

# Preview



Australian Society of Exploration Geophysicists

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### *Sydney Conference a great success*

I am sure that all those fortunate enough to attend the ASEG's 17th International Conference and Exhibition will want to congratulate those responsible for planning and organising such a successful event. Well done Tim Pippett, Barry Smith and their team; it was a real geophysical celebration and the society should be very pleased with the outcomes.

In this issue of *Preview* we review some of the main happenings during the conference. It is impossible to comment on all the highlights because the meeting covered a whole range of issues, but for me the technical sessions, the exhibition and dinner would be the top three, - but then I was not able to attend the workshops or interact with the visiting students.

We will be publishing summaries of some of the keynote addresses in this and subsequent editions of *Preview* and start with two papers on airborne gravity by Tom Whiting and Phil Harman. Airborne gravity has really come of age in the last few years and all the hard R&D effort is starting to pay off. It is interesting to look at some of the recent results and also some of the commercial considerations that had to be addressed to enable the R&D investment to be made. We are also able to include the best petroleum paper, which was presented by Andrew Long.

### *Jill Slater new WebWaves writer*

I would like to welcome Jill Slater as the new WebWaves compiler. Jill takes over from Margarita Norvill, and is based in

Perth; although she will be moving to Adelaide at the end of the year. More details of her activities and interests are in the People Section of this issue.

### *Australia wins 34th International Geological Congress*

Australia has succeeded in its bid, on behalf of the Oceania region, to host the prestigious 34th International Geological Congress (IGC) in Brisbane from 5-15 August 2012.

The congress, which will be called **Australia 2012**, is expected to attract at least 5000 delegates from about 100 countries. It will be held at the Brisbane Convention and Exhibition Centre and will showcase the region's geoscience strengths, innovations and natural wonders.

The theme of **Australia 2012** will be 'Unearthing our Past and Future', which will enable us to show the important role that geoscience is playing in the quest for sustainable development by contributing directly to the future of Australia's core agriculture and resource based industries. The congress will include a GeoExpo, an education outreach program and a support program to facilitate attendance by worthy young delegates.

A strong and experienced IGC Preparatory Committee has been convened. The Australian Geoscience Council will be the formal organising body responsible for **Australia 2012**. The President and Secretary General of the Preparatory Committee are Neil Williams and Ian Lambert, respectively, illustrating Geoscience Australia's strong commitment to the Congress. Regional involvement will be through the New Zealand Institute of Geological and Nuclear Sciences and the South Pacific Applied Geoscience Commission. Malaysia, Indonesia and the Philippines are interested in organising field trips in their environs.

The bid for **Australia 2012** was supported financially by the Australian Government through a grant from the Innovation Access Programme, a *Backing Australia's Ability* initiative, and by the Queensland Government.

The decision to award the 34th IGC to Australia was made at the 32nd IGC, which

was held in Florence during August this year. Morocco (through their Minister for Resources) and India made strong bid presentations.

Congratulations to Neil and the Australian team that worked hard in Florence to achieve this excellent outcome.

### *National vision lacking in election rhetoric*

By the time you read this *Preview* the outcome of the Federal Election will be known. So far the campaign has been focused on how best to spend the taxpayers' money, rather than how to secure national wealth and a sustainable Australia.

Our current prosperity is undoubtedly due to the structural reforms that have taken place in the last ten years. During this period we have cut tariffs, introduced competition policy, freed up financial markets, rebuilt our tax system and made our labour market more flexible.

However, our wealth has mainly been built on the strength of our resource industries and the growth of the Chinese and Indian economies.

We are now effectively sitting on our laurels and our imports have grown as though there is no tomorrow. We are now running current account deficits of nearly 6% of GDP and our foreign debt is increasing by almost \$50 billion each year. Another warning sign is the fall in our share of world exports, which I understand is now less than 1% for the first time since records began.

Neither of the major parties appears to have addressed the big picture of encouraging wealth generating strategies.

Ken Baldwin of FASTS articulated the issue very well recently by pointing out that: "The only way we can increase our share of the world's wealth is through innovation.

"But we are not doing very well in this sector. The average OECD investment in total R&D spending as a percentage of GDP was 2.33% in 2001, compared with Australia's lowly 1.53%. Our latest figure of 1.62% in 2002/3 is still less than the peak of 1.65% in 1995/6.

"Look at what our international competitors are doing. They have placed enormous trust in science for their future. The EU and Canada have recently committed to spending 3% of GDP on R&D by 2010 to compete with similar current levels in Sweden, the United States and Japan."

However, these long term big picture issues hardly rate a mention in the election. It seems to be all about looking after marginal electorates and trying to make sure that the hand outs will benefit the voters that matter the most.

### ***Newmont goes from Sydney to New York***

Rupert Murdoch's likely move for NewsCorp from the Sydney ASX to the US will be nothing new. Newmont Australia Ltd, a wholly owned subsidiary of Newmont Mining Corporation, the world's largest gold producer transferred, in August this year, over \$4 billion worth of shares listed on the ASX to Newmont's primary New York listing, to take advantage of additional liquidity following its takeover of Normandy Mining.

As a result, instead of being in the top 50 companies on the ASX and having a market capital of ~\$4.6 billion it is now only worth ~\$0.4 billion and is one of the smaller resource companies on the ASX. – Is this going to be a future trend for other multinationals?



**David Denham**

### **Preview Information**

*Preview* is published by RESolutions Resource & Energy Services Pty Ltd (brian@resolutions-group.com.au) for the Australian Society of Exploration Geophysicists. It contains news of topical advances in geophysical techniques, news and comments on the exploration industry, easy-to-read reviews and case histories, opinions of members, book reviews, and matters of general interest. Potential contributions should be sent to the Editor: David Denham (denham@webone.com.au).

### **Deadlines**

Preview is published bi-monthly, February, April, June, August, October and December. The deadline for submission of all material to the Editor is the 15th of the month prior to the issue date. However, because of Christmas, the deadline for the **December 2004 issue is 12 November 2004.**

### **Advertisers**

Please contact the publisher, RESolutions Resource and Energy Services, (see details elsewhere in this issue) for advertising rates and information. The ASEG reserves the right to reject advertising, which is not in keeping with its publication standards.

Advertising copy deadline is the 22nd of the month prior to issue date. However, because of Christmas, the advertising copy deadline for the December 2004 issue will be 19 November 2004. A summary of the deadlines is shown below:

Preview Issue	Text & articles	Adverts Copy In
<b>113 Dec 2004</b>	<b>12 Nov 2004</b>	<b>19 Nov 2004</b>
114 Feb 2005	15 Jan 2005	22 Jan 2005
115 Apr 2005	15 Mar 2005	22 Mar 2005
116 Jun 2005	15 May 2005	22 May 2005





## Occupation oscillation – good in the long run?

Nowhere is the law of supply and demand more evident than in the world of resource markets. Read about a sabotaged oil pipeline in Iraq today, and watch the oil price rise tomorrow. Note the copper price rise on the back of an announced strike at a mine in Chile. Marvel as the 8% growth rate in China sparks an even greater growth in nickel prices. This sensitivity is the driver behind the wild roller coaster of boom and bust cycles that we have come to expect in the resource industry. The two graphs below will highlight the industries' peaks and, of course, valleys with which most readers will be all too familiar.

For as long as I have been in the minerals industry, over two decades now, conversations continually revolve around the need to smooth out the peaks and troughs of the resources cycle. There seems to be a general agreement that stockpiles should be controlled, that producers should study more history and that universities should put more effort into recruiting students in the down times. The consensus is that for resource

consumers, shareholders, and employees, the up-down oscillation of the resource business is bad in both the short run and the long run.

But is this volatility really bad for geoscientists? Clearly retrenchments are bad for any individual who loses their job. Every round of downsizing leads to broken careers, brilliant minds lost to other industries, and a myriad of misery for individuals who depend on the resource industries for employment. This serious consequence should never be minimised. At the same time, the inherent volatility in oil and minerals may well have a salutary effect on employees, as a group, in the long run.

To illustrate, let's look at an industry where job numbers and graduate hirings are almost always stable, predictable, and possibly even increasing. Teachers in many jurisdictions fit this description. I have included the graph on the next page of teacher numbers in the state of Colorado in the USA as an illustrative example. The future looks good for the teachers of Colorado; predictable, with no cyclic fluctuations. This kind of stability attracts a steady stream of first year education students and makes life easy for school educators. A slow steady increase in teachers' salaries follows this trend. The Public Education Enquiry in New South Wales documented that the average salaries of four year teachers in NSW increased 13% between 1995 and 2002, from \$40,144 to \$45,403.

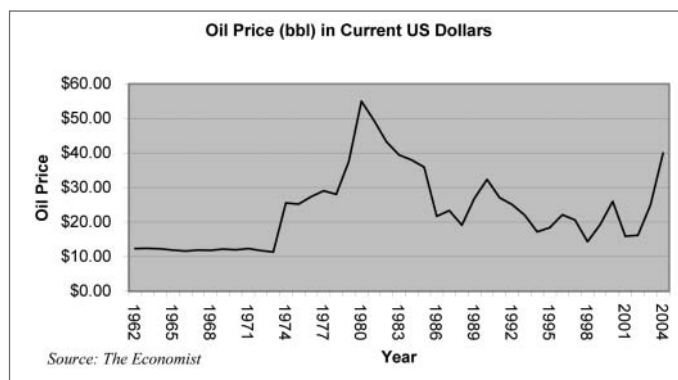
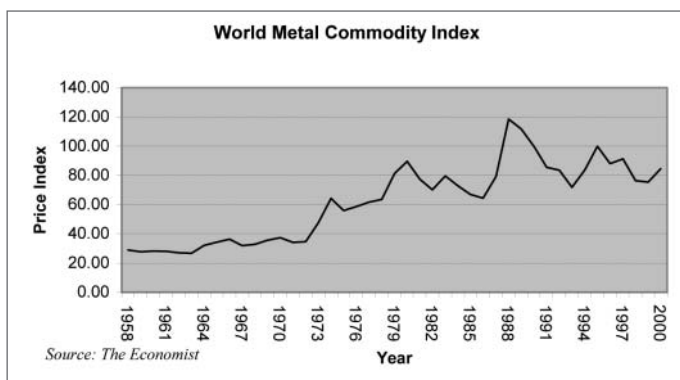
Now contrast this with the graph of mineral exploration employees in Australia, where the future is never certain, except to say that long-term consistent growth in job numbers seems to be out of the question. The conclusion to which most geophysicists jump to is that this unpredictability is by its

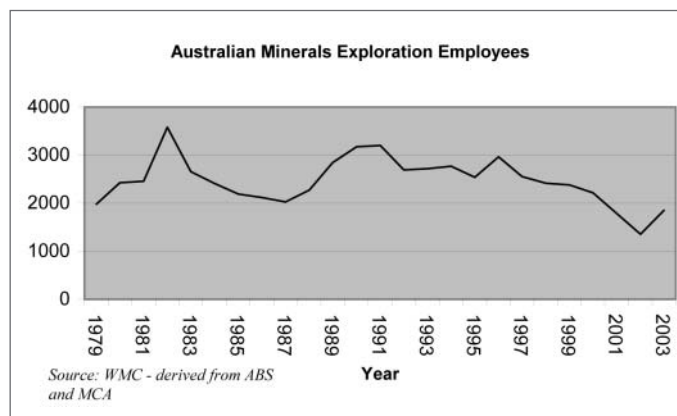
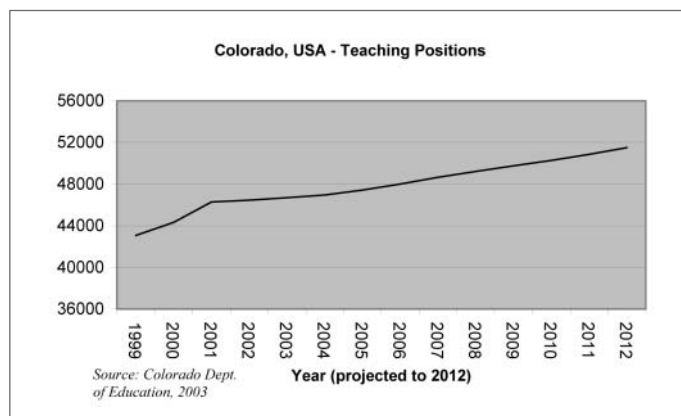
very nature bad for us as individuals and as a profession.

So, where would you rather be – in a profession with a constant professional supply and demand or in one with unpredictable swings? The answer to that may lie in the current boom period, with petroleum and mineral prices at their highest in many years. Although reliable published salary information is scant in the resources industries, WMC Resources reports an industry-wide increase in geophysicists' average salaries from 1995 to 2002 from \$52,400 to \$84,200, or 58%. In the current boom, anecdotal evidence points to a shortage of geophysicists and a level of high salaries not seen before. History tells us that, although another low cycle is inevitable, the salary and benefits that accrue during the booms create a consistent upward income trend that continues to make geoscience jobs very attractive in terms of employee compensation.

Teaching, on the other hand, is a noble profession; one which we all agree is of vital interest to us all. The other aspect of teaching on which we would all concur is that salaries are far too low and increase at an intolerably low rate, despite a predictable level of employment and new graduates and well organised trade unions for support. Although this may well be an inherent feature of government employment, consider that government geoscientists are paid well above the average government employee, at least partly thanks to the long term upward pressure of the boom and bust effect of supply and demand.

So, do we want to continue to see massive retrenchments every eight years? Of course not. Is it good for the industry to experience educational phase lags where few graduates





are available in high demand periods and a glut occurs in the low? In its extreme this is undesirable as well. But while aiming to minimise the negative effects of the cyclic nature of the resource industry, it may be wise to understand that in the final analysis many of the material benefits that geophysicists enjoy in their employment are perhaps a result of that very oscillatory phenomenon.

In the end, both the business cycle and human nature dictate that the volatility of the resource industry is something that we will all have to live with for a long time. In the meantime, we can take heart in the good news for geophysicists – employment benefits over the long term look to continue to outpace many professions, and even in the bad times the non-material challenges of the job keep geophysicists coming back for

more. The fact that so many talented geophysicists remain in the business through good times and bad is a testament to this. So, count on volatility, count on good times and bad times, but count on being part of a group that, as a profession, can see a prosperous future doing fulfilling work.

**Howard Golden**

## SAGA and ASEG sign agreement in Sydney



Sydney 2004 was the venue for the signing of a Cooperative Agreement with the South African Geophysical Association (SAGA). ASEG President Howard Golden is pictured above at the signing ceremony along with

David Hatch, representing SAGA President Declan Vogt.

SAGA, founded in 1977 to foster and encourage the development of geophysics in

South Africa, boasts more than 350 members worldwide. The association hosts regular monthly talks, produces a topical newsletter, has its own academic journal (*the SA Geophysical Review*), and runs biennial technical meetings. SAGA also maintains a test site where new geophysical equipment can be tried out and students/technicians can be trained.



Declan Vogt,  
President of SAGA

ASEG is proud to be associated with SAGA and its members, many of whom have been associated with some of the world's richest gold, diamonds, and base metals deposits in southern Africa. As the world becomes smaller, creating and enhancing connections with colleagues worldwide continues to be a priority of ASEG and other societies worldwide. Both organisations look forward to a rewarding exchange of ideas, publications and good will.

## 2004

### 22-23 November

Theme: Orebody Modelling and Strategic Mine Planning Uncertainty and Risk Management

Sponsored by: AusIMM

Venue: Hyatt Regency, Perth, W A

Website: <http://www.ausimm.com/ommp2004/home.html>

Email: [conference@ausimm.com.au](mailto:conference@ausimm.com.au)

### 24-26 November

7TH SEGJ INTERNATIONAL SYMPOSIUM – IMAGING TECHNOLOGY

Theme: Interdisciplinary integration of the geosciences for better understanding and Modelling.

Location: Sendai, Japan

Sponsors: SEG Japan, SEG, Australian SEG, EAGE, Korean SEG, EEGS

Website: <http://www.segj.org/is7/>

### 13-17 December

2004 AGU FALL MEETING

San Francisco, California, USA

Website: [www.agu.org/meetings](http://www.agu.org/meetings)

## 2005

### 31 January - 4 February

THE 16TH BIENNIAL CONGRESS OF THE AUSTRALIAN INSTITUTE OF PHYSICS

Theme: Physics for the Nation

Venue: The Australian National University, Canberra ACT, Australia

Website: <http://aipcongress2005.anu.edu.au/>

### 4-7 April

SAGEEP

Venue: Atlanta Airport Hilton Hotel, Atlanta, USA

## 2005

### 10-13 April

2005 APPEA CONFERENCE & EXHIBITION

Venue: Perth (at the new Convention Centre facility)

Contact: Julie Hood

Email: [jhood@appea.com.au](mailto:jhood@appea.com.au)

### 23-27 May

2005 AGU JOINT ASSEMBLY

Venue: New Orleans, Louisiana, USA

Website: [www.agu.org](http://www.agu.org)

### 6-7 June

11TH ANNUAL SOUTH EAST ASIA AUSTRALIAN OFFSHORE CONFERENCE

Venue: Darwin, NT

Email: [rreilly@iir.com.au](mailto:rreilly@iir.com.au)

Website: [www.seaoc.com](http://www.seaoc.com)

### 13-16 June

67th EAGE Conference & Exhibition

Venue: Madrid, Spain

Website: <http://www.eage.nl/conferences/>

### 16-18 August

CENTRAL AUSTRALIAN BASINS SYMPOSIUM (CABS) 2005

Theme: Minerals and petroleum potential

Venue: Alice Springs (details TBA)

Contact: Greg Ambrose, Northern Territory Geological Survey

Email: [greg.ambrose@nt.gov.au](mailto:greg.ambrose@nt.gov.au)

### 19-23 September

22ND INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM

Sponsors: The Association of Exploration Geochemists

Theme: From Tropics to Tundra

Venue: Sheraton Hotel, Perth, WA

Website: [www.promaco.com.au/conference/2005/iges](http://www.promaco.com.au/conference/2005/iges)

## 2005

### 6-11 November

SEG INTERNATIONAL EXPOSITION & 75TH ANNUAL MEETING

Venue: Houston, Texas, USA

Website: [www.seg.org](http://www.seg.org)

### 5-9 December

2005 AGU FALL MEETING

Venue: San Francisco, California, USA

Website: [www.agu.org/meetings](http://www.agu.org/meetings)

## 2006

### 2-7 July

THE AUSTRALIAN EARTH SCIENCES CONVENTION 2006

ASEG, IN COLLABORATION WITH GSA;

ASEG'S 18TH INTERNATIONAL

CONFERENCE AND EXHIBITION,

AND GSA'S 18TH AUSTRALIAN

GEOLOGICAL CONVENTION

Venue: Melbourne, Vic, Australia

Website: [www.earth2006.org](http://www.earth2006.org)

## 2007

### 18-22 November

ASEG'S 19TH INTERNATIONAL CONFERENCE AND EXHIBITION

Venue: Perth, WA

Contact: Brian Evans

Email: [Brian.Evans@geophy.curtin.edu.au](mailto:Brian.Evans@geophy.curtin.edu.au)



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## Sydney Conference an outstanding success

ASEG conferences are the life blood of the society, and the Sydney meeting, hosted with the NSW Branch of PESA, was no exception. It was a geophysical celebration. Tim Pippett and Barry Smith led a fine team to deliver a most successful meeting.



Fig. 1. Co-Chairmen, Tim Pippett and Barry Smith with Louise Pitney of Conference Action.

From the pre-conference workshops, through to the special symposia, held at the end of the meeting, it offered a fine range of geophysical themes that impact not just in the resource industries but throughout a whole range of sectors in our society. Most of these were on show in Sydney.



Fig. 3. Some of the attendees at the Ted Lilley Symposium, with Ted, his wife Penny and some more of the Lilley family on the front row.



Fig. 2. Most of the Conference Organising Committee. From the left: Simon Stewart, David Schmidt, Phil Cooney, Dave Robson, Barry Smith, Tim Pippett, Dave Kirkham, Peter Gunn, Mike Smith and Graham Butt.

The increasing role of geophysics in environmental matters has been well known for many years and was represented at the meeting. What was new in Sydney was a strengthening of the links between the more basic geophysical research and the focused task of searching for new resources. There were two major examples of these linkages.

The first was the airborne gravity gradiometry work that is now starting to show excellent results after an eight year journey to produce the Holy Grail of a workable airborne gravity system.

The second was the Ted Lilley Symposium, which also contributed to develop this link. Ted has always worked hard to ensure that academia and industry interact, and it was fitting that he was awarded Honorary Membership of the ASEG at the Sydney meeting.

### Some statistics

The basic numbers involved with the conference speak for themselves:

- Total budget over \$1million;
- 594 registered attendees;
- Attendees from 23 countries;
- Enough papers to fill four concurrent sessions over four days;

- 64 exhibitors occupying 94 booths;
- 26 sponsors;
- 194 registrants at the nine pre-conference workshops, including 72 at the very successful airborne gravity workshop; and
- Field trips to the Lachlan Fold Belt and the Sydney Basin.

All in all, an excellent event.

### Opening Ceremony

The international flavour of ASEG Conferences was on display at the Opening Ceremony. The President of the SEG, Peter Duncan; the Japanese Society of Exploration Geophysicists, Keisuke Ushijima; and the Vice-President of the EAGE, Gareth Williams; were all involved, and Neal Newman, the NASA representative in Australia gave a keynote address.

In addition we had the several overseas participants delivering keynote addresses and the signing of the Agreement between the ASEG and the SAGA, our South African equivalent.

### Media impact

For the first time we had a full time media person (Jessica Tyler of The SciBiz Media Group) in attendance to alert the outside



world of key happenings and also produce media releases. Some of the media releases and 'teasers' are listed below:

**Integrated exploration in a changing world:** applying state-of-the-art technologies to resource exploration in a changing economic and political world will be explored at a major geophysics industry conference and exhibition in Sydney next week.

**Sea ice modelling:** using airborne techniques are being investigated as a potential regional mapping tool in the Antarctic region because the distribution of the sea ice (coverage and thickness) is an important parameter for modelling global climate, as well as planning Antarctic shipping operations.

**Diamonds:** De Beers recently embarked on a project to evaluate using borehole geophysical techniques to detect and map the contact of the kimberlite pipe - home to diamonds - at Finsch diamond mine in South Africa.

**Research dollars at work:** a range of large-scale mapping studies is underway at national geoscience research agencies to investigate large slabs of the earth's surface and to make this information available to industry, to create a single interface that delivers all validated spatial geoscientific data independent of database structure and location.

**Geothermal energy:** South Australia is uniquely endowed with high heat-producing rocks that present targets for hot dry rock (HDR) geothermal exploration.

**Helicopter-based earth studies:** Geotech has developed a helicopter system to meet the needs of a broad range of natural resource problems related to earth conductivity mapping Meteorites: The Roebuck/Canning Basin at the Australian NW Margin (NWAM) has recently been re-interpreted as a massive impact structure that appears to be associated with the global Permian/Triassic extinction event (the dinosaur killer).

**Salinity:** Dryland salinity, a growing problem over much of Australia, cannot be mapped or predicted without a thorough understanding of the landscape in three dimensions and the hydrological processes that operate within it. Hydrology is the key for understanding how salt stores are mobilised through the earth, both in a vertical and horizontal sense. A range of talks presented in a special forum.

**Geosequestration:** Seismic methods are expected to be an efficient tool for delineation of geological features of geosequestration target zones to 'lock away' greenhouse emissions - the subject of the recent Energy White Paper released by the Prime Minister.

**Space imagery:** NASA's Shuttle Radar Topography Mission collected around 12 terabytes of raw data which is currently being processed into a digital elevation model of the Earth.

**Locating weapons:** Unexploded Ordnance (UXO) is a major problem in a large number of areas throughout the world. As most of the older ordnance is of ferrous composition, total field magnetism is an eminently suitable tool finding these timebombs.

**Isle of the Dead:** Searching for gravesites using geophysical techniques.

If anyone would like the full releases or any further information, they should contact Jessica on (03) 6231 6648 or at: [jtyler@scibizmedia.com.au](mailto:jtyler@scibizmedia.com.au).




Fig. 4. Suzanne Haydon, co-convenor of the 2006 Australian Earth Sciences Convention inviting us all to Melbourne in two years time.

## Melbourne 2006

After such a successful meeting, we can look forward in anticipation to the next convention, which will be in Melbourne on 2-7 July 2006.

The meeting will combine the ASEG's 18th International Conference and Exhibition, and the GSA's 18th Australian Geological Convention. It will be called: The Australian Earth Sciences Convention 2006. Suzanne Haydon is the ASEG's joint convenor. Figure 4 shows Suzanne inviting all members to Melbourne at the Closing Ceremony in Sydney.

It's a pity we have to wait so long. However, the website is already operating at: [www.earth2006.org.au](http://www.earth2006.org.au), so you can start planning now.



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## ASEG Awards at Sydney 2004\*

**Honorary Membership of the ASEG, for distinguished contributions to the profession of exploration geophysics**

### F. E. M. (Ted) Lilley

Dr Lilley's geophysical career has spanned more than 40 years, during which time he has made major contributions to Australian and international geophysics. Until his retirement from active research at the close of 2003, 'Ted', as he is affectionately called, has been a Senior Fellow at the Research School of Earth Sciences, Australian National University.

Ted has been an active and enthusiastic member of the society since its inception in 1970. He was a foundation member of the ACT Branch in 1979 and served as its President in 1980/81 and Vice-President in 1981/82. He served as Editor of the *Bulletin of the ASEG* between 1981 and 1983 and has been involved as an author, session chair or topic organiser in 14 of the society's 17 conferences.

Ted's geophysical career began in the early 1960s with the BMR. During two years in the regional aeromagnetic survey team he conducted experimental work to determine the feasibility of using proton-precession magnetometers in lighter aircraft than the existing DC3. This pioneering work laid the foundation for a method that has since become an essential component of Australian resource exploration and environmental studies. From this beginning, Ted's research has developed on a variety of fronts and has produced a number of



Ted Lilley (left) receives his Honorary Membership of the ASEG from President Howard Golden

important results for exploration geophysics, including:

- pioneering efforts to map the electrical conductivity structure of the Australian continent using magnetotellurics and magnetometer-array studies,
- compilation of a comprehensive model of the electrical conductivity structure of the Australian continent and Tasman Sea,
- ground-breaking analysis of the impact on aeromagnetic data of non-uniform electromagnetically induced fields, and,
- inventive observations of the aeromagnetic signatures of ocean currents and waves.

Ted has published over 100 papers during his career, including 17 papers and abstracts published in the *Bulletin of the ASEG* and *Exploration Geophysics* and six papers in *Geophysics*.

Intertwined with his research, Ted has been an excellent educator and mentor. He has supervised 10 PhD students, many of whom continue to make active contributions to geophysics. For 24 years he was guest lecturer in geophysics in the ANU Geology Department where his enthusiasm prompted a number of geology students to pursue careers in geophysics.

Ted has been a stalwart of Australian and international earth sciences for over four decades. He has been an inimitably warm and generous mentor and an exemplary ambassador for geophysics. He richly deserves Honorary Membership of our society.

### Ted Lilley's response

Thank you Howard. My thanks also to those who prepared the nomination for this award, which I am delighted to receive.

I should first ask if people of my age are allowed to have heroes? I think it important that we do, and let me say that many of my heroes are to be found on the Honorary Membership roll of the ASEG. It is a great distinction to now join them, and I thank you very much for this honour.

My initial introduction to geophysics occurred during summer jobs as a field assistant. Subsequently I benefited greatly from the training and friendships of my first employment with the Bureau of Mineral

\* The citations for the Service Medal and the Service Certificates will be published in the December 2004 issue of *Preview*.

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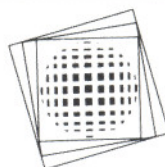
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Resources. I spent three years there, in between studies at the University of Sydney and the University of Western Ontario in Canada. Most recently, I have enjoyed the benefits of working with students and colleagues at the Australian National University, where I have spent 35 very happy and rewarding years, interspersed with visits to other places.

Canberra has a rich environment of earth scientists, and the ASEG both locally and nationally has been an extended family to me. Thus I particularly value this award of Honorary Membership. It is also a delight to have students and colleagues, past and present, gathered at this meeting.

I thank the members of my family for supporting my career, and especially Penny, who married into the BMR chapter of the world-wide geophysics clan in January 1963. Her career, in molecular biology, has been a treat to be part of.

In conclusion, the latter half of the 20th century, during which the ASEG came into existence and demonstrated such activity, has been a marvellous time to be doing geophysics. Australia is a quite remarkable happy hunting ground. I am sure the excitement, satisfaction and spectacular results will continue.

### **Lindsay Ingall Memorial Award for the promotion of geophysics to the wider community**

#### **Peter Hatherly**

Dr Peter Hatherly receives the 2004 Lindsay Ingall Memorial Award, for his energetic and effective promotion of geophysics in the coal industry, and the development of improved techniques tailored to that industry. While his primary expertise and contribution is in seismic applications, he has also systematically encouraged the introduction of all appropriate methodologies, such that he is now looked upon as the 'face of geophysics' by geologists and engineers throughout the coal industry, both here and overseas.

For the past 11 years Peter has been with CSIRO Exploration and Mining, during which time he also led the Geophysics Group in the CRC for Mining Technology



*Peter Hatherly (right) receives his Lindsay Ingall Memorial Award from President Howard Golden*

and Equipment. He also spent 10 years with ACIRL and, before that, in the NSW Department of Mineral Resources.

In addition to his direct and/or leadership roles in introducing In Seam Seismic (ISS), the Radio Imaging method (RIM), crosshole seismic imaging, microseismic monitoring, his support for electromagnetic monitoring, and the list continues, he has made pioneering contributions to coal mining through the successful application of shallow high resolution 3D seismology to mining; through the deduction of quantitative geomechanical properties from core and borehole data and by the prediction of drill bit performance from seismic data.

He has made his results known through more than 100 publications and presentations in the geological, geophysical and mining forums. He has done all this through a combination of his energy, technical excellence and persuasive personality. By any standards his is a truly outstanding record for a scientist still in mid-career. Considering the importance of coal as one of Australia's major exports, Peter's work has made an important impact on the nation's economic life. From this it is clear why he is so highly regarded in the industry. He has brought credit to geophysics as a science as well as to himself.

Peter's role has already been recognised by an unusually large number of industry and CSIRO awards and by the Laric Hawkins Award of the ASEG. He has been a member of the ASEG for 29 years. He is now a very worthy recipient of the ASEG Lindsay Ingall Award.

#### **Peter Hatherly's response**

Thank you all. I am honoured to be receiving the Lindsay Ingall Memorial Award.

The coal industry in Australia is huge. It is our major export earner by a large margin and geophysics now plays an important role in coal mining. While the uptake of geophysical techniques within the coal industry continues to gather pace, there are still many outstanding geological issues at the coal face and in more general mine planning. Geophysicists with soft rock and geotechnical skills have much to offer. It has been a privilege for me to work within Australia's coal mining industry and if it is seen that I have assisted with the development of our profession in that industry, I am greatly honoured.

Over my years in coal mining, I have had the pleasure of working with many of you here. Thank you all for your contributions. I especially acknowledge my closest colleagues, Iain Mason, Binzhong Zhou, Xun Luo, Greg Poole, Milovan Urosevic Brian Evans and Keeva Vozoff. Derecke Palmer was an important mentor earlier in my career.

Finally, please allow me to comment more generally on the future. Both the coal and petroleum industries are now facing significant challenges concerning environmental management. Solutions to the problems of greenhouse gas and other emissions don't lie in shutting us down. Instead the disposal of waste needs to be managed through sequestration and the use of other geological repositories.

In addition, there are other solutions and environmental insights waiting to be taken up as geophysical challenges. An example is the generation of geothermal energy through accessing hot dry rocks. It is unfortunate that the debate within the media and put forward by green interests is so biased and uninformed. Hopefully this situation will improve sometime soon and our profession can start to take a lead in these absolutely important areas.

Thank you again for this honour.



## Conference Awards

**Laric Hawkins Award for the most innovative use of geophysical techniques from a paper presented at the ASEG 2004 Convention**

*Passive seismic methods using the microtremor wave field* by Michael Asten.

**Best booth in the ASEG 2004 Exhibition**  
Fugro Instruments

**Best technical presentations:**

**Overall Presentation:** *The in-situ stress field of the West Tuna area, Gippsland Basin:*



Michael Asten (right), receives his Graham Sands Award from President Howard Golden

*implications for natural fracture-enhanced permeability and wellbore stability*, by Emma Nelson, Richard Hillis, Scott Mildren and Jeremy Meyer (presented by Emma Nelson).

**Petroleum Geophysics:** *An efficient explicit 3D prestack depth migration*, by Jiaxiang Ren, Clive Gerrard, James McClean, Mikhail Orlovitch and Andrew Long (presented by Andrew Long).

**Environmental/Groundwater Research:** *The use of borehole radar for the delineation of thin tabular orebodies ahead of mining*, by Petro du Pisani and Declan Vogt (presented by Petro du Pisani).



Simon Stewart, representing Fugro Instruments, receives the award for the best Exhibit at the Conference from Roger Henderson of the Organising Committee

**Minerals Geophysics:** *An improved pseudo-gravity magnetic transform technique for investigation of deep magnetic source rocks*, by David Pratt and Zhiqun Shi (presented by David Pratt).

**Poster:** *Basic experiments of seismic while drilling using a percussion drill as an energy source*, by Toshiyuki Yokota, Kyosuke Onishi, Hirokazu Karasawa, Tetsuji Ohno, Akinori Ota, and Tsutomu Kaneko, Tokyo, Japan.

**Student Poster:** *The geophysical exploration of the Ohura fault, North Wanganui Basin, NZ*, by Marion Walls, University of Wellington, NZ.



Emma Nelson (left), receives her 'Best Overall Presentation Award' from Peter Gunn, Co-chairman of the Technical Program Committee



Petro du Pisani shows her award for the 'Best Environmental/Groundwater Paper' at the closing ceremony with Peter Gunn, Co-chairman of the Technical Committee



David Pratt (right) receives his award for the 'Best Minerals Paper' from Peter Gunn, Co-chairman of the Technical Committee



KSEG Toshiyuki Yokota (left) with his Award for the Best Poster and Peter Gunn, Co-chairman of the Technical Committee



Marion Walls displays her 'Best Student Poster' Award at the closing ceremony in the company of Peter Gunn, Co-chairman of the Technical Committee

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### 3D EM modelling of Antarctic sea ice pressure ridges

*Julian Vrbancich (julian.vrbancich@dsto.defence.gov.au), James Reid, David Annetts, Andreas Pfaffling, Fred Sugeng and Tony Worby*

The use of airborne electromagnetic (AEM) surveys to measure Antarctic sea ice thickness is being investigated as a regional mapping tool to aid global climate studies. Undeformed sea ice floes are modelled as 1D structures; however, sea ice pressure ridge sails (in air) and keels (undersea) form convenient 2D and 3D targets. In order to use AEM techniques to study the distribution of ice thickness, it is first

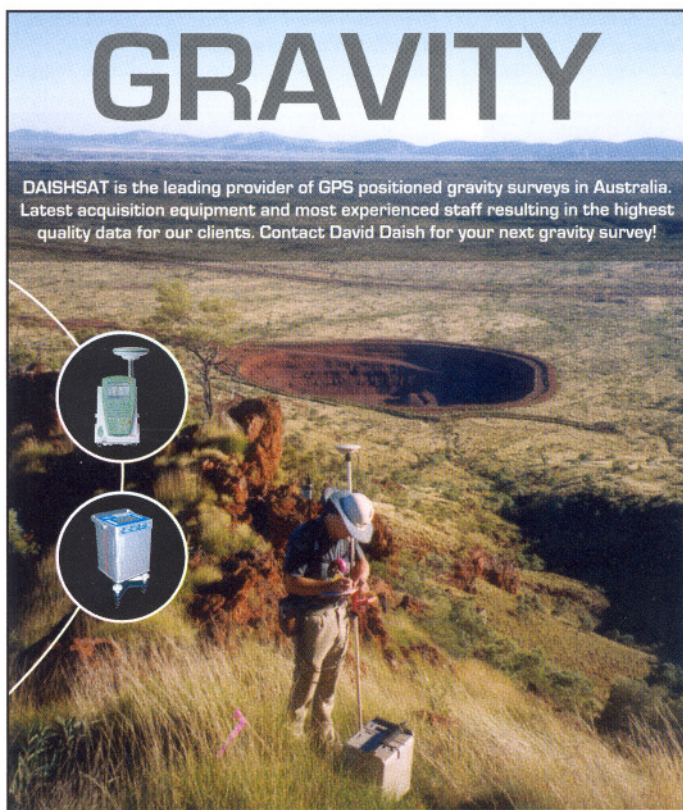
necessary to test if realistic sea ice structures can be modelled electromagnetically.

Pressure ridge structures from drill-hole sampling can in some cases be constructed from simple block models. Finite element and integral equation 3D EM modelling programs can then be applied to these structures to test for agreement, and to predict the AEM response, including topography (sails). EM modelling of frequency domain systems shows that good agreement is obtained at certain frequencies, and that a vertical coaxial (VCX) transmitter-receiver coil configuration laterally resolves the ice keel better than a horizontal coplanar (HCP) configuration. Cross-sectional dimensions of the sails and keels are relatively small and mesh design is

critical in order to avoid discretisation errors. Software and hardware constraints may limit successful EM modelling of multiple keels that combine sub-metre structures and coarser structures. For a given mesh, discretisation errors may lead to noisy EM response profiles depending on the frequency, coil geometry, and component (in-phase or quadrature). Adaptive mesh structures may be required to minimise discretisation errors.

#### Note:

The Abstract should have been printed in the Conference Preview, we apologise to the authors for this omission. The paper was presented in the General Studies, Ted Lilley Stream.

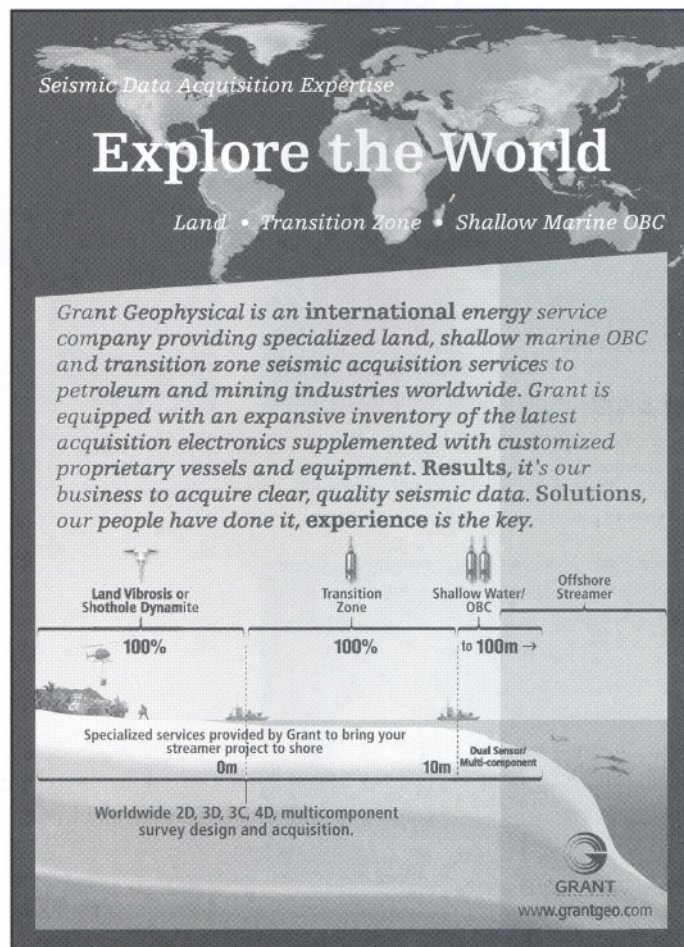


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# Poster Session Abstracts, Sydney 2004<sup>\*</sup>

<sup>\*</sup> The abstracts for the poster sessions were not available at the time the Conference *Preview* was published. These are included in this issue so that readers now have a full set of abstracts for the presentations at the meeting.

## Structural synthesis of the Sydney Basin using potential field data: an integrated, systematic approach to improving geological confidence

A.J. Buckingham<sup>1</sup>, S.A. Griffin<sup>2</sup>,  
C.J. Woodfull<sup>3</sup> and S.M. Munroe<sup>4</sup>

<sup>1</sup> SRK Consulting, 1064 Hay Street  
West Perth, WA 6005, Australia

<sup>2,3,4</sup> SRK Consulting, Level 9, 1 York St,  
Sydney, NSW 2000, Australia

A regional structural framework and basin model have been developed for the Sydney Basin and the eastern part of the Gunnedah Basin, incorporating a wide variety of geological and geophysical information. Exploration under cover is heavily reliant on remote sensing technologies and the ability to effectively integrate a wide variety of datasets with sound geological reasoning.

Datasets used in this synthesis include drill hole/well logs, geological mapping, geophysical surveys (seismic, magnetic, gravity, radiometric), digital elevation, satellite imagery (Landsat/ASTER), stress measurements, heat flow, age dating, published geological maps, reports and research/technical papers. Using a GIS-based work platform, SRK has developed methodologies for interpreting these datasets to define a 4D geological and structural/tectonic model, including the likely depth to 'economic basement'. The methodology relies on the integration of all appropriate geophysical and geological information, as individual datasets when interpreted in isolation often produce poorly constrained results. The development of a well-constrained geological model is fundamental to a cost effective, risk-based mineral or hydrocarbon exploration strategy, particularly beneath cover.

Potential field data provide the foundation on which the structural framework is built. Target specific reduction, filtering and enhancement of magnetic and gravity data are carried out to improve the interpretability of the data and reveal information on the geometry and structure of the basement. Magnetic datasets of varying resolution and coverage are both merged (into a single grid) and mosaiced (superimposed to maintain original resolution) to maximize the use of data from both regional surveys and the 'postage stamp' high resolution aeromagnetic (HRAM) surveys. Several automated depth to source methods are used to approximate the depth to basement and the depth to intra-sedimentary sources such as heavy mineral deposits (fans) and dykes/sills. Comparison between results using various methods and seismic/well data reveal information on the suitability of each technique and the possible geometry of the physical property contrasts being detected. Isostatic residual gravity data, highlighting density variations in the mid to upper crust, are particularly useful for interpreting basin architecture and structure, and underpin the development of the economic basement topography model.

## Results from the application of Euler Deconvolution to airborne EM data

G.R.J. Cooper<sup>5</sup>, M. Combrinck<sup>6</sup>,  
and D.R. Cowan<sup>7</sup>

<sup>5</sup> School of Geosciences, University of the  
Witwatersrand, Johannesburg,  
South Africa

<sup>6</sup> Department of Geology, University of  
Pretoria, South Africa

<sup>7</sup> Cowan Geodata Services,  
12 Edna Road, Dalkeith, WA

Airborne electromagnetic methods are used in exploration for conductive mineralisation, most commonly for massive metallic

sulphide deposits, although alternatives such as kimberlite pipes may be the target. Airborne EM surveys can collect several hundred line kilometers of data per day so large volumes of data accumulate rapidly. A wide variety of AEM systems are used by, the most important was being time-domain towed bird systems and frequency domain helicopter-borne fixed boom systems. Time-domain EM systems generate a primary electromagnetic field which induces currents and hence a secondary electromagnetic field in nearby conductive material. The decay of the secondary field is then measured (when the primary field is switched off) as a function of time.

Euler's equation has traditionally not been used with electromagnetic fields because of a belief that it does not apply as EM data obey Maxwell's wave equations rather than Laplace's equation. However if two approximations are employed then this is not the case. The approximations are: 1) The effects of displacement currents are neglected (valid at low frequencies) and 2) The contribution of the country rock is assumed to be small, due to its much lower conductivity than the target.

In these situations then the wave equation reduces to Laplace's equation. With frequencies <5000Hz and an overburden target conductivity ratio of <0.05 this approximation is valid. If Laplace's equation is valid then Euler's equation is also valid, and it may be used as a semi-automatic interpretation method in a similar manner to that with which it is used with magnetic and gravity data. It also allows for the downward continuation of EM data.

The application of Euler deconvolution to airborne EM data is demonstrated both on data from synthetic models and on real data over massive Ni-Cu sulphides associated with basic intrusive rocks.



## Optimally inverse modelling the evolution of the Australian stress field with ABAQUS™ and Nimrod/o

Scott Dyksterhuis

University of Sydney,  
Institute of Marine Science,  
NSW 2006 Australia  
scottd@geosci.usyd.edu.au

Although the low-order present stress field of most continents is fairly well established, information on palaeo-stress fields is generally sparse. Knowledge of paleo-stresses is crucial for understanding brittle tectonic reactivation through time. We use the commercial software ABAQUS™ in conjunction with program Nimrod/o to optimally inverse model the Australian stress field using data from the Australian Stress Map. We reconstruct the plate boundary configuration and age-area distribution of ocean crust around Australia through time to obtain estimates for ridge push, slab pull and collisional forces acting on the Indo-Australian Plate since the Eocene. Other model parameters we explore are the effects of the Australia Antarctic Discordance, the continental topographic force and the mechanical stiffness of the Australian continental margin. We apply these constraints to model the orientation of the maximum horizontal compressive stress ( $S_{Hmax}$ ) regime for the present, early Miocene and early Eocene. We use an elastic 2D plane stress finite element model with realistic elastic properties representing different rock types and geologic provinces for the Australian continent in order to model the stress field of a heterogeneous plate. We show that spatially significant rotations of  $S_{Hmax}$  directions can be modelled as a consequence of perturbations of  $S_{Hmax}$  in areas of juxtaposed strong and weak rheologies. Stress directions over the northern Australian continent in the early Miocene in particular show large disparity with present stress directions while stress orientations for the Australian plate during the early Eocene vary substantially with stress directions in the early Miocene and the present due to the drastically different plate geometry and boundary configurations. Fault reactivation histories that impacted on the migration and trapping of petroleum and that are observed on the

northwest shelf of Australia and in the Bass Strait region are consistent with modelled changes in stress directions through time.

## The Tanami 3D geological model

A.J. Meixner, L.C. Vandenberg, R. Larson and R. Hay

Geoscience Australia, Canberra, ACT

This poster is complementary to the extended abstract and presentation submitted as Vandenberg & Meixner (The Tanami 3D Geological Model - Integrating Geology and Potential Field Data). The extended abstract details the science behind integrating potential field modelling with geology to construct 2D sections, the basis for 3D model construction. The poster will deal primarily with the availability of the Tanami 3D model and associated data sets as web accessible and deliverable products.

The following is a brief outline of the poster content:

### Introduction

Overview of the 3D model, including location and model extents, a brief overview of how the model was constructed and the platform used for web display and delivery.

### 3D Model

Basic features of the 3D model, including the 2D potential field modelled sections and 3D surfaces (faults, granite plutons, geological units, etc).

### 3D Model Visualisation

Display features available, e.g. Demonstration movie, dynamic slicing, image draping etc.

### 3D GIS

Datasets for display and download, including: raster datasets (magnetics, gravity, DEM, satellite imagery etc.), databases (Mineral occurrences, geochronology, rock property etc.) mapped geology, solid basement geology interpretation, magnetic and gravity worms etc.

## The discovery and delineation of the Daybreak and Flying Fox Deeps nickel sulphide deposits – a case history of DHEM at Forrestania, Western Australia

Russell Mortimer

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The Daybreak and Flying Fox Deeps nickel sulphide deposits are situated within the Forrestania Greenstone Belt about 400 km east of Perth, and approximately 150 km south of Southern Cross, WA. Both deposits are intimately associated with the basal contact of an Archaean komatiite and comprise of semi-massive to massive nickel sulphide locally remobilised into footwall meta-sediments. The recent discovery of these nickel sulphide deposits can be directly attributed to the testing of historic, downhole time-domain electromagnetic (DHTEM) anomalism in areas of limited geological control.

Daybreak was discovered in mid-2002 during the first campaign of Forrestania exploration by Western Areas NL. Significant massive nickel sulphides were intersected in the first diamond hole drilled to test the highest priority DHTEM target within the Forrestania Project. This target was assigned the highest priority status given the close association with the prospective basal ultramafic contact and the presence of a clearly anomalous inductive-limit response in the associated historic DHTEM. Flying Fox Deeps was discovered in mid-2003 by applying the same geophysical and geological principles as utilised at Daybreak. High-grade massive nickel sulphides were again intersected in the first hole drilled to test the highest priority DHTEM target identified in a subsequent second stage geophysical review. The identification of multiple, inductive-limit responses within somewhat ambiguous historic DHTEM was crucial in strengthening the resolve to pursue such a deep exploration target. Following the discovery of the two deposits continued DHTEM surveys guided delineation diamond drilling and accurately mapped the extent and attitude of the massive sulphide systems.

The rapid targeting, discovery and delineation of Daybreak and Flying Fox Deeps clearly demonstrates the importance of DHTEM as a primary exploration tool in the search for highly conductive massive nickel sulphide. This principle applies to both greenfields exploration and exploration within nickel properties previously believed to be effectively explored. Work to date has highlighted that continued assessment and persistence on historic geophysical targets in light of modern DHTEM concepts can be very rewarding. Daybreak may provide sufficient additional resources to generate a viable mining proposition at New Morning while the Flying Fox Deeps deposit, although at an early stage could develop into a stand-alone high-grade mine.

### Attenuation and dispersion in partially saturated porous rocks: theory and numerical simulation

**Tobias M. Mueller, Benjamin Hardy and Boris Gurevich**  
Curtin University, WA

Existing models for seismic wave velocity dispersion and attenuation in porous rocks containing a mixture of two pore fluids are based on the assumption of regular distributions of the fluid phases. However, in reality fluids are distributed in a random fashion forming fluid patches of varying shape and size. We developed a model to predict velocity dispersion and attenuation of such random structures based on the theory of statistical wave propagation. We demonstrate that the assumption of random fluid distribution results in a significantly different behaviour of velocity and attenuation as functions of frequency and saturation. In order to test these theories we performed numerical simulations of wave propagation in a partially saturated rock model, containing water with periodically and randomly distributed gas inclusions. We used a finite-difference code to solve Biot's wave equation in 2D. The results were then compared to the theoretical predictions of frequency-dependent attenuation and velocity dispersion. We obtained P-wave velocity and quality factor as a function of saturation and frequency and found reasonable agreement between theory and simulation. Furthermore, we were able to

accurately infer information about the average size of the patches from our numerically modelled attenuation. This underlines the possibility that the size of the fluid patches can be estimated from seismic data.

### Ground radiometric acquisition – navigation processes for precise location in the field

**S. E. Petrie, D.I. Gray and G. D. Reed**  
Mineral Resources Group, Department of Primary Industries and Resources, South Australia

Primary Industries and Resources South Australia's (PIRSA) state-wide radiometric ground-truthing project required a process to accurately and rapidly navigate to a target location in the field. A laptop and GPS facilitated a detailed graphic environment for navigation, while Des Newman's Ozi Explorer application was chosen because it was necessary to read and display ECW images and Arc View shape files along with a real time location display.

Map-based products comprised Geoscience Australia's 1:250 000 NATMAP Raster Mapsheets, Department for Environment and Heritage's 1:50 000 Topomap products and Landsat 7 ESI2000 Mosaic from ImageMapSA. Using ESRI's Arc View 3.x, target point locations for the project were selected with the flight paths for the radiometric data created from the original XYZ ASCII files using Desmond Fitzgerald and Associates' Intrepid, and exported into Arc View shape files.

Earth Resources Mapping's ERMMapper was used to clip and stitch ECW images as well as to browse the ImageMapSA website and to subset the data. Standard off the shelf GPS units used (Garmin models GPS12XL and GPS 2+) were positioned on the dashboard of the vehicle to gain appropriate satellite coverage.

The system has the advantage of being cheap and intuitive while providing enough positional accuracy for PIRSA's radiometric ground truthing project.

### Multi-phase traveltimes in complex layered media using a Fast Marching Method

**N. Rawlinson and M. Sambridge**  
Research School of Earth Sciences,  
Australian National University, Canberra  
ACT, Australia

The accurate prediction of seismic travel times in layered media is required in many areas of seismology. In addition to simple refractions and reflections, complex phases comprising numerous transmission and reflection branches may exist; for instance, the so-called 'multiples' frequently identified in marine reflection seismology. We present a grid-based method for the accurate determination of multi-phase travel times in layered media of significant complexity. A fast and robust finite difference eikonal solver known as the Fast Marching Method (FMM) is used to track wavefronts within a layer, and can be used sequentially to track the multiple refraction and/or reflection branches of virtually any required phase.

Although FMM was initially introduced as a first-order scheme, higher order operators can be used provided causality is respected. However, schemes that use such operators will always suffer from first-order convergence due to high wavefront curvature and first-order accuracy in the vicinity of the source singularity. To overcome this problem, we implement local grid refinement about the source. In order to retain stability, the edge of the refined grid conforms to the shape of the wavefront, so that information only flows out of the refined grid, and never back into it.

Application of our new scheme to heterogeneous velocity media shows that grid refinement is capable of improving accuracy by an order of magnitude, with only small increases in computing time (~5%). Significantly, first-order convergence is replaced by near second-order convergence, even in media with velocity contrasts as large as 8:1. In one example, with a velocity grid defined by 257,121 nodes, reflection traveltimes from a strongly undulating interface were calculated with an error of only 0.001% in approximately 5 s of CPU time (on a Sun Blade 150). This level of accuracy is



sufficient for calculating meaningful amplitude values via solution of the transport equation.

### 3D gravity and magnetic modelling and integration of constraints using open GIS: the IGMAS software package

*S. Schmidt<sup>1</sup>, H.-J. Götze<sup>1</sup>, A. Sieh<sup>2</sup> and Z. Tašárová<sup>3</sup>*

<sup>1</sup> *Institut für Geowissenschaften, FR Geophysik, Christian-Albrechts-Universität zu Kiel, Germany (email: hajo@geophysik.uni-kiel.de)*

<sup>2</sup> *Geologisches Institut, Universität Bonn, Germany.*

<sup>3</sup> *Institut für Geologische Wissenschaften, Freie Universität Berlin, Germany*

Three-dimensional interactive modelling with IGMAS permits integrated processing and interpretation of geoid, gravity and magnetic fields, yielding improved geological interpretation. IGMAS 3D models are constructed using triangulated polyhedra to which constant density and/or induced and remnant susceptibility are assigned. Interactive modifications of model parameters (geometry, density and susceptibility), access to the numerical modelling process, and direct visualisation of both calculated and measured fields of gravity and magnetics, enable the interpreter to design the model as realistically as possible. The modelling method is embedded in an Interoperable Geoinformation System (IOGIS) which is built on top of an object-oriented database management system.

IGMAS allows easy integration of constraining data into the interactive modelling process by means of visualising and combining geodata with the density/susceptibility model. This visual combination of different 2D and 3D datasets enables quantitative comparison and adjustment and results in a model that is constrained by as much independently derived information as possible. The definition of 'geo-objects', which link geoscientific vocabulary with geometrical elements of the model, provides a

comfortable environment for discussions of interpretation in front of the computer monitor.

To demonstrate the capabilities of IGMAS, we present two examples. The first covers a large area in the southern part of the Northwest German Basin where a substantial database of constraining information includes geological maps, borehole data, vertical seismic cross-sections and depth information from seismic reflection surveys. The second example is a model that uses the database of the Collaborative Research Centre 267 Deformation Processes in the Andes.

Based on these Andean data, comprehensive 3D density models have been constructed. Because of the integration of a wide range of constraints, these models have a high degree of compatibility with structural (geological) information.

### Simple levelling of frequency-domain helicopter electromagnetic data using ground-truth measurements

*I.J. Wilson and J.E. Reid*  
*School of Earth Sciences,*  
*University of Tasmania*

A subset of frequency-domain helicopter electromagnetic (HEM) data collected for the Western Tasmanian Regional Minerals Program was processed to remove levelling related errors. The electromagnetic data had already been processed to correct for drift, by removal of high altitude zero levels, and to remove obvious 'line busts' but it was thought that a degree of error remained, affecting quantitative interpretation of the data. Levelling was undertaken by means of ground-truth data gathered using DC resistivity techniques. The theoretical EM response was calculated above the layered earth resistivity model for each point, at the height of the nearest HEM measurement, and these values used as reference points from which to adjust the rest of the dataset.

Significant along-line improvements in the quality of the data were shown to result, expressed as improvements in the conductivity-depth images (CDIs) produced

from the corrected data. These post-levelling CDIs can be seen to better reflect the inferred geology than those produced from the 'raw' data, and show good agreement with conductivity-depth sections produced from surface transient electromagnetic data. Some improvement to the plots of HEM apparent resistivity calculated with an Inphase-Quadrature algorithm have also been shown to occur, with improved data quality leading to less null points in the post-levelling apparent resistivity maps. It has been concluded that the use of a limited number of ground-truth points (one per square kilometre, in this case) to level HEM data can improve quantitative interpretation of the data.

### Predictive modelling of seismic velocities in sediments

*Michael Wiltshire*  
*Wiltshire Geological Services*

Most sedimentary sequences are volumetrically dominated by shale, and in normally pressured sequences, depth-related changes in gross seismic performance are dominated by shale compaction, while departures from shale lithology are the source of higher frequency seismic performance variation. Seismic-critical matrix attributes (density, bulk and shear moduli) change systematically due to burial compaction. When available and reliable, wireline log P and S wave velocities and bulk density data allow extraction of shear and bulk moduli; analysis of these data yield characterisation of burial-related matrix compaction and elasticity changes. We continuously compute matrix bulk and shear moduli from matrix density (which is itself computed from shale compaction theory). Continuous prediction of matrix compression and shear wave velocities follows.

Wireline logs usually provide sufficient data to characterize the volume and lithology of departure from matrix material. Seismic p-wave performance of the mixed sequence is computed by transforming this departure into a measure of seismic performance which is added to the matrix P-wave estimate. Mixed sequence shear modulus and bulk density are computed using

conventional mixing theory, and seismic shear wave performance follows. Modelling of these data allow extraction of a complete suite of formation elasticity and hardness attributes, with numerous potential applications. In particular, where formation performance attributes extracted from seismic data are observed to significantly depart from those expected; those departures can then be interpreted qualitatively and quantitatively in terms of departures from assumed rock properties.

### Basic experiments of seismic while drilling using a percussion drill as an energy source

Toshiyuki Yokota<sup>1</sup>, Kyosuke Onishi<sup>2</sup>,  
Yasukuni Okubo<sup>1</sup>, Hirokazu Karasawa<sup>1</sup>,  
Tetsuji Ohno<sup>1</sup>, Akinori Ota<sup>1</sup>, and  
Tsutomu Kaneko<sup>3</sup>

<sup>1</sup> National Institute of Advanced  
Industrial Science and Technology  
<sup>2</sup> Graduate School of Engineering, the  
University of Tokyo  
<sup>3</sup> Furukawa Co. Ltd.

Seismic While Drilling (SWD) is a kind of seismic survey which utilising a drill bit as an energy source and the observation geometry is similar with Reverse-VSP. Since the method does not require an additional artificial seismic source, it is generally economical. However, conventional SWD, using drilling vibrations of rotary drilling, always implies potential problems such as low S/N ratio and poor data quality because of the insufficient energy power.

Since the percussion drilling excites stronger seismic energy than the conventional rotary drilling, it is promising as an SWD energy source. The main objective of this research is to estimate the

applicability of a percussion drill as an SWD energy source by conducting basic experiments which observe digging vibration of a percussion drill by the arrayed 3-component geophones deployed on the surface. The experiments revealed following results:

1. The total energy output of percussion drilling is about five times per unit time as compared with that of conventional rotary drilling.
2. Frequency contents of percussion drilling vibrations are widely spread between 10 Hz to 150 Hz with the central frequency about 20-50 Hz.

To sum up the results of the basic experiments, we conclude that percussion drilling is suitable as an SWD energy source because its vibrations have sufficiently strong seismic energy outputs and wide spectral coverage.



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Tel: (08) 8346 8277 Fax: (08) 8346 0924  
email: sologeophysics@aol.com  
Regional office: MT ISA.

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 Pty Ltd  
 Tel: (08) 9446 3039  
 Fax: (08) 9244 3714  
 Email: brian@resolutions-group.com.au

**EDITOR:** David Denham  
 7 Landsborough Street, Griffith ACT 2603  
 Tel: (02) 6295 3014  
 Email: denham@webone.com.au

**ASSOCIATE EDITORS:**

**Petroleum:** Mick Micenko  
 Email: micenko@bigpond.com

**Petrophysics:** Don Emerson  
 Email: systems@lisp.com.au

**Minerals:** Peter Fullagar  
 Email: p.fullagar@mailbox.uq.edu.au

**Book Reviews:** David Robinson  
 Email: david.robinson@ga.gov.au

**Web Waves:** Jill Slater  
 Email: jill.slater@geophy.curtin.edu.au

**ASEG HEAD OFFICE & SECRETARIAT:**

Ron Adams  
 Centre for Association Management  
 PO Box 8463  
 Perth Business Centre WA 6849  
 Tel: (08) 9427 0838  
 Fax: (08) 9427 0839  
 Email: secretary@aseg.org.au  
 Web site: <http://www.aseg.org.au>

**FEDERAL EXECUTIVE 2004**

**PRESIDENT:** Howard Golden  
 Tel: (08) 9479 0576  
 Email: howard.golden@wmc.com

**PRESIDENT ELECT AND PUBLICATIONS:**  
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 Tel: (08) 9385 9626  
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 Email: lisa.vella@wmc.com

**PAST PRESIDENT AND INTERNATIONAL AFFAIRS:**  
 Kevin Dodds  
 Tel: (08) 6436 8727  
 Email: kevin.dodds@csiro.au

**ASEG RESEARCH FOUNDATION:**  
 Phil Harman  
 Tel: (03) 9909 7699  
 Email: phil.harman@mineraldeposits.com.au

**MEMBERSHIP COMMITTEE:** Koya Suto  
 Tel: (07) 3876 3848  
 Email: koyasuto@optusnet.com.au

Helen Anderson  
 Tel: (08) 9273 6400  
 Email: handerson@fugroairborne.com.au

David Howard  
 Tel: (08) 9222 3331  
 Email: david.howard@doir.wa.gov.au

Barry Smith  
 Tel: (02) 9247 9324  
 Email: bsmith@mosaiccoil.com

**ASEG BRANCHES****ACT**

**President:** Ben Bell  
 Tel: (02) 6249 9828  
 Email: ben.bell@ga.gov.au

**Secretary:** Jacques Sayers  
 Tel: (02) 6249 9609  
 Email: jacques.sayers@ga.gov.au

**NEW SOUTH WALES**

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**Secretary:** Natasha Paton  
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**SOUTH AUSTRALIA**

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 Tel: (08) 8303 5377  
 Email: graham.heinson@adelaide.edu.au

**Secretary:** Tania Dhu  
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**TASMANIA**

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## New South Wales – by Naomi Osman

In July, Steve Webster presented a very interesting and informative talk entitled: *Use of potential field data and modelling to complement detailed geological mapping in the Braidwood – Goulburn area, NSW*. This and other branch presentation abstracts are available on the State Branch website.

NSW members featured strongly in awards presented at the ASEG-PESA Conference held in Sydney. Peter Hatherly (CSIRO) was presented the Lindsay Ingall Memorial Award for his contributions to geophysics in the coal mining industry. Dave Pratt and Zhiquan Shi (Encom) received the award for the Best Minerals Paper – entitled: *An improved pseudo-gravity magnetic transform technique for investigation of deep magnetic source rocks*. Simon Stewart (Fugro Instruments) received the Best Exhibit Award.

Five geophysics students were financially supported by the branch to attend the ASEG-PESA conference: Andrew Spyrou (Honours student, UNSW), Ramin Nikrouz (PhD candidate, UNSW), Brad Bailey (PhD candidate, Macquarie University), Bin Guo (PhD candidate, Macquarie University), Kathleen McMahon (PhD candidate, Macquarie University) and Carina Simmat (PhD candidate, Sydney University). Through the initiative of our Student Liaison

Officer and third year Geophysics Tutor – Carina Simmat, students from the Sydney University campuses were given approval to attend the conference for half a day at no charge, to sit in on paper presentations and peruse the exhibits. With Carina's encouragement, some of the almost unrecognisably well attired students were also successful in negotiating vacation employment.

Interstate or overseas visitors who are in Sydney on the third Wednesday of each month are more than welcome to attend our monthly meetings. The meetings are held at the Rugby Club, Rugby Place (near Pitt & Alfred St), starting at 5:30 pm.

## South Australia – by Graham Heinson

As a change from our evening meetings, the SA Branch was involved with two lunchtime talks in July. On 21st July, we hosted the SEG 2004 Spring Distinguished Lecture by William L. Abriel: *Earth Model Complexity and Risk Description in Resource Exploration and Development* at the Medina Grand Treasury Adelaide. The following week, on 29th July, PESA and ASEG co-hosted the ESSO Distinguished Lecturer Presentation: *Recent Advances in Deep Water Sequence Stratigraphy and Reservoir Prediction*, by Professor Stephen Flint of the University of Liverpool, at the Mercure Grosvenor Hotel.

The SA Branch took an innovative step in promoting this year's national ASEG wine offer. The arduous tasting process undertaken by the local branch was brought forward to July, so that the selected wine could be advertised at the ASEG-PESA Conference and Exhibition in Sydney 15th – 18th August. At the exhibition, a dozen bottles of each wine (Chapel Hill Shiraz and Leconfield Riesling) were offered in a free raffle.

In spirit of the Olympic Games, gold, silver and bronze draws were made: gold winners receiving one bottle of red and one bottle of white wine; silver winners receiving one bottle of red; and bronze winners receiving one bottle of white wine. The 20 winners spanned a broad cross-section of the geophysical community, including Canadian and Australian explorers, Texan, Singapore and Australian service providers, local researchers, contractors and publishers.

A flyer for the wine offer was also made available at the conference and is included in this edition of *Preview*. Another fine selection is offered this year, to match the quality of previous years. The Chapel Hill McLaren Vale Shiraz 2000 is offered at \$155 per dozen and Leconfield Coonawarra Riesling 2004 at \$115 per dozen. The offer will close on 12th November 2004 ready for delivery well before Christmas.

## New Members

The ASEG welcomes the following new members to the society. Their membership was approved at the Federal Executive meetings on 28th July and 25th August 2004.

Name	Organisation	State	Name	Organisation	State
Eddie Peter Butt	Landmark Graphics	WA	Prasanth Nallanchakravartula	Halliburton	WA
Kevin James Cahill	Geoscience Australia	WA	Joshua Sebastian Newman	Curtin University	WA
Astrid Carlton	Alpha Geoscience	NSW	Geoffrey David Peters	W.M.C.	WA
Richard Chopping	University of Tasmania	Tas	Hasan Sidi	Fugro - Jason Australia BV	WA
Susannah Elvey	ARC Energy	WA	Mark Stanley	BHP Billiton	WA
Lachlan Henry Gibbins	Adelaide University	SA	Shaun Regen Strong	Velseis	Qld
Shawn Gregory	Woodside	WA	Andrew John Watts	Fusion Oil & Gas	WA
			Robert Weeden	Strike Oil Limited	WA



## Jill Slater to write WebWaves

We would like to welcome Jill Slater to the Preview team. Jill will write the WebWaves column and in this issue she examines sites



that provide information on career options in the geosciences; a very important topic for both educators and students.

Jill Slater is presently completing her BSc (Hons) in Geophysics (Petroleum) at Curtin University of Technology in Perth. Her honours project is entitled: *Appraisal of fault connectivity and reactivation potential, Laminaria High, North West Shelf: implications for the preservation of hydrocarbons.*

Jill worked for Amity Oil for two and a half years (2001-2004) as a geophysical assistant, and is looking forward to joining Santos as a graduate geophysicist in 2005.

We would also like to thank Margarita Norvill who has done a great job writing this column since April 2003.

## Careers in Geosciences

Most people are familiar with the angst a lot of young people face when trying to make decisions about their future career. Despite the efforts of schools to educate students about all the career opportunities that are available, many are not fully aware of the challenging, rewarding and the variety of career opportunities available in the field of geosciences. How often have you had to explain to friends, family or even colleagues, what a geophysicist does? Broadly speaking, the general public is uninformed about career opportunities available in geosciences. It is no wonder school leavers and undergraduate students find it so daunting, deciding what career path to take.

In addition to the traditional areas of mining and exploration, geologists and geophysicists are employed in areas such as

hazard monitoring, coastal management, urban and rural planning, environmental management (e.g. Salinity management), and water resource exploration and management. There are also numerous research opportunities available to work for academic institutions and government departments.

There is an increasing number of geoscience related companies and organizations who recognise the need to educate young people in the career opportunities available in the field of geoscience. There is a multitude of websites existing that are aimed at promoting geoscience to school age students through to post graduate students. I believe all geoscience professionals should make an effort to promote geoscience as a dynamic, diverse and rewarding career. It is important, despite the cyclic nature of the industry, to maintain a steady flow of new graduates into the work force. If you know of students who are indecisive of their career pathway, or people who are interested in or are studying the geosciences, then point them in the direction of these websites:

**SEG Student Connections** ★★ ★ 1/2  
<http://students.seg.org>

### SEG STUDENT CONNECTIONS

The SEG Student Connection is an organisation set up by the SEG for students to learn more about their field, to develop their skills and to network with peers, educators, employers and experienced professionals. On their website, you will find some interesting articles relating to careers, which were published in The Leading Edge. Written by geophysicists, the articles give a personal view of their careers, and insight into the variety of jobs available. The site also has a basic animated introduction to geophysics under 'What is geophysics', and a detailed description of the role of a geophysicist.

It's worth noting that *SEG student membership is free*, and offers members access to the online journal archives of Geophysics and The Leading Edge. You will find links to the application form under the SEG and Students tab.

**Environmental & Engineering Geophysical Society** ★★ ★ ★  
<http://www.eegs.org/whatis/>



EEGS is an organisation that promotes the science of geophysics, especially as it is applied to environmental and engineering problems. Their website devotes a page to 'What is Geophysics?' This page gives a comprehensive introduction to the field of environmental and engineering geophysics, with links to websites for more detailed information. This site includes descriptions of geophysical methods, data interpretation and even the costs of geophysics in environmental and engineering surveys. Given that this site is not hosted by a minerals or petroleum organisation, it gives a refreshing insight into unique applications of geophysics.

**Geological Society of Australia – Careers in Geosciences** ★★ ★  
<http://www.gsa.org.au/education/careers.htm>



The best feature of this site is the extensive list of contact information and links to international and national geological societies, recruitment agencies and employment contacts. A must see for students, graduates and professionals seeking employment in the geoscience industry. The site also includes links to educative sites for secondary schools.

**Minerals Council of Australia** ★★ ★ 1/2  
<http://www.minerals.org.au/careers>

The Minerals Council of Australia has recently launched a website devoted to careers in the minerals industry. The site explores a range of jobs available in the minerals industry, which are grouped according to the type of workplace. Some of them include corporate, laboratory, underground mine, processing and exploration site. Under each workplace is a choice of 2-4 careers, each with a job description, a question and answer style job profile and information on education and training. I found this site most easy to navigate using the site map.

### **The Chamber of Minerals and Energy of Western Australia: Your future Your Choice** ★★★★★

<http://www.cmewa.com/careers/index.html>



The Your Future Your Choice website is about empowering young people to make their own decisions about their choice of career. It encourages them to evaluate their talents, their favourite subjects, and their desirable future lifestyle to make an informed decision about their choice of career. Aimed at high school age students, it exposes them to a huge range of jobs available in the minerals industry. This website features career profile videos, careers by school subject, A-Z of careers in the industry (over 100 of them!), with detailed job descriptions, typical salaries and much more. This one has everything. Well worth a look.

### **The Australasian Institute of Mining and Metallurgy** ★★★★★

<http://www.ausimm.com/education/professions.asp>



The Australasian Institute of Mining and Metallurgy is an organisation which represents professionals in the minerals and associated industries.

Their website has a section designed for students, which covers a broad range of topics relating to careers. There is advice on networking, finding vacation work, information on student conferences and scholarships, as well as a number of useful career links. The site describes various mining related careers, giving information on the job description, career opportunities and suitability. There are several career profiles for each job type, where the interviewee answers questions like what made them choose their career, what they most like/dislike about their job, and then some advice to students.

### **Queensland University of Technology School of Natural Resource Sciences: Careers in Geoscience** ★★★

<http://nrs.sci.qut.edu.au/careers/geoscience/index.jsp>

The School of Natural Resource Sciences, a division of the Queensland University of Technology has a page dedicated to careers in geoscience. Some of the career descriptions include hydrogeology, engineering geology, exploration geology and environmental science. The page also includes four job profiles of past students, where they give a brief description of their job responsibilities, why they like their job,

and how their geoscience degree has prepared them for their career.

### **Minerals Council of Australia: Industry Experience for Undergraduates** ★★★★★

<http://www.minerals.org.au/ieu>

The IEU Website is an on-line recruitment program, run by the Minerals Tertiary Education Council, which introduces students who are seeking work experience to employers in the minerals industry offering job placements. Registration is free, and students are contacted when new jobs are advertised. Students apply online (usually takes about 10 minutes), and employers can then source, screen, shortlist and contact students online. The IEU Website is utilized by various companies including Xstrata, Rio Tinto, Newmont Australia, Roche Mining and BHP Billiton. The site also includes information on careers, scholarships and has direct links to participating company websites.

#### **Star Rating**

Content/information available on web pages	2
Navigation friendly	1
Aesthetically Pleasing	1
Currency	1
<b>TOTAL</b>	<b>5</b>











## Sons of Gwalia calls in Administrators

On 29 August 2004, the 3rd largest gold producer in Australia called in Administrators to deal with liabilities totalling approximately \$862 million.

How a company that produces upwards of 15 tonnes of gold and over 50% of the world's tantalum on annual basis could become suddenly insolvent is reportedly being investigated by the ASX and ASIC. There could also be questions asked to Peter and Chris Lalor who founded Sons of Gwalia in 1983 and left the company in April this year.

Since 1983 the company has produced approximately 150 t of gold from its three key gold producing regions, all in WA, - Leonora, Southern Cross and Laverton. Each region consists of a number of open pit and/or underground mines that supply ore to a central processing facility.

Sons of Gwalia is the world's largest producer of tantalum concentrate from its two West Australian mines, Greenbushes and Wodgina, that together contain approximately 75% of the global tantalum reserve base and produce over 50% of global tantalum demand. Since 1991, the company has sold all of its tantalum production to two customers, Cabot Corporation of the USA and HC Starck, a division of the Bayer Group in Germany.

In essence however, the main problem for Sons of Gwalia was due to the company not

being able to supply enough gold to meet its hedging commitments.

At face value, the company looked to be sound after the 2002/03 result; it produced 18 t of gold and 950 t of tantalum in that financial year. At 30th June 2003, gold reserves were estimated as 102 t with an additional 264 t of gold resources and tantalum reserves were 49 000 t with an additional 47 000 t of tantalum resources. However, it is evident that the rate of production was not enough.

The share market has, since mid-2002, continually discounted the value of the company. Its market value rose to a maximum of approximately \$1.4 billion for a very short period in 2002 and from being the 81st largest company on the ASX in February 2002, it dropped out of the top 150 company list in October 2002. In August this year it only had a market capital of approximately \$200 million. The Figure below tracks the market capital value from July 2000 until October 2002, when it dropped out of the top-150 list.

## Havilah Resources finds Cu-Au in the Curnamona Craton SA

Havilah Resources has announced some encouraging results from its Kalkaroo and North Portia prospects approximately 100 km west of Broken Hill in the Curnamona Craton, South Australia.

The Curnamona Craton is a world class Proterozoic basemetal-gold province, that hosts the massive Broken Hill basemetal orebody and numerous other promising prospects, but so far, because of the ubiquitous regolith in the region, exploration has been difficult

In the Kalkaroo prospect a 78 m section containing an average 0.90% copper, 0.61 gm/t gold and 544 ppm molybdenum, between 102m and 180m was encountered. Within the 78 m section was 33 m of higher grade copper and gold, averaging 1.8% copper and 0.96 gm/t gold between 111 m and 144 m.

The Kalkaroo drilling program was based around testing a potential copper resource outlined by Havilah's 3D modelling of

earlier data from exploratory drilling undertaken by majors including Placer, Newcrest and MIM.

In the North Portia prospect, 40 km from Kalkaroo, a 36 m section was recovered containing 0.82% copper and 1.0 g/t gold from one of the drill holes. This intersection came from within a 96 m core that averaged 0.52 % Cu and 0.59 g/t Au. Another hole on the same prospect intersected 24 m assaying 1.26% Cu and 1.0 g/t Au between 84 m and 108 m.

These successes follow a string of strong copper-gold intersections on the prospects, which were previously explored by the Pasminco-Werrie Gold joint venture.

## Tanami boosted by high-grade Kookaburra hits

Tanami Gold NL has received a boost from drilling at its Coyote Project in the western Tanami region, with drilling at the Kookaburra and Sandpiper deposits highlighting the potential for an increase in resources.

The Perth-based gold group said the latest high-grade intersections should add considerable value to the resource for treatment at the Coyote Gold Project, which comprises high-grade gold resources totalling 18 tonnes at Coyote and the nearby Sandpiper/Kookaburra deposits, 35 km north of Coyote.

The best intersections from Sandpiper included 16 m at 9.5 g/t gold from 8m, 10 m at 4.8 g/t from 17 m and 3 m at 4.4 g/t from 129 m; very encouraging.

## De Grey Mining also announces good gold values

De Grey Mining has advised that recent resource definition drilling at Wingina Well, 60 km south of Port Hedland, has intercepted high grade gold in plunging shoots to vertical depths of approximately 150 m.

The best of these holes intercepted 13 m at 8.0 g/t from 62 m and a further 32 m at 2.5g/t from 82 m; another promising discovery.

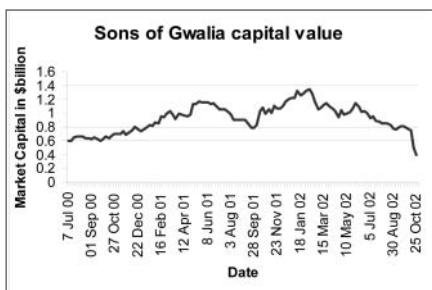


Fig.1. Value of Sons of Gwalia from July 2000 until it dropped from the top 150 companies list in October 2002. Its value in mid-2004 was about \$0.2 billion. The decline in value was due to the fall in the price of tantalum and the difficulties caused by not producing enough gold to meet its hedging commitments. Data obtained from the Sydney Morning Herald's 150 largest companies on the ASX.





# Australia's research investment unimpressive

The Australian Bureau of Statistics released the 2002/03 data on Australia's Gross Expenditure on R&D (ABS 8112.0 - GERD) and the Business Expenditure on R&D (ABS 8104.0 - BERD) in September 2004. The results are not impressive, particularly as the economy is supposed to be at its strongest ever.

## GERD

The GERD estimates are only published every alternate year, so it is not possible to make a full comparison with BERD. However, in 2002/03 the Australian GERD was estimated to be \$12,250M at current

prices, 17.6% higher than that recorded in 2000/01 (less in real terms although ABS haven't provided an adjusted figure).

The largest increase was in the Higher Education sector which increased from \$2.7 billion to \$3.4 billion (however the actual R&D number for this sector remains contentious because the Government makes certain assumptions about how much time academics actually spend on research - thus it is widely believed that this component is consistently overstated). Table 1a shows the results from the last four surveys. Although the contributions are similar in percentage terms (Table 1b), it is clear that the

Commonwealth Government's share has declined steadily over the last six years. The large drop in the States' contributions is unexpected given the recent incentives by the States to provide major capital works funding for R&D infrastructure.

GERD as a percentage of GDP has risen from 1.55% in 2000-01 to 1.62% in 2002-03. However, the GERD/GDP ratio remains low compared with other OECD countries. Table 2 lists some of these; Australia is clearly not a high flyer and there is huge room for improvement. If we don't get cracking now when governments are running substantial surpluses, it may be too late.

## Research activity sectors

Experimental development in 2002/03 remained the predominant activity for GERD, accounting for 38.6% (\$4,727M) although this proportion was down from 39.5% in 2000/01. The proportions of GERD on the other activities were:

Applied research 35.7% (\$4,379M), up from 34.7% in 2000/01;

Strategic basic research 15.5% (\$1,904M), virtually unchanged from 15.6% in 2000/01; and,

	1996-97	1998-99	2000-01	2002-03
<b>Business</b>	4,234.7	4,094.7	4,982.6	5,978.6
<b>Govt-Commonwealth</b>	1,266.6	1,179.4	1,404.8	1,531.3
<b>Govt - State/Territory</b>	797.7	863.6	951.0	950.9
<b>Higher Education</b>	2,307.6	2,555.1	2,789.8	3,429.6
<b>Private non-profit</b>	185.8	225.3	289.0	359.5
<b>Total</b>	<b>8,792.4</b>	<b>8,918.1</b>	<b>10,417.1</b>	<b>12,249.9</b>

Table 1a: Gross Expenditure on R&D (\$M)

	1996-97	1998-99	2000-01	2002-03
<b>Business</b>	48.2	45.9	47.8	48.8
<b>Govt-Commonwealth</b>	14.4	13.3	13.5	12.5
<b>Govt-State/Territory</b>	9.1	9.7	9.1	7.8
<b>Higher Education</b>	26.2	28.6	26.8	28.0
<b>Private non-profit</b>	2.1	2.5	2.8	2.9

Table 1b: Percentage breakdown of the main sectors

	2000-01	2002-03	Change
Finland	3.40	3.46	0.06
Japan	2.99	3.12	0.13
Iceland	2.75	3.09	0.34
Korea	2.65	2.91	0.26
USA	2.72	2.67	(0.05)
Germany	2.49	2.52	0.03
Denmark	na*	2.52	na*
France	2.18	2.20	0.02
Austria	1.86	1.93	0.07
Canada	1.92	1.91	(0.01)
United Kingdom	1.84	1.88	0.04
Norway	na*	1.67	na*
<b>Australia</b>	<b>1.55</b>	<b>1.62</b>	<b>0.07</b>
Czech Republic	1.33	1.30	(0.03)
Spain	0.94	1.03	0.09
Hungary	0.80	1.02	0.22
Portugal	0.80	0.93	0.13

na\* not available

Table 2: GERD/GDP for OECD countries\*

\*These tables list OECD countries with comparable data - not all OECD countries are listed. Source for the above tables is ABS 8112.0 Research and Experimental Development, All Sector Summary, Australia (13/9/04)

	2000-01	2001-02	2002-03
Finland	2.41	2.42	2.41
Japan	2.12	2.26	2.32
Korea	1.96	2.23	2.18
United States of America	2.04	2.00	1.87
Iceland	1.55	1.80	1.77
Germany	1.75	1.75	1.75
Denmark	na*	1.65	1.75
Belgium	1.48	1.60	1.64
France	1.41	1.36	1.37
United Kingdom	1.21	1.24	1.26
Canada	1.21	1.15	1.05
Netherlands	1.10	1.11	1.03
Norway	na*	0.96	0.96
<b>Australia</b>	<b>0.74</b>	<b>0.81</b>	<b>0.79</b>
Czech Republic	0.78	0.80	0.79
Spain	0.50	0.50	0.56
Italy	0.53	0.55	0.54

na\* not available

Table 3: BERD/GDP for OECD countries

Pure basic research 10.1% (\$1,240M), virtually unchanged from 10.2% in 2000/01.

In 2002/03, the Higher Education sector accounted for 78.6% (\$975M) of expenditure on pure basic research and 42.2% (\$803M) of expenditure on strategic basic research. It was the main contributor to each of these activities.

The business sector accounted for 35.2% (\$1,540M) of expenditure on applied research and 85.5% (\$4,040M) of expenditure on experimental development activity and was the main contributor to each of these activities.

## BERD

As shown above, Business Expenditure on R&D in Australia in 2002/03 was estimated to be \$5,979M at current prices, 3.6% higher than that recorded in 2001/02. This is the highest level recorded and is the third successive year of increase following the declines from 1995/96 to 1998/99 and the levelling off between 1998/99 and 1999/2000.

However, as the President of FASTS, Snow Barlow, said, "the decline in BERD as a percentage share of GDP was a disturbing result in view of the buoyant state of the national economy."

"The ABS figures show that BERD has declined as a percentage share of GDP from

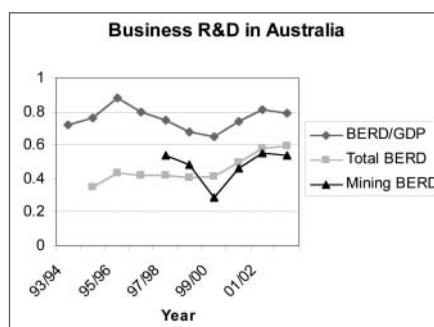


Fig. 1. R&D expenditure in Australia; BERD/GDP in %; total BERD in \$billion/10 (in current \$); Mining BERD in \$billion (in current\$).

0.81% in 2001/2 to 0.79% in 2002/3. Australia's national investment in R&D is declining relative to OECD averages and today's ABS figures confirm the gap is widening."

"Australia's strong GDP growth is not sustainable while Australia's national investment in R&D continues to decline as a percentage of GDP."

"Governments cannot simply rely on record consumer spending to underpin GDP growth.

For 14 years Australia's strong economic growth has been built on financial and labour market reforms but there are diminishing returns with this approach. Economic growth in the global economy is increasingly dependent on the quality and capacity of the science and technology knowledge base."

"The ABS results follow this year's budget figures, which show Government investment in R&D is projected to fall to 0.62% of GDP in 2004/05 – down from 0.66% in 2002/03. The Coalition and Labor must offer the electorate credible policies that prioritise building our national investment in R&D", concluded Professor Barlow.

Table 3 shows where Australia stands with respect to other OECD countries and Figure 1 shows how we have tracked since 1993/94.

Investments in the mining/resource sector have declined from \$553M in 2001/02 to \$536M in 2002/03. By itself this is not cause for concern; the real worry is that the number of research personnel has fallen from 836 to 608 in the same period.

In 2000/01, 1194 people were devoted to R&D, so the number has almost halved in three years. However, the number of businesses undertaking research has increased from 92 in 2000/01 through 119 in 2001/02 to 137 in 2002/03.

This indicates a major restructuring of the research profiles in this sector, indicating that the large national and multi-nationals are cutting down on their research efforts in Australia.

As expected the 'experimental development' category dominated the BERD activity, and accounted for \$338M of the \$536M total being invested; 'applied research' with \$153M was next and basic research was last at only \$45M.

*Cont'd on page 25*

These numbers are consistent with the optimism shown by the Gold Council, which in September estimated that more than \$8.1 billion will be invested on capital works, exploration and operational activities in 2004-5.

However, Deloitte Tax Partner Greg Fitzgerald said the survey had also revealed that gold exploration activity was lagging behind gold industry investment in capital works and operations.

Exploration activity still accounts for just 3.3% of total gold investment activity, dwarfed by investment in capital works and

operations, and if exploration levels stay that low, Australia will be unable to sustain current gold production and investment levels.

In the first six months of 2004, the gold production has only reached 127 tonnes, well down on the 155 tonnes produced in the same months during 1998.

## Petroleum

As expected, petroleum exploration expenditure returned to near-normal levels in June quarter 2004, after low levels in the March quarter. The increase was \$87.6M (51.9%) over the previous quarter, and amounted to \$256.4M.

Expenditure on both production leases (up \$18.7M or 87.4%) and all other areas (up \$68.9M or 46.7%) increased this quarter.

Western Australia dominated the numbers. It recorded a large increase of \$90.6M over the last quarter's results, to a massive \$197.5 M or 77% of the national total.

Offshore exploration had a strong increase of \$83.3M (72.0%), while onshore exploration expenditure increased by \$4.2M (7.9%). Figure 5 shows the time series over the last 29 years. Surprisingly, even with the large increase in the oil price since the Iraq war, there has been no long term upward trend in exploration activity.





# 175 Years Ago

## Some underground exploration by Robert Were Fox (1789–1877)

On the 10th June 1830 the President of the Royal Society of London presented a paper at the regular society meeting; it was titled *On the electro-magnetic properties of metalliferous veins in the mines of Cornwall* and had been submitted by Robert Were Fox of Falmouth, Cornwall. This historic paper in exploration geophysics reported Fox's pioneering underground measurements on the self-potential (SP) of mineral veins in a number of mines in Cornwall. Two paragraphs from the paper are worth repeating.

"My apparatus consisted of small plates of sheet copper, which were fixed in contact with ore in the veins by copper nails, or pressed closely against it by wooden props, stretched across the 'levels' or galleries. Between two of these plates at different stations, and a galvanometer, a communication was made by means of copper wire one-twentieth of an inch in diameter, which was at first coated with sealing-wax; but afterwards this precaution was dispensed with ..... In some instances nearly 300 fathoms of copper wire were employed.

"The intensity of the electro-magnetic action differed greatly in different places: - in some cases the deviation of the needle was inconsiderable, in others it went completely round the circle. In general it was greater, ceteris paribus, in proportion to the greater abundance of copper ore in the veins, and in some degree perhaps to the depth of the stations; - and where there was little or no ore, there was little or no action. Hence it seems likely that electro-magnetism may become useful to the practical miner in determining with some degree of probability at least, the relative quantity of ore in veins, and the directions in which it most abounds."

In his paper, Fox illustrated over 20 examples of underground SP surveys that he had made (mostly with his brother) and one example is included here of the Main Lode

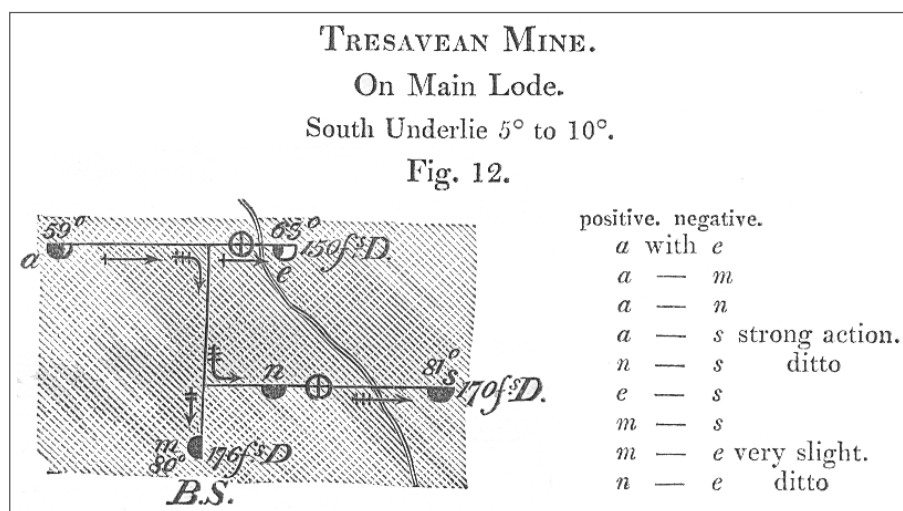


Fig. 1. An example of one of Fox's vertical SP sections. Note his words "strong action" for SP responses across the spreads 'a - s' and 'n - s'. In both instances the copper bearing vein was crossed.

of the Tresavean Mine (see Figure 1). Fox described his illustrations well and in this case he indicated the main mineralised copper vein with a double freehand line. He also indicated the location of his galvanometer with a 'Ø' symbol and the location of his copper plates with half circles with them being 'shaded in proportion to the richness of the veins'. His SP measurements, showing the direction and relative strength

of 'positive electricity through the wire', were indicated by arrows with a varying number of crossmarks. Temperatures were shown in Fahrenheit degrees and Fox, for some reason, which may have been standard practice, used the fathom as his unit of measurement for distances and depths. The initials 'B.S.' in his illustration indicated the bottom of the shaft.

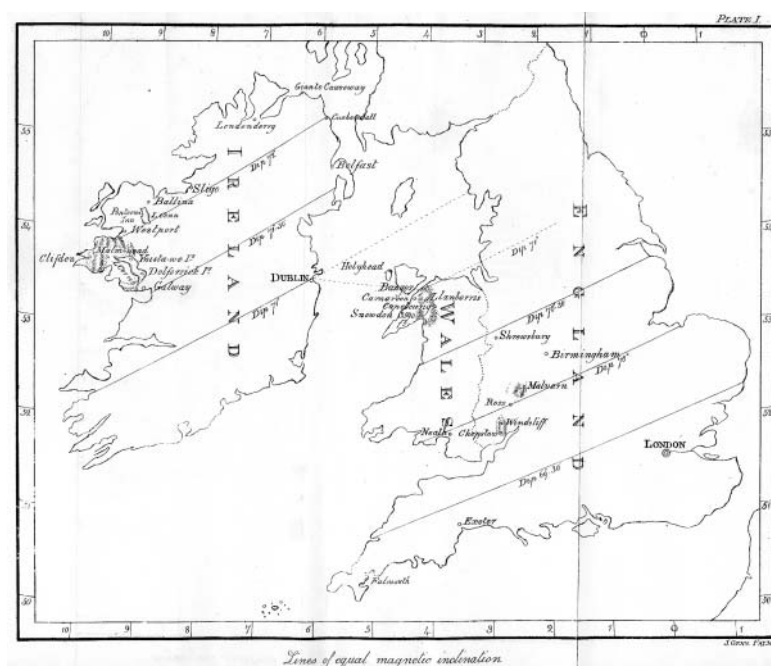


Fig. 2. Fox's 1835 map showing lines of equal magnetic inclination over the UK (see text for more details).

## Other scientific and geophysical work by Fox

Fox's self-potential surveys in the Cornish mines were not his first scientific forays into the mines, for in 1812, at the age of 23, he had worked with his friend, Joel Lean, in improving the design and efficiency of the Watts-built high-pressure steam-driven mine pumps and later (1822) he is importantly credited with being the first to prove conclusively that heat increases with depth and that it also increases 'in a diminishing ratio as the depth increases'. Fox had commenced his detailed temperature measurements by imbedding thermometers in mine walls from as early as 1815.

By the early 1830s Fox had extended his interest to the measurement of terrestrial magnetism – he became particularly interested in instrumentation and actively did something about improving both existing instruments and measurement standards. His paper *Description of some improvements in the Dipping Needle Deflector, together with a Chart and Table of the Dip, and Intensity, of the Terrestrial Magnetism in some parts of England, Ireland, and Wales* appeared in the 1835 Report of the Royal Cornwall Polytechnic Society, where he describes his newly built dip and magnetic intensity instrument and then goes on to list measurements he made with it in England, Wales and Ireland. His published measurements were regionally scattered and were, along with those made by James Clark Ross, Humphrey Lloyd, John Phillips and Edward Sabine, used to produce the first "magnetic map" of Great Britain and Ireland (Sabine, 1839).

Fox's first dip measurements in Wales and Ireland confused him somewhat and the contour map he constructed from his measurements, reproduced here, shows an offset in the 71° contour across the Irish Sea (see Figure 2). Fox went to great lengths in his paper to explain the cause for this discrepancy. It is a classic example of insufficient data.

Fox's combined dip and intensity instrument<sup>2</sup> became the instrument of choice for many, including the Royal Navy, where they were the standard issue dip circles on HM survey vessels for a number of decades.

## Fox's instruments down under

In the early 1840s James Clark Ross and Francis Crozier on their historic voyage to Antarctica in the ships *Erebus* and *Terror*, acquired dip and intensity measurements using Fox instruments (both ships carrying them) and in the process proved Gauss's theoretical position of the Magnetic South Pole, something they had set out to do. The instruments were also used to tie their newly constructed magnetic observatories at St. Helena, Cape Town and Hobart<sup>3</sup> to those in Great Britain and Europe. On the 15th July 1841 during a short stopover, Ross and Crozier also made a series of onshore measurements with the Fox instruments at Garden Island, Sydney.

A later Fox-designed instrument was used to map the offshore magnetic anomaly near Bezout Island, Western Australia circa 1890 (see *Preview* 110, June 2004). A number of famous polar expeditions carried Fox dip

circles including John Franklin's tragic NW Passage expedition and the Nares' expedition to the Arctic in 1875-76.

The original 1834 Fox Dip and Intensity Circle is currently held by the Science Museum in London.

Robert Were Fox was a pioneer in mineral exploration, and his work in applied geophysics entitles him to be remembered for this alone, but as it turns out he is more remembered along with his family, for their wonderful gardens, now open to the public, at Penjerrick and Rosehill, Falmouth; two of the finest gardens in southwest England. But that's okay.

## Reference

Sabine, E., 1839, Report on the Magnetic Isoclinical and Isodynamic Lines in the British Islands, from observations by Professors Humphrey Lloyd, and John Phillips; Robert Were Fox, Esq.; Capt. James Clark Ross; and Major Edward Sabine: Royal Society, London, 1839.

## Postscript

There is a possibility that the Cornish miners and engineers who came to South Australia in the 1830s and 40s (Kapunda, etc) may have brought Fox's SP technology with them – the author would appreciate hearing of any information that may suggest this.

<sup>1</sup> Thomson's Annals of Philosophy, On the Temperature of Mines 1822.

<sup>2</sup> The first being built by W. George of Falmouth.

<sup>3</sup> Ross, his crew and scientists were ably assisted in building the Hobart Magnetic Observatory by his old friend Lt. Governor John Franklin, interested residents and convicts – it was constructed (in stone) in just nine days.



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## Introduction to Geomagnetic Fields, second edition

Introduction to Geomagnetic Fields, 2nd Edition uses five chapters to introduce the reader to the Earth's magnetic field and its interactions with the solar-terrestrial environment. A small number of exercises are included at the end of each chapter for the benefit of astute readers who would like to challenge their understanding of the material.

Chapter 1 'The Earth's main field' sets the scene by describing terminology and covering the fundamentals of magnetism. Topics such as the dipole field, the source of the Earth's main field and the representation of the field are all covered.

Chapter 2 'Quiet-time field variations and dynamo currents' describes the components of the magnetic field that can be measured on a normal or quiet day. Daily variations, the ionosphere, spherical harmonic analysis and lunar effects are all introduced.

Chapter 3 'Solar-terrestrial activity' discusses the complex field generator that is our Sun.

Sunspots, coronal holes, mass ejections, solar wind and geomagnetic storms are all described among other solar related activity. Campbell continues in this chapter by noting the effect that solar activity has on the terrestrial environment. In particular the deformation of the magnetosphere, ionospheric currents and auroras are all explained and monitoring techniques such as geomagnetic indices defined.

Chapter 4 'Measurement methods' describes the plenitude of observational techniques that are available to the modern day scientist and the historic explorer alike. The techniques discussed range from the bar magnet compass through to a variety of different magnetometers. The complexities of satellite based measurement of the magnetosphere are also explained.

Chapter 5 'Applications' covers the diverse range of ways that geomagnetism has impacted our lives. A discussion of induction in pipelines and electrical power grids, satellite damage and tracking, as well as disruption to communication systems and GPS, demonstrates how magnetic fields impact on the built environment. Campbell

describes the impact that magnetic surveying has had on our understanding of continental drift, conductivity of the Earth and the Earth structure. Finally the chapter concludes with a discussion of global monitoring and collaboration.

Introduction to Geomagnetic Fields discusses geomagnetic fields without relying heavily on mathematical detail. Whilst this limits its usefulness to the research community it makes the book more widely applicable as a general reference and starting point. As such I recommend Introduction to Geomagnetic Fields to advanced undergraduate and graduate students who are interested in geomagnetism but do not wish to wade through the detailed mathematics that is often associated with magnetism.

**Author:** Wallace H. Campbell  
Cambridge University Press, 2003, 337 pages, Paperback, A\$110  
ISBN: 0-521-52953-0



## COMPANY PROFILE

### UTS Geophysics: a brief company profile

UTS Geophysics is an airborne geophysical survey company, with its head office in Perth. Since incorporation in 1991, UTS has developed many new airborne geophysical techniques and has acquired and processed more than 3.0 million line-km of airborne geophysical survey data for exploration companies, government bodies and consultants both in Australia and around the world.

UTS Geophysics currently employs a approximately 25 full time and part time staff directly associated with the company's airborne geophysical survey division. It is acknowledged as a world leader in ultra-high resolution airborne geophysical surveys.

UTS Geophysics' range of services includes:



- fixed wing magnetics and radiometrics using specialised low level aircraft (Fletcher FU24 and Cessna 210 aircraft);
- ultra low level (<20 m), ultra detailed (20 m traverse spacing) fixed wing surveys, which were initiated in 1995;
- helicopter magnetics, electromagnetics and radiometrics using both stinger and towed bird mounted installations;
- airborne gravity acquisition and processing using the Canadian Micro Gravity GT1-A gravimeter; and

- high quality data processing, enhancement, mapping, imaging and presentation.

Currently over 500,000 line-km of ultra-detailed airborne surveys are flown and processed each year with surveys ranging from regional (400 m line spacing, 80 m height) to ultra-detailed surveys pioneered by UTS Geophysics (from 10 m line spacing and 10 m height).

It has recently been awarded a 175 000 line-km contract by the WA Government over the South Yilgarn Hyden-Southern Cross and Ravensthorpe-Newdegate-Bremer Bay areas of the South Yilgarn (see Geophysics in the Surveys, this issue)

This work follows on from the Kirkalocka survey flown from Mount Magnet in WA for Geoscience Australia and the GSWA. The picture shows the two Cessna 210 aircraft, which were used on this survey.

# FALCON™ – lessons on the commercialisation of technology

## Introduction

*FALCON™* is a story of technology breakthroughs, synergies, teamwork and success in achieving desired goals. It was a high risk, high reward research and development project, the successful outcome of which was then coupled with an innovative commercial model.

For the last 50 years airborne geophysical techniques, which allow rapid, low cost surveying of large areas, where access problems can be difficult and expensive, have been developed as one of the most important tools in the mineral explorer's armoury. During the 1990s cheap and effective magnetic, radiometric and spectral scanning techniques were further progressed by using GPS technology, advances in computer speed and power and improvements in instrumentation. Airborne EM also progressed rapidly with better instrumentation, visualisation and interpretation techniques.

High resolution, airborne gravity was the missing element, almost the Holy Grail for mineral explorers. Such a tool, in the form of a gravity gradiometer, would allow rapid detection and improved discrimination of mineral deposits, especially when coupled with other techniques such as airborne magnetics and EM. This is particularly the case in Australia (or similar terranes), where much of the continent is covered by a pervasive regolith, and where land gravity surveys are slow and expensive, even with the recent developments in GPS technology.

The technical challenges to achieving high resolution airborne gravity gradiometry appeared to be insurmountable. If we examine the gravity anomalies associated with major mineral deposits we can see that we need a system with sensitivity of around 10 Eö over approximately a 200 m resolution to achieve results that allow not only detection of these deposits, but also discrimination from other geological sources of gravity anomalies (Figure 1).

The main milestones in the development of the Airborne Gravity Gradiometer are shown below:

- 1970 Bell Aerospace US Navy GSS gravity gradiometer program
- 1989 Berlin Wall falls
- 1990 Discovery of Cannington Ag-Pb-Zn deposit

- 1991 BHP Billiton begins feasibility studies on Bell Aerospace technology
- 1996 Construction of *FALCON™* AGG system begins
- 1999 Demonstration airborne survey over the Bathurst Camp
- 2000 Two *FALCON™* AGG systems in routine operation
- 2004 Delivery of digital system

The fall of the Berlin Wall may appear to be an odd event in this succession, but without the end of the Cold War it probably would not have been possible to obtain the Bell Aerospace technology, which had been developed for the US Navy's nuclear submarines. We were able to use the window of opportunity between the Cold War and the War on Terror.

As a result of being able to adapt existing technology, there was a significantly reduced development risk with US\$200M having already been spent on the existing system. The reduced capital cost required to modify the system amounted to approximately US\$30M and the time frame from concept to production was only eight years.

The discovery of the Cannington Ag-Pb-Zn deposit near Cloncurry in Queensland (now the world's largest Ag deposit) under 40 m of Cretaceous cover, gave BHP Billiton the technical and exploration management resolve to pursue airborne gravity gradiometry. This capability was seen as a key element to driving further discovery of world class deposits under cover in similar settings across the globe.

Technical challenges were not the only ones to overcome, the project was nearly stopped a number of times during the eight year development period. Without an inspiring champion, we would have probably failed. As can be seen in Figure 2, BHPB shares did not perform well in the 1997/1999 period, and although the noise reduction in the gradiometer was spectacular, it was not a good time for R&D investment. This related to a number of events culminating at the time, including the Asia crises, Bre-X scandal and a number of failed projects within BHPB (many of which involved technological innovation).



Exploration Strategist,  
Minerals Exploration,  
BHP Billiton  
Melbourne, Victoria

tom.h.whiting@  
bhpbilliton.com



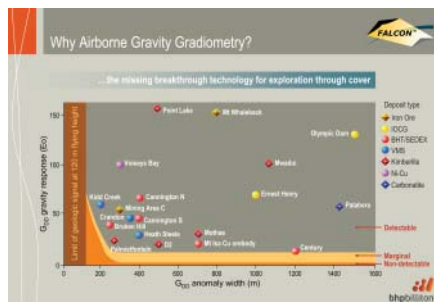


Fig. 1. Gravity anomalies associated with major mineral deposits.

## Commercialisation

There was also considerable debate concerning the commercialisation model for *FALCON*<sup>TM</sup>. *FALCON*<sup>TM</sup> was seen as a breakthrough technology, which many wanted to restrict to 100% proprietary use by the company. However the prize for the company was clearly a World Class deposit. As can be seen in Figure 3, World Class deposits (the core assets of BHP Billiton's business units) are hard to find and appear to be getting harder due to a combination of factors including exploration maturity in the historically explored terranes of the world.

This situation is confirmed in Figure 4, which shows that in the last 20 years the cost of finding World Class discoveries have increased dramatically. In fact, during this period there have been 16 World Class discoveries, 125 Large discoveries and 172 'Other' discoveries.

The high exploration risk had to be factored into the Business Plan we adopted. We considered three main options:

1. BHP Billiton flying and owning 100%;
2. Spin-out, contract back and earn royalties; and
3. Share the technology for a share of project equity.

We adopted the third option, to maximise the chance of a World Class discovery. This required a cultural change at exploration and senior management levels but has led to:

- Win-win deal structures for BHP Billiton & partners where:

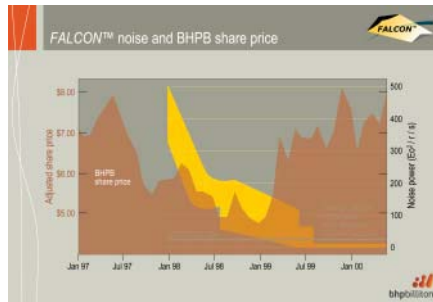


Fig. 2. BHPB's share price plotted against target specifications of 10 Eo at 200 m resolution and a flying cost of US\$50/km. Notice that the final specifications were better than the target specifications.

- BHP Billiton has buy back rights to World Class deposits
- Partners retain equity in World Class deposits and majority equity in others.
- Deal structures which have adapted to the minerals business cycle and competitor activity
  - Using a mixture of capability, reputation and technology to gain access to attractive ground held by others
  - Support for **Alliance Partnerships** through the public markets
  - Competitive advantage increasingly means *FALCON*<sup>TM</sup> has been combined with the generative core competence of BHP Billiton and key ground positions.

## Outcomes

As a result of these technical and commercial decisions we have achieved very successful outcomes in terms of surveys flown and system improvements.

Figures 5, 6 and 7 summarise the kilometres flown, deal structures, system improvements achieved and where and what commodities *FALCON*<sup>TM</sup> has been used to search for. Given the original specifications back in the late 1990s it is testament to the technical improvements that the main targets have been kimberlite pipes, which have small amplitudes and high frequency signatures. This was one of the less expected outcomes from flying the system.

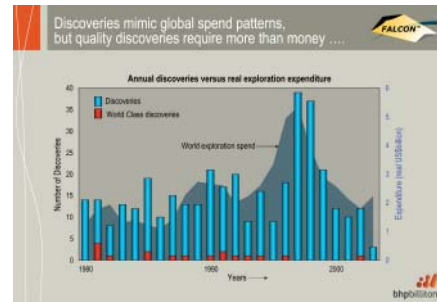


Fig. 3. Discoveries and World Class discoveries from 1980 - 2003. Notice that in this period the number of World Class discoveries has been slowly declining, but that overall the smaller discoveries follow exploration expenditure.

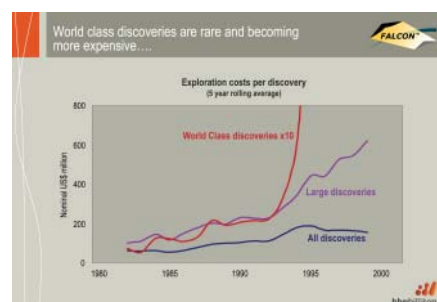


Fig. 4. World class discoveries are rare and appear to be becoming more expensive. This diagram shows the exploration costs for World Class, Large and All discoveries over the last 20 years.

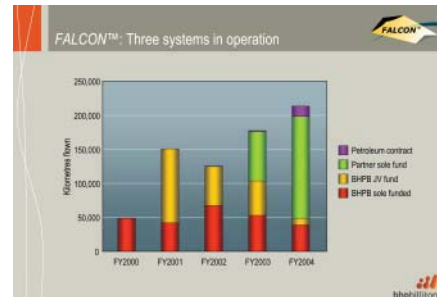


Fig. 5. Kilometres flown by *FALCON*<sup>TM</sup> in the last four years, with three operating systems. Notice the large increase in partner funded surveys.

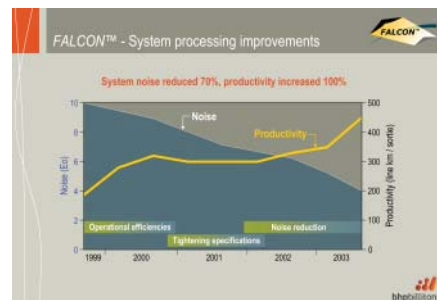


Fig. 6. System processing improvements during the last four years. Notice that the noise levels are now down to ~4 Eo, and the productivity levels have increased from 200 km to more than 400 km per sortie.

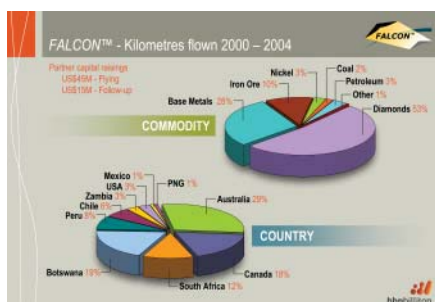


Fig. 7. The commodity/country mix for FALCON™ surveys during the last four years. Notice that more surveys have been carried out in Australia than any other country, and that diamonds are the main sort-after commodity.



Fig. 8. Locality diagram for the target areas in the Lower Cretaceous Iron Belt of Northern Chile. The green lines outline the tenement boundaries.

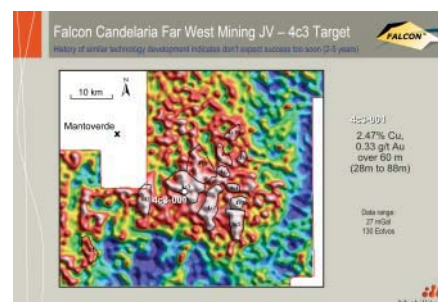


Fig. 9. Results of the FALCON™ survey near Mantoverde. The borehole 4c3-001 provided 2.47% Cu, 0.33 g/t Au over 60 m (28 to 88 m). The data range is 27 mGal and 130 Eö. Notice that the high anomalies coloured white are probably all attractive targets for drilling.

## An example from Chile

I would like to show some of the results from a FALCON™ / Candelaria /Far West Mining, Joint Venture in northern Chile. The JV is exploring for iron oxide copper gold deposits in the Lower Cretaceous Iron Belt (see Figure 8). The green lines define the main search areas. Figure 9 shows the results over the area near Mantoverde.

Although the results so far are very encouraging, history of similar technology development indicates that we shouldn't expect success too soon (two-five years).

## Key lessons

- Smart adaptation of an existing technology is much better than starting from scratch.
- One must have a powerful champion to see the whole project through to the operational stage.

- Develop a business plan that maximises chances of World Class discovery and spreads the risk
  - Major cultural change required to achieve this approach
  - Win-win deal structures have evolved with the minerals business cycle and competitor activity.
- Access to partners' ideas/innovation brought the most promising discoveries so far.
- Don't expect success before two-five years
- Necessity is the mother of invention
  - System and business plans are still evolving in response to exploration challenges and the business cycle
  - Noise levels reduced 70% and productivity increased 100% ....so far!

## The way forward

The way forward is to couple airborne gravity gradiometry with all other available sensing techniques on a single platform in the air; i.e. aeromagnetics, radiometrics, AEM etc.

The challenge is to then image and invert these data sets to allow better discrimination of ore deposits versus other geological features giving rise to geophysical responses. **Discrimination**, not simply detection, is the key! So imaging and joint inversion of multiple data sets is the way forward. This is the closest the minerals industry is likely to get to 3D seismic which (together with understanding of petroleum genesis) allows such rapid reduction in the risk profile for Petroleum versus the high risk inherent in Minerals exploration.

## Acknowledgements

Finally, I would like to thank, BHP Billiton, the many colleagues who have made Falcon possible, Far West Mining and BHP Billiton's Falcon partners.



# Experiences with Falcon®



Phil Harman  
Managing Director  
Gravity Capital Ltd  
Phil.Harman@  
mineraldeposits.com.au

## Introduction

I have been involved with the Falcon® since the late 1980s and today I would like to describe some of the recent results we have obtained in a number of different exploration environments.

I would also like to say a few words about my experience as an entrepreneur with Falcon®, and describe the business model we use to try and generate new exploration discoveries.

## Falcon® Gravity Gradiometer

Falcon®, is an airborne geophysical system that is being applied as an ore body detector and is also proving to be a powerful mapping tool. The gravity gradiometer is based on technology developed by Lockheed Martin for the US Navy at a cost of ~A\$400M. BHP Billiton has invested more than A\$50M since the early 1990s on the development. I would like to take this opportunity to acknowledge not only the scientists, engineers and technicians who worked on the project but also the people within BHP Billiton who championed and supported the project through difficult corporate times.

The high resolution gravity gradiometer is complemented by a stinger magnetometer, a GPS navigation system, a laser scanner and a radiometrics detector. These instruments are all housed in a Cessna Grand Caravan.

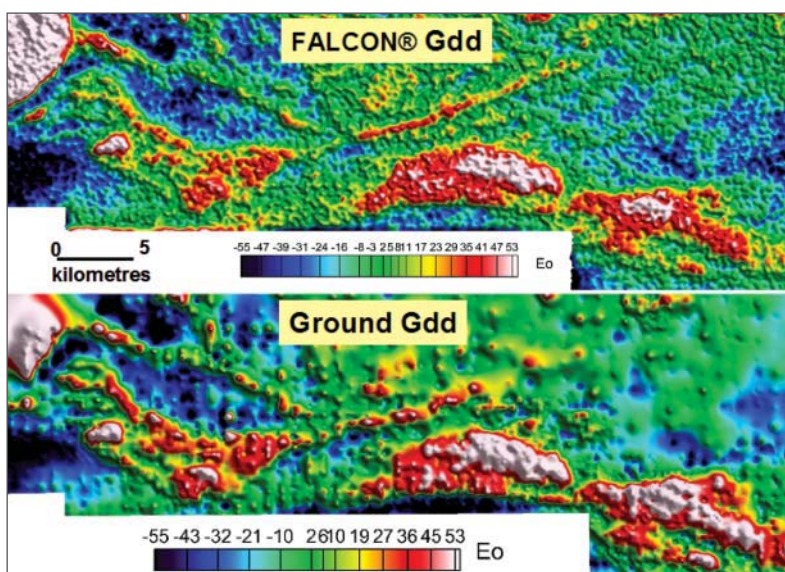


Fig. 1. Diagrammatical response over a simple source, which shows the two measured components Gne and Guv over a sphere. The components have complicated lobate responses, sensitive in the horizontal plane

The Falcon® gradiometer is described elsewhere. It uses complementary accelerometer pairs on a disc that rotates in the horizontal plane. Horizontal curvature gradients Gne and Guv are measured from which other components such as Gdd and gD are derived by transformation. Highly sophisticated signal processing is required to extract the signals and minimise 'noise' of accelerations created by turbulence and other vibrations.

The Falcon® gravity gradiometer system has been designed to target the top kilometre or so of crust. Unlike measuring gravity directly, it effectively maps the mass distribution around the aircraft and builds the picture to cover the longer the wavelengths (the larger deeper mass distribution) as the survey area expands. In general therefore it 'sees through' the long regional wavelengths that need to be removed from conventional gravity data, making targeting more directly intuitive. The basic curvature gradient components have lobes of sensitivity in the horizontal plane that make Falcon® ideal for mapping linear features, providing there is sufficient density contrast. Many Falcon derived maps directly highlight dykes and faults not obvious on normal gravity maps.

A diagrammatic representation of the processing stream is shown in Figure 2. Other than signal to noise ratio enhancement, accurate removal of the effect of terrain response is key to producing a geologically meaningful map. This is achieved through a terrain density model generated by data extracted from the laser terrain scanner.

Other systems (magnetics and radiometrics) receive standard data reduction schemes.

The basic capabilities of the Falcon® derived gravity gradiometer data are best illustrated by example. The resolution depends on signal to noise ratio at the wavelengths of interest. Signal to noise ratio is determined both geologically (strength of density

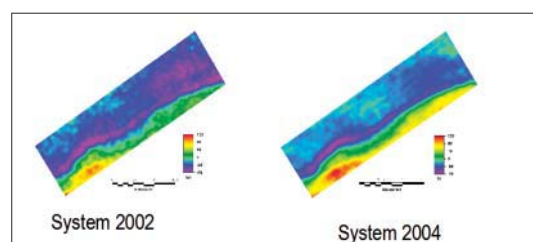


Fig. 2. The Falcon® processing system showing the standard outputs: Gz, Gzz, DEM, Magnetics and Radiometrics.

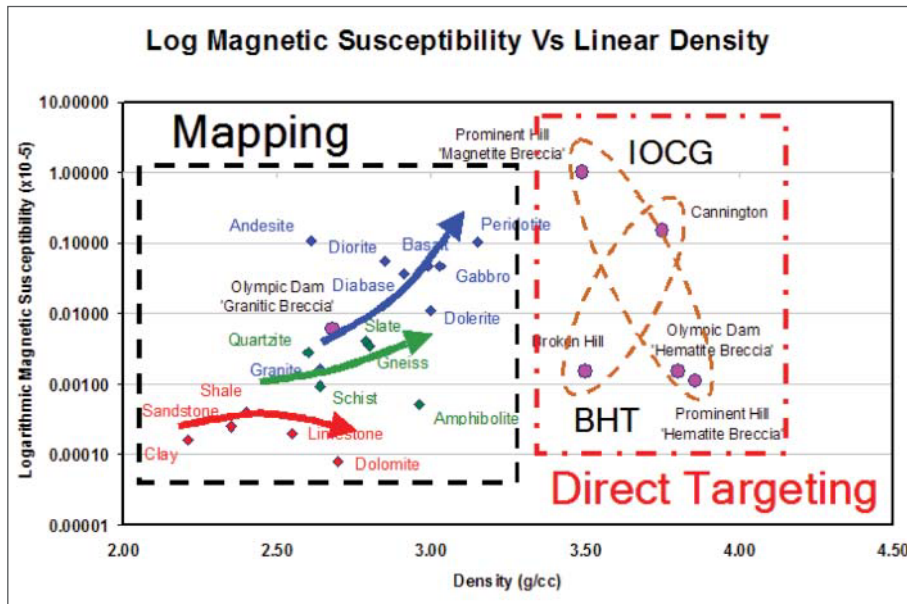


Fig. 3. An image of Gdd. Two north striking dykes separated by about 300 m are resolved. The data are equivalent to a ground survey with stations positioned on a 150 m grid. The airborne survey was flown at 80 m height with flight-line spacing of 100 m.

contrast) and by the system capabilities determined by the measuring instrument capabilities, data processing and survey design (line spacing, aircraft speed etc.).

Data shown in Figure 3 are from a survey flown in an exposed cratonic area in Canada. The survey was flown on east west lines 100 m apart at an average flying height of 80 m. The Gdd data maps two northerly striking dykes that are resolved from one another down to a spacing of about 300m. BHP Billiton estimates that under optimum conditions Falcon® derived data are equivalent to ground data collected on a 150 m square grid (ref BHP Billiton Falcon® brochure).

Figures 3, 4 and 5 give three examples of the present capabilities of the Falcon® gravity gradiometer.

A comparison between Falcon® derived Gdd data and ground data from an area in the Mt Woods inlier, South Australia, is shown in Figure 4. Depth to Proterozoic basement throughout the area averages 100 m. Falcon® data were collected on east west lines 200 m apart at a flying height of approximately 80 m over a period of about one week. Ground data were acquired over a 10 year time period. Station spacings vary from 1 km at a regional level down to 100 m over specific targets.

The airborne data are internally consistent

compared with the ground data. The two data sets are comparable over specific targets where there is detailed ground gravity, however where the station spacing is greater than 300 m the ground data are highly aliased and geological features are poorly resolved.

The Falcon® data also highlight subtle linear structures not obvious in the ground data. One less obvious difference is that the

Falcon® data is corrected for the effect of terrain, unlike the ground gravity data.

The location of the Prominent Hill discovery is indicated on the figure.

Since the Falcon® system was first introduced to regular prospecting considerable improvements have been made in the system performance both through adjustments to the gradiometer instruments and also developments in noise rejection algorithms. BHP Billiton scientists estimate that there has been a greater than 50% improvement in the system performance. Figure 5 is illustrative of this and shows two data sets from the same area. The first was acquired using early parameters and the second with more recent improved settings. The improvement in resolution and signal to noise ratio is obvious.

## Falcon® as a Total System

The airborne gravity gradiometer is installed in a Cessna Grand Caravan, which also carries magnetic and radiometric acquisition systems. The vertical gravity gradient maps derived from the gradiometer data are similar in detail to the magnetic data acquired concomitantly.

Figure 6 shows a cross plot of average magnetic susceptibility versus average

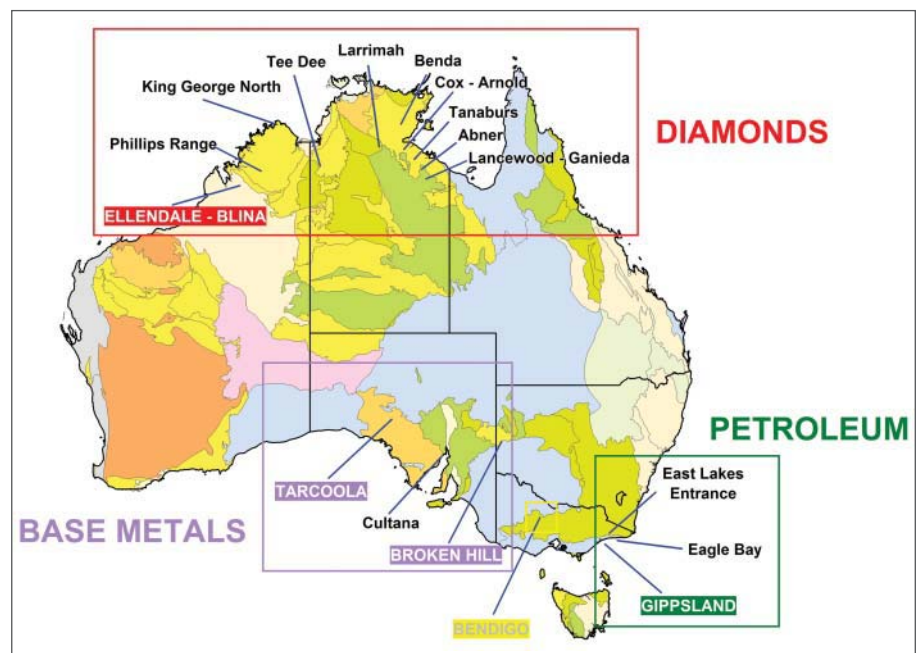


Fig 4. A comparison of Falcon® Gdd with derived ground Gdd from the Mount Woods Inlier, S.A. The ground gravity observations were made over a ten year period at station spacings between 100 m and 1 km. The Falcon® data were acquired from a survey flown at 80 m height along EW lines 200 m apart.



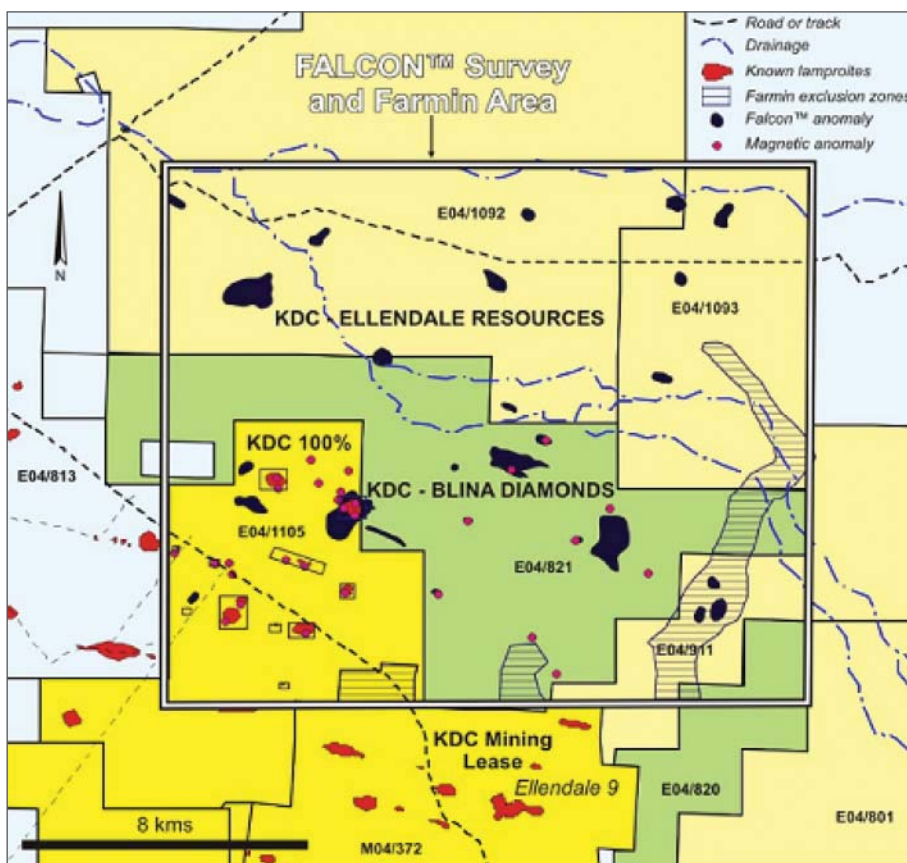


Fig. 5. Improvements in the data acquisition system between 2002 and 2004. The data were acquired at a line spacing of 200 m and a flying height of 80 m.

density for a variety of rock types derived from tables in Telford *et al.*, 1990. Also highlighted are density susceptibility variations for the two common ore body types targeted by the Australian Falcon® campaign, Broken Hill type Ag/Pb/Zn and Olympic Dam style iron oxide-copper-gold.

The figure illustrates how for any given rock type the addition of the density to the susceptibility provides a powerful new discriminator, particularly as exploration heads further under surficial cover. Both properties define quite separate characteristics of the rocks, their chemistry and thermal history.

The two parameters together are not only providing a powerful direct targeting system but also providing new insights into lithological and structural mapping for less direct targeting of commodities such as gold and petroleum.

\* BHP Billiton retains the right to use Falcon® on its own projects.

## Gravity Capital Ltd – an exploration company

Gravity Capital Limited is an ASX-listed company which creates exploration joint ventures using the Falcon® airborne gravity gradiometer as a unique capability. It is not a geophysical contractor. The operation of the Falcon® system is under the control of the BHP Billiton Falcon® operations team and its various airborne contractors. Gravity has the exclusive\* right to deploy Falcon® in diamond joint ventures in Australia, through its 40% owned company Diamond Mines Australia Pty Ltd and has a further arrangement where it may readily bring Falcon® to bear on exploration projects for other commodities.

On 1 July 2003 Gravity announced a capital raising of \$7.4M for its diamond projects, through its 40% owned company Diamond Mines Australia Pty Ltd. In October 2003 it announced further capital raising of \$8.5M to fund its other Falcon® based projects.

Gravity's programs are driven by the deals that it can capture and by funding it can bring to projects along with Falcon®. The company's principal aim is to generate new targets with Falcon® and to test them to capture an interest in any new discoveries for its shareholders.

Its arrangement with BHP Billiton defines terms under which the company may be partially or wholly displaced in the event that a discovery, should it be large enough to meet BHP Billiton's investment criteria.

Gravity Capital Ltd and other similar alliance companies around the world are the means by which BHP Billiton is sharing the technology with the industry at large at cost (net of the substantial development costs) while at the same time increasing its own chances of participating in any world class discoveries that may result.

While the participation arrangements have been seen as a disincentive to some players in the industry, on the whole, those who understand the substantial risks involved in

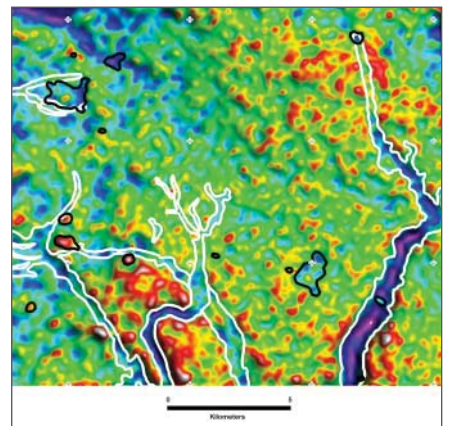


Fig. 6. Average magnetic susceptibilities versus densities for several rock types.

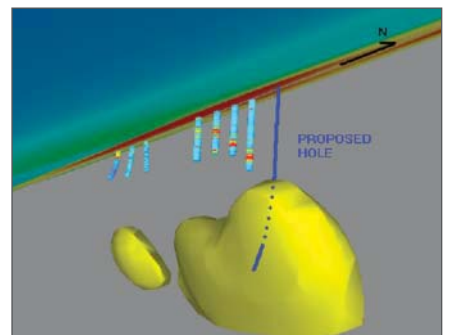


Fig. 7. Shows the areas of interest for diamonds, base metals, copper/gold and petroleum that will be discussed.

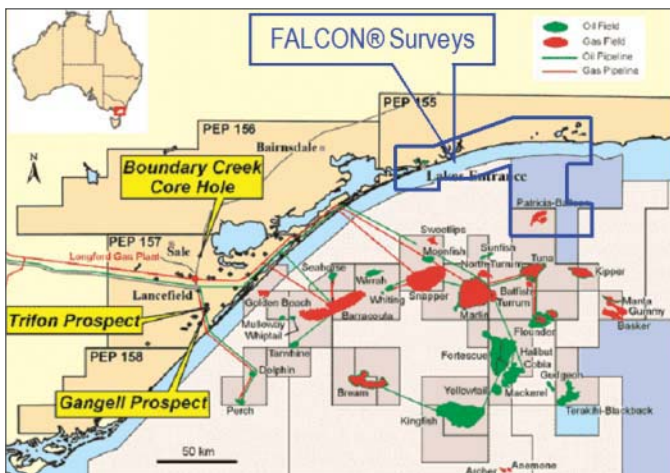


Fig. 8. Area of Ellendale Field that was flown by Falcon®. Areas coloured red indicate the lamproite bodies known at the time of the survey and those in black are new targets interpreted as a result of the Falcon® survey. Red circles indicate magnetic targets generated by the Falcon® survey.

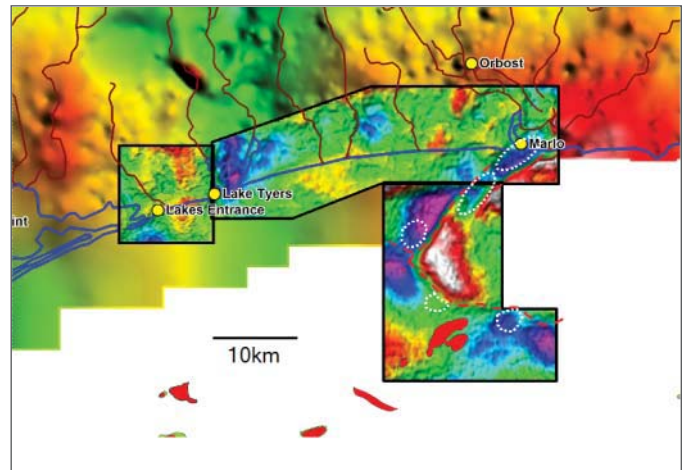


Fig. 9. A combined gravity image of vertical gravity  $gD$  draped on vertical gravity gradient  $Gdd$  indicating the locations of proposed follow-up drilling and the interpreted location of palaeochannels outlined in blue. Of testing carried out to date, two new small diamondiferous pipes have been located along with new palaeochannels containing indicator minerals.

mineral exploration have embraced the business model.

So far the direct targets have been for diamonds, Broken Hill Type deposits and Iron Oxide/Cu/Au deposits. The indirect targets have been for petroleum and gold. The company holds significant areas in its own right and controls exploration ground over an area of almost 40,000 km<sup>2</sup>. It has been able to generate a large suite of brand new targets. Prioritisation and field follow-up of thirty or so of these targets so far has led to new mineralisation being located in nine of them. Further testing of the diamond discoveries will prove potential commercial viability. Of the other targets so far none have led to a commercial discovery however for such an early stage of the program the technical success rate so far is excellent.

The table below lists the details of the surveys undertaken so far.

I would now like to show some results from these surveys.

## Survey results

### Diamonds at Ellendale

Figure 8 shows the 50/50 JV Farmin area (with the Kimberley Diamond Company) that was flown by Falcon® during 2003, along with some of the anomalies that have been identified. The survey targeted non magnetic lamproite pipes and palaeochannels and covered sections of the Ellendale lamproite field and its possible northern extension into the Fairfield Valley to the north.

About 30 anomalies, consistent with non-magnetic lamproite pipes and two targets considered likely to be paleochannels, were interpreted from this survey. Follow-up drilling of nine of these anomalies was completed late in 2003 and two small diamondiferous lamproite pipes were identified. The two palaeochannel targets were also drilled and gravels containing indicator minerals were recorded from both.

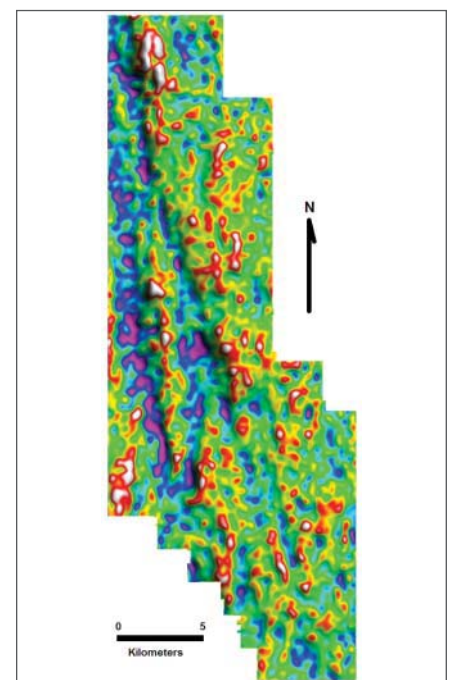


Fig. 10. Gravity draped over magnetic anomalies in the Broken Hill region. The red and black ellipses are possible targets. Also shown are the Line of Lode and the Goldfinger anomaly.

Commodity	Surveys	Line spacing (m)	Survey km	Areasq km	No. of targets	Tested	Hits
Diamonds	10	100	47084	4300	200	20	5
Base metals	3	200	13203	2443	24	11	4
Gold	1	200	2307	3630	3	Untested	0
Petroleum	3	330	3912	1152	4	Untested	0
Total	17		66506	11525	231	31	9



### Broken Hill Project

Broken Hill is the largest Ag/Pb/Zn deposit ever discovered. It has produced over 280 Mt of ore from the one lode. In spite of extensive exploration activity in the 2nd half of the last century no other similar sized deposit has been discovered in the vicinity. In 2003, a Falcon® survey, funded through the Predictive Mineral Discovery CRC was flown to identify suitable targets in the Broken Hill vicinity. Figure 10 shows the gravity superimposed on the magnetics and some of the potential targets identified as a result of this work.

Of the 20+ possible targets nine have been tested so far. Four of these have had anomalous mineralisation associated. Goldfinger gravity anomaly is the most exciting target to result from the 2003 Falcon® survey at Broken Hill (see Figure 11).

It is around 2.5 km long and occurs in a structurally permissive area within confirmed Broken Hill Group rocks. Initial shallow drilling in April 2004 returned strong indications of alteration and low order base metal anomalism with strong similarities to the Broken Hill ore body environment.

Integration of detailed mapping with the drill hole data and 3D gravity modelling was carried out earlier this year by BHP Billiton utilising proprietary software. This work concluded that the main body of the source of the gravity anomaly was likely to be deeper than the initial drill holes and consequently a (500 m) diamond drill hole has been designed to intersect the predicted location of the source of the anomaly. Figure 11 shows the site of this hole and the interpreted target.

### Ealbara project, Gawler Craton

The Ealbara project, in the Gawler Craton, SA, is owned 100% by Gravity Capital Ltd. The area contains Tarcoola basin sediments intruded by Hiltaba aged granites. High amplitude magnetic complexes in the area indicate potential for Prominent Hill style iron oxide copper-gold mineralisation and middleback style iron ore mineralisation. A Falcon® survey located 12 new targets. These are shown in Figure 13, which shows

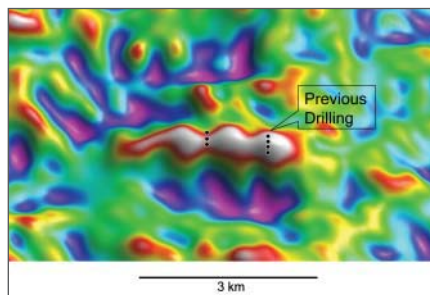


Fig. 11. Goldfinger gravity anomaly showing the sites of previous drill holes.

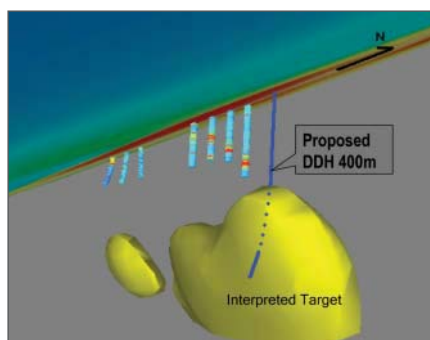


Fig. 12. Site of deep drill hole and interpreted model at the Goldfinger anomaly, near Broken Hill.

the vertical gravity gradient draped over the magnetics. Three of these targets have so far been tested and one has shown evidence of new base metal mineralisation.

### Gippsland Basin

The Gippsland Basin is a mature offshore basin that has been producing oil and gas for over 30 years. The early discoveries were

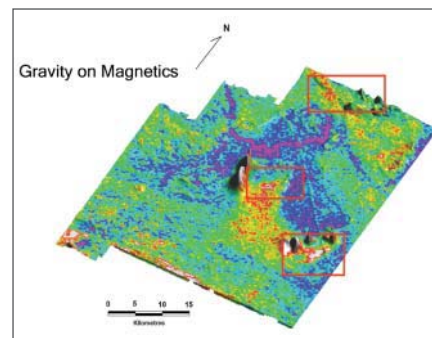


Fig. 13. Vertical gravity gradient draped over magnetics from the Ealbara Falcon® survey in South Australia. The identified targets are outlined.

structurally controlled and located in deeper water. The area within 20 km of the shore has been poorly explored. In total three Falcon® surveys have been flown in conjunction with Lakes Oil, along the northern margin of the basin near Lakes Entrance. The total cost of these surveys is of the order of \$200,000 and they cover an area where seismic coverage is limited. Several direct targets controlled by previously poorly mapped structure have been identified as a result. Figure 14 shows the location of the surveys with respect to the known oil and gas fields and Figure 15 shows the results merged with the onshore regional gravity.

### Bendigo Goldfields

The final example is from the Bendigo Goldfields in Victoria. This is an area which

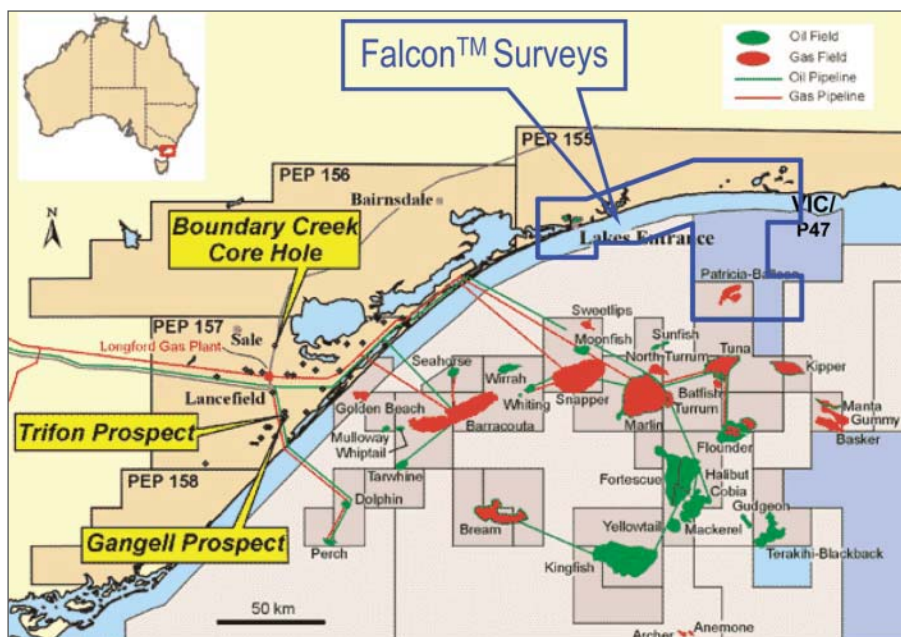


Fig. 14. Location of the Falcon® survey over the Gippsland Basin with respect to the known oil and gas fields.

has been mined for over 150 years. Substantial potential for the discovery of further gold deposits exists in the large areas where the prospective Palaeozoic rocks are covered by younger formations of the tertiary Murray Basin. Exploration beneath this cover has been hindered by a viable technique for targeting exploration through this younger cover.

Figure 15 shows the Falcon® results over the regional gravity near Bendigo and Figure 16 shows the in more detail the results of the survey.

The results show that Falcon® results provide a powerful mapping tool in areas of extensive regolith cover. They can be used to map the extension of known structures, cross structures and potential target zones.

## Conclusions

### *Falcon® as an Exploration System*

Falcon® has shown itself to be a powerful exploration system, with the resolution of the airborne gravity gradiometer now approaching that of airborne magnetics. The ability of the gravity gradiometer to cost effectively detect and distinguish direct gravity targets for testing as potential new ore bodies has been demonstrated over a wide range of applications from diamonds to base metals.

Further than its direct targeting role, the combination of the magnetic and the gravity data at similar resolution over large areas provides the geoscientific industry with an important new system for mapping geology under cover. The combination of gravity (density) and magnetics (susceptibility) allows a clearer discrimination among rock types. Furthermore, the inherent nature of the way the Falcon® system measures the gravity gradients makes it particularly effective at highlighting linear features such as dykes and structures, providing there is sufficient density contrast. Although the application in exploration for non direct targets such as petroleum and gold, which are more structurally controlled, remains relatively untried, limited surveys flown by Gravity to date demonstrate a real potential for Falcon® to make a cost effective contribution to exploration programs and targeting.

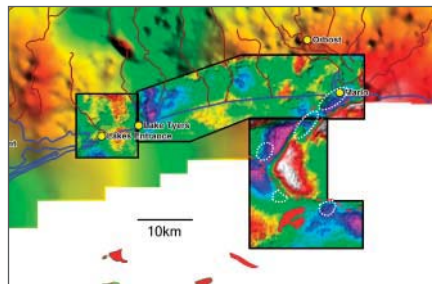


Fig. 14 Gravity anomalies from Falcon® survey and some of the targets for detailed seismic work.

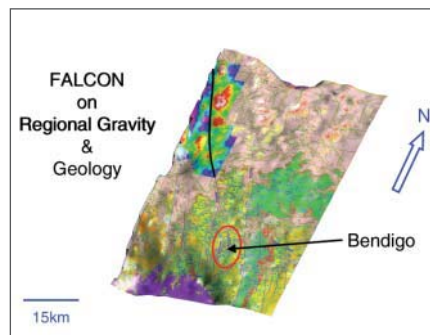


Fig. 15. The Falcon® survey shown on the regional gravity and geology near Bendigo, Victoria. The Falcon® survey is shown over the northwest part of the diagram.

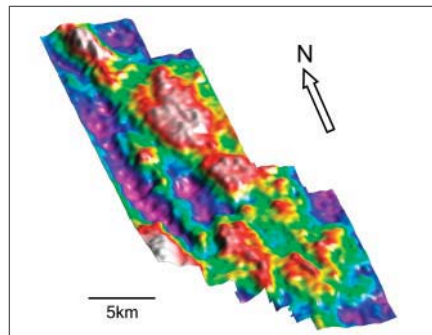


Fig. 16 Detail of the Falcon® survey near Bendigo.

### *Gravity Capital's Business Model*

Raising money for exploration based on the technology alone has been difficult. There has been scepticism in the industry about the use of the system by Gravity to capture equity in projects along with the shadow of BHP Billiton in the background should major discovery be made.

This has to some extent been driven by a misunderstanding of the intent of the

business model. Gravity Capital is not a contracting company, but rather an explorer that seeks to bring Falcon®, expertise and cash to an exploration project. It only seeks to earn equity in any discovery that results from testing of a Falcon® generated target. This has been achieved with a variety of different partners with many different deal structures, each one tailored to the needs of both Gravity and its partners. In the unlikely event that a world class discovery is made, unless it is specified otherwise for the project, the BHP Billiton buyout only applies to Gravity's equity. This is the only way in which BHP Billiton can justify making a system available more broadly in the industry after such an expensive and high risk research and development project.

Nevertheless Gravity has been successful in raising around \$16M in the past year or so. We have successfully generated a large number of new greenfields targets and testing of 30 to date has generated nine associated with anomalous mineralisation. Of these, four have the potential to deliver discovery success.

## Acknowledgements

This presentation was put together with the assistance of David Isles and Thong Huynh of Gravity Capital Limited. A number of examples of data have been provided by the Falcon® Operations group of BHP Billiton, and use of these is gratefully acknowledged. Figures 1 and 2 are courtesy of Peter Diorio of BHP Billiton Minerals Exploration.

Data used in a number of the examples were acquired as part of joint venture programmes and our partners, Kimberley Diamond Company Limited, Lakes Oil, and Providence Gold and Minerals, in particular are acknowledged for their support.

The data over the Broken Hill block was acquired by the pmd CRC under funding support from the NSW Department of Mineral Resources.

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W. M., Telford, L. P. Geldart, and R. E. Sheriff, 1990, *Applied Geophysics*, 2nd ed., Cambridge University Press, Cambridge, p. 6–61.



# An efficient 3D explicit finite-difference prestack depth migration\*



## Authors:

Jiaxiang Ren<sup>1</sup> <sup>††</sup>  
Clive Gerrard<sup>1</sup>  
James McClean<sup>1</sup>  
Mikhail Orlovich<sup>1</sup>  
Andrew Long<sup>2</sup>

## Key words:

depth migration,  
wavefield  
extrapolation,  
explicit finite-  
difference operator,  
constrained  
operator,  
interpolation.

## Summary

An explicit, constrained operator is presented here for wavefield extrapolation in 3D wave equation depth migration. The migration cost and image quality benefit from its reduced number of independent coefficients within the operator, negligible numerical anisotropy, and flexibility that allows for different propagation angles and step sizes in the inline and cross-line directions. In order to further reduce the computational workload we dynamically select operator lengths and extrapolation step sizes based on the wavenumber of the wave components being migrated. The phase-shifted linear interpolation that we propose for interpolating the extrapolated wavefield is suitable for the explicit migration, and significantly improves the accuracy of the result when compared with the linear interpolation typically used in implicit migrations.

## Introduction

Downward extrapolation of the seismic wavefield is the key element of wave equation based migrations because it determines the image quality and computational cost. Extrapolation by finite difference methods is considered to be superior, especially in handling lateral velocity variations. It can be classified into explicit and implicit methods. Accomplished simply by convolving known wavefields with an extrapolation operator, the explicit method is easier to implement, and can be more efficient than the implicit method. In addition, the explicit method can be extended to 3D in a straightforward manner, whereas the implicit method requires inline and cross-line splitting of the extrapolation process at each depth step, resulting in phase errors and artifacts.

Even with symmetrical operators (Blacquiere *et al.*, 1989), 3D depth migrations based on explicit extrapolation may still be expensive, due to a full 2D convolution being performed at each depth. The scheme based on the McClellan transform proposed by Hale (1991) is much more efficient, but introduces numerical anisotropy at the same time. Among the many alternatives, or improvements to the scheme (Soubaras, 1992; Sollid and Arntsen, 1994; Biondi and Palacharla, 1995; Mittet, 2002), the constrained operator proposed by Mittet (2002) is attractive. It overcomes the numerical anisotropy problem and still keeps the computational cost comparable to the Hale-McClellan scheme.

## Method and Results

### Constrained operator

As demonstrated in Figure 1, the explicit finite-difference operator is separated into two areas during the operator design. The operator is a function of the local wavenumber at each output grid location, and is able to handle lateral velocity variations. As usual for explicit finite-difference migration operators, the operator assumes a circular symmetry. What is unique about the operator presented here is that it divides the coefficients into core and constrained areas. In the core area the coefficient layout is the same as that for a full operator. In the constrained area the coefficients in a series of rings are assigned an identical value. Figure 1 shows the layout of a constrained operator with the  $\Delta y/\Delta x$  ratio of 1.5, x-direction half-length of 12, y-direction half-length of 8, and core half-length of 6.

The constrained operator reduces the number of independent coefficients. By factorising out the coefficients in a ring during the convolution, the number of complex multiplications is reduced. Because the complex multiplication is expensive, using the constrained operator improves the extrapolation efficiency.

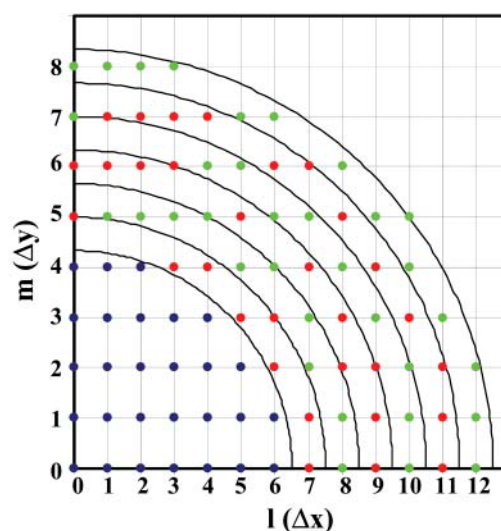


Fig. 1. Coefficient layout for one quadrant of a constrained operator. The axes are the inline and cross-line directions for a given depth level. As the operator size increases, the maximum dip that can be migrated increases, however, the computational cost also correspondingly increases. In order to reduce computational cost, the operator design in this example imposes equal coefficient values within each circular band. This design process is pursued prior to the actual migration, and ensures that migration accuracy is still extremely high. From Mittet (2002).

\* This is based upon the 'Best Petroleum Paper', recently presented by Andrew Long at the 17th ASEG Meeting in Sydney (An efficient 3D explicit depth migration, by Ren *et al.*, 2004).

<sup>1</sup> PGS Marine Geophysical, USA;  
<sup>††</sup> jiaxiang.ren@pgs.com

<sup>2</sup> PGS Marine Geophysical, Australia;  
andrew.long@pgs.com

The operator half-length,  $M$ , in the  $y$  direction, is determined from the operator half-length,  $L$ , in the  $x$  direction, using the relationship  $M=(\Delta y/\Delta x)L$ . If  $\Delta y$  is greater than  $\Delta x$ , as is usually the case for marine acquisition, the total number of operator coefficients and the computational cost is reduced.

The coefficients of the constrained operator are designed using the exact extrapolator in the frequency-wavenumber domain, that is, the phase shift operator. The design strategy is to optimize the constrained operator such that its wavenumber-domain response approaches that of the exact phase shift operator. For any given local wavenumber, the optimisation is performed on the operator's real and imaginary parts, using an  $L_8$  norm for all inline and cross-line wavenumbers ( $k_x$  and  $k_y$ ) up to the critical wavenumber  $k_c^e = (k_x^e, k_y^e)$  determined by:

$$\frac{(k_x^e)^2}{k_{\omega}^2 \sin^2 \theta_x^{\max}} + \frac{(k_y^e)^2}{\xi_y k_{\omega}^2 \sin^2 \theta_y^{\max}} = 1, \quad (2)$$

where  $\theta_x^{\max}$  and  $\theta_y^{\max}$  are the maximum propagation angles considered in the  $x$  and  $y$  directions.

We design the constrained operator for a sufficient set of  $k_{\omega}$  and form an operator table. For a given accuracy, the operator length required varies with  $k_{\omega}$ . Our extrapolation process selects the shortest operator that satisfies the accuracy required based on the wavenumber value of the wave component being migrated. This measure avoids using unnecessarily long operators, and can reduce computational cost.

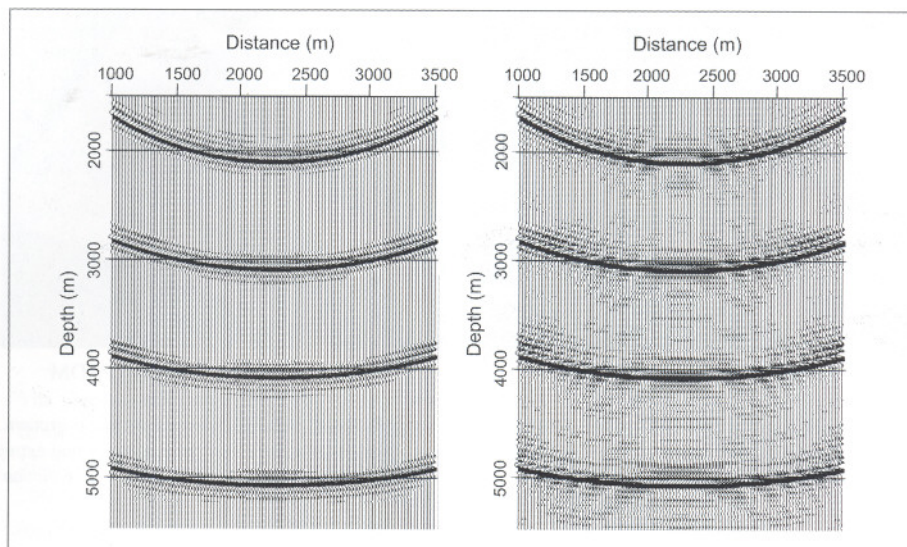


Fig. 2. Source wavefields obtained with phase-shifted linear and linear interpolation. As observed, the application of an appropriate phase shift correct after wavefield extrapolation (left) significantly reduces the artifacts that might arise when interpolating to the final output depth grid.

#### Variable extrapolation step size and interpolation

To reduce the number of extrapolations we use a variable step size that is determined dynamically by the wavenumber value. To interpolate the extrapolated wavefield onto a regular output depth grid we propose a phase-shifted linear interpolation. We do not consider the linear interpolation used in implicit migrations where the interpolation is performed only on the 'diffraction' term, and the 'thin-lens' term is calculated exactly. In an explicit migration those two terms are not separated, and the use of linear interpolation on the 'thin-lens' term will generate a large error. The phase shifts are applied to each extrapolated wavefield frequency prior to the linear interpolation to the output depth grid, and eliminate the influence of the 'thin-lens' term.

Figure 2 shows a part of the source wavefield snapshot obtained with the constrained operator and phase-shifted linear interpolation. The extrapolation interval is 25 m and the interpolation interval is 5 m. The source function used contains 4 wavelets with a flat frequency spectrum between 1 – 39 Hz. The model has a constant velocity of 2000 m/s. The wavefield obtained with the phase-shifted linear interpolation is clean, and does not have obvious amplitude distortions and phase errors. For comparison, also shown in Figure 2, is the result obtained with linear interpolation. We note that the linear interpolation generates strong noise cutting through the wavefronts, and obvious amplitude distortions and phase errors can be observed, especially around the low dip portions of the wavefront.



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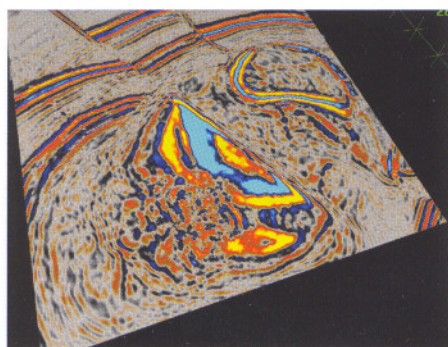
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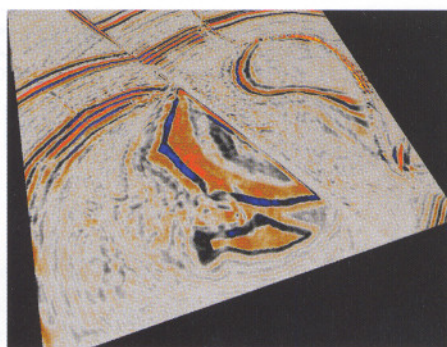
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Depth Slice: Kirchhoff PSDM



Depth Slice: Wave Equation PSDM



Depth Slice: Velocity - Depth model

Fig. 3. Images from the SEG/EAGE model dataset, obtained using Kirchhoff and explicit wave equation migrations. The image on the left is obtained using energetic raytracing and Kirchhoff migration. The image in the middle is obtained using the constrained operator and extrapolation with a variable step size, plus the phase-shifted linear interpolation. The image on the right is the velocity model used in both cases. Note that the wave equation migration yields much better focussing, and less artifacts.

### Examples

To illustrate the performance of the explicit 3D wave equation migration, we have applied it to the SEG/EAGE salt model dataset. Figure 3 compares Kirchhoff and explicit finite-difference migrations. In comparison to Kirchhoff migration, the image from the wave equation migration has a lower noise level, does a better job imaging the salt boundaries, and, most importantly, it produces a much more focused and continuous image.

We have also applied the explicit wave equation migration to a real dataset from the southern North Sea (Figure 4). Not only does the explicit finite-difference migration yield significantly better steep dip imaging in the centre area of the example shown, but the coherency and resolution of low dip events are also much better than the Kirchhoff result. A thin, high-velocity chalk layer confronts imaging quality for deeper events in this region, as evidenced in the Kirchhoff result.

### Conclusions

The constrained operator is accurate and reliable for wavefield extrapolation in explicit depth migrations. The smaller number of independent coefficients offered by the operator leads to a reduced migration computational cost. Its flexibility to allow for a larger grid interval and shorter operator length in the cross-line direction makes it a useful and efficient method for migrating marine data. The measures we take, including the dynamic selection of the operator length and extrapolation step size based on the wavenumber, also contribute to

the efficiency of the method. The phase-shifted linear interpolation method proposed for interpolating the extrapolated wavefield is suitable for explicit migration, and is more accurate than the linear interpolation.

### Acknowledgements

The authors would like to thank Rune Mittet and John Anderson for their useful suggestions and discussions. We also thank Sandy Carroll, Boris Tsimelzon and Peter Wijnen for their assistance with processing.

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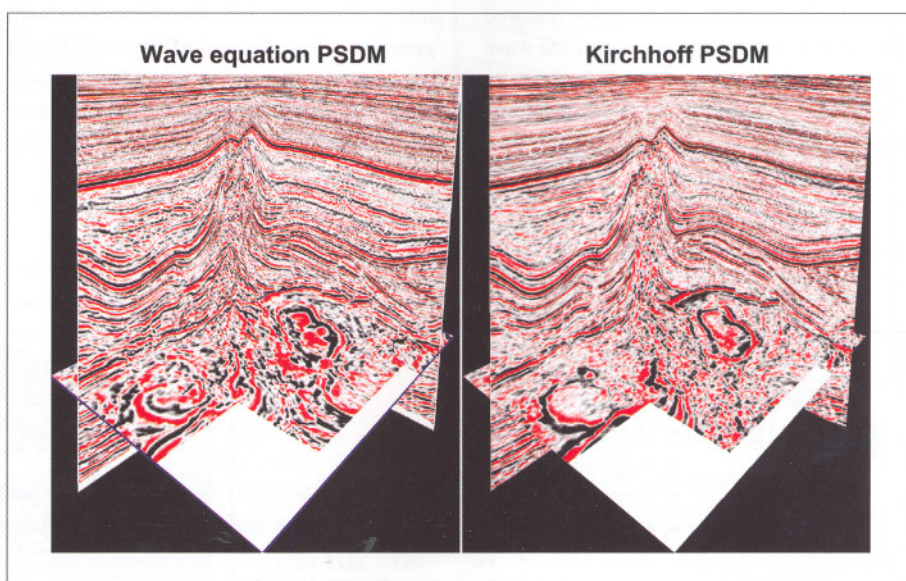


Fig. 4. Explicit finite-difference vs. Kirchhoff migration; example from the southern North Sea. Note the better steep dip imaging, and the better imaging below the fast flat layer on the left. The wave equation migration is able to significantly improve steep dip imaging and general resolution, whilst being pursued with an efficient implementation.



## Geoscience Australia

### Gravity base station descriptions now available via the Web

Station location descriptions of the 945 gravity base stations that make up the Australian Fundamental Gravity Network can now be accessed on the Geoscience Australia website at <http://www.ga.gov.au/bin/AFGNmap>

Each station description consists of one or more diagrams with, in many cases, up to two photographs showing the station and its surroundings. The gravity value, latitude, longitude and elevation of the station are also displayed. For more information or to provide feedback on the gravity base stations, contact Ray Tracey by phone on 02 6249 9279 or by email on [Ray.Tracey@ga.gov.au](mailto:Ray.Tracey@ga.gov.au)

There is no longer any excuse for gravity surveys not being properly tied in to the national network.

## NSW

### New name and new address for NSW Mineral Resources

by Graham Butt

*Geological Survey Executive Officer*  
[graham.butt@minerals.nsw.gov.au](mailto:graham.butt@minerals.nsw.gov.au)

As we approach the 130th anniversary of the Geological Survey of NSW on 1st January

2005, significant changes both in the Survey and in its Department are underway. From 1st July 2004, the Department of Mineral Resources has been merged with its sister Departments of Agriculture and Fisheries and State Forests of NSW into the new Department of Primary Industries. The name of our new entity is the Department of Primary Industries Mineral Resources (DPIMR). The Geological Survey of NSW is one of seven Branches in DPIMR.

The Geological Survey will start operations from new premises at 516 High Street, Maitland NSW 2310 on 22nd November 2004. This move has been in the planning for more than three years. A purpose-built facility (see picture) has been constructed to house not only the Geological Survey but also the Mine Safety, Minerals Development and Environmental Sustainability Divisions of DPI Mineral Resources. A Mine Safety Technology Centre is also being constructed at Thornton, near Maitland and will include mine safety training facilities as well as a large archival storage area. As part of this reorganisation, the Specialist Geological Services group previously housed at Lidcombe will be moving to the Londonderry Core Library building in western Sydney.

Both the Maitland and Thornton facilities are located a comfortable two hours drive north from Sydney along the Sydney-Newcastle Freeway.

The Geological Survey now consists of three programs focussed on minerals and petroleum geoscience:

1. Resources & Land Use Assessment;

2. Regional Mapping & Exploration Geoscience; and
3. Geoscience Information.

Funding of the government's special Exploration NSW initiative continues as originally planned until 2007, including ongoing airborne geophysical survey projects designed to support the focus of Exploration NSW on detailed minerals and petroleum mapping programs, particularly in the Lachlan Orogen, Broken Hill, Cobar-Bourke and the Darling Basin.

These changes represent another step in the significant history of the Geological Survey of NSW and of the Department. This history started on 1st January 1875 when the Geological Survey of New South Wales was formed under the leadership of Charles Smith Wilkinson in the fledgling Department of Mines, which had been established one year earlier.

The appearance of copper at Carcoar, Molong and Bathurst, the discovery of iron ore at Berrima and the many unconfirmed reports that gold had been found in several places west of the Blue Mountains, had prompted the government to call, on 1st March 1849, for the appointment of a Geological Surveyor of NSW. In 1850 Samuel Stutchbury arrived from England to take up his appointment to carry out a mineralogical and geological survey of the Colony. After Stutchbury's return to England in 1855 there was no subsequent Geological Surveyor in the State until 1874, when clear evidence of the Colony's mineral resources forced the government to act and the Department of Mines was established that year.

It is no surprise that 130 years later, following revolutions in the understanding of plate tectonics and in mapping technologies, gold production in the Bathurst region is still underway, at record levels, assisted by the information framework put in place by the Geological Survey of NSW. The Geological Survey will continue to make major contributions to the exploration industry and to assist natural resource management in New South Wales<sup>1</sup>.

<sup>1</sup> With acknowledgement to Jim West and John Watkins of the Geological Survey for providing the historical notes.



Fig. 1. The new home for the Geological Survey of NSW at 516 High Street, Maitland, NSW 2310; where it will start operations on 22nd November 2004.



## WA

## South Yilgarn airborne magnetic and radiometric survey commences

The first large regional survey project of the government's four-year, \$12 million program to increase airborne magnetic and radiometric coverage of Western Australia has started in the South Yilgarn.

Data from new survey flying will be merged with existing data acquired from private companies to provide magnetic and radiometric coverage of an area approximately 112 000 km<sup>2</sup> in a region extending from Kellerberrin to Ravensthorpe (Figure 1). When completed, the project will add a total of almost 400 000 line-km of magnetic and radiometric data to the public data inventory.

UTS Geophysics and Fugro Airborne Surveys have been contracted to fly approximately 270 000 line-km between September 2004

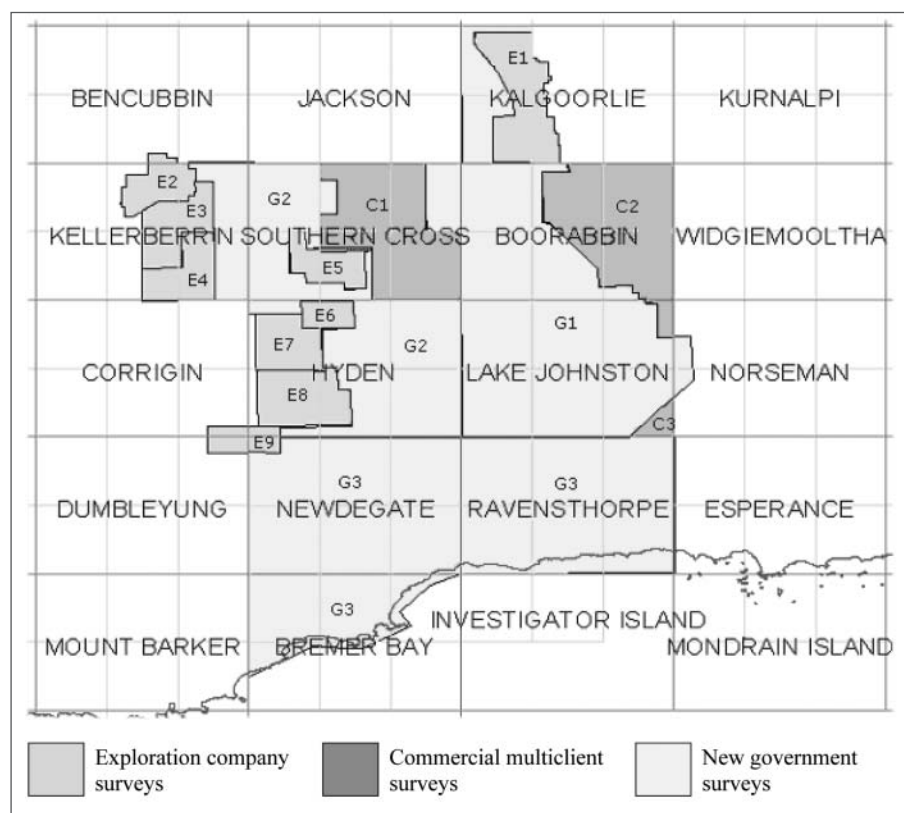


Fig. 1 South Yilgarn Airborne Geophysical Survey Project Area.

Survey name (GSWA Reg. No.)	Date	Line spacing	Direction	Height	Data release*
<b>EXPLORATION COMPANY SURVEYS</b>					
E1: Beetle Rock (60173)	1997	250 m	180	60 m	Oct 2004
E2: Trayning (60035)	1999	150 m	090	50 m	Oct 2004
E3: Merredin (60019)	1997	200 m	180	50 m	Oct 2004
E4: Bruce Rock (60018)	1997	150 m	180	50 m	Oct 2004
E5: Holleaton North (56629)	1997	400 m	090	40 m	Open File
E6: Gibb Rock (56630)	1997	200 m	180	40 m	Open File
E7: Hyden North (56631)	1997	400 m	090	40 m	Open File
E8: Pingaring (56632)	1993	400 m	090	60 m	Oct 2004
E9: Lake Grace (60481)	1995	200 m	090	60 m	Oct 2004
<b>COMMERCIAL MULTICLIENT SURVEYS</b>					
C1: Southern Cross (60488)	1995	200 m	090	50 m	Oct 2004
C2: Boorabbin (tba)	1996	200 m	090	80 m	Oct 2004
C3: Peak Charles (tba)	1996	400 m	090	60 m	Apr 2005
<b>NEW GOVERNMENT SURVEYS</b>					
G1: Boorabbin – Lake Johnston	2004	400 m	090	60 m	Apr 2005
G2: Southern Cross – Hyden	2004	400 m	090	60 m	Apr 2005
G3: Newdegate	2005	400 m	090	60 m	Jun 2005
G3: Bremer Bay	2005	400 m	180	60 m	Jun 2005
G3: Ravensthorpe	2005	400 m	180	60 m	Jun 2005
* Data release dates are provisional estimates. Actual dates will be announced on the DoIR and GA websites.					
For further details, contact David Howard by telephone on 08 9222 3331 or by email at david.howard@doir.wa.gov.au.					

and March 2005 in three survey blocks. These new data will be acquired at a line spacing of 400 m at a mean altitude of 60 m above ground level. Geoscience Australia is managing the flying program.

In addition, the Department has acquired the intellectual property rights to approximately 130 000 line-km of existing data from commercial multiclient surveys and exploration company surveys.

Basic specifications of each survey are shown below. Data will be released as they become available with a final release of the full dataset anticipated for mid-2005.