprietary WesternGeco technology including the UniQ integrated point receiver land acquisition system (Figure 2) and the 80 000 lb tracked Desert Explorer DX80 vibrator (Figure 3) employing a low-frequency enhancing maximum-displacement sweep. Dr Dupuis stated that: 'This collaboration with WesternGeco and Schlumberger is an exceptional opportunity for the students to have access to industry-leading technology and resources that are generally unattainable by Universities.'

WesternGeco and Schlumberger have also sponsored a third student, Hayan Nasreddin. His project involves the evaluation of the trade-off between productivity and quality for a range of recently introduced high-productivity Vibroseis techniques. Along with scholarships for the students and practical assistance Schlumberger and WesternGeco have also donated Petrel and Omega seismic data processing system licences in order to assist students in their research. The results of the studies should be available by the end of 2011.

For further information please contact Christian Dupuis (C.Dupuis@curtin.edu.au) or Timothy Dean (tdean2@slb.com).

References

Black, B., Dawoud, M., Herrmann, R., Largeau, D., Maliva, R., and Will, B., 2008, Managing a precious resource: *Oilfield Review*, **20** (2), 18–33.

Bradley, C.C., Ali, M.Y., Shawky, I., Levannier, A., and Dawoud, M.A., 2007, Microgravity investigation of an aquifer storage and recovery site in Abu Dhabi: *First Break* **25** (November), 63–69.

Update on Geophysical Survey Progress from the Geological Surveys of Queensland, Western Australia, New South Wales, Tasmania, and Geoscience Australia (Information current at 13 May 2011)

Tables 1–3 show the continuing acquisition by the States, the Northern Territory and Geoscience Australia of new gravity, airborne magnetic and radiometrics, and airborne EM over the Australian continent. All surveys are being managed by Geoscience Australia.

This issue reports one new airborne electromagnetic survey over the Central Australian Palaeovalley (see Figure 1) for Geoscience Australia.

Final infill survey data from the Pine Creek AEM survey were released by

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
South Officer 1 (Jubilee)	GSWA	Thomson	1 Jun 10	180 000	200 m 50 m N–S	32 380	64.1% complete @ 3 Apr 11	TBA	148 – Oct 10 p23	TBA
South Officer 2 (Waigen – Mason)	GSWA	Thomson	28 Jun 10	113 000	400 m 60 m N–S	39 890	100% complete @ 5 Jan 11	TBA	148 – Oct 10 p24	QA/QC of final data in progress
East Canning 3 (Stansmore)	GSWA	Thomson	14 Jul 10	114 000	200 m (east) 400 m (west) 50 m N–S	25 934	100% complete @ 2 Nov 10	TBA	148 – Oct 10 p24	Data in preparation for release before the end of June
Eucla Basin 2 (Loongana)	GSWA	Fugro	20 Jun 10	113 000	200 m 50 m N–S	20 320	100% complete @ 3 Dec 10	TBA	148 – Oct 10 p24	Data in preparation for release before the end of June
Eucla Basin 4 (Madura)	GSWA	Fugro	1 Jul 10	102 000	200 m 50 m N–S	18 220	100% complete @ 22 Nov 10	TBA	148 – Oct 10 p24	Data in preparation for release before the end of June
Eucla Basin 5N (Forrest)	GSWA	Fugro	16 Jun 10	75 000	200 m 50 m N–S	13 040	100% complete @ 12 Sep 10	TBA	148 – Oct 10 p25	Data released via GADDS 14 April 2011
Eucla Basin 5S (Eucla)	GSWA	Fugro	6 Jul 10	87 500	200 m (onshore) 400 m (offshore) 50 m (onshore) 100 m (offshore) N–S	16 100	100% complete @ 5 Nov 10	TBA	148 – Oct 10 p25	Data released via GADDS 14 April 2011
South Canning 1 (Madley – Herbert)	GSWA	Aeroquest	19 Jul 10	95 000	400 m 60 m N–S	33 520	100% complete @ 12 Nov 10	TBA	148 – Oct 10 p25	Data released via GADDS 14 April 2011
South Canning 2 (Morris – Herbert)	GSWA	Aeroquest	1 Jul 10	125 000	400 m 60 m N–S	45 850	100% complete @ 11 Jan 11	TBA	148 – Oct 10 p25	Data in preparation for release before the end of June
North Canning 4 (Lagrange – Munro)	GSWA	Aeroquest	20 Sep 10	103 000	400 m 60 m N–S	36 680	71% complete @ 9 May 11	TBA	148 – Oct 10 p26	Survey re-mobilised 4 May 2011
Southeast Lachlan	GSNSW	Fugro	1 Mar 10	107 533	250 m (NSW) 500 m (ACT) E–W	24 660	100% on 9 Sep 10	TBA	144 – Feb 10 p15	QA/QC of final data in process
Grafton – Tenterfield	GSNSW	GPX	TBA	100 000	250 m 60 m E–W	23 000	TBA	TBA	151 – Apr 11 p16	TBA

Table 1. *Continued*

Survey name	Client	Contractor	Start flying	Line (km)	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
West Kimberley	GSWA	Aeroquest	TBA	134 000	800 m 60 m N–S Charnley: 200 m 50 m N–S	42 000	TBA	TBA	150 – Feb 11 p20	Expected to commence June 2011
Perth Basin North (Perth Basin 1)	GSWA	Fugro	TBA	96 000	400 m 60 m E–W	30 000	TBA	TBA	150 – Feb 11 p20	Expected to commence May 2011
Perth Basin South (Perth Basin 2)	GSWA	Fugro	22 Mar 2011	88 000	400 m 60 m E–W	27 500	28.2% on 8 May 2011	TBA	150 – Feb 11 p20	TBA
Murgoo (Murchison 1)	GSWA	Thomson	28 Feb 11	128 000	200 m 50 m E–W	21 250	5.6% complete @ 7 Mar 11	TBA	150 – Feb 11 p20	Survey resumes at the completion of the South Officer 1 survey
Perenjori (Murchison 2)	GSWA	GPX	TBA	120 000	200 m 50 m E–W	20 000	TBA	TBA	150 – Feb 11 p21	Expected to commence September 2011
South Pilbara	GSWA	GPX	TBA	136 000	400 m 60 m N–S	42 500	TBA	TBA	150 – Feb 11 p21	Expected to commence May 2011
Carnarvon Basin North (Carnarvon Basin 1)	GSWA	GPX	TBA	104 000	400 m 60 m E–W	32 500	TBA	TBA	150 – Feb 11 p21	Expected to commence May 2011
Carnarvon Basin South (Carnarvon Basin 2)	GSWA	GPX	TBA	128 000	400 m 60 m E–W	40 000	TBA	TBA	150 – Feb 11 p21	Expected to commence February 2012
Moora (South West 1)	GSWA	Aeroquest	TBA	128 000	200 m 50 m E–W	21 250	TBA	TBA	150 – Feb 11 p22	Expected to commence June 2011
Corrigin (South West 2)	GSWA	GPX	TBA	120 000	200 m 50 m E–W	20 000	TBA	TBA	150 – Feb 11 p22	Expected to commence September 2011
Cape Leeuwin – Collie (South West 3)	GSWA	Fugro	25 Mar 2011	105 000	200/400 m 50/60 m E–W	25 000	32.2% complete @ 8 May 11	TBA	150 – Feb 11 p22	TBA
Mt Barker (South West 4)	GSWA	GPX	24 Apr 2011	120 000	200 m 50 m N–S	20 000	3.7% complete @ 8 May 11	TBA	150 – Feb 11 p22	TBA
Offshore East Coast Tasmania	MRT	Fugro	28 Feb 11	30 895	800 m 90 m E–W	19 570	100% complete @ 21 Apr 11	TBA	150 – Feb 11 p23	TBA
Galilee	GSQ	TBA	TBA	125 959	400 m 80 m E–W	44 530	TBA	TBA	151 – Apr 11 p15	Anticipated start date mid May 2011
Thomson West	GSQ	TBA	TBA	146 000	400 m 80 m E–W	52 170	TBA	TBA	151 – Apr 11 p15	Anticipated start date mid May 2011
Thomson East	GSQ	TBA	TBA	131 100	400 m 80 m E–W	46 730	TBA	TBA	151 – Apr 11 p16	Anticipated start date mid May 2011
Thomson Extension	GSQ	TBA	TBA	47 777	400 m 80 m E–W	16 400	TBA	TBA	151 – Apr 11 p16	Anticipated start date mid October 2011

TBA, to be advised.

Table 2. Gravity surveys

Survey name	Client	Contractor	Start survey	No. of stations	Station spacing (km)	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Albany – Fraser North	GSWA	Atlas	21 Oct 2010	9200	2.5 km regular	50 980	100% on 30 Jan 2011	TBA	146 – Jun 10 p17	Data released via GADDS 14 April 2011
Sandstone	GSWA	IMT	Early Oct 2010	6300	2.5 km regular	35 640	100% on 17 Dec 2010	TBA	146 – Jun 10 p17	Data released via GADDS 5 May 2011
South Gascoyne	GSWA	IMT	9 Aug 2010	9700	2.5 km regular	55 760	100% on 27 Oct 2010	TBA	146 – Jun 10 p17	Data released via GADDS 12 May 2011
Galilee	GSQ	IMT	3 May 2011	6400	2.5 km regular	TBA	9% complete @ 8 May 11	TBA	151 – Apr 11 p15	TBA
Thomson	GSQ	Daishsat	1 Apr 2011	7670	2.5 km regular	TBA	44% complete @ 8 May 11	TBA	151 – Apr 11 p15	TBA

TBA, to be advised.

Table 3. Airborne electromagnetic surveys

Survey Name	Client	Contractor	Start survey	Line (km)	Spacing AGL dir	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Frome	GA	Fugro	22 May 10	34 986	5000 and 2500 100 m E–W	95 450	100% on 31 Oct 2010	TBA	146 – Jun 10 p18	Final data released by GA on 31 March 2011
Central Australian Palaeovalley	GA	Aeroquest	Late May 2011	5000	1000 m and tie lines at 30 km	4113	TBA	TBA	This issue (Figure 1)	TBA

TBA, to be advised.

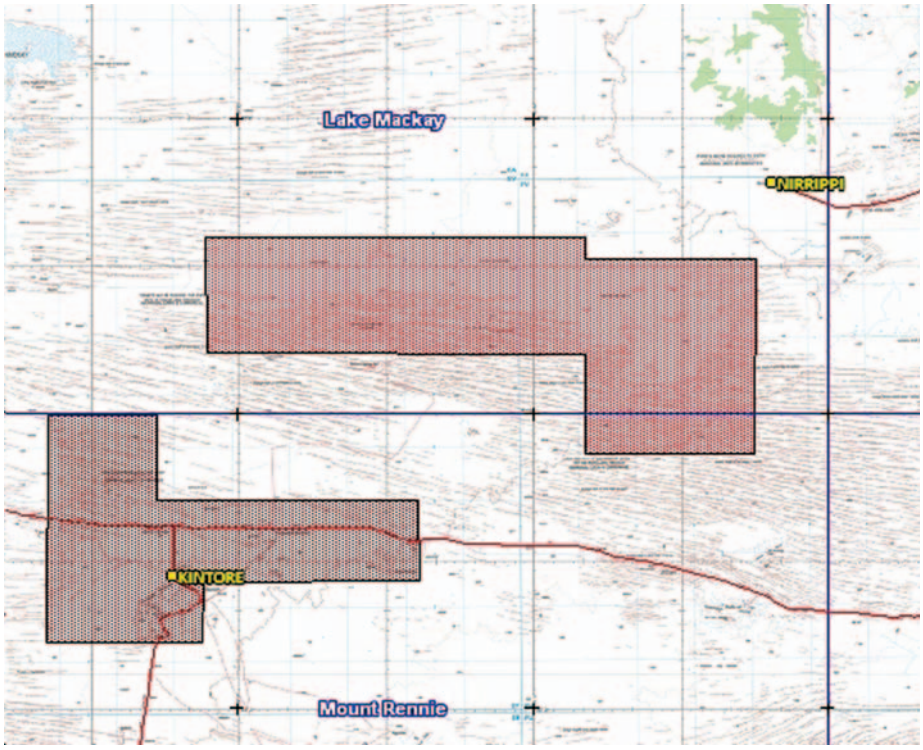

Fig. 1. *Survey boundary for Central Australian Palaeovalley AEM survey in the Northern Territory.*

Geoscience Australia on 4 April 2011. This data release consists of 23 blocks of infill flying funded by private exploration companies. The company infill data are being released 12 months after the official release of the data funded by Geoscience Australia. The release contains point located electromagnetic, magnetic and elevation data and EmFlow™ conductivity estimates and derived conductivity depth slices. Also included are gridded conductivity, magnetics and digital elevation data. For further information on this release please visit the Geoscience Australia web site at: http://www.ga.gov.au/minerals/projects/current-projects/airborne-electromagnetics.html.

To order the data please visit the Geoscience Australia web site at http://www.ga.gov.au/oracle/agsocat/textonly.jsp and search for product number 71641.

Queensland Greenfields 2020 geophysical survey progress

Daishsat commenced data collection on the Thomson gravity survey in the Cunnamulla area on 1 April. Production has been steady and over 35% of the field work was completed by 1 May 2011. Estimated finish date for the data collection is mid June. Preliminary data indicate that the 4km station spacing is providing excellent results.

Integrated Mapping Technologies commenced data collection on the Galilee gravity survey around Alpha on 3 May. Wet weather and helicopter availability delayed the initial start. Estimated finish date for the data collection is early July.

The start of both the Thomson and Galilee airborne magnetic and radiometric surveys has been delayed by wet weather. These surveys are now expected to start in late May/early June.

Information on these surveys can be obtained from Bernie Stockill, Geological Survey of Queensland, (Ph: 07 3035 5272).

The release of the 2011 gravity grid of South Australia

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The previous gravity grid of South Australia was constructed from 382 206 stations of gravity data. It was created using the Intrepid Geophysics gridding tool, using a Variable Density gridding algorithm, interpolated to 100 m pixel size and was first uploaded to SARIG in November 2009. While this was an excellent grid, several problems were identified that required resolving.

The primary issue related to point anomalies: points in the grid that occur at each gravity station. These points are particularly prominent when viewing the first vertical derivative of the grid. Various strategies were put forward to remove these points. A successful technique has been to split all of the gravity station data in South Australia into several layers, gridding each layer separately to an appropriate resolution, and then merging the grids together, effectively undertaking a manual variable density gridding process.

Gravity information in South Australia was split into numerous layers. Each layer is a collation of gravity surveys from a specific era that can be gridded smoothly to a particular grid size. For example, the base (lowest) layer consisted of all regional data collected in the 1960s and 1970s. It was gridded using a minimum curvature algorithm to 2000 m. The top layer consisted of the Northern Olympic Domain and Curnamona surveys, gridded to 200 m and resampled to 100 m. In between these are 12 other layers, all gridded to approximately ¼ of the station spacing, and ranked by data quality.

Data prior to 1960 have not been included in the production of this grid, and 2455 duplicate points have been removed. A total of 417 173 points were used in the production of the new grid which includes 34 967 new additional stations. Various commercially available gridding packages were trialled as part of the compilation of the grid. Ultimately, all gridding was undertaken using Encom Profile Analyst (Pitney Bowes Software Pty Ltd) and grid merging undertaken using Intrepid Geophysics software (Desmond Fitzgerald & Associates Pty Ltd).

The point anomalies in the new grid are far less prominent than they were in the previous grids, and the Intrepid feathering and grid merging process has produced a grid where boundaries between surveys are less visible. Figure 2 shows an example around the Northern Olympic Domain Gravity Survey.

All gravity ASCII data (including the data not used in the state grid) are still available for download through SARIG and SA_GEODATA. A project is currently underway to incorporate a ranking of gravity surveys described above for the purpose of statewide gridding into SA_GEODATA. This will involve extra fields available for download that will illustrate which grids have been used in our state grid. By doing this, no gravity data will be withheld from users.

The new gravity grid is available from SARIG 2020 through the Databases & Geophysical Data tab (powered by Intrepid's Jetstream technology), and is available as a sunshaded and colour-draped geoTIFF image directly from SARIG. At the time of writing SARIG 2020 is in beta version (https://sarigbeta.pir.sa.gov.au/Map) and is best viewed in Google Chrome, Safari & Firefox. It is also accessible in Internet Explorer.

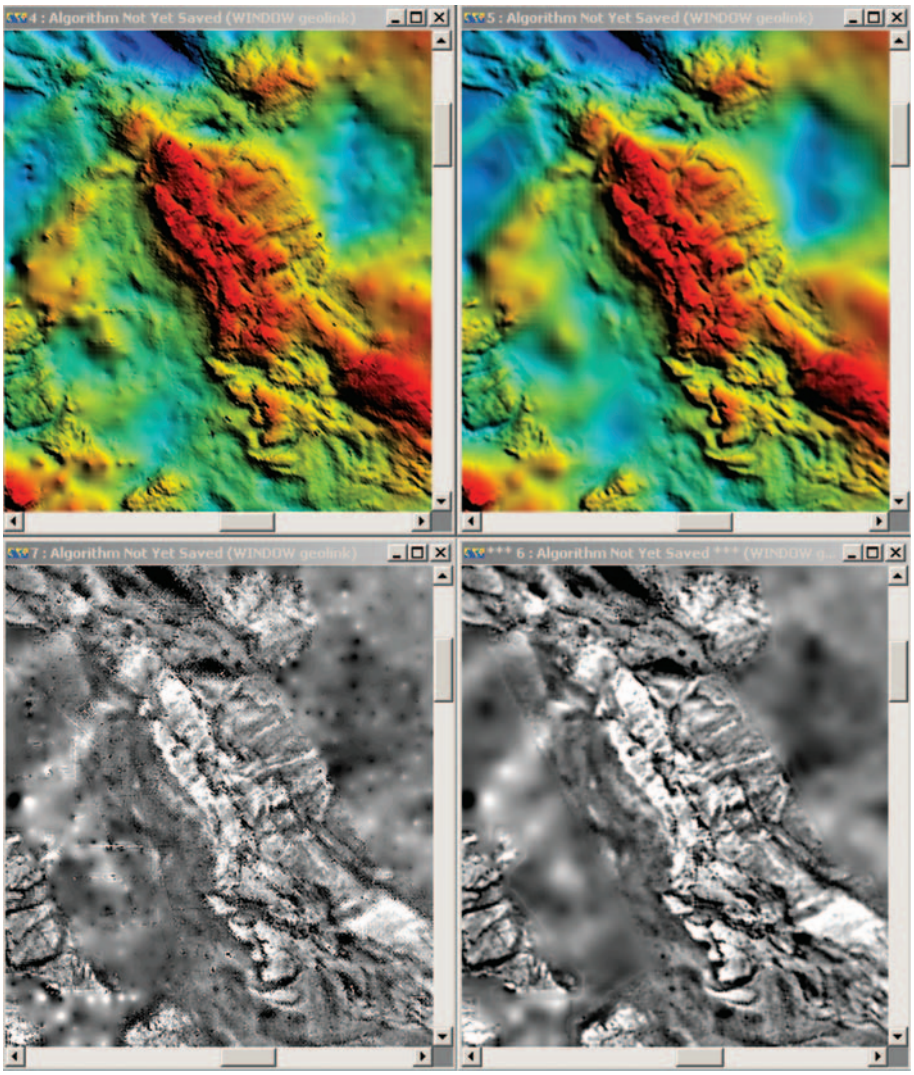

Fig. 2. *Top left: a portion of the previous gravity grid, around the 2007 Northern Olympic Domain survey. Top right: the same area of the new grid. Lower left: the first vertical derivative of the previous gravity grid. Lower right: the first vertical derivative of the new gravity grid.*

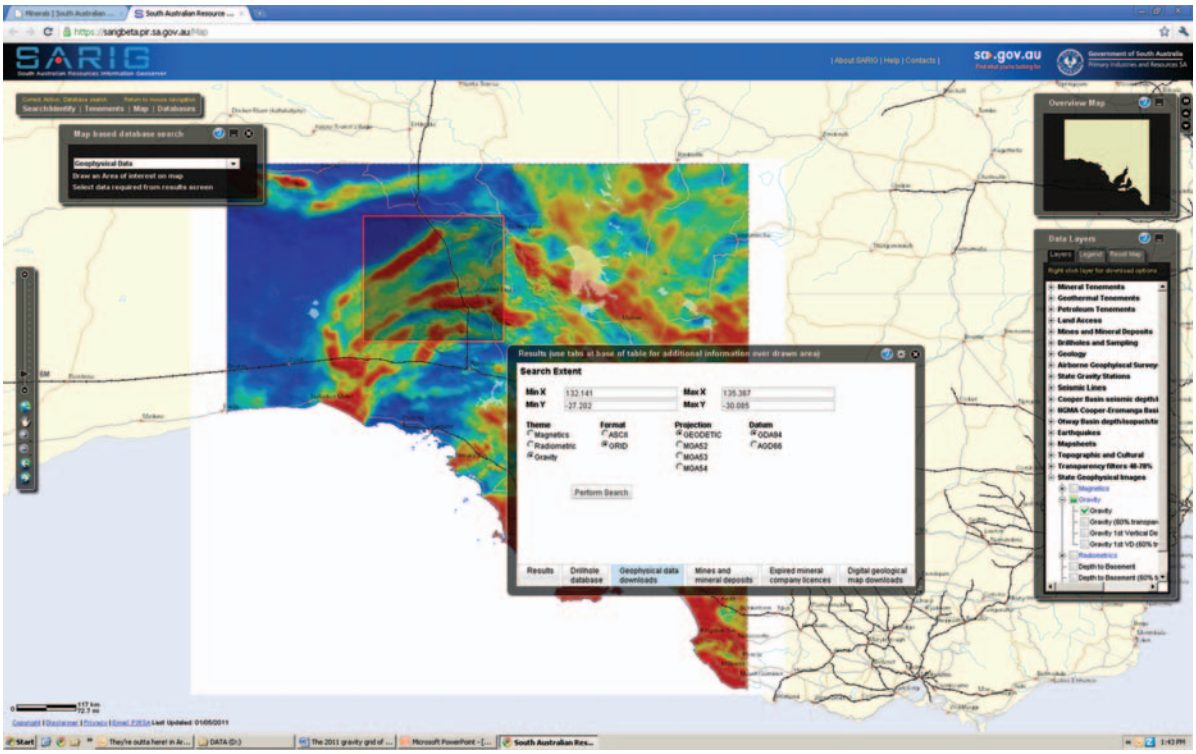

Fig. 3. *Visualising the new gravity grid in SARIG 2020 is simply a case of ticking the Gravity box on the right hand side of the screen under 'State Geophysical Images'. By right clicking on the word 'Gravity' in the submenu you have the option to download the entire state as a GeoTIFF. To download the ASCII data or .ers, use the 'Geophysical Data' option under 'Databases' (top left hand side of the screen) and draw a box over your area of interest and follow the on-screen prompts.*

Figure 3 shows a screengrab of SARIG 2020 with the gravity grid overlying the state. To download a GeoTIFF of the entire state, find 'State Geophysical imagery' on the list on the right hand side of the screen. The submenu contains four gravity options: the Bouguer Anomaly and 1VD, as well as two partially transparent layers. Right click on the word 'Gravity' to download the image.

To download a specific area of gravity as ASCII or .ers files, go to the 'Databases' tab on the top left hand side of the screen and select 'Geophysical Data'. Select your area of interest and follow the onscreen prompts. The new grid is named 'SA_GRAV'. For help using SARIG 2020 please contact PIRSA customer services on +61 8 8463 3000 or via email PIRSA.CustomerServices@sa.gov.au.