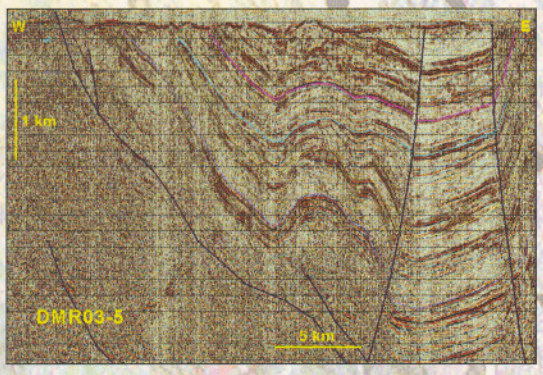
Preview

Australian Society of Exploration Geophysicists

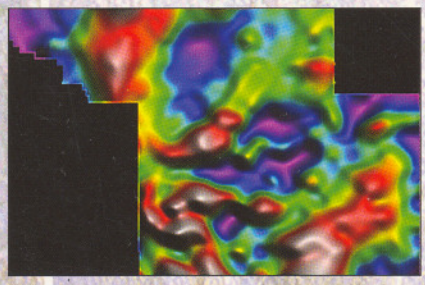
ABN 71 000 876 040 ISSN 1443-2471 February 2004 Issue No.108

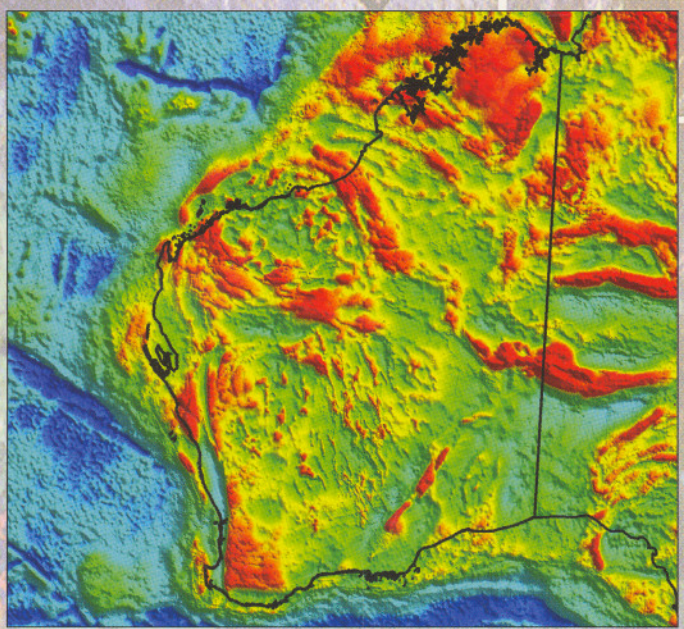


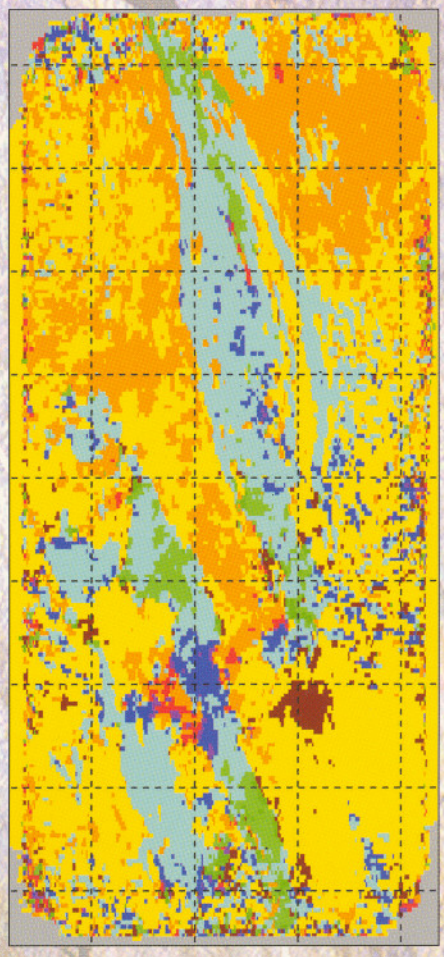
Geophysics in the Surveys

... page 18–23

- Prospectivity of the Darling Basin
- NTGS Releases Simpson Desert and West Arnhem Airborne Data
- Geological Survey of Victoria: Restructure
- Isostatic and decompensative gravity anomalies over Western Australia







Seismic - Advances in Converted-Wave Seismic Exploration

... page 27

Contents

Advertisers' Index

Alpha Geoscience 6
Baigent Geosciences Pty Ltd 12
Daishat 26
ElectroMagnetic Imaging Technology . . . . . OBC
Encom Technology 3, 7
Flagstaff GeoConsultants Pty Ltd 5
Fugro Ground Geophysics 26
Fugro Instruments 26
Geoimage (Sylvia) 7
Geoimage (Tony) 11
Geophysics Data Processing Pty Ltd 2
Leading Edge Geophysics 9
Outer-Rim Exploration Services 4
Pitt Research 26
Professional Investment Services 12
Quadrant Geophysics 11
Systems Exploration (NSW) Pty Ltd 13
Universal Tracking Systems (UTS) 5
ZONGE Engineering 13

2004 Corporate Plus Members

Santos Ltd
Velseis Pty Ltd
Xstrata

2004 Corporate Members

Beach Petroleum NL
BHP Billiton Minerals Exploration
Chevron Australia Pty Ltd
Earth Resource Mapping
Encom Technology Pty Ltd
Fugro Airborne Surveys
Geosoft Australia Pty Ltd
Haines Surveys Pty Ltd
Normandy Exploration Ltd
Origin Energy Resources Ltd
Outer-Rim Exploration Services Pty Ltd
Petrosys Pty Ltd
PGS Australia Pty Ltd
Primary Industries & Resources South Australia
Professional Investment Services Pty Ltd
Rio Tinto Exploration Pty Ltd
Veritas DGC
WesternGeco
WMC Resources Limited
Woodside Energy Ltd
Zonge Engineering & Research Organisation

Editor's Desk 2
President's Piece 3
Preview Information 4
ASEG Officers 5
Calendar of Events 6
Conferences 7
Company Focus 8
- Santos

People 9
Heard in Canberra 10
Book Reviews 13
- Petroleum Geoscience: First Edition
- Uncertain Science.....Uncertain World

Web Waves 14
Letters 16
Geophysics in the Surveys 18
- Prospectivity of the Darling Basin
- NTGS releases Simpson Desert and West Arnhem airborne data
- Geological Survey of Victoria: Restructure
- Isostatic and decompensative gravity anomalies over Western Australia

Fimiston Open Pit 24
- The Super Pit ready to get even bigger

Seismic 27
- Advances in converted-wave seismic exploration

Industry News 35
- Is Shell's downgrading of oil reserves the tip of the iceberg?

Research Notes 36
- ASEG Foundation
- Mictrotremor research
- Down to earth from space

Branch News 40

David Denham

Happy New Year

I hope that every one is refreshed after the holiday break and ready to tackle the issues of the year. It should be very eventful. We have an election, probably at the end of October or the beginning of November, and we also have a great conference coming up during August, with our colleagues from PESA, in Sydney. Apparently, over 230 papers have been submitted and although this has caused the organisers some challenges, to schedule everybody into the program, it is evident that we are going to have a top quality meeting at the side of Darling Harbour.

There will also be a change in the Executive on March 2nd at the AGM, which will be held in Perth. The current Executive has done a splendid job in leading the Society. Membership has increased and we appear to be in a sound financial position. However, this is not a time for complacency and we must all be active in efforts to support and promote the ASEG.

It seems to me that we now have a paradox to wrestle with.

Although Australia will have to rely more and more on our resource industries for our wealth, there will be fewer 'classical' geoscientists going through our universities and into jobs directly related to exploration.

Consequently, the pool of possible members will shrink if we just restrict our activities to mainstream resource exploration. We can tackle this by working together more closely with other geoscience societies and also by expanding our activities into other areas.

Whichever paths we follow, we must all try to ensure that Australia has the skills base to find more mineral and petroleum, in both the research and teaching sectors; but it is not going to be easy.

There are certainly problems in the longer term strategic research area because it is not clear where this work is going to be done in the future. The universities will clearly be focusing their efforts on basic research funded by the ARC, so they will not be doing any. There is pressure on CSIRO to earn more external earnings so don't look to a big program there. And the key selection criteria from the new guidelines for CRCs will, if they are strictly adhered to, result in the death knell for any 'Public Benefit' research under the CRC banner.

Let me quote from key selection criteria from the new Guidelines: "Applications will be assessed on the extent to which they meet the following selection criteria:

1. The outcomes will contribute substantially to Australia's industrial, commercial and economic growth (*Further to this criterion, it is also stated that '...business cases that rely solely on public benefit outcomes are unlikely to be competitive'*).
2. The path to adoption (commercialisation/utilisation) will achieve the identified outcomes.
3. The collaboration has the capability to achieve the intended results.
4. The funding sought will generate a return and represents good value for the taxpayer.

Selection criteria (1) and (2) will be given greater weight in the overall judgment at each assessment stage."

The guidelines provide a clear statement that CRCs focused solely on public benefits outcomes are unlikely to be successful. So who is going to do research on climate change, floods droughts and greenhouse gas emissions?

Who is going to work on dry land salinity and land degradation?

Who is going to work on environmental factors affecting the coastal zone and urban development?

Who is going to work on developing new techniques to explore the earth?

Not at all clear.

Anyway, to finish on a brighter note, I would like to congratulate the South Australian Branch for its choice of wines in the ASEG 2003 Wine Offer. Both the Tapestry Cabernet Sauvignon 2001 and the Hamilton Slate Quarry Riesling 2003 were outstanding selections. So good drinking, if you have any left, and good reading in the February *Preview*.

David Denham

My last President's report, and farewell Australia

This is already the last opportunity I have to write this column: by the time the next *Preview* arrives a brand new Federal Executive will be in place and a new face will appear besides this column. It has been very rewarding for me to help out in our Society over the past two years and I have also very much enjoyed working with the truly excellent people who carry the Society.

Having only recently arrived in Australia, it amazes me to this day that I have been so readily welcomed in the organisation of the Society and been given the opportunity to help out. It is great that the ASEG can do this because in our profession everyone's life has become very fluid: even if you are available now, there are just no guarantees that you are available next year as well. Personally, I will move to New Orleans the week after the new Executive take over to start a new job...

The various committees did a great job in delivering exactly what they said they would do in the past year. If you need a reminder of what that was, have a look at the business plan on the web and the *Preview* issue of last October. They all deserve our congratulations on a job well done! The ASEG is currently in good shape to survive the continuous scrutiny, in terms of costs and value, of its current and prospective members. I wish the new team success in their efforts to grow and mature the Society.

If I have regrets it is probably that I haven't focused more on stirring up a larger portion of our membership to become active in the Society. It is after-all just as much, if not more, your Society as it is mine. There must surely be more than a few percent of the membership who have an opinion on what they want the Society to be for them now and in the future.

I have said it before, but will say it again: initiative is always welcome!

The first step is to contact your local State Branch or someone on the Federal Executive and they will help you get started. You might be surprised to find out how many people share your interest in the subject and will make time and money available to participate.

Before this all happens we will of course first have our Annual General Meeting[1] preceded by a half-day meeting of the Representative Council. This AGM promises to be an important one: we will not only move to approve the usual (last year's finances, the new office bearers) but also the new constitution.

I hope to welcome many of you there!

Klaas Koster

[1] *The AGM takes place at 6pm on Wednesday 2nd March 2004 in the ARRC Building Technology Park, Kensington, Perth.*

Klaas Koster

Aims and Scope

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

Contents

The material published in *Preview* is neither the opinions nor the views of the ASEG unless expressly stated. The articles are the opinion of the writers only. The ASEG does not necessarily endorse the information printed. No responsibility is accepted for the accuracy of any of the opinions or information or claims contained in *Preview* and readers should rely on their own enquiries in making decisions affecting their own interests. Material published in *Preview* becomes the copyright of the Australian Society of Exploration Geophysicists.

Contributions

All contributions should be submitted to the Editor via email at denham@atrax.net.au. We reserve the right to edit all submissions; letters must contain your name and a contact address. Editorial style for technical articles should follow the guidelines outlined in *Exploration Geophysics* and on ASEG's website www.aseg.org.au. We encourage the use of colour in *Preview* but authors will be asked in most cases to pay a page charge of $440 per page (including GST for Australian authors) for the printing of colour figures. Reprints will not be provided but authors can obtain, on request, a digital file of their article, and are invited to discuss with the publisher, RESolutions Resource and Energy Services, purchase of multiple hard-copy reprints if required.

The text of all articles should be transmitted as a Word document. Tables, figures and illustrations should be transmitted as separate files, not embedded in the Word document. *Raster images should be supplied as high-resolution (300 dpi) tiff files wherever possible. Vector plots can be supplied using software packages such as Corel Draw or Illustrator*. Illustrations produced in any other software packages should be printed to postscript files. Authors are encouraged to contact the publisher, RESolutions, for information to assist in meeting these requirements.

References

References should follow the author (date) system as used by the SEG (see their website for full details). When reference is made in the text to a work by three or more authors, the first name followed by *et al*. should be used on all occasions. References should be listed in alphabetical order at the end of the paper in the standard form:

Blackburn, G. J., 1981, Seismic static corrections in irregular or steeply dipping water-bottom environments: *Expl. Geophys.*, 12, 93–100.

Abbreviations and units

SI units are preferred. Statistics and measurements should always be given in figures e.g. 10 mm, except where the number begins a sentence. When the number does not refer to a unit of measurement, it is spelt out, except where the number is greater than nine. Confusing mathematical notation, and particularly subscripts and superscripts, should be avoided; negative exponents or the use of a solidus (i.e. a sloping line separating bracketed numerator and denominator) are acceptable as long as they are used consistently. The words 'Figure' and 'Table' should be capitalised (first letter) and spelt in full, when referred to in the text.

Deadlines

Preview is published bi-monthly, February, April, June, August, October and December. The deadline for submission of all material to the Editor is usually the 15th of the month prior to the issue date.

Advertisers

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

Advertising copy deadline is the 22nd of the month prior to issue date. Therefore, the advertising copy deadline for the April 2004 issue will be 15 March 2004. A summary of the deadlines for future issues is shown below:

Preview Issue	Text & articles	Advertisements
109 Apr 2004	15 Mar 2004	22 Mar 2004
110 June 2004	15 May 2004	22 May 2004
111 Aug 2004*	3 July 2004	19 July 2004
112 Oct 2004	15 Sep 2004	22 Sep 2004

*Conference Issue, abstracts and biographies to be submitted by 28 May 2004

Published for ASEG by:
Publisher: Brian Wickins
RESolutions Resource & Energy Services Pty Ltd
Tel: (08) 9446 3039
Fax: (08) 9244 3714
Email: brian@resolutions-group.com.au

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

Associate Editors:
Petroleum: Mick Micenko
Email: micenko@bigpond.com

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

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

Engineering, Environmental & Groundwater:
Geoff Pettifer
Email: geoff_pettifer@ghd.com.au

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

Web Waves: Margarita Norvill
Email: margarita@geophy.curtin.edu.au

ASEG Head Office & Secretariat:
AMCO Management Pty Ltd
PO Box 42, Everton Park Qld 4053
Tel: (07) 3855 8144
Fax: (07) 3855 8177
Email: secretary@aseg.org.au
Web site: http://www.aseg.org.au

Federal Executive 2003[1]

President: Klaas Koster
Tel: (08) 9348 5762
Email: klaas.koster@woodside.com.au

1st Vice President: Howard Golden
Tel: (08) 9479 0576
Email: howard.golden@wmc.com

2nd Vice President: Jenny Bauer
Tel: (07) 3858 0601
Email:
jenny.bauer@upstream.originenergy.com.au

Honorary Treasurer: John Watt
Tel: (08) 9222 3154
Email: john.watt@mpr.wa.gov.au

Honorary Secretary: Lisa Vella
Tel: (08) 9479 8476
Email: lisa.vella@wmc.com

Past President and International Affairs:
Kevin Dodds
Tel: (08) 6436 8727
Email: kevin.dodds@csiro.au

Publications Committee: Terry Crabb
Tel: (02) 6230 1211
Email: tcrabb@sms.com.au

ASEG Research Foundation: Phil Harman
Tel: (03) 9909 7699
Email: phil.harman@mineraldeposits.com.au

Membership Committee: Koya Suto
Tel: (07) 3876 3848
Email: koyasuto@optusnet.com.au

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

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

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

ASEG Branches

ACT
President: David Robinson
Tel: (02) 6249 9156
Email: david.robinson@ga.gov.au

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

New South Wales
President: Stephen Webster
Tel: (02) 9858 5559
Email: sstevewebster@aol.com

Secretary: Michael Moore
Tel: (02) 9901 8398
Email: moorem@minerals.nsw.gov.au

Northern Territory
President: Gary Humphreys
Tel (08) 8999 3618
Email: gary.humphreys@nt.gov.au

Secretary: Roger Clifton
Tel: (08) 8999 3853
Email: roger.clifton@nt.gov.au

Queensland
President: Werner Dutler
Tel: (07) 3228 6514
Email: werner.dutler@santos.com

Secretary: Natasha Hui
Tel: (07) 3228 6813
Email: natasha.hui@santos.com.au

South Australia
President: Graham Heinson
Tel: (08) 8303 5377
Email: graham.heinson@adelaide.edu.au

Secretary: Tania Dhu
Tel: (08) 8344 4518
Email: tania.dhu@student.adelaide.edu.au

Tasmania
President: Michael Roach
Tel: (03) 6226 2474
Email: michael.roach@utas.edu.au

Secretary: James Reid
Tel: (03) 6226 2477
Email: james.reid@utas.edu.au.

Victoria
President: James Cull
Tel: (03) 9905 4898
Email: jcull@earth.monash.edu.au

Secretary: Ashley Grant
Tel: (03) 9558 8333.
Email: ashley.grant@nre.vic.gov.au

Western Australia
President: Donald Sherlock
Tel: (08) 6436 8729
Email: don.sherlock@csiro.au

Secretary: Kirsty Beckett
Tel: 0402 436 663
Email: kirsty.beckett@geophy.curtin.edu.au

[1] *Members of the standing and ad hoc committees are listed on the ASEG website*

2004

8–14 March
The Mining Executive Development Program (MEDP)
WA School of Mines, Curtin University of Technology
Venue: Joondalup Resort (Country Club Boulevard, Connolly, WA GPO Box U1987)
Email: mineral_economics@curtin.edu.au

28–31 March
APPEA Conference & Exhibition
Venue: National Convention Centre, Canberra
Contact: jhood@appea.com.au
Website: www.appea.com.au/Events/AppeaEvents.asp

31 March – 4 April
International Conference and Exposition (SEG Beijing/SPG/SEG) - postponed from 2003
Venue: Beijing, China
Website: www.spgol.org

17–21 May
Joint Meeting: AGU and the Canadian Geophysical Union (CGU)
Sponsors: AGU, CGU
Venue: Montreal, Canada
Website: www.agu.org/meetings

7–11 June
66th EAGE Conference and Exhibition
Venue: Paris, France
Website: www.eage.nl

15–19 August
ASEG, in collaboration with PESA
17th International Conference and Exhibition,
Theme: Integrated Exploration in a Changing World
Venue: Sydney Convention Centre, Sydney NSW
Website: www.aseg-pesa2004.org.au

19–22 September
PESA Eastern Australasian Basins Symposium
Venue: Adelaide Convention Centre, Adelaide
Website: www.eabs.info
and

Pacrim 2004
Theme: Hi Tech and World Competitive - Mineral Success Stories Around the Pacific Rim
Adelaide, SA
Website: www.ausimm.com
Note, both the above events will take place at the same time at the same venue.

27 September – 1 October
SEG 2004
Theme: Predictive Mineral Discovery Under Cover
Sponsor: Society of Economic Geologists, Society of Geology Applied to Mineral Deposits and Geoconferences (WA) Inc.
Venue: Perth, WA
Website: www.cgm.uwa.edu.au/geoconferences/seg2004/index.asp

10–15 October
SEG International Exposition & 74th Annual Meeting
Venue: Denver, Colorado, U.S.A.
Website: www.seg.org

13–17 December
2004 AGU Fall Meeting
Venue: San Francisco, California, U.S.A.
Website: www.agu.org/meetings

2005

10–13 April
2005 APPEA Conference & Exhibition
Perth (at the new Convention Centre facility)
Contact: Julie Hood
Email: jhood@appea.com.au

23-27 May
2005 AGU Joint Assembly
Venue: New Orleans, Louisiana, U.S.A.
Website: www.agu.org

16-17 August
Central Australian Basins Symposium (CABS) 2005
Theme: Minerals and petroleum potential
Venue: Alice Springs (details TBA)
Contact: Greg Ambrose,
Northern Territory Geological Survey
Email: greg.ambrose@nt.gov.au

6-11 November
SEG International Exposition & 75th Annual Meeting
Venue: Houston, Texas, U.S.A.
Website: www.seg.org

5-9 December
2005 AGU Fall Meeting
Venue: San Francisco, California, U.S.A.
Website: www.agu.org/meetings

Sydney ASEG-PESA Conference overwhelmed by papers

The organisers of August's ASEG-PESA Conference in Sydney have been overwhelmed with good quality papers. A total of 230 papers have been submitted with a strong response from the petroleum geophysics community.

The organising committee had anticipated running three concurrent technical sessions during the conference. Four concurrent sessions are now planned to accommodate the large number of papers. Presentations may need to be restricted to 20 minutes each.

The sessions are still being assembled. Some of the preliminary session titles are as follows:

marine seismic acquisition, seismic processing, seismic interpretation, AVO and reservoir characterisation, effects of fluids on seismic response, innovative methods, anisotropy and the effects of fractures on seismic response, technology case studies and PNG case studies.

The regular technical sessions will cover three days (Monday to Wednesday). A day of special symposia is planned for the Thursday after the conference. The symposia will allow longer presentations and more discussion than the normal sessions.

Both minerals and petroleum geophysics themes are being considered for the symposia. Under minerals geophysics two themes have already been established: ***inversion in mineral exploration*** and ***salinity studies***. Ideas are still being collected for the petroleum themes.

It looks like being a good one!

Ken Grieves

ASEG sponsors Imaging Technology Meeting in Japan

The ASEG is one of the organisations sponsoring the 7th SEGJ International Symposium - Imaging Technology, which is being held in Sendai, Japan from November 24-26th 2004.

The program focuses on ***imaging technology with a special emphasis on:***
Interdisciplinary integration of geosciences for better understanding and modelling of underground.

This reflects the increasing demands of integrated and multi-disciplinary interpretation of geoscientific data in various case studies. A wide scope of technical sessions in both methodological and application aspects is planned. Examples of sessions are: seismic methods (reflection, refraction, tomography, surface waves), electrical and electromagnetic methods, ground penetrating radar, gravity and magnetics, borehole geophysics, airborne geophysics, laboratory tests, geophysical data managements and GIS, environmental problems (contamination, groundwater, subsidence, urban geosciences), natural resources (oil and gas, methane hydrate, coal, minerals, geothermal), geotechnical and near surface engineering (tunnel, highway, dam, utility, archaeology), underground managements (nuclear waste disposal, CO2 sequestration), natural and artificial hazards (earthquake, volcano, landslide, rock slope, void and cavity, UXO, TXO), and interdisciplinary geosciences.

The sponsors are: SEG Japan, SEG, ASEG, EAGE, Korean SEG, and EEGS

The Abstract Deadline is April 30th 2004 and full papers are required by July 1st 2004.

Send abstracts via web site at *http://www.segj.org/is7/* or e-mail to *segj7th@segj.org*

Teruki Miyazaki

Santos

Santos is a major Australian energy company with a market capital of $3.8 billion, assets of over $5 billion, annual production of 57.3 million barrels of oil equivalent and reserves of 732m boe. The Company's business is oil and gas exploration and production with interests in every major Australian petroleum province. It has ~1740 staff and is the largest producer of gas for the Australian market supplying gas to all mainland Australian States and Territories and also sells oil and liquids to a number of domestic and international customers.

The core of Santos' business is a majority working interest in the Cooper/Eromanga Basins oil and gas fields located in central Australia. Santos produces gas, ethane, oil and gas liquids from the Basins and is the Operator of production and exploration operations.

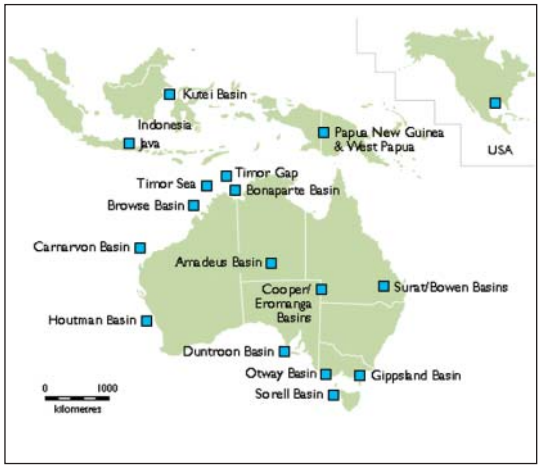
Santos also has exploration and production interests in the Surat and Amadeus Basins and the Denison Trough (onshore Australia), the Carnarvon Basin, Houtman Basin, Timor Sea and Timor Gap (offshore Australia) and the United States (onshore and Gulf of Mexico). Additional exploration acreage is held in the Browse Basin, Bonaparte Gulf, the Gippsland Basins (offshore Australia), the Otway Basin (onshore and offshore Australia), the Sorell Basin, Indonesia and Papua New Guinea (See the diagram in the next column for the locations).

Exploration program

Santos will maintain an active exploration program in 2003[1], comprising 26 wildcat wells targeting mean-risked resource potential of 90 million boe. The exploration budget for 2003 will be approximately $146 million, compared to $133 million in 2002. The program will focus on the highest ranked wildcat wells in value terms with an emphasis on opportunities that can have a material impact.

Santos plans to drill three wells in the Otway Basin, four wells in the Carnarvon Basin, one well in the Gippsland Basin, 11 wells in onshore Australia, two wells in Indonesia, one well in Papua New Guinea and four wells in the United States.

In addition, 4250 km of 2-D and 2130 square km of 3-D seismic will be acquired.



In December 2003, Santos Limited was awarded its fourth offshore exploration permit in the Sorell Basin, offshore Tasmania, by the Commonwealth and Tasmanian Governments.

Exploration block T/36P is approximately 5 km off Tasmania's south western coast and covers approximately 4500 square km.

Santos has been awarded the block for an initial period of three years and has agreed to a work program which may result in expenditure of up to $2 million in the permit.

This builds on Santos' other prospects in the waters of the Otway and Sorell Basins, where they now hold the exploration rights to seven blocks. (see also Industry News on page 36 of this *Preview*).

(1) The 2003 numbers will not be available until March 2004.

Rodney George Alan Tuson: 1941-2003

Rodney (Rod) George Alan Tuson died suddenly as the result of a car accident on the 6th of October 2003.

Rod was born in Invercargill, New Zealand on 17th November 1941, the youngest son of George and Thelma Tuson. He commenced his training as a Survey Cadet in 1960 becoming registered as a Land Surveyor in 1965 following completion of the New Zealand Survey Board examinations. In New Zealand he worked for the New Zealand Lands and Survey Department and later as Chief Surveyor on the Deep Cove tailrace tunnel project.

He travelled to Australia in 1969 in response to an advertisement by L A Richardson & Associates Pty Ltd and started work with this firm as a field geophysicist engaged in geophysical field work in many parts of Australia, data processing and software development. L A Richardson & Associates was a geophysical consultancy and contracting company servicing the oil and minerals exploration industry. Its principal client was the Peko-Wallsend company, one of the largest mining and exploration groups in Australia at that time.

Rod's knowledge of surveying and mapping was a great asset to have within our small team of geophysicists, mathematicians and engineers. We were always concerned that the location of a geophysical measurement was just as important as the measurement itself. This became more critical with increasing use of detailed airborne geophysical surveys and the purpose of these surveys progressed beyond mere "anomaly hunting" to geological mapping applications. During the late 60's and early 70's, positioning techniques progressed from simple air-photo recovery, through stereo-photo recovery, Doppler radar and range-range radar and, in conjunction with airborne survey and data processing contractors, we experimented with all available forms of positioning for airborne surveys. Rod Tuson played an essential role in these activities. His involvement in airborne geophysics coincided nicely with a passionate interest in aircraft and flying, which commenced as a young man with the New Zealand Air Force Reserve.

Through this period L A Richardson & Associates developed a leading understanding of airborne geophysical technology from data acquisition through to processing and interpretation. This culminated in Peko-Wallsend winning a contract in 1976 to perform a large airborne geophysical survey for the government of Iran. Rod was an important member of the team that negotiated with the Iranians and our sub-contractors Geosearch and Pittmen Data. A new company, Austirex Aerial Surveys Pty Ltd, owned by Peko-Wallsend and L A Richardson & Associates was formed to be the principal contractor and Rod Tuson was appointed as its Operations Manager. The Iran contract was regarded as the largest (318,000 line-km) and most technically advanced of its type in the world at that time, utilising two Nomad aircraft equipped with state-of-the-art airborne geophysical systems and producing approximately 5000 individually machine contoured maps.

Subsequently L A Richardson & Associates was acquired by Peko-Wallsend in 1979 and Austirex was sold to World Geoscience in 1985. Rod then returned to the surveying profession. One of his favourite jobs during this period was as Surveying Superintendent for the dredging of the trench for the Sydney Harbour Tunnel.

Rod married Marion in 1978. In 1985 they purchased land at Murrays Run, 100 km north of Sydney and built a house for retirement; much of the work done by Rod. Following retirement in 1999 Rod became very involved with the Rural Fire Service. He served as president of the Bucketty Brigade for two years and was training officer at the time of his death.

I have very fond memories of Rod. He was clear thinker and had a wonderful ability to work through problems calmly in times of chaos and there were many of these during the Iran contract period, including an armed revolution. Rod was a man of high principles and while he could be forceful when necessary he was a gentle and friendly person who will be missed by many.

Bob Richardson

New Members

The ASEG welcomes the following new members to the Society. Membership was approved by the Federal Executive at its meeting on December 3rd 2003.

Name	Organisation	State
Nicholas Davies	Xstrata	Qld
Russell Neil Mortimer	Newexco Services Pty Ltd	WA
Andrew Charles Davis	RMIT University	Vic
Fathi Ali Swaid	University of Technology, Sydney	NSW

FASTS Top Ten for 2004 announced

The Federation of Australian Scientific and Technological Societies (FASTS) has announced its top ten policy issues for the election year 2004.

The most important issue is *Backing Australia's Ability (II)*

1. Bring on 'Backing Australia's Ability II'

BAA was a first step to invest in Australian science. It's time to take the second step and increase our national investment to match the OECD average.

In 2001 the Australian Government committed an investment in Australia's research capacity, through the $2.9 billion *Backing Australia's Ability* package. This was a positive step, and one critical to future national economic and social development.

Most of the investment through *Backing Australia's Ability* is set to end in 2006. Other than an additional year of increased funding for the Australian Research Council, we face the possible withdrawal of nearly $700 million from our national innovation system.

Australia now urgently needs a renewed long term commitment to future research.

The need to invest in research and innovation is well understood by our major trading partners and competitors. The United States and Canada continue to strengthen their research capacity.

The EU has set a target for investment in research to reach 3% of GDP by 2010. Japanese investment in research and development as a proportion of GDP is among the top five in the OECD, and our other Asian neighbours are likewise significantly investing in their education and research base.

In the latest UNDP numbers (1996-2000) Australia is 20th in the ladder of R&D expenditure in terms of GDP (1.5%). Australia should set an R&D target of 3% by 2020.

2. Retain our bright young research scientists

Recent science graduates have plenty of employment opportunities, but postdoctoral researchers have run into a career bottleneck. The best ideas will flourish if BAA II creates attractive career opportunities in research and industry.

3. PhD science graduates to invigorate industry

BAA II should provide matching government funds to employ new PhD graduates in industry for two years, to bring fresh scientific ideas for new methods and new products, and to forge science-based industry career paths.

4. Encourage industry to be more inventive

Give increased tax breaks on a sliding scale to reward companies prepared to increase their investment in research, because enterprising and inventive companies grow and provide more jobs.

5. Attract venture capital into new industries

Venture capital is in short supply. Make it more attractive to invest in new ideas and new industries that have long term payoffs by lowering capital gains tax for long term investments.

6. Now we have the map, Australia needs a compass

The National Mapping exercise has shown us where we are. We should create a plan for up to 10 years into the future that sets goals and national directions, including national action plans on limiting climate change and on sustainable energy strategies.

7. HECS breaks for science and mathematics teachers

Science and maths teachers are in short supply in Australia, but they pay higher HECS fees than other teachers and thus take home less pay. Bring in HECS breaks for science graduates when they take on teacher employment.

8. Collaboration, not competing silos

Destructive competition between separate research organizations for the funding dollar limits research outcomes. Provide more collaborative funding incentives to build on the different strengths of universities and government funded research agencies.

9. Quality science graduates

Quality science and technology graduates are vital to Australia's economic and environmental future. We need measures to ensure that the new Higher Education Funding arrangements help reverse the current decline in higher education science enrolments.

10. We are now 20 million and growing

Australia is a fragile continent with an expanding population. We need to develop a scientifically based population strategy that takes into account limits to growth determined by, for example, water resources and soil salinity.

AGC urges Government to act now to encourage resource exploration

In the meantime, the Australian Geoscience Council has called on the government to act to boost resource exploration so that we can find new mineral and energy resources and ensure Australia's future wealth and sustainability.

In 2003, the government received 40 excellent recommendations, from the Minerals Exploration Action Agenda (MEAA) and the report of the House of Representatives Committee on Industry and Resources, on ways to encourage resource exploration in Australia. Both these reports, which were based on inquiries initiated by the Minister for Industry, Tourism and Resources, Ian Macfarlane, identify the key issues we need to address to boost exploration activity and make the mineral and energy industries more innovative and effective.
The AGC urges the government to implement the strategies and recommendations outlined in these reports and has identified five key areas where actions are needed:

1. Improved access to land for exploration: without fair and efficient access, the discovery process to replace depleted supplies of natural resources will be delayed, and Australian export revenues will inevitably decline.

2. We need a globally competitive environment to attract capital for exploration. Private sector investment is essential to nurture entrepreneurial junior companies with fresh and exciting ideas, great technologies or clever products. The AGC supports the MEAA recommendations, which include a flow through share arrangement, a 125% tax deduction for greenfields exploration expenditure and tax deductibility for the costs of Native Title compliance.

3. Improved coverage of, and access to, geoscience information are needed to open up new areas for exploration. The AGC recommends continued cooperation between the states/territories and the commonwealth, and increased funding to complete basic geoscience survey data sets over the continent, augmented by new mapping technologies. It welcomes the initiatives by Geoscience Australia and some of the sates/territories to provide internet access to geoscience datasets generated by both governments and industry.

4. Investment in human capital is vital if the industry is to remain globally competitive. We need to maintain and develop world class research and teaching facilities for the geosciences in Australia. The AGC supports the proposal that the Australian Government assists 50 new geoscience graduates to be rotated through research groups and industry to gain valuable experience.

5. We need to ensure that exploration is undertaken in an environmentally friendly manner. The AGC recommends that the states/territories and the commonwealth, in consultation with the industry, draw-up simple nation-wide guidelines to cover environmental aspects of exploration activities.

Watch what happens in the May budget.

Higher Education Reforms pass the Senate

The *Higher Education Support Bill 2003* passed through the Senate on December 4th and was given royal assent later in December 2003.

Unfortunately, the Government was not prepared to provide adequate indexation of operating grants. As a result, the value of the additional funding will be eroded in the not too distant future, without increased contributions from government.

The main changes were:

- Doubling the growth places from 1,400 to 2,800 in 2007.
- Introduction of a 20% loan fee to apply to loans for undergraduate courses under FEE-HELP and all loans under OS-HELP.
- The maximum student contribution amounts per place have been set at an amount equivalent to current HECS rates plus 25%.
- An increase to the repayment threshold at which students begin to repay their HECS and other loans to $35,000 in 2004-05. As is current practice this will be indexed to bring it up to $36,184 in 2005-06.
- An additional 7,500 Commonwealth Accommodation Scholarships by 2008.
- Commonwealth Learning Scholarships will not be subject to the social security income test.
- A review of cost adjustment factor indexation for commonwealth funding of universities from 2007-08.
- Removing the interest charge on FEE-HELP and OS-HELP.
- Extending the learning entitlement to seven years while maintaining the capacity for extra years if necessary.
- Relaxation of the Workplace Relations requirements necessary to receive an increase in the basic grant amount under the Commonwealth Grant Scheme.
- A review of indexation must be completed prior to February 2005.
- A review of the impact on the higher education sector of the reforms enacted through the legislation must be commenced prior to December 31st 2006.

According to the numbers provided in the *DEST Newsletter No 5*, which was produced in December 2003 (see: http://www.backingaustraliasfuture.gov.au/implementation/newsletter/news5.htm), the government contribution has increased considerably compared to the numbers in the original document: *Our Universities - Backing Australia's Future*, which was tabled in May 2003. The table below compares the overall funding increases between May and December 2003.

Additional Commonwealth contribution to Higher Education ($M)

	2004	2005	2006	2007	Total
May 2003	68	249	486	661	1464
Dec. 2003	98	373	584	723	1778

The bottom line is that the government will provide an additional $314 million over four years and the draconian workplace relations proposals have been softened.

Eristicus

Petroleum Geoscience: First Edition

The first edition of 'Petroleum Geoscience' by Jon Gluyas and Richard Swarbrick is now out on the shelves! The book was written over a 10-year period in which the authors have kept up-to-date with the ever-increasing operational and technological advances in the petroleum industry. Professor Jon Gluyas is Director of Geoscience at Acorn Oil and Gas, and honorary Chair of Petroleum Geoscience at the University of Durham. Dr Richard Swarbrick is Reader in Petroleum Geology at the University of Durham, and Managing Director of GeoPressure Technology Limited. Both authors have combined to write what is a well integrated book.

'Petroleum Geoscience' is uniquely structured to reflect the sequential and cyclical processes of frontier exploration, exploration and exploitation, appraisal, and development and production. The book starts off with the description of many of the basic petroleum terms, concepts and tools in Chapters 1 and 2. The authors begin in Chapters 3 – 6 by describing the concepts and tools in the above mentioned field areas, which are then followed by a description of case histories for each area.

Links between geology, geophysics, drilling, reservoir engineering, petrophysics, petroleum engineering, petrophysics, petroleum engineering, facilities design and health and safety are made consistently throughout the book.

Although 'Petroleum Geoscience' does not contain as much material as for example 'Petroleum Geology' written by F.K. North, I found the book easy to read and written in a concise way! As such, the reader is able to get an up-to-speed understanding of petroleum geoscience in a relatively short period of time. Additionally, constant links are made to current industry practice and as such, 'Petroleum Geoscience' is a lot more applied in its context; something that the authors acknowledge to be a main driver in writing the book.

'Petroleum Geoscience' was written for final-year undergraduates, post-graduate MSc and PhD students, and non-geological technical staff within the petroleum industry. It summarises very concisely petroleum concepts, terminology and tools and will be most valuable to geophysicists and others entering the petroleum industry.

By Jon Gluyas and Richard Swarbrick
Blackwell
ISBN: 0632037679
Paperback, 376p, 2003
RRP A$145.20

Reviewed by
Jacques Sayers
Geoscience Australia
Email:
jaques.sayers@ga.gov.au

Copies can be purchased directly from Blackwell Publishing Asia on Tel: 1800 333 678, 03 8359 1011 or E-mail: books@blackwellpublishingasia.com.

Uncertain Science.....Uncertain World

The influence of science is now ubiquitous throughout our society. All the major issues we are dealing with depend on science, and the results of science are often uncertain.

Whether we are dealing with terrorism, SARS, GM foods, climate change and greenhouse gases, CFCs and the ozone layer, cloning, defence capabilities, transport options, ethanol in petrol, pharmaceuticals, communications, transport, share market trends, water policy, energy or just about anything else you care to mention, science is now central to the issue.

Unfortunately science, by its very nature, is uncertain. Observations are made, models are developed, more observations are made and better models are developed until we think we 'understand' how and why things happen. Unfortunately, things are not that simple. Sometimes a whole set of models collapses as new observations are made (e.g. Newtonian physics ? quantum quantum physics, and static continents ? plate tectonics).
Henry Pollack's book deals with the uncertainty of science and how this is often unappreciated and misunderstood. Worse still how this uncertainty is manipulated by politicians, the media and big business for their own selfish ends. One only has to consider the health affects of smoking or the impact of fossil fuels on CO2 concentrations in the atmosphere and the inevitable global warming, for examples of how governments and big business operate to serve their purposes.

Anyway, Henry considers these issues in a very readable style, as you would expect. He has been professor of geophysics at the University of Michigan for over forty years and is one of the world's leading experts on the thermal history of the Earth. In recent years he has taken a special interest in helping leaders in government and business, as well as the general public, understand the factors controlling global climate change. In fact, climate change is the one theme that pervades the whole book with a real passion. His frustration with the politicians and big business on this issue is there for all to see and for this alone the book is well worth reading.

However, I was disappointed that there were no illustrations to indicate how the temperatures and atmospheric compositions have changed over the last few thousand years. A few pertinent diagrams would have been a welcome addition, but there are none. We do not even see his own heat flow results that provided estimates of temperature variations in the last few thousand years. This is a pity because a good picture is worth many pages of plain text and there are some good graphs around.
As one would expect, most of the examples and case studies are sourced from the earth sciences. However, there are many other examples in the agricultural and medical sectors that should perhaps have been mentioned to show that other branches of science are afflicted by uncertainty. In summary, a good read, but it could have been even better with some pertinent diagrams, and examples of uncertainty from outside the earth sciences. I suppose the latter should not bother us geophysicists, and it certainly leaves space for more books on the effects of uncertainty in other sectors of science.

By Henry N.Pollack

Cambridge University Press
ISBN 0 521 78188 4
hardback
243p, 2003
RRP $59.95

Reviewed by
David Denham
Email:
denham@webone.com.au

Museums Galore

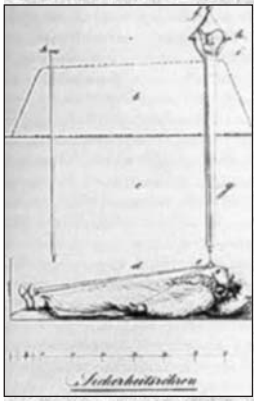
By Margarita Norvill

Email: margarita@geophy.curtin.edu.au

There are many museums scattered across the globe. Museums are interesting places that display history art and science. Check out some of these great web-museum sites and learn something new or liven up your dinner conversation.

Australian Museum (Sydney)
http://www.amonline.net.au ★★★★★

The site is updated each month with events at the museum and critics on previous exhibits. The December site featured a précis on the exhibition 'Death – the last taboo' (http://www.deathonline.net/what_is/safety.cfm). The exhibition explored the history of determining death, what happens after death, explaining rigor mortis and grave wax, the insects that aid in decomposition including the pictorial decay of a pig up to fifty days after death, 'safety' coffins to prevent mistaken burial and personal options including having your carbon remains transformed into a gem. Fear of premature burial was widespread in 18th and 19th century Europe, leading to the invention of the safety coffin. Over thirty different designs were patented in Germany alone during the second half of the 19th century.



The common element was a mechanism for allowing the 'dead' to communicate with people above ground. The figure shows one such safety coffin designed by Dr Johann Gottfried Taberger in 1829. It was supposed to alert a cemetery night watchman by a bell which was activated by a rope connected to strings attached to the hands, feet and head of the 'corpse'. The bell housing prevented the alarm from sounding by wind or birds landing on it. The design of the tube prevented rain water from wetting the 'corpse', and contained mesh to stop nuisance insects. On the event of the bell sounding, a second tube was to be inserted at the foot of the coffin and air pumped through with a bellows.

An excerpt from the exhibition explained that the first stethoscope was invented in 1819 by Rene Laennec to enable doctors to detect a heartbeat with greater confidence, and helped Dr Eugene Bouchut to win a prize from the Academy of Sciences in Paris in 1846 for 'the best work on the signs of death and the means of preventing premature burials'. Bouchut believed that if a heartbeat was absent for more than five minutes, a person could be considered dead, however, death determined by a lack of heartbeat was only slowly accepted. Several of Bouchut's chief critics were fellow contestants for the prize. They advanced ideas like introducing leeches near the anus, applying specially-designed pincers to the nipples, or piercing the heart with a long needle with a flag at the end, which would wave if the heart were still beating.

Currently on display at the museum is Gold and Sacrifice: Ancient Treasures of Peru, Wildlife photographs of the year (2003). Permanent exhibitions include: biodiversity, birds, Chapman collection, indigenous Australia, insects, kids' island, minerals, more than dinosaurs, research library, search & discover, skeletons, tracks through time.

The Exploratorium (San Francisco)
http://www.exploratorium.edu/ ★★★★½

Online since 1993, the Exploratorium was one of the first science museums to build a site on the World Wide Web. The site now contains over 15,000 Web pages exploring hundreds of different topics, currently serving 15 million visitors a year. That makes it one of the most visited museum Web sites in the world.

The Exploratorium's focus is on investigating the science behind the ordinary subjects and experiences of people's lives. When investigating these topics, It also looks at the historical and social issues surrounding them, thus providing a context for scientific exploration.

The site contains instructions for over 500 simple experiments a variety of online exhibits and webcasts to special events. Exploring a range of themes from sport science, planet earth, observatory, human body, machines and tools, mind and perception, living things, society and culture, food and other activities.

The Exploratorium's Web site, like the museum itself, is a work in progress, continuing to grow and provide visitors with meaningful, revealing experiences.

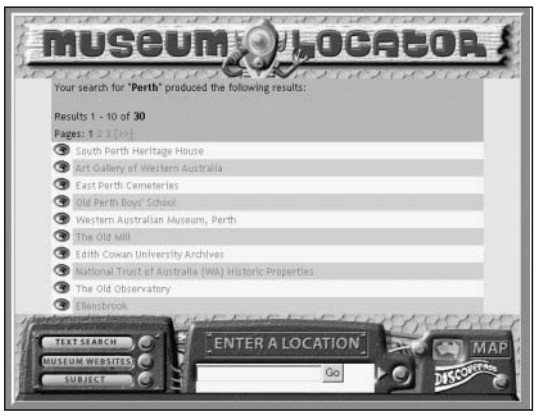
Nobel *e*-Museum
http://www.nobel.se/ ★★★★★

The Nobel Prize is the first international award given yearly since 1901 for achievements in physics, chemistry, medicine, literature and peace. The Nobel e-Museum site opened in 1995. It offers information on all 758 Prize Winners to date, the Nobel Organization, Alfred Nobel, and Nobel events, as well as educational material and games. Nobel e-Museum

consists of more than 9,000 static documents, several databases and a number of multimedia productions with Nobel Prize connection. *(A complimentary exhibition of Australian Nobel Prize Winners was shown in Old Parliament House Canberra in late 2003- Ed.).*

Try playing the crystallite game or the mainstream game (see if you can beat my high score!) and learn about liquid crystals, a substance that flows like a liquid but maintains some of the ordered structure characteristic of crystals. In the 1960s, a French theoretical physicist, Pierre-Gilles de Gennes turned his interest to liquid crystals and soon found fascinating analogies between liquid crystals and superconductors as well as magnetic materials. His work would later be rewarded with the Nobel Prize in Physics (1991). Today, liquid crystals are found in every home, for example in thermometers and computer screens.

Powerhouse Museum (Sydney)
http://www.phm.gov.au ★★★★½



Australia's largest and most popular museum is located in Darling Harbour, why don't you check it out in August when you attend the ASEG PESA conference. Its collection of 385,000 objects, is unique and diverse spanning social history, music, science, technology, design, industry, decorative arts, transport and space exploration. The Museum also includes the historic Sydney Observatory. The two make up the Museum of Applied Arts and Sciences.

Part of the online web projects include soundbyte.org which allows visitors to discover electronic and computer music production through a range of tutorials, Discovernet which locates museums and galleries around Australia, search the Research Library catalogue, the collection dates from the establishment of the Museum in 1880 and contains over 30,000 books. Try their online inquiries form to find out more about a particular science, design or history topic.

Smithsonian (Washington and New York City)
http://www.si.edu/ ★★★★½

The Smithsonian Institution comprises 16 museums and galleries and the National Zoo. It is the world's largest museum complex.

The Smithsonian Institution holds more than 142 million artifacts and specimens. The institution, also a center for research, is dedicated to public education, national service and scholarship in the arts, sciences and history. The Smithsonian was established in 1846 with funds bequeathed to the United States by James Smithson, an English scientist, "for the increase and diffusion of knowledge."

The online resources for the Smithsonian are divided into three categories; Art & Design, History & Culture, Science & Technology. The Science & Technology sector cover the fields of animals, astronomy, aviation & transport, computers and communication, ecology & environment, evolution & paleontology, geology, health and human sciences, industry, machines & electricity, marine, plants, history of science and technology. Check out 'Chandra's Celestial Fireworks' Showing X-ray images of supernova and bird friendly coffee. Check out the Smithsonian Institution Libraries, uniting 20 libraries into one system supported by an online catalog of the combined collections. http://www.sil.si.edu/

Annals of Improbable Research
http://www.improbable.com/ ★★★½

Whilst not a museum the Annals of Improbable Research is the journal of record for inflated research and personalities. It documents some of the more interesting research that has taken place over the years. Each year the Ig® Nobel Prize is awarded to researches in engineering, physics, medicine, psychology, chemistry, literature, economics, interdisciplinary research, peace and biology for research that first makes people laugh and then think.

The 2003 winners include; in the physics category, Jack Harvey, John Culvenor, Warren Payne, Steve Cowley, Michael Lawrance, David Stuart, and Robyn Williams of Australia, for their report, 'An Analysis of the Forces Required to Drag Sheep over Various Surfaces'. For medicine Eleanor Maguire, David Gadian, Ingrid Johnsrude, Catriona Good, John Ashburner, Richard Frackowiak, and Christopher Frith of University College London, for presenting evidence that the brains of London taxi drivers are more highly developed than those of their fellow citizens. For Chemistry, Yukio Hirose of Kanazawa University, for his chemical investigation of a bronze statue, in the city of Kanazawa, that fails to attract pigeons. For Biology C.W. Moeliker, of Natuurmuseum Rotterdam, the Netherlands, for documenting the first scientifically recorded case of homosexual necrophilia in the mallard duck.

Star Rating

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

Interpretation of EM data for salinity models

I found the two articles about salinity mapping (*see Preview October 2003*) very interesting and topical. Just the sort of articles for *Preview*.

However, I am very curious and confused about the conductivity maps of the same area (Honeysuckle Creek, Vic) presented in the two papers. Fig 1 (p 28) is ostensibly the same as Fig 2a (p 32) as they have the same titles (although the CDI in Fig 2b is somewhat different to Fig 2a as it is processed using a different version of software).

Are Figs 2a, 2b (p32) for a CDI slice 15-20 m, as is Fig 6? I presume the difference between Fig 1 (p28) and Fig 2 (p32) is that they are different depth slices?

The paper by Anthony Christensen (*Calibration of Honeysuckle Creek Conductivity Depth Imaging*) shows how important it is to ground truth the conductivity calculated from the airborne survey (as it is for any airborne survey).

Do his results affect the conclusions of Lawrie *et al*. (*Reducing the Acquisition Costs etc*)?

Christensen's results indicate how isolated the real areas of salinity are once the EMFlow software has been properly calibrated.

How much do the recalculations affect the deeper CDI slices in Lawrie's paper?

Should Lawrie *et al.* not derive their conclusions from the shallow calibrated results derived by Christensen rather than from deeper soil/rock profiles, as these are more representative of areas of salinity?

Nigel Hungerford
Hungerford Geophysical Consultants
Email: nigel1@netspace.net.au

Anthony Christensen replies:

I thank Nigel for his interest in the two AEM salinity articles presented by Lawrie *et al* (2003) and Christensen (2003) in *Preview* 106. I shall attempt to answer the questions posed by Nigel as directly as possible.

Nigel's queries of the figures presented in the two articles are addressed by Richard Lane's response to his letter and need not be repeated here.

Q. Do my results affect the conclusions of Lawrie *et al*. (2003)?

A. Lawrie *et al*.'s article advocates an approach to survey design accounting for the nature of the elements controlling the 'salinity problem' and the purpose for which the survey is intended. This is a fundamentally sound approach.

Lawrie *et al*. show that by collecting TEMPEST data on 1 km and even 2 km spaced lines can be used to define catchment to sub-catchment scale salt stores and identify many landscape elements. Within a given catchment there will be numerous problems for which such data will provide answers or at least valuable insight.

However, as is acknowledged in their article, problems for which data collected upon such a broad scale are sufficient are not universal. For example, should one have had a primary survey goal of mapping salinity in the near surface at Honeysuckle Creek?

Based upon pre-existing outbreak mapping and current AEM results, I am certain a line spacing of less than 1 km (and likely a different acquisition system) would have been preferred.

For mine, Lawrie *et al*.'s article is both a reminder and an invitation to those planning salinity mapping surveys to consider keenly the processes controlling the salinity problem being investigated, the resolution of the acquisition system and the land management objectives of the survey. Airborne survey cost reductions may not universally result from this approach but cost effectiveness should.

Q. How much do the re-calculations affect the deeper CDI slices in Lawrie *et al*.?

A. I cannot state the exact effect the re-calculations would have on the output of Lawrie *et al*, as their paper has used a later version of EMFLOW than that available to me. In Christensen (2003) AEM geometry adjustments (especially altitude) were used to obtain the most satisfactory match

between calculated and observed conductivities throughout the survey area.

Applying this process resulted in near surface CDI conductivity distributions better defining mapped salinity outbreaks than initial CDI products.

As is well known, the most pronounced effect of such altitude variations will be on near surface conductivity solutions; therefore the significant difference between initial and reprocessed 0-5 m depth slices is not necessarily indicative of similar differences at depth. Initial and reprocessed conductivity images at depths 15 m and greater show much more subtle differences and resemble in form those shown in Lawrie *et al*. and earlier publications.

The better matching of calculated and observed conductivities to depth in Christensen (2003) generally thickened the conductive section and consequently deepened AEM depth to bedrock estimations. Such results were more in accordance with information from drill holes.

Q. Should Lawrie *et al*. not derive their conclusions from the shallow calibrated results derived in my article rather than from deeper soil/rock profiles as these are more representative or areas of salinity?

A. In light of the comments above this is not strictly necessary and would depend very much upon the purpose of the survey.

I hope I have answered Nigel's queries satisfactorily.

Anthony Christensen
Department of Primary Industries, Victoria.
Email: anthony.christensen@dpi.vic.gov.au

Richard Lane replies

It is very pleasing to see the level of interest surrounding articles by Christensen (2003) and Lawrie *et al*. (2003) in *Preview* Issue No. 106. On behalf of Ken Lawrie, Matt Gray, Andrew Fitzpatrick and Paul Wilkes, I would like to thank Nigel Hungerford for his comments and questions.

The two articles in question are complementary and entirely consistent with each other. Christensen (2003) presents an example where independent borehole conductivity data were used to assess the accuracy of AEM conductivity predictions, allowing a degree of optimisation to be achieved in the transformation of measured response to conductivity.

Lawrie *et al*. (2003) calls for the matching of system capabilities and acquisition parameters to the scale and characteristics of the landscape elements to be mapped in land management applications. There are issues to be investigated not only at shallow depths (i.e. the root zone) but throughout a range of depths and scales governed by the geometry of groundwater flow and the distribution of salt stores.

Similar revisions to the conductivity transformation parameters advocated by Christensen (2003) were applied in the preparation of the Honeysuckle Creek conductivity data presented in Lawrie *et al*. (2003), together with the benefits of a newer version of EMFlow software.

The purpose of Figure 2 in Lawrie *et al*. (2003) was to highlight the continuing improvements in EMFlow conductivity transformation software. Figure 2(b) is the 15-20 m slice processed with EMFlow v5.22-3, and is the same slice shown in Figure 6. Figure 2a shows the 10-15 m slice as supplied by the contractor using an earlier version of the software.

Without the benefit of independent borehole conductivity data, the contractor was not able to optimise or 'calibrate' the conductivity transformation parameters. When this information became available, Christensen (2003) showed that a decrease in the effective terrain clearance of the transmitter loop by around 5 m improved the match between the observed borehole conductivity logs and the AEM conductivity predictions.

Although not strictly a direct comparison, the 10-15 m slice of the original conductivity data was roughly equivalent to the 15-20 m slice in the revised set of conductivity predictions.

Richard Lane
CRCLEME (Geoscience Australia)
Email: richard.lane@ga.gov.au

References

Christensen, A., 2003, Calibration of Honeysuckle Creek Conductivity Depth Imaging: *Preview*, 106, 27–30.

Lawrie, K., Gray, M., Fitzpatrick, A., Wilkes, P. and Lane, R., 2003, Reducing the Acquisition Costs of Airborne Electromagnetic Surveys for Salinity and Groundwater Mapping: *Preview*, 106, 31–38.

Prospectivity of the Darling Basin

By P. Cooney and R. Mantaring

Department of Mineral Resources, NSW

Email: phillip.cooney@minerals.nsw.gov.au

With an area of over 100,000 km^2 and more than 8000 m of mainly Devonian sediments, the Darling Basin is one of the largest onshore sedimentary basins in Australia. On account of its area and volume of sediments, the basin is considered to have possibly the greatest "up-side" petroleum potential within New South Wales. In addition the Moomba-Sydney gas pipeline cuts right across the basin.

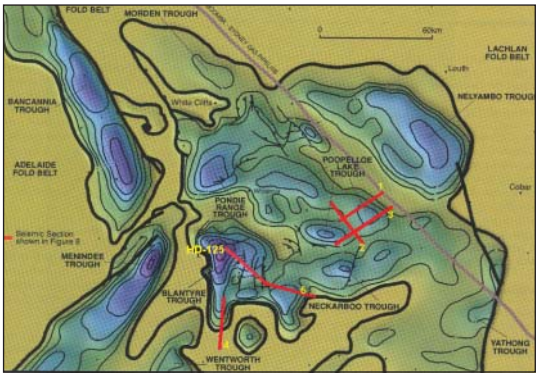


Fig. 1. 1995 interpretation of depth to basement by Encom, contoured every 2000 m. Also shown are the DMR03 seismic line locations.

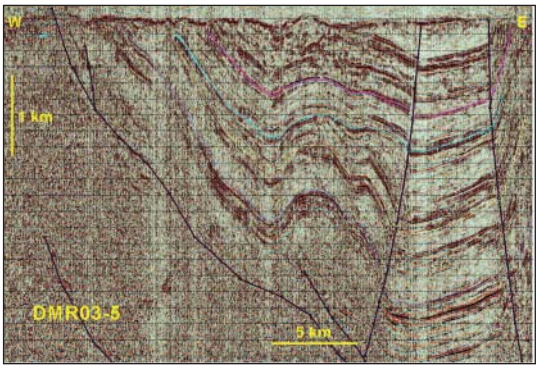


Fig. 2. Seismic Line DMR03-5.

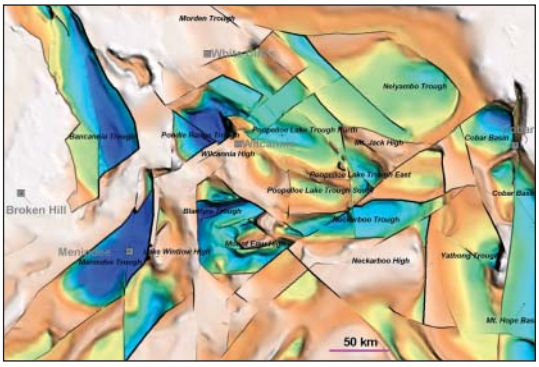


Fig. 3. 2003 interpretation of depth to basement by SRK Consulting; dark blue areas contain over 6000 m of section.

Despite its acknowledged potential, the basin is very under-explored with only 20 wells mostly drilled in the 60's and 70's and less than 1800 km of modern multi-fold seismic data. Virtually none of the wells drilled to date can be considered a valid test of the targetted structures. This is mainly due to inadequate seismic coverage and/or limited depth penetration by the wells.

The last major reassessment of the geophysical data in the Darling Basin was carried out in 1995 by Encom Technology Ltd. Encom's picture of the basin is shown in Figure 1. Based on the data then available, Encom interpreted the base of the sedimentary section to closely reflect the available gravity data. This interpretation was supported by the seismic data available at the time and formed the basis for the locations of the Wilcannia 2003 seismic survey as also illustrated by Figure 1.

Figure 2 shows the results from line DMR03-5 of the Wilcannia 2003 seismic survey, (line 5 in Figure 1). Trending roughly east-west and 33.5 km long, it shows a major depo-centre at its eastern end adjacent to the Menara Fault. The line also shows a most interesting large structure, which has been reactivated and is optimally located immediately up-dip of a major depo-centre, and at its western end the line shows possible thrusting over the Mt Emu high. The upper part of the seismic section is made up of Middle to Late Devonian sediments, the sediments in the depo-centre may be from early Devonian to Cambrian in age.

Since the 1995 interpretation by ENCOM, approximately 250 km of new seismic data, 3 deep stratigraphic wells and a considerable quantity on new gravity and high resolution aeromagnetic data have been acquired. All the new seismic and potential field data have been incorporated into a new evaluation of the potential field data by SRK Consulting, in July 2003, using their *SEEBASE™ program.

*SEEBASE™ is the culmination of a number of calibration and integration steps involving:

- Integrated structural/kinematic interpretation,
- Geophysical modeling,
- Seismic & well calibration, and
- Integration of tectonic events & responses.

Figure 3 is SRK Consultants' new interpretation.

This view shows the location of the major "troughs" and "highs" that comprise the Darling Basin. The geometry and basement depths have been revised from earlier interpretations and this picture is a snapshot in time based on the integration of all presently available information.

A new seismic program to be carried out by the Department in 2004 will investigate some of the features identified by the new interpretation.

NTGS releases Simpson Desert and West Arnhem airborne data

Simpson Desert

The first images of the Simpson Desert airborne magnetic/radiometric survey which was completed in December 2003 have now been released. The survey area was about 200 km southeast of Alice Springs, and acquired approximately 65 000 km of data collected along 400 m-spaced north-south flight lines.

See Figure 1 below for the survey location.

The first magnetic images from NTGS's Simpson program are now available on the NTGS Image Web Server at: www.dme.nt.gov.au/ntgs/geophysics/airborne.html#Simpson

West Arnhem Gravity Program

NTGS has started a program of semi-regional gravity surveys over selected areas that have unresolved geological problems and unrealised mineral potential. There is growing awareness in the exploration industry that semi-regional gravity surveys can assist greatly in understanding rock distribution in the mineable zone.

As part of this program, NTGS and Geoscience Australia have collaborated to trial the new Russian-developed GT-1A airborne gravimeter, operated by Canadian Micro Gravity Pty Ltd. The GT-1A is capable of high resolution acquisition from an airborne platform, at considerably less cost than gravity gradiometry. Results from the trial survey, being conducted at 2 km line spacing, are similar resolution to the 2km x 2km planned for last year's aborted conventional ground West Arnhem Gravity Program, and have been acquired from the same area.

Free-air images from the West Arnhem airborne gravity survey are now available via: www.dme.nt.gov.au/gs/geophysics/regional_grav.html#2003Gravity Program

Note that these have not been corrected for topographic effects. A fully terrain-corrected Bouguer gravity version should be available soon.

Figure 2 shows the area of the survey and Figure 3 shows the preliminary free-air anomalies.

Questions can be directed to:

Andrew Johnstone (Simpson survey)
Email: andrew.johnstone@nt.gov.au
Tel: (08 8951-5663), and

Mark Duffett (West Arnhem survey)
Email: mark.duffett@nt.gov.au
Tel: (08 8951-5393).

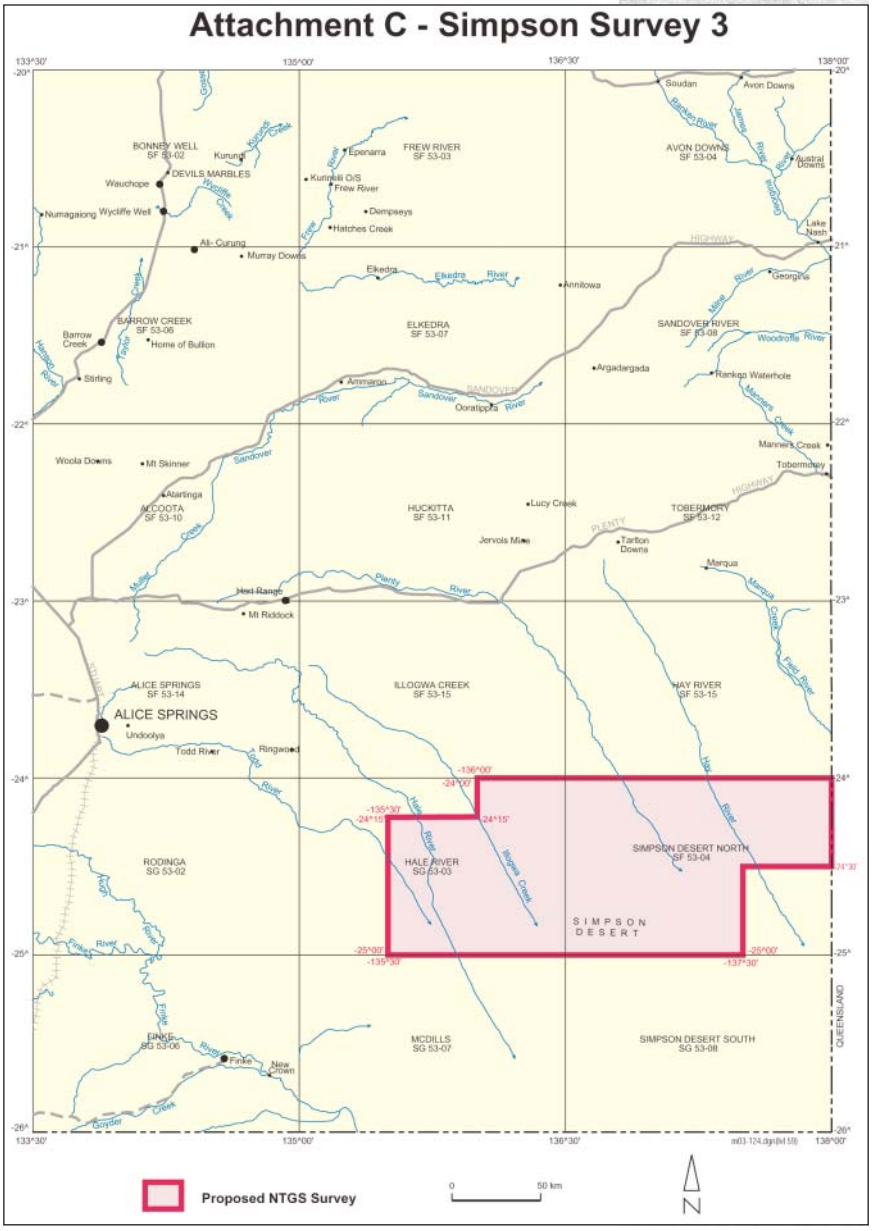


Fig. 1. Location of Simpson Desert airborne magnetic/radiometric survey.

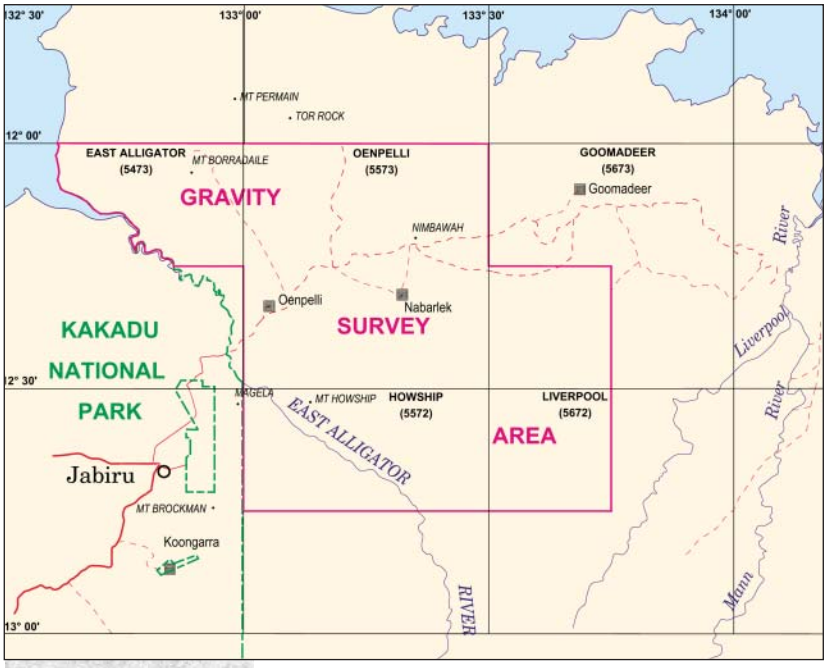


Fig. 2. Location of West Arnhem airborne gravity survey.

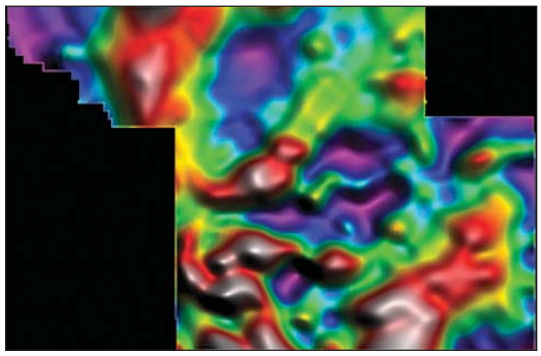


Fig. 3. Preliminary results of the free-air anomalies, illuminated from the NW. Resolution is equivalent to that of the original i.e. 400 m/pixel.

Geological Survey of Victoria

Restructure

In 2003 the Geological Survey of Victoria (GSV) examined its role as a modern geological survey and decided that to better meet the geoscience information needs of its clients, more focus was needed to be placed on information management.

To facilitate this need, a restructure of the GSV in October 2003 resulted in the formation of the new Geoscience Information and Geophysics Group (Figure 1).

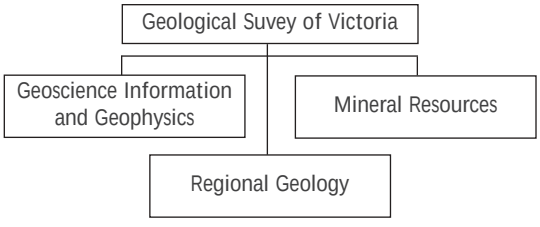


Fig. 1. Organisational chart of the Geological Survey of Victoria.

This group combines functions from the old geophysics and cartography sections into one group, with a focus on data management and product development. The group will ensure a higher profile and a coordinated approach to information management within the GSV.

The geophysics focus of the group will be database management and distribution of state wide geophysical data, as well as working in innovative and challenging areas, such as airborne EM, salinity and land management. The regional geophysical interpreters have been transferred to the Regional Geology Group.

Woods Point – Walhalla Goldfields

The Regional Geology Group has commenced the geological mapping and geophysical interpretation of the Woods Point – Walhalla Goldfields (Figure 2) in December 2003. The team consists of six mapping geologists, two mineral resources geologists and a geophysicist, with backup support from technical officers and cartographers.

Airborne magnetic and radiometric surveys, with 200 m line spacing, were flown over the area in 1999 and 2000 as part of the Victorian Initiative for Minerals and Petroleum (VIMP) Program. Prior to the geological mapping starting, the project geophysicist, Suzanne Haydon (ASEG Victorian Branch Vice - President), interpreted the semi-detailed data. The geophysical interpretation provides a focus for the geological mapping and will aid in the formation of a new geological model for the goldfields.

The project will run over two and a half years, with maps, reports and digital data due for release by the end of 2006.

Rupanyup regolith project

The regolith mapping program within the Regional Geology Group is focussed on the central Victorian goldfields and the adjacent margin of the Murray Basin. The project involves regional mapping of the regolith-landforms, as well as detailed studies aimed at characterising the regolith geochemistry over selected prospective areas.

A fundamental component of the work involves interpreting semi-detailed airborne radiometric data in a regolith context, to target areas for field mapping and to assist in characterising the regolith-landform units and their boundaries.

Mapping of the Rupanyup 1:100 000 map area was completed in December 2003 and interpretation of new and existing information is continuing. It is anticipated that preliminary products will be available by late 2004.

MapShare

The GSV along with other groups within the Minerals and Petroleum Division released version 2 of its web mapping application, MapShare, in November 2003 (Figure 3). This release represents a completely new version, with considerable improvements from the version previously released in March 2003. The most significant increase in functionality is the ability to group layers into folders. This has enabled the combining of previously two separate Geological Survey and Tenements views into a single view. This unified view now holds over 70 layers of geospatial information in 14 folders and allows the user to overlay layers, and search and view the results in a web browser interface.

Other increased functionality includes better search and select facilities, the ability to download ESRI shape files for key layers and the ability for the user to save their session.

A number of new datasets have been added to MapShare, including 1:250 000 geological polygon and line data, Extractive Industry Interest Areas, the digital geological model of the Latrobe Valley coal resource, seismic survey lines and points, and gravity reading locations and measurements.

MapShare can be accessed at
http://www.dpi.vic.gov.au/minpet
and clicking on the 'MapShare - Mapping Tool' icon.

For more information about what's going on in Victoria contact; Alan Willocks
Geoscience Information and Geophysics
Geological Survey of Victoria
Alan.willocks@dpi.vic.gov.au

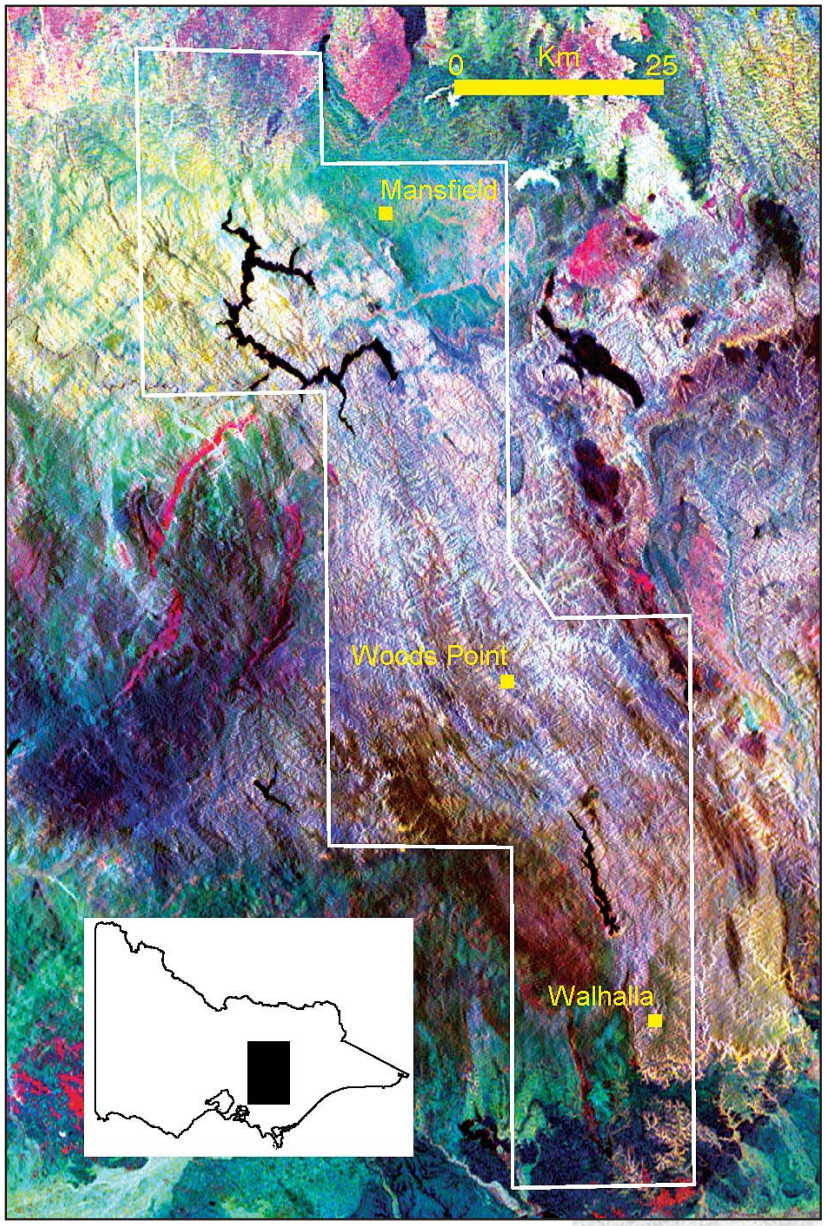


Fig. 2. Radiometric ternary (K, Th, U) image with project area outline.

Fig. 3. MapShare showing Pre-Permian geology over first vertical derivative magnetics.

Isostatic and Decompensative Gravity Anomalies over Western Australia

By Andrew Lockwood

Geological Survey of Western Australia

Email: Andrew.Lockwood @doir.wa.gov.au

The conversion of satellite altimetry to Free-Air gravity anomaly data (Sandwell and Smith 1997) has proved to be a useful tool in offshore regions, and various versions of the processed altimetry data can be downloaded free of charge from the web. Although the accuracy of the data is limited to around 50 $\mu m/s^2$ (5 mGal), it is extremely useful for regional geological studies.

A Bouguer correction can be applied to the offshore data to make them compatible with the onshore data, by predicting the gravitational effect of replacing the seawater column with material of the appropriate density and adding it to the Free-Air anomaly.

It is worth noting that the bathymetry data used to determine the offshore Bouguer correction should not be derived from the same satellite altimetry dataset that is to be corrected.

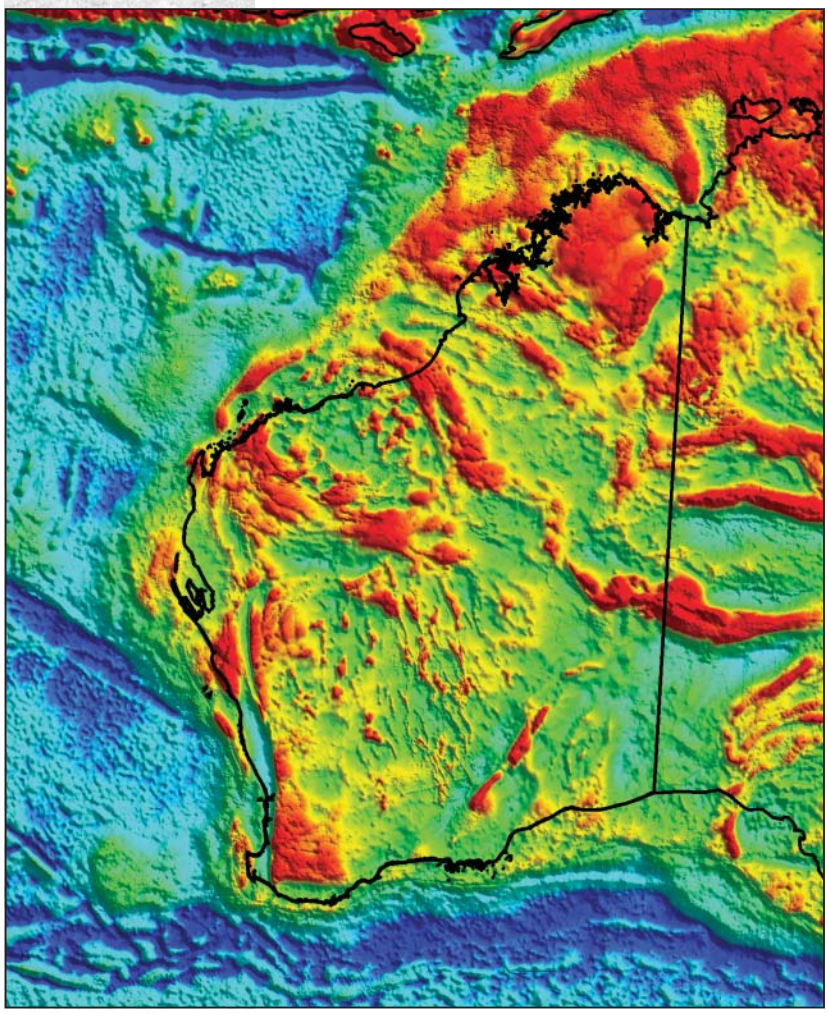


Fig. 1. Isostatic residual gravity anomalies over Western Australia.

Combined offshore and onshore Bouguer Anomaly images are dominated by a large positive gravity feature below the ocean, due to the rapid shallowing of the mantle as the bathymetry falls from the continental shelf to the abyssal plains. Isostatic models can be used to predict the mantle depth as a function of topographic load, as long as the density of the continental crust, oceanic crust and mantle are known, as well as the mantle depth at sea-level, and the rheological properties of the crust.

The gravity field of the predicted mantle interface is calculated and subtracted from the Bouguer anomaly to obtain the Isostatic Residual (IR) Anomaly (Simpson *et al*., 1986). In the algorithm used to generate the accompanying images, the continental/ocean boundary defines a lateral density contrast in the lithosphere, and is smoothed over a 50 km wide transition zone.

The simplest Isostatic Residual is determined using the Airy isostatic model and the assumption that the crust is in equilibrium. The Airy model assumes that the crust has zero strength, suggesting that even metre-scale topographic features have a corresponding compensating feature in the mantle. A slightly more sophisticated model simulates the crust as an elastic plate supported by a liquid. Implementing this model is as simple as applying a low-pass filter, whose shape is determined by the elastic parameters of the crust, to the Airy model.

A more sophisticated model further modifies the crust according to a visco-elastic model that allows the crust to slowly come to equilibrium. The predicted regional field due to the different models is virtually indistinguishable over continental crust, but differs where the bathymetry is steep, such as over the continental slope. The elastic-plate model provides an ideal compromise between the number of parameters and predicting the complex behaviour of the lithosphere.

The age of the Western Australian lithosphere is such that the entire crust should be in isostatic equilibrium, if it were not under any external stress. The presence of long wavelength anomalies in the IR image indicates that this is not the case.

Several regions in the image appear to be dominated by very deep features, such as the Bonaparte and Browse

Basins, which are known to contain thick sedimentary sections yet appear as positive gravity anomalies.

Forsyth (1985) introduced the concept of bottom loading; arguing that variations in the depth to the base of the lithosphere could be caused by processes originating in the mantle, and that some of the topography of the lithosphere was in response to a load applied at the base.

This model was successful at explaining the apparent discrepancy between estimates of the crustal strength based on petrological models and estimates determined from the relationship of the topography to the gravity anomaly.

The advantage of using a purely top-loaded model is that all the mantle-depth sources consistent with the topography are removed by the IR correction, leaving only the gravity anomaly caused by lateral density changes in the crust, sedimentary basins, and regions that are not in isostatic equilibrium.

The Decompensative Anomaly (DA) (Cordell *et al*., 1991) attempts to remove the anomalies associated with sources below the lithosphere. This technique makes use of the result published by Jacobsen (1987) that the optimum filter, in a least squares sense, for separating two layers is upward continuation.

Upward continuing the Isostatic Residual 40 km results in an estimate of the regional field due to sources deeper than 40 km. The DA is then determined by subtracting the upward continued field from the IR.

The ambiguity inherent in potential field interpretation means that it is impossible to guarantee that the upward continued field contains only signals from the deeper sources.

Jacobsen is careful to emphasize that the results of separation filtering processes applied to potential field data should be interpreted qualitatively rather than quantitatively, and this caution naturally extends to the DA image of Western Australia.

The images and grids shown in the figures are available from the Geological Survey of Western Australia by contacting the digital data administrator (gsd.dda@doir.wa.gov.au).

References

Cordell, L., Zorin, Y. A., and Keller, G. R., 1991, The decompensative gravity anomaly and deep structure of the region of the Rio Grande rift: J. Geophys. Res., **96**, 6557–6568.

Forsyth, D. W., 1985, Subsurface loading and estimates of the flexural rigidity of continental lithosphere: J. Geophys. Res., **90**, 12623–12632.

Jacobsen, B. H., 1987, A case for upward continuation as a standard separation filter for potential-field maps: Geophysics, **52**(8), 1138–1148.

Sandwell, D. T., and Smith, W. H. F., 1997, Marine gravity anomaly from Geosat and ERS 1 satellite altimetry: J. Geophys. Res., **102**, 10039–10054.

Simpson, R. W., Jachens, R. C., Blakely, R. J., and Saltus, R.W., 1986, A new isostatic residual gravity map of the conterminous United States with a discussion on the significance of isostatic residual anomalies: J. Geophys. Res., **92**, 8348–8372.

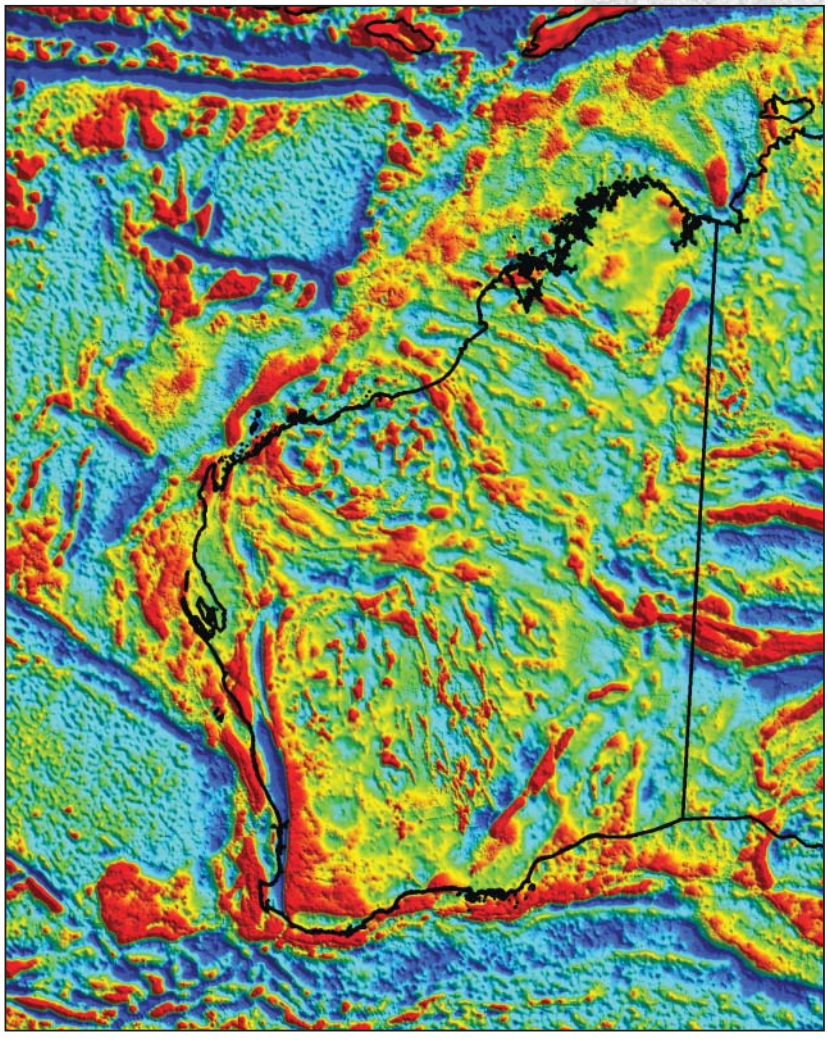


Fig. 2. Decompensative gravity anomalies over Western Australia.

The Super Pit ready to get even bigger

John Shipp

Russell Cole

Australia's largest open cut gold mine is the Fimiston Open Pit at Kalgoorlie. In 2002, in spite of some operational problems 22.5 t of gold w ere produced during the year. This was increased to 27.1 t in 2003, of which 24.4 t were produced from the Open Pit. The increase was attributed to higher grade ore being mined and better recovery in the mill.

Super Pit manager Kalgoorlie Consolidated Gold Mines (KCGM) achieved the highest ever material movement (89 million tonnes) in the pit during 2003. KCGM was a contract miner at the Super Pit for ten years before taking over as mine operator in 1999.

The Fimiston Open Pit is located on the eastern boundary of the Kalgoorlie-Boulder City and is mining an area traditionally known as the Golden Mile. The pit area has been continuously worked since 1893, predominantly by underground mining methods and more recently through open cut methods.

A number of small operations used to mine the Golden Mile until Alan Bond bought up the individual leases (for these operations) to form one giant pit to be controlled by one company: The Kalgoorlie Consolidated Gold Mines (KCGM).

When Bond failed to complete the takeover in 1989, KCGM was formed to oversee the management and mining of all joint interests on the Golden Mile held by the 50:50 partnership of Newmont Mining Corporation (through the 2002 takeover of Normandy Mining Ltd) and Barrick Gold Corporation (through the 2001 merger with Homestake Mining Company).

The southern end of the pit, which is currently undergoing development, will result in the Super Pit being 3.7 km long, 1.4 km wide and 600 m deep.

One of the challenges in developing the pit is to deal with the old underground workings. According to, John Shipp, the company has performed to a world class standard in void management, a very important activity given that there are over 3000 km or so of old workings situated beneath the pit floor.

"That's a huge area - if you put it all together, it would stretch from Perth to Sydney - there's a lot of tunnels underneath there", Mr Shipp said.

KCGM Manager of Mining Open Pits, Russell Cole said, "void detection involved a combination of technology and human skill to interpret the data the technology provides." Jiang *et al*., (2003) have reviewed the techniques used to attack this problem.

KCGM has interpreted and digitised the underground mine plans and stope sections into a common database. A 2D-model software package, called Pits, was developed in-house and allows old workings to be displayed at any bench level; this is integrated with 3D Vulcan modelling software, which allows triangulated surfaces to be displayed.

It is of primary importance to accurately define the location and outline of underground workings in advance. Probe drilling has been used as the key tool for that purpose. Various geophysical methods have also been trialled on site to detect underground workings.

These include:

Cavity mapping using laser scanner

A Cavity-Auto-Laser- System (CALS) for open stope (void) mapping has been deployed into an open stope, through a grade control RC hole with a diameter of 165 mm. The data strings from such surveys can be easily imported into Vulcan and then triangulated for 3D display.

Ground Probing Radar (GPR)

Ground Probing Radar (GPR) has been investigated for void detection in the Fimiston Pit since 1990 by various researchers and organisations. Three types of GPR have been tested and with the current technology available, these all operate at their performance limits in the rock types present within the open pit. The complex geological structures and the high attenuation in most of the rock mass also contribute to the challenges faced by this method.

Micro-gravity

Micro-gravity surveys on a 5 × 5 m grid were used to identify voids. As the pit floor was relatively rough, it was quite difficult to level the gravity meter, taking about six to eight minutes at each point. After the data are acquired, terrain corrections have to be applied to correct for the effects of the pit walls. The residual negative anomalies show missing mass and potential voids. The major disadvantages with micro-gravity are the slow data acquisition on site and the complication of data processing such as terrain correction.

Multi-electrode Resistivity

The Multi-electrode Resistivity Methods were used in the pit in 2001. Voids should have a higher resistivity than the surrounding rock and therefore should be delineated from the host rock mass. However, some of the host rocks also

have high resistivity and in any case the properties and extent of the underground water will also contribute significant unknown effects. Consequently the interpretation is difficult and is often time-consuming.

Cross-Hole Radio Wave Tomography

Cross-Hole Radio Wave Tomography utilises the absorption characteristics of electromagnetic waves when they travel in different medium. The underground workings are assumed to have different conductivities when compared to the host rock and as such would cause the reflection and refraction of electromagnetic waves. The system consists of a single transmitter (source) and multi-receivers. Two boreholes are required; the source wave is induced at a given point in one of the boreholes and is received in the other hole at multiple consecutive points along the hole. Then the source point is moved to the next point along the hole and received in the same way in the other hole. By repeating the process, numerous compact rays are recorded and form the cross net in the investigation area. Tomography is used to model the cross net and outline the spatial location of any anomalies. Reasonable results can only be achieved if the borehole depth is much greater than the void height. The crosshole accuracy could also be improved by using multi-sections scanning if time allowed.

Transient Electromagnetic Method (TEM) and Micro-Seismic Tomography

The Transient Electromagnetic Method (TEM) and Micro-Seismic Tomography have been tried with little success. The major obstacle for micro-seismic tomography is the broken layer on the pit floor. The broken material absorbs most of the seismic energy and prevents it being transmitted efficiently into ground. The major difficulty with the TEM seemed to be the penetration depth and resolution.

So, although geophysics can be useful it cannot normally provide definitive models easily in the time scale required. According to John Shipp, "Most of the systems we've looked at are pretty slow and labour intensive, and to date, the best tool for us is a mixture of the old plans, some experienced underground mining engineers reviewing those plans, planning where we put our drill holes, monitoring those drill holes and updating our plans so we have a safe pit floor."

A real geophysical challenge!

Seismic Monitoring

One other geophysical challenge associated with developing the pit concerns the significant seismic events and rock bursts that occur beneath and around the pit. It has been known for over twenty years that most of the Yilgarn Craton is under east-west compressive stress. In this situation, when the stress is released near the underground workings, seismic events can be triggered. For mining safety and the viability of the operation, it is therefore important that the mine-induced and regional seismicity is understood (see Hudyma *et al*., 2003).

The seismic system trials were initiated in the Fimiston Open Pit in 1996 using two triaxial geophone arrays and two triaxial accelerometer arrays installed into two boreholes. The main objectives of the trial were to investigate the suitability of the two types of sensors and the detectability of seismicity in the pit. The trial was regarded as a success and the system has been expanded and improved. The current system consists of 12 triaxial geophone and accelerometer arrays and nine uniaxial geophones. The 12 triaxial arrays are installed in nine boreholes drilled from the pit and the nine uniaxial geophones are installed from underground level workings about 660 m below the original surface elevation. The system is designed to provide seismicity coverage for the entire pit area that is about 3.0 km long, 1.2 km wide and 300 m deep. From 1998 to 2002, more than 280 mine-wide seismic events ranging from ML -2.2 to +2.3 have been located.

These events were mainly clustered at specific locations under the pit. The results have been used to identify significant failure mechanisms in and near the pit and in the underground workings under the pit.

Environment

Operating a mine as large as the Fimiston Open Pit close to 30,000 people means there is a lot of public interest in the company's activities.

"Obviously, managing that situation, getting the public perception correct and getting people on board is a big effort", John Shipp said.

With residences in close proximity, it's understandable the mine is subject to such scrutiny.

"Dust can be an issue and we control our blasting such that if the wind is in an adverse direction, we don't blast. That's only in certain parts of the pit but we do have dust monitors right along that band between ourselves and the community, and we monitor dust levels on an ongoing basis, so we can manage that but we have to put a lot of effort into it.

Mr Shipp said KCGM believes the best way to go about rehabilitation of the mining environment is to conduct it concurrently with mining. "If you leave it to the end, you've got to bring back special equipment. Concurrent

rehabilitation has two main benefits: one, it gets the job started while you're still mining with the equipment, and two, it puts a better face out to the community."

"In the Goldfields, you'll never going to have a jarrah forest living here. You do get native species and they're slow growing but some of those trees are now several metres high."

"I think, at the end of the day, you have to be accountable to your community and make sure that your standards are the best. We bring our own families up in this community so we also want to maintain a good standard."

Acknowledgements and References

This contribution was compiled from interviews carried out by Brian Wickins and discussions with Jin Jiang, who provided copies of the two excellent papers presented at the Large Open Pit Conference 2003, 3-5 November 2003, Kalgoorlie, WA.

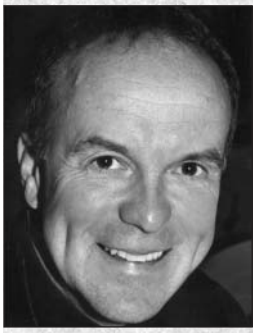
The full text of the papers can be obtained through the AusIMM website: http://www.ausimm.com.au/.

The two articles sourced are:

Jiang, J. J., Karunaratna, K., and Jones, T., 2003, Mining Through Underground Workings in Fimiston Pit KCGM: Paper presented at the Large Open Pit Conference Kalgoorlie, WA, (available from AusIMM).

Hudyma, M. R., Jiang, J. J., and Reimnitz, M., 2003, Seismic Monitoring at the Fimiston Open Pit Kalgoorlie Consolidated Gold Mines (KCGM): Paper presented at the Large Open Pit Conference, Kalgoorlie, WA, (available from AusIMM).

Advances in Converted-Wave Seismic Exploration



Robert R. Stewart
Department of Geology & Geophysics
University of Calgary
Calgary, Alberta
CANADA T2N 1N4
E-mail:
stewart@ucalgary.ca

Abstract

Multicomponent seismic recording (measurement with vertical- and horizontal-component geophones and possibly a hydrophone or microphone) captures the seismic wavefield more completely than conventional single-element techniques. Multicomponent surveying has developed rapidly, allowing creation of converted-wave or *P-S* images. *P-S* imaging uses downgoing P waves that convert on reflection, only at their deepest point of penetration, to upcoming S waves. Current *P-S* sections are approaching (and in some cases exceeding) the quality of conventional *P-P* seismic data. The advancements in multicomponent seismic acquisition, processing, and interpretation techniques have led to a number of applications for converted-wave surveys. Uses that have arisen include structural imaging (e.g., "seeing" through gas-bearing sediments; improved fault definition; enhanced near-surface resolution), lithological estimation (e.g., sand versus shale content; porosity), anisotropy analysis (e.g., fracture density and orientation), subsurface fluid description, and reservoir monitoring.

Introduction

The reflection seismic technique has been remarkably successful in providing subsurface images over a wide range of depths and environments. The method has been especially useful in the search for hydrocarbons in sedimentary basins, but has also found application in hardrock regions (Eaton *et al.*, 2003). The history of development of the seismic method includes: 1) acquiring more and higher-fidelity measurements of vibrations induced in the ground, 2) making ever better calculations about how these seismic waves propagate, and 3) improving our inferences about what the resultant pictures mean in terms of rock and fluid properties. As part of the ongoing refinement of the method, we must take into account the elastic nature of Earth materials and the vector reality of the seismic survey. After as full an analysis as possible of the compressional (*P-P*) wavefield (perhaps including attribute, AVO, and anisotropy analysis, pre-stack depth migrations, and inversions), we still may not have an adequate image or understanding of our subsurface target.

We can extend the conventional single-sensor method of analysing *P*-waves to include more measurements (horizontal sensors in addition to the vertical geophone or hydrophone) for recording the full vector seismic wavefield. This multicomponent seismic method, now using three or four sensors, has the potential to record many more wavetypes - in particular converted-waves that may tell us more about the target (Stewart *et al.*, 2002; 2003).

The simplest, and usually most energetic, converted-wave is composed of *P*-energy propagating downward, converting upon reflection to an upcoming *S*-wave (Figure 1). In isotropic materials, the conversion point is shifted toward the receiver - closer as V_P/V_S increases. However, if the Earth displays vertical transverse isotropic (that is, VTI where velocity varies with angle from the vertical, but not around the vertical), then the conversion point can be displaced toward the mid-point (Thomsen, 1999; Garotta *et al.*, 2003). Most multicomponent processing companies provide VTI assessment as a routine service (as well as analysis of horizontal transverse isotropy, HTI, where the velocity varies with azimuth).

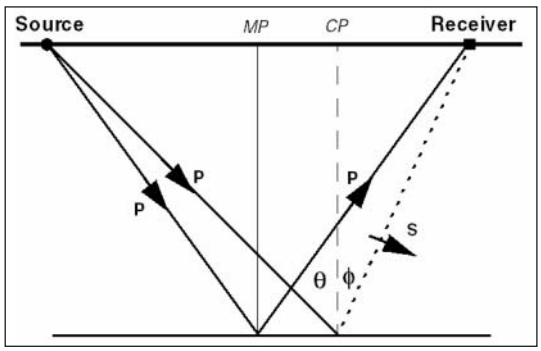


Fig. 1. A converted-wave (P-S) reflection at its conversion point (CP) compared to a pure P-wave reflection at its midpoint (MP) in an isotropic layer (from Stewart et al., 2002). Note the CP is shifted toward the receiver. The P-wave angle of incidence and S-wave angle of reflection are given by θ and ϕ respectively. Snell's Law gives the relationship between the layer's velocities and the ray angles:

$$\frac{\sin\theta}{V_P} = \frac{\sin\phi}{V_S}$$

where V_P and V_S are the P- and S-wave velocities, respectively. Since $V_S < V_P$, ϕ is less than θ, and the S-wave leaves the interface closer to perpendicular than the incident P-wave. Directions of positive phase, as shown by arrowheads, are according to Aki and Richards (1980).

Another aspect of converted-wave propagation is that the reflectivity with offset is quasi-sinusoidal (Figure 2). Generally, we see the amplitude of the conversion fall off to zero at zero offset. However, some careful investigators have noticed that non-zero amplitudes can actually occur at zero offset. Artola *et al.* (2003) have recently offered theoretical derivations that in certain complicated anisotropic contacts this should occur. Refinements continue! In addition, we usually assume that fluids do not alter the rigidity or *S*-wave velocity of a material substantially. Again though, in fractured and thus anisotropic materials, fluids can change the rigidity considerably. Thus, the *S*-velocity and consequent reflectivity may be changed.

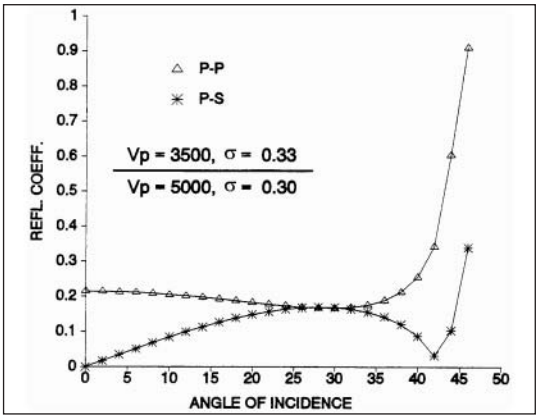


Fig. 2. P-P and P-S plane-wave reflection coefficients as a function of P-wave angle of incidence. Note that the absolute value of the P-S reflection coefficient is plotted. The S-wave velocities for the upper and lower layers are 1750 m/s and 2650 m/s, respectively. Density is constant (from Stewart et al., 2002).

New digital and optical sensors (e.g., Tessman and Maxwell, 2003; Fischer, 2003) and recording systems promise to provide higher fidelity data, fewer field errors, and greater recording efficiency. Additionally, a number of service companies now have multicomponent seismic capability and growing experience. Survey design codes have been developed and are allowing better designed surveys (e.g., Lawton and Cary, 2003). The economics of multicomponent seismic surveying (Gibson *et al*., 2003) have been revisited and some costs are improving. Modelling and processing of the elastic wavefields are becoming more and more realistic. Interpretation is taking a leap forward with automatic registration and correlation techniques (Gaiser, 1996; Ogiesoba and Stewart, 2003). Interpretation is stepping forward with specialized elastic-wave interpretation packages such as Hampson-Russell's ProMC. So we would like *S*-waves and their subsequent analysis to provide improved subsurface images as well as give a measure of *S*-wave properties relating to rock type and saturation. If we do have *P-S* reflectivity, what specifically can it be used for? Various authors (e.g., Kristiansen, 2000; Yilmaz, 2001) have suggested or shown a number of applications of *P-S* data that include: enhanced imaging, lithology estimation, fluid description, anisotropy analysis, and reservoir monitoring.

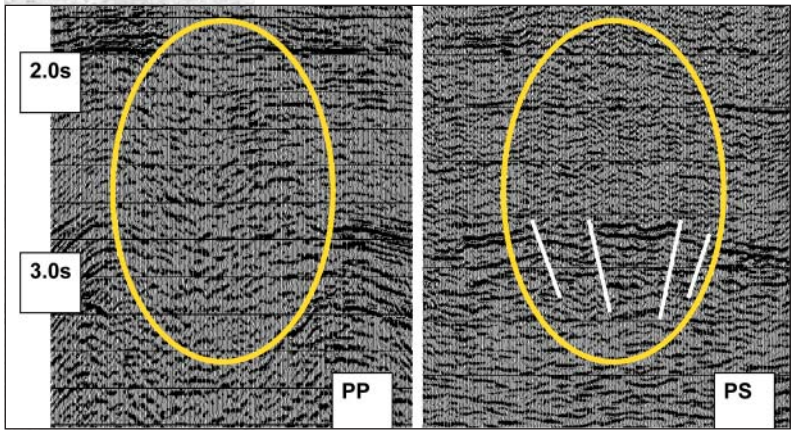


Fig. 3. P-P and P-S sections from the Valhall Field, Norway showing improved imaging across the anticlinal structure (after Rodriguez, 2000). The yellow ellipses outline the upper region of the chalk reservoir.

Let's look in more detail at a sample of these applications. First, I'll provide an imaging case, then lithology estimate, followed by anisotropy analysis, then fluid description example, and close with a reservoir monitoring survey.

Imaging

'Seeing' through gas-charged sediments

P-wave energy is delayed, scattered, and attenuated when passing through a gas-bearing sediment. Leaky gas reservoirs can create a gas plume or chimney that makes conventional *P*-wave imaging and characterization of the reservoir very difficult. *S*-waves, being generally less sensitive to rock saturants, can be used to penetrate gas-saturated sediments. Rodriguez (2000) analysed a 4-C case from the Valhall Field, Norway (originally conducted by Amoco Norway Oil Co. and the Valhall Licence partners). He used prestack equivalent-offset migration for converted waves (Bancroft, 2000) to image through a gas cloud. The results provided a more interpretable image of the chalk reservoir beneath the gas cloud, especially near its anticlinal top at about 2.8 s on the *P*-wave section (Figure 3).

Structural imaging

Resolution of steeply dipping features can be improved using converted waves in certain circumstances. Purnell (1992) showed examples from physical-modeling data where high-dip anomalies were more visible on migrated *P-S* data than on migrated *P-P* data. Cary and Couzens (2000) gave examples from the Mahogany Field in the Gulf of Mexico where *P-S* images show excellent definition of faults associated with salt intrusion (Figure 4). It is not obvious, at this point, why faults should appear to be better defined on the *P-S* versus *P-P* sections. Explanations could include more prominent *P-S* scattering from non-welded or fluid-saturated contacts (Chaisri and Krebes, 2000), larger lateral *S*-wave changes across the faults, or *P-S* raypaths from steeply dipping features that are more conducive to capture with given receiver apertures.

Near-surface Imaging

We often see more highly resolved reflectors in the near surface on *P-S* sections than on collocated *P-P* sections. This may be the result of a number of factors, including greater relative changes in *S* versus *P* velocity, a greater impact of density changes on the *P-S* reflectivity than on *P-P* reflectivity, or a shorter *S* wavelength. For example, a 3-C seismic line was acquired over the Steen River impact structure, Alberta by Gulf Canada Resources Ltd. (now ConocoPhillips) in partnership with the CREWES Project at the University of Calgary (Mazur *et al*., 2002). The resultant *P-P* and *P-S* sections are shown in Figure 5, where the *P-P* data are stretched by a factor of 2 (a V_P/V_S value of 3) to match the *P-S* data. The sections are spliced together at a central point on the line. We note the greater detail evident on the *P-S* sections above the pre-Cretaceous unconformity (at time 1000 ms on the *P-S* section). However, the *P-P* data are generally more continuous

beneath the pre-Cretaceous unconformity (at about 480 ms on the *P-P* section).

Richardson (2003) discusses shallow seismic imaging to investigate coal deposits. She notes the importance of fault assessment in coal mine design and the benefits that multicomponent seismic imaging can bring to coalfield understanding. An example of multicomponent surveying to provide enhanced visibility of a coal seam over a coal mine in the Bowen Basin in Australia is shown in Figure 6 (Velseis, 2003).

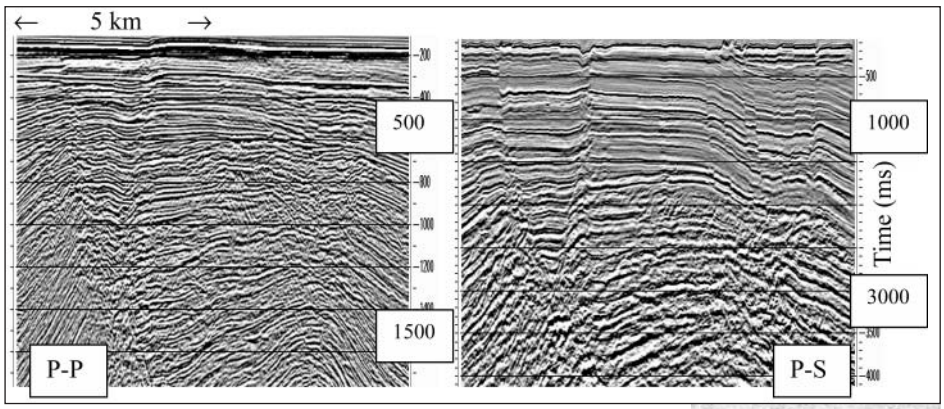


Fig. 4. (a) Poststack time migration of the vertical geophone component from the Mahogany 4-C survey (left). Poststack time migration of the depth-variant CCP stack of the in-line component data on the right (from Cary and Couzens, 2000).

Lithology Estimation

Sand/Shale

P-wave imaging has proven particularly adept at making structural pictures of the subsurface; that is, providing an image of strata interfaces in reflection time. However, beyond the configuration of interfaces, we would like to know what kind of rock and fluids are in the section. *P*-wave images may be limited or ambiguous in these regards. *S*-wave measurements provide additional constraint on the rock properties (especially on density and rigidity contrasts). Much *P-S* analysis is targeted at finding an *S*-wave velocity or determining a V_P/V_S value (e.g., Li *et al*., 1999). Both V_S and V_P/V_S can be good indicators of rock type, especially in combination with V_P (Tatham, 1982).

A series of seismic experiments in the Blackfoot Oil Field, Alberta was conducted to identify sand reservoir facies from non-reservoir rocks (Stewart *et al*., 1996; Dufour *et al*., 2002). The surveys included broad-band 3C-2D data, 3C-3D data, and 2-D and 3-D VSP surveys. The field was originally discovered and developed using *P*-wave amplitude anomalies (Figure 7a); however, there are also amplitude anomalies not associated with sand channels (that is, false positives). *P-P* isochron maps are also indicative of the channel but again with some ambiguity.

Modelling, VSP surveys in the area, and a 2D-3C seismic line over the middle of the main pool all indicated promise for *P-S* images to reduce the ambiguity. So, a 3C-3D survey was conducted. The resultant *P-S* amplitude seems to give a more definitive (but lower resolution) image of the sand channel (Figure 7b). A *P-S* isochron map that included the channel is perhaps more compelling (Figure 8a). The V_P/V_S maps, calculated from *P-P* and *P-S* isochron map ratios, are another strong indicator of the reservoir sand channel trend (Figure 8b).

MacLeod *et al*. (1999a) showed a case (now a classic!) of converted waves successfully delineating sand channels encased in shale at the Alba field in the North Sea. A strong contrast in *S*-wave velocity (from shale to sand) is associated with the top of the reservoir. On the other hand, there is relatively little *P*-wave velocity change across this lithological boundary. Thus, the reservoir top generates strong converted-waves, but weaker reflected *P*-waves.

The impact of the 4-C OBC survey on the development of Alba has been positive (MacLeod, *et al*., 1999b). To date, a number of successful wells have been drilled based primarily on the interpretation of the new converted-wave data. Wilkinson (2003, pers. comm.) indicated that up to 100 million barrels of oil had been added to the estimate of the Alba field on the basis of the converted-wave assisted interpretation.

Anisotropy Analysis

Many hydrocarbon reservoirs are fractured. The volume of oil or gas in place and the reservoir's ability to produce it can be dependent on the fracture state of the reservoir.

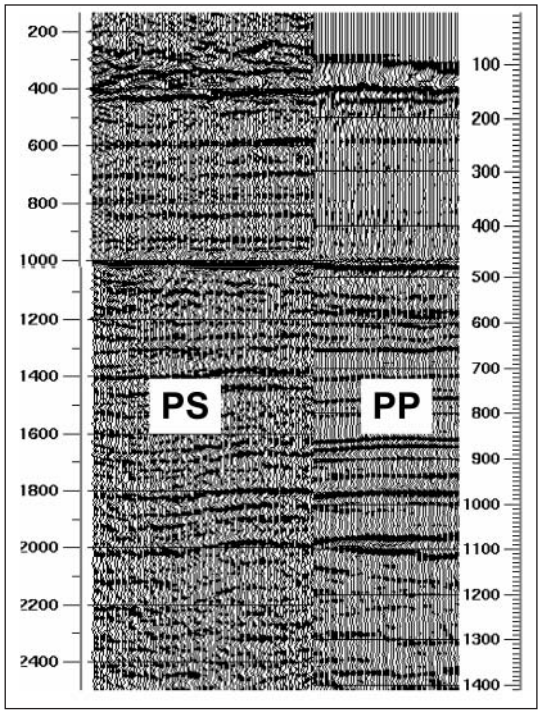


Fig. 5. Seismic data over the Steen River meteorite impact structure, Alberta. The pre-Cretaceous unconformity is expressed at about 480 ms on the P-P section and 1000 ms on the P-S section. We note that some events are more clearly defined in the shallow P-S section, whereas the deeper events are less noisy on the P-P section. The data were acquired by Gulf Canada Resources Ltd. (now ConocoPhillips) and the CREWES Project at the University of Calgary.

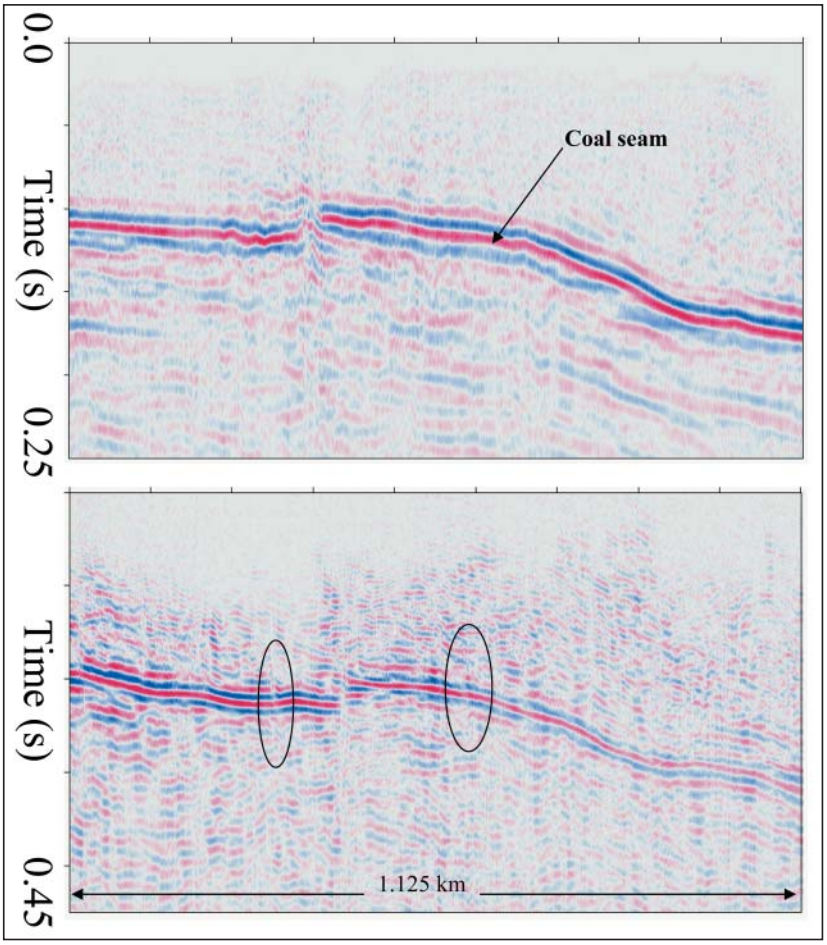


Fig. 6. P-wave and converted-wave sections over a faulted coal seam in Australia. The P-S and P-P sections are in their raw two-way vertical traveltimes, but the P-S section has been squeezed to provide an approximate correlation with the P-P section. The P-S section appears somewhat more resolved than the P-P image in addition to its indication of further faulting as shown in the annotated ovals (after Velseis, 2003).

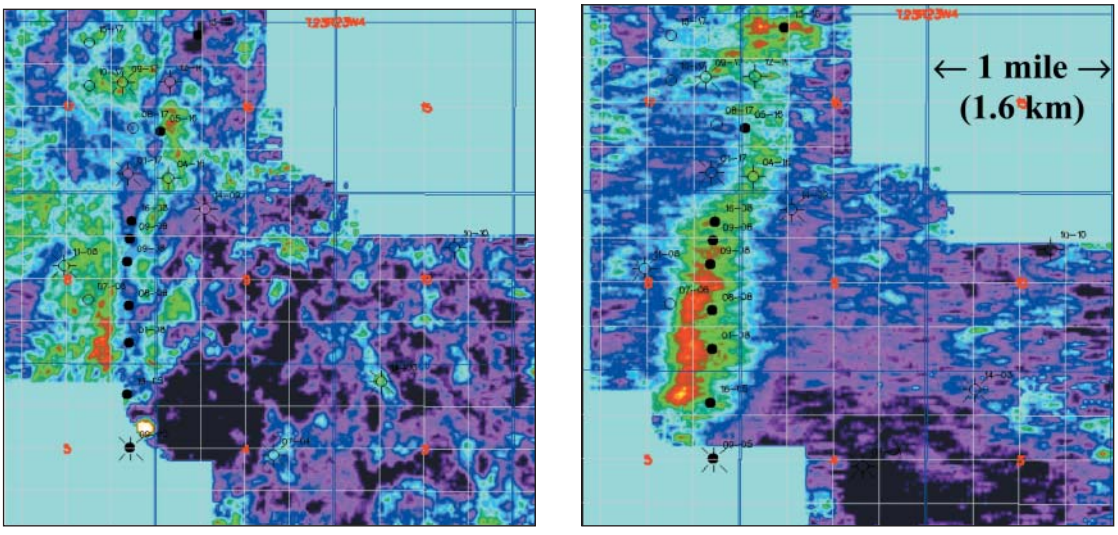
Determining fracture density and orientation from seismic data has thus been a subject of considerable effort (e.g., Probert *et al.* 2000; Crampin, 2001).

Gaiser *et al.* (2002) showed the results of applying an Alford (1986) anisotropic rotation procedure and layer stripping (where off-diagonal components are minimized) to data from a 4C-3D seismic survey conducted over the Emilio Field in the Adriatic Sea, Italy. They found that *S*-wave splitting was in evidence and the fast *S*-wave was polarized in the NNW-SSE direction, which was consistent with faulting in the area (Figure 9).

Numerical modeling (Li *et al.*, 1996) suggests that gas-saturated and oriented fractures may have an effect on anisotropic *P-S* reflectivity. This is in contrast to the isotropic case, where fluid saturation appears to have less impact on *S*-wave velocities. In fact, Guest *et al.* (1998) interpreted anomalies in *S*-wave splitting over a gas reservoir in Oman as evidence of an effect of gas on shear waves.

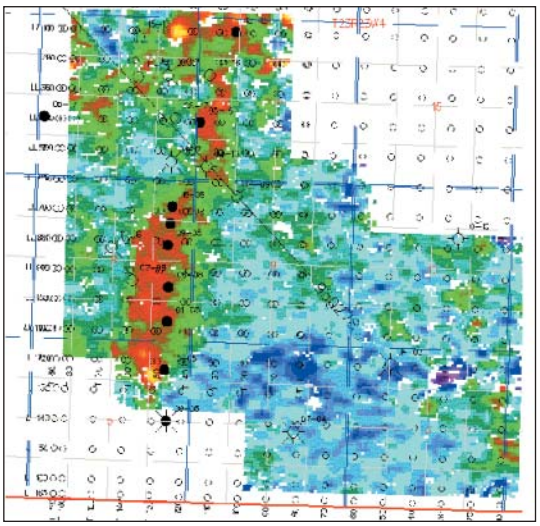
Fluid Description

Thompson *et al.* (2000) presented early results from a 30 km 2-D multicomponent line, in 750 m of water, shot over the Fles Dome, offshore Norway. There is a flat spot on the *P-P* data set that could be an event caused by a fluid contact (Figure 10). However, it could also be generated by a lithological change. The continuity of dipping strata in the *P-S* section (lack of a flat spot) supports the possibility that the *P-P* anomaly is caused by fluids not a lithological change.

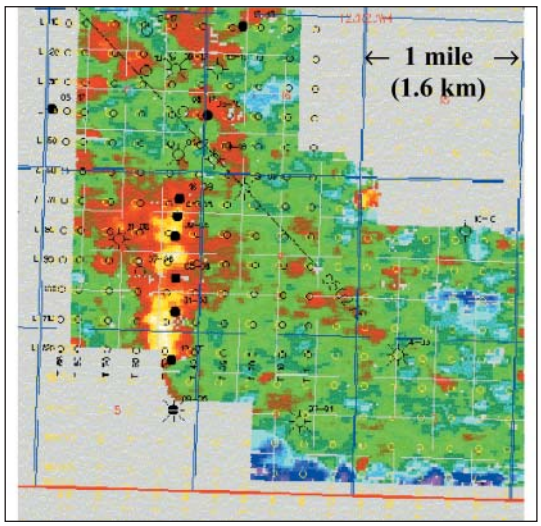


(a) *(b)*

Fig. 7. (a) P-P time slice at the interpreted sand channel level from the Blackfoot 3C-3D survey (the channel is interpreted to be the purple N-S feature) and (b) P-S associated time slice. The grid lines indicate a section (1 mile by 1mile or approximately 1.6 km by 1.6 km).



(a)



(b)

Fig. 8. (a) P-S isochron map between the Mannville and Mississippian horizons (white/yellow indicate a time thickness of 140 ms through purple with a value of 90 ms) and (b) the VP/VS value as determined from the P-P and P-S isochron maps between the interpreted top of the channel and Wabamun horizons. White/yellow represent a VP/VS value of 1.5 through purple indicating a value of 2.8.

Reservoir Monitoring

Isaac (1996) showed *P-P* and *P-S* sections from a heavy-oil reservoir at Cold Lake, Alberta undergoing steam flooding (Figures 11a and 11b). There are variations in the reservoir rock properties associated with temperature and saturation changes. These, in turn, are associated with changes in the seismic character of both *P-P* and *P-S* sections. Using surveys in 1993 and repeated in 1994, she found that the variation in V_P/V_S values correlated with the temperature of the reservoir. The V_P/V_S values stay fairly constant in areas away from the injection wells (CDPs 20-70 in Figures 12a and 12b). However, in the areas steamed in 1994, there is an increase in V_P/V_S that causes the ratio of the V_P/V_S values from the two years to drop (Figure 12c).

What's Left To Do?

Converted-wave exploration has come a long way in recent years, but there is still plenty of room for progress. The *P-S* method will undoubtedly become more widely practised and useful as costs decrease. The expense of land multicomponent surveys is decreasing significantly, but marine costs are still well above those of towed-streamer methods. Processing and analysis of *P-S* data have become much more effective and sophisticated, especially by incorporating prestack techniques and anisotropy. Seismic theory has much more to teach us – for example, about non-linear wave propagation. Processing *P-P* and *P-S* data together to provide consistent images in depth (Mikhailov *et al*., 2001) and improved rock property estimates (Margrave *et al*., 2001) are critical current developments. For example, Spitz (2001) showed a case from the North Sea where *P-P* and *P-S* inversion was used to derive a density estimate (which compared favourably with a density log in their area). Further refinements await.

More detailed analysis of existing images may provide us with greater understanding of the targets under consideration or even new ones. Better interpretation tools

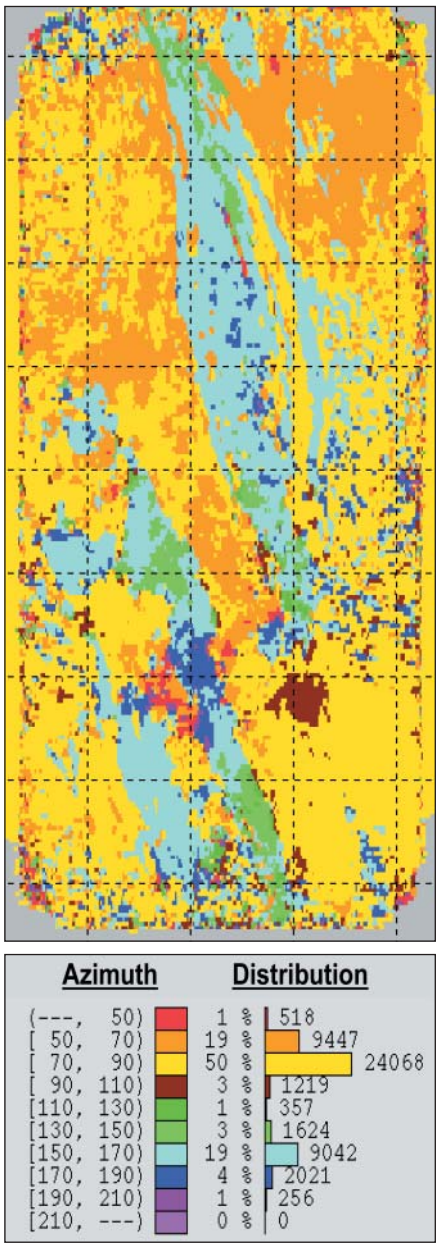


Fig. 9. Fast S polarization direction from a 4C-3D seismic survey over the Emilio field, offshore Italy. Major fracture and faulting trends are NNW-SSE in the regions of interest as are the fast S polarizations (Gaiser et al., 2002).

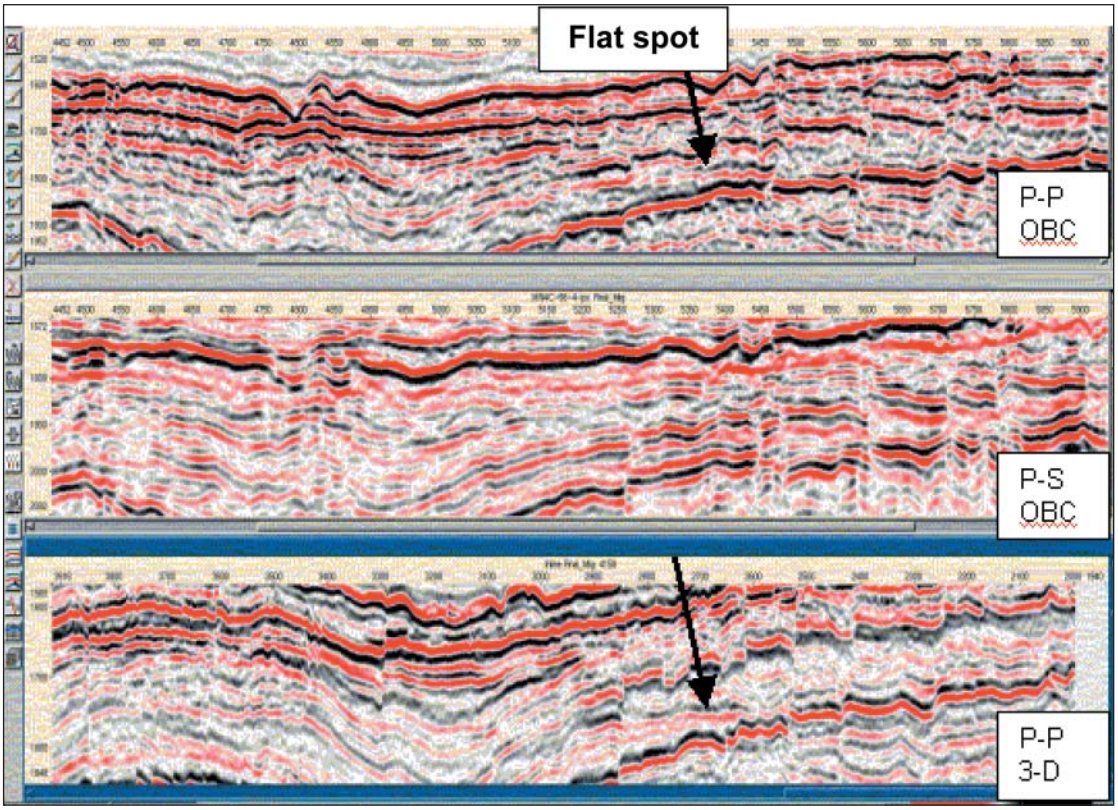


Fig. 10. Flat spot analysis on P-P and P-S from the Fles Prospect, offshore Norway (Thompson et al., 2000). The top section shows the P-wave data from the 2-D OBC survey, the middle section the P-S data from the OBC survey, and the bottom section a line extracted from a 3-D towed streamer volume. There is no obvious flat spot on the P-S data suggesting that the P-wave anomaly is a fluid contact not a lithology change.

are under development, especially with respect to correlation and depth conversion, but additional advances would be welcomed. Continued education and experience will further unravel what converted waves have to show us (Cary, 2001).

Looking farther ahead, we anticipate making use of other modes that propagate in a seismic survey – such as a wave, otherwise *P*, that has an *S*-wave leg through a high-velocity region. In cases where there are high-velocity

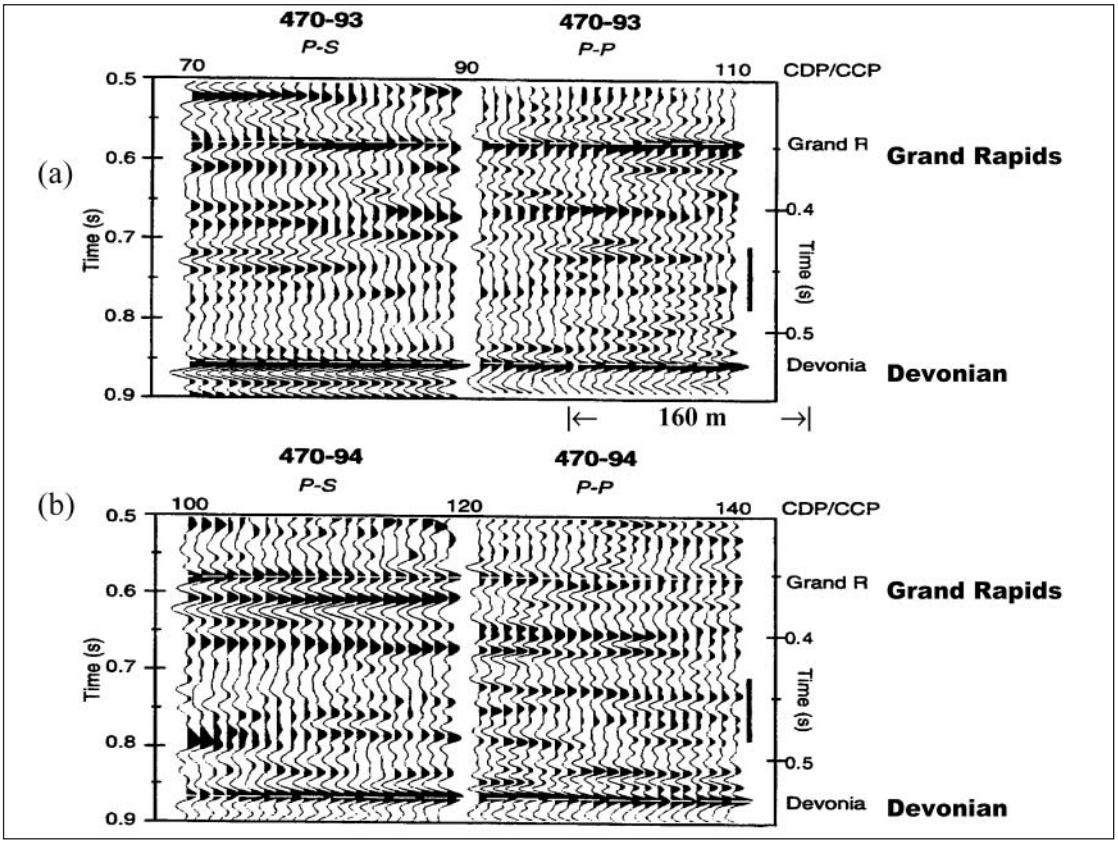


Fig. 11. Comparison of the (a) 1993 and (b) 1994 3-C seismic lines from the Cold Lake, Alberta steam injection site. Note the similar data quality and resolution among all lines (from Isaac, 1996). The area of interest is indicated by the vertical bar. CDP/CCP trace spacing is 8 m.

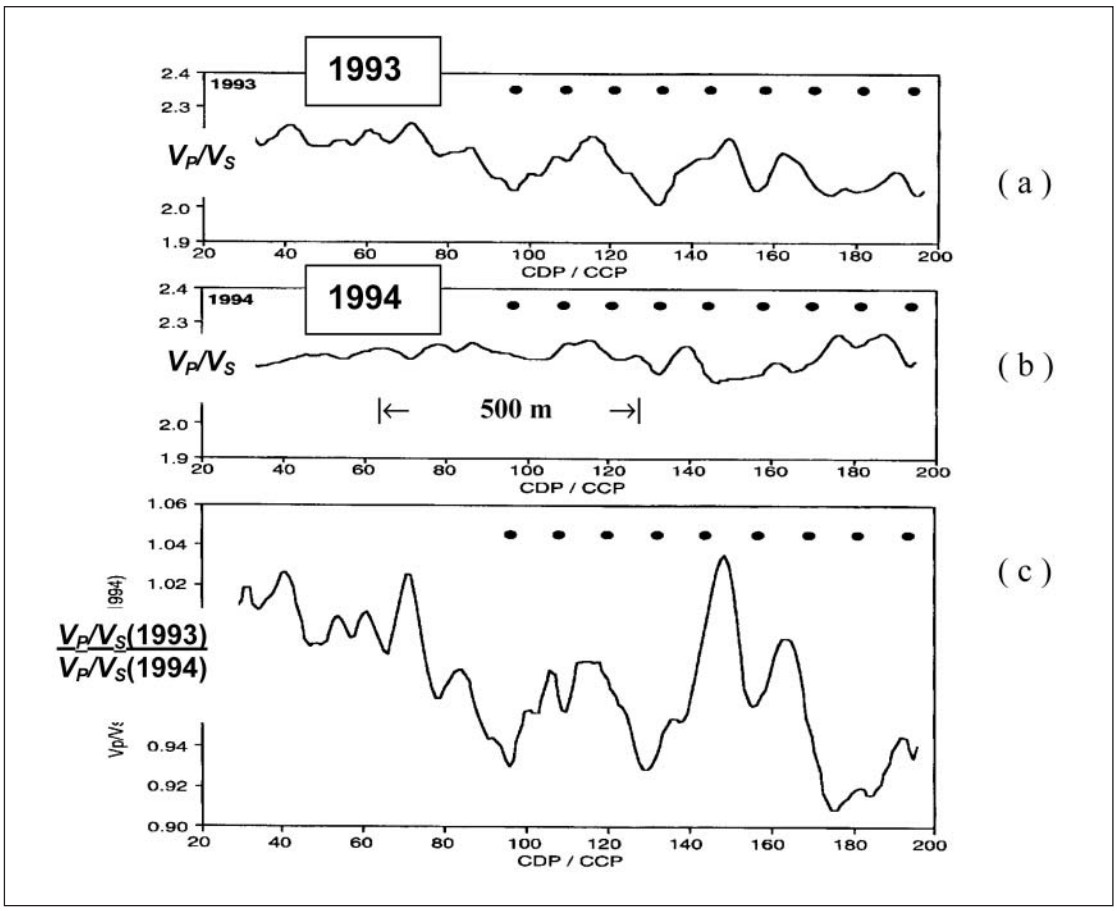


Fig. 12. V_P/V_S plots for (a) 1993 lines, (b) 1994 lines, and (c) the ratio of those two. Note that the V_P/V_S value is fairly constant in the unsteamed regions away from the wells - CDP numbers 20-70 (from Isaac, 1996). However, the V_P/V_S values increase in 1994, with steaming. CDP/CCP trace spacing is 8 m. The lines were 1800 m long.

layers – basalts, carbonates, salts, or even permafrost in the near surface – seismic imaging may be complicated or compromised.

The possibility of high-quality, fully elastic and anisotropic images of the subsurface opens many doors to new interpretation. Accurately repeating these surveys (4C-4D) to look for changes associated with fluid movement is a very exciting prospect (Grechka, 2001; Jack, 2001). Permanent seismic monitoring of oilfields, either with active sources or passive listening, using surface and/or borehole measurements will provide considerably more guidance for reservoir production.

And even farther out on the horizon, we are beginning to see the imaging use of other kinds of energy conversions (e.g., seismic to electromagnetic). Multicomponent seismic recording with electric and magnetic field sensors may provide estimates of Earth properties that are more closely tied to subsurface fluids.

Conclusions

The reflection seismic method has used *P*-waves for many years – and with great success. The extension of the reflection method to include *P*-*S* waves has been effective in yielding new cases of improved imaging of resource targets. Particularly well documented cases exist for gas-cloud imaging, sand/shale discrimination, and anisotropy analysis. There is more to be done in converted-wave exploration seismology, especially in making full use of these new pictures.

Acknowledgements

I would like to express my deep appreciation to the sponsors of the Consortium for Research in Elastic Wave Exploration Seismology (the CREWES Project) for their commitment to the development of multicomponent seismology. Chris Thompson formerly of Chevron graciously donated the Fles example and the Amoco (now BP) group of companies provided the Valhall 4-C data set for analysis.

References

Aki, K. and Richards, P. G., 1980, Quantitative seismology: Theory and methods: W. H. Freeman and Sons, Vols. 1 and 2.

Alford, R. M., 1986, Shear data in the presence of azimuthal anisotropy: Dilly, Texas, 56th Ann. Internat. Mtg., Soc. Expl. Geophys., Houston, S9.6, 476–479.

Artola, F. V. A., Leiderman, Fontoura, S. A. B., and Siva, M. B. C., 2003, Zero-offset C-wave reflectivity in horizontally layered media: Presented at the 73rd Ann. Intl. Soc. Explor. Geophys. Meeting.

Bancroft, J. C., 2000, A practical understanding of pre- and post-stack migration: Vol. 2, Course Note Series, Soc. Explor. Geophys.

Cary, P. W., 2001, Multicomponent seismic exploration in Canada - One person's perspective: Recorder, Can. Soc. Explor. Geophys., 26, 62–67.

Cary, P. W. and Couzens, R. A., 2000, Processing 4-C data from Mahogany Field, Gulf of Mexico: Presented at the SEG/EAGE Summer Research Workshop, Boise, Idaho.

Chaisri, S. and Krebes, E. S., 2000, Exact and approximate formulas for *P-SV* reflection and transmission coefficients for a nonwelded contact interface: J. Geophys. Res., **105**, 28, 045–28, 054.

Crampin, S., 2001, Shear-wave anisotropy: A new window into the crack-critical rockmass: Recorder, Can. Soc. Explor. Geophys., **26**, 11–27.

Dufour, J, Squires, J., Goodway, W. N., Edmunds, A., and Shook, I., 2002, Integrated geological and geophysical interpretation case study, and Lamé rock parameter extractions using AVO analysis on the Blackfoot 3C-3D seismic data, southern Alberta, Canada: Geophysics, **67**, 27–37.

Eaton, D. W., Milkereit, B., and Salisbury, M. H., Eds., 2003, Hardrock seismic exploration: Soc. Explor. Geophys., Geophys. Dev. Series, no. 10.

Fischer, P. A., 2003, What's new in sensor technology: World Oil, Gulf Publ. Co., **224**(9), 29–34.

Gaiser, J. E., 1996, Multicomponent V_P/V_S correlation analysis: Geophysics, **61**(4), 1137–1149.

Gaiser, J. E., Loinger, E., Vetri, L., Lynn, H., and Walters, R., 2002, *PS*-wave birefringence analysis at the Emilio field for fracture characterization: Presented at the 10th Intl. Workshop Seis. Aniso.

Garotta, R., Granger, P. Y., and Audebert, F. 2003, About gamma ratios and their combinations: Presented at the 73rd Ann. Intl. Soc. Explor. Geophys.

Gibson, J., Watt, H., and Roche, S., 2003, Multicomponent seismic data acquisition... The economics revisited: CSEG Recorder, **28**(8), 16–21.

Grechka, V., 2001, Seismic anisotropy: Yesterday, today, tomorrow: Recorder, Can. Soc. Explor. Geophys., **26**, 9–10.

Guest, S., Vander Kolk. C., and Potters, H., 1998, The effect of fracture filling fluids on shear-wave propagation: Presented at 68th Ann. Intl. SEG Mtg., Expd. Abst., 948–951.

Isaac, J. H, 1996, Seismic methods for heavy oil reservoir monitoring: Ph.D. thesis, Univ. of Calgary.

Jack, I., 2001, The coming of age for 4D seismic: First Break, **19**(1), 24–28.

Lawton, D. C. and Cary, P., 2003, Some considerations with *P-S* survey design: Presented at the 73rd Ann. Intl. Mtg., Soc. Explor. Geophys.

Kristiansen, P., 2000, 4 years experience with 4C seismic: what we have learned: Presented at the SEG/EAGE Summer Research Workshop, Boise, Idaho.

Li, X., Kuhnel, T., and MacBeth, C., 1996, Converted-wave AVO and its implications: Extended Abst., 58th Ann. Conf., Euro. Assn. Geosci. Eng., M046.

Li, X., Yuan, J., Ziolkowski, A., and Strijbo, F., 1999, Estimating V_P/V_S ratio from converted waves - a 4C case example: Extended Abst., 61th Ann. Conf., Euro. Assn. Geosci. Eng., P066.

MacLeod, M. K., Hadley, M. J., Reynolds, K. J., and Tura, A., 1999a, Multicomponent analysis of OBC data, 31st Ann. Off. Tech. Conf., Houston, OTC 10940.

MacLeod, M. K., Hanson, R. A., Bell, C. R., and McHugo, S., 1999b, The Alba field ocean bottom cable seismic survey: Impact on development, Off. Euro. Conf., Aberdeen, SPE 56977.

Margrave, G. F., Stewart, R. R., and Larsen, J. A., 2001, Joint *PP* and *PS* seismic inversion: The Leading Edge, **20**, 1048–1052.

Mazur, M. J., Hildebrand, A. R., Hladiuk, D., Schafer, A., Pilkington, M., and Stewart, R. R., 2002, The Steen River crater seismic refraction project: Presented at the 33rd Lunar and Planetary Science Conf., Houston.

Mikhailov, O., Johnson, J., Shoshitaishvili, and Frasier, C., 2001, Practical approach to joint imaging of multicomponent data: The Leading Edge, **20**, 1016–1021.

Ogiesoba, C. and Stewart, R. R., 2003, V_P/V_S from multicomponent seismic data and automatic *PS* to *PP* time mapping: Presented at the 73rd Ann. Intl. Mtg., Soc. Explor. Geophys.

Probert, T., Ronen, S., and Bryan, R., 2000, A case study of azimuthal anisotropy analysis from a N. Sea 3D 4C project: Presented at the SEG/EAGE Summer Research Workshop, Boise, Idaho.

Purnell, G. W., 1992, Imaging beneath a high-velocity layer using converted waves: Geophysics, **57**, 1444–1452.

Richardson, S. E., 2003, Multicomponent seismic applications in coalbed methane development, red Deer, Alberta: M.Sc. thesis, Univ. of Calgary.

Rodriguez, C., 2000, Advanced marine methods: Ocean-bottom and vertical cable analyses: Ph. D. thesis, Univ. of Calgary.

Spitz, S., 2001 Seismic analysis with multi-components: Recorder, Can. Soc. Explor. Geophys., **26**, 7, 57–61.

Stewart, R. R., Ferguson, R., Miller, S. L. M., Gallant, E., Margrave, G., 1996, The Blackfoot seismic experiments: Broad-band, 3C-3D, and 3-D VSP surveys: CSEG Recorder, **6**, 7–10.

Stewart, R. R., Gaiser, J. E., Brown, R. J., and Lawton, D. C., 2002, Converted-wave seismic exploration: Methods: Geophysics, **67**(5), 1348–1363.

Stewart, R. R., Gaiser, J. E., Brown, R. J., and Lawton, D. C., 2003, Converted-wave seismic exploration: Applications: Geophysics, **68**(1), 40–57.

Tatham, R. T., 1982, V_P/V_S and lithology: Geophysics, **47**, 336–344.

Tessman, D. J. and Maxwell, P., 2003, Full-wave digital seismic recording and the impact of vector fidelity on improved *P*-wave data: CSEG Recorder, **28**(8), 22–24.

Thomsen, L., 1999, Converted-wave reflection seismology over inhomogeneous anisotropic media: Geophysics, **64**, 678–690.

Thompson, C., Helgesen, H. K., and Battié, J. E., 2000, 2D-4C seismic exploration data for risk reduction, Fles prospect, offshore Mid-Norway: Presented at the SEG/EAGE Summer Research Workshop, Boise, Idaho.

Velseis, 2003, Investigation of converted-wave seismic reflection for improved resolution of coal structures: Final Report, ACARP Project C10020, 75pp.

Yilmaz, O., 2001, Seismic data analysis: Processing , inversion, and interpretation of Seismic Data: Soc. Explor. Geophys., Investigations in Geophysics, No. 10., Vol. 2.

Is Shell's downgrading of oil reserves the tip of the iceberg?

Remember Friday January 9th 2004. That was the day Shell announced a reduction in its proven global oil and natural gas reserves by 20% from 19.5 billion to 15.6 billion boe. Based on current production of ~3.9 million boe/day, this cuts its reserve life from 13.4 to 10.6 years.

The big questions are:

- Are we seeing the first significant indication that global production is close to peaking within the next few years?
- Will other major oil producers follow suite and revise their reserves downwards as well?

As we all know new discoveries and reserves are the lifeblood of the petroleum industry. Shell is the world's third largest oil company, in terms of production, but in each of the last three years its discoveries have fallen below its production rates. For example in 2003 it expects to replace between 70%-90% of its reserves with new finds.

In a world where demand is expected to continue to rise significantly, particularly as the Indian and Chinese economies continue to expand, this situation does not bode well.

The main impact in Australia has been the downgrading of the gas reserves in the Gorgon Field (previously assessed at 12.9 trillion cubic feet) from proved to unproven. However, Shell said that it remained committed to the A$11 billion development of the filed.

Clearly, an opportunity for the government to ensure that it develops and maintains policies to encourage more exploration in Australia.

Five new exploration permits awarded

There was a good start to the year, on January 23rd, when Federal Resources Minister Ian Macfarlane announced the award of five new offshore exploration permits in commonwealth waters off Tasmania, Western Australia and South Australia. Almost $70 million of new petroleum exploration activity will be generated as a result of the granting of these new permits. Details of the exploration planned are given below, and maps showing the areas involved can be accessed through the ITR website at: Maps of the permit areas can be found at www1.industry.gov.au/acreagereleases/.

Permit T/36P (originally released as area T03-4) in the Sorrell Basin has been awarded to Santos Offshore Pty Ltd and Unocal South Australia Pty Ltd, which proposed a guaranteed program for the first three years of reprocessing 1100 km of existing 2D seismic data, acquisition of 576 km of new 2D seismic data and geological and geophysical studies at an estimated cost of $2.10M. The consortium also proposed a secondary program of geological and geophysical studies, 210 km^2 of 3D seismic surveying and a well at an estimated cost of $15.3M.

In the Otway Basin, permit EPP 33 has been awarded to Kerr-McGee NW Shelf Australia Energy Pty Ltd and Kerr-McGee Australia Exploration and Production Pty Ltd, which have proposed a guaranteed program for the first three years of geological and geophysical studies and acquisition of 1125 km of new 2D seismic data at an estimated cost of $2.7M. The consortium also proposed a secondary program of geological and geophysical studies and 1000 km of new 2D seismic data at an estimated cost of $2.45M.

In the Carnarvon Basin, permit WA-350-P has been awarded to Woodside Energy Ltd, which proposed a guaranteed program for the first three years of 406 km^2 of 3D seismic surveying, a well, and geological and geophysical studies at an estimated cost of $21.6M. The company also proposed a secondary program of geological and geophysical studies and reprocessing 330 km of 2D seismic data at an estimated cost of $1.05M.

Permit WA-351-P in the Carnarvon Basin has been awarded to BHPBilliton Petroleum Pty Ltd, which proposed a guaranteed program for the first three years of geological and geophysical studies and 500 km of 2D seismic data at an estimated cost of $1.4M. The company also proposed a secondary program of a well and geological and geophysical studies at an estimated cost of $16M.

Permit WA-349-P (originally released as area W03-14) in the Perth Basin has been awarded to Chimelle Petroleum Ltd, which proposed a guaranteed program for the first three years of geological and geophysical studies and acquisition of 360 km of new 2D seismic data at an estimated cost of $0.7M. The company also proposed a secondary program of 150km^2 of 3D seismic surveying, a well and geological and geophysical studies at an estimated cost of $6.6M.

Minara Resources Limited: a new name in mineral resources

On December 12th 2003, Minara Resources Limited was born. It is based in Perth and with a market capitalisation of ~$1.4 billion; Minara Resources is one of Australia's Top 100 public companies.

Minara Resources (*formerly Anaconda Nickel Limited*) was founded in 1994, owns and operates the world-class

Cont'd on page 36

Monash wins USGS support for passive seismic method

Michael Asten
School of Geosciences
Monash University
Melbourne VIC 3800

Email: Masten@mail.earth.monash.edu.au

The passive seismic method, making use of microtremor seismic energy generated by road traffic, industrial machinery, and meteorological sources such as wave action, is a subject of research efforts world-wide in the task of site investigation, especially for earthquake hazard zonation.

Michael Asten, Professorial Fellow at Monash, is working with groups in Geoscience Australia, the US Geological Survey and IGNS New Zealand to develop the method and compare results with alternative active seismic technologies. The US Geological Survey recently recognised the contributions made by Monash University, with the award of a grant of US$55,000 under its External Research Grants Program, for studies assessing the method for site zonation in the Santa Clara Valley, California. The valley is at significant risk of earthquake damage due to its proximity to the San Andreas Fault, and to its large thickness of up to 1 km of soft Holocene-Pleistocene sediments.

The collaboration between Monash and the USGS builds on a series of three seed projects funded by Geoscience Australia. These projects are trialling microtremor array methods in the Newcastle (NSW), Perth (WA) and Botany Bay (NSW) metropolitan areas with contributions from GA geoscientists Trevor Jones, Trevor Dhu and Andrew Jones.

Michael Asten commented: "The microtremor array method works well in the very areas where conventional seismic methods are difficult to justify for reasons of cultural noise, environmental restraints and safety. Green belts and sports grounds are ideal sites for investigations, with the only environmental impact from a survey being worm-holes created by geophone spikes."

Monash is also investigating the method for geotechnical site studies as part of a project by PhD student, James Roberts. Work in progress demonstrates how the method can resolve the thickness of paleo-river valley sediments (order 20 m thick) under high-velocity Pleistocene basalt (order 15 m thick).

The ASEG has played a significant part in making available to the western world recent developments in Japan in microtremor methods. A Japanese text by Prof. Okada (University of Hokkaido) was translated by Koya Suto, and has just been listed by the SEG as a joint SEG-SEGJ-ASEG publication, with Michael Asten as Volume Editor.

Michael Asten (R) and James Roberts examine a seismometer mounting fabricated at Monash, designed to maximize ground coupling while causing minimal damage to turf-covered survey sites.

Cont'd from page 35

Murrin Murrin nickel cobalt joint venture project (60% Minara, 40% Glencore International AG) near Leonora in Western Australia's historic northern goldfields region.

Murrin Murrin is a world-class hydrometallurgical project, using sulphuric acid in high-temperature, high-pressure autoclave vessels to aggressively leach nickel and cobalt from low-grade lateritic (oxidised) ores.

At design capacity, the Murrin Murrin nickel plant produces 40,000 tonnes of LME A Grade nickel metal at a cash cost of between US$4.5-$5.5/kg, making it one of the world's largest and lowest cost nickel producers.

The Murrin Murrin project has total resources of 327 million tonnes, using a cut off grade of 0.8% nickel, and total mining reserves of 145 million tonnes at 1.07% nickel (Ni) and 0.085% cobalt (Co).

Based on current reserves and resources, the Murrin Murrin project has sufficient ore for the next 30 years of operations.

ASEG Research Foundation

More project results

The ASEG Research Foundation has been supporting students in all facets of applied geophysics at the BSc (Honours), MSc, and PhD (or equivalent) levels for 13 years. In this issue of Preview we summarise the work carried out by Daniel Galda at Macquarie University.

Project Title: A non-invasive and economical surface seismic method, which provides estimates of elastic moduli of near-surface layers

Honours Title: Determination of the elastic properties of alluvium

Supervisor: Mark Lackie (Macquarie University)

Funding: $3,956

Project Summary

The elastic properties of alluvium are of use in geotechnical, engineering and geophysical projects, with applications in borehole stability, predicting sand production and compaction/subsidence studies just to name a few. This project aims to provide an effective, efficient, non-intrusive and inexpensive way of determining the elastic properties of alluvium.

Using both vertical and horizontal geophones, both *P*-wave and *S*-wave records were recorded in the very near subsurface (top 0-50 m) on a field site located near St Albans, NSW. The methods of collecting, as well as processing the data, were analysed to determine which methods are the most effective. All lines were shot a total of three times, once with the vertical geophones, once with the horizontal geophones aligned parallel to the direction of the line (inline) and once with the horizontal geophones aligned perpendicular to the line (crossline). This enabled good three-component seismic data to be gathered.

Using three separate processing packages, the subsurface of the study site was interpreted to contain three main layers and the elastic properties of the upper two layers (consisting of alluvium/sand) were determined from this data. The seismic velocities were interpreted to be in the expected range of sand for the top layer, more compacted sand and highly weathered material for the second layer and Hawkesbury Sandstone for the third bedrock layer. The near subsurface, consisting of unconsolidated sand and highly weathered sandstone has very low *P*-wave velocities of between 250 and 400 m/s. *S*-wave velocities are also very low, between 188 m/s and 216 m/s, showing a marked anisotropy which can be attributed to lithological anisotropy, such as grain alignments or fine layering caused by the geomorphological effects of the fluvial environment.

The methods used were successful in detecting minor changes in the subsurface caused by changes of the environment in the past. The elastic properties, Young's Modulus, Shear Modulus, Bulk Modulus and Poisson's Ratio, were also calculated to be in the expected and accepted range for sand/alluvium and sandstone.

The elastic properties were all sensitive to relatively small changes in the density and seismic velocities, which in turn were sensitive to small changes in subsurface composition and structure (e.g. grain alignments, fine bedding). The elastic properties showed good correlation with published values.

Outcomes

The principal outcomes of the project were:

1. A surface seismic method using horizontal and vertical geophones could determine the elastic properties of alluvium; and

2. Analysing *S*-wave data allowed the anisotropy of the near-surface layers to be determined; this could assist understanding the geomorphology of a site.

Fig. 1. 'The S-wave Source' and four-wheel-drive as used in the field.

Fig. 2. Daniel Galda at work; sledgehammer and metal base plate for P-wave source as used in the survey.

Down to Earth Space Technology

A project by the Australian Space Network and the Australian Space Industry Chamber of Commerce to bring technologies developed in pursuit of scientific objectives in space to Australia's minerals, mining and exploration activities.

Overview

Australia's minerals, mining and exploration industries demand better exploration and mining technology; needs which are made abundantly clear in reports by the Strategic Leaders Group, the Australian Bureau of Agricultural and Resource Economics and others. The benefit to Australia of improved technology in these areas is enormous, potentially billions of dollars a year. The overall objective is to provide Australian (David - What does SME stand for - write out in full first time) SMEs the knowledge and contacts necessary to take up technologies developed by and for the European Space Agency (ESA) that are applicable to many mining and exploration endeavours. These technologies will be of interest to many companies who are involved in such activities, particularly SMEs who do not have headquarters overseas or ready access to technology produced by large international efforts such as ESA undertakings. The project will be conducted in two phases: firstly an initial round of workshops to consult with industry leaders, associations and other interested organisations; and secondly workshops for all relevant companies and organisations to introduce them to the technologies considered by the first round to have the most potential benefit.

The phase 1 series of workshops with industry leaders and industry associations will:

- Discuss ESA technologies which have found relevance to European mining and exploration interests;
- Discuss the particular needs of Australian companies, particularly SMEs, for technological improvements in their activities;
- Consider whether needs uncovered might benefit from ESA technologies other than those initially considered;
- Produce a set of technologies and a draft program that will be suitable for the phase 2 workshop series to be held at a later date, in which all relevant SMEs and other companies will be invited to participate.

These workshops will be conducted by the European Space Agency Office of Technology Transfer and Promotion (ESA/TTP). Participants will be given ample opportunity to present the concerns and views of their member companies and industry associates. In this way we will ensure that the major workshops to come will be driven by industry demand rather than technology push. This initial series in and of itself will be of enormous benefit to Australia's mining and exploration companies as they learn about the outcomes through their respective industry associations and organisations.

The document resulting from this workshop series will be widely distributed to interested parties.

Market Drivers and Opportunities

The report "Research and Development in Exploration and Mining: Implications for Australia's Gold Industry" from the Australian Bureau of Agricultural and Resource Economics notes the value of gold exports alone rising from around $500 million p.a. in 1985 to $4.7 billion today with an additional $3.6 billion p.a. possible by 2015, largely thanks to scientific advances in gold exploration. The Federal Parliament's Prosser Inquiry into Impediments to Exploration, the Federal Minister's Strategic Leaders Group (SLG) report (part of the Mineral Exploration Action Agenda) and the West Australian Government's Bowler report all emphasise the benefit of better exploration technology.

Technology derived from European Space Agency (ESA) activity flows fairly quickly to companies with a European or Canadian base. However, Australia has minimal involvement with ESA and to date there has been no systematic program to bring such technologies to Australian SMEs involved in minerals, mining and exploration, who are therefore at a disadvantage.

With industry restructuring having made it more difficult for SMEs to access capital, and with decision making in larger companies tending to move offshore, according to the SLG report, it is more important than ever to give our SMEs the tools they need to be competitive and efficient. Technologies covered in this project will have application in several areas such as enhanced pre-competitive geoscience data and increased efficiency through automation.

The Workshops

Six workshops will be held across Australia, beginning June 1st in Perth and finishing June 10th in Adelaide. The main purpose of the workshops is to discuss with the leaders and representatives of Australia's SMEs in the minerals, mining and exploration sector applicable ESA-derived technologies. These technologies have been developed by and for the European Space Agency in pursuit of its space science and exploration activities. Topics will include:

- Small Scale Mining
- Georange Superconducting Quantum Interference Devices
- Results of the Harsh Environment Initiative
- Development of ground penetrating radar for mining
- Application of shape memory alloys to ornamental stone splitting

- Robotics and Automation at ESA
- Life Support for space missions and their potential for technology transfer
- Galileo/EGNOS Navigation systems for the future
- Drilling and sampling in ESA programmes: development and mission applications
- Technologies and benefits from a lunar exploration
- Technology Transfer opportunities within the Mars Express Lander - Beagle

A second purpose is to look at the needs of the MM&E sector in Australia in order to discover whether there are other ESA technologies not presented which could be of value.

The workshops will discuss how these technologies can benefit the minerals, mining and exploration industries. They will also elicit from the attendees their particular problems and needs and look at ways of addressing these needs with the technologies presented or other technologies sourced from ESA and partners or members of the Australian Space Industry Chamber of Commerce and the Australian Space Network.

The output of these workshops is designed to serve as a means of generating a program for the phase 2 technology transfer workshop series. While the follow-on series is aimed at all industry participants, particularly SMEs, this first series is a necessary part of the process that ensures that technologies covered in the larger workshops will be driven by industry demand rather than technology push. This first series will have great value in and of itself by way of educating industry organisations about ESA-derived technologies and how to access them but viewed in the context of the larger program including the follow-on technology transfer workshops its value is considerably enhanced.

Industry associations and organisations, as well as senior industry people, are invited to attend. They will meet a senior representative from ESA/TTP, as well as being introduced to the Australian Space Network and Australian Space Industry Chamber of Commerce. Workshop attendees who identify technologies suitable to their needs will be able to access these technologies through these bodies.

Follow-up Activities

The document resulting from the workshops will be distributed to workshop participants, industry associations, CSIRO Minerals and Exploration, the Australian Space Network, Australian Space Industry Chamber of Commerce, and interested government organisations. It is expected that these organisations will pass the results of the workshops back to their constituents. This will serve to raise awareness of the issues and generate high interest in the major technology transfer workshops to follow.

With the output of the workshops, a program will be crafted for the upcoming major technology transfer workshops which are planned to run in the July-September quarter, 2004.

Benefit to Australia

There are many aspects to mining and exploration and many products - mineral and energy - which are extracted as a result. The technologies discussed in these workshops apply to several of these aspects and to many of the products. Broad categories are:

- Increasing the efficiency of exploration
- Drilling and sampling
- Automation and robotics
- Autonomous operation and navigation
- Safety: life support systems
- Operating in harsh environments

Improvements in any of these areas will increase the competitiveness of those companies involved.

The Federal Minister's Strategic Leaders Group report, part of the Mineral Exploration Action Agenda, in Recommendation 8 (p20) underlines the value of pre-competitive geoscience information by recommending program expenditure of $25 million p.a. through 2014 in this area. Technologies covered in this workshop are directly relevant here.

Besides geophysical data, other new tools required by Australia's SMEs include ways to reduce drilling costs and automation (see 'Lifting the Lid' by Mike Sydell, *earthmatters*, CSIRO Exploration and Mining, Dec 03). Technologies for these areas are also included in the workshops.

A key challenge that this workshop series addresses is that our SMEs do not have a programmatic way of learning about and gaining access to cutting-edge technologies developed overseas. It is not that we need just one, or several, of the technologies discussed. Australia does some excellent work in the exploration and mining area but as a middle-sized country our research and development contributions are limited by modest budgets and facilities compared to our larger overseas competitors. Our SMEs are therefore at a disadvantage. This is compounded by Australia not being systematically involved in the large global space programs which, being scientific and heterogeneous in nature, consistently produce technologies applicable to many areas of the economy for their participants.

Cont'd on page 40

Australian Capital Territory

By Benjamin Bell
Email: ben.bell@ga.gov.au

The final technical meeting of 2003 saw Alexey Goncharov from Geoscience Australia present his re-interpretation of the Bedout High in the offshore Roebuck/Canning Basin at the Australian North West Margin as a massive impact structure that appears to be associated with the global Permian/Triassic extinction event.

This impact appears to have significantly modified the crustal structure in the region. Trying to explain some of Roebuck Basin features, Goncharov hypothesised that the meteorite impact may have initiated a major episode of crustal under-plating in the basin.

The protracted thermal/fluid events associated with this under-plating may have rendered the Roebuck Basin 'sterile' of Triassic-Jurassic sourced hydrocarbons which are ubiquitous across other parts of the North West Australian margin, and thereby explain recent deep water exploration well failures in the region.

The 2003 activities of the ACT Branch concluded with a Christmas Party where oversized steaks were washed down with cold pints of beer. By all accounts, it was an enjoyable and relaxing event successfully organised by Trevor Dhu.

I would also like to remind members of the Branch's upcoming AGM on Wednesday March 3rd at Geoscience Australia, commencing at 4:00pm. Nominations, or questions pertaining to the duties of a particular position, should be directed to David Robinson on 6249 9156 or David.Robinson@ga.gov.au.

Cont'd from page 39

Technology derived from ESA activity flows fairly quickly to companies with a European or Canadian base. However, Australia has minimal involvement with ESA and to date there has been no program to bring such technologies to Australian SMEs involved in minerals, mining and exploration. The current project aims to remedy this in two ways. Firstly, by introducing current ESA technology to Australian SMEs, the existing technology gap can be closed. Secondly, by creating contacts and relationships through networking at the workshops, and having ASN and ASICC to maintain institutional knowledge of ESA activities and personnel, it becomes possible for technology transfer to occur on a continuing basis.

The benefit to Australia is therefore that Australian SMEs gain knowledge of and access to technologies that will make them more efficient in a number of areas, thus making them more competitive with respect to international companies large and small. A further benefit is that relationships formed amongst the workshop participants will allow this process to continue more easily in future.

Specific Outcomes:

1. Australian mining and exploration organisations and associations are made aware of a range of relevant technologies, together with contacts necessary to access these technologies.
2. Tools and techniques needed but not covered by this workshop series will be flagged so that other relevant technologies may be incorporated in the follow-up series.
3. A program will be developed for a subsequent, more detailed series of technology transfer workshops, which will be customised to ensure it is driven by Australian industry demand.
4. The outcome of the workshops will be made available to participating bodies and industry leaders. This will summarise both the technology talked about and Australian industry concerns. It will also serve to publicise the follow-on workshops to the members and constituents of these organisations.

Why are ASN and ASICC Promoting This Workshop Series?

Demonstrating the value of space-derived technologies to other economic sectors will increase the profile of, and appreciation for, space-related activities. ASICC is an industry association; the Australian Space Network encompasses both industry and the research community. Both organisations believe that by promoting this event, even though the featured technologies are global rather than local, the benefits of Australian space-related efforts will be better understood by the community at large and that further opportunities for Australian companies and researchers will flow from this.

Also, by having the opportunity to discuss technologies currently in use by the minerals, mining and exploration communities with a view to possible transfer to the aerospace sector, there is a possibility of providing direct economic benefits to the memberships. Increasing the visibility of Australian endeavours in the area of space, and increasing opportunities for Australian business and science is very much core work for ASICC and ASN.

For more information please contact:

Philip Young,
Network Coordinator,
Australian Space Network,

Tel: 02 9614 1900;

Email:
philipyoung@optushome.com.au