

Preview



Australian Society of Exploration Geophysicists

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Australia's Infrastructure Report Card for 2005 released

As Engineers Australia chief executive, Peter Taylor said when he launched the 2005 Report Card on Australia's infrastructure, "World-class infrastructure is vital to the Australian economy. It underpins the delivery of essential services, drives economic growth, supports social needs and is closely linked to the high quality of life that Australians enjoy today."

Since 1999, Engineers Australia (EA) has critically examined several key infrastructure sectors and assigned ratings. The ratings range from A (very good) to F (inadequate). The definitions of the ratings are:

A: Very Good. Infrastructure is fit for its current and anticipated purpose in terms of infrastructure condition, committed investment, regulatory appropriateness and compliance, and planning processes.

B: Good. Minor changes required in one or more of the above areas to enable infrastructure to be fit for its current and anticipated purpose.

C: Adequate. Major changes required in one or more of the above areas to enable infrastructure to be fit for its current and anticipated purpose.

Infrastructure Type		Year		
Category	Sub-category	2005	2001	1999
Roads	National	C+	C	C
	State	C	C-	C-
	Local	C-	C-	C-
	Overall	C	C-	C-
Rail		C	D-	D-
Electricity		C+	B-	
Gas		C+	C	
Ports		C+	B	
Water	Wastewater	C+	C-	D-
	Potable water	B-	C	C-
	Stormwater	C-	D	
	Irrigation	C-	D-	
Overall		C-	D+	C-
Airports		B	B	
Overall Rating		C+	C	D+

D: Poor. Critical changes required in one or more of the above areas to be fit for its current and anticipated purpose.

F: Inadequate. Inadequate for current and future needs.

The table below summarises the national results for three of the past six years (see www.infrastructurereportcard.org.au).

The results show a gradual improvement in this period, but there is still considerable room for progress. For example, in the airport category I would think that anyone who arrives in Sydney early in the morning from overseas and transfers to a domestic flight, or just parks a car at the airport would testify both to the slow processing and the high cost of parking. The other airports must be very good to reach level-B in the national assessment.

This report is clearly a very useful product provided by EA, as it generates discussion on infrastructure and raises awareness that it is a national issue. Each of the states and territories were assessed in the 2005 report, with the Northern Territory achieving the top rating of level-B, while Tasmania and New South Wales achieved C-ratings.

Next year EA hopes to include hospitals, schools, and broadband access in the annual report. We may be achieving good ratings for schools and hospitals but compared to other OECD countries, we are close to the bottom of the heap in broadband access.

According to the most recent OECD report, which was generated at the end of 2004, (http://www.oecd.org/document/60/0,2340,en_2649_34225_2496764_1_1_1_1,00.html#data2004) we ranked 21st in a table of 30. The ranking listed 7.7 broadband subscribers per 100 inhabitants for Australia, while South Korea was first with 24.9 broadband subscribers per 100 inhabitants and Canada ranked fifth with 17.8. Maybe the government is too preoccupied with selling Telstra to encourage national broadband access.

HR crisis looms for industry – in Canada

'Within the next decade, a human resources crisis will challenge the mining and minerals industry.' If you have already read words like this recently you will not be surprised. However the statement does not relate to

Australia where geophysicists are as scarce as hens' teeth, it is from the Prospectors and Developers Association of Canada (PDAC).

The statement is the key finding of a two-year project that researched and analysed major human resources issues that could affect the Canadian industry in the next decade. The preliminary report of the project reveals, 'some worrisome trends'. 'Approximately 16.9% of employees are expected to retire in the next five years, and as many as 40% in the next decade. During the next 10 years industry growth will create up to 25,000 positions, but 56,000 positions could be vacant due to retirement. The industry will need 81,000 people to fill these positions and only 11,000 will be taken by graduates of post-secondary institutions. The remaining 70,000 individuals will have to be recruited from other sources such as the aboriginal community, new Canadians and other industries.'

The research also reveals a worldwide shortage in many skilled trades, including engineering and geology occupations. Evidence suggests that skill gaps may begin to emerge during the next decade as automation and other advanced technologies become increasingly important to the viability of Canadian mines.'

The final report will be issued later this year and is expected to include the following recommendations:

1. Greater coordination and communication among industry, educators, government and industry associations.
2. Promoting the importance of the minerals and metals industry in Canada and to develop an industry-wide training and education strategy to ensure a skilled labour force.
3. Developing and implementing an industry-wide standardisation of credentials to enable increased labour mobility within Canada and ensure minimum standards for mining-specific occupations.
4. It will be important to develop a targeted marketing and promotion campaign that attracts women, aboriginals and new Canadians to the industry;
5. Establishing a system to recognise foreign credentials that will facilitate integration of new Canadians into the industry.

The similarities between Australia and Canada are very clear. For further information, visit the web site at www.prospectingthefuture.ca



Exploration Geophysics

By the time you receive this issue of *Preview*, you would've already

received the September edition of *Exploration Geophysics*, Volume 36, Number 3.

The editor of this flagship publication for the society, Lindsay Thomas is to be commended for bringing the publication back on-schedule, which will enable ISI listing and professional recognition of participating authors.

Lindsay admits that the timely publication of our journal is dependent on its associate editors. Nine associate editors are listed on the front cover of the latest edition but every associate editor commits considerable time and effort reviewing papers to a schedule that will ensure publication deadlines are met.

One particularly associate editor, Todd Grant needs special commendation for his efforts in the past few years, as an active and relatively young consultant. Due to a change in professional circumstances, Mr Grant has withdrawn his services as Mining Geophysics associate editor to the society. The membership would like to extend its gratitude to Mr Grant for his support and also to wish Mr Grant every success in his future endeavours.

The membership also commends and appreciates the continuing commitment of other associate editors Brian, Leonie, Binzhong, Syd, Suzanne, John, Greg, and Bob.

Anyone who feels the urge to maintain the internationally recognised high standards of this publication by assisting with associate editor support, please contact Lindsay directly. Lindsay's contact details are on the first page of *Exploration Geophysics*.

ASEG Web Site

We had been hoping that:

- By now you would have been able to receive your edition of *Exploration Geophysics* via the web, if that was your preference
- Your membership renewals this year were painlessly processed via credit card debit over the web
- Your membership details would be automatically updated
- Access to privileged membership databases and publications could be managed with a password.

A number of options are currently being investigated to provide these services and a decision to proceed with one overall option will hopefully be quickly defined.

I hope to have these services in place before my presidential tenure expires.

Discovery@Depth Summer School in Kalgoorlie 2006 to 2007

Immediate ASEG past president, Howard Golden, along with other ASEG members have been actively involved in developing a proposal for a Discovery@Depth summer school program. The program is an innovative

and exciting concept, which could provide a stimulus to our profession.

The program aims to draw strength from all Australian universities and research organisations, and the business community, and will enjoy the active participation of the Australian Geoscience Council and its member organisations, particularly ASEG.

The school will target tertiary students who have completed their third or honours year in physics, applied maths or geoscience. The course-content will offer these students opportunities to undertake Masters or Doctorates in topics that will meet the needs of industry and provide excellent career prospects.

Stimulating research, innovation and teaching resource exploration at-depth, the program will provide appropriate knowledge and skills required for modern and successful mineral exploration in the immediate future, in Australia.

It will also produce a data-set that will be made available electronically to any Australian student for further research. As the course is meant to be a self-supporting annual event, the data from each year will be added to the data from previous year's to create a virtual laboratory for all Australian geophysics students.

The ultimate objective of the program is to establish an accredited and prestigious geophysics summer school course that will maintain the technical leadership position that Australian exploration geophysics holds throughout the world and to contribute positively to the Australian economy and culture.

Terry Crabb

LETTER

Fullagar Geophysics pledges funding to the ASEG Research Foundation

I would like to thank Peter Fullagar of Fullagar Geophysics Pty Ltd who has pledged \$500 per year for the next three years to the ASEG Research Foundation. The Research Foundation was set up to support geophysical research projects specifically by funding project related costs of carrying out geophysical field work. Since 1998 the Foundation has supported 40

projects at a total cost of \$287,693. This has helped 40 students to complete their research and has provided a valuable contribution to geophysical knowledge with many of the projects resulting in publications in *Exploration Geophysics*.

The Foundation only exists through the support of the ASEG and its individual and corporate members. Assured funding is an on-going issue and contributions of this nature are an excellent way to help secure the Foundation's activities.

I encourage similar generosity from other members of the ASEG.

Once again I would like to thank Fullagar Geophysics for setting a great example.

Yours sincerely,

Phil Harman

Chairman

ASEG Research Foundation

2005

6-11 November

SEG INTERNATIONAL EXPOSITION & 75TH ANNUAL MEETING

Venue: Houston, Texas, U.S

Website: www.seg.org

13-16 November

2005 NEW ZEALAND MINERALS CONFERENCE

Venue: CARLTON HOTEL, AUCKLAND, NZ

Website: www.nzmineralsconference.org.nz

13-17 November

GREENHOUSE 2005: ACTION ON CLIMATE CHANGE

Main sponsors: CSIRO, AGO and BOM.

Venue: Carlton Crest Hotel, Melbourne

Website: <http://www.greenhouse2005.com>

28-29 November

NEWGENGOLD 2005

Venue: Burswood Convention Centre, Perth, WA

Website: www.newgengold.com

5-9 December

2005 AGU FALL MEETING

Venue: San Francisco, California, USA

Website: www.agu.org/meetings

2006

2-6 April 2006

SAGEEP '06: 19TH ANNUAL SYMPOSIUM ON THE APPLICATION OF GEOPHYSICS TO ENGINEERING AND ENVIRONMENTAL PROBLEMS

Organisers: Environmental and Engineering Geophysical Society

Venue: Seattle, Washington, USA

Email: staff@eegs.org

Website: www.eegs.org

19- 21 April

AAS ELIZABETH AND FREDERICK WHITE CONFERENCE

Theme: Mastering the data explosion in the Earth and Environmental sciences.

Venue: Shine Dome of the Australian Academy of Science, Canberra

Website: <http://rses.anu.edu.au/cadi/Whiteconference>

7-10 May

2006 APPEA CONFERENCE

Venue: Gold Coast Convention and Exhibition Centre, Qld

Deadline for receipt

of Abstracts: 1 September 2005

Website: <http://www.appea.com.au/conference/CallforPapers2006.pdf>

12-15 June

68TH EAGE CONFERENCE & EXHIBITION

Venue: Vienna, Austria

Contact: <http://www.eage.org/conferences/>

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.

Website: www.earth2006.org.au

1-6 October

SEG INTERNATIONAL EXPOSITION & 76TH ANNUAL MEETING

Venue: New Orleans, Louisiana, U.S.

Contact: <http://seg.org/meetings/calendar>

2007

18-22 November

ASEG's 19TH INTERNATIONAL CONFERENCE AND EXHIBITION

Venue: Perth, WA

Contact: Brian Evans

Email: brian.evans@geophy.curtin.edu.au

2-6 JULY 2006
MELBOURNE CONVENTION AND EXHIBITION CENTRE
VICTORIA AUSTRALIA

australian earth sciences convention 2006

KEY DATES

Call for Abstracts Opens	1 June 2005
Online Registration Opens	1 June 2005
Deadline for Receipt of Abstracts	15 December 2005
Early Bird Registration closes	28 February 2006

www.earth2006.org.au

GEOLOGICAL SOCIETY OF AUSTRALIA 18TH AUSTRALIAN GEOLOGICAL CONVENTION AND AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS 18TH INTERNATIONAL GEOPHYSICAL CONFERENCE AND EXHIBITION

Australian Earth Sciences Convention 2006 – Resourcing Our Future

Second call for abstracts

Now is the time to prepare an abstract for the 2006 ASEG Conference.

Submissions are invited on the five main convention themes:

- Mineral Resources
- Energy Resources
- Environmental and Engineering Geoscience
- Geodynamics of Earth's Evolution
- Resourcing and Innovation

Titles of specific symposia in each theme can be found at the convention website at: www.earth2006.org.au

You should submit your 100 word short abstract by 15 December 2005. Selection of papers for oral presentation will be based on the short abstract submissions. You may also submit your abstract for poster presentation. If you are unsure of which symposium suits your abstract, please submit it under one of the main themes, and the Technical Program Committee will allocate it to an appropriate place within

the program. If you have any difficulties with your submission via the convention website, please contact the convention office.

If your paper is selected for oral presentation, you will be invited to submit an extended abstract (10 Mbyte limit) for publication on the convention DVD. Submissions should be made via the convention website prior to 31 March 2006. The DVD provides valuable information about your presentation and will be available to all delegates from the beginning of the convention.

For those authors who would like their papers published in a refereed journal, a list of abstracts will be supplied to the ASEG's Exploration Geophysics and GSA's Australian Journal of Earth Sciences. You may then be contacted by one of the journals and invited to submit your paper for peer review and publication. Of course you are free to submit papers directly to either journal.

The convention is being jointly organised by the ASEG and the Geological Society of Australia (GSA). The name is new, to emphasise that this is something different for both ASEG and GSA. We expect 1,000 delegates, 100 trade booths, a program of lectures with five major geoscience themes, pre- and post- conference workshops and excursions, plus a variety of social activities.

If you would like to support the convention, the exhibition prospectus and sponsorship prospectus are available from the convention website or through the convention office.

Major Sponsors to date:

- Platinum Sponsor – Inco Resources (Australia) Limited
- Gold Sponsor – Department of Primary Industries, Victoria
- Silver Sponsor – Veritas DGC Australia

Key Dates:

- Trade booth allocation – 2 December 2005
- Abstract Submission Deadline – 15 December 2005
- Early Bird Registration Deadline – 28 February 2006
- Extended Abstract submission by – 31 March 2006
- Australian Earth Sciences Convention 2006 – 2 to 6 July 2006.

For more information please visit www.earth2006.org.au or contact the Convention Office:

The Meeting Planners
91-97 Islington St,
Collingwood, Vic., 3066
Tel: 03 9417 0888 Fax: 03 9417 0899
Email: earth2006@meetingplanners.com.au

Suzanne Haydon

New Members

The ASEG welcomes the following new members to the society. Their membership was approved at the Federal Executive meetings on 27th July and 31st August 2005:

Robert Jonathan Angus		David Dickinson		Leigh Warwick Scoby-Smith	
<i>Rama Geoscience</i>	<i>Qld</i>	<i>Woodside Energy Ltd</i>	<i>WA</i>	<i>Chevron Texaco Australia</i>	<i>WA</i>
Martin Paul Bayly		Anthony Paul Gartrell		Michael Paull Sykes	
<i>WesternGeco</i>	<i>WA</i>	<i>CSIRO</i>	<i>WA</i>	<i>Fugro Seismic Imaging</i>	<i>WA</i>
Kelly Beaglehole		Melanie Gayne		Peter Vaughan	
<i>Fugro Seismic Imaging</i>	<i>WA</i>	<i>CGG Australia Services Pty Ltd</i>	<i>WA</i>	<i>Chevron Texaco Australia</i>	<i>WA</i>
Steven Carroll		Dina Makarynska		Austin Vermeulen	
<i>University of WA</i>	<i>WA</i>	<i>Curtin University</i>	<i>WA</i>	<i>Curtin University</i>	<i>WA</i>
Kirsten Dahl		David John McInnes		Michael Whitford	
<i>University of WA</i>	<i>WA</i>	<i>Heathgate Resources</i>	<i>SA</i>	<i>Resource Potentials</i>	<i>WA</i>
		Glenn Morgan		Christopher Wijns	
		<i>Oil Search Limited</i>	<i>NSW</i>	<i>Resolute Mining Ltd</i>	<i>WA</i>
		Michael Adedayo Opadokun		Augelika-Maria Wulff	
		<i>Woodside Energy Ltd</i>	<i>WA</i>	<i>Woodside Energy Ltd</i>	<i>WA</i>
		Thomas Alan Ridsdill-Smith			
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¹ Members and chairpeople of ASEG's Standing and ad hoc Committees can be found on the ASEG website.

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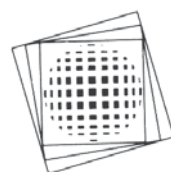
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ASEG 2005 WINE OFFER

The ASEG SA Branch is pleased to be able to present the following wines to you after tasting a field of wines in the price range. These wines were found by the tasting panel to be enjoyable drinking and excellent value. The price of each wine includes bulk delivery to a distribution point in each capital city in mid-December. Stocks are limited and orders will be filled on a first-come, first-served basis.

Please note that this is a non-profit activity carried out by the ASEG SA Branch committee. The prices have been specially negotiated with the wineries and are not available through commercial outlets. Compare prices if you wish but it is important that you do not disclose them to commercial outlets.

Hugo 2003 McLaren Vale Shiraz

The 2003 Hugo Shiraz is spicy and floral like in style with a fragrant nose and a generosity of flavour, typical of the McLaren Vale Wine Region.

Being dark plum/maroon in colour, this wine exhibits aromas of plum and dark berry over a complex bouquet of chocolate syrup, liquorice and black pepper. Supple velvety tannins pervade, carrying the concentrated, juicy plum and dark berry-fruit the full length of the palate. Generous fruit and firm tannins compliment this well structured wine adding dimension to the existing complex flavours.

An excellent accompaniment to seared Kangaroo fillets, lamb braise or some good strong cheeses.

Awarded 4 Stars - Winestate Magazine, July/August 2005.



Retails at around \$240/case

Angove's Clare Riesling 2004

Angove's Clare Riesling is part of their Vineyard Select premium wine range, and has been sourced from two distinctly different mature vineyards in the Clare Valley. Each impart a differing array of flavours and aromas, and the two parcels are kept separate until fermentation and settling is complete, when they are blended to provide an outstanding example of the Clare Valley style.

This wine leaps from the glass with intense aromas of citrus and passionfruit. The palate is also intense with lemon, lime, grapefruit and passionfruit all present to tantalise the tastebuds. The finish is clean and crisp with the flavours lingering long after the wine has gone. Enjoy with Summer salads, grilled chicken and smoked salmon.

This wine will age gracefully over the coming years.



Retails at around \$180/case

2005 ASEG WINE OFFER: orders close NOVEMBER 9th 2005

Please supply:

Number of dozens	Wine	Price per Dozen	Total
	Hugo Shiraz 2003	\$140	
	Angove's Clare Riesling 2004	\$120	
	TOTAL		

Name: _____ Daytime telephone: (____) _____ Email address: _____

Address: _____ Capital city for collection: _____

I would like to pay by: ☐ Cheque – payable to ASEG SA Wine Offer (enclosed) ☐ Bankcard ☐ Visa

☐ Mastercard Card Account number: _____

Card Expiry date: ____ / ____ Signature: _____

Order and payment by mail or fax to:

ASEG Wine Offer, c/o David Cockshell, PIRSA, GPO Box 1671, Adelaide 5001.

Telephone: 08 8463 3233, Fax: 08 8463 3229, email: cockshell.david@saugov.sa.gov.au

Enquiries: Jill Slater, Tel: 08 8218 5405, Fax: 08 8224 7765, email: jill.slater@santos.com

Australian Capital Territory – by Adrian Hitchman

Matthew Purss conducted a presentation at Geoscience Australia on 27th July entitled: *A new iterative method for computing the magnetic field at high magnetic susceptibilities*.

As a researcher with the Nuclear Monitoring Project at Geoscience Australia, Matt is responsible for seismic monitoring of underground nuclear explosions as part of Australia's commitment to the Comprehensive Nuclear-Test-Ban and Nuclear Non-Proliferation Treaties.

Matt reported on a new method that has been developed to calculate the magnetic field from arbitrary finite bodies with high magnetic susceptibility, while also minimising approximation errors due to the use of self-demagnetisation corrections for non-ellipsoidal bodies. His technique uses a segmented model that is defined by spherical elements (or voxels) of arbitrary diameter and an iterative computation of the magnetic field at the centre of each voxel in free space and then with respect to the surrounding voxels. Matt's presentation generated a significant amount of interest among attendees.

The ACT committee gathers periodically for lunch to discuss branch needs and map-out a plan for future activity. There is little heat flow as committee members are induced to reflect on issues of gravity. While our discussions are seldom seismic, the signal-to-noise ratio can tend to decrease after too much beery inversion (depending on members' susceptibility).

The ACT Branch conducts a regular program of talks from invited guest speakers, together with a range of activities of professional interest to its members. We welcome new members and visitors who may wish to participate in branch activities. For further information, phone the secretary, Adrian Hitchman (02) 6249 9800 or email adrian.hitchman@ga.gov.au, or phone the president, Jacques Sayers (02) 6249 9609, or email jacques.sayers@ga.gov.au.

South Australia – by Selina Donnelley

The last few months have been very busy for the South Australian Branch. On the evening of July 22nd, the committee and invited guests participated in the annual wine tasting evening. The Chapel Cafe in Adelaide was the chosen venue, and for those brave enough to tackle the entire line-up of wines, there were 29 whites and 45 reds to taste. The evening was a great success and enjoyed by all who attended. A huge thanks must go to Sandy Watters and Jill Slater who organised the event. The chosen red, a McLaren Vale Shiraz and white, a Clare Valley Riesling are available to order now. You should have received an order form via email, and there is another in this edition of Preview. For more information regarding the 2005 wine offer contact jill.slater@santos.com.

On July 27th, 27 people attended a technical meeting, which was presented by Jill Slater from Santos, at the SA Branch of the ASEG. Jill completed an honours degree last year at Curtin University of Technology in Perth and presented the results of her honours thesis entitled, Appraisal of fault connectivity and reactivation potential – Laminaria High, during the meeting.

Jill also recently presented this talk at EAGE in Spain. Trap integrity is considered a major exploration risk in the Timor Sea and Jill's research investigated trap integrity risk and it's relation to the present distribution of hydrocarbons in the Laminaria Region. The combination of several techniques such as 3D seismic interpretation, seismic attribute analysis, stress-based reactivation potential, and VSP analysis was required to gain a better understanding of fault seal risk.

On August 18th we were lucky enough to have an interstate speaker visit us. Matt Lamont from Downunder GeoSolutions in Subiaco Western Australia, presented an excellent speech entitled, Spectral Decomposition: An evolving technology for interpretation. Matt described the QI flow undertaken to get the most out of 3D seismic volumes and covered petrophysical trends, amplitude modelling, high resolution spectral decomposition (the main focus of his talk), amplitude extraction for lithology determination, fluid prediction, Bayesian wavelet extraction, sparse spike inversion, and Bayesian model based inversion.

Matt's informative and interesting talk was the first of a series called speaker-swapping, which we plan to continue in collaboration with the WA and NSW Branches of the ASEG.

The SA Branch of the ASEG held a memorable geophysical nostalgia night on September 7th. A significant range of slides, photos, video clips and cartoons of geophysical events and personalities highlighted the depth of geophysical activities in SA. The presentation was complimented by a display of old geophysical equipment, records, maps, and memorabilia that delighted and confused newer ASEG members and a few older members. The wearing and display of ties, T-shirts, caps and stubby holders added to the heritage atmosphere of the occasion. Highlights of the evening included photographic memories of the 1988 ASEG-SEG conference when Norpac was a key seismic service contractor, extracts from the Delhi collection of jokes and articles (vintage early 1980s) and photos of recently retired Alan Appleton conducting seismic surveying at Lake Eyre in 1986. A total of 25 members, past members and guests enjoyed the night and the shared stories. The evening was a great success and thanks must go to Dave Cockshell for organising the event.



Fig. 1. The ACT Committee hard at work. From left to right: David Robinson, Matt Purss, Alice Murray, Adrian Hitchman, Leonie Jones, Jacques Sayers and Brian Minty (missing out on all the fun are Mario Bacchin, Peter Milligan and Nick Rawlinson).

We again thank our sponsors PIRSA, Schlumberger, Santos, Cooper Energy, Australian School of Petroleum, Minotaur Resources, Petrosys, Zonge Engineering, Beach Petroleum, Stuart Petroleum, and PGS Reservoir for the technical meetings in 2005.

We welcome new members and urge interested persons to come along to our technical meetings, usually held on a Wednesday night at the Duke of York hotel at 5:30pm. Please contact Selina Donnelley (selina.donnelley@santos.com) for details.

Victoria – by Ashley Grant

We had two speakers at our meeting in June, BRGM France senior researcher Antonio Guillen, who is currently on a secondment for 12 months to Intrepid Geophysics as part of the Geomodeller Consortium to support its research, development and commercialisation agenda and GeoScience Victoria geologist Cameron Quinn. Antonio provided an overview of the recent developments to make creating 3D geology models easy for geologists and geophysicists and then test using potential field data.

Cameron presented the results of his work on GSV's flagship Walhalla-Woods Point mapping project where he used a 3D GeoModeller.

On August 22nd, University of Wales computer science lecturer, Horst Holstein conducted a presentation on gravimagnetic field tensor gradiometry for uniform polyhedra. His current interest in geophysics is focused on the rigorous formulation of algorithms for potential anomalies of polyhedral targets, and in this capacity he is visiting Melbourne at the invitation of Intrepid Geophysics.

Meanwhile, the conference committee is working hard to make the Melbourne 2006 Earth Science Convention a big success.

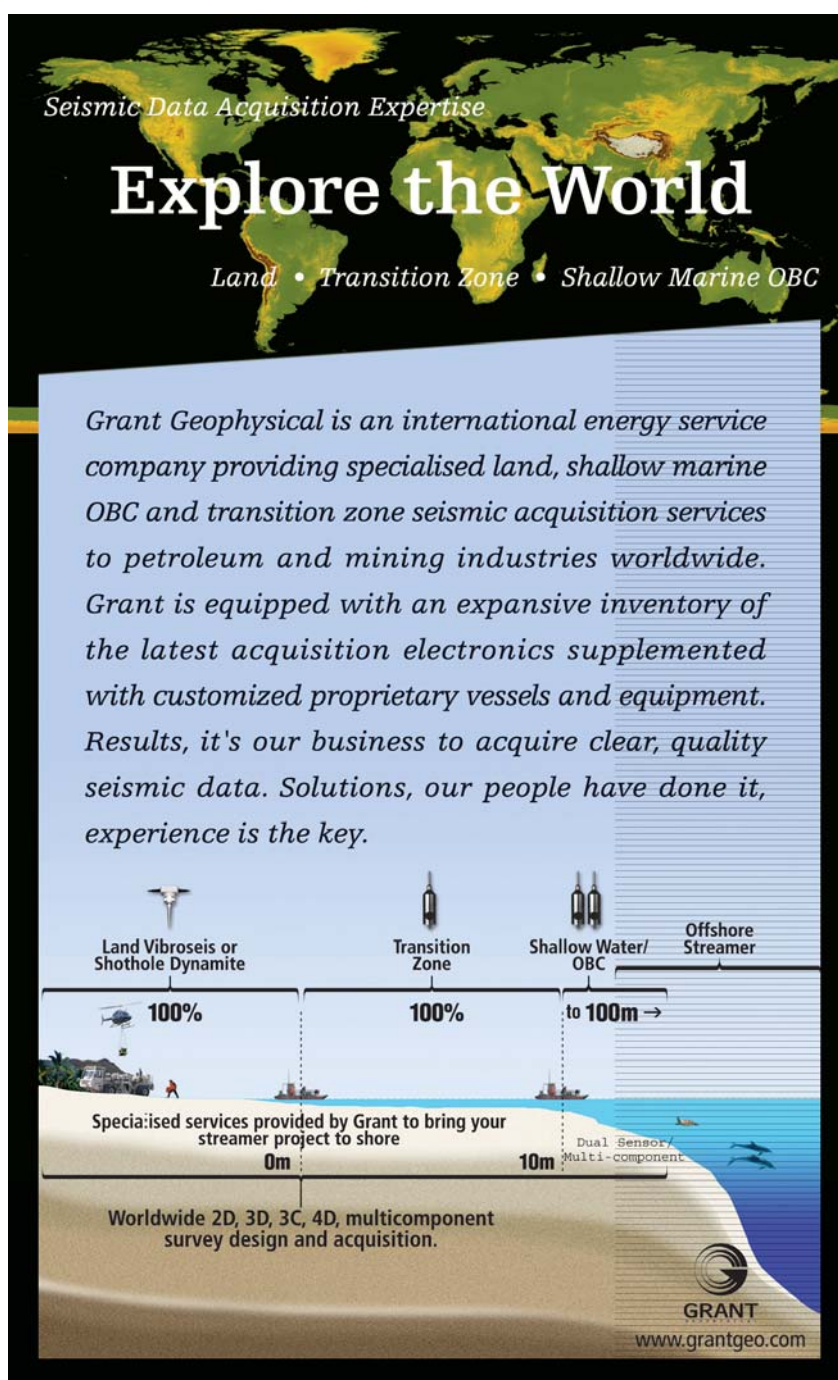
Western Australia – by Andre Gerhardt

The 2005 SEG/EAGE/ASEG Distinguished Instructor short course entitled, Insights and Methods for 4D Reservoir Monitoring and Characterisation was conducted by Dr. Rodney Calvert on August 23rd at the ARRC in Perth.

The course was designed for a broad audience and was very well attended. However, only one reservoir engineer attended.

Dr. Calvert began the course by presenting a few striking examples where 4D has significantly contributed to understanding reservoir properties and architecture. It did not take long before most of us were convinced that 4D could potentially present a significant impact on business and would probably be part of any future development project. Dr. Calvert then delved into more technical subjects.

The highlight of the course was the analysis of repeatability of acquisition and processing parameters. 4D requires a different acquisition and processing strategy than the standard 3D seismic. Acquisition geometries and processing parameters should be repeated as much as possible, and small differences between the two can lead to very large anomalies that are not production-related. Therefore, the evil is really in the detail. But I felt somewhat reassured when Dr. Calvert said that we were doing the right thing if we repeated the same mistakes when acquiring the baseline survey.



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That is certainly an interesting concept, if we stuff up once we just have to do it again and everything will be OK!

I really enjoyed his rather detailed analysis of the distortion effects caused by heterogeneous overburden (although it severely damaged my belief in routine AVO). Apparently, a large part of what we normally associate as noise is actually scattered signal that correlates only over a short distance as a result of a heterogeneous Earth. Analysis of this signal has applications not only in 4D but also for our understanding of amplitudes in general.

Some new concepts that aim at minimising these effects were also discussed. The "Virtual Source" is one such approach that promises to significantly improve image quality by using fixed receivers placed under complex overburden.

Time-lapse reservoir monitoring gives us the opportunity to identify produced volumes and locate bypassed areas, revealing the underlying reservoir connectivity which is usually largely unknown in between the wells. In the process, we also gain a better understanding of the meaning of amplitudes and the various types of noise present in our ordinary 3D data. With the potential for such great achievements, I believe it is our job as petroleum geophysicists to promote this technology as much as we can, especially

with our fellow reservoir engineers, to try and put Australia on the map as a 4D country.

Having attended a number of 4D courses in the past, I think this one was certainly the one with the best technical content. It was accompanied by superb course notes which must have taken a lot of time to put together. I thank Dr. Calvert for his effort in preparing and presenting this course to us, as part of his marathon trek throughout the world. Congratulations also to SEG/EAGE/ASEG for organising such a quality event.

Wine Tasting Evening for the 2005 ASEG Wine Offer Friday 22 July, 2005

Each year, the South Australian Branch of the Australian Society of Exploration Geophysicists selects two SA wines to promote to more than 1,000 national and international members. Thus we consider it our duty, on behalf of all the ASEG members to taste, rank, and select the very best red and white wines for the 2005 ASEG wine offer.

The evening unfolded at the lovely Chapel Café in Adelaide, which was built in 1865 and is full of character. The wine tasting team consisted of committee members, their partners, and special guests. Upon arrival, tasters were briefed on

wine tasting options, and asked to commit to tasting reds, whites, or a mixture of the two.

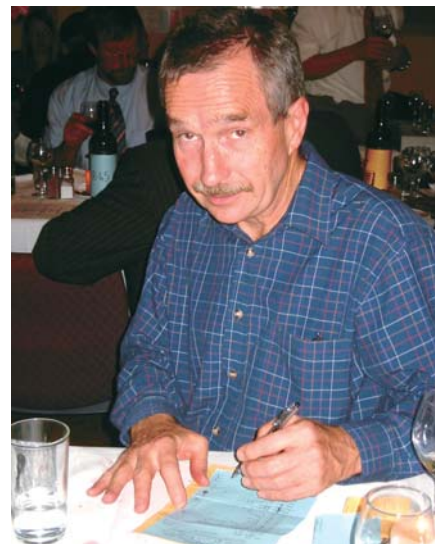
It wasn't a simple process, as we received a record number of red and white wine submissions this year. Just 34 tasters were required to sample 46 reds and 33 whites. To make things a little easier on our tasters (and in their best interests), we divided the selection of wines into two groups. This way, tasters could elect to drink half the red and white wines, all the red, all the white or just half the red or white. Sounds confusing doesn't it? We even



Event organisers, Jill Slater, left, and Sandy Watters.



Dave McInnes, Ted Tyne, Rod Lovibond and Andrew Shearer – willing participants.



Doug Roberts, concentrating hard on the job at hand.

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built flow charts to make the process clear for our tasters. Once the tasters understood how the evening was to progress, the function proceeded very smoothly.

All tasters were asked to commit to their wine tasting plan with no pulling-out halfway through. And another catch, the wines were to be tasted blind – that is, with no information given to the taster on the winery, variety of wine, vintage, tasting notes or price. This ensured that tasters didn't anchor on to their favourite wine variety or winery.

Following their briefing, and with pen and ranking forms in hand, our tasters were equipped and ready to begin their blind tasting. It was not an easy feat to get through the large group of white and red wines. Sixteen white wines to taste before the main meal, and 23 reds to taste afterwards. Non-stop tasting was conducted for four hours, and three breaks were allotted between the tastings to enjoy a delicious entree, main and dessert.

With good food, some great wines, good company, and a great atmosphere the evening proved to be a complete success. Most tasters were committed to the task, tasting all the whites and reds they had intended to taste without defaulting from their original tasting plans. For the majority of tasters, the reds were tasted after the white. Late into the night it became quite tricky to decipher the excellent reds from the good reds. But thanks to our faithful red-only drinkers, we trust our results are accurate, with the top red and the top white standing well above the rest.

Sandy and Brett's worked diligently with the calculator, which revealed the top red and white wine from the final taste-off at the end of the evening.

It was looking like a close rank between three wines of different varieties towards the end of the white-wine taste-off. The results between the final four, a Chardonnay, a Riesling, a Semillon / Sauvignon Blanc and a Sauvignon Blanc were so close that we needed a final taste-off to separate the exceptional from the excellent. Of course, we had a final winner.

The top red was a stand-out best from the high calibre of submitted wines. On behalf of the ASEG SA Committee, I am pleased to announce that the top wines, as judged by our tasters are **Angove's 2004 Clare Riesling** and

Hugo 2003 McLaren Vale Shiraz.

The winning white and red wines are selling \$120 and \$140 by the dozen respectively. You will find the ASEG 2005 wine offer order form in this edition of preview, as well as on the ASEG SA website at www.aseg.org.au/sa

The function drew to a close at midnight, with the last of the dedicated wine tasters tripping over the step as they walked out the door of The Chapel and bottles of wine tucked under their arms. An excellent evening was enjoyed by all.

Thanks must go to the wineries that submitted their wines and made the event possible. Twenty-six wineries participated this year and 15 of had not submitted in the past. The submitted were derived from a range of districts in SA, including the more well known regions such as the McLaren Vale, Barossa, and Clare Valley, as well as boutique wineries like Burra, Flinders Rangers and Langhorne Creek.

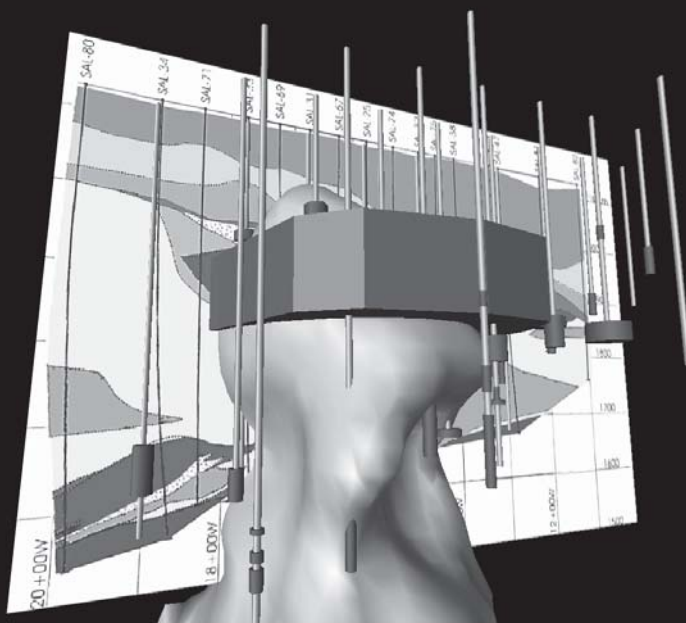
Thanks must also go to the wonderful staff at Chapel Café for hosting our event, to the tasters, and to the wine committee for organising the event.

Jill Slater

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Australian Wine

"Wine improves with age. The older I get, the better I like it" – Anon.

With the launch of the 2005 ASEG Wine Offer this month, I thought it might be a great excuse to review some "wine" websites. Whether it is a glass of wine mid-week or several on the weekend, wine is an indulgence that many of us enjoy. Whether you are a wine "buff" or a wine "bluff", these websites offer loads of information on Australian wines.

Wine Region Tours

★★★★

www.wine-region-tours.com

If you are planning a trip to a wine region you have not yet visited, this is a must see site. Wine Region Tours allows you to plan your itinerary to any wine region in Australia or New Zealand. You have the option of using their services to organise all the details for your next visit, or you can print or download their wine travel guides to help you plan your own self-drive tour. There is a travel guide for every wine region in Australia and New Zealand. As well as direct links to winery websites, they

provide information on wineries and vineyards, opening hours, facilities (picnic, dining, accommodation, mail order, cellar door, art and craft, local produce), road conditions, travel time estimators and weather. This website also caters for overseas visitors.

On Wine – Australian Wine with Jeremy Oliver
www.onwine.com.au

★★★★1/2



OnWine is the personal website of Jeremy Oliver, one of Australia's leading and most influential wine critics. It has been said, "A 100% independent source, Jeremy's site provides an unrivalled resource and functionality for those wishing to explore the world of Australian wine". Always up-to-date, it has everything you need to know about Australian wine, from ratings, education, articles, news and opinion. Full access to this site comes with registration costing A\$39.95 (+GST) per year. This also gives you access to the expanded online version of the Australian

Wine Annual. As a non-subscriber, I found that access to this website is quite limited.

The Grape Unknown – Premium Cleanskins

★★★★

www.thegrapeunknown.com.au




The Grape Unknown primarily sources Australia's finest wines available in unlabelled bottles (cleanskins). By bypassing all the marketing and label cost associated with wines, their cleanskins can sell at up to 50% off their normal recommended retail price.

The website is very straightforward, allowing customers to search for wine by varietal and purchase cleanskins online. Orders within Australia are delivered within 3-5 business days. They also specialise in personalising wine labels for any function, event or fundraiser.




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The Boutique Wine Company

www.BoutiqueWineCo.com.au

★★★★1/2

The Boutique Wine Company is an independent wine retailer and wholesaler which offers wine from boutique producers in South Australia. They provide the opportunity for consumers to purchase wines from many producers who may not have the opportunity to retail through bottle shops. Their website allows you to select and purchase wines from their extensive wine list. All their wines have descriptions and tasting notes. The Boutique Wine Company also offers wine packs which make great gifts for family and friends. The website includes a selection of recipes with recommended wines to match.

Wine Australia

www.wineaustralia.com

★★★★



This website provides some interesting information on the history of wine grape growing in Australia and the wine industry. It comes packed with information and fact sheets on Australia's wine regions, wineries and wines.

I really liked the easy-to-use food and wine matcher function. Perfect for those people wanting to make an impression at their next dinner party – or for anyone wanting to learn more about what wine goes with what food.

Australian Cleanskin Wine

www.cleanskins.com.au

★★★

If you are after some quality clean skins, check out the Adelaide based company, Australian Cleanskin Wine. They have a selection of cleanskins available, with tasting notes and wine ratings.

The Wine Maker's Choice

www.winemakerschoice.com.au

★★★★



The Wine Makers Choice is a one-stop online wine shop. As well as wine, they sell beer, spirits, liqueurs and a huge range of wine accessories. You can search, select, and order your wine in a matter of minutes, with your order delivered to your door or office within a week. Like most wine clubs, they offer various wine plans to suit everyone's needs, allowing the customer to dictate the price, the quantity

and the frequency of delivery. The benefit of these sorts of companies is their tremendous buying power, equating to low prices for their customers. They also have access to limited release wines, otherwise inaccessible to the average consumer. The company is based in NSW, meaning that freight is a little less expensive to the eastern states. If you get a chance, check out their trivia competition. Not only will you learn a bit of wine trivia, you may just win a bottle of wine like I did.

Australia – Wine Diva

www.winediva.com.au

★★★★1/2



This website has everything wine-related. A very comprehensive Australian wine directory online, with everything from online wine guides, wineries, education, reviews, tourism and employment.

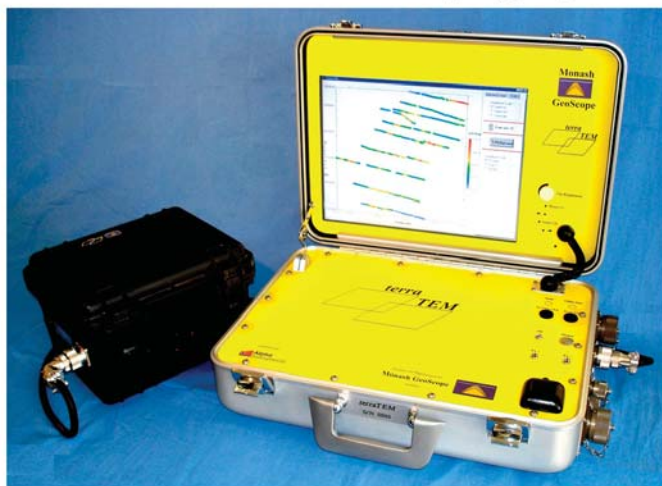
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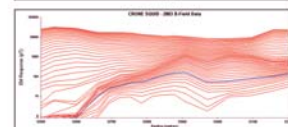
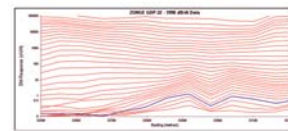
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Comparison of LANDTEM and conventional coil data over Western Areas NL's Daydown deposit, Central Yilgarn, WA.

Minerals Down Under: a bid for new Flagship in CSIRO

A bid is currently being prepared to establish a new National Research Flagship (NRF) in CSIRO with the theme, *Minerals Down Under* (MDU).

Driving the introduction of an MDU flagship is the importance of the minerals industry to Australia's wellbeing in terms of its contribution to the nation's wealth. The goal is to find \$1,000 billion of new reserves by developing ways of *finding* new ore and *extracting* currently uneconomic resources profitably.

Flagships

CSIRO's resources are increasingly focused on its NRF program, which is one of the largest scientific initiatives ever undertaken in Australia and is designed to integrate and direct our national scientific resources. Currently, there are six flagships operating within the program, including:

- **Preventative Health** – Improving the health and well being of Australians and save \$2 billion in annual direct health costs by 2020 through the prevention and early detection of chronic diseases.
- **Light Metals** – Leading a global revolution in light metals, doubling export income and generating significant new industries for Australia by the 2020s while reducing environmental impact.
- **Food Futures** – Transforming the international competitiveness and add \$3 billion annually to the Australian agrifood sector by the application of frontier technologies to high-potential industries.
- **Energy Transformed** – Halving greenhouse gas emissions and double the efficiency of the nation's new energy generation, supply and end use, and to position Australia for a future hydrogen economy.

- **Water for a Healthy Country** – Achieving a tenfold increase in the social, economic and environmental benefits from water by 2025.
- **Wealth from Oceans** – Positioning Australia by 2020 as an international benchmark in the delivery of economic, social and environmental wealth based on leadership in understanding ocean systems and processes.

CSIRO allocated \$62.3 million to the Flagships initiative in 2004/05. When this amount was added to other CSIRO, partner and industry contributions the total resources available for the Flagships in the last financial year was approximately \$145 million.

The government has now awarded an additional \$305 million of funding for Flagships in the next seven years.

Minerals Down Under

The MDU business plan will be considered in November 2005 and if the bid is successful, research funding will start in July 2006. However, the bidding process within CSIRO will be very competitive and the bid will need substantial support from industry to succeed.

There will be three themes in the MDU program:

Theme 1 – **Discovery** – technology for finding world class deposits in Australia

- under cover
- at depth
- with lower technical risk.

Theme 2 – **Recovery** – technology to convert inaccessible and low grade resources to ore

- deeper, lower operational costs
- minimum dilution, sterilization
- zero waste, small footprint.

Theme 3 – **Minerals Futures** – a forum for integrated analysis of:

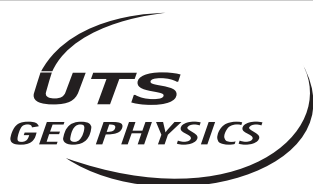
- mineral economics

- licence to operate
- regulation and incentives.

The major issues and commodities will focus on:

- Iron – rapidly depleting high grade reserves with P and Al_2O_3 in the remaining resource, approximately \$300 billion.
- Low Grade Nickel – most of these new resources are marginal or uneconomic approximately \$260 billion to \$430 billion.
- Murray Basin Heavy Minerals – large resources that can't be mined, approximately \$50 billion.
- Thick Seam Coal – existing long-wall techniques will sterilize up to 80% of thick seams approximately \$500 billion to \$1,000 billion.
- Gold – increasing cost of discovery as exploration goes under cover...replacement only over 20 years, approximately \$60 billion.
- Base Metals – as for gold..... \$? billion.
- Uranium – licence to operate.
- Steady improvement in:
 - geophysical tools but no new magic bullets
 - geochemistry of mineral phases and water, with some exciting new possibilities in biogeochemistry.
- Target selection will be based on predictive models, integrated data and sophisticated risk management.
- Cheaper, data-intensive drilling will provide the next breakthrough by providing totally new maps of sub-surface mineralogy and geochemistry.
- Vastly expanded, easily accessible, pre-competitive data will be critical. All the data from every exploration hole in Australia captured in pre-competitive data bases.

The above is a very short summary of the proposal which is being led by Andy Green. If you think you can provide input or support, or if you would just like more information, please contact him on email andy.green@csiro.au



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Fred Kroh



Paul Williamson

Preliminary AVO results from the Bremer Sub-basin SW Australia

By F. Kroh and P. E. Williamson

Geoscience Australia

Email contact for more information

fred.kroh@ga.gov.au

paul.williamson@ga.gov.au

Introduction

The preliminary amplitude versus offset (AVO) anomalies that we are reporting on are of two types and are identified in seismic reflection data collected by Geoscience Australia.

The data was collected as part of Geoscience Australia's southwest frontiers survey (s280) conducted in the Bremer Sub-basin of southwest Australia in October and November 2004 (Figure 1).

The survey was designed in consultation with industry and the 1,300 line-km of data were collected as part of the big new oil (BNO) program that was announced in the May 2003 Commonwealth budget. The BNO program of data collection and preservation extends through four years and is intended to stimulate the search for new oil provinces in Australia to meet the projected decline in oil production throughout the country, as initially reported by Powell (2001). The 2001 study indicated that the current rate of discovery of oil would be insufficient to replace production.

The southwest frontiers survey is only one of a number of commercially collected seismic surveys which will form part of the data collection phase of the BNO program by Geoscience Australia. Along with the availability of new high quality data from the program, the Innovation and Specialist Studies Group in the Petroleum and Marine Division of Geoscience Australia underwent reorganisation in July, which has increased the emphasis on the use of the newly acquired and existing seismic data to assess petroleum prospectivity.

Part of this effort involves AVO studies and the development of AVO products to look for

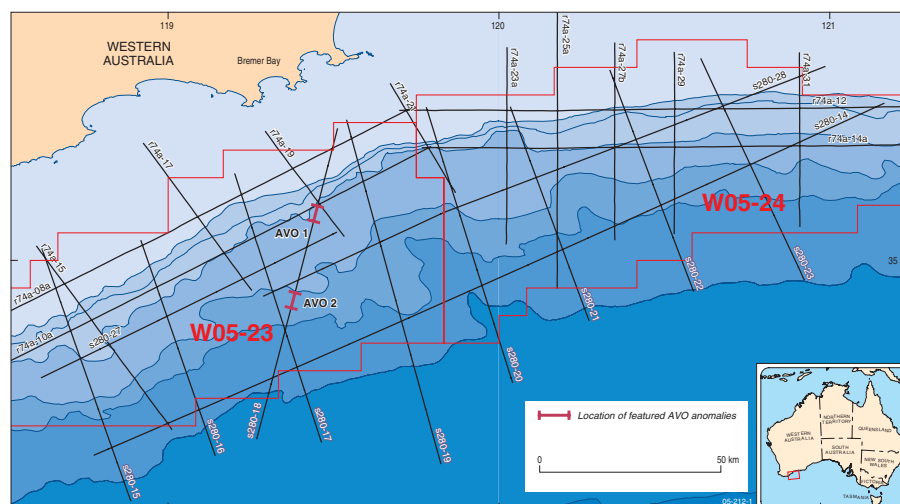


Fig. 1. Location of the preliminary Amplitude Versus Offset anomalies on Line 18 on Geoscience Australia Survey 280.

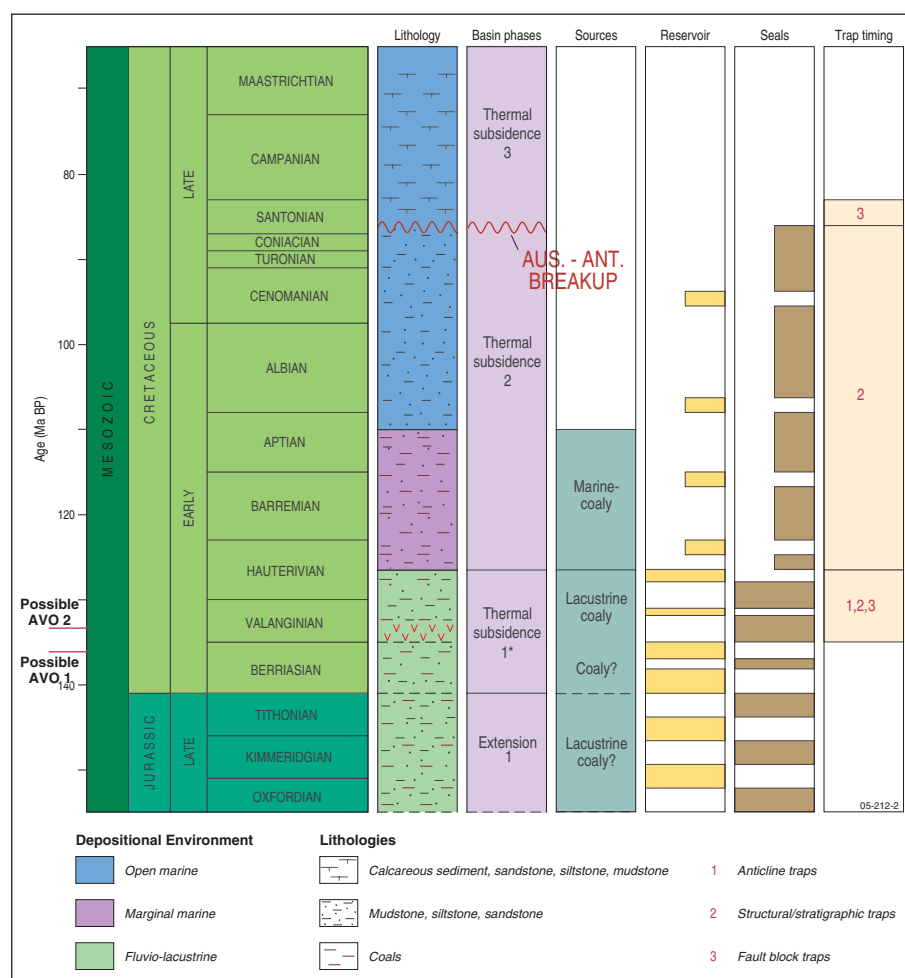


Fig. 2. Stratigraphy and petroleum systems elements of the Bremer Sub-Basin showing the stratigraphic intervals of the preliminary AVO anomalies.

indicators of possible hydrocarbon occurrences. The two AVO anomalies featured in this preliminary report are shown in Figure 1.

The Bremer Sub-basin is the location of the featured anomalies and is a largely Jurassic

to Cretaceous sedimentary basin (Figure 2) occurring on the south western Australian margin (Blevin, in press; Bradshaw, 2005). It has not been explored to any great extent in the past largely because of water depth. Previous exploration consists of the coarse

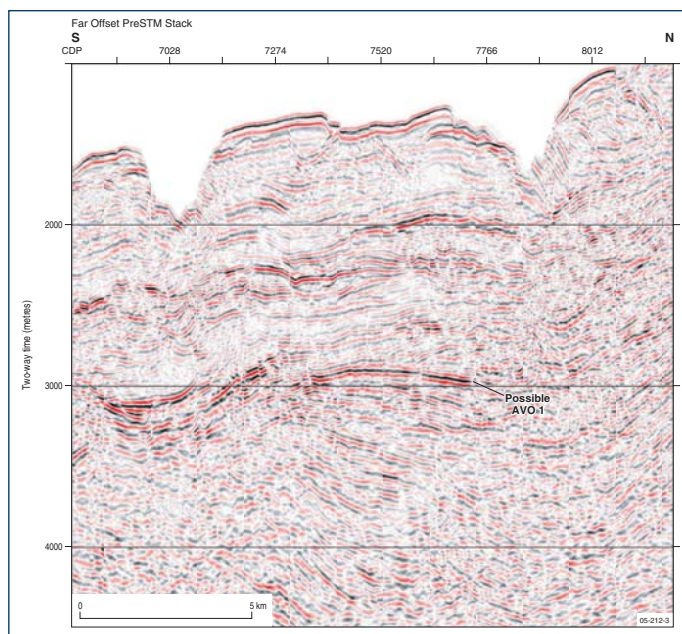


Fig. 3. Far offset stacked section of possible AVO anomaly 1.

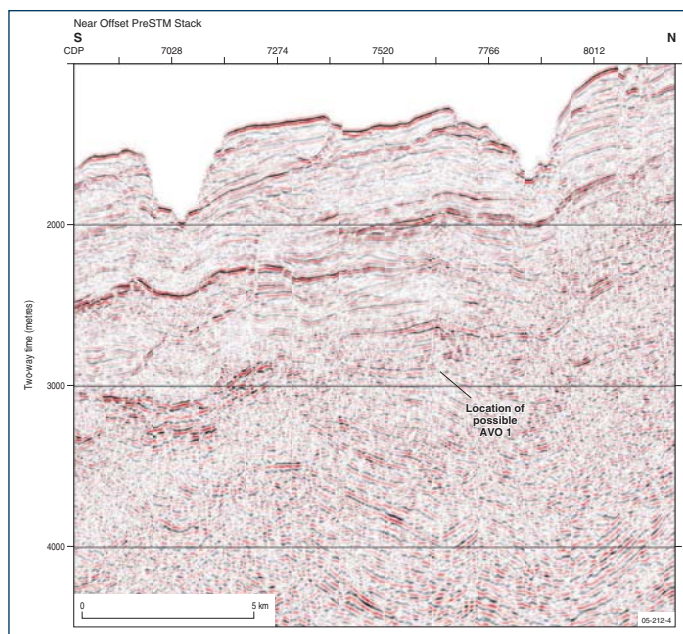


Fig. 4. Near offset stacked section of the AVO anomaly 1.

Esso 1974 seismic grid. With developments in exploration and production technology deep water no longer presents the impediment to petroleum exploration and production that it once did and the sub-basin is receiving renewed attention.

The Bremer Sub-basin acreage was released for petroleum exploration permit bidding in early 2005 with bids to close in April 2006. This acreage attracts 150 % tax uplift as part of the Commonwealth Government's promotion of frontier acreage. Results of studies undertaken by Geoscience Australia on the Bremer Sub-basin data were made publicly available in a workshop on October 13th and 14th, 2005. Seismic data from the Bremer Sub-basin were already available for the cost of transfer. Common depth point (CDP) pre-stack time migrated gathers plus near, middle, and far trace stacks derived from further processing are also now available.

Geology

The Bremer Sub-basin forms part of the rifted southern margin of Australia. Main unconformities within the section are at Base Cretaceous and Mid-Cretaceous levels (Figure 2). There are up to 11 km of sediment in the Bremer Sub-basin. Consequently, maturation of hydrocarbons would have occurred if suitable source rocks existed at depth (Bradshaw, 2005).

The geological setting of strata possibly relating to the first AVO anomaly (Figures 3, 4 and 5) is in the basal section in the Berriasian (B. Bradshaw, pers. comm.) above the Base Cretaceous unconformity. It is in an interval where fluvial sands are believed to occur beneath lacustrine mudstones. The seismic expression of that AVO anomaly suggests a broad anticlinal structure. A stratigraphic column indicating the interval where the AVO feature occurs is shown as Figure 2.

The geological setting of strata possibly relating to the second AVO anomaly (Figures 6, 7 and 8) is higher in the Lower Cretaceous section in the Valanginian (B. Bradshaw, pers. comm.) as shown in Figure 2. Again it is in an interval where fluvial sands are believed to occur beneath thick lacustrine mudstones. The seismic expression of that AVO anomaly suggests a down faulted feature.

AVO Processing

As an extension to the original processing, near, middle and far trace stacks were derived from pre-stack, time migrated gathers. Due to time constraints, these gathers still require further processing to make them fully AVO compliant. The intent is to show possible AVO anomalies but it is expected that further work would be required for phase and amplitude corrections to allow more detailed analysis. The initial processing sequence was AVO amplitude compliant.

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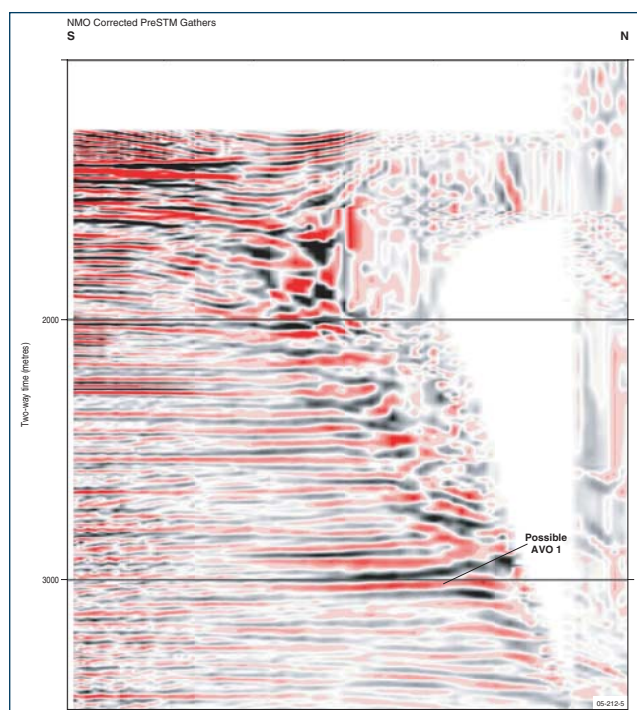


Fig. 5. Common Mid-Point stack for shot point 1671 on AVO anomaly 1.

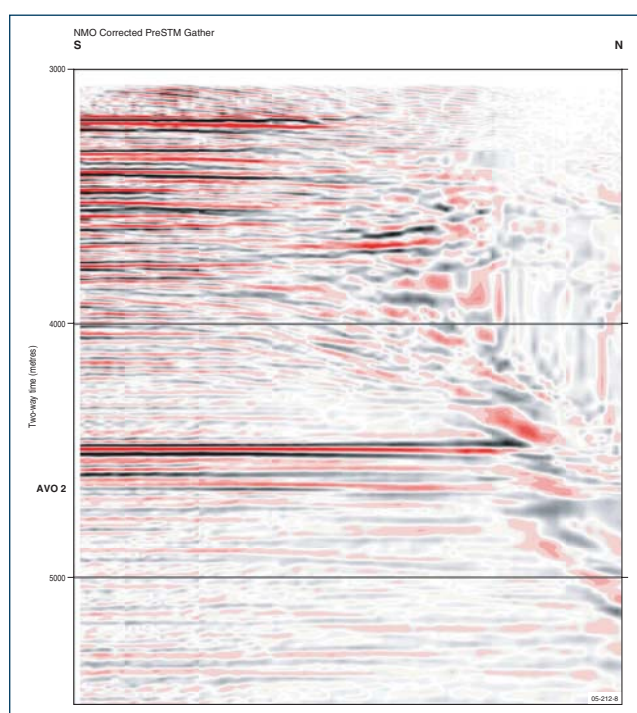


Fig. 8. Common Mid Point stack for shot point 2473 on AVO anomaly 2.

The stack and post processing parameters were as follows:

- Near Offset Stack - An Angle Mute was applied with an inner mute of 4 degrees, and an outer mute of 18 degrees;
- Middle Offset Stack - An Angle Mute was applied with an inner mute of 18 degrees, and an outer mute of 34 degrees;
- Far Offset Stack - An Angle Mute was applied

with an inner mute of 32 degrees, and an outer mute of 48 degrees.

Discussion

As the data has only just become available, a very basic analysis of these stacks and gather datasets has to date been undertaken only on three lines. Only the line presented, S280-18 has been completely analysed. Initial results

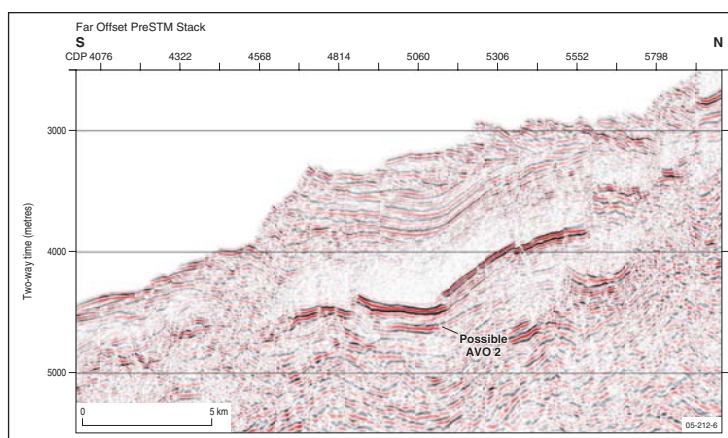


Fig. 6. Far offset stacked section of possible AVO anomaly 2.

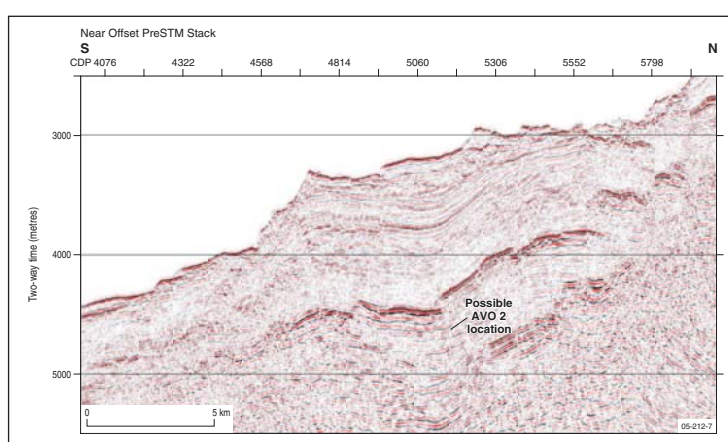


Fig. 7. Near offset stacked section of the AVO anomaly 2.

show potential AVO anomalies which warrant further investigation.

The AVO anomalies occur in the Cretaceous section, and as such may not have the high amplitude expressions of direct hydrocarbon indicators associated (for example) with gas accumulations in the Miocene of the Gulf of Mexico. Neither feature is seen as an amplitude anomaly on the stacked and migrated seismic section, but both are apparent in the AVO processing.

The AVO anomalies occur on a regional seismic grid with no cross lines over the anomalies. Consequently, it has not been possible to map the aerial extent of the features. It also has not been possible to map the anomalies to investigate whether down dip terminations are consistent with their mapped extent, as would be expected for a fluid contact such as a gas or water contact in an anticline, or for the down-dip fluid contact in a fault trap.

What is known is that the first anomaly is approximately 5 km long on this seismic line.

There is also the suggestion of a flat event at its base.

Also lacking in this frontier basin is well data on the strata that could be associated with the AVO anomalies. Such information would assist to model geological features with associated fluids to provide insights into the cause(s) of the anomalies. Dredge information associated with the Bremer study provides some insights into the stratigraphic framework. It is insufficient however for confident modelling of the AVO anomalies.

The characteristics of the two AVO anomalies are different, but it is uncertain if this relates to different causes or different lithological associations. The first anomaly is deeper in the Cretaceous section and appears to have a hard response at far offset, which is the same polarity as the water bottom seismic event. The second anomaly appears to have a soft response, which is opposite in polarity to the water bottom event. The anomalies may benefit from additional processing to provide more confidence in their true seismic phases.

Volcanic intrusions are known to occur in Early Cretaceous strata from the Bremer Sub-basin. However, the amplitude versus offset features of the AVO anomalies are different from those associated with events which are considered to be volcanics in our data set. The events considered to be volcanics have consistent amplitude from near to far offsets of the CDP gathers, whereas the AVO anomalies have weaker expression on near offsets and stronger expression on far offsets.

The geological feasibility in relation to structure and rock type, particularly of the first AVO feature (on one line only) being associated with a gas accumulation, may be a positive aspect in its interpretation. In both the Carnarvon and Gippsland Basins, both gas and oil occur in the same region. Therefore, the occurrence of these anomalies, if it does transpire that they are associated with gas, does not preclude the occurrence of oil in the region. What it does do, is indicate that there may be viable plays for hydrocarbons in the Bremer Sub-basin.

Conclusion

This preliminary presentation of AVO anomalies in the Bremer Sub-basin suggests that the technique may have value for exploration in the basin. The Geoscience Australia Southwest Frontiers Survey augments the coarse-grid of seismic data previously obtained in the sub-basin. More seismic data, more detailed AVO and structural evaluations, and AVO modelling are required to establish with confidence the validity of the AVO anomalies and to possibly define potential drilling sites.

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Farewell to WMC

By Lisa Vella
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The WMC story dates back to 1933 when the company, originally incorporated as Western Mining Corporation Ltd., was formed as the Western Australian arm of Gold Mines of Australia Ltd. Before and after the Second World War, WMC was purely a gold miner, operating several gold mines in Western Australia. In 1953, the Board decided to become involved in base metal exploration and by 1955, the first copper project had been started at Ravensthorpe. Although this was only a small project, it heralded the move into base metals that would turn WMC into a very successful multi-commodity explorer and miner. With such a long and fascinating history, it will be impossible to do justice to the WMC story in such a brief article. Therefore, I thought I would just touch on some of the highlights.

One of WMC's early and very successful undertakings was in the area of bauxite exploration. In early 1957, the Consolidated Zinc Group announced the discovery of the Weipa bauxite deposit at Cape York, in Queensland. Prior to this, the major known bauxite resource in Australia was at Gove (NE of Arnhem Land) and conventional wisdom held that bauxite ore was mainly found in tropical areas. However, Don Campbell, a geologist who had been with WMC since 1933, believed that the bauxite search should commence in the Darling Range of Western Australia. The source of this belief was apparently a map he had seen in the 1930s showing the extent of bauxitic laterites in south-west Western Australia, compiled during the First World War, at a time when the British Government was concerned about security of their supply of bauxite.

In 1957, Don Campbell followed up his lead. The main source of information then was a Bureau of Mineral Resources report on bauxite resources, which briefly mentioned the Darling Range. At that time the consensus on the Darling Range bauxite laterites was that they were uneconomic, with low-grade alumina. Fortunately for WMC, this proved to be incorrect. With encouragement from Roy



Fig. 1. Aerial view of Olympic Dam, showing the massive capital investment required in this remote and inhospitable part of South Australia.



Fig. 3. Olympic Dam showing more of the on-site infrastructure.

Woodall (another geologist who commenced with WMC in 1953), existing analytical data were re-interpreted and reconnaissance and then detailed exploration was carried out, the result of which was the discovery of a substantial resource of bauxite.

A footnote to the bauxite story is that in 1959, WMC was negotiating with the Mines Department on how best to consolidate leasing over such a laterally extensive deposit. As a gesture of goodwill, WMC reduced the total leasing package, excising the Mt Saddleback area, on the basis of its remoteness from ports and different geological character. In later years it became apparent that this decision cost WMC both a major bauxite deposit and a significant part of the Boddington gold deposit.

Close on the heels of the bauxite discovery, WMC also had success in the exploration for iron ore. Early geological reports discussed the potential of the Pilbara for huge iron ore deposits, but the region was very remote. WMC geologists Roy Woodall and David Barr conducted aerial reconnaissance of this area, as well as the Fortescue and Murchison. There was early cooperation with Rio Tinto, however, this was short-lived. In 1961, WMC decided to enter the industry via the Talling

deposit, east of Geraldton. Despite the obvious potential of the Pilbara, WMC decided to stay out of this area as the huge capital investment required was beyond WMC's capacity.

1961 was the pivotal year for WMC in the iron ore game. Its tender for Talling Peak had been accepted by the Western Australian government and the Koolanooka deposit was discovered 16 km east of Morewa. In the years that followed, other deposits were found and WMC was shipping iron ore until around 1974. Although these operations had been relatively small, the cash flow helped sustain WMC's exploration effort in the late 1960s when Kambalda would be discovered.

The first major nickel deposit discovered in Australia (in 1953) was the Wingellina nickel laterite in the Musgrave Block of Western Australia. Several North American companies had been actively exploring for nickel in Australia for some time, but as of 1965, the Yilgarn Craton of Western Australia was not known to host any nickel mineralization. In early 1966, WMC drilled the Kambalda discovery hole (KD1), and intersected 2.75 m @ 8.3% nickel in the Lunnon shoot. This discovery triggered the West Australian Nickel Boom, with the ultimate result being that today

the Yilgarn is one of the great nickel provinces of the world.

Following its initial discovery of nickel in the Yilgarn, WMC made several other significant discoveries in the Kambalda region. The Nickel Boom effectively ended in 1972 and there was a long hiatus in nickel expenditure which lasted until 1987. However, WMC continued to explore and mine in the Yilgarn and in 1986 was the only nickel producing company there. This situation did not change until some years after the revival of nickel exploration in 1988. The Kambalda discovery was a turning

point for WMC, providing the company with a substantial cash flow and giving it the means to become one of Australia's major mining houses.

In 1968, support from Sir Arvi Parbo was received for the establishment within WMC of an autonomous Exploration Division, with Roy Woodall being its Exploration Manager and Chief Geologist. Roy Woodall believed greatly in exploration by multi-disciplinary teams and geoscientific technical expertise throughout the organisation was strongly encouraged. In the late 1960s, a tradition

of an annual geoscientific conference (held in Kalgoorlie) and conference dinner was started. This tradition, aimed at the exchange of knowledge and ideas, has continued until very recently.

In 1970, the newly formed Exploration Division found itself in a bit of a dilemma. In March of that year a Bureau of Mineral Resources aerial magnetic and radiometric map of the Sandstone 1:250,000 Sheet area was published, and this showed a very prominent radiometric anomaly north west of Yeelirrie Station homestead. A field visit suggested that this anomaly coincided with the Yeelirrie drainage channel. At that time the craziness of the Nickel Boom had reached such a point that the Minister of Mines had introduced a pegging ban, until the Mines Department could deal with the paperwork of all the existing tenement applications. Exploration Division Geoscientists thought it possible they had a major discovery on their hands with Yeelirrie, but had no way of protecting it.

The pegging ban was lifted in June. Great secrecy had to be maintained within the Exploration Division and much planning went into the resumption of pegging. When the ban was lifted would-be peggers were in a frenzy, but no competitors observed WMC quietly peg the main anomaly over Yeelirrie and several other look-alike drainage channels within the Yilgarn. Detailed evaluation of Yeelirrie resulted in WMC announcing in 1972 that they had discovered a major ore location, with a potential resource of over 40,000 tonnes of uranium oxide. Anti-nuclear attitudes of subsequent governments have meant that development of this resource is yet to be realized.

Ironically, WMC's greatest success in the uranium search came in the form of the giant Olympic Dam iron-oxide copper-gold deposit, discovered in 1975. There is probably nothing new that can be said about this truly incredible ore body (see Figures 1-3). Several factors contributed to the discovery of Olympic Dam including, but not limited to, the geological model of Douglas Haynes (a geologist who joined WMC in 1967), lineament studies undertaken by Tim O'Driscoll, compilation and interpretation of gravity and magnetic data by Hugh Rutter (a geophysicist with WMC between 1968 and 1977) and lastly, there was the commitment of management who gave their support to the exploration team as they



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Fig. 2. Olympic Dam headframe.

drilled nine very deep holes before RD10, the discovery hole. The Olympic Dam discovery was a multi-disciplinary team effort and a model for how exploration would be conducted in WMC in the years that followed.

In the intervening years since, WMC continued to place a great deal of importance on both green field and brown field exploration. In the 1990s, like many other companies, WMC expanded its exploration activities across the globe exploring in countries from Burkina Faso and Eritrea, to Kazakhstan and Uzbekistan, to China and the Philippines, to Brazil and Chile, to the USA and Canada, and many places in between. There have been great successes: Ernest Henry iron-oxide copper-gold (Queensland), Meliadine gold (Canada), Tampakan porphyry copper (Philippines), West Musgrave nickel (Western Australia) and Collurabie nickel (Western Australia), among others. And there have been some failures...

Unfortunately, the WMC story ended somewhat abruptly with the failed take-over bid by Xstrata in October 2004 and the subsequent successful take-over by BHP-Billiton in August 2005 (the date they gained 100% ownership).

For the countless geoscientists who have worked in WMC, many have had interesting and satisfying careers, attested to by the longevity of their tenure. Many remained with

the company for 10, 20, even 30 years. Of those who have left WMC, most have gone on to other great adventures – some working in other large mining houses, some heading up other companies, some starting consultancies, some in research. The network of ex-WMC geoscientists is a large one and those people have taken their knowledge and expertise to every corner of the industry.

For the WMC employees who are now BHP-Billiton employees, they too will go on to other great adventures within their new company. In turn, BHP-Billiton will have the benefit of

a group of geoscientists with demonstrated exploration success. WMC's name will live on through these people, and the ore bodies on which the company was built.

I would like to acknowledge that much of the material for this piece was derived from a publication, "They Searched: A History of Exploration Within Western Mining Corporation", written by a long-serving Geoscientist, Don Reid, and from personal comments by Jon Hronsky (another long-serving WMC Geologist) and Howard Golden who provided the pictures.

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Heavy and Bituminous Oils: Can Alberta Save the World?



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Abstract

The oil sands deposits of Alberta represent a significant fraction of the world's current reserves. The viscosity of these oils however requires special enhanced oil recovery techniques to be applied. Both capital and operational costs are significant for these methods. Remote monitoring of the production process holds substantial opportunity for the geophysical community. In this contribution, I describe the heavy oil deposits and the methods of enhanced production, discuss briefly some of the issues of rock physics that would contribute to monitoring of such a resource, and show some examples of seismic data obtained in such regions. Although geophysics shows promise for monitoring, there is a great deal of work that must be done to convince other geoscientists of its value.

Introduction

Canada's bituminous oil sand deposits have likely been in place since the mid-Cretaceous, and were used by Canada's First Nations to seal birch bark canoes. The deposits were first seen by Europeans in 1788, and have already been supplying upwards of 30% of Canada's total petroleum production.

Despite this, it was only in 2003 that their size was officially noticed outside of Canada. At the end of that year, The Oil and Gas Journal revealed in its annual report on global petroleum supplies and consumption (Radler, 2003), a large ~20% jump over those of 2002 in overall global reserves by simply including the bituminous oil sands of Canada in its estimates.

This jump also lifted Canada's reserve standing from near 5 Gbbl ($772 \times 10^6 \text{ m}^3$)¹ to 180 Gbbl ($28.6 \times 10^9 \text{ m}^3$), a number exceeded only by the presumed 260 Gbbl

(41.3×10^9) of Saudi Arabia and surpassing those of all the other Middle Eastern countries.

The size of these deposits had long been recognised (see, for example, Mossop, (1980) for additional background information and a review of the geological studies prior to that time) but had not been included prior to 2003, primarily because of the difficulties involved in producing such highly viscous oils.

The development of a variety of both surface mining and in situ recovery technologies however has reached the point of being economic, even before the rapid rise in the price of oil in the last year. Three other factors, the flattening of global conventional light oil reserves, the growth of consumption in Asia, and the political stability of Canada relative to other major producing areas are currently driving the startup of a large number of projects. Through the decade ending in 2004, CDN\$29 billion has already been invested in oil sands projects with an estimated sum of \$79.5 billion of direct- and \$16.5 billion of sustaining- capital to be spent potentially in this coming decade (Alberta Economic Development, 2005).

Clearly, this is a large investment for Alberta, Canada and perhaps even the entire world. Here I give a brief background to the developments now taking place in Alberta, then shift the focus towards the role of geophysics in the development of this resource.

World hydrocarbon supplies

One simple characterisation of oils is based on its mass density. Generally, as mass density increases, the proportions of long-chain hydrocarbons ($> \text{C}_{16}$ to C_{20}) becomes larger in the oil. Different classifications exist but it is useful to compare those of the Canadian government (based on kg/m^3) to those of the American Petroleum Institute specific gravity ($^\circ \text{API}$)². In Canada, only the terms heavy ($> 900 \text{ kg/m}^3$) and light ($< 900 \text{ kg/m}^3$) are employed while the API provides four classifications from bitumen to light (Figure 1). Chemically, aside from the lengthening of hydrocarbons, bitumen is deficient in hydrogen, relative to lighter oils. Aside from the issues in production, this heavy material was economically undesirable as it must be upgraded by the addition of hydrogen to make a lighter and more valuable synthetic crude. Other problems arise due to relatively high sulphur

¹ $\text{m}^3 \sim 6.29$ barrels.

² The API values are a measure dependent on the relative density of the fluid of interest ρ to that of water ρ_w both taken at a temperature of 60°F (15.56°C) according to $\text{API}^\circ = 141.5 \rho_w / \rho - 131.5$. Water has an $\text{API}^\circ = 10$.

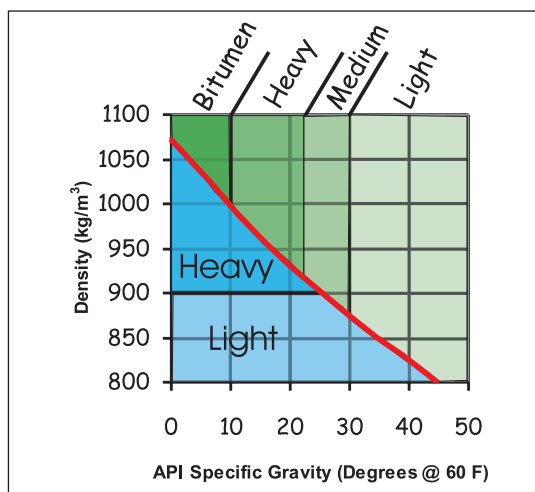


Fig. 1. Relationships between Canadian government (in kg/m^3) along vertical axis and the American Petroleum Institute (in 'degrees' API) along the horizontal axis; classifications of crude oils on the basis of density.

content of approximately 5% and small but not insignificant concentrations of metals such as titanium, tungsten, and iron. This bitumen and heavy oil is essentially the residue from a lighter oil that has lost its lighter fractions in part by bacterial degradation.

It is worthwhile to briefly look at some of the societal factors that are influencing the growth of the oil sands development. Including both light and intermediate oils that are produced by conventional techniques, the distribution of global reserves according to type shows that both heavy oil and bitumen account for approximately half of the established reserves³ of 2234 Gbbl⁴ (Figure 2a). An interesting pattern appears when the distribution of

these various reserves is examined by region, (Figure 2b-d) revealing large inequalities. Essentially, the bulk of the conventional, heavy, and bitumen reserves are located in three regions, being respectively: the Middle East, South America (principally Venezuela), and North America (principally Canada).

Consumption patterns by region (Figure 3) also highlight important trends. After actually reaching a minimum in the early 1980s, consumption has generally increased in all areas and today is about 0.08 Gbbl/day (29.2 Gbbl/year). The growth in consumption has not been rapid in the developed world generally. However, both China's and India's needs have nearly doubled in the decade ending in 2003 and this growth is expected to continue as the economies of these two large nations expand. This consumption growth is occurring in a situation in which it is becoming increasingly difficult to maintain and increase production of conventional light and intermediate oils, and is placing a strain on global supplies that, in part, have led to the rapid increase in the price of oil since 2003. Indeed, an oversimplified face value examination of the numbers above would suggest that the current global reserves would be depleted in less than a century.

Geology of the Oil Sands

There are three major oil sand accumulations in Alberta: the Peace River, the Cold Lake, and the Athabasca deposits; the locations of which are highlighted in Figure 4. The areas are distinguished primarily on the basis of differences in the geology, the geography, and the oil content. These areas cover upwards of 60,000 km², an area roughly equivalent to that of Tasmania. The Athabasca (sometimes referred to the Athabasca-Wakiska deposits)

are the largest. AEUB say established reserves are 177 Gbbl ($28.1 \times 10^9 \text{ m}^3$) with the definition of established being those reserves that are producible given current technology. Estimates of the reserves that are but ultimately recoverable is 332 Gbbl ($52.8 \times 10^9 \text{ m}^3$). The initial total oil in place, however is a staggering 1,700 Gbbl ($270 \times 10^9 \text{ m}^3$) with some estimates of the ultimate oil in place (National Energy Board, 2004) even going as high as 2520 Gbbl ($400 \times 10^9 \text{ m}^3$). It is currently unknown how much could eventually be obtained.

The geology of the three oil sand regions differs, but in many ways can be similarly summarised. It is useful to first briefly examine the overall geological structure of Alberta, (Figure 5) which begins in British Columbia in the Rocky Mountains. The tectonic history of the basin essentially consists of two parts (Price, 1994). First, from the later Proterozoic to the late Jurassic the western edge of North America essentially consisted of passive margin sedimentation, primarily sourced from the east. The second is characterised as the foreland basin stage that incorporated passively deposited supracrustal sediments that were detached from the metamorphic basement and thrust to the east from the late Jurassic to

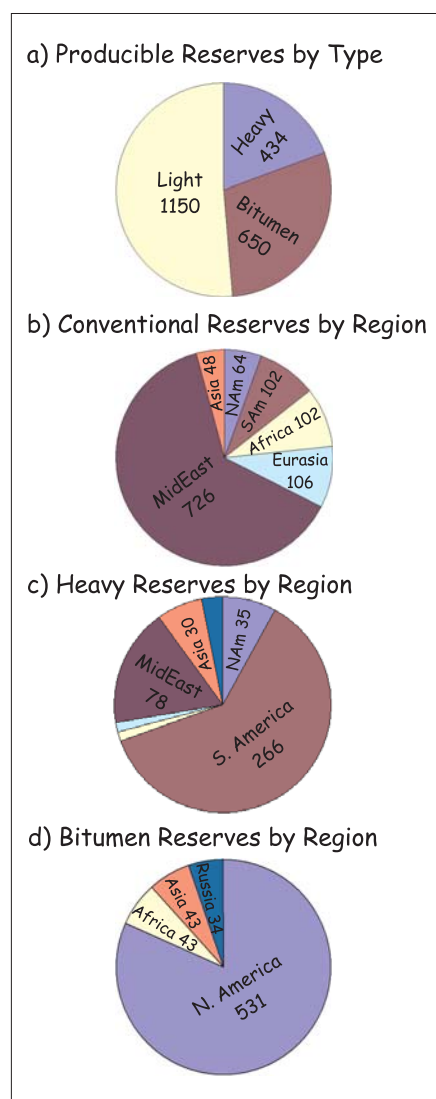


Fig. 2. Summary of currently recoverable petroleum reserves according to a) type of reserve, and the regional distributions of b) conventional (light), c) heavy, and d) bituminous oils. Numbers represent reserves in units of BBO (Billion (10⁹) Barrels of Oil, 1 Barrel = 158.984 litres by volume). The statistics quoted are derived from the Meyer and Attasi, 2003.

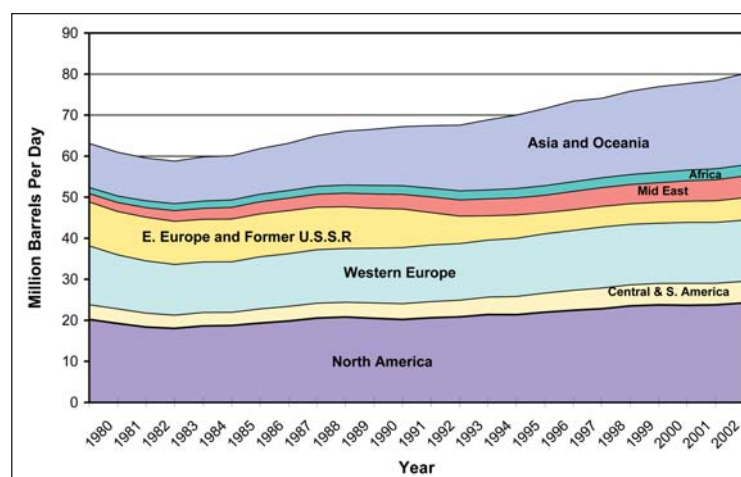


Fig. 3. Summary of daily consumption of petroleum in Millions of Barrels per Day for various regions, data from U.S. DOE (2005).

³ The careful reader will note some inconsistencies in the volumes given to the various reserves. These arise due to differences in the criteria employed by different reporting agencies in deriving their final statistics; in all cases the original source of the information used here is given. This author is not qualified nor prepared to defend any of these statistics, and indeed, as reserve devaluations continue to come to light in the media and in recent books, one may question actually who is able to do this difficult prognostication.

⁴ 1 BBO = Billion barrels of oil = $159 \times 10^6 \text{ m}^3$ = 1 Gbbl = 10^9 barrels.

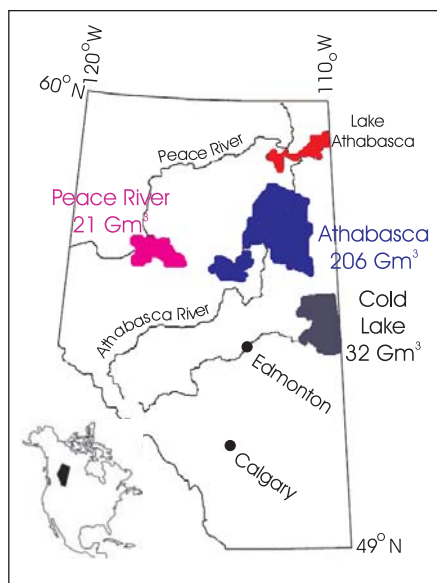


Fig. 4. Map of Alberta indicating the three regions in which concentrations of bituminous sands lie with the estimated reserves of each in Gm^3 . Summary map based on that available from the Alberta Department of Energy (2004). Volumes of bitumen are estimates of that existing in place according to the Alberta Energy and Utilities Board (2004) based on analysis of well log and other information. The total area of Alberta is 660,000 km^2 , for comparison New South Wales has just over 800,000 km^2 .

the early Eocene. The load of these thickened thrust sheets induced flexure of the lithosphere, bending the crust to produce a basin, which subsequently filled with Mesozoic siliclastic sediments primarily of Cretaceous age. The first ranges of the Rocky Mountains are thrust sheets of a fold and a thrust belt, formed during the late Cretaceous and early Tertiary Laramide orogeny.

Within this overall framework, and using the Athabasca reservoir as representative, the host sands were deposited on top of a major angular unconformity that truncates Paleozoic limestones and calcareous shales. Valleys were established in the carbonates by a major river system running from south to north. After the sea levels rose in the early Cretaceous, the valleys were subsequently filled with a series of earlier fluvial and estuarine deposits and later marginal-marine sediments. As might be expected, the finer structure of the sands is similar to that of sand bars in a meandering river system that features numerous sandbars

⁵ This theory that has actually led to drilling of the metamorphic basement in the Athabasca region in search of an even larger potential reservoir believed to lie at depths of 6 km., unfortunately the funding for this endeavor only allowed for a much shorter wellbore and the theory yet remains untested.

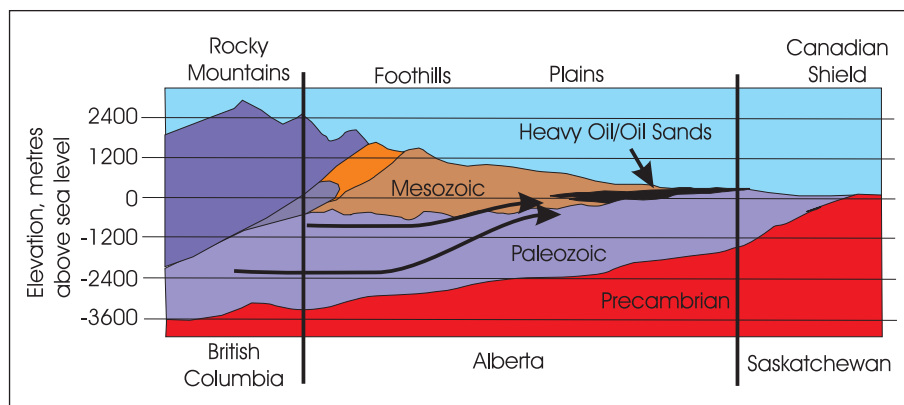


Fig. 5. Illustrative geological cross section of Alberta, this cross section runs from west to east following along the Athabasca River and continuing NE past the Athabasca oil sand region in Figure 4. Black arrows represent migration paths of the oil from the west to the east.

and crosscutting channel complexes (see Pemberton and James, 1997 for detailed discussions). This deposition occurred in the Lower Cretaceous of Aptian to Albian age (~120 to 100 Ma) in a formation regionally referred to as the Mannville Group. It must be noted that some of the resource may also be found in the older Paleozoic carbonates, particularly in the Peace River region.

The source rocks, the timing, and the migration mechanisms for the bitumen remains controversial. Such a large deposit will attract attention as well as unconventional explanations attempting to explain where the oil came from. For example, one theory maintains that both the sand and the oil resulted from a large terrestrial 'gastroleme', which conveniently spewed forth the sands and then the oil⁵. More conventional theories are perhaps less dramatic but still retain a good deal of mystery. Generally, it is believed that the oil migrated to the east from the west across the basin (Figure 5) with a number of workers suggesting the generation and migration was roughly contemporaneous with the late Cretaceous – early Tertiary Laramide orogeny mentioned above. A variety of shales with ages from the Mesozoic to the Paleozoic have also been suggested (see Riediger *et al.*, 2000 for a brief background to this discussion). However recent geochemical studies using a new Re-Os dating technique on the bitumens (Selby and Creaser, 2005) has been carried out. The work suggests 112 ± 5.3 Ma as the date for the generation and migration of the oils, which is contemporaneous with the deposition of the final host sands. This early date precludes generation of the oil during the Laramide orogeny and points the source towards older and more voluminous Paleozoic source rocks. This scenario is consistent with

both the unconsolidated nature of the oil sands (cementation being further hampered by the oil) and the large degree of biodegradation of the original oil, the residue of which is bitumen. It is also more consistent with numerical flow and hydrological studies (Adams *et al.*, 2004).

Characteristics of the oil sand materials

The best sands have a number of favorable petrophysical characteristics (e.g. Mossop, 1980). The sand typically consists of moderately sorted, fine grained (62.5 to 250 μm) grains, of which 95% are quartz with less frequent feldspars, micas, and clays. As might be expected for such a material, the absolute permeability is high although the bitumen itself is essentially immobile due to its viscosity. Shale stringers however lie within the deposits and can restrict the flow of fluids. The sorting allows for high porosities from 25% to 35%. The high porosity is also the result insufficient mineral cementation indicative of the shallow burial depth and lack of diagenetic modification that these sands experienced. As such, the material is unconsolidated and defined as sand, not sandstone.

Workers have long been concerned about the microscopic distribution of the fluids within the pore space as this has direct implications on how the oil is produced. One longstanding model of this fluid distribution (Figure 7) suggests that the bitumen should be kept apart from the mineral grains by thin layers of water along surfaces and by pendicular menisci at grain contacts (Takamura, 1982; Ofosuasiedu *et al.*, 1992). Preferential wetting in smaller pore spaces keeps the matrix material water wet. There is some evidence however that

this model may not be completely accurate. Zajic *et al.* (1981) examined a frozen oil sand using transmission electron microscopy with resolutions of 10 nm but saw no evidence at this scale for a thin layer of water. Czarnecki *et al.* (2005) has also questioned the water wetting assumptions, which can be traced to some early conjectures in the 1920s that suggest a lack of serious supporting evidence but have since been repeated in the literature. This may be an important consideration in future rock physics studies as the distribution of fluids controls the effective fluid properties, the complexity of the electrical conduction networks within the rock, and the cohesive surface forces between adjacent mineral grains.

Production technologies

To provide a background for geophysical discussions that will occur later, it is also important to reveal how these oils are produced. Essentially the very high viscosity of heavy oils and bitumens makes producing them difficult. Indeed the bitumen is immobile under conditions existing naturally within the earth and considerable production methodologies are required. The problem boils down to reducing the viscosity of the bitumen and heavy oils so that they flow through the porous rock. This may be done by injecting solvents but the most popular methods have lowered the viscosity by heating the formation. The viscosity of such liquids is highly sensitive to temperature (Figure 6) and changes by many orders of magnitude over a range from 0 to 300° C.

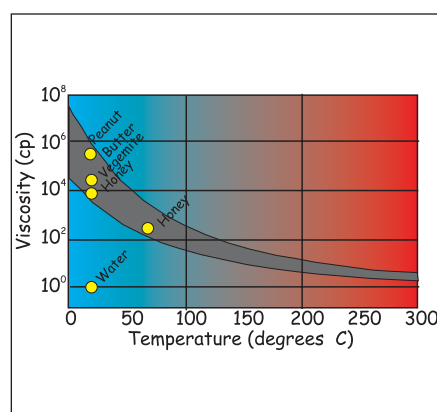


Fig. 6. Temperature dependence of Alberta heavy oils and bitumens versus temperature. Ranges of viscosity values fall within the gray zone. The lower bound and upper bounds are typical of Lloydminster heavy oils and Athabasca bitumen, respectively. For comparison, the viscosities of a number of food products recognizable in Australia are shown by the yellow filled circles, most are given at 20 °C.

Natural in situ temperatures fall in a range of approximately 10° C and the oils move very slowly.

This problem is overcome by a variety of strategies, principally by heating the reservoir. It is interesting to note that some of the first suggestions for heating the oils during the 1950s relied on the use of peaceful nuclear explosions. Fortunately, this suggestion was not implemented. Since then, production methods have essentially fallen into two categories:

1. Surface strip mining of oil sand 'ore' and processing for removal of the oil, and
2. In situ enhanced recovery techniques.

A large fraction of Canada's total oil production is currently derived from the upgraded synthetic crude, which is produced at just two mines operated by Syncrude Canada Ltd. and Suncor Energy Inc. These mines straddle the Athabasca River north of Fort McMurray, Alberta. The oil sands are relatively shallow at these locations and allow for the economical removal of the overburden and extraction of ore. Typical daily production from these two mines and the associated upgrading facilities is approximately 380,000 bbl/day (~ 60,000 m³).

It is estimated however that approximately 10% of the bitumen deposits could be accessed by these surface strip mining methods. In situ recovery techniques must be used to get at the bulk of the deposits. It is this in situ recovery that may be of the most interest and

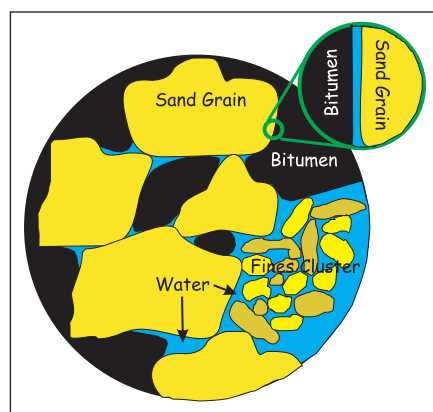


Fig. 7. Conventional model of the distribution of fluids within the oil sands. Blue, black, and yellow represent water, bitumen, and mineral grains, respectively. (after Czarnecki *et al.*, 2005).

opportunity to the geophysics community. First, current exploration of the resource is conservatively carried out by drilling, which is expensive and provides relatively low resolution. Geophysical techniques can be used to assist by helping to locate the thickest and richest oil sand materials. Due to the shallow nature of the deposits, electromagnetic airborne techniques (e.g. Cristall *et al.*, 2004) and electrical resistivity tomography (e.g., Kellett and Maris, 2005) have been applied to find the best deposits. High resolution seismic techniques (e.g. Siewert *et al.*, 1998) have shown promise for delineating finer details of the complex fluvial and estuarine sedimentary structure (e.g. Langenberg *et al.*, 2002).

There are a number of in situ technologies that have been developed to produce the heavy oils and bitumens that range from cold heavy oil production to steam assisted gravity drainage. A recent and more detailed review was recently provided by Butler and Yee (2002). However a few of the more popular methods are presented and some examples of geophysical observations related to monitoring such processes are given.

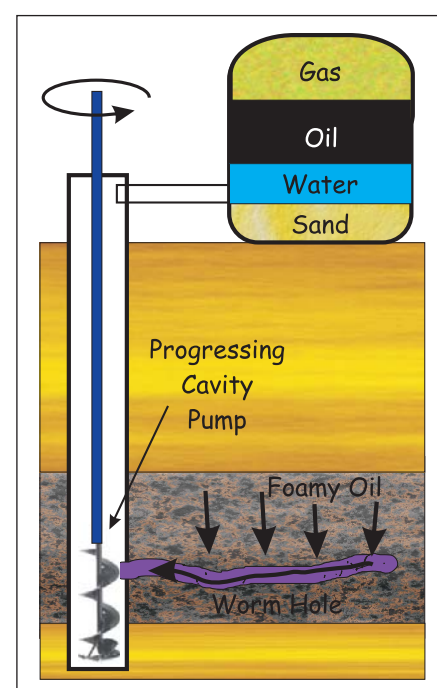


Fig. 8. Cartoon illustrating the 'cold production' method of heavy oil production. A progressing cavity pump returns a mixture of sand and fluids to the surface. The pump is essentially an auger that continuously removes material from the bottom of the wellbore.

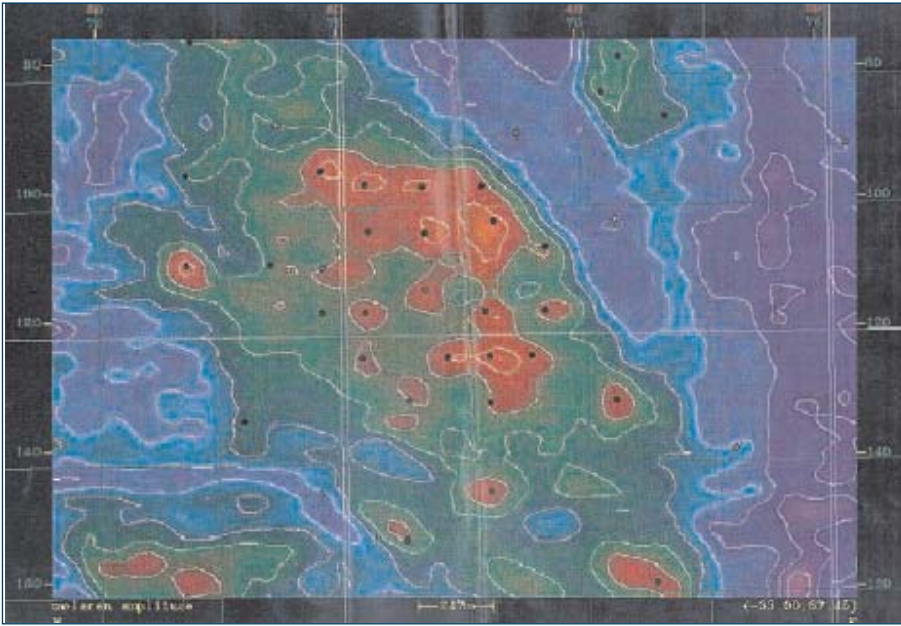


Fig. 9. Seismic amplitude map obtained over a cold production zone showing high returned amplitudes in the vicinity of the producing wells (indicated by dark circles). Map from Lines *et al.*, 2003 courtesy of the Society of Exploration Geophysicists via their fair use policy.

- Cold heavy oil production (CHOP) is a method of producing heavy oils inexpensively without the addition of expensive enhanced recovery techniques although this method leaves more than 85% of the oil in the formation. In this method, vertical wellbores are drilled into the heavy oil sand reservoir and material is extracted with a special progressing cavity pump that consists of an auger screw (Figure 8). The screw or stator is the only moving part and is made of a tough synthetic elastomer that resists wear. The reason such wear resistance is desired is because cold production requires that sand also be produced with oil, water, and gas. Where exactly within the reservoir the sand comes from and how it assists the production of the oil is not completely understood. One model that appears to reasonably predict production histories is the creation of wormholes in the reservoir. These wormholes, which have been produced in laboratory situations, are essentially long cavities that progressively extend away from the producing wellbore while sand and fluids are removed. The wormholes are additionally valuable in that they produce a large effective surface area to the wellbore that allows for more effective production (*e.g.* Tremblay and Oldakowski, 2004).

Direct geophysical detection of the wormholes is unlikely as their dimensions are much smaller than seismic wavelengths (*e.g.* Chen

et al., 2004). However, during production the pore fluid pressure (*i.e.* reservoir pressure) is drawn down by 50%, or more. The pressure drops below the bubble point and gas exsolves from the mixture to produce bubbles. The exsolution process maintains pressure within the reservoir and promotes the production of fluids and sand. Recent theoretical and experimental work by the Alberta Research Council (Lillico *et al.*, 2001) suggests that initially large numbers of micron scale bubbles are nucleated. It is the reductions in the overall fluid compressibility, caused by nucleation of these bubbles that is likely to be responsible for strong changes in seismic amplitudes in the immediate vicinity of cold production wells (*e.g.* Lines *et al.*, 2003), as shown in the seismic amplitude map (Figure 9) of Mayo (1996).

- Steam assisted gravity drainage (SAGD) is a horizontal well steam injection technology developed in Canada in the past 20 years. This technique has become popular for in situ production in heavy oil and bitumen reservoirs. In SAGD, two parallel and horizontal wellbores are drilled one on top of the other, separated by approximately 2 m. The lower bore is near the bottom of the oil containing sands. At the beginning of this process, high quality steam is injected into both wellbores until the viscous oils between them are sufficiently mobile to enable good communication. At this point,

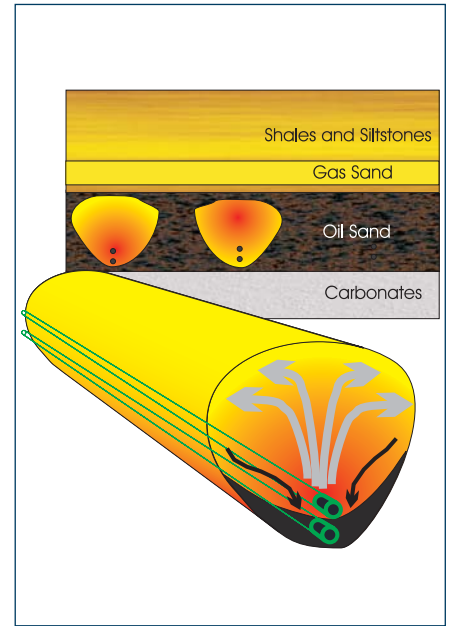


Fig. 10. Conceptual model of steam assisted gravity drainage technique. Steam is injected via the upper horizontal wellbore to heat the bitumen which then runs down along the sides of the steam zone to be produced in the lower horizontal wellbore. The steam zone extends along the length of the horizontal wells. A bank of such horizontal well pairs will typically be developed in order to access as large a proportion of the reservoir as possible. The geological structure shown is representative of the Athabasca situation.

injection continues only from the top well. Engineering models suggest that a steam chamber begins to grow both laterally away from the wellbore (at rates ~ 5 cm/day) and vertically within the oil sand. The growth of this steam zone occurs by the displacement of the now hot and lower viscosity oil which flows down along the sides of the chamber to its bottom (Figure 10). The pooled oil is then recovered through the lower wellbore with production rates of 100 m³/day and estimated recovery rates of 50%.

There are a number of variations on this theme (Butler and Yee, 2002). Methane gas may be injected in order to provide a region of low thermal conductivity at the top of the steam zone and reduce heat loss. This technique is referred to as steam and gas push (SAGP). In another technique that is now undergoing preliminary field trials and is referred to as vapor extraction (VAPEX), light hydrocarbon solvents such as ethane and propane are injected instead of steam. These solvents also reduce oil viscosity and allow it to flow in a manner similar to SAGD. This method is intended for reservoirs that are too thin for application of SAGD, which is inefficient in such situations due to the conductive heat losses. Another

process which has been employed on a large scale is cyclic steam stimulation (CSS). This process takes place from banks of deviated and vertical wells and involves injecting steam into the formation, at pressures approaching the lithostat. The heat from this injected steam and hot water is then allowed to diffuse into the formation, which heats the oil and lowers the viscosity. After a suitable period, the same wells are then turned onto production with the presumption that the heated oil will flow back to the well.

Geophysical monitoring

The in situ technologies for producing heavy oils and bitumens require large capital investments and have high ongoing operational costs. Despite the high economic input, there is often no guarantee that a given project will necessarily meet its initial expectations. A number of difficulties can arise in developing such a reservoir. A major problem can arise in well completion where the liquid access ports in the steel casings can collapse, restricting the flow of fluids both in and out of the wellbore. This can cause substantial sections of the reservoir to be bypassed. Nature herself is not always amenable to simplified models of the subsurface. There can be both barriers to permeability that deny the steam access to sections of the reservoir and other lean or barren zones of high permeability that can steal the costly steam by routing it away from where it was intended to go. These problems can be difficult to detect as the tools available to the production engineer typically remain limited to history-matching of the fluid injection and production history. Concerns are raised only if these fluid histories substantially miss the initial expectations.

Issues related to the common solutions of history-matching aside, there are few tools that allow technical problems within the wellbore to be located or even detected. Determining the consequences of geological complexity in the three dimensional world away from the wellbore can be even more difficult to understand. Geophysical techniques have the potential to provide additional information away from the wellbore that could highlight both technical and geological problems. This has been long recognised and the pioneering seismic monitoring projects began in the oil sands in the mid-1980s (see Schmitt, 2004 for a listing of this work). These early studies demonstrated that the changes induced by

enhanced oil recovery methods were substantial and could be detected using geophysical methods. Typically, the seismic reflectivity of the disturbed zones is greatly enhanced for a variety of reasons.

Injection of steam and the formation of a steam chamber can dramatically effect physical properties, particularly at the low effective confining stress of the shallow Athabasca oil sands. There are many changes occurring in the reservoir during such types of production and have been reviewed previously (Schmitt, 2004). Briefly however, the conditions of temperature (T), confining stress (P_c), pore fluid pressure (P_p), gas saturation state (S_g), and geomechanical damage (D) (e.g. Chalaturnyk and Li, 2004) are continuously evolving spatially and temporally. These extrinsic variables will influence the intrinsic physical properties of P-wave and S-wave velocities (V_p and V_s , respectively), the bulk density ρ , the porosity ϕ , and the quality factor Q (i.e. the inverse attenuation). The influence table (Figure 11), revised from Schmitt (2004), outlines the linkages between the extrinsic conditions and the intrinsic properties. This revised table also now includes the frequency F at which observations are made as it is likely that oil sands materials behave anelastically (Solano, 2004). This table represents more

	V_p	V_s	Q	ϕ	ρ
T	↓	↓	↓		↓
P_c	↑	↑	↑	↓	↑
P_p	↓	↓	↓	↓	↓
S_g	↓	↑	↓		↓
D	↕	↕	↕	↕	↕
F	↓	↓	↕		

Fig. 11. Influence table showing the expected responses in the intrinsic physical properties (V_p = compressional wave velocity, V_s = shear wave velocity, ϕ = porosity, Q = quality factor, ρ = bulk density) of the material dependent on the variations in the extrinsic reservoir conditions (T = temperature, P_c = confining stress or pressure, P_p = pore fluid pressure, S_g = gas saturation, D = geomechanical damage, F = frequency of elastic waves). The directions of the arrows in the cells indicate whether the intrinsic property is expected to increase (blue upward pointing arrow) or decrease (red downward pointing arrow) with a corresponding increase in the magnitude of the extrinsic condition.

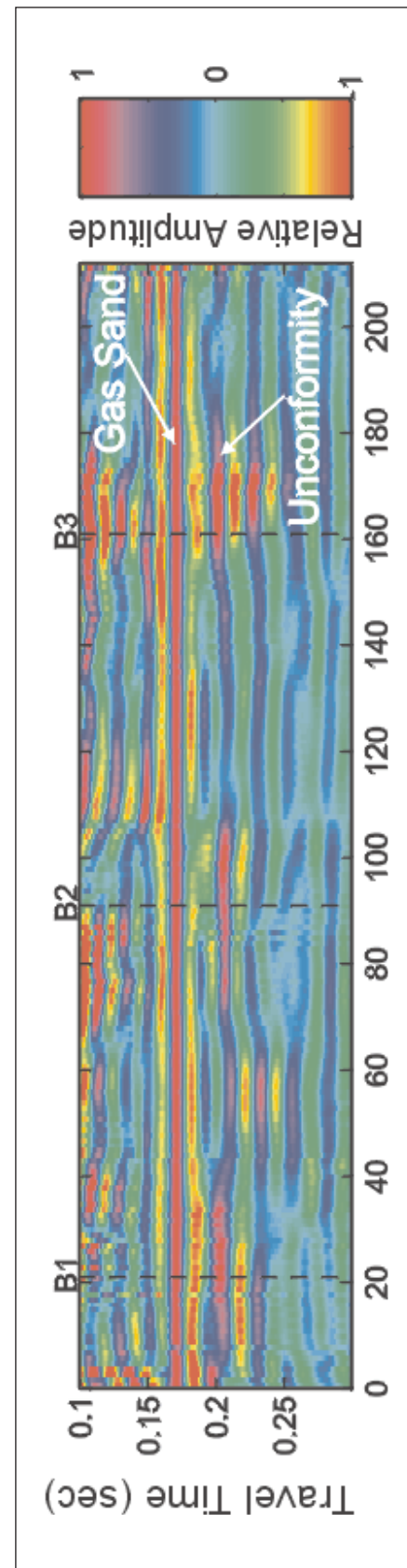


Fig. 12. Example of high resolution seismic profile acquired perpendicular to three SAGD well pairs in an Athabasca reservoir from Schmitt, 1999, courtesy of the Society of Exploration Geophysicists via their fair use policy. A close CMP spacing of 1 m is used in this study.

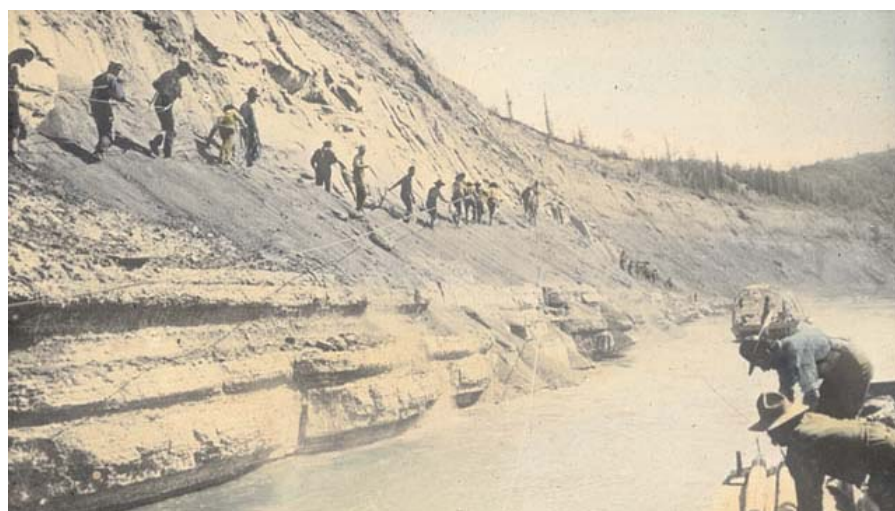
or less the behavior of the intrinsic properties due to changes in the extrinsic conditions. However, current understanding is far from being able to provide a reliable model for what the changes in such unconsolidated materials might be during production and further work is necessary.

Seismic monitoring over such production zones also differs from normal geophysical exploration in that the scales of the former are usually much smaller. Typical spacings between pairs of horizontal wellbores, for example, are less than 100 m and the wellbores extend for upwards of 1,000 m. As such, standard exploration seismic exploration techniques, while certainly useful, may not provide optimal spatial resolution.

My group has been involved with a series of 2D time lapse profiling for an Athabasca reservoir in the last few years. Figure 12 is an example of a profile acquired perpendicularly across three horizontal wellbore pairs (B1, B2, and B3), near the bottom of the reservoir at a depth of about 150 m (Schmitt, 1999). Large amplitude anomalies are associated with each of the three pairs and are presumably caused by the changes in the reservoir due to steaming. At the time the data was acquired, connection between the three different zones, as evidenced by temperature monitoring from observations wells, was just being established and the temperatures between the wells remained substantially cooler. This profile has been repeated 11 times since 1995 taking care to ensure that the source and receiver positions were unchanged between surveys. The results of this work will be forthcoming⁶. However, it is worth commenting that seismic response is not necessarily symmetrical with respect to the wellbores; suggesting that movement of fluids may not exactly occur in a uniform fashion. This should not be surprising given the complex nature of sedimentary structures within the reservoir (McGillivray *et al.*, 2005); but such suggestions are not necessarily met with enthusiasm by reservoir simulators who prefer a simpler earth⁷.

Directions for the Future

These are exciting times for the Alberta geophysical community; the oil sands provide an opportunity to carry out good science with a direct practical application. However, much work remains to be carried out. This work is not only directly technical, but in my humble



opinion the community may need some shift in its operating paradigm from one of exploration, in which careful imaging of the geological structure has been paramount, to one that may be more quantitative such that the geophysical observations can be translated more precisely to the needs of production geologists and engineers. Only when this is done will we be able to convince them of the value of time-lapse monitoring in locating, for example, bypassed resources.

Aside from the production methodologies already mentioned, one future area of research that is now being discussed is that of 'in situ upgrading' in which some portion of the refining process is actually carried out as part of the production. This is currently only a concept, but it is likely that such processes will be substantially more complex than simply injecting steam. One could easily speculate that such production strategies would make seismic monitoring even more desirable. The client community, which will come more from the refining side of chemical engineering, understand the value of process monitoring and are likely to be receptive to any technology that can assist them towards these goals.

Finally, Alberta's oil sand resource is large and as production from the heavy oils, and bitumens increase they will have an important impact. The subtitle to this paper: 'Can Alberta Save the World' suggested to me by David Denham must be put in context of the overall global demands. As mentioned earlier, global requirements in 2003 were closing in on **30 Gbbl ($4.6 \times 10^9 \text{ m}^3$) per year**. This means that even if we were able to squeeze every last drop of the highest estimate of the ultimate

in-place hydrocarbons in the oil sands given above, the world-wide community would consume it in less than a decade. Clearly, we will soon have to seriously begin to seek additional supplementary sources of energy with conservation being one component of an overall strategy, as even our giant reserves cannot last forever.

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⁶ A 'movie' of these 11 seismic frames may be accessed from my webpage www-geo.phys.ualberta.ca/~doug

⁷ The author has been informed that the seismic observations collected in the field must be in serious error as they did not agree with a particular computer generated reservoir simulation!

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The role of downhole TEM in the discovery of the Daybreak, Daybreak Deeps and Flying Fox T1 to T5 nickel sulphide deposits

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Summary

Downhole, time-domain electromagnetics (DHTEM) played a pivotal role in the discovery of the Daybreak, Daybreak Deeps and Flying Fox T1 to T5 nickel sulphide deposits, which are associated with the basal contact of an Archaean komatiite, in a greenstone belt situated approximately 400 km east of Perth, Western Australia.

The discovery of these nickel sulphide deposits between 2002 and 2004 within brownfields nickel prospects can be attributed largely to the testing of downhole time-domain electromagnetic (DHTEM) anomalies. Following the discovery of each of these deposits, DHTEM surveys guided the drilling program to accurately map the position, extent and attitude of the massive sulphide systems. The rapid targeting, discovery and delineation of the deposits clearly demonstrates the importance of DHTEM as a primary exploration tool in the search for highly conductive, massive nickel sulphides. This principle applies to both greenfields exploration and exploration within nickel properties previously believed to be effectively explored.

Mine development is currently underway at Flying Fox where the inferred resource for T1-T2 and T5 is

946,000 tonnes at 6.6% Ni. Daybreak and Daybreak Deeps are thought likely to provide sufficient resources to generate a second viable mining proposition in the future.

Introduction

The Daybreak, Daybreak Deeps and Flying Fox T1 to T5 nickel sulphide deposits are situated in the Forrestania Greenstone Belt within the Barlee Terrane of the Archaean Yilgarn Craton about 400 km east of Perth as shown in Figure 1. This greenstone belt has been explored for nickel since the late 1960s and significant nickel mineralization has been discovered at New Morning, Flying Fox, Cosmic Boy, Digger Rocks, Mount Hope, Liquid Acrobat and Seagull.

These nickel deposits are associated with the basal contact of an Archaean komatiite and comprise semi-massive to massive nickel sulphide, commonly remobilised into footwall meta-sediments. Discovery of these deposits within brownfield nickel properties between 2002 and 2004 was substantially due to the testing of DHTEM anomalies.

Daybreak was discovered in August 2002 during the first exploration campaign at Forrestania by Western Areas NL. Significant massive nickel sulphides were intersected within footwall meta-sediments in a hole drilled to test the first of several; high priority DHTEM targets identified during a review of historic DHTEM data. Subsequent drilling showed that all remaining high priority DHTEM targets correlated to massive nickel sulphides.

Daybreak Deeps was discovered in March 2003 during exploration for a plunge extension to the Daybreak deposit. DHTEM surveying of a hole where a dyke had intruded the ultramafic-meta-sediment contact showed an offhole target of significant areal size immediately north of the hole. A follow-up daughter hole intersected a wide zone of nickel sulphide mineralisation within footwall meta-sediments.

The Flying Fox T1-T2 deposit was discovered in September 2003 by applying the same geophysical and geological principles used at Daybreak. Wide intervals of high-grade massive nickel sulphides were intersected in the first two holes drilled to test the upper extents of a high priority DHTEM target. The recognition of

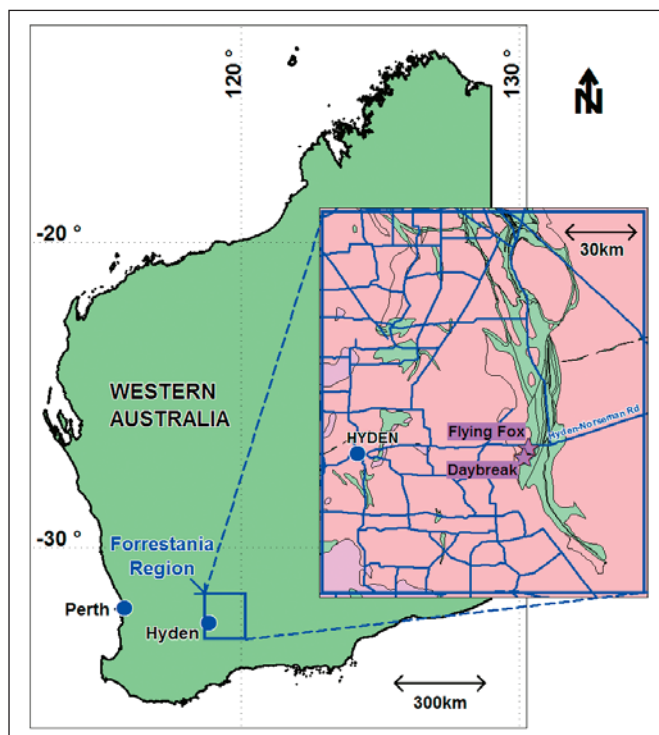


Fig. 1. Map showing location of the Daybreak and Flying Fox Deposits.

strong anomalous distortions in the current ramp channel within somewhat ambiguous historic DHTEM was crucial in strengthening the resolve to pursue an exploration target at a depth of more than 400 m. DHTEM surveying of subsequent deep exploratory holes combined with comprehensive modeling and interpretation, and an optimistic approach to ongoing exploration, led to the discovery of the Flying Fox T3, T4 and T5 deposits.

Exploration History

A short summary of the exploration history is given below:

- Prospector discovers gossanous outcrop at New Morning in 1969 exciting exploration interest in the Forrestania region.
- Regional nickel exploration during the 1970's by Amax/Amoco leads to the discovery of nickel sulphide mineralization at New Morning, Flying Fox, Cosmic Boy, Digger Rocks, Mount Hope, Liquid Acrobat and Seagull. This successful regional exploration program involved geological mapping, ground magnetic surveys and extensive RAB pattern drilling.
- New Morning discovered by drilling gossan targets in 1971, while the Flying Fox nickel deposit was discovered in 1977 during RAB drill testing of a narrow, ground magnetic anomaly (Marston, 1984).
- Ongoing evaluation of the three main nickel deposits (Cosmic Boy, Digger Rocks and Flying Fox) continued during the late 1970's and 1980's. The Flying Fox deposit was detected during a trial fixed TEM surveying (Amoco) in 1982 (Staples, 1984).
- Outokumpu farms into the Forrestania Project during 1989 and completes mining evaluation. Mining operations commence during 1992 and continued until 1999. Extensive regional exploration recommenced during the mining phase, but this did not succeed in locating significant new nickel sulphide occurrences.
- Western Areas NL farms into the Forrestania Project during early 2002. Newexco Services Pty. Ltd. completes a comprehensive due diligence review of the main areas of interest (Cosmic Boy, Digger Rocks and New Morning) and several other high priority nickel prospects. A full geophysical review is completed at both a prospect scale and regional scale. Multiple, high priority DHTEM targets are identified at New Morning South.
- Drilling of the New Morning South targets during August 2002 results in the discovery of the *Daybreak* nickel sulphide deposit.
- High priority DHTEM target identified at ~150 m below and east of the Daybreak deposit. A subsequent targeted daughter drillhole discovers the *Daybreak Deeps* Deposit).
- A second stage geophysical review of other nickel prospects at Forrestania outside the scope of the original study is completed during July/August 2003. Of immediate interest are two high priority DHTEM anomalies at depth below the historic Flying Fox nickel mine with signatures very similar to Daybreak. DHTEM re-logging of the deep historic drillholes is completed during early September 2003 with new data clearly highlighting targets both above and below historic drilling.
- Drilling of the upper DHTEM target is completed during September and October 2003 and discovers *Flying Fox T1-T2*. DHTEM surveying of these two drillholes indicates that the massive sulphide system is of significant areal size and step out drilling and DHTEM evaluation continues.
- Drilling of the lower DHTEM target is completed during December 2003 and discovers *Flying Fox T3*.
- DHTEM anomaly interpreted in the lowermost section of a deep exploration drillhole at Flying Fox during December 2003. Modelling suggests the source is a considerable distance east and it is postulated that the target could represent fault offset mineralisation. In July 2004 a hole is drilled to ~1130 m and subsequent DHTEM logging suggests that the hole is approaching an anomaly of interest. The hole is extended and intersects *Flying Fox T5*. Also of interest in the DHTEM is the presence of a target of significant areal size, sub parallel to the hole. Drilling of this target during August 2004 intersects *Flying Fox T4*.

Geology

Regional Setting

The nickel deposits of the Forrestania group occur within an Archaean greenstone belt situated in the southern quarter of the Southern Cross - Forrestania supracrustal belt (Marston, 1984). This narrow curvilinear belt which strikes between north and north-west, extends for some 300 km, from Hatters Hill in the south to Trough Well in north. The supracrustal rocks

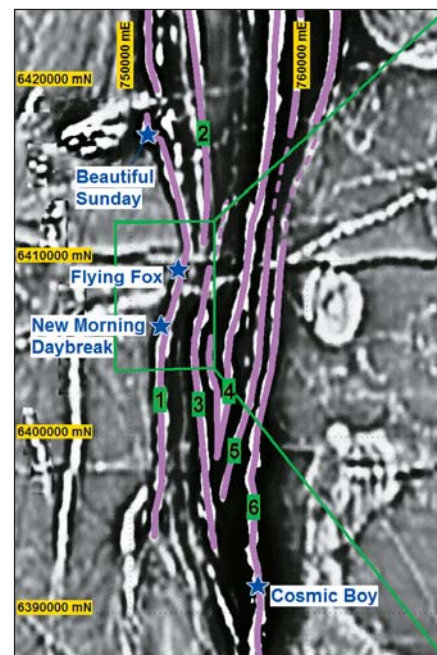
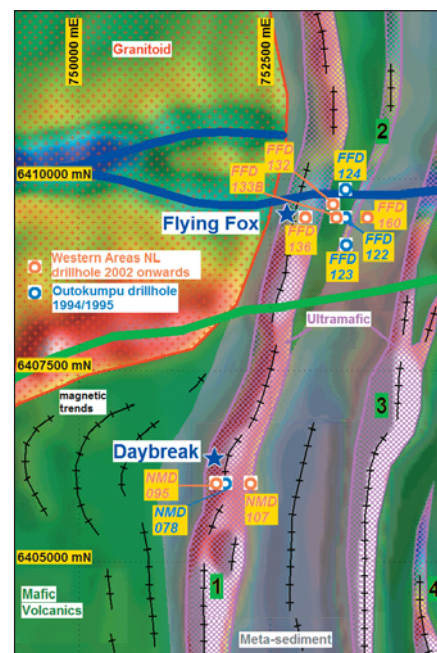


Fig. 2. Map showing Forrestania Greenstone Belt, individual ultramafic belts and regional first vertical derivative aeromagnetics. Cross-cutting dykes and granitoid intrusions show clearly defined magnetic anomalies.



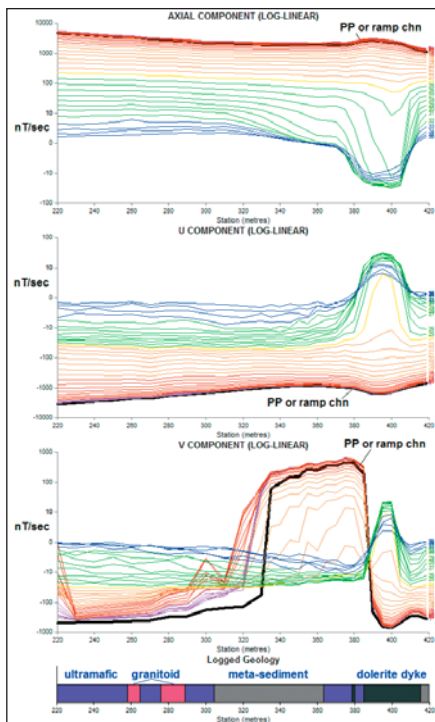


Fig. 4. DHTeM data from drillhole NMD078 showing multiple, strong offhole anomalies and distortions in current ramp (anomalous step response) – Crone PEM, 50 ms time base – acquired by Outer Rim 1994

The Forrestania Greenstone Belt consists of up to six separate ultramafic belts (Figure 2), which can be summarized, from west to east, as follows:

1. Western Ultramafic Belt
2. Mid-Western Ultramafic Belt
3. Takashi Ultramafic Belt
4. Central Ultramafic Belt
5. Mid-Eastern Ultramafic Belt
6. Eastern Ultramafic Belt

Regional geological attributes of the Forrestania Greenstone Belts are summarized below, with much of this information stemming from the extensive exploration carried out by Amax in the late 1960's and 1970's (Marston, 1984).

- Bedrock geology and olivine-rich target lithologies are commonly concealed beneath deep weathered/lateritized profiles and transported overburden.
- The stratigraphy has variable dips ranging from steeply inclined to both west and east to near flat lying. The Western Ultramafic Belt faces east and the Eastern Ultramafic Belt faces west.
- The sequence is bounded by Archaean granitoids and intruded by late stage pegmatites-granitoids. Proterozoic dykes crosscut the stratigraphy in an east-west fashion and are commonest in the north.

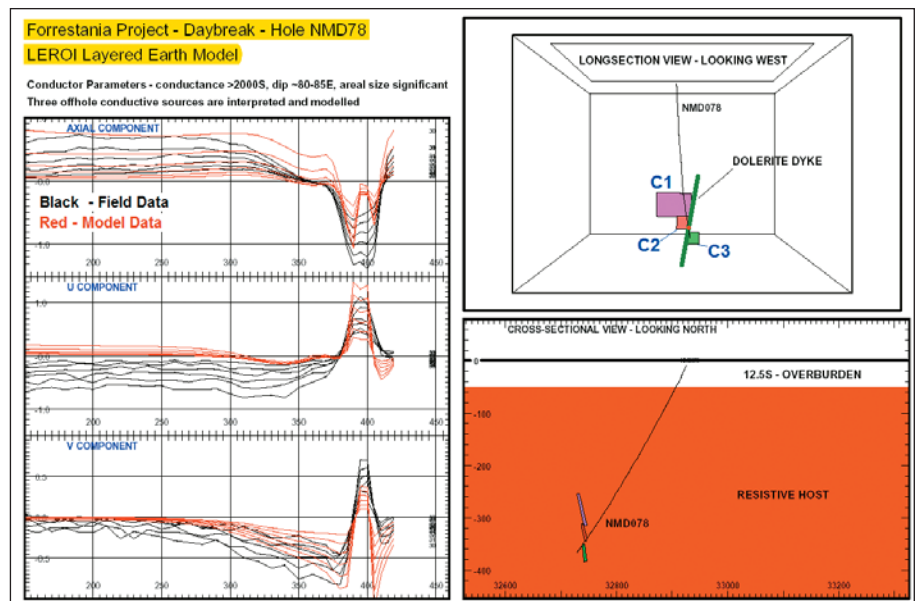


Fig. 5. LEROI layered earth model results for historic NMD078 DHTeM – highlighting multiple, strong conductors (C1, C2 and C3) split by a dolerite dyke.

- The stratigraphy has been metamorphosed to high amphibolite facies.
- Nickel sulphide mineralization is common to the Western and Eastern Ultramafic Belts with very few nickel sulphides identified in the ultramafic belts between them.
- Nickel sulphide mineralization typically occurs at the structural/stratigraphic base of the host ultramafic. Deposits consist of disseminated, breccia and massive ores. Massive and breccia ores are commonly near the base of the ultramafic sequence, either at the basal contact, within the disseminated ore or offset into the footwall meta-sediment.

Daybreak and Flying Fox

The Daybreak and Flying Fox T1 to T5 nickel deposits in the Western Ultramafic Belt (Figure 3) are both at significant depth below any previously known mineralisation and, in the case of Flying Fox and Daybreak Deeps, offset a considerable distance east of the known mineralization.

The stratigraphy at both Daybreak and Flying Fox is similar and can be generalised from west to east as follows:

Meta-sediment	(Footwall) – West
Olivine-rich ultramafic (<200 m thick at Daybreak, <50 m thick at Flying Fox)	
Sulphidic chert	
High magnesian basalt, low magnesian ultramafic	
Sulphidic black shale-chert	
High magnesian basalt	
Meta-sediment	(Hangingwall) – East

At Daybreak the lithologies dip steeply east (~70-90°), while at Flying Fox the sequence dip varies considerably from ~40°E to near vertical. At both locations the stratigraphy strikes between north-south and NNE-SSW and facing direction is east. There are clearly defined, lateral facies changes associated with the basal ultramafic unit from thick, mineralised ultramafic pathways to narrow, barren units. At both Daybreak and Flying Fox the massive nickel sulphides occur adjacent to the basal contact of the lowermost olivine-rich ultramafic. Commonly the nickel sulphides are remobilised into the footwall meta-sediments and are often associated with granitoid intrusions. Both nickel deposits are bounded by near flat-lying granitic dykes, which appear to have exploited late stage faults.

DHTeM and the discovery of the Daybreak and Daybreak Deeps deposits

Daybreak – discovered August 2002

A review of the historic geophysics in high priority prospect areas was completed as part of a due diligence study of the Forrestania Project on behalf of Western Areas NL during February 2002. This re-evaluation revealed a number of high priority DHTeM signatures which were not investigated by Outokumpu (the previous explorer).

High priority target conductors were identified in historic DHTeM data for drillhole NMD078

Of immediate interest was the significant, classic offhole anomaly (C) at ~635 m downhole in FFD123 (source below and north) with supporting current ramp data. The later explanation is preferred and supported in some part by the presence of a granite intrusion adjacent to the basal contact.

The presence of a strong offhole anomaly (C) and a somewhat ambiguous inhole response (B) at the target stratigraphic level, where minor nickel sulphides had been intersected, prompted a recommendation to locate, rehabilitate and re-survey historic drillholes FFD122 and FFD123. Two transmitter loops were used to remove some of the ambiguity observed in the historic data and also to vary the coupling, given that the geological dip was not well constrained. Detailed re-surveying of FFD122 and FFD123 in September 2003 using offset east and west transmitter loops confirmed the historic anomalies as discussed above. However, the work also detected the presence of an additional, high priority offhole conductor directly updip of FFD122 in close proximity to the expected basal ultramafic contact (Figure 10 - West Loop). The associated anomaly (D) centred at ~620-640 m showed

significant uphole migration in late offtime channels and had a strongly defined anomaly in the current ramp data (anomalous step response). Interpretation of the data from both loops indicated that the significant conductor updip of FFD122 was oriented near vertical to steeply east dipping. Therefore it had been poorly coupled (null coupled) by the historic transmitter loop, which had been located assuming the sequence was moderately east dipping, much like the stratigraphy in the Flying Fox mine to the west (Figure 11). The original inhole response in FFD122 was not evident in this dataset and is most like related to the null coupling of this target with the west loop.

By early October 2003 both FFD132 and FFD133B (Figure 3) had tested the upper DHTEM anomaly (A) returning broad zones of high grade, semi-massive to massive nickel sulphide (FFD132, ~6.6 m @ 7.9% Ni and FFD133B, ~21.4 m @ 7.8% Ni – *Flying Fox T1-T2 deposit*). DHTEM logging of FFD133B clearly indicated that the wide interval of massive nickel sulphide is extremely

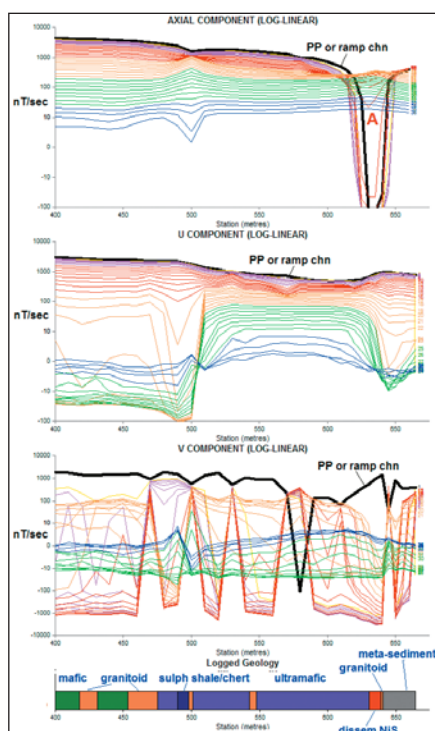


Fig. 8. DHTEM data from drillhole FFD122 showing a strong and broad inhole response at ~630 m (A) and distortions in current ramp (anomalous step response) - Crone PEM, 40 ms time base - acquired by Outer Rim, 1994. This inhole response (A) is situated in close proximity to the basal ultramafic contact and disseminated nickel sulphide profile.

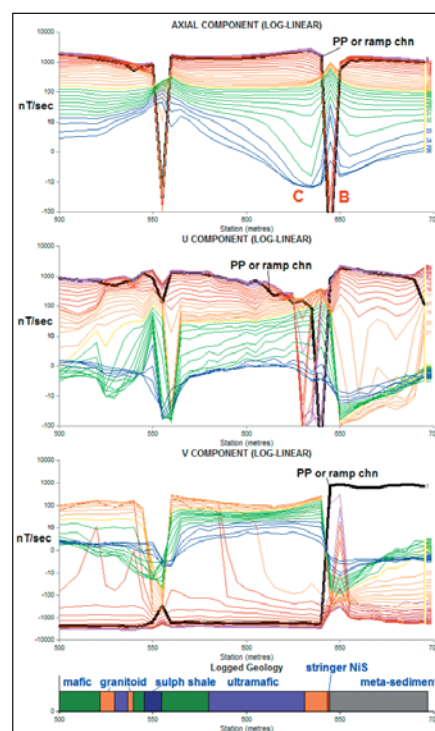


Fig. 9. DHTEM data from drillhole FFD123 showing a strong offhole response at ~635 m (C) and narrow inhole response at ~645 m (B) plus distortions in current ramp (anomalous step response) - Crone PEM, 40ms time base - acquired by Outer Rim, 1994. The dominant offhole response (C) is related to a granite intruded basal ultramafic contact.

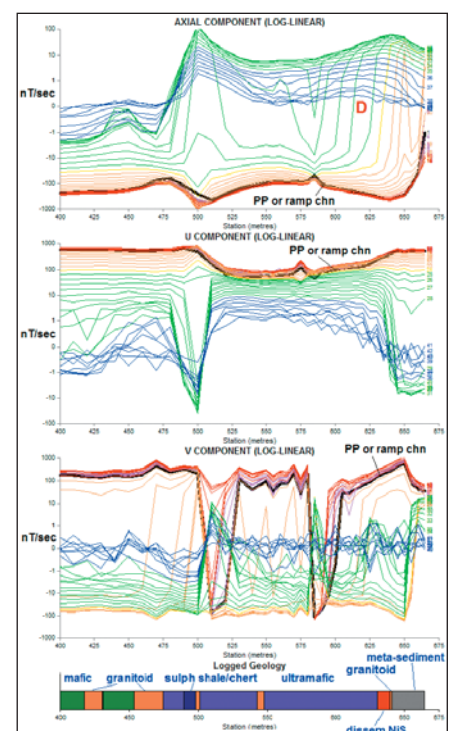


Fig. 10. DHTEM data from drillhole FFD122 (resurveying 2003 - west loop) highlighting a strong offhole response (D) at ~620-640 m (conductor directly above hole – note reverse coupling and polarities) plus strong distortions in current ramp - Crone PEM, 150 msec time base – acquired by Outer Rim 2003. A significant migration in the anomaly peak is apparent with respect to delay time, from ~640 m in early channels to ~620 m in late channels.

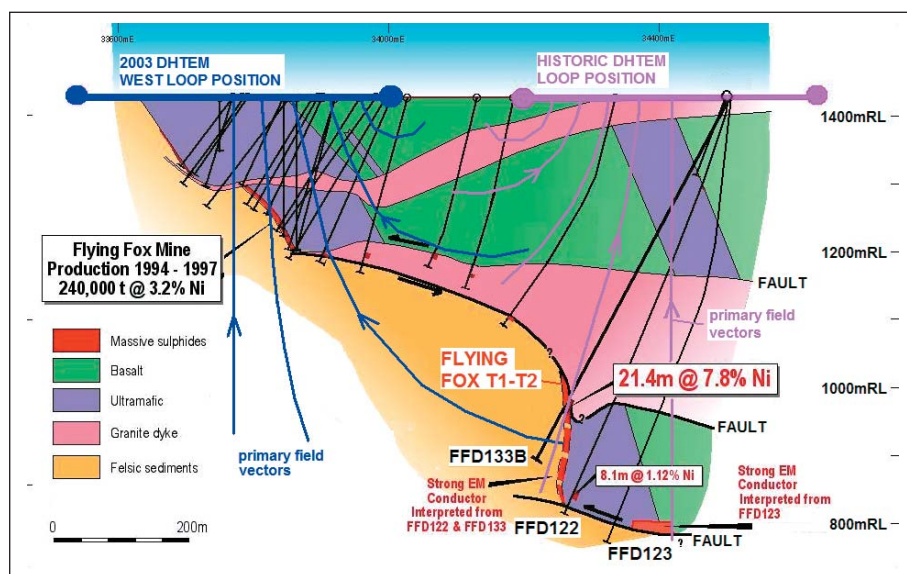


Fig. 11. An early cross-sectional view of the Flying Fox T1-T2 deposit showing the poor coupling associated with the historic loop as opposed to optimal coupling with the 2003 west loop.

conductive with a near zero decay through all offtime channels (Figure 12). All additional Flying Fox drill testing intersected nickel sulphides and these holes provided excellent DHTEM platforms with which to screen for, and delineate the massive nickel sulphide system. At the time of writing the indicated and inferred mineral resource at the Flying Fox T1-T2 deposit had been estimated to be 316,000 tonnes at a grade of 5.9% Ni.

After the initial period of delineation drilling at the Flying Fox T1-T2 deposit it was decided to drill test anomaly (C) observed in FFD123; offhole of source of which was interpreted to be below or east of the hole and extend north of the drillhole. It was mostly near horizontal and of significant areal size. Drill testing of this DHTEM target occurred during December 2003 (FFD136W1 – Figure 3) and results confirmed the presence of significant massive nickel sulphide aligned along a sub-horizontal structure intruded by a granitoid (~1.5 m @ 6.9% Ni – Flying Fox T3).

Flying Fox T4 and T5 discovered July–August 2003

Broadly anomalous DHTEM results were identified in the lowermost section of a deep exploration drillhole during December 2003 (FFD136). Ongoing modelling during early-mid 2004 suggested that the source could be consistent with the presence of a significant conductor, at a considerable distance east of the hole and it was postulated that the target could represent fault offset mineralisation.

Based on this information and the continued aggressive exploration approach, the decision to extend the drillhole FFD136 was then made and drilling commenced in July 2004. Initially the daughter hole (FFD136W2W2) was drilled to ~1130 m and remained in monotonous footwall meta-sediments. However, subsequent DHTEM logging suggested that the hole was approaching a conductor of interest, possibly situated along a fault offset, basal ultramafic sequence. It was for these reasons that the hole was deepened and eventually intersected a wide zone of massive nickel sulphide ~50 m below the initial end of hole (FFD136W2W2, 12.4 m @ 5.2% Ni – Flying Fox T5). Also of interest in the original DHTEM log for FFD136W2W2 to 1130 m was the presence a target of significant areal size, situated at >100 m above and sub-parallel to the hole (Figure 13). Drill testing of the DHTEM model during August 2004 intersected significant nickel sulphides at the approximate target depth (FFD160 – Figure 3, ~2.9 m @ 3.1% Ni – Flying Fox T4). Ongoing DHTEM logging of many of the deep drillholes targeting Flying Fox T4 and T5 continues to this day and the resultant information remains an invaluable tool for guiding step out drilling. At the time of publication the inferred mineral resource at the Flying Fox T5 deposit had been estimated to be 630,000 tonnes at a grade of 6.9% Ni.

Whilst completing the initial discovery geophysics work on the Flying Fox T5 deposit several DHTEM surveys of FFD136W2W2 were performed using both a conventional dB/dt system (Crone PEM) and a recently

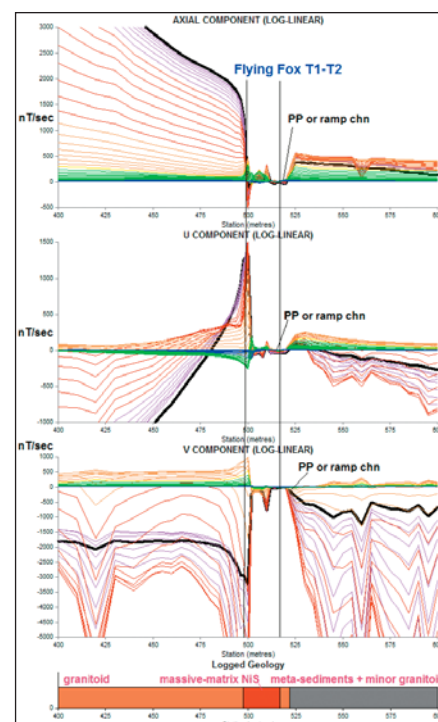


Fig. 12. DHTEM data from hole FFD133B showing a wide, muted response across the highly conductive Flying Fox T1-T2 mineralisation – Crone PEM, 150 ms time base – acquired by Outer Rim 2003.

developed B-field system (Atlantis Fluxgate). Figure 14 provides an axial or uphole component comparison of the two methods at late offtimes (~50–135 ms) and also includes the calculated residual step response derived from the Crone PEM dataset (S1 residual, % total theoretical). There is clearly a significant difference between the upper and lower peaks of the T4 anomaly defined in the dB/dt (~775 m–1050 m) as opposed to the B-field data (~925–1075 m). This can be explained to some degree by the significant, late offtime, downhole migration of the upper peak of the T4 anomaly. Overall the DHTEM data indicate that the lowermost section of T4 is strongly conductive (~925–1075 m), whereas the uppermost section (~775–925 m) which is clearly related to T3 is moderately conductive, and most likely not related to well developed nickel sulphide.

The residual late step response (S1 residual – anomalies opposite in polarity) has been included to show that although the late offtime dB/dt anomaly varies considerably from the late B-field anomaly, the late step response of Crone PEM dB/dt data or channel routinely monitored for the presence of near-perfect conductors (Ravenhurst, 2001) is consistent with the late B-field anomaly extents. An alternative approach for monitoring DHTEM

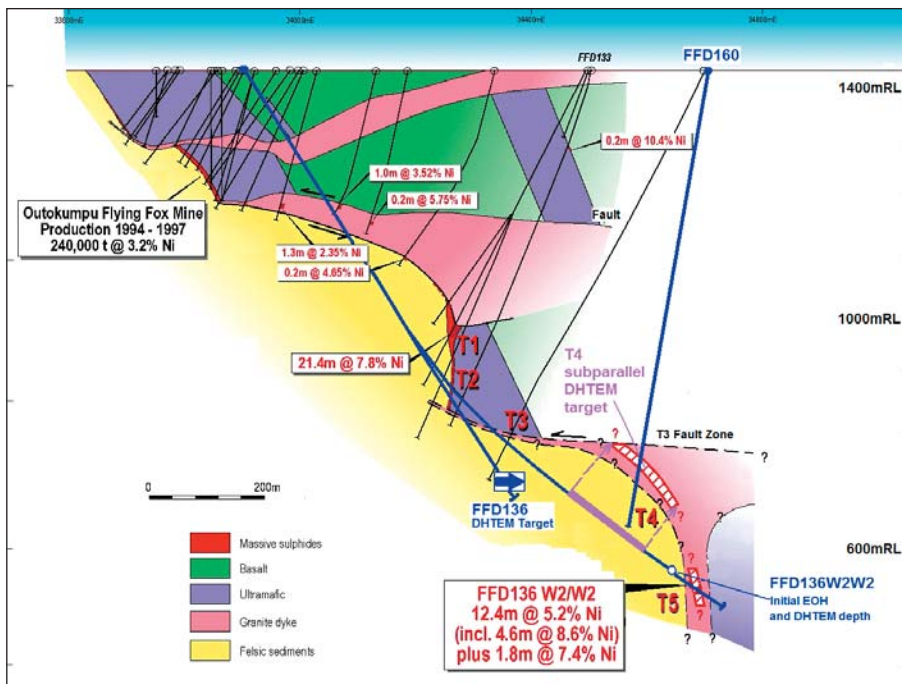


Fig. 13. Cross-sectional view of the Flying Fox deposits highlighting the critical DHTeM holes (FFD136, FFD136W2W2 and FFD160) that guided the deep exploration drilling and culminated in the eventual discovery of T4 and T5.

data for the presence of near-perfect conductors would be to integrate the full ramp and offtime dB/dt data and obtain the inphase response (Smith and Balch, 2000).

Conclusions

- The discovery of the Daybreak, Daybreak Deeps and Flying Fox T1 to T5 nickel sulphide deposits between 2002 and 2004 within brownfields nickel properties can be attributed largely to the use of DHTeM.
- DHTeM can accurately and cost effectively, provide the critical, initial vectors to focus exploration efforts toward deep and highly conductive, massive nickel sulphide orebodies.
- Where geological dip is poorly constrained, two transmitter loops should be employed to ensure adequate coupling to a potential target by at least one loop. Flying Fox T1-T2 would not have been detected without the use of a reverse coupled loop.
- The residual, late step response or inphase (integrated) response of conventional dB/dt DHTeM should be routinely calculated and used to monitor for the presence of near-perfect conductors, which are those commonly of interest in the search for massive nickel sulphides. This should be done for historic DHTeM surveys, particularly those completed within brownfields nickel prospects.

Acknowledgements

Permission from Western Areas NL to present and publish these data is appreciated, and the author wishes to thank the management, in particular, directors Julian Hanna and Terry Streeter for their optimism during the ongoing pursuit of these deep geophysical targets. Thanks are also extended to Richard Stuart for his assistance in providing relevant data for publication.

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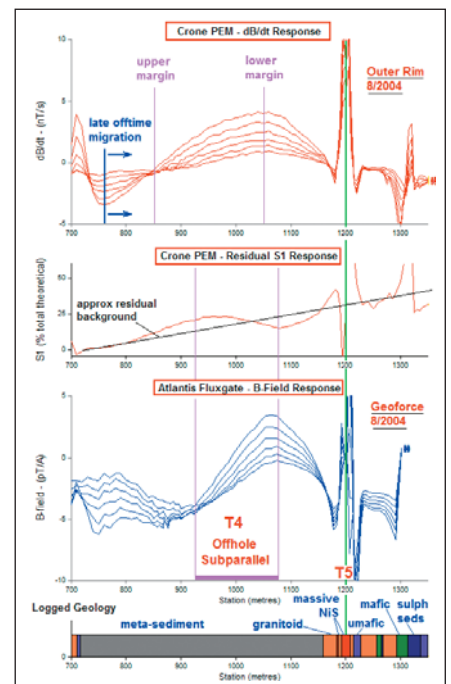


Fig. 14. Comparison of axial component Crone PEM (dB/dt - Outer Rim 8/2004) and Atlantis fluxgate (B-field - Geoforce 8/2004) DHTeM data acquired from FFD136W2W2 in the vicinity of the T4 and T5 deposits. Residual S1 late step response has also been provided for comparison.

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Geoscience Australia and New South Wales

Broken Hill High Resolution Seismic Survey

A high resolution seismic survey coincident along a portion of the 1996-1997 AGSO deep seismic reflection line 9697AGS-BH1B was acquired in early August. A total of 12 km of high fold data was acquired across the Broken Hill Synform and Stephens Creek Shear Zone. Presentation of results from this survey is tentatively scheduled for the next BHEI conference to be held in Broken Hill in October, 2006. This is a collaborative project between Geoscience Australia and the New South Wales Department of Primary Industries – Mineral Resources (DPI-MR).

Figures 1 and 2 show some of the crew's activities near Broken Hill.

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Fig. 1. Two of the Hemi 60 vibrators, raising the dust near Broken Hill.



Fig. 2. Close up of a vibrator, note the geophones planted nearby.

Thomson-Lachlan Seismic Project

ANSIR, the National Research Facility of Earth Sounding completed the collection of deep seismic data in the Bourke-Wilcannia region of northwestern New South Wales on Sunday, September 4th. Traverses completed were:

- 05GA-TL1 – 99.20 km
- 05GA-TL2 – 115.56 km
- 05GA-TL3 – 87.12 km

This now provides 300 km of seismic data across the Thompson-Lachlan Boundary and through the Nelyambo Trough, and Mt Jack High structures. The data will help solve one of the key problems in the Tasmanides of



Fig. 4. Recording truck raising the dust on traverse 05GA-TL2



Fig. 5. Juggy planting geophones with right heel.

eastern Australia, namely the location and nature of the east-west boundary between the Lachlan and Thomson Orogens in northwest NSW. This is a collaborative project between the NSW Department of Primary Industries – Mineral Resources (DPI-MR), Geoscience Australia, and the predictive mineral discovery Cooperative Research Centre (pmd*CRC).

Figure 3 shows the location of these traverses and Figures 4 and 5 show the crew working on the traverse.

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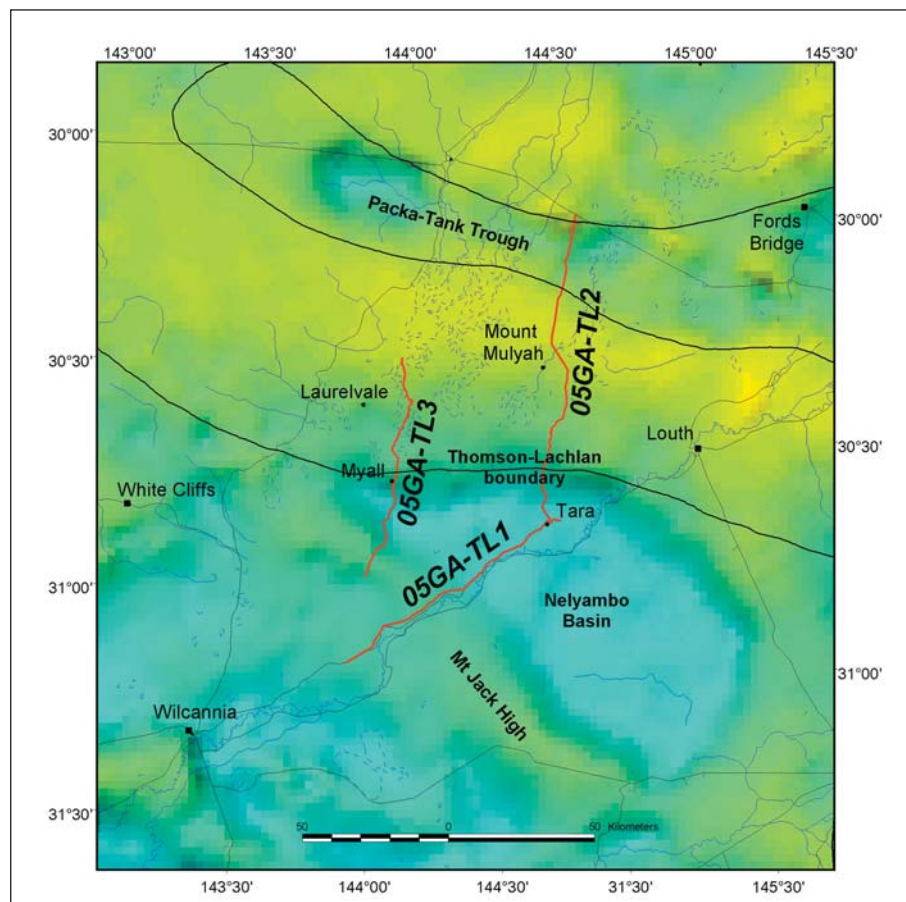


Fig. 3. Location map of the three traverses

NSW a place to explore: current and future activities of the Geological Survey of NSW

By David Robson
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Focus on New South Wales

The mining industry in New South Wales now directly employs more than 30,000 people and indirectly offers almost twice as many jobs through related industries and services. In 2004-2005, the mining industry output in NSW was approximately \$9 B and in the past 10 years mining leases have been granted to more than 40 major projects worth \$3 B. In the past year, NSW received a silver medal for producing more than 29 t of gold (worth \$525 million) while copper production rose to 177,000 t (worth over \$740 million). NSW has also seen a surge in petroleum exploration with almost \$23 MM spent in 2004/2005, which is a 66% increase from the previous year.

NSW Department of Primary Industries

In July 2004, the former NSW Department of Mineral Resources was incorporated with NSW Agriculture, State Forests NSW and NSW Fisheries into the NSW Department of Primary Industries (DPI). DPI incorporates 3,900 staff and has offices in 130 localities across NSW. The Department is now NSW's largest provider of science.

The move of the Geological Survey to Maitland in late 2004 brought with it a variety of challenges along with a purpose-built building fitted with modern staff accommodation and support facilities. The survey lost many experienced staff with the relocation but now that recruitment is firmly underway, the survey is being reborn.

The Geological Survey of NSW continues to deliver enhanced geophysical coverages of the state and to extend the coverage of modern geological maps. Much of this work is conducted under the government's ongoing Exploration NSW initiative, which is a \$30 MM, seven year (2000-2007) program to accelerate geoscience data acquisition and increase private-sector investment in exploration for minerals and petroleum. At the Department's biannual NSW Mineral Exploration and Investment 2005 conference held in Sydney in early September, Department staff announced data releases and updates on the current major projects. These include:

1. Release of the Darling Basin Petroleum Data Package on DVD that provides an excellent compilation of previous exploration together with recent interpretative studies.
2. Update of the current large airborne magnetic and radiometric survey costing \$1.6 MM. The largest government survey ever undertaken is in progress with sequential data releases in 2005 and 2006. It covers an area in excess of 90,000 km² in the far west and central NSW with the acquisition of more than 280,000 line-km of data. The results of the first survey over the Southern Darling Basin were released at the conference.
3. Update on the high resolution seismic reflection data acquired in September to determine the nature and location of the east-west boundary between the Lachlan and Thomson Orogens in north-central NSW.
4. Preliminary results from the trial of high resolution seismic reflection survey at Broken Hill across the northern extension of the line-of-lode. These will assist in the correlation of the surface geology with the deep geological structures identified during previous surveys at this location.
5. Release of the Southern Koonenberry Geophysical Interpretation Map which highlights the extension of prospective lithologies under cover that could host mineralisation.

6. Release of 785 geochemical results from the re-assay of high iron float samples collected on the Cobar and Nyngan 1:250 000 map sheet areas during the late 1970s.
7. Updates on the Cargelligo, Cobar, Tibooburra and Lachlan mapping programs together updates on new collaborative studies on the Tasmanides and the Cobar Minerals projects.



Darling Basin Petroleum Data Package

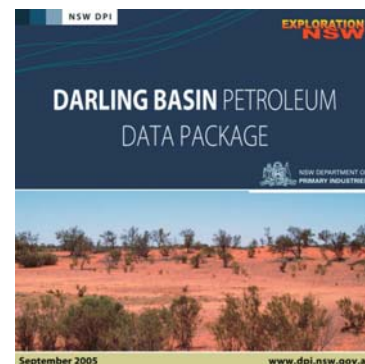
The Darling Basin Petroleum Data package includes more than 4 gigabytes of data and is now available on DVD. It is a comprehensive compilation of geological, seismic, well, petrophysical, geochemical, and cultural data, which has been presented as a digital geospatial data product. The package is an update to the 1993 Darling Basin Petroleum Data Package and includes recently collected and processed data and the latest interpretations of geology and petroleum prospectivity of the Basin. A new feature of the data package is the presentation of spatial data as interactive GIS maps, shapefiles and georeferenced raster images.

The appendix includes an extensive collection of reports and raw data, including well-completion and seismic survey reports, SRK Consulting SEEBASE™ basement modelling, geochemical and petrophysical analyses, and WinBury burial and thermal history modeling.

The following recently acquired and reprocessed seismic line data in SEG Y format are not included in this data package, but are available from the survey as separate data products:



NSW Mineral Exploration and Investment Conference, Sydney, September 2005



Darling Basin Petroleum Data Package - DVD cover

- Darling Basin NSW - Wilcannia 2003 Seismic Data Package;
- Darling Basin - Wilcannia 2004 Seismic Survey ;
- Darling Basin - Reprocessed Seismic Data Release, August 2004
- DMR -04-03 - AVO Processing

Major Airborne Geophysical Survey Mapping Program

The \$1.6 MM airborne geophysical survey currently being contracted to Fugro Airborne Surveys covers three survey blocks over parts of the Southern Darling Basin, the Murray Basin and the Eromanga Basin, which have not previously been systematically surveyed using modern high resolution technologies. Details of individual surveys are as follows:

Southern Darling Basin Survey

Coverage: 6,700 km²; 18,300 line-km
Release Date: 1st September 2005
Survey aircraft: Rockwell Shrike Commander
Line spacing: 400 m line spacing, aligned N-S
Ground clearance: 60 m

Murray Basin Survey

Coverage: 34,800 km²; 96,600 line-km
Release Date: Late 2005
Survey aircraft: Rockwell Shrike Commander
Line spacing: 400 m aligned E-W
Ground clearance: 60 m

Eromanga Basin Survey

Coverage: 46,100 km²; 166,750 line-km
Acquisition: started early July
Release Date: early 2006
Survey aircraft: Cessna 210
Line spacing: Either 400 m and 250 m aligned either N-S or E-W
Ground clearance: 60 m

With the conclusion of this survey, more than 80% of NSW will have been covered by high resolution airborne geophysical surveys.

Trial of high resolution seismic at Broken Hill

Under the Broken Hill Exploration Initiative between the NSW Department of Primary Industries and Geoscience Australia, the Australian National Seismic Imaging Resource (ANSIR) conducted a trial of high resolution seismic survey with Vibroseis technology at Broken Hill in mid-August 2005. The objective was to use high resolution seismic reflection survey profiles to assist in correlating the surface geology with deep geological structures identified during the previous seismic survey acquired in 1996-1997. This latest type of Vibroseis technology was not available when the previous seismic lines were surveyed using explosive energy sources.

The following seismic reflection sections show an extract of the 1996/1997 data that was re-surveyed with Vibroseis data in 2005. Although the 2005 seismic reflection data has undergone only preliminary field processing, it displays significantly improved resolution. A particularly good example of this improvement can be compared with the data within the red box on both sections (see Figures below). With the data collected in 2005, geological detail and structures within the upper few kilometres (1 s data) of the subsurface can be identified. The data, together with other geological and geophysical information, will greatly improve the understanding of how the deep geological structures correlate with observed geological structures near surface. This will contribute to an improved scientific understanding of the

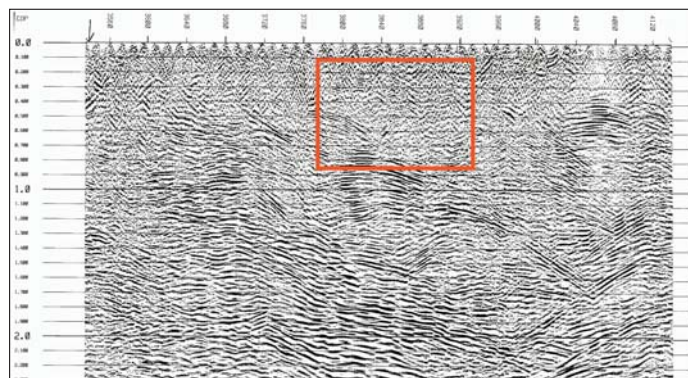
three-dimensional geometry of the geology and mineral systems of the Broken Hill area.

Southern Koonenberry Belt geophysical interpretation map

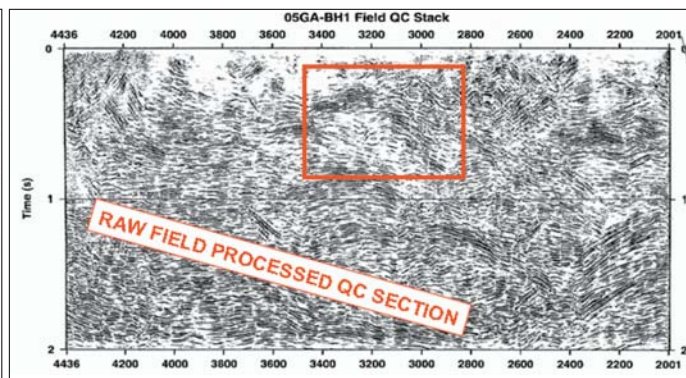
An interpretation of the geology and structure of an 11,000 km² area of Neoproterozoic to Early Cambrian rocks which wrap around the southern margin of the Broken Hill Block has now been completed using Exploration NSW airborne magnetic and radiometric surveys, regional gravity data, outcrop geology and drill-hole data. Over fifteen zones were defined with known geology, observed geophysical signatures and drill-hole data. The interpretation identifies a series of elongated zones with no outcrop, except near Scropes Range in the far north, but cover-thicknesses are mostly shallow. Features that could be prospective for mineral exploration include three suites of volcanic rocks:

- Interpreted equivalents of the late Neoproterozoic alkaline Mt Arrowsmith Volcanics, which are currently being explored further north for nickel.
- Interpreted equivalents of the Early to Middle Cambrian Gnalta Group, calc-alkaline volcanics, the near-surface extension of an island arc assemblage buried under the Bancannia Trough. Drilling on the Wahratta prospect (Platsearch NL & CRA Exploration) intersected copper gold porphyry-style alteration in these rocks.
- Tholeiitic basalts and gabbros that are interpreted equivalents of the Middle Cambrian Ponto Group.

Further exploration interest are intrusive bodies that may have affinities with layered ultramafic bodies anomalous in platinum group elements and nickel, such as the Black Hill Norite found in similar rocks



A 12 km extract of the Broken Hill 1996/97 seismic reflection section. The data within the red box outline an identical area to the red box outline on the 2005 seismic reflection section.



The 2005 Broken Hill preliminary seismic reflection section covering the 12 km extract (above) of the 1996/97 seismic reflection section. The increased resolution of the 2005 data is particularly evident within the red box outline.

along strike in South Australia. The presence of small granodiorite bodies and faults of regional extent are also favourable indicators for gold mineralisation.

Thomson Orogen Project

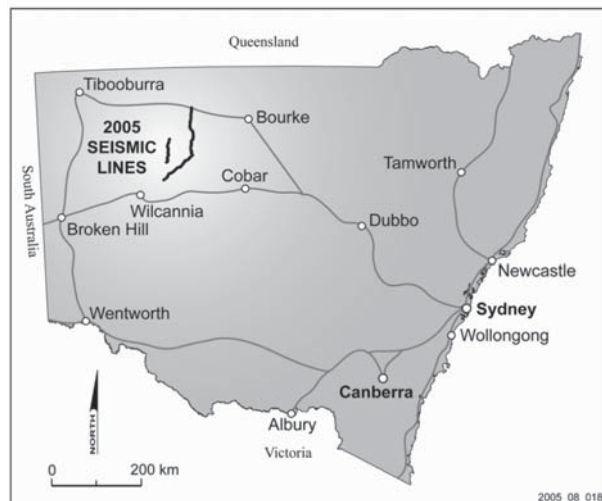
The Thomson Orogen Project area is in far north NSW. As part of this project, a high resolution seismic reflection survey was conducted in September 2005 to gain a greater understanding of the nature and location of the east-west boundary between the Lachlan and Thomson Orogens. The seismic data is expected to provide new insights into the nature of this boundary and provide data on the Thomson Orogen that is thought to have potential for arc and ocean-crust related gold and base metal deposits. The project will also investigate the potential for Cobar style deposits and Mississippi Valley style silver and zinc deposits and will collect new data on the Nelyambo Trough, which is a key Devonian Trough with hydrocarbon potential, by providing data on thermal maturity, migration pathways, and trap developments.

The seismic survey is a collaborative project between the NSW DPI and the *pmd**CRC. The project is directly funded by NSW DPI (\$500,000) and Geoscience Australia (\$200,000), and has attracted additional industry funding (\$75,000). The Australian National Seismic Imaging Resource (ANSIR) has acquired approximately 300 km of high resolution seismic data on three lines within a 100 km radius of Tilpa, between Bourke and Wilcannia. Before the start of this survey, an

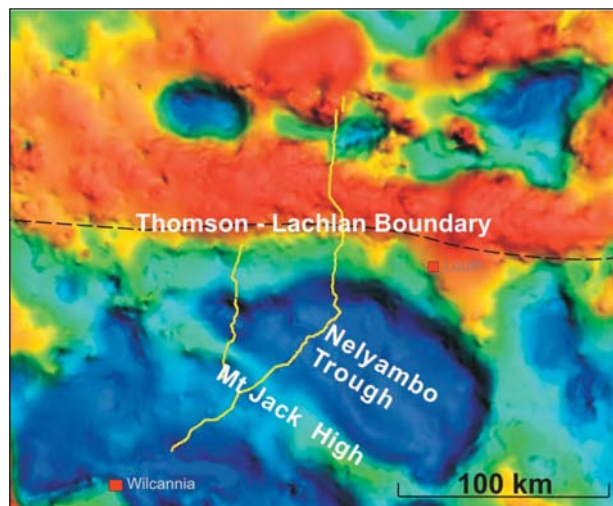
Aboriginal Cultural Heritage Survey and a Review of Environmental Factors (REF) were completed to ensure that the work program had a low impact on the environment and to that the correct procedures were being employed to minimise disturbance. The majority of the seismic lines were along existing shire roads and station tracks. Processing will be conducted by the *pmd**CRC and interpretation will be jointly completed in early 2006 by staff from NSW DPI, Geoscience Australia, and the *pmd**CRC.

Release of new geochemical results on the Cobar and Nyngan 1:250 000 map sheet area

The Geological Survey has gained access to the pulps from 6,390 high-iron content rock-chip samples that were collected on the Cobar and Nyngan 1:250 000 map sheets during the late 1970s. Originally, most of these samples were not assayed for gold and 785 samples were recently analysed for gold and 18 other



Location of high resolution seismic survey, Thomson Orogen Project.



Location of the seismic lines (yellow lines) superimposed on a colour image of the Bouguer gravity data.

elements. A number of samples returned approximately 3g/t Au, while other samples returned anomalous Ni, Cu, Pb and Zn.

Victoria

Victoria's mineral exploration licence reports available on line

The next release of the Minerals and Petroleum Division web mapping tool, GeoVic will be at Mining 2005 in October. New components will include links to:

- Exploration tenements to the expired exploration reports
- Geophysical interpretations
- Historical mine plans linked to mine sites
- Symbolised geological structures with the geological data

By identifying the tenement of interest, the explorer is able to click on a link to view a summary of the exploration that has taken place at that tenement. The reports submitted for each tenement can be downloaded as a zip file and then viewed or printed.

Detailed geophysical interpretations undertaken as part of GSV projects are available and cover approximately 50% of Vic. These can be readily overlaid with magnetic, gravity and radiometric images.

Petroleum themes were released at APPEA 2005 and include the following layers:

- Petroleum tenements
- Current petroleum acreage release
- Petroleum wells and some well interpretations
- 3D seismic survey boundaries
- 2D seismic surveys lines

To access the application, visit www.dpi.vic.gov.au/minpet/ and click on "Explore Victoria Online - GeoVic".

For further information regarding GeoVic please contact us at mbc.info@dpi.vic.gov.au or contact: Rob Lane, on (+61 3) 9658 4574.

Queensland, Western Australia and Geoscience Australia

New Geophysical Surveys

Smart Exploration Initiative Queensland – Airborne Geophysical & Gravity Surveys

Planning is underway for the Queensland Government's \$20 MM Smart Exploration initiative by the Department of Natural Resources and Mines to stimulate exploration investment in the state. Five airborne magnetic and radiometric surveys, and six ground gravity surveys are proposed as part of the initiative during the next two years (see Figures 1 and 2).

The new airborne data will be acquired on east-west lines spaced 400 m apart with a clearance of 80 m above ground level. The new gravity data will be acquired at station spacings of 2 km x 2 km and 4 km x 4 km. Geoscience Australia will manage the data acquisition program.

When completed, the projects will release more than 1, 200,000 line-km of magnetic and radiometric data and more than 39,000 gravity stations to the public domain.

See Preview 117 (August 2005 – Page 35) for further information on the Smart Exploration Initiative.

For further details, contact Bernie Stockill by telephone on (07) 3362 9357 or by email at bernie.stockill@nrm.qld.gov.au or Murray Richardson by telephone on 02 6249 9229 or by email at murray.richardson@ga.gov.au.

Update on Geophysical Survey Progress

Paterson Province WA – airborne magnetic and radiometric surveys

UTS Geophysics started data acquisition on the Paterson Central and Paterson South-East surveys on June 24th. Approximately 123,000 line-km of magnetic and radiometric data will be acquired over an area of approximately 42,000 km².

By the end of August, UTS Geophysics had completed 14% of this survey.

Maryborough/Gympie Qld – Airborne Magnetic and Radiometric Survey

UTS Geophysics completed data acquisition on this survey on August 1st. When the survey is completed approximately 51,700 line-km of new data will be released to the public domain. Anticipated date for data release is early October 2005.

East Yilgarn WA – Airborne Magnetic and Radiometric Survey

Fugro Airborne Surveys started data acquisition on this survey on August 14th. By the end of August 8% of the survey had been completed. See Preview 117 (August 2005 – Page 34, Figure 3) for a locality diagram of this survey.

Gascoyne WA – Airborne Magnetic and Radiometric Survey

UTS Geophysics is scheduled to commence data acquisition on this survey in the first week of October. See Preview 117 (August 2005 – Page 34, Figure 4) for a locality diagram of this survey.

Paterson Province WA – Gravity Survey

Daishsat commenced data acquisition on this survey on August 31st. Approximately 4,000 new gravity stations are being acquired on a 2.5 km by 2.5 km grid. Final gravity data delivery is anticipated to be in October 2005, with the data release to the public occurring shortly thereafter.

In the first five days of the survey, Daishsat had covered 8% of the survey area.

See Preview 115 (April 2005 – Page 33, Figure 1) for a locality diagram of this survey. For further details, contact David Howard by telephone on 08 9222 3331 or by email at david.howard@doir.wa.gov.au or Murray Richardson by telephone on 02 6249 9229 or by email at murray.richardson@ga.gov.au.

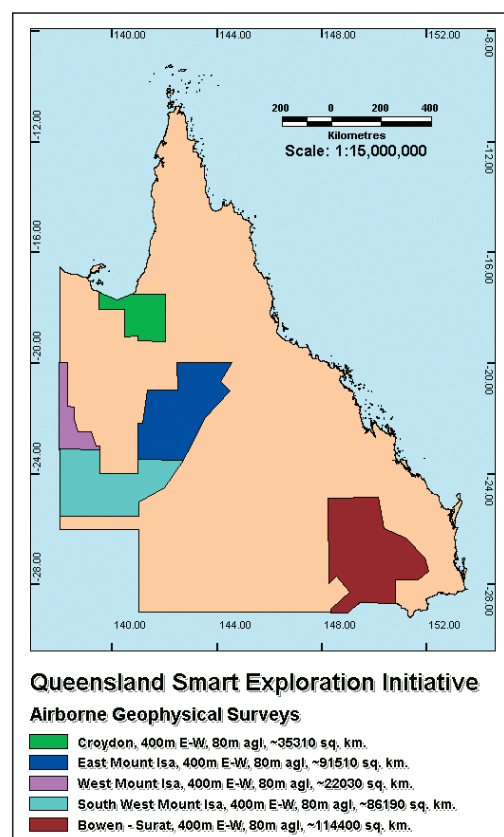


Fig. 1. Locality diagram for the Queensland Smart Exploration Initiative Airborne Geophysical Surveys.

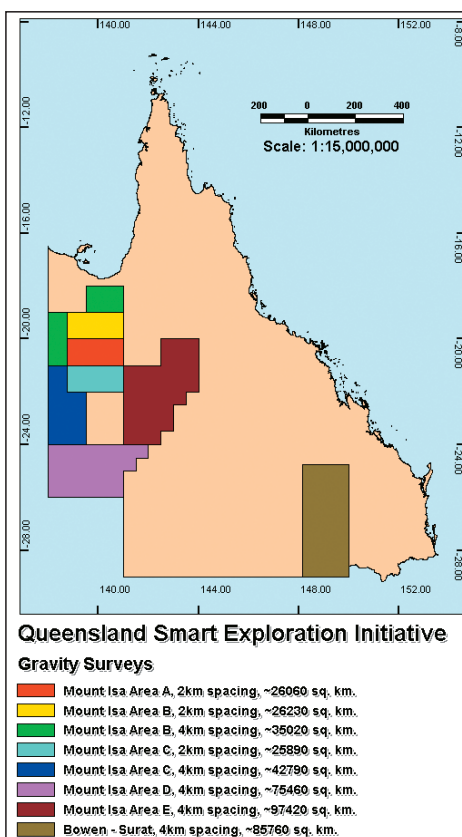


Fig. 2. Locality diagram for the Queensland Smart Exploration Initiative Gravity Surveys.

Northern Territory, South Australia, Western Australia and Geoscience Australia

New data added to the Australian National Gravity Database

New gravity data from a recent survey over the majority of the Birrindudu 1: 250 000 sheet area has now been incorporated into the Australian National Gravity Database (see Figure 1).

The new data is from a survey project managed by Geoscience Australia on behalf of the Northern Territory Geological Survey.

Data was acquired at a station spacing of 2 km by 2 km. Figure 2 is an image generated from the new and pre-existing Birrindudu gravity data.

Data from two recent surveys over the Central Gawler Craton and the Central Curnamona Province by Primary Industry and Resources South Australia has been supplied to Geoscience Australia and added to the Australian National Gravity Database. Data from SA cover parts of the following 1:250 000 sheet areas: Tarcoola, Childara, Streaky Bay, Elliston, Kimba, Whyalla, Yardea, Port Augusta and Gairdner on the Central Gawler Craton Survey and Callabonna, Frome and Curnamona on the Central Curnamona Province Survey.

Processing of the gravity data collected along the 2004 Curnamona seismic line on the Parachilna and Curnamona 1:250 000 sheet areas has been completed, and the data has been added into the Australian National Gravity Database. Figure 3 shows the areas covered by these South Australian gravity surveys.

Data supplied by the Geological Survey of Western Australian and collected along traverses in the Gascoyne and Bangemall Region on the Edmund and Mount Phillips 1:250 000 sheet areas and in the Musgrave Region on the Scott and Cooper 1:250 000 sheet areas have been added to the Australian National Gravity Database. Figures 4 and 5 show the locations of these traverses.

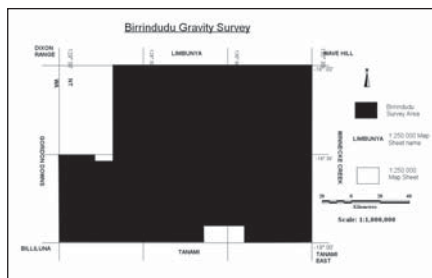


Fig. 1. Locality diagram for the 2005 Birrindudu Gravity Survey.

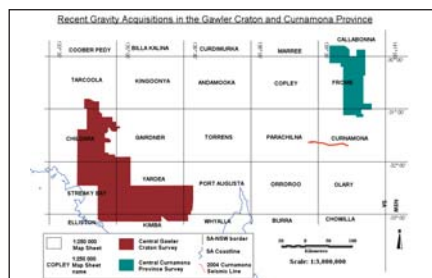


Fig. 3. Locality diagram for recent South Australian gravity surveys.

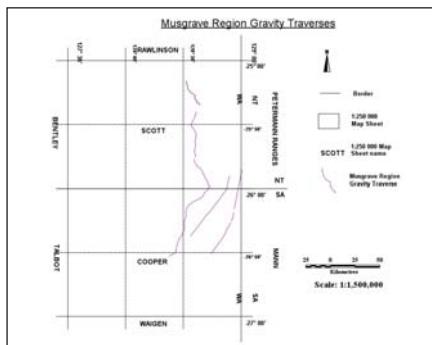


Fig. 5. Gravity traverses in the Musgrave Region of WA.

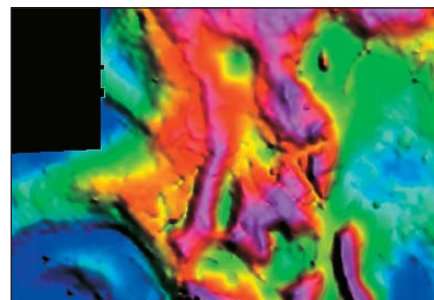


Fig. 2. Gravity image incorporating the new and existing data over the 2005 Birrindudu survey area. The area covered by the image is shown in Fig. 1.

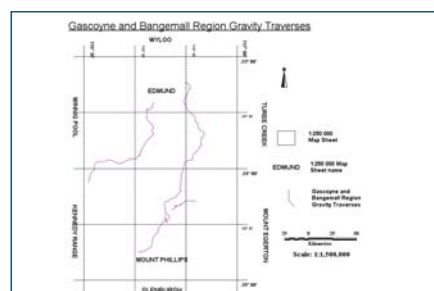


Fig. 4. Gravity traverses in the Gascoyne and Bangemall Region of WA.

New accuracy fields for location, ground elevation, and observed gravity have recently been entered into the database for all onshore gravity data.

In this recent upgrade 14,445 new stations have been added to the database, bringing the total of open file stations up to 1,336,200. The really good thing is that all data in the

Geoscience Australia

Seismic data tape preservation passes quarter million

The Commonwealth Government budget of May 2003 provided resources for copying and concatenation onto high density media, old (and mostly unreadable) industry and Geoscience Australia offshore seismic tapes held in the GA repository. The media being transcribed are 9 and 21 track tapes as well as 3,480 cartridges. Half a million tapes and cartridges are to be remastered over four years and the project has just passed the half way mark. More than 265,000 tapes have been remastered onto 3,590 cartridges. The Remastering Project has been in operation since January, 2004 and will continue till June, 2007.

All transcription, quality control, and physical disposal are being carried out by contracting companies in Perth. The transcription contracts were awarded to Guardian Data and Spectrum Data. All quality control is being carried out by GeoCom Services Australia.

Remastering of the data has enabled easier access and coincided with steadily increased borrowing by companies (at cost of transfer), largely for reprocessing of field tapes, using new processing algorithms and the increased computing capability. In the past year, processed data from 387 surveys and field data from 87 surveys totalling 23.1 Terrabytes of data (23,100 Gigabytes) have been accessed by the petroleum industry. The data comprises raw field, processed, re-processed, navigation and velocities data, and acquisition, processing and interpretative reports. For further information, please contact Paula Cronin, Geoscience Australia, on email: paula.cronin@ga.gov.au

Mineral resources exports achieve a new record for 2004-2005

Export earnings by the Australian minerals and energy sector increased by 29% to a record \$67.4 billion in 2004-05, according to the September issue of ABARE's *Australian Mineral Statistics*.

According to ABARE chief executive, Brian Fisher: "This strong performance reflects higher export prices across almost 80% of all minerals and energy commodities exported,

along with increased export volumes for more than two thirds."

The major commodities to record the largest increases in export earnings in 2004-2005, included coking coal, up \$4,220 million (65 per cent) to \$10,730 million; iron ore and pellets, up \$2,808 million (53 per cent) to \$8,085 million; and steaming coal, up \$1,964 million (45 per cent) to \$6,336 million.

"Each of these commodities recorded increases in both export prices and volumes, particularly in the June quarter, following substantial

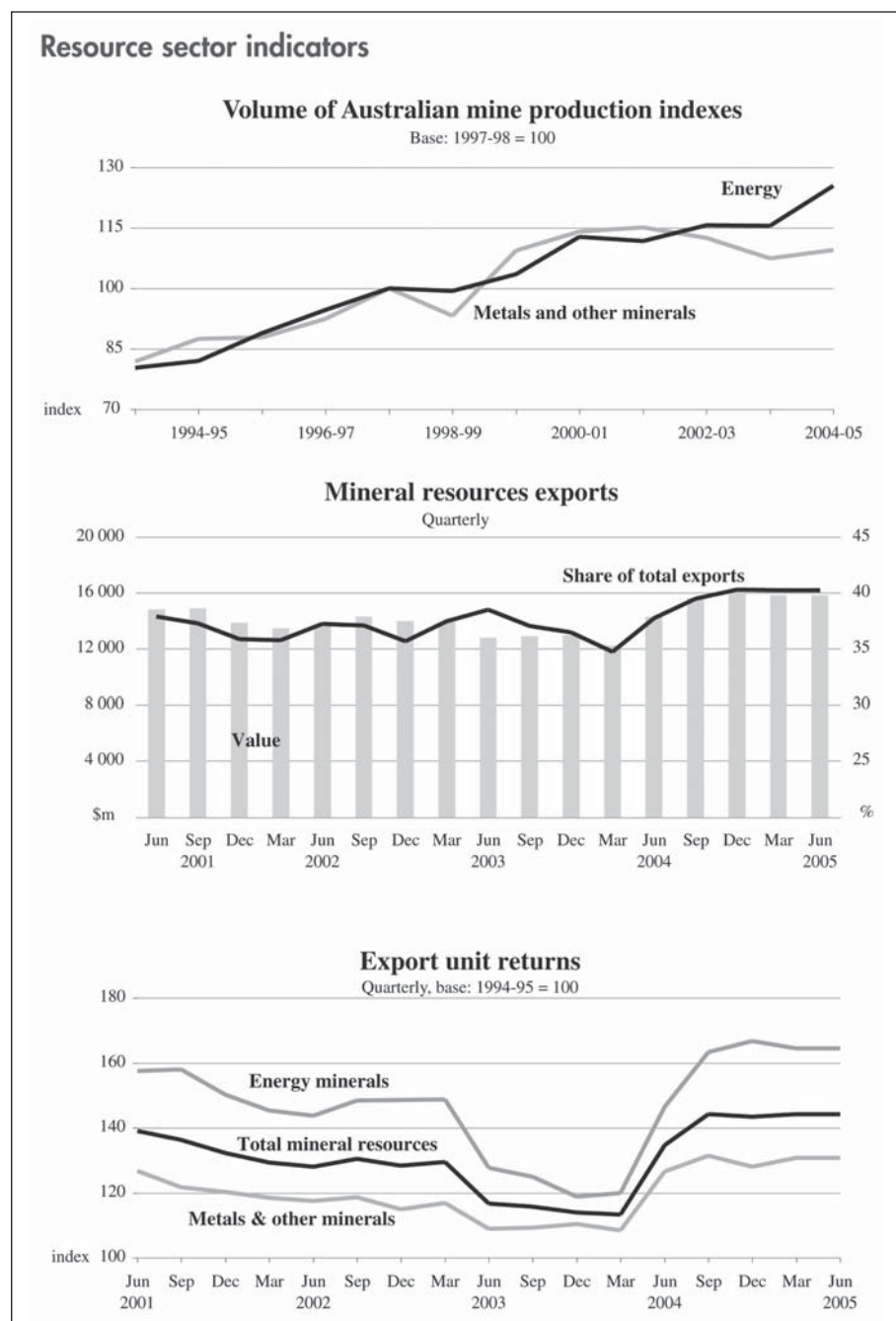
increases in contract prices from Asian steel mills and electricity generation plants", Dr Fisher said.

The index of export prices of Australian mineral resources (export unit returns) increased by 29% in 2004-2005 compared with 2003-2004 (see Figure below). Prices for energy minerals increased by 43%, while metals and related minerals prices increased by 19%.

"These increases in 2004-2005 reflect significantly higher world prices for most commodities compared with a year ago", he said.

Brian Fisher noted that mineral resource imports also reached a new high in 2004-05 of \$20.9 billion, an increase of \$5.5 billion (36 per cent) on 2003-04. The main import commodities contributing to this rise were crude oil, which increased by \$3417 million or 52 per cent to \$10011 million, and refined petroleum products, up by \$1559 million or 43 per cent to \$5155 million – not good news.

To download the full report go to: <http://abareonlineshop.com/product.asp?prodid=13260>



Some resource sector indicators as per the ABARE report. The situation is offset by the increase in crude oil imports (see text below) which will no doubt continue to rise unless we find more petroleum.

Green Rock Energy finds hot rocks near Olympic Dam

Green Rock Energy's first geothermal exploration well, Blanche No 1, 8 km from the Olympic Dam mine reached the target granite at 1800 metres in mid-September. The temperature at this depth is reported as reaching 82°C. It had been expecting temperatures of between 85°C and 100°C at a depth of 2500 m, so these results are better than expected.

The plan now is to complete the hole at 2000 m, log the hole and drill another exploratory hole at the site of an existing hole, SAP 1, which is 17 km south-west of Blanche 1. This hole was completed in sediments at 1369 m, and if thermal tests are encouraging it will be deepened to reach crystalline basement.

The company hopes to drill a third hole to test the geothermal anomaly later this year, and if successful to drill two 5 km holes are planned for 2006.

Geosciences, Environment and Man

Author: H. Chamley

Developments in Earth and Environmental Sciences – Volume I

Elsevier Science B.V. 527 pp

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ISSN: 1571-9197

This 11-chapter book is the first volume of the series: 'Developments in Earth and Environmental Sciences'. It is targeted towards a broad range of geoscientists, including physical geographers and environmental engineers to seismologists and exploration geophysicists. The book is divided into three parts to address the questions of how natural materials (such as mineral ores, water reserves, and nuclear energy) form, how man exploits and manages these materials, and what are the effects and consequences of human activity on the Earth's environment.

Part I. Man Facing the Earth's Hazards

Chapter one describes the impact of earthquakes on human populations. It gives an overview of the areas of global seismic hazard and the methods of quantifying and assessing this hazard, with particular mention of the devastating earthquakes in Turkey of 1999. There is also mention of other artificial seismic hazards such as, building dams; liquid burial; and nuclear explosions. Much of the second half of the chapter is devoted to earthquake forecasting and prevention techniques.

Chapter two deals with the impact of volcanic eruptions on human populations with attention drawn to the Mount St. Helens eruption in 1980. It describes both the direct effects of volcanic hazards, including the main eruptive mechanisms and the associated phenomena such as mudflows, volcanic induced earthquakes, tsunamis and the emission of noxious gases. The indirect effects of volcanic hazards are also considered, like climatic variations resulting from the eruption of fine ash into the upper atmosphere and the beneficial aspects of soil revitalisation. This chapter also gives an overview of eruption forecasting techniques and the methods used to assess the level of risk to local communities.

Chapter three is concerned with the impact of land movements on human populations. It gives an overview of the main types of land movements such as, landslides, turbidites,

dissolution and subsidence and the mechanisms that initiate and drive the movements.

Chapter four deals with the effect of wind and water hazards on human populations, with reference to major flooding of the Mississippi River in 1993, wind storms in France in December 1999, and the role of hurricanes on the loss of coastal wet zones in Louisiana over the last century. Also described are the physical mechanisms, natural factors and methods of prevention, and mitigation for each of these types of hazard (flood, wind, and coastal hazard).

Part II. Man and Geological Resources

Chapter five presents an overview of the main materials and ores exploited by man and the economic value placed on these materials. It discusses varying types of resources and the various extraction and processing methods required to produce commodities. The environmental impacts of these activities are also discussed, including the collapse or subsidence of underground mines; the management of mine waste and drainage water; and the indirect impact of mining on river environments, the atmosphere and human health. The chapter closes with a discussion of mine site restoration methods employed either during mine operations or after mining has ceased.

Chapter six considers the use, exploitation and management of water resources. It begins with a discussion of the issues associated with the strong demand for limited water resources and continues to describe the various types of surface and underground water resources and their uses. Particular emphasis is given to groundwater use and the exploitation of geothermal energy. The impacts of over exploiting water resources are also considered with a focus on soil salinity. The chapter concludes with a discussion on the responsible management of water resources.

Chapter seven discusses natural radioactive resources and exploitation for nuclear energy. It begins with an overview of natural radiation, the basic mechanisms of radiation and the impact of radiation on man. This is followed by a discussion of the requirements and use of natural radioactive resources to produce nuclear energy. This discussion also considers the advantages and disadvantages of nuclear power and the risks associated with its use (the explosion of a nuclear reactor at Chernobyl in April 1986 is presented as a prime example

of this). A brief overview of the use of nuclear technology in military weapons is also included in this discussion. The chapter concludes with a discussion on the types of nuclear waste and methods of waste disposal.

Part III. The Earth Facing Man's Activities

Chapter eight deals with the impact of man's activities on soils and the types of vegetation that are supported by soils. It begins with an analysis of the impact of deforestation, including a discussion on soil erosion, remedial measures, and reforestation techniques. A large part of this chapter is devoted to an assessment of the nature and origin of soils, natural and anthropogenic depletion of soils, and methods of soil restoration. The chapter closes with a discussion on the mechanisms of desertification.

Chapter nine assesses the impact of cities and urbanisation on the Earth. It discusses the local impact of covering the ground surface with concrete and asphalt, the implications of aquifer exploitation, the importance and risks associated with urban and industrial waste, and the natural and anthropogenic weathering of buildings.

Chapter 10 investigates the chemical contamination of the Earth. It discusses the types and modes of contamination, the monitoring of these contaminants, and methods of remediation and mitigation for both continental and oceanic environments.

Chapter 11 investigates the regional and global impacts of human activity on the earth's environment. It gives an overview of the greenhouse effect and the concept of global warming. It also discusses the causes and mitigation of acid rain.

This book would be of interest to a broad spectrum of the geoscientific community engaged in the study of the interaction between man and the environment. It should be an essential reference for both students and professionals studying environmental science or engineering geology.

Copies can be purchased directly from Elsevier Australia Customer Service. Tel: 1800 263 951, Fax: (02) 9517 2249 or Email: service@elsevier.com

