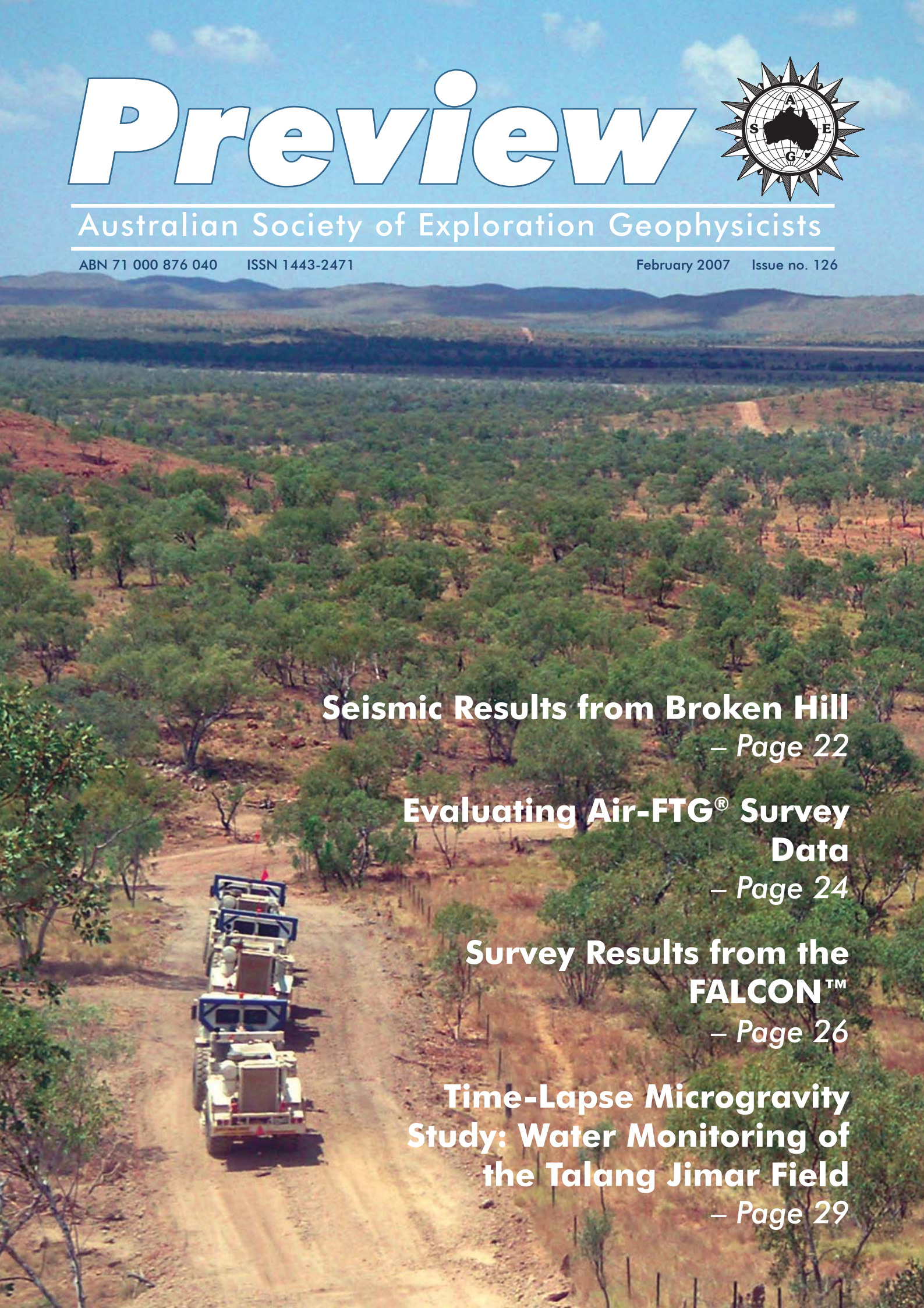
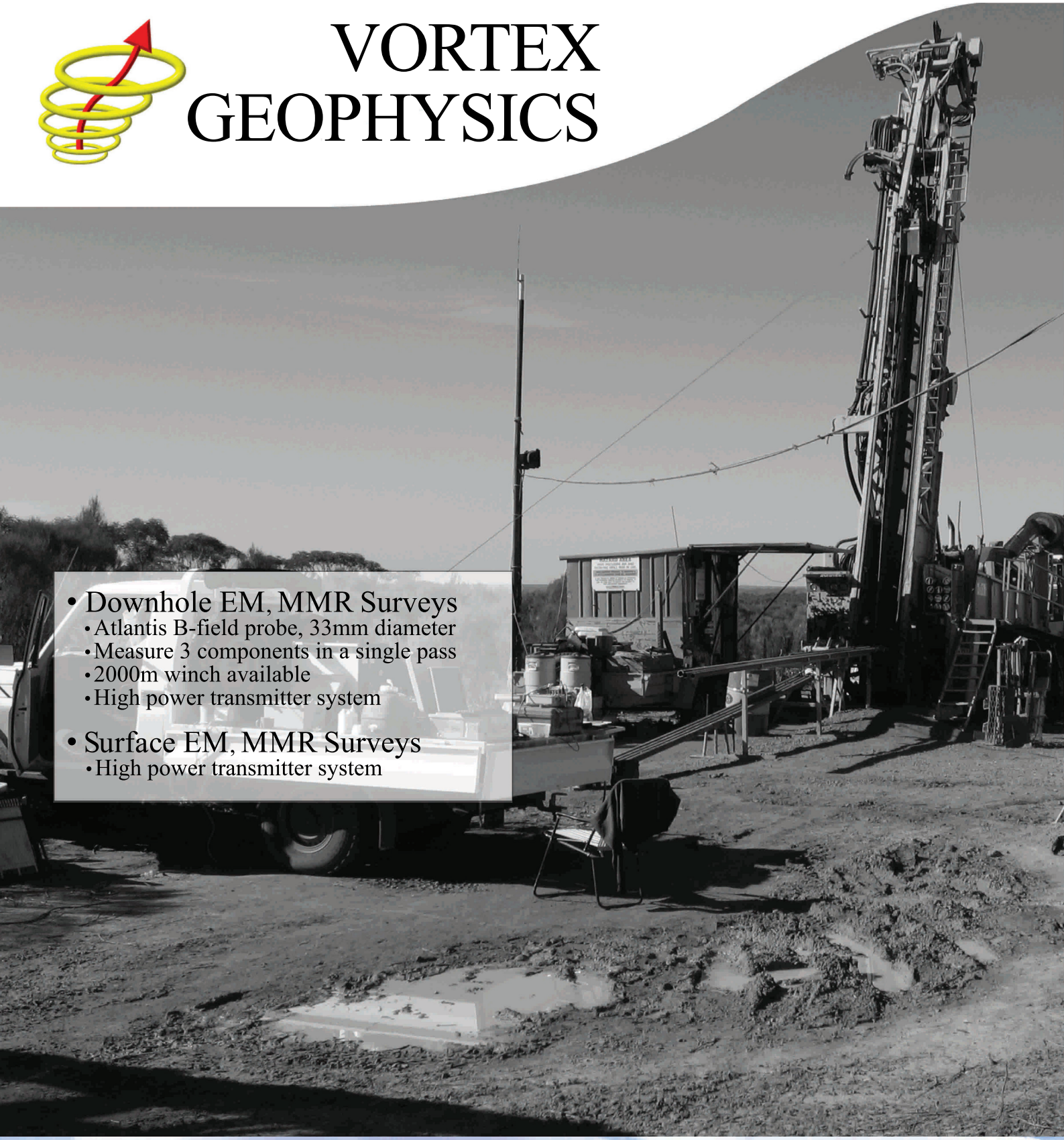
Preview

Australian Society of Exploration Geophysicists

ABN 71 000 876 040 ISSN 1443-2471 February 2007 Issue no. 126



VORTEX GEOPHYSICS



- Downhole EM, MMR Surveys
  - Atlantis B-field probe, 33mm diameter
  - Measure 3 components in a single pass
  - 2000m winch available
  - High power transmitter system
- Surface EM, MMR Surveys
  - High power transmitter system

Contact: Allan Perry, Manager
8 Hart St, Lesmurdie W.A. 6076 AUSTRALIA. Ph (08) 9291 7733 Fax (08) 9291 7737 Email: sales@vortexgeophysics.com.au
www.vortexgeophysics.com.au

10.1071/PVv2007n126

Advertisers

2007 Corporate Plus Members

BHP Billiton Minerals Exploration
Velseis Pty Ltd

2007 Corporate Members

Beach Petroleum NL
Chevron Australia Pty Ltd
Department of Primary Industries Victoria
Earth Resource Mapping
Encom Technology Pty Ltd
Eni Australia Limited
Fugro Airborne Surveys
Geosoft Australia Pty Ltd
Geoscience Australia
Haines Surveys Pty Ltd
Inco Resources (Australia)
Multiwave Geophysical Company
Oil Search 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
Santos Ltd
Seismic Asia Pacific Pty Ltd
Veritas DGC
WesternGeco
Woodside Energy Ltd
Zonge Engineering & Research Organisation

CONTENTS

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

Editor
David Denham
Tel. & Fax: (02) 6295 3014
Email: denham@webone.com.au

Publisher
CSIRO Publishing
Production Editor: Helena Piraino
Tel.: (03) 9662 7644
Fax: (03) 9662 7611
Email: helena.piraino@csiro.au

Advertising: Elspeth Gardner
Tel.: (03) 9662 7668
Fax: (03) 9662 7555
Email: elspeth.gardner@csiro.au

Associate Editors

ASEG Head Office & Secretariat

Content

Advertising and editorial content in *Preview* does not necessarily represent the views of the ASEG unless expressly stated. 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 ASEG. Permission to reproduce text, photos and artwork must be obtained from ASEG through the Editor. We reserve the right to edit all submissions.

Contributions

All editorial contributions should be submitted to the Editor via email at denham@webone.com.au.

The text of all articles should be transmitted as a Word document. Figures and illustrations should be transmitted as separate files, not embedded in the Word document. Photographs and line drawings should be of the highest quality and, if not created digitally, should be scanned at high resolution: photographs at 300 dpi at final size, saved as .jpg files; hand-drawn line drawings at least 600 dpi at final size, saved as .tif files. Computer-generated graphs and diagrams should be saved in one of the following formats: Excel, Powerpoint, encapsulated postscript (.eps), Adobe Illustrator (.ai), Windows metafiles (.wmf). In all cases they must be editable vector graphic files. Please contact the Production Editor for further information.

References

References should follow the author (date) system. They 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. 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 in, February, April, June, August, October and December. The deadline for submission of material to the Editor is the 15th of the month prior to the issue date. Therefore the deadline for the April 2007 issue is 15 March 2007.

Advertising copy deadline is the 19th of the month prior to issue date. Therefore the advertising copy deadline for the April 2007 issue will be 19 March 2007. A summary of the forthcoming deadlines is shown below:

Preview issue	Text and articles	Advertisements
127 Apr 2007	15 Mar 2007	19 Mar 2007
128 Jun 2007	15 May 2007	19 May 2007
129 Aug 2007	15 Jul 2007	19 Jul 2007
130 Oct 2007	15 Sep 2007	19 Sep 2007

ASEG ANNUAL GENERAL MEETING

The 2007 Annual General Meeting of the Australian Society of Exploration Geophysicists will take place at **5:30 pm, on Wednesday, 30th May 2007, at Chifley on the Terrace, St Georges Terrace, Perth, WA.**

Be there to make a difference!

For more information, contact Lisa Vella c/- ASEG Secretariat at secretary@aseg.org.au, or Tel: +61 8 9427 0838.

INVITATION FOR CANDIDATES FOR THE FEDERAL EXECUTIVE

In accordance with Article 14.1.12 of the ASEG Constitution, any Member may nominate any other eligible Member for any of the following elected offices of the Federal Executive:

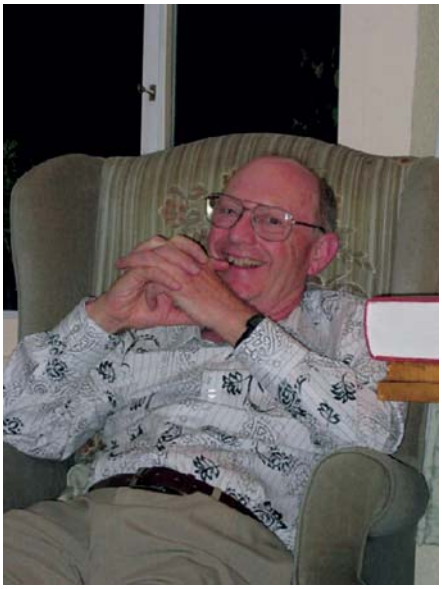
- President
- President-elect
- Secretary
- Treasurer

by forwarding the name of the nominated candidate to the Secretary

Lisa Vella
c/- ASEG Secretariat
PO Box 8463, Perth Business Centre, WA 6849
Tel: +61 8 9427 0838
Fax: +61 8 9427 0839
Email: secretary@aseg.org.au

All candidates must be willing to give written consent when requested, and support from nine additional members will be sought for all nominations.

Nominations must be received via post, fax, or email no later than Wednesday, 21st March, 2007. Positions for which there are multiple nominations will then be determined by postal ballot of Members and results declared at the Annual General Meeting.



David Denham

New Publisher for ASEG

2007 is the beginning of a new era for ASEG with the appointment of a new publisher for the Society. As of 1 January 2007 **CSIRO Publishing** will be responsible for publishing Preview, Exploration Geophysics and the Membership Directory. This edition of Preview is the first product under the new arrangements.

CSIRO Publishing is an autonomous business unit within Australia's premier research group CSIRO. Its range of products includes journals, books and magazines in both print and digital formats. Every year it produces approximately 50 new scientific and technical books and CD-ROMs with a backlist of over 1200 titles.

It has over 55 year's experience of publishing journals, which contain the latest research by leading Australian and overseas scientists over a broad range of subjects. All their journals are peer-reviewed and are widely indexed, with a broad international readership and subscribers in over 100 countries. ***Exploration Geophysics*** will now be added to its list of journals.

CSIRO Publishing also produces the magazine ***ECOS***, which is arguably Australia's most authoritative magazine on sustainability. It is published bi-monthly both in print and online, and contains lively, incisive articles on key sustainability research and issues from across Australia and the Asia Pacific region. It will now add ***Preview*** to its magazine stable.

CSIRO Publishing will also be managing sales and marketing, including advertisements, in all the ASEG publications.

The key people in CSIRO are:

Richard Hecker, who will oversee and coordinate CSIRO Publishing's work with the ASEG and both ***Preview*** and ***Exploration Geophysics***; Helena Piraino who will be responsible for the production of ***Preview*** and Elspeth Gardner, who will be responsible for sales and marketing.

Their contacts are:

Richard Hecker
Tel: 03 9662 7632,
Email: richard.hecker@csiro.au

Helena Piraino
Tel: 03 9662 7644,
Email: helena.piraino@csiro.au
Elspeth Gardner
Tel: 03 9662 7668,
Email: elspeth.gardner@csiro.au

And their address is:

CSIRO PUBLISHING
150 Oxford Street (PO Box 1139)
Collingwood VIC 3066
AUSTRALIA

For those who would like to find out more about CSIRO Publishing, their website is: http://www.publish.csiro.au/.

I look forward to a fruitful partnership between ASEG and CSIRO Publishing.

I would also like to take this opportunity to thank RESolutions for their endeavours over the past seven years in producing 33 issues of Preview, and would like to wish Brian Wickins and his team well in the future.

Australian Tsunami Warning Centre launched

The Geoscience Australia Operations Hub of the newly established Australian Tsunami Warning Centre (ATWC) was opened in December 2006 in Canberra by the Industry Minister, Ian Macfarlane, as part of the Australian Government's response to the 2004 Indian Ocean tsunami.

GA's Hub will detect earthquakes in the region and determine whether they are likely to cause a tsunami by examining the

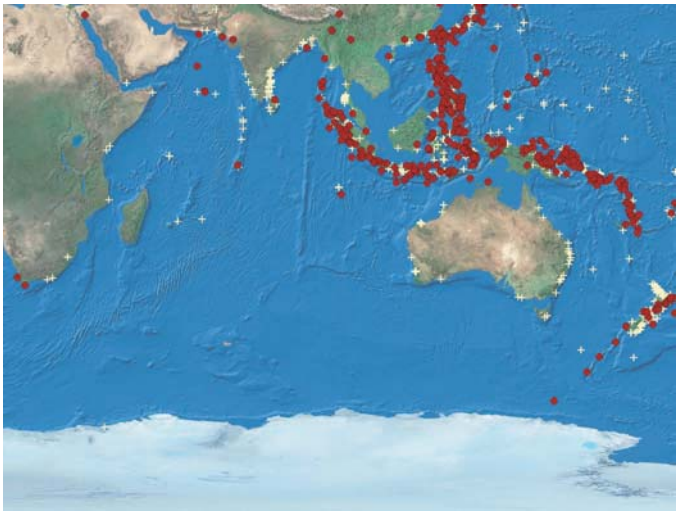


Fig. 1. The locations of tsunamigenic earthquakes (red disks) and places where tsunami run-ups have been measured (yellow crosses) in the Australian region.

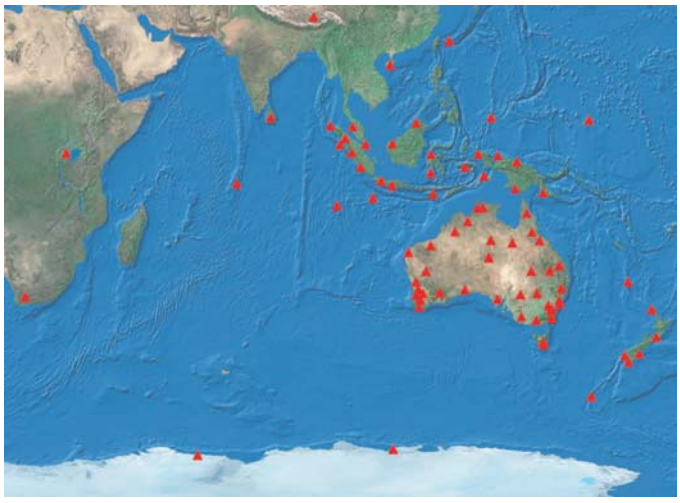


Fig. 2. Seismic stations in the Australian region currently monitored by Geoscience Australia.

magnitude, location, depth and other seismic parameters (see Figure 1). The Bureau of Meteorology will collect tide-gauge data, and the two agencies will work together to determine whether a tsunami warning should be issued.

The Hub will run a 24/7 operations, monitoring around 39 Australian seismic stations and 70 overseas stations at any one time (see Figure 2). This information will be shared with other countries in the region.

The ATWC, to be launched by mid-2007, is part of the Australian Tsunami Warning System (ATWS): a collaborative project involving Geoscience Australia, the Bureau of Meteorology, Emergency Management Australia, and AusAID. The program is coordinated by the Department of Foreign Affairs and Trade.

The role of the ATWS is to provide a comprehensive tsunami warning system for Australia, support international efforts to establish an Indian Ocean Tsunami Warning System and contribute to the facilitation of tsunami warnings for the South Pacific.

In opening this Operations Hub, Minister McFarlane said 'I hope it never has to function in the face of a catastrophe on the scale of the Indian Ocean earthquake and tsunami of 26 December 2004. This Operations Hub is a step towards increasing Australia's capability to respond effectively in the face of another natural disaster.'

The establishment of the Operations Hub within two years of the Indian Ocean Boxing Day tsunami, is testament to the political commitment of the government and the technical skills and facilities at Geoscience Australia. It is an excellent achievement and all those involved are to be congratulated. It is not easy to overcome the political, technical and fiscal challenges in such a short time for such a major undertaking.

$68.9 million was allocated over four years only in the May 2005 Budget; so the current system has taken only about 18 months to come to fruition – quite remarkable.

The ATWS will be one of the first Indian Ocean regional warning systems, and will join the planned network of national systems, which collectively will form the Indian Ocean Tsunami Warning System (IOTWS). The ATWS will also facilitate warnings issued in the South-west Pacific through the Pacific Tsunami Warning System (PTWS).

There will be an enhanced tsunami modelling capability together with an improved sea level monitoring network, which will include an expansion and upgrade of existing sea level stations and deployment of new Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys.

A very impressive achievement.

For more information contact, Spiro Spiliopoulos 02 6249 9494 or via email at: spiro.spiliopoulos@ga.gov.au.

Geophysicists scarce as hens' teeth

Following on from ***Is the sky falling?*** which was an account of a Canadian's view of the geophysics skills shortage, reported in the December 2006 *Preview* (p. 3), another report on this topic crossed my desk the other day. It was written by the British Geophysical Association, which is a joint Association of the Royal Astronomical Society and the UK Geological Society. The study aimed to:

- Assess the present state of geophysics education in the UK
- Identify the problems that need to be addressed and
- Make recommendations that will ensure a healthy crop of geophysics graduates able to satisfy the short-term national requirement, and train the next generation in the longer term.

Surprise, surprise, the main findings were that: 'If current rates of decline continue there will be no geophysics undergraduates by 2030 and that the problem is global.'

The report contained all the usual words:

'Geophysics is fundamental to the needs of society. It is essential in exploring for energy, water, and mineral resources; monitoring environmental impact and change; assessing natural and manmade hazards; in subsurface investigations for engineering and archaeology; and forensic science. The growing demands of industry and government service are facing a severe shortage of trained UK graduates with geophysics skills. For example, by 2030, despite efforts to develop alternative sources, nearly 2/3 of the world's energy will still be coming from oil and gas requiring many geophysicists to explore for the 50% increase in supply required by that time. However the population in the industry is aging while the numbers of students entering university to read geophysical science are falling and courses are being discontinued.'

Recommendations

The recommendations were also hardly surprising:

- Increase the awareness of geophysics in schools by including more geophysical topics in the physics curriculum.
- The learned societies should work with industry to increase the promotion in schools and universities of geophysics as a career.
- There is an urgent need to develop geophysics courses for physics teachers.
- A Geophysics Promotion Officer should be appointed, for two years at least, to facilitate these new activities.
- Websites like the *Schools Network* and the Science Council's *Careers from Science* should highlight information on geophysics and the careers it offers.

It's time we tried to make a bigger impact on this issue in Australia, because there must be common ground in the exploration companies and the professional geoscience societies. Maybe we should aim to fund a promotions officer from our resources and help from the companies. It seems to me the time is ripe for such a move.

Congratulations to Jennie and Selina

Finally, it is a real pleasure to announce two marriages. Over the festive season, Jennie Powell of Web Waves fame changed her name to Carson, while Selina Donnelly, the Chairperson of the SA Branch of the ASEG changed her's to Wallace. On behalf of the ASEG, I would like to extend our congratulations and very best wishes for the future both to Jennie and Selina and their spouses.

David Denham

Plans for Perth, November 2007

The 19th International ASEG Conference and Exhibition is to be held at the Perth Convention Centre from 18–22 November, 2007. This is scheduled to allow for DISC and workshops on Sunday 18th November, followed by up to five streams of technical sessions from Monday to Wednesday 21st November, with specialist workshops on Thursday 22nd November. The Exhibition will be open during the icebreaker on Sunday, and then Monday through Wednesday (3 days + icebreaker).

The conference will be jointly run with the Petroleum Exploration Society of Australia (PESA), and the Formation Evaluation Society of WA (FESWA), which will have its own additional stream all day Tuesday. Thursday will also be the ASEG/PESA Golf Day.

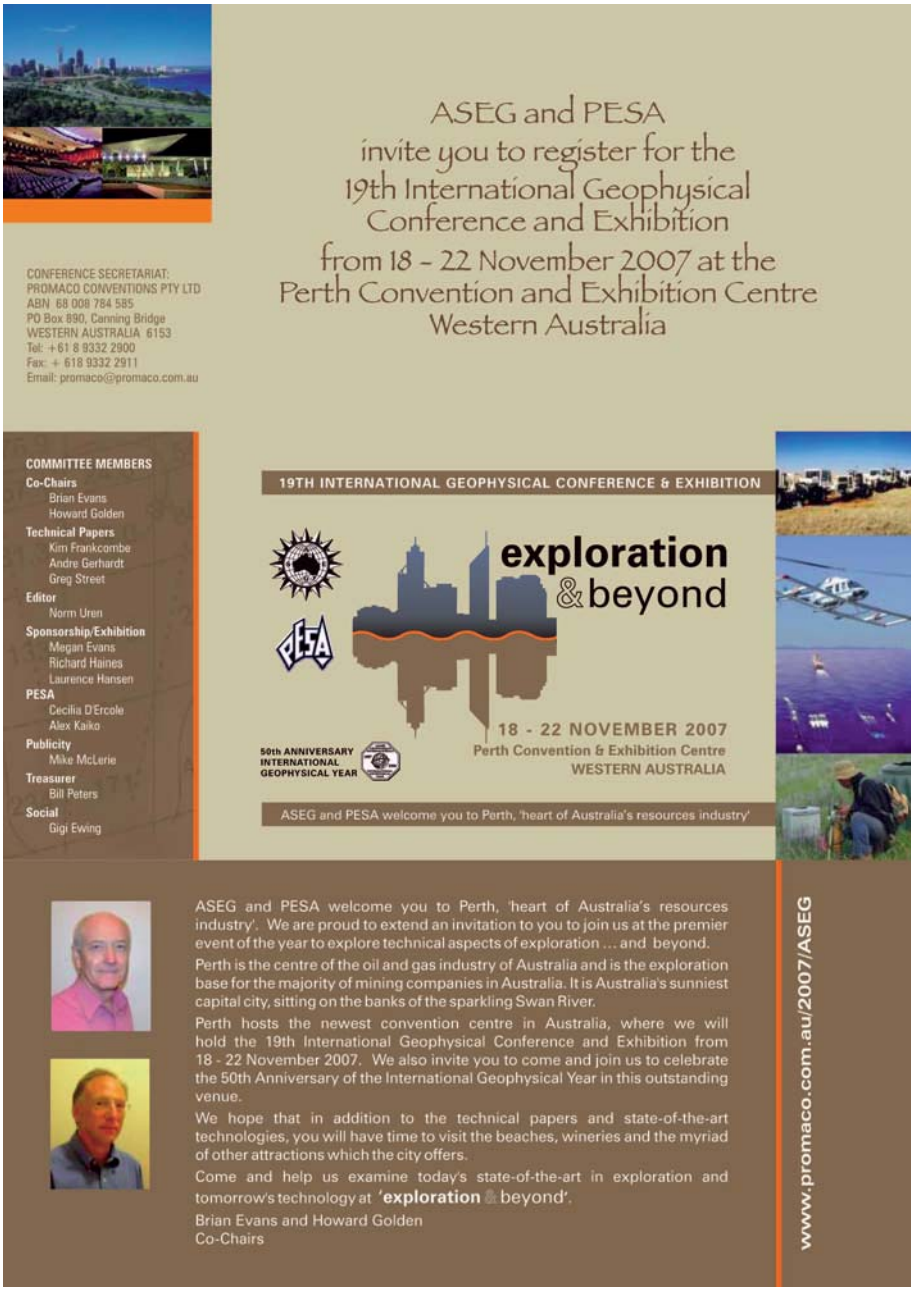
The technical streams are as follows, and the final *Call for Papers* will be sent out during February:

Minerals

- Case histories – WA
- Case histories – Rest of World
- Iron Ore
- Uranium
- Sea-bed exploration
- Deep penetration geophysics
- Crustal-solid earth
- Global data sets
- Inversion
- Seismic in mineral exploration

Petroleum

- Seismic acquisition
- Anisotropy and multicomponent
- AVO



- Formation evaluation/petrophysics/ borehole geophysics
- Interpretation and case histories
- Reservoir characterisation
- Rock properties
- Seismic modelling and inversion
- Seismic processing
- Time lapse/CO_2 sequestration

Non-seismic

- Electromagnetics
- Gravity and magnetics

Environmental

- Groundwater
- Soil mapping
- Mine site environmental and engineering geophysics
- Forensic geophysics and Archeology
- Contaminated site geophysics
- Environmental impact of surveys

General

- We are planning the opening session to be focused on *Peak Oil*.
- There will be one or two sessions on the solid earth.
- There will be an Instrument Forum.
- It is proposed to hold presentations on case histories of specific world areas such as the Gulf of Mexico, the Middle East and the Far East.
- The Environmental streams will be run as a Groundwater Day, a general Environmental Day and an Engineering Day.
- FESWA will run their stand-alone stream all day Tuesday.

For further information please contact

Brian Evans (evans@geophy.curtin.edu.au), Howard Golden (golden1@iinet.net.au), Kim Frankcombe for minerals (kfrankcombe@iinet.net.au), Andre Gerhardt for petroleum (andre.gerhardt@woodside.com.au), Greg Street for environmental (gstreet@iinet.net.au), Steve Pickering for petroleum workshops (spickering@gxt.com), or Barry Bourne for minerals workshops (bbourne@barrick.com).

Any of the above would also welcome any comments on the proposed program and proposals to present papers.

Third International Seminar of the AEG, Hyderabad, India, 6–12 November 2006

The Indian Association of Exploration Geophysicists (AEG) was established in

Colourful students from Osmania University who, along with others, stood all day at the doorways to 'welcome' delegates.

Mr & Mrs Sivasubramanian of Electrotek (Roger's agents) with the terraTEM making its first appearance in India.

1974 (soon after the ASEG) but despite the country's growing population of well-educated professionals, its membership is only 1493. Nevertheless, it holds an annual meeting in a different city every year and in Hyderabad this year, it was combined with the 3rd International meeting. Previous international meetings were also held in Hyderabad, the location of the National Geophysical Research Institute (NGRI) and Osmania University.

This year, the venue was a brand new convention center/hotel combination. For those not staying in the very expensive conference hotel, it meant an agonizing car trip from the city and airport lasting up to an hour depending on how horrendously chaotic was the traffic. The plenary auditorium was 3 storeys high with seating for 2000 and adjacent to it was a smaller hall for the exhibition which had 30 booths. Only a few local organizations had more than one standard-sized booth and the largest and winner of the best exhibit prize was the Directorate General of Hydrocarbons (DGH).

Two workshops were held in the two days before the main sessions, one on Resistivity Imaging by AGI from Austin, Texas and the other on Airborne Geophysics, convened at the request of AEG by Colin Reeves of the Netherlands. Colin also convened a similar workshop at the 2nd International meeting 10 years earlier and he is regarded in India as the authority on the country-wide compilation of airborne surveys.

Of the three days of technical sessions, all of the first day, the morning of the second and the late afternoon of the third were plenary. Three parallel sessions were held in smaller rooms for the remaining 1.5 days. The categories were generally hydrocarbons, minerals and ground water/engineering. Uranium exploration was a popular topic, not surprisingly given India's commitment to nuclear power generation. A paper titled 'The Fallacy of Bouguer Anomaly in Geophysical Exploration' caused more heated questioning than was sometimes the case with other papers. The full program can be seen at: http://www.aegindia.org/Program Schedule.aspx.

I was pleased to renew acquaintance with John Sumpton, who, while still a member of ASEG, is now a resident of Bangalore, where he is in charge of De Beers' exploration program for diamonds in India. John explained that the Zeppelin airship they use in Botswana as a platform for gravity gradiometry, and about which David Hatch gave a paper at the conference (as he did at the 18th ASEG conference), can only be transported intact and hence only by ship and is therefore unlikely to be used in India.

Roger Henderson

18th IAGA Workshop on Electromagnetic Induction in the Earth, 17–23 September 2006

Since 1972, the International Association of Geomagnetism Aeronomy (IAGA) Working Group I-2 on Electromagnetic Induction in the Earth has organised a biennial Workshop on Electromagnetic Induction in the Earth. In September 2006, this was hosted by the Universitat de Barcelona at El Vendrell, Spain. This was a truly international workshop with over 200 participants fairly drawn from the Australasian, African, Asian, European and North and South American EM research and exploration communities. The Australian contingent was represented by The University of Adelaide, CSIRO Exploration and Mining, RMIT University and Woodside.

The workshop program spanned five and a half days, including a full day excursion to Barcelona. Historically, the workshop has been biased towards magnetotelluric methods. However, the technical program was broad and included sessions dedicated to data processing, modelling, inversion, instrumentation, solid earth geophysics, petrophysics and case studies for environmental, mineral and hydrocarbon applications. Open floor discussions were also held each day. Invited review papers on joint inversion, EM methods for

Call for manuscripts for Exploration Geophysics

ASEG has changed publishers from RESolutions to CSIRO Publishing. CSIRO Publishing is an independent, non-profit business unit of CSIRO dedicated to publishing high-quality scientific literature. Our Publications Committee takes this opportunity to invite ASEG members to submit manuscripts to Exploration Geophysics. Although everybody is very busy in the current buoyant exploration industry, the current boom has provided unique opportunities to describe new techniques and provide case histories. Put these into Exploration Geophysics first and contact Lindsay Thomas, 03 9328 1722 or 04 2735 4828 (thomas@unimelb.edu.au), if you have any material of interest.

Alan Jones of the Dublin Institute for Advanced Studies asks another pertinent question of the speaker.

hydrology, EM monitoring and lithospheric imaging were also delivered. The full program, including expanded abstracts, is accessible from the MTNET website, www.mtnet.info.

The workshop was attended by a large number of graduate students and early career researchers. The Mediterranean setting also attracted many of the EM community's eminent academicians from the past thirty years. This eclectic mix of youth and sage in a very social setting ensured an intellectually stimulating and most enjoyable week. The next workshop will be held in Beijing in September 2008.

Glenn Wilson

Calendar of Events 2007/2008

2007

25–30 March
3rd New Caledonia Nickel Conference
Including a review the global nickel industry and its markets
Le Meridien Noumea
http://www.informa.com.au/ni07

1–5 April
20th Environmental and Engineering Geophysical Society, Annual Meeting (SAGEEP 2007)
Marriott City Center, Denver, Colorado
http://www.eegs.org/sageep/index.html
Email: john_nicholl@urscorp.com

15–18 April
2007 APPEA Conference & Exhibition
Adelaide Convention Centre, South Australia
http://www.appea.com.au/Events/AppeaEvents.asp#2007
Contact: Julie Hood at jhood@appea.com.au

21–25 May
American Geophysical Union Joint Assembly
Acapulco, Mexico
http://www.agu.org/meetings/ja07/

11–14 June
69th EAGE Conference & Exhibition incorporating SPE Europec 2007
Venue: ExCel London, UK
http://www.eage.org/events/

9–12 September
5th Decennial International Conference on Mineral Exploration (Exploration 07)
Theme: *Exploration in the new millennium*. Exploration 07 will review the current state of the art in geophysics, geochemistry, remote sensing, data processing and integration.
Venue: Toronto, Canada
www.exploration07.com

23–28 September
SEG International Exposition & 77th Annual Meeting
Venue: San Antonio, Texas, USA
http://seg.org/meetings/calendar

27–30 September
4th International Symposium on 3D Electromagnetics (3DEM-4)
Venue: Freiberg, Germany
Sponsor: Gerald W. Hohmann Memorial Trust
Contact: Klaus Spitzer
klaus.spitzer@geophysik.tu-freiberg.de
http://www.geophysik.tu-freiberg.de/3dem4

18–22 November
ASEG's 19th International Conference and Exhibition
Perth, WA
Contacts: Brian Evans
Email: brian.evans@geophy.curtin.edu.au
http://www.promaco.com.au/2007/aseg
promaco@promaco.com.au

10–14 December
American Geophysical Union, Fall Meeting
San Francisco, California
http://www.agu.org/meetings

2008

6–9 April
2008 APPEA Conference & Exhibition
Perth Convention & Exhibition Centre
Contact: Julie Hood, 07 3802 2208
jhood@appea.com.au=20

9–12 June
70th EAGE Annual Conference & Exhibition
Rome, Italy
http://www.eage.org/events/

Federal Executive 2006/07

President: James Reid
Tel: 08 9209 3070
Email: james@geoforce.com.au

President Elect: Joe Cucuzza
Tel: (03) 8636 9958
Email: joe.cucuzza@amira.com.au

1st Vice President: Jenny Bauer
Tel: (07) 3858 0601
Email: jenny.bauer@upstream.originenergy.com.au

Immediate Past President: Terry Crabb
Tel: (08) 9385 9626
Email: tncrabb@westnet.com.au

Past President: Howard Golden
Tel: 0417 912 171
Email: howardgolden@gravitec.co.nz

Secretary: Lisa Vella
Tel: (08) 9321 4936
Email: lisa.vella@teckcominco.com

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

2nd Vice President and International Affairs: Koya Suto
Tel: (07) 3876 3848
Email: koya@terra-au.com

Membership: Emma Brand
Tel: (07) 3858 0601
Email: emma.brand@upstream.originenergy.com.au

Publications: Phil Schmidt
Tel: (02) 9490 8873
Email: phil.schmidt@csiro.au

States' Representative: Megan Evans
Tel: (08) 9382 4307
Email: meganevans@mail.com

ASEG Research Foundation: Phil Harman
Tel: (03) 9909 7699
E-mail: phil.harman@gcap.com.au

Technical Committee: John Hughes
Tel: (08) 8224 7952
Email: john.hughes@santos.com

ASEG Branches

ACT

President: Adrian Hitchman
Tel: (02) 6249 9800
Email: adrian.hitchman@ga.gov.au

Secretary: Matthew Purss
Tel: (02) 6249 9383
Email: matthew.purss@ga.gov.au

New South Wales

President: Vacant

Secretary: Glenn Wilson
Tel: (02) 9490 5416
Email: glenn.wilson@csiro.au

Northern Territory

President: Jon Sumner
Tel: 0407 089 261
Email: jon.sumner@nt.gov.au

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

Queensland

President: Nigel Fisher
Tel: (07) 3378 0642
Email: kenmore_geophysical@bigpond.com

Secretary: Emma Brand
Tel: (07) 3858 0601
Email: emma.brand@upstream.originenergy.com.au

South Australia

President: Selina Wallace
Tel: (08) 8224 7560
Email: selina.wallace@santos.com

Secretary: Matthias Densley
Tel: (08) 8224 7674
Email: matt.densley@santos.com

Tasmania

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

Secretary: Vacant

Victoria

President: Suzanne Haydon
Tel: (03) 9658 4515
Email: suzanne.haydon@dpi.vic.gov.au

Secretary: Ashley Grant
Tel: (03) 8687 8179
Email: ashley_grant@ghd.com.au

Western Australia

President: Megan Evans
Tel: (08) 9382 4307
Email: meganevans@mail.com

Secretary: Julianna Toms
Tel: (08) 9266 35210
Email: julianna.toms@geophy.curtin.edu.au

New Members

The ASEG welcomes the following new members to the Society. Their membership was approved at the Federal Executive meeting held on 29 November 2006.

Name	Organisation	State
Darren Ferdinando	ARC Energy Ltd	WA
Ghassan Sweidan	Integrated Geophysical Solutions	WA

Eve Howell receives award for contributions to industry in WA

Congratulations to Eve Howell, Woodside's Director of the North West Shelf Venture. She has been awarded Western Australia's annual Gas Industry Development Award for outstanding contributions to the industry in Western Australia.

Howell has only recently joined NWSV; the award recognises her achievements as managing director of Apache Energy's Australian operations.

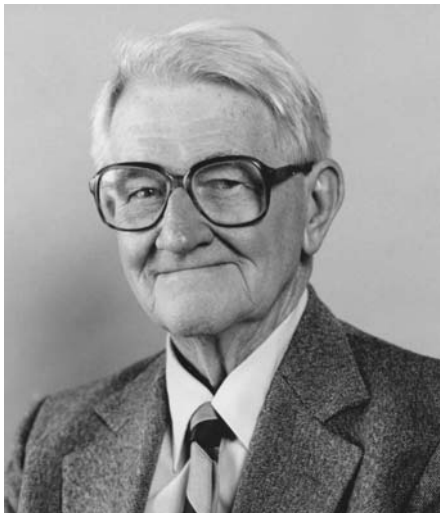
Under Howell, Apache built a strong record of exploration and development in northwest Australia. It discovered and brought into production the John Brookes Gas Field, and developed a gas hub at Varanus Island, northeast of Barrow Island.

Chamber of Minerals and Energy chief executive Tim Shanahan said Howell oversaw an increased volume of gas sales into WA's domestic market. Today Apache provides about 40% of the state's domestic gas – about 230 petajoules a year.

In her new role with NWSV, Howell oversees all liquefied natural gas, domestic gas and condensate production from the giant petroleum development.

Previous winners of this Award include former premier Sir Charles Court, environmentalist and consultant to Chevron Harry Butler, former Woodside chief Bill Rogers, and AlintaGas' founding chief executive Phil Harvey.

And for those who do not know Eve, she was President of the ASEG in 1988.



Anton Linder Hales

1 March 1911–11 December 2006

Anton Hales, a distinguished geophysicist whose career spanned three continents, died peacefully at Queanbeyan on 11 December 2006 aged 95. He served as the first Director of the Research School of Earth Sciences (RSES) of the Australian National University (ANU) from 1973 to 1978 and during this period RSES became one of the leading geoscience institutions in the world.

Anton was born on 1 March 1911 in Mossel Bay, South Africa. Showing an early brilliance for science, he graduated from the University of Cape Town at age 18 in physics and mathematics, awarded with distinction, and received an MSc the following year. At age 20 he was appointed a junior lecturer in Applied Mathematics at the University of the Witwatersrand in Johannesburg. The following year he went to the University of Cambridge, where he studied with the famous mathematician and geophysicist Harold Jeffreys. Jeffreys' influence can be seen in the geophysical pursuits he followed for the rest of his life. He finished the 'maths tripos' at Cambridge in 1933, and returned to the Applied Mathematics Department at Witwatersrand, where he carried out geophysical research, notably in seismology. He was awarded his PhD from the University of Cape Town.

World War II interrupted his scientific career, and he served as an engineering officer in the North African Campaign, exploring for sources of fresh water. After the war, Hales joined the Bernard Price Institute of Geophysical Research at Witwatersrand, developing seismic equipment, and gravity measurements using pendulums, before returning to Cape Town as Professor and Head of Applied Mathematics. In 1954 he was appointed Director of the Bernard Price Institute, and put great energy into advancing geophysical methods. These included paleomagnetism, which was used at the time to demonstrate continental drift.

In 1962 Hales moved to the USA where he became first head of a new geoscience program at the Southwest Center for Advanced Studies (later the University of Texas) at Dallas. This decade was one of great activity in geophysics and geochemistry, and Hales made his laboratory a front-runner in a number of key areas. One was seismology, in which he conducted experiments designed to understand the structure of the crust and upper mantle, an interest which he was to develop further at ANU.

After 11 years building a new department and a new university in Texas, Hales, at an age when many people contemplate retirement, joined the ANU and established the RSES. He accomplished this task with distinction, and was a strong supporter of a non-departmental structure, so that the science would not be constrained within traditional boundaries. His bold style of leadership with minimal bureaucracy was indicative of the period, and led to successes such as the development of the SHRIMP ion microprobe.

Hales actively pursued science which was focussed on the Australian continent and its setting, in all of field studies, laboratory analyses and instrument development.

Continued on p. 14

Australian Capital Territory – by Matthew Purss

Since the September issue of Preview we have held one meeting, in November, where Spiro Spiliopoulos provided a comprehensive update of the state of development and future plans for the Australian Tsunami Warning System. At the conclusion of his seminar, Spiro lead a tour of the newly operational ATWS Command Centre.

Once again the annual PESA golf day hosted by the ACT Branch of PESA on 21 November 2006 was a great success. The attendance of at least one member of the ASEG provided an excellent opportunity for interaction and networking between the two premier professional associations of Australia's geophysics industry.

The other key event of the end of 2006 which had significant input and participation from the ASEG ACT Branch was the joint AusIMM/GSA/ASEG Christmas function. The function was an informal BBQ at GA held on 1 December 2006. All up there were about 65–70 people in attendance, out of which 9 were solely from the ASEG. Like all previous joint meetings/activities between the ASEG and other professional associations, the event was an excellent opportunity for members of the ACT geoscience community to socialise and network in an enjoyable and informal setting.

Northern Territory – by Roger Clifton

After four years as Director of the Northern Territory Geological Survey, Richard Brescianini has moved on to new challenges in Perth.

Since Richard Brescianini became NTGS's Chief Geophysicist in 1999, the NT has been almost covered in high-resolution airborne geophysics surveys, including the first airborne gravity survey. He also installed the first Image Web Server to get geophysical images out over the Web.

During his tenure as Director, NTGS also delivered other leading edge geophysical products, such as the world's first state-wide radiometric stitch. He was the architect behind the very successful, 4-year ***Building the Territory's Resource Base*** exploration initiative, which has helped generate renewed interest in the Territory's petroleum and mineral resources. Colleagues and clients will greatly miss his leadership.

South Australia – by Selina Wallace and Dave Cockshell

On November 23 we joined with PESA in convening the Annual Student's Night. This particular Student's Night was a first in that all presenters were female! Christine Sealing from the University of Adelaide gave a fine presentation on magnetotellurics and geochemical investigation of intra-plate volcanism of SE Australia. Simone Mercer won the ***best presentation*** award for her dissertation on multidisclipinary mapping of water and salt in a River Murray disposal basin. Alison Hickson from the Australian School of Petroleum was awarded the ***best paper*** for her work on regional rock property modelling of the Dampier Sub-Basin. As with previous years all presentations were of high quality and judges had a difficult time in picking the best of them. Congratulations to Simone and Alison for their efforts. Thirty-nine members and guests enjoyed these presentations at our new meeting venue – The Historian Hotel.

The Christmas Party for the SA Branch was held on 14 December. It was attended by 24 members who braved the unseasonably cool and drizzly weather to enjoy a sumptuous meal, good cheer and geophysical fellowship. Thanks go to Kurt Chambers who volunteered his home for the event.

We thank our sponsors for technical meetings in 2006: PIRSA, BHP, Santos, Australian School of Petroleum, Minotaur Resources, Petrosys, Zonge Engineering, Beach Petroleum and Stuart Petroleum. We appreciated the continued support of the South Australian Meetings.

We welcome new members and interested persons to come along to our technical meetings, usually held on a Thursday night at the Historian Hotel at 5:30pm. Please contact Selina Wallace (selina.wallace@santos.com) for details.

Western Australia – by Louise Middleton

December 5 saw a very successful Christmas & AGM event at the Chifley on the Terrace, Perth. With approximately 40 people attending plenty of Christmas Cheer was shared and we were fortunate enough to receive a visit from Santa who made sure everyone received a Santa's Visit Application.

Please make sure you have marked your diaries for this year's events:

27 February:	Technical Evening
14 March:	Social/Networking Event
16 April:	SEG DISC: Biondo Biondi – Concepts and Applications in 3D Seismic Imaging
9 May:	Workshop
13 June:	Technical Evening
14 July:	ASEG WA Gala Ball
8 August:	Workshop
12 September:	Technical meeting
10 October:	Student Night
22 November:	Annual ASEG-PESA Golf Classic
12 December:	AGM/Social/ Networking Event

WA President, Megan Evans presenting Owen Davies with his Student Presenter of the Year Award

Santa with party goers

Jennie Carson
jenns_walkabout@hotmail.com

Geoscience resources on line

A wealth of theoretical and technical contributions in the field of geophysics is presented each year via papers, conferences and workshops. With the constant influx of new avenues being explored it is indispensable to be aware of databases which have the most recent documentation available.

http://www.osti.gov/energycitations/

OSTI (Office of Scientific and Technical Information) is a free-of-charge web interface which is linked to the Energy Citations Database. Since 1948, this database has been meticulously maintained with bibliographic records of geophysical reports, conference papers, journal articles, books, dissertations, and patents.

OSTI is a sub-unit of the US Department of Energy, therefore all the available information and research is centred within the United States. Though there are some seismic references, the majority of the available information land-based exploration methodologies. The search engine can be a bit slow so it is a good idea to have a coffee while you wait for the results to come in.

http://www.usgs.gov/pubprod/publications.html

The USGS database is based on a functional system that allows the user the opportunity to view, download and order online articles.

The search engine is partitioned into a generalised section of all ~67,000 bibliographic citations and recent publication of the U.S. Geological Survey. More topical sections are available to cater for geophysical specific queries in relation to metadata, mapping, articles, and geoscience referencing criteria. Researches of all segments of the geophysical field are available and the search engine for the site is efficient in locating the most relevant information based on the user's input. This site is extremely easy to navigate through and recommends other possible links in relation to certain topics.

http://www.geo-guide.de/

The Geo-Guide website was created by the Gottingen State and University Library (SUB, Germany) and has been an ongoing project since 1996. Geo-Guide describes itself as a gateway to scholarly websites relevant to earth sciences. The site allows the user to combine subjects (i.e. applied or regional geophysics) with specific resource requirements (e.g. journals or books only, etc).

Geo-Guide's geophysics segment has links to 117 highly reputable professional and educational resources. Each search on the site is recorded in 'Search History' and the search results can be presented by 'Timestamp', 'Hide Description' and 'Show Source Data'. A login account can be created to maintain your past interaction with the site which is extremely handy during long project studies. This webpage is particularly professional and continuously updates of homepage features guaranteed to interest any researcher (e.g. showcasing and reviewing available weblinks).

http://www.uh.edu/~jbutler/geophysics/seg.html

The University of Houston uses the Google search engine to navigate through their extensive research collection. The site is advertised as a 'key resource of geology and geophysics topics' and has been meticulously maintained since 1997 thanks to partial funding from the Society of Exploration Geophysicists (SEG). The homepage is broken into six categories (Data, Virtual Geoscience Professor, Introduction, Directory, Reference Materials, and Careers) which accommodates researchers' at all academic levels.

An innovative feature of this site is the 'Virtual Coffee Room' which is a forum for professors, students, researchers and industry members to discuss geophysical topics on an international scale (e.g. 'Geoscience Course Materials').

http://www.ngdc.noaa.gov/ngdc.html

The National Geophysical Data Centre (NGDC) in Boulder, Colorado, promotes a range of 'scientific stewardship, products and services for geophysical data from the Sun to the Earth's sea floor'. This site is extremely comprehensive with a data holding of over 300 digital and analogue databases.

The majority of searches within this site require a nominal payment prior to the user being able to access the records. However, teachers interested in introducing geophysical concept to their students can utilise a more generic database via the 'Education' link. NGDC states that they are continually developing data management programs to deal with the ever-changing science of geophysics. Input is encouraged with a 12-question survey available to rate the service standards of the webpage.

Australia, State of the Environment 2006

by Eristicus

Minister Ian Campbell launched the 2006 State of the Environment Report in December 2006. This is the third such report prepared by an independent committee, which was chaired by Bob Beeton from the School of Natural and Rural Systems Management, University of Queensland.

The Australian State of the Environment Committee reports every five years. The first one was published in 1996.

The SoE 2006 system includes individual reports on:

- 263 environmental indicators
- 8 theme commentaries
- 10 integrative commentaries on important environmental issues for Australia and
- 33 short reports on important but discrete current or emerging issues.

The key findings are:

Environmental data

'It is still not possible to give a comprehensive national picture of the state of Australia's environment. This is because we the lack accurate, nationally consistent environmental data.'

This must be a major concern, but obviously it is impossible to measure everything, so it is really a 'length of a piece of string' issue.

In preparing the report, the Committee used 263 indicators selected from the original 500 environmental indicators proposed in 1999. They were chosen on the basis of measurability and usefulness of information. The Committee assessed that there are good national data for 37 per cent of these, some data for 51 per cent and no data for 12 per cent. Land, biodiversity, coasts and oceans, inland waters, and natural and cultural heritage were each assessed as more than 50 percent data deficient. Surprisingly, groundwater was not even listed.

Consumption

Many of the pressures from human activity that were reported in the 2001 State of the Environment Report still exist, and some have intensified. For example the total energy consumption continues to increase,

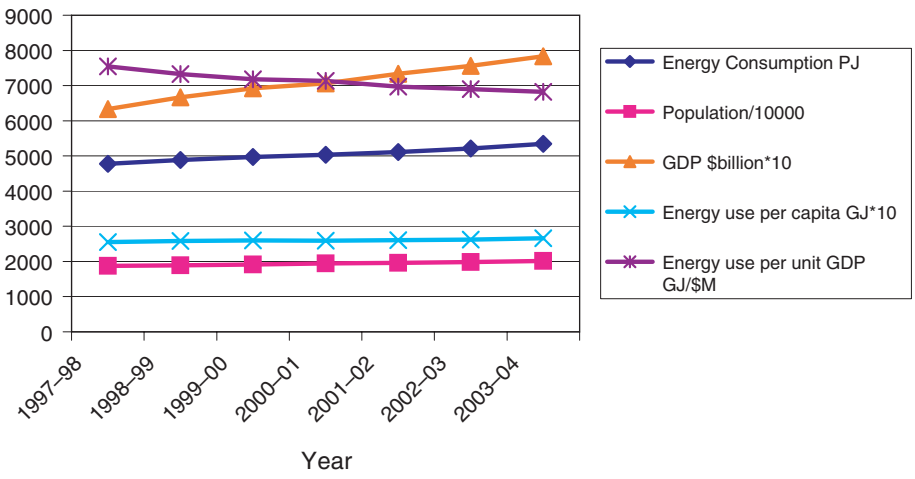


*Fig. 1. Energy consumption in Australia from 1997–98 to 2003–04. From the top down the graphs represent: Energy use per unit GDP GJ/$M, GDP $billion*10, Total energy consumption in PJ, Energy use per capita GJ*10, and Population of Australia/10000. Notice that the GDP factor is probably the most significant of the parameters contributing to energy use. Data taken from the SoE report, p. 11, available at: http://www.deh.gov.au/soe/2006/index.html*

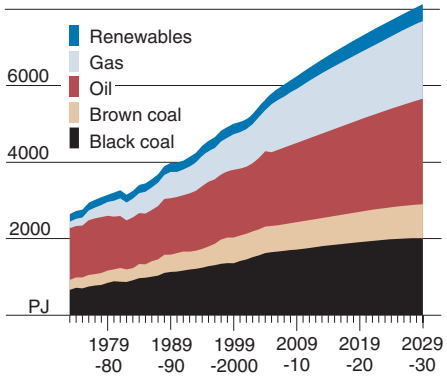


Fig. 2. Primary energy consumption in Australia, by fuel type, taken from the ABARE report: Energy in Australia 2006, p. 57, produced for the Department of Industry Tourism and Resources and published by ABARE. It is available from the website: http://www.industry.gov.au/content/

although the per capita consumption is almost constant, only increasing from 255 GJ to 266 GJ over the seven year period 1997–98 to 2003–04 (see Figure 1).

According to ABARE this trend is likely to continue (see Figure 2).

Australia is dominated by three sectors – electricity generation, transport and manufacturing. Combined, these sectors have accounted for almost 80 per cent of total energy consumption throughout the past 25 years, albeit with their relative shares changing significantly over time. There is clearly going to be an increased demand for energy into the foreseeable future.

Land clearing

Positive steps have been taken across all jurisdictions to reduce land clearance with one consequence being to slow biodiversity decline in those areas. This reduction in land clearing has also had a positive impact on net greenhouse emissions. However, as shown in Figure 3 there is still a net loss of vegetation, and when the effects of the 2007 bushfires are taken into account the report card will look even worse.

Climate change and climate variability

The authors of the report identify climate change and climate variability as very important issues. They state:

'Climate change is undoubtedly a threat to Australia's environment. Although Australia's climate is so variable that the extent of change is uncertain, there is clear evidence for some warming and changes to rainfall distribution. The so-called millennium drought of the last five years was not the driest period on record in all parts of Australia, but the combination of low rainfall and warm temperatures exacerbated its effects.'

However, the report falls short of linking the recent warming with increases in greenhouse gases. The response is almost a George W Bush approach: we need more knowledge of climate variability before we do anything about greenhouse gas emissions.

The SoE2006 Committee has some observations on the way forward

This could and probably should have been one of the more interesting parts of the report. Unfortunately it is non-specific

when the reader would have really liked some well defined actions.

Improving measurement of environmental progress

'Preparing a State of the Environment report, or any other environmental report, requires data and information collected over time and from different places that are consistent and reliable. There is still not enough good quality accessible data and information on the condition of Australia's environment to prepare unambiguous environmental reports.'

However, it does not say which datasets are needed and which could be discarded.

Adaptation is crucial to survival

'Whether environmental change is caused by people, by the variable climate or by actions in restoring environmental assets, is important. However, the primary concern is that Australia should build its capability to live with its environment and respond appropriately to changes in that environment. An adaptive approach to environmental issues where we learn by doing, and modifying approaches as needed, should be the underlying basis of actions and policies. Cooperation across all levels of governance is critical for this to be effective.'

This is really too vague and full of motherhoods. If you were a Minister of The Crown and read this, what would you be expected to do?

Regulation and incentives

'Governments should continue to encourage environmental stewardship through appropriate investment, governance and regulation at the right scale of intervention. New approaches to stewardship, including accreditation, certification and, where appropriate, markets for environmental services, should continue to be explored urgently.'

Motherhood wins again!

Managing our land at the right scale

'Much of the present regulation is not targeted at the appropriate scale, and some incentives encourage environmentally perverse results. Management at a whole-of-landscape level, integrated with the local actions of all agencies, landholders and people, is necessary to achieve landscape-scale objectives.' So where should governments start to fix this? Where are the bottlenecks and the log jams that need attention?

Maintaining and building a capability to manage

'Environmental progress will depend on having more technologies, knowledge, skills and investment strategies to turn scientific knowledge into practical products. For example, Australia will need improved water use, reuse and recycling systems very quickly.'

What more can I say?

Sharing responsibility

'The environment is not something for which only rural and regional people have responsibility. Building understanding, knowledge and skills in environmental management for urban people, Indigenous people in their country, and rural and regionally located people would allow all sectors and people to play their part. Australia's environment is valuable for practical reasons, such as producing food, as well as being important for its natural and cultural values. One of the implications of this is that as environmental services are needed and valued by all, they must be paid for by all. There is also a need to manage for the benefit of future generations.'

You have to agree with this but where is the way forward?

Improving Australia's environment

'We can expect future pressures on the environment from population growth and from economic growth. These pressures will continue to increase unless there is some decoupling of growth from the non-sustainable consumption of resources, particularly energy, land, water and products dependent on limited natural resources (such as forestry and fisheries). This is a major adaptive challenge.'

Once again, more motherhoods.

Summary

In summary, I would say that the report is beautifully presented with some magnificent photographs and diagrams. The maps showing trends in annual for several different periods from 1900 to the present are illustrative of the variability of our climate and are well worth a look.

But for me the best parts are contained in the Theme Reports provided on the CD. These are well researched and contain really good scientific summaries. For example, in the atmosphere section, it covers skin cancer from ozone depletion and makes no bones about global warming, rather than the rather wishy washy words in the printed summary.

So we could have done with more of the science and less of the glossy pages.

By the way if you would like to read the report you can download it from: http://www.deh.gov.au/soe/2006/index.html.

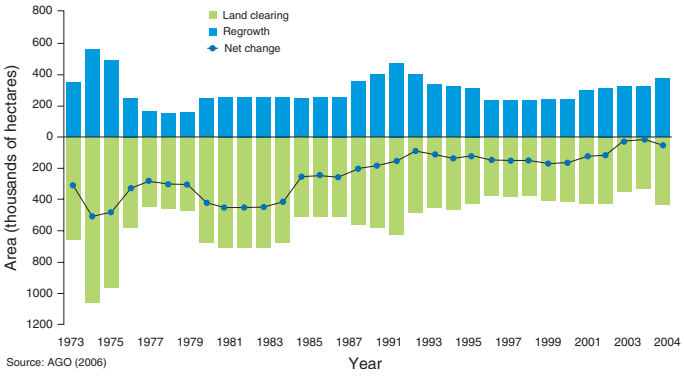


Fig. 3. Net forest change in Australia (using forest regrowth and deforestation data) 1973–2004. Taken from the SoE 2006 report, p. 71, available at the website: http://www.deh.gov.au/soe/2006/index.html

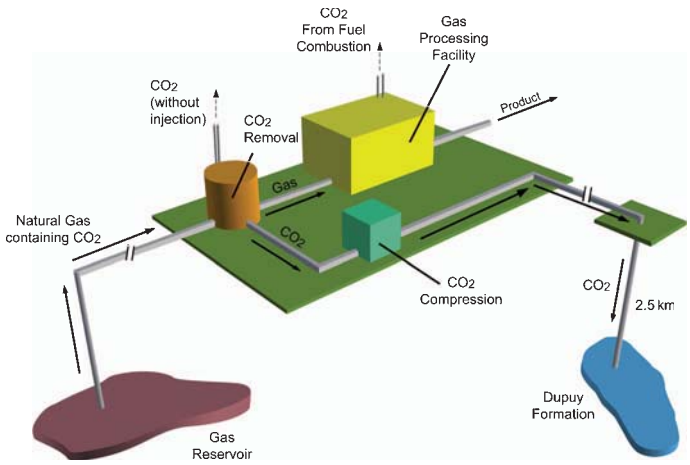


Fig. 4. Schematic diagram of the Barrow Island processing facility for sequestering CO_2 from the Gorgon Gas Fields.

Chevron Texaco awarded $60 million to bury CO_2 beneath Barrow Island

The Australian government has awarded a $60 million grant from the 'Low Emissions Technology Demonstration Fund' to Chevron Texaco. The grant will be used on a CO_2 geosequestration project on Barrow Island associated with the development of the Gorgon Gas Fields, which are located bout 200 km offshore, west of Dampier, on the north-west coast of Western Australia.

A total investment of about US$11 billion will be required by the Gorgon Joint Venture to fully develop the gas fields. Chevron Texaco is the operator with ExxonMobil and Shell being the other joint venture partners. It will be a massive project with the China National Offshore Oil Corp Ltd (CNOOC) by itself purchasing up to 100 million tonnes of gas over 25 years.

The plan is to pipe all the gas from the Gorgon Fields to Barrow Island where the CO_2 will be stripped from the LNG, liquefied and pumped into the Upper Jurassic Dupuy Formation at a depth of about 2.5 km. Figure 4 shows schematically what is envisaged.

The aim will to bury 3 million tonnes of CO_2 per year over the 40 year length of the project. As a consequence (according to a Chevron media release) the greenhouse gas emissions from the Gorgon LNG Development are forecast to be reduced from 1.22 to 0.81 tonnes of CO_2-equivalent per tonne of produced LNG. So the CO_2 will not be eliminated completely but will be reduced significantly.

The only question I have is; why does the government have to give $60 million to Chevron, which in 2006 made a profit of US$14.1 billion?

The precedent has now been set for all the new coal fired power stations and all the new LNG developments to queue up for government handouts for sequestering the unwanted CO_2 by-products. I would have thought that if the government was serious in reducing greenhouse gas emissions it would require all new projects of this nature to have a sequestration strategy in place before approval was given.

Continued from p. 9

He encouraged his staff to become globally engaged and led by example, serving as President of the Inter-Union Commission on Geodynamics and being active in the International Union of Geodesy and Geophysics.

After his retirement from ANU in 1978, Hales resumed his research activities in Dallas as a professor of geosciences, at the same time maintaining his family home in Canberra. He retired from Dallas in 1982, and back in Australia the great energy that remained with him went into establishing a new family house and garden on a bush block in Wamboin (NSW). His geophysics interests continued, with him contributing and mentoring in a visiting position at RSES. Hales career spanned much of the twentieth century, and his scientific honours included Fellowships of the Royal Society of South Africa, the American Geophysical Union, and the Australian Academy of Science. They indicate the esteem in which he was held in these three continents.

Anton married Marjorie Carter in 1936, and they had two sons, James and Peter. Marjorie died in 1957, and his second marriage was in 1962 to Denise Adcock, to whom two further sons were born, Mark and Colin. Mark died in a car accident in 2004. Denise provided strong support throughout the forty-four years of their marriage, and her love and care ensured that Anton enjoyed his retirement up to the end. He is survived by Denise, three sons, and seven grandchildren.

Ted Lilley (with contributions by Kurt Lambeck and Charles Barton)

Satoru Ohya

25 February 1932–13 November 2006

Satoru Ohya, a former President of the Society of Exploration Geophysicists of Japan (SEGJ) died on 13 November 2006 from injuries he sustained after a cycling accident.

Satoru was President of SEGJ in 2001 and came to the Brisbane ASEG conference in August that year, where he was instrumental in negotiating a cooperation agreement, between ASEG and SEGJ. He also initiated the publication of the joint Exploration Geophysics issues involving the ASEG, the SEGJ and the Korean SEG.

He was a champion of increasing cooperation in Exploration Geophysics in the Asian region.

Satoru Ohya was born in February 25, 1932. He graduated with Masters in Geology from the University of Tokyo in 1955. In 1957 he joined OYO Corporation (a Japanese geotechnical consulting company) where he worked for many years serving as its President and CEO from 1993–2001.

In recent years he served as a member of many advisory boards of Government and non-Government organisations including: the Advisory Board in Geosciences, Stanford University; Board of Directors of World Seismic Safety Initiative (WSSI); Chairman of Geohazard International National Institute of Advanced Industrial Science and Technology (AIST); Chairman of the Geological Information Utilization and Promotion Initiative (NPO-REIC); member of the Technical Committee of the Japan Geotechnical Consultants Association (JGCA) and Vice Chairman of the Real Time Earthquake Information Consortium (NPO-REIC).

Satoru Ohya never retired. On Saturday 11 November, he was bicycling to his office when he remembered that he had left something at home and U-turned. He was then hit by a motor bike, was severely injured, and died in hospital two days later, primarily from the loss of too much blood.

He will be greatly missed by all his colleagues for his encouragement and optimism. His wake in 16 November and funeral on the following day were attended by more than 1000 mourners each.

Koya Suto

ASEG Research Foundation

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 16 years. In this issue of Preview we provide a summary of a research project undertaken at the University of Melbourne.

A palaeomagnetic interpretation of the Kewell Prospect in Western Victoria

Student: Charles Funk; BSc Honours Student 2006 at The Melbourne University

Supervisor: Chris J. L. Wilson

Funding: $5000

The Kewell Dome within the Moornambool Metamorphic Complex is a gold prospect that underlies ~120 m of Murray Basin sediments. It is one of a number of prospective basalt domes hosted within turbiditic mud and sandstones with a similar tectonic and alteration history to the better-understood Magdala Dome ~100 km to the SSE, which hosts the Stawell Gold Mine. The geophysical response of the dome shows a simple gravitational anomaly with a complex total magnetic intensity (TMI) image (Figure 1). The image shows NNW-SSE trending positive highs and reversely oriented lows appearing to flank the dome to the south. This complexity is the result of highly remanence dominated pyrrhotite mineralisation in mudstone surrounding the basalt dome.

Sampling drill holes from the north of the dome, the rock units could be geophysically divided into two classes. Sulphide-rich rocks occur proximal to the basalt/sediment contact and have very high Koenigsberger ratios and magnetic susceptibilities. They dominate the TMI response. Both non-sulphidic mudstones, distal from the basalt dome and non-magnetic basalt from within the dome are induction dominated. They have very low magnetic susceptibilities so will only impact upon the image as zones of weak magnetisation if no stronger magnetised response occurs nearby. Some basalt close to the basalt/sediment contact is altered, becoming magnetic, remanence dominated with significant impact upon the TMI image (Table 1). The TMI imagine is therefore formed almost exclusively by the <50m pyrrhotite rich halo surrounding the basalt.

Table 1. Geological groups at Kewell categorised on geophysical response with sulphide percentages and geophysically significant data

Class	Class description	Po_{AVG} (wt %)	Py_{AVG} (wt %)	K_{AVG} ($\times 10^{-5}$ SI)	Q_{AVG}	Density (t m^{-3})
A	Pyrrhotite and pyrite rich mudstone	11.8	11.9	1272	59.3	3.2
B	Pyrrhotite rich mudstone	30.3	0.23	3299	54.6	3.2
C	Pyrite rich mudstone	0.06	6.48	54.81	1.80	2.7
D	Non-sulphide bearing mudstone	0.25	0.25	22.79	0.04	2.7
Ei	Basalt (non-magnetic)	0.25	0.05	59.38	0.09	2.8
Eii	Basalt (magnetic)	0.05	0.00	273.1	38.9	2.9

These samples plot into two hysteresis populations: population A, sulphide-rich rocks proximal to the basalt due to high fluid mobility or population B, non-sulphidic mudstone distal from basalt or non-magnetic basalt due to low fluid mobility (Figure 2). The fluid flow model proposed by Musgrave *et al.* (2006) is supported at the north of Kewell. Though the suggestion that the cause of the population offset being variation in the iron deficiency of pyrrhotite was shown to be incorrect.

Pyrrhotite mineralisation dominates the magnetic response so its paragenesis is significant. The earliest mineralisation of pyrrhotite occurred between syn-D_3 and pre-D_{4b}, this pyrrhotite retains a normally oriented palaeoremanent magnetisation. The second pyrrhotite formation is associated with D4b and initial gold mineralisation. The pyrrhotite forms unusual euhedral hexagonal porphyroblasts while the gold occurs in low concentrations associated with pyrrhotite spotting. The polarity of the initial gold-forming event could not be determined due to a pervasive core-barrel overprint of palaeomagnetic vector data. The third and final pyrrhotite mineralisation is only observed in the south of the Kewell Dome. The pyrrhotite is associated with remobilisation and enrichment of the gold into late brittle veins post-D_{4b} and has the reversely polarised palaeo-remanence forming the negative flanks on the TMI image.

Reference

Musgrave, R. J., Funk, C., Grewar, J. and Vega, M. E., 2006, Magnetic petrophysics in the Stawell Gold Field: relating aeromagnetic anomalies to mineralizing fluid flow: Australian Earth Sciences Convention 2006, Melbourne, Expanded Abstracts CD and Conference Handbook, p. 158.

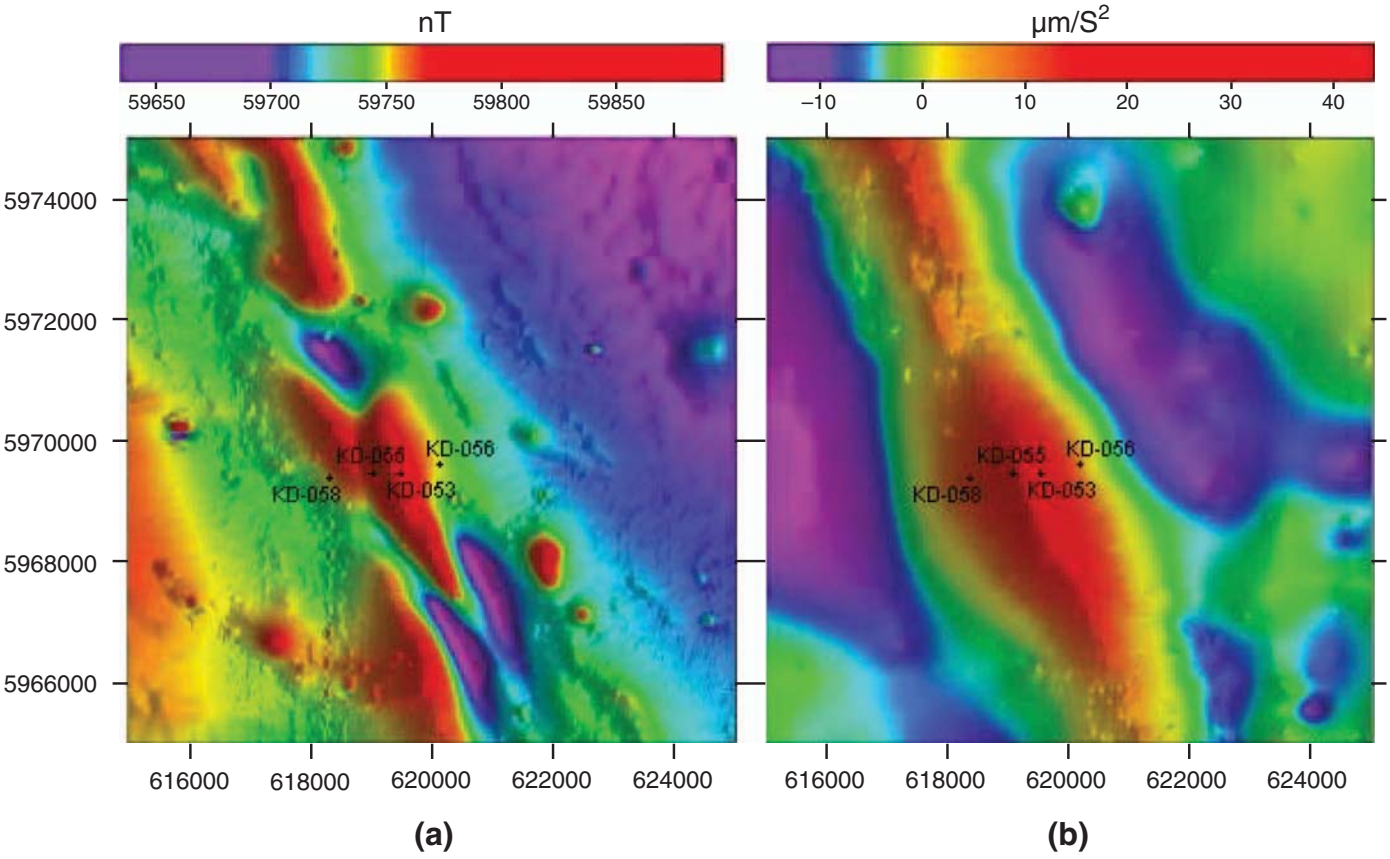


Fig. 1. (a) Total magnetic intensity (TMI) image and (b) Residual Gravity (illuminated from the east) image of the Kewell Dome, both with drill hole locations plotted (modified from Musgrave et al. 2006).

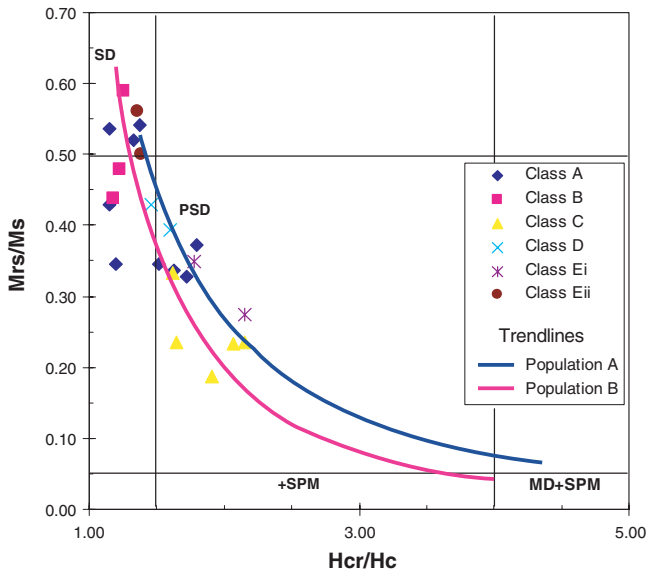


Fig. 2. Day plot of hysteresis parameters for all samples divided into geophysical classes with population trendlines from Musgrave et al. (2006). Fields for populations of ferrimagnetic grains are indicated: SD – single domain, PSD – pseudo-single domain, MD – multidomain, SPM – superparamagnetic.

Geoscience-related ARC Grants for 2007

In the December 2006 Preview the bulk of the 2007 Australian Research Council Geoscience related Discovery Grants were listed. The remainder of the Discovery Grants, all the Linkage Grants and the NCRIS Awards are summarised below.

Discovery Grants (Part 2)

Micromechanical modelling of fault gouge dynamics: towards an improved fault constitutive relation

Researchers: PR Mora, A Tordesillas and F Alonso-Marroquin

Funding:
2007: $120,773 2008: $110,773
2009: $110,773 2010: $57,773

Administering institution: The University of Queensland

Project summary: The human and economic costs of geological and other particulate media related problems in Australia are staggering. These include geological hazards (e.g. landslides and earthquakes; the Newcastle earthquake cost around $4 billion and 13 lives), to particulate processes prevalent in Australia's major export industries (e.g. coal export valued at $9.3 billion, iron ore at $3.8 billion, and wheat at $3.4 billion), to Australia's 810,000 km granular paved road network that costs around $5.5 million per day to maintain. The program will deliver new knowledge and advanced analytical and predictive modelling tools capable of fuelling breakthroughs in earthquake forecasting research and industrial innovations.

Proterozoic crustal evolution of the Northern Australian Craton revealed from hafnium-oxygen isotope systematics of granite-hosted and detrital zircons

Researcher: AI Kemp

Funding:
2007: $115,000 2008: $120,000
2009: $125,000 2010: $115,000
2011: $105,000

Administering institution: James Cook University

Project summary: This project will provide a detailed view of continental crust formation during a key period of Earth's history. Through an innovative approach and the use of sophisticated micro-analytical techniques, it will enhance the profile and global competitiveness of Australian research. The project is an integral part of a national collaboration on Proterozoic terranes involving universities, Geoscience Australia and state geological surveys, and datasets generated by this study can potentially lead to refined mineral exploration strategies. The project is linked to the development of a major new analytical facility at James Cook University that will support local and international research and research training.

Are humans responsible for recent changes in the behaviour of tropical cyclones? Decoupling natural variability from human influence using isotopes

Researchers: JF Nott, MI Bird and SG Smithers

Funding:
2007: $80,000 2008: $50,000
2009: $90,000 2010: $70,000
2011: $25,118

Administering institution: James Cook University

Project summary: An increase in the frequency of intense landfalling tropical cyclones will have a major impact upon Australia's economy and the safety of its citizens and visitors. There is little doubt that global climate change will cause this increase. Understanding when this might occur and the extent of this change over and above that which could also occur naturally will help reduce economic loss and save peoples' lives. Using isotope records of tropical cyclones and global climate models we will differentiate natural from human induced changes and ascertain the likely future impact of this hazard on Australia and its near neighbours.

Molecular fossils, environmental genomics and the natural history of an Australian salt lake

Researchers: JJ Brocks, SC George and JF Banfield

Funding:
2007: $90,000 2008: $88,000
2009: $85,000

Administering institution: The Australian National University

Project summary: Increasing salinity of lakes is a critical problem for sustainable water supply in Australia. To comprehend the consequences of human-induced salinisation, it is crucial to understand salt lakes at their most fundamental level. This project develops pioneering technologies to elucidate the microbial ecology and geochemistry of salt lakes in unprecedented detail. It will open new pathways to unravel how microbial ecosystems adapt to increasing salinisation, and how they reacted to climate fluctuations in the past. Students will gain multidisciplinary skills in environmental genomics, proteomics and geochemistry, a unique combination that will become decisive for understanding and preserving ecosystems on our continent.

The composition and transport of Australian air-borne dust: critical to continental and marine environments

Researchers: P De Deckker, NJ Tapper, GE Allison, D De Beer, K Hinrichs, E Schefuss and JW Stuut

Funding:
2007: $255,000 2008: $250,000
2009: $240,000

Administering institution: The Australian National University

Project summary: This project will determine the composition of Australian airborne dust and effects on the environment and in particular soils, rainforests and the marine realm, including reefs. 'Fingerprinting' the chemical and microbiological content of aeolian dust is of particular relevance to determining its impact on the health of the Australian people and environment. Atmospheric conditions propitious for dust entrainment and transport will be determined, and in particular atmospheric exchanges between Indonesia, southern Africa and Australia will be established. The relevance of aeolian dust to climate, ecosystems and biosecurity in our region will be established through the study of marine and lacustrine cores.

The Southern Ocean's role in determining atmospheric CO_2 levels: new insights from novel biogenic silica records of seawater pH

Researchers: SM Eggins, MJ Ellwood and M Kelly

Funding:
2007: $112,000 2008: $78,000
2009: $72,000

Project summary: About half the emissions from the burning of fossil fuel since the Industrial Revolution have been absorbed by the oceans. However, considerable uncertainty surrounds the consequences of and the extent to which the oceans will continue to sequester CO_2 into the future. This research will improve existing limited knowledge of the key biological and related ocean processes that transfer CO_2 between the surface and depth, and the poorly understood effects on marine ecosystems of increasing ocean acidity due to CO_2 absorption. This knowledge will contribute to predicting the course of future climate change and gauging the impacts on marine life and production systems.

Microbial oceanography: community heterogeneity fuelled by environmental variability

Researchers: JR Seymour, M Middelboe and M Polz

Funding:
2007: $80,000 2008: $80,000
2009: $80,000

Administering institution: The Flinders University of South Australia

Project summary: The ocean is a crucial resource to Australia. This work will open a new area of research within Australian habitats, which will improve our understanding of how the base of the ocean food web functions, and build a new perspective from which to look at the microscopic plankton that influence fisheries yield and species invasions. Appreciating how microbial communities respond to environmental perturbations will provide an improved vantage-point to predict future changes to the Australian marine environment. Leading international scientists will provide conceptual and technical expertise in an Australian based project, applying novel analytical tools not currently employed within oceanographic surveys within Australian waters.

Southern Ocean nutrients and their links to climate change: insights from the isotope and elemental signature of diatoms and sponges

Researchers: WA Maher, MJ Ellwood and M Kelly

Funding:
2007: $140,000 2008: $139,000
2009: $111,000

Administering institution: University of Canberra

Project summary: It is not possible to respond effectively to climate change and variability associated with increases in atmospheric carbon dioxide without understanding the role that marine phytoplankton play in the uptake and sequestering of carbon dioxide. The proposed research will lead to a greater understanding of how nutrients such as silica have limited phytoplankton growth, and ultimately the role the ocean plays in the sequestration of carbon dioxide over time. Such knowledge will benefit possible ocean-based carbon dioxide mitigation strategies, i.e. ocean fertilisation to stimulate ocean productivity and carbon dioxide drawdown.

Study of the ionospheric E-region during disturbed geomagnetic conditions using stereoscopic HF radar observations

Researcher: R Makarevich

Funding:
2007: $50,000 2008: $40,000
2009: $40,000

Administering institution: La Trobe University

Project summary: This project is expected to benefit Australia by: maintaining and expanding Australia's traditionally strong research positions in the field of space physics; conducting leading edge research in the rapidly expanding field of geomagnetic storm effects on technological systems; establishing bi-directional transfer of radar technology between Australia and international partners; providing unique training in space science and advanced data processing highly valued by industry, government and academia potentially leading to significant improvements in performance and stability of satellite communication and positioning systems; and supporting Australia's critical infrastructure such as surveillance and power distribution networks.

What controls the shift from a hot house climate to a cold house climate: the Eocene/Oligocene climate transition and greenhouse warming

Researcher: WP Sijp

Funding:
2007: $81,030 2008: $81,030
2009: $81,030

Administering organisation: The University of New South Wales

Project summary: This study contributes to putting Australia on the map as a centre of excellence in the study of past climates as well as in global warming research. It aims at a greater understanding of the dynamics of past warm climate states. This could ultimately lead to a better knowledge of the formation of the ancient deposits that we mine in Australia today. Furthermore, the study of these past warm climates tells us something about current global warming as both involve increased levels of carbon in the atmosphere. The impact of climate change on Australia is likely to be large. Our study of past warm climates helps to gain an understanding of the mechanisms behind climate change and help quantify the risks of climate change posed to Australia.

Improving climate models through new insights on long-term inter-hemispheric climate synchronicity from speleothems

Researchers: RN Drysdale, JC Hellstrom, R Maas, G Zanchetta, AE Fallick and G Lohmann

Funding:
2007: $150,000 2008: $142,00
2009: $37,000

Administering organisation: The University of Newcastle

Project summary: It is important that palaeoclimatologists continue to improve understanding of how the Earth responds to climate forcing, so that climate models can be rigorously validated and refined. Since the Earth responds to most of this forcing over time scales that exceed the length of instrumental weather measurements, the recovery of datable palaeoclimate archives that are highly sensitive to past climate changes is essential. Our project will provide important new palaeoclimate data from both hemispheres on how key regions of the Earth responded to past climate changes. This will bring improved understanding of past oceanic-atmospheric

processes that can be fed into climate models, ultimately producing better forecasts to the benefit of all Australians.

Unravelling the last great Gondwanan mystery: the first land vertebrate fauna from the Tertiary of New Zealand

Researchers: S Hand and M Archer

Funding:
2007: $182,902 2008: $171,000
2009: $160,000

Administering organisation: The University of New South Wales

Project summary: This project will dramatically increase knowledge about Australia's and New Zealand's shared biodiversity and the history of trans-Tasman dispersals. By comparing Australian and New Zealand fossil records, it will be possible to assess the speed at which evolving vertebrates of one landmass invade another, as well as the biotic consequences of such events, and provide data important for predicting and responding to future potentially-damaging events of this kind. Developing an understanding about the timing and intensity of antipodean faunal response to past climate change will improve ability to anticipate and manage processes that threaten ecosystem resilience in both lands.

Geoscience-related Linkage Projects

Linkage projects are funded under the umbrella of the National Competitive Grants Program, which is managed by the Australian Research Grants Commission. Linkage projects are all about brokering research partnerships within the Australian innovation system and capturing the economic, social and cultural benefits of research. The main aim is to encourage excellent collaborative research within universities and across the innovation system.

The total funding for new Linkage Grants, starting in 2007 was $59 million – much smaller than the $275 million provided for the Discovery Grants. However, the good thing about the Linkage grants is that you have a much better chance of getting one.

Whereas the Discovery Projects only had a success rate of 20.4% in 2006 the Linkage Awards had a 44.8% success rate. Out of the 208 successful grants the Earth Sciences only received 10 (from 21 submissions), so we only account for about 5% of the total. The moral is clear. Link in with your colleagues in industry or government and go for it!

Here are the successful ones:[1]

A new approach to the collection of a large suite of dinosaur specimens

Researchers: P Vickers-Rich and TH Rich

Funding: 2007: $47,713

Partner organisation: Big Island Pictures

Administrative organisation: Monash University

Project summary: Monash University and the University of Alaska, Fairbanks, propose to cut of a tunnel in permafrost on the North Slope of Alaska during the early spring. This is expected to lead to the acquisition of a new assembly of dinosaur fossils. An important aspect of the project is its sponsorship by Big Island Pictures, Brisbane, which will produce a documentary about this unique experiment in palaeontological engineering. This novel approach to recovering dinosaurs will lead to a new and perhaps more complete assemblage of specimens, whilst attracting a vast audience and conveying to the public how innovative science is done. The public interest is attested to by the consortium of sponsors that has been assembled by Big Island Pictures including major television stations in Australia, USA, England, France, and Germany and the Film Finance Corporation of Australia.

Environmental Evolution of the Willandra Lakes World Heritage Area

Researchers: R Grun, SG Webb, AS Fairbairn, EJ Rhodes and N Stern

Funding:
2007: $229,739 2008: $151,312
2009: $189,833

Collaborating/partner organisations: Department of Conservation and Environment and three Traditional Tribal Groups

Administrative organisation: The Australian National University

Project summary: The Willandra Lakes World Heritage Area ranks as the most significant area for documenting Australia TMs unique cultural and environmental history. Parts of this remarkable archive are being lost through erosion. This project is the basis for a strategic research alliance between the custodians and managers of the area and leading Australian research institutions to build a picture of the continent TMs human and environmental history before this evidence is irretrievably lost. Lake Mungo is known to Australians as the site of the world TMs earliest cremation and a window into our remote past. We will provide novel insights into the evolution of the Australian landscape, its fragile environment and the history of its resilient inhabitants.

New developments in 3D electrical resistivity imaging of the shallow subsurface

Researchers: SA Greenhalgh and J Zhe

Funding:
2007: $45,000 2008: $47,000
2009: $47,000

Collaborating/partner organisation: ZZ Resistivity Imaging Pty Ltd

Administrative organisation: The University of Adelaide

Project summary: This project is concerned with developing improved procedures for electrical imaging of hidden geological features in the subsurface. These techniques are required to solve urgent problems associated with important issues, such as natural hazards, disposal of dangerous waste, groundwater and construction of major buildings and tunnels. The project will develop new hardware, software and interpretation aids, as well as providing postgraduate training in an area of vital national importance.

Three-dimensional magnetotelluric imaging of lithospheric-scale mineral systems from source to deposit

Researchers: GS Heinson, D Giles, JA de Witt, L Vella, S Bilben and M Cawood

Funding:
2007: $124,534 2008: $140,904

Collaborating/partner organisations: BHP Billiton and Teck Cominco Australia Pty Ltd

Administrative organisation: The University of Adelaide

Project summary: Geochemical studies indicate that world-class mineral deposits are partly sourced from fluids emerging from Earth's mantle and lower crust. Finding major mineral deposits in the future will therefore require knowledge of which parts of the crust and mantle yield

[1]Only 9 projects have been listed. The tenth in the Earth Science category was focused on the Earth's Atmosphere.

the most prospective locations. However, there are few methods that can image deep Earth resources, and these can be very expensive. We propose to develop the magnetotelluric method as a low-cost and rapid approach for delineating 3D information on deep mineral systems beneath existing major deposits, and adapting this to explore in greenfield locations.

The Cambrian Population Explosion of Arthropods in Australia: Ediacaran origins, evolution and biodiversity

Researchers: MS Lee, JR Paterson, JG Gehling, GD Edgecombe and JB Jago

Funding:
2007: $90,000 2008: $90,000
2009: $90,000

Collaborating/partner organisations: Beach Petroleum Pty Ltd, The South Australian Museum and The Australian Museum

Administrative organisation: The University of Adelaide

Project summary: This project addresses key questions on the origin and diversification of life, by investigating the evolution of the most important fossil group (arthropods) across arguably the most important event after the origin of life (the Cambrian explosion of macroscopic life). It will also excavate, promote and conserve two key geological resources of national importance, in the Flinders Ranges and Kangaroo Island. Also, it will lead to increased knowledge of the palaeoecology and geology of the economically-important Adelaide geosyncline, and benefit rural SA communities through ecotourism, a rural schools education program, and public outreach.

Trace element analysis of diamond: new applications to diamond fingerprinting and genesis

Researchers: SY O'Reilly, WL Griffin and NJ Pearson

Funding:
2007: $77,823 2008: $73,426

Collaborating/partner organisation: Rio Tinto (Operational and Technical Excellence)

Administrative organisation: Macquarie University

Project summary: The project will provide new insights into the processes by which diamond crystallises in the Earth's mantle. A better understanding of these processes can lead to improved models and techniques for diamond exploration, enhancing the prospect of finding new deposits in Australia and abroad. The project will test the potential of trace-element microanalysis to fingerprint diamonds by source. If successful, this technology will provide economic benefits by reducing theft and illegal mining, which represent significant losses to legitimate companies. Application of this Australian development could reduce the circulation of "conflict diamonds", which would have real social benefits worldwide, especially in some developing countries.

Assessing the risk of ocean acidification for the Great Barrier Reef

Researchers: SG Dove, WP Leggat, D Yellowlees, JM Lough, PA Hutchings and KG Caldeira

Funding:
2007: $176,650 2008: $110,288
2009: $71,836

Collaborating/partner organisation: Great Barrier Reef Research Foundation

Administrative organisation: The University of Queensland

Project summary: The increase in greenhouse gases such as CO2 represents a challenge for coral reefs such as Australia's Great Barrier Reef (GBR). While the impact of greenhouse warming on coral reefs has been partially explored, the potentially serious implications of a decrease in ocean pH due have not been properly assessed. Detecting and understanding changes to carbonate concentrations and reef calcification are of great importance if managers are to respond strategically to potential ecological changes. This project directly addresses National Research Priority 1 of achieving 'An Environmentally Sustainable Australia' by addressing the priority goal of 'Responding to climate change and variability'.

Quantifying near-surface diffuse discharge from the southwest Great Artesian Basin

Researchers: AW Western, MH Tyler and JP Walker

Funding:
2007: $114,754 2008: $110,288
2009: $71,836

Collaborating/partner organisations: BHP Billiton Olympic Dam, Great Artesian Basin Coordinating Committee, South Australian Arid Lands Natural Resource Management Board and Santos Ltd

Administrative organisation: The University of Melbourne

Project summary: Groundwater from the Great Artesian Basin (GAB) supplies one of Australia's largest mining operations and many pastoral enterprises. The GAB is the only significant water resource through much of arid central Australia and supports unique environmental values in this region. This project will provide vital data on natural, near-surface leakage rates from the GAB that can be used to gain a greater understanding of the amount of water available for sustainable extraction. This will assist in the improved management of the GAB resource and in doing so contribute to greater certainty for the mining and pastoral users of the GAB groundwater and provide greater protection for unique ecosystems associated with natural discharge springs.

Sediment transport in upwelling currents and its relevance to an active petroleum system in the Morum Sub-basin, South Australia

Researchers: TH Payenberg, DM McKirdy, PJ Boult and K Grice

Funding:
2007: $35,118 2008: $60,118
2009: $28,118

Collaborating/partner organisation: Petroleum Group, Primary Industries South Australia

Administrative organisation: The University of Adelaide

Project summary: Australia had a trade deficit of $3.5 billion in petroleum products in 2005 and this is forecast to increase dramatically in the future. Giant oil fields may exist in the Morum Sub-basin and their exploitation could significantly reduce Australia's trade deficit in petroleum products. It would also reduce Australia's reliance on oil form politically unstable parts of the globe. Any exploration activity and subsequent exploration success would have a significant effect on the rural economy based around Portland, the main port in the area, through which most of the logistics would flow.

$43 million from NCRIS for Geoscience

AuScope has been awarded $42.8 million over five years as part of the government's $542 million National Collaborative Research Infrastructure Strategy (NCRIS) to undertake a program on the ***Structure and Evolution of the Australian Continent***.

However, according to FASTS, the NCRIS funding is essentially a clawback of the Systemic Infrastructure Initiative (SII) and Major National Research Facilities (MNRFs) programs. In other words, no new money.

For more information the NCRIS program, visit the website:
http://www.ncris.dest.gov.au/capabilities/default.htm

The AuScope program is one of the 13 successful infrastructure proposals approved by the Minister for Education, Science and Training, Julie Bishop late in 2006. AuScope Ltd will manage the program. It is a non-profit company with members including the CSIRO, Geoscience Australia, 15 universities, 8 state government agencies as well as AMIRA, NASA and the Victorian Partnership for Advanced Computing. Scott McTaggart (Tel: 07 3346 4115; Email: scott@connait.com, has been chosen to be initially the CEO of AuScope.

Structure and Evolution of the Australian Continent

According to the NCRIS website AuScope will develop an 'integrated national infrastructure system– featuring the world's first continental-scale, four-dimensional data model. The system will significantly enhance the impact of our already internationally competitive geoscience capability'.

The main program comprises two parts:

The ***Underground History*** project receives $27 million from NCRIS to develop advanced systems for acquiring and analysing geophysical and geochemical data. This will include a geotransect facility for imaging large-scale cross sections of the earth's crust, an Ion Probe for advanced analysis of earth samples and the development of a virtual library of drill core samples from across Australia.

A key feature will be a world-leading geoscience data network to draw together information from the national infrastructure and other sources to provide advanced simulation and computing modelling tools for geoscientists from a wide range of organisations. The data and associated products will be highly accessible to researchers, mining engineers and the public. They will be used to build an open-access, four-dimensional model of the Australian continent that will provide a journey across space and time in the nation's geology.

High Precision Positioning is the second project. It will receive $15.8 million to develop an enhanced national geospatial reference system. This will support work in precision agriculture, mining and large-scale engineering as well as providing detailed observations about the geological movement of Australia. This system will encompass national and State-owned global positioning system (GPS) sites, satellite laser ranging systems, very long base interferometry and gravity measurement systems.

Figures 1 and 2 show the current high precision network and an indication of what will be installed over the next five years.

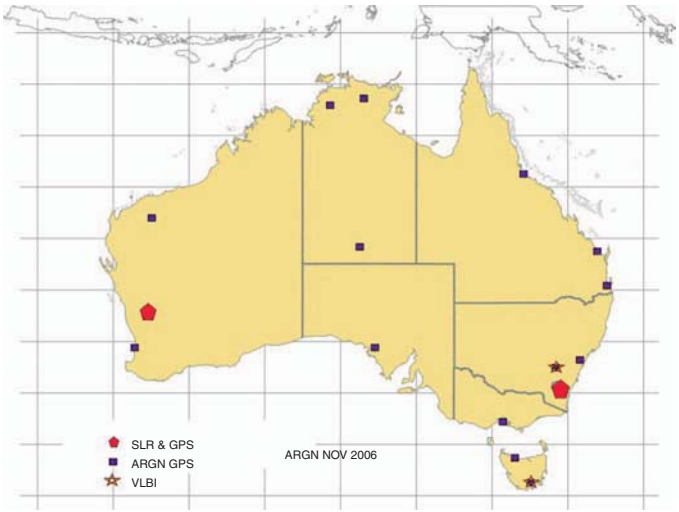


Fig. 1. The Australian Regional GPS Network (ARGN) in November 2006. SLR indicates Satellite Laser Ranging stations and VLBI is the Very Long Baseline Interferometer site.

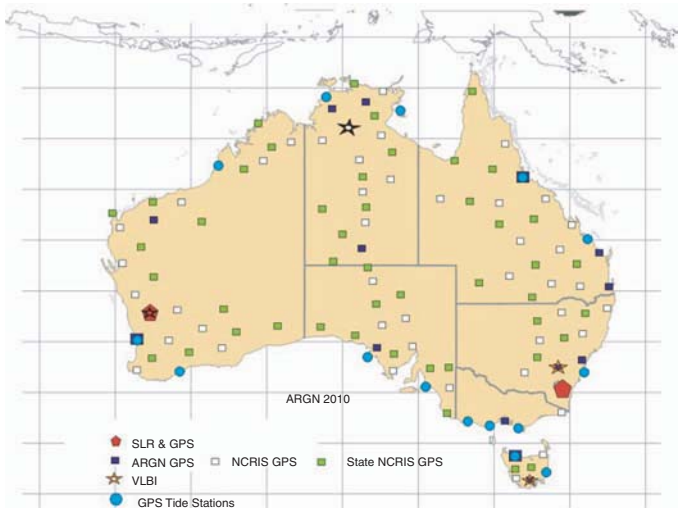
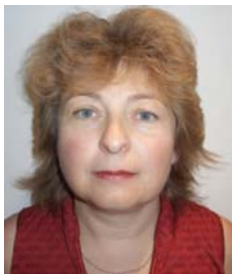
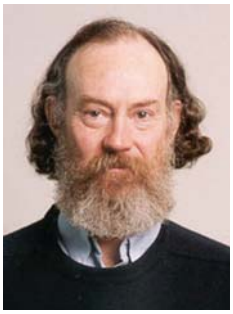


Fig. 2. Indicative Australian Regional GPS Network (ARGN) in 2010, after installation of NCRIS stations.

2005 Broken Hill High Resolution Vibroseis Seismic Reflection Survey



Tanya Fomin
Geoscience Australia
Email: tanya.fomin@ga.gov.au



Russell Korsch
Geoscience Australia
Email: russell.korsch@ga.gov.au

In August 2005, a high resolution seismic reflection survey was carried out at Broken Hill as a collaborative research project between the New South Wales Department of Primary Industries–Mineral Resources and Geoscience Australia. A ~12 km profile was acquired with vibroseis sources along a portion of the 96AGS-BH1B dynamite deep seismic reflection line in the Broken Hill region (Figure 1).

The purpose of the new survey was to provide a high resolution seismic image of the uppermost part of the crust across an economically important area along strike from the world class Broken Hill Ag-Pb-Zn deposit and to compare high resolution vibroseis seismic data (120 fold) with low fold explosive source seismic data (6–12 fold) that had been acquired along the same line in 1996–97.

Two HEMI-60 Vibroseis trucks were used as energy sources for the survey, and a total of 12.2 line-km of 120 fold seismic reflection data were acquired to 16 s TWT (Korsch *et al*. 2006a).

The seismic data were processed using the Disco/Focus seismic processing package. The processing steps, such as the application of refraction and residual statics, velocity analysis, dip move out corrections (DMO) in common-offset domain and post-stack migration provided a considerable improvement to the resolution of seismic data, particularly in the upper 1 s TWT (~3 km depth) (Korsch *et al*. 2006a).

The dynamite data from the original 1996–97 Broken Hill reflection seismic survey have been reprocessed recently using modern seismic processing techniques (Korsch *et al*. 2006b; Fomin *et al*. 2006). The major improvement in resolution of the dynamite seismic data appears after a detailed velocity analysis and vertical stacking technique using a range of different velocity functions (Figure 2a, b).

The major result of this reprocessing is a demonstration of comparability of resolution of dynamite and vibroseis deep seismic data. Nevertheless, the new high resolution data have resulted in much better resolution of the geological structures in the shallow part of the section, compared to the regional scale low-fold data recorded using a dynamite source, and reveals some new features that were not visible in the dynamite data (Figure 2c, d). It has provided a good correlation with some aspects of the mapped geology, allowing the extension of known mapped shear zones to depths of as much as three kilometres, and has also identified some previously unrecognised structures, also interpreted as shear zones.

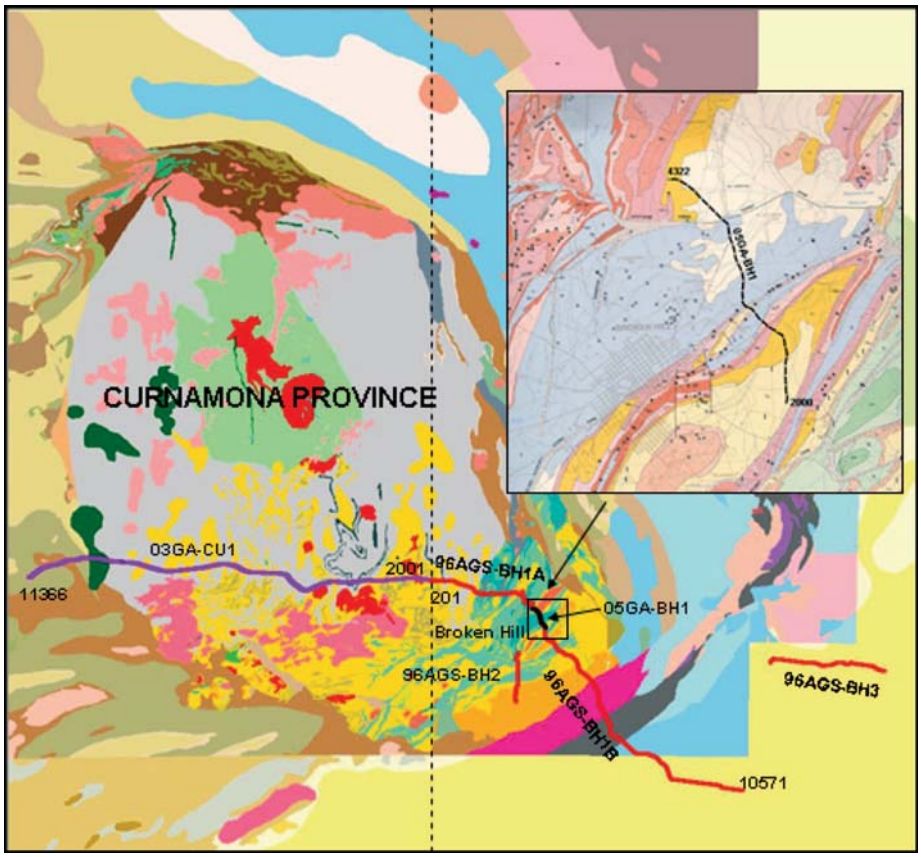
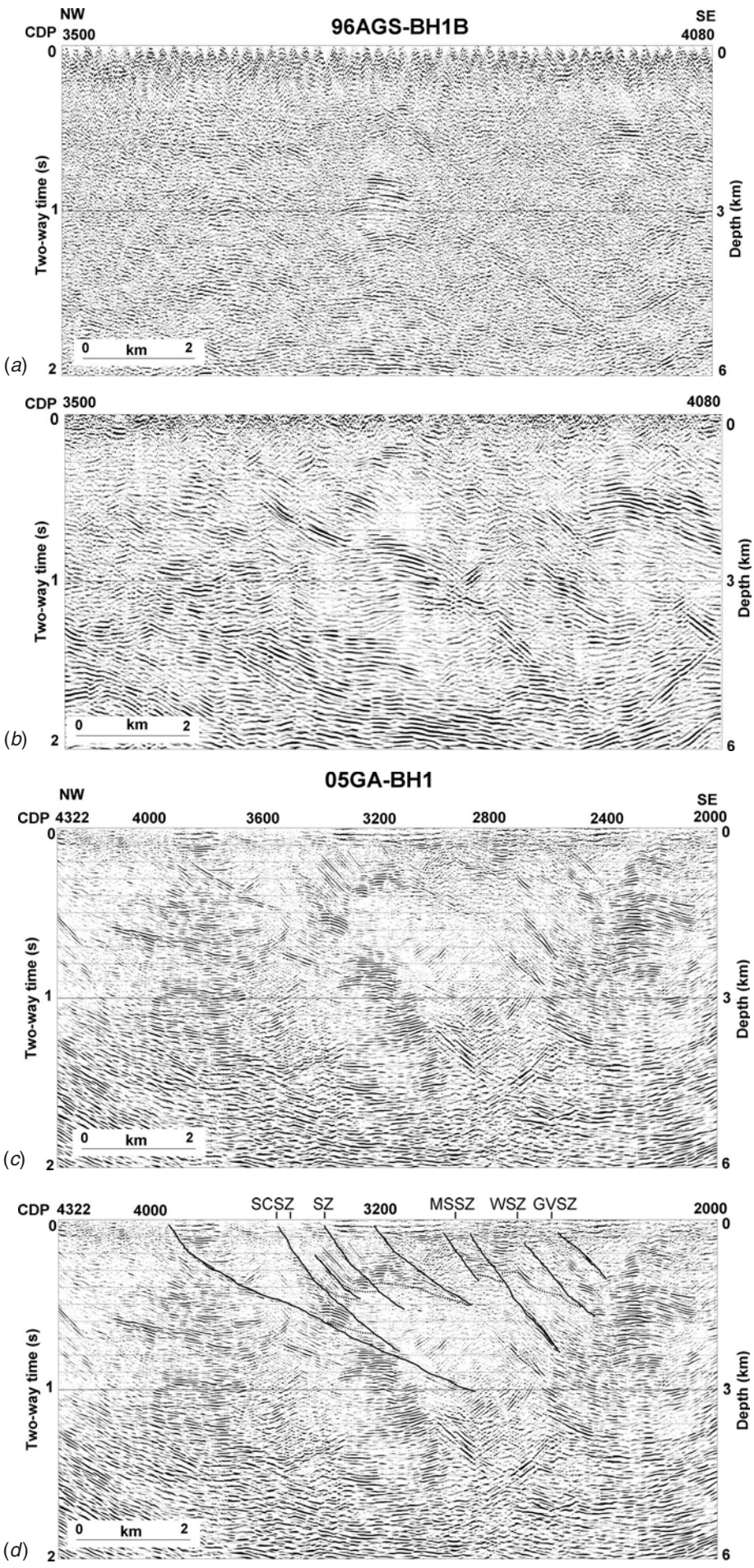


Fig. 1. Map showing the solid geology of the Curnamona Province, the locations of the deep seismic lines in SA and NSW, and the location of the 2005 high resolution line to the east of Broken Hill. Enlargement of geological map of the area around Broken Hill showing the location of the high resolution seismic line 05GA-BH1.



Acknowledgements

We thank ANSIR for acquiring the data, Tim Barton for managing the acquisition phase, and Barney Stevens for his input during the acquisition and preliminary interpretation phases. Published with permission of the CEO, Geoscience Australia.

References

Fomin, T., Korsch, R.J., and Goleby, B.R., 2006, Combining data from dynamite and vibroseis sources: deep seismic transect in the Curnamona Province, Australia: 12th International Symposium on Deep Seismic Profiling of the Continents and Their Margins, Shonan Village Center, Hayama, Japan, September 24–29, 2006, p. 69.

Korsch, R.J., Fomin, T., and Stevens, B.P.J., 2006a, Preliminary results of a high resolution seismic reflection survey at Broken Hill: Geoscience Australia Record, 2006/21, 110–115.

Korsch, R.J., Fomin, T., Conor, C.H.H., Stevens, B.P.J., Goleby, B.R., Robertson, R.S., and Preiss, W.V., 2006b, A deep seismic reflection transect across the Curnamona Province from the Darling Basin to the Flinders Ranges: Geoscience Australia Record, 2006/21, 102–109.

Fig. 2. Comparison of dynamite regional seismic data (a portion of 96AGS-BH1B section) with vibroseis high resolution (05GA-BH1) data collected along the same line. Migrated dynamite section: (a) before and (b) after reprocessing, (c) uninterpreted migrated high resolution seismic section and (d) preliminary geological interpretation of high resolution seismic section showing a series of shear zones with an apparent dip to the southeast. Display shows the vertical scale equal to the horizontal scale, at a crustal velocity of 6.0 km/s. Horizontal scale is based on 1 CDP equals 20 m for regional data and 5 m for high resolution data. The dotted line is a form surface that marks the base of a series of strong reflections. SCSZ – Stephens Creek Shear Zone, MSSZ – Morgan Street Shear Zone, WSZ – Western Shear Zone, GVSZ – Globe-Vauxhall Shear Zone.

Evaluating Air-FTG® survey data: bringing value to the full picture

Colm A. Murphy
Bell Geospace Limited
Aberdeen, UK
cmurphy@bellgeo.com

James Brewster
Bell Geospace Inc.
Houston, USA
jbrewster@bellgeo.com

James Robinson
Bell Geospace Limited
Aberdeen, UK
jrobinson@bellgeo.com

Summary

Fixed wing Air-FTG® data is now accepted as a viable technique in an exploration program. Since its first commercial survey campaign in early 2003, data quality has improved from 15+ E resolution to a more acceptable 5 to 7 E over 400 to 600 m wavelengths. Resolution has been determined against available ground gravity data. Where not available, we propose an alternative method. This involves computing a single potential field from the 5 independent gradiometer outputs and then recalculating the individual components. We make comparison with previously processed outputs. Such results allow us to statistically monitor residual noise inherent to each project.

Introduction

Bell Geospace first acquired commercial fixed wing Air-FTG® surveys in early 2003 in Southern Africa. Data resolution at the time was demonstrated to be quite poor, but showed significant improvement by its 2nd campaign later that same year (Hatch 2004; Murphy 2004). Much of this was attributed to surveying conditions (during winter due to reduced turbulence), but also to improvements in data processing.

These early Air-FTG® surveys had the benefit of access to available ground gravity data to determine the accuracy of response. These analyses were performed on airborne data that were processed to a levelled status only. Nevertheless it clearly demonstrated Air-FTG®'s ability to improve from 15+ E to the more acceptable 5.4 E resolution over 300 to 400 m spatial wavelengths (Hatch 2004). The level of improvement is significant as more subtle geological responses of 300 to 400 m wavelength are now detectable.

Ground gravity data are not always available and so a more independent means of establishing survey accuracy is required. One mechanism is to take the levelled data through one more processing sequence that exploits the integrity of the full tensor data and then to compare the outputs against those previously produced. The result of this technique is a harmonic model of the tensor components, which can then be used to isolate and remove certain noise characteristics. Bell Geospace names this procedure 'Full Tensor Processing' (FTP). It is now routinely employed on all projects.

The FTP'd data sets are then compared against their levelled counterparts. The resultant plots help demonstrate the advances made with Air-FTG® technology in recent years in terms of S/N and improved detectability of geological features.

This paper describes this analysis and makes reference to 2 Air-FTG® data sets, one acquired in Brazil and the other to a data set first described by Hinks *et al*. (2004) called Kokong that was acquired in Botswana.

Methodology: quantifying noise

Power Spectral Densities (PSDs) are computed for the levelled and FTP'd data for each survey and then compared. PSDs are a useful mechanism to understand the S/N ratios in a data set. However, the interpretation of such plots may not be entirely accurate as residual noise can be difficult to isolate. Nevertheless, this is a good mechanism to statistically monitor the minimalisation of residual noise inherent to each processed data set.

However, the units in which these analyses are expressed are not intuitive. They are typically given in the form of E/√Hz, but it is preferred to express these in terms of distance on the ground. A simple multiplication by the speed of the platform allows for easier comprehension of what the PSD reveals in terms of noise thresholds, e.g. a 15 E/√Hz noise threshold on an aircraft travelling at 60 m/s translates to a noise threshold of 13.5 E^2 km.

PSDs for Air-FTG® data used in this analysis are shown in Figures 2 and 4.

The next part of the analysis is to take the computed noise thresholds, the known line spacing of each survey, and for increasing target size, predict the minimal Tzz response detectable. This can be described as:

$$\mathrm{Tzz} = \sqrt{(N_e/2nR)}$$

where N_e is the noise threshold of the survey, n the number of lines to transect a target and R the length of the target.

Figures 3b and 4 show Detectability Charts for the two surveys presented in this analysis.

The analysis

Figure 1 shows the levelled and FTP'd Tzz response from a survey acquired for Aurizonia Petroleum in eastern Brazil in 2005. The purpose of the survey was to locate possible areas of hydrocarbon entrapment beneath the low lying mud-flats for a more comprehensive follow-up seismic exploration program. The anticipated targets are expected to yield short to intermediate wavelength anomaly responses. The survey was flown on a tight drape 80 m above ground with 400 m line spacing oriented NW.

The improved imagery of the short to intermediate wavelengths are evident in the FTP'd data with a more precise definition than that evident in the levelled data (see where highlighted). This improvement is summarised in the PSD plots shown in Figure 2a. The levelled data yield a noise threshold of 24.2 E^2 km whereas that for the FTP'd data is 10 E^2 km. The noise

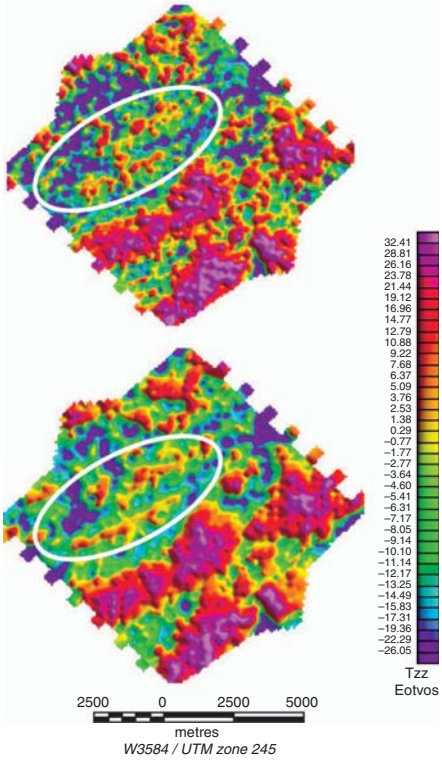


Fig. 1. Air-FTG® Tzz data from Brazil. Data acquired for Aurizonia Petroleum in 2005. Upper image is levelled data, bottom result from Full Tensor Processing. See text for details.

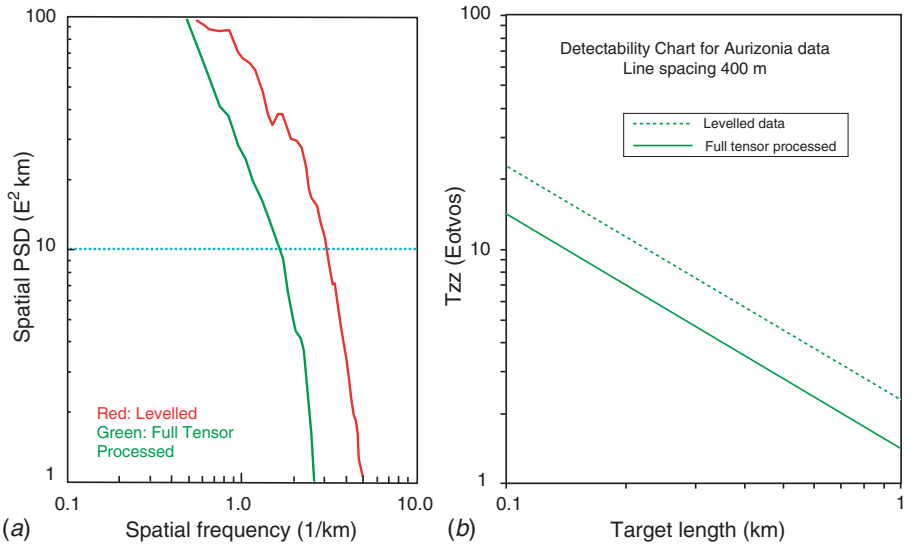


Fig. 2. (a) PSD for levelled and FTP'd Tzz data. Note the marked improvement in the FTP'd data; and (b) Detectability Chart for levelled and FTP'd Tzz responses. Large targets require low detectability threshold.

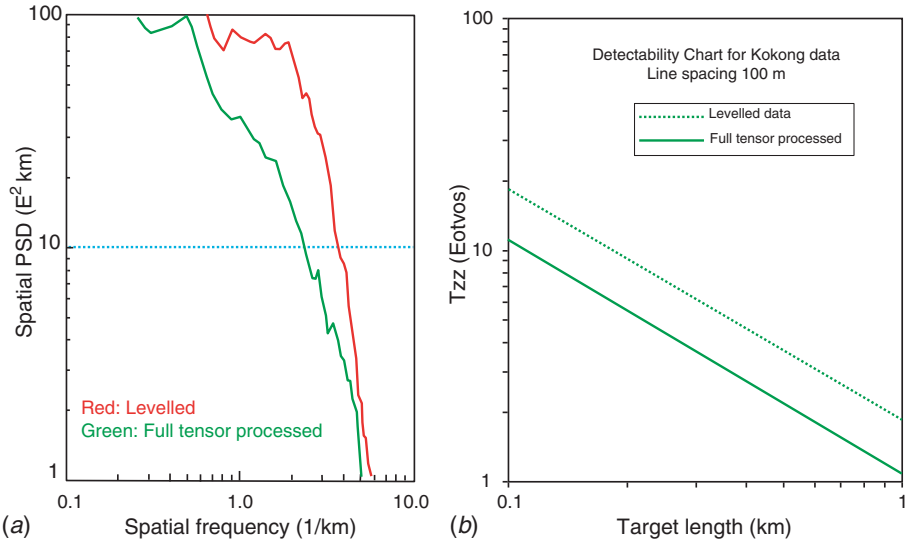


Fig. 3. (a) PSD for levelled and FTP'd Tzz data from Kokong. Note the marked improvement in the FTP'd data; and (b) Detectability Chart for levelled and FTP'd Tzz responses. Large targets yield low noise values.

threshold concept is extended to investigate detectable responses for targets of varying size. The Detectability Chart shown in Figure 2b predicts that for increasing target size, the lower the noise threshold. More important is that FTP'd data will enable more subtle small scale geological features to be detectable. For spatial targets of 400 m surveyed with 400 m line spacing this improvement in resolution is in the order of 3.5 E versus 5.8 E in the levelled data.

The level of improvement offered by FTP is evident and gives an overall accuracy of 3.5 E over 400 m spatial wavelengths. This has been demonstrated for surveys acquired with 400 m line spacing. The result compares favourably with that previously described by Hatch (2004) and Hinks et al. (2004). The latter noted that Air-FTG® as offered in early 2003 was probably of insufficient quality to be of use in resolving small scale geology such as Kimberlites in Botswana. A useful means to assess this is to reprocess that particular dataset acquired near Kokong in Botswana using FTP.

The Kokong data set was acquired on a tight drape 80 m above ground with 100 m line spacing. Figure 3a shows the PSD for the levelled data (Hinks et al. 2004) and the FTP'd result. The difference is remarkable with the noise threshold improving from 70.6 E^2 km to 23.7 E^2 km. The corresponding Detectability Chart (Figure 3b) indicates that the resolution of the Kokong data set is now 5.44 E for a 200 m sized target versus 9.4 E in the levelled data. This improvement is significant in that more discernable geology becomes detectable.

Discussion

The analyses presented in this paper suggest that Air-FTG® has improved in quality since deployment in early 2003. The Aurizonia survey data acquired in 2005 suggest a 10 E^2 km resolution for Tzz as compared to values in excess of 23 E^2 km for the Kokong survey acquired early 2003. A better assessment of Air-FTG® would include its ability to resolve geology on the ground.

Given that Air-FTG® now has accuracies of 10 E^2 km, we can expect better detectability on tight line spaced surveys than that possible for Kokong. Figure 4 assesses this concept. The blue curves plot the minimal responses for a survey with 100 m line spacings assuming a noise threshold of 10 E^2 km. Comparing with the Kokong result described above, we now would expect to resolve a 200 m sized target generating a 3.54 E response.

Continued on p. 28

First test survey results from the FALCON™ helicopter-borne airborne gravity gradiometer system

David B. Boggs
BHP Billiton Mining & Exploration Technologies,
GPO Box 86A,
Melbourne, VIC 3001, Australia.

R. Arthur M. Maddever
BHP Billiton Mining & Exploration Technologies,
PO Box 188,
Wallsend, NSW 2287, Australia.

James B. Lee
BHP Billiton Mining & Exploration Technologies,
PO Box 188,
Wallsend, NSW 2287, Australia.
Corresponding author.
Email: jim.b.lee@bhpbilliton.com

Robert J. Turner
BHP Billiton Mining & Exploration Technologies,
PO Box 188,
Wallsend, NSW 2287, Australia.

Mark A. Downey
BHP Billiton Mining & Exploration Technologies,
PO Box 188,
Wallsend, NSW 2287, Australia.

Mark H. Dransfield
BHP Billiton Falcon™ Operations,
180 Lonsdale St,
Melbourne, VIC 3000, Australia.

Summary

In May 2005, the fourth Falcon™ airborne gravity gradiometer system, called Feynman, flew a helicopter test survey over Bulgary Ridge in western New York. Feynman differs from its predecessor Falcon™ systems, using fully digital electronics, making it sufficiently light and compact to fit in a small helicopter. The test survey successfully demonstrated Feynman's ability to produce low-noise gravity data in the presence of the high vibration levels of a helicopter whilst flying at 60 knots and low elevation. The processed survey data demonstrate the expected higher signal levels resulting from flying low and slow.

Introduction

The Falcon™ airborne gravity gradiometer (AGG) systems have given BHP Billiton a competitive advantage in the search for minerals for the past 6 years. The systems are based on Lockheed-Martin rotating disk gradiometer technology (Lee 2001) and are configured to measure the two horizontal differential curvature gradients.

The original three Falcon™ AGG systems were developed specifically to improve upon original full-tensor-gradiometer (FTG) technology originally used in Trident submarines, allowing collection of high quality data in the presence of high vibration levels and turbulence experienced in aircraft. These are all flown in Cessna Grand Caravans.

Last year, a fourth system developed by Lockheed-Martin for BHP Billiton was successfully put into service (Boggs et al. 2005). This fourth system, called Feynman, is the result of a 2 year development program and differs from the previous three Falcon™ gravity gradiometer systems in several respects; digitization of the system electronics, reduced noise floor as well as reduced system weight and size.

As well as performance improvements that came with the new digital AGG system, the reduction in system weight and size has allowed use of alternate platforms for carrying the AGG system. This paper describes the first test results of the Feynman installed in a Eurocopter AS350-B3 helicopter.

Helicopter platform description

In May 2005, the Digital AGG system was integrated into a Eurocopter AS350-B3 helicopter as shown in Figure 1.

The helicopter has specific advantages over the Cessna Grand Caravan that have traditionally been used to carry the Falcon™ gravity gradiometer systems:

- High agility allows better terrain following capability than other aircraft types.
- Increased spatial resolution results from flying at lower altitude and lower speed.
- Ability to safely fly at lower altitudes, closer to sources provides increased signal amplitudes. This is very important when measuring gravity gradients, as signal strength reduces as $1/r^3$ of the distance to sources.
- Detailed follow-up of interesting targets can be performed without having to resort to ground methods.
- Less affected by turbulent conditions than most other types of aircraft.

As in the Cessna mounted systems, the Helicopter platform has an integrated laser

Fig. 1. Feynman Eurocopter AS350-B3 Helicopter Platform. The platform allows collection of gravity, magnetics, laser-scanner DEM and electromagnetic datasets simultaneously.

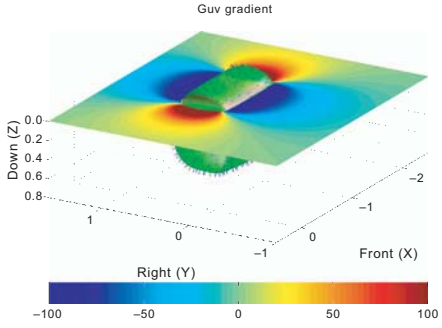


Fig. 2. Eurocopter AS350-B3 fuel tank solid model and the resultant Guv gradient in the horizontal plane of the gradiometer. The gradiometer location is at the origin.

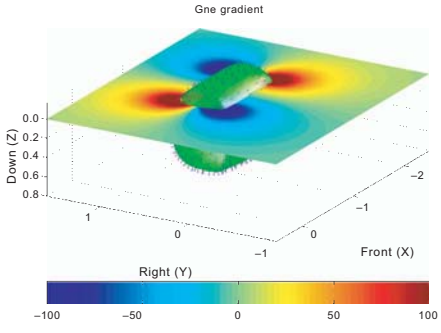


Fig. 3. Eurocopter AS350-B3 fuel tank solid model and the resultant Gne gradient in the horizontal plane of the gradiometer. The gradiometer location is at the origin.

scanning system to capture a co-registered digital terrain model (Stone and Simsky 2001). An accurate model is essential to properly correct AGG data for terrain and is particularly critical at the lower clearances that will be flown using the helicopter. Dual laser scanners have been incorporated for this purpose and provide sub-metre pixel density with better than 20 cm vertical resolution.

Several other aspects of the helicopter operation have been investigated during the development program, including implications of the closeness of the pilots and fuel load, which all have measurable gradients well above the noise floor of the new digital gradiometer system. Typical effects of a fuel load are shown in Figures 2 and 3. As a result, systems to measure and compensate for fuel load and pilot position have also been incorporated into the helicopter system.

Bulgary Ridge test results

System benchmarking of all BHP Billiton's gradiometer systems has involved flight testing over a 14 km × 7 km area in upstate New York, known as Bulgary Ridge. The 40 m high ridge is the most prominent feature within a mostly flat landscape.

A digital elevation map of the area, as measured by the Falcon™ systems integrated laser scanner, is shown in Figure 4. The gravity gradient anomalies produced by the ridges in this area range up to 50 E at 120 m ground clearance, and are typical of the expected target sizes being explored for with the Falcon™ gradiometer systems.

The first Falcon™ gradiometer system (Einstein) was originally tested at this site in

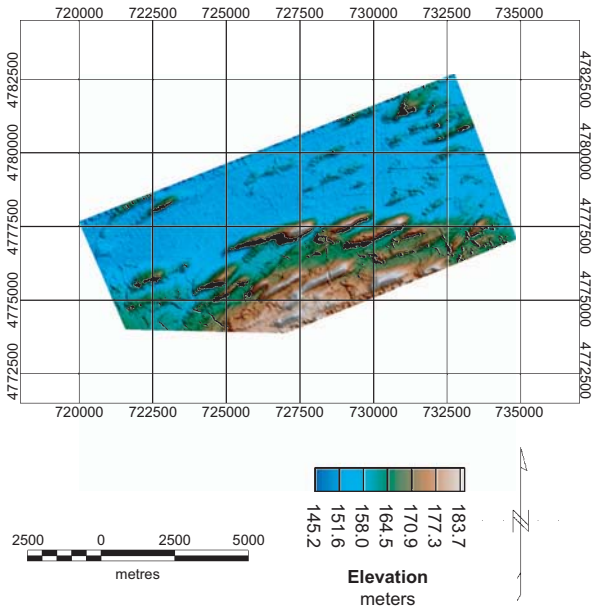


Fig. 4. Digital elevation model of the Bulgary Ridge test area captured using the integrated Falcon' laser-scanner system.

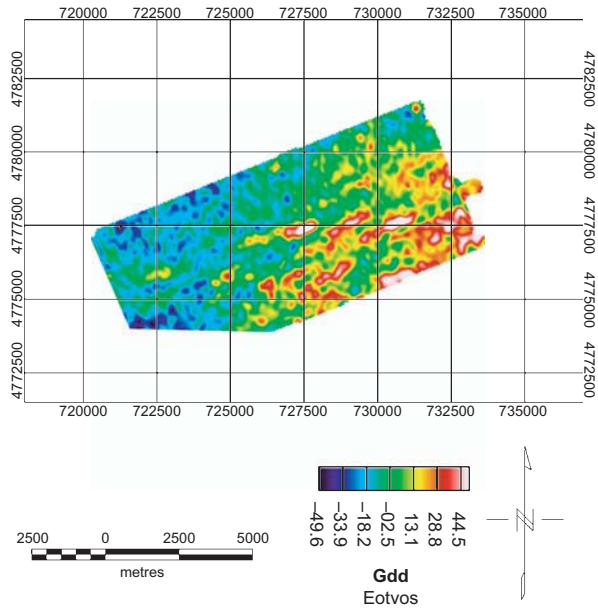


Fig. 5. Original analogue AGG survey data collected at Bulgary Ridge test site in late 1999. Line-spacing was 200 m over the entire site and mean ground clearance was 120 m.

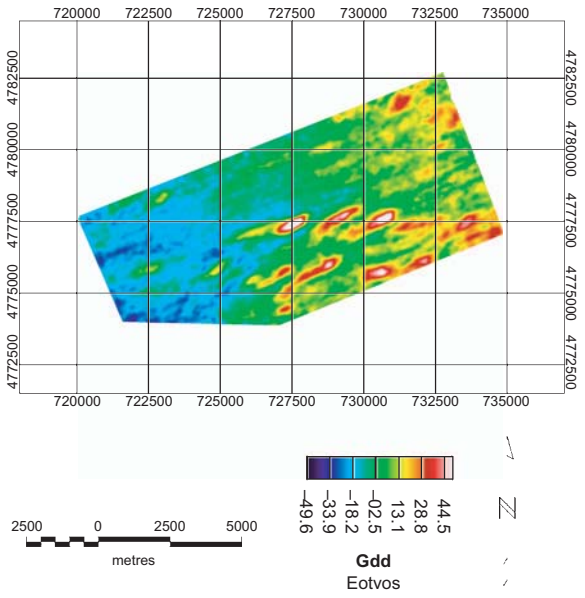


Fig. 6. Feynman survey data collected from a Cessna Grand Caravan over the Bulgary Ridge test site in early-2005. Line spacing was 100 m and mean ground clearance was 120 m.

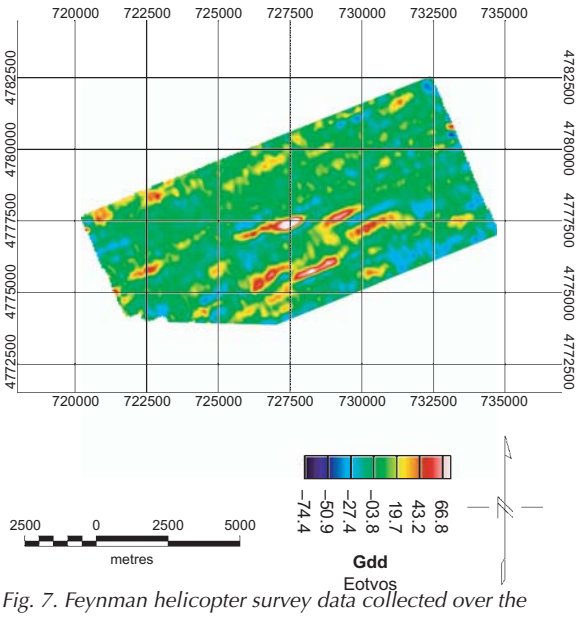


Fig. 7. Feynman helicopter survey data collected over the Bulgary Ridge test site in mid-2005. Line spacing was 200 m/400 m and mean ground clearance was 100 m. Signal amplitudes are approximately 1.5 times greater even with this modest decrease in survey altitude.

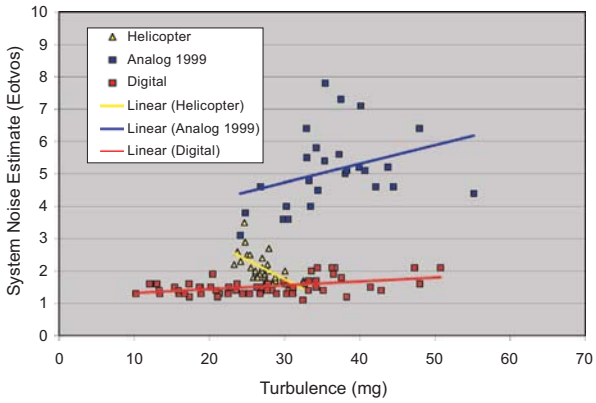


Fig. 8. Comparative noise in Gne and Guv differential curvature gradients from the three test surveys shown in Figures 5, 6 and 7. Noise statistics are estimated by differencing redundant measurements obtained along each survey line. Noise in vertical gravity derived from the Falcon™ instruments has been assessed previously by Boggs and Dransfield (2004).

1999, proving the ridges in the area to be quite detectable, as shown in Figure 5. Since that time, successive operational and processing improvements have progressively reduced noise levels in the three original Falcon™ gradiometer systems from approximately 7–10 E to between 2 and 4 E within the nominal 0.18 Hz bandwidth.

The first test results for Feynman operating in a Cessna Grand Caravan were obtained in early 2005 and are described in Boggs et al. (2005). In this test, noise levels of approximately 1.4 E within the 0.18 Hz bandwidth were achieved, with the resultant data shown in Figure 6.

Subsequent tests with the system installed in the helicopter were conducted in mid-2005 and are shown in Figure 7. Due to the increased vibration levels inherent in the helicopter environment, noise levels were slightly increased over those obtained from the Cessna Grand Caravan platform. A summary of the performance of all the systems tests described in this paper is shown in Figure 8.

Conclusions

Results from the helicopter-borne digital gravity gradiometer test program confirmed good performance and that the desired increases in sensitivity and resolution using this platform are achievable. Table 1 summarizes the typical operating characteristics for these tests.

Table 1. Digital AGG operating characteristics

	Platform	Helicopter Platform
Typical flying height	80 m AGL	50 m AGL
Survey speed	55 m/s	30 m/s
Filter full wavelength	300 m	150 m
Gne/uv noise	2.5 E	3.0 E

Subsequent work to address issues surrounding operation in the helicopter environment has further improved the performance to nearly that obtained during tests of the Feynman system in the Cessna Grand Caravan.

References

Boggs, D.B., and Dransfield, M.H., 2004, Analysis of errors in gravity derived from the FALCON™ Airborne Gravity Gradiometer: Extended Abstract, ASEG-PESA Airborne Gravity 2004 Workshop, August 2004, Sydney.

Boggs, D.B., Lee, J.B., Maddever, R.A.M., van Leeuwen, E.H., Turner, R.J., Downey, M.A., McCracken, K.G., and Liu, G., 2005, The BHP Billiton Digital Gravity Gradiometer: Preview, **117**, 21–22.

Lee, J.B., 2001, FALCON™ gravity gradiometer technology: Exploration Geophysics, **32**, 247–250.

Stone, P.M., and Simsky, A., 2001, Constructing high resolution DEMs from Airborne Laser Scanner Data: Extended Abstract, ASEG 15th Geophysical Conference and Exhibition, August 2001, Brisbane.

Continued from p. 25

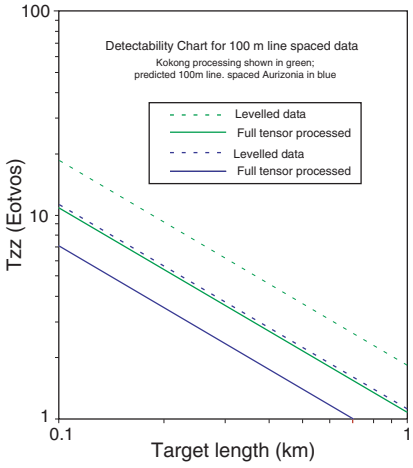


Fig. 4. Comparison of Tzz Detectability responses for Kokong (green) and a simulated 100 m line spaced Aurizonia survey (blue).

This compares favourably with figures reported by Hatch (2004) describing Air-FTG® accuracy as 5.4 E over 300 to 400 m. The analysis described in this paper suggests that this figure is now improved to 2.0 to 3.0 E over 300 to 400 m spatial wavelengths.

Conclusions

Air-FTG® is a viable technology in any exploration program. Its accuracies are now improved since 2004 and typically have noise thresholds of 10 E^2 km. This translates to an on-the-ground detectability threshold of 2 to 3 E for targets 300 m in size.

Acknowledgements

The authors wish to acknowledge Aurizonia Petroleum and Bell Geospace for access and permission to publish the Air-FTG® data presented in this paper.

References

Hatch, D.M., 2004, Evaluation of a Full Tensor Gravity Gradiometer for Kimberlite Exploration, in R.J.L. Lane, ed., Airborne Gravity 2004 – Abstracts from the ASEG-PESA Airborne Gravity 2004 Workshop: Geoscience Australia Record 2004/18, 73–79.

Hinks, D., McIntosh, S., and Lane, R.J.L., 2004, A Comparison of the Falcon™ and Air-FTG® Airborne Gravity Systems at the Kokong Test Block, Botswana, in R.J.L. Lane, ed., Airborne Gravity 2004 – Abstracts from the ASEG-PESA Airborne Gravity 2004 Workshop: Geoscience Australia Record 2004/18, 125–134.

Murphy, C., 2004, The Air-FTG®Airborne Gravity System, in R.J.L. Lane, ed., Airborne Gravity 2004 – Abstracts from the ASEG-PESA Airborne Gravity 2004 Workshop: Geoscience Australia Record 2004/18, 7–14.

Time-lapse microgravity study for injection water monitoring of the Talang Jimar Field

Summary

Time-lapse microgravity mapping in the Talang Jimar Field, Indonesia was carried out three times: January 2003, May 2003 and September 2003. From these results we made three different maps of the time-lapse microgravity anomalies. We then produced a density distribution map by applying the forward and inverse modelling approach. The results show that the trends of relatively high anomalies correspond to a fault distribution pattern showing northeast–southwest trends. The faults are sealed for horizontal water flow, but they are open for vertical water flow. We confirm this by forward modelling based on geology and well data.

As the geological structure of this area is a graben type, the microgravity anomalies caused by water injection are distributed along the both sides of the graben. Some high microgravity anomalies found in the southern part are caused by the existence of the faults trending northeast–southwest. This study provides an understanding of the injected water distribution and the role of faults in channelling water flow. Therefore, we conclude that the injection well should be placed in the middle part of the graben and the production wells should be placed in both sides of the graben.

Introduction

A microgravity survey is the observation of the gravity values at the scale of microgals. The result is accurate enough to detect very small changes in the subsurface density.

Injection of water to an oil reservoir is one of the methods used to get the oil to flow towards production wells. The Talang Jimar Field is one of the oil fields located in the South Sumatra Basin (Figure 1). The discovery well was drilled by the Dutch Company BPM in 1937 into the Talang Akar Formation of Miocene age at the total depth of 1338 m. After producing oil for some years, the production rate of the Field started to decrease. In order to retain production, water was injected into the Field by using injection wells.

This study was carried out in order to monitor the movement of water in the reservoir by observing the microgravity values over the Field. This could be done by interpreting changes of density distribution from microgravity measurements at different times. The difference, known as the time-lapse microgravity anomaly, could be interpreted as the change of density due to water injection.

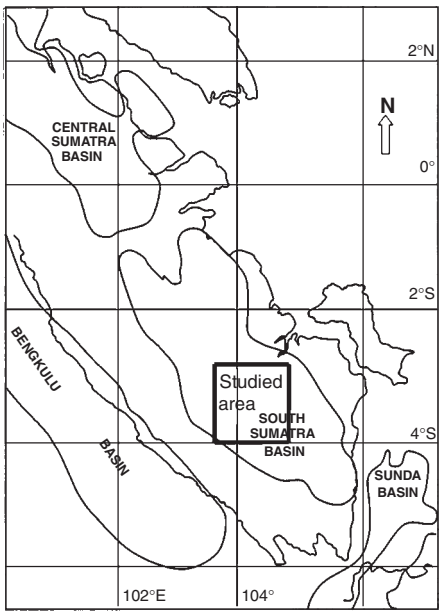


Fig. 1. Location map of South Sumatra Basin.

Geology of the Talang Jimar Field

The South Sumatra Basin was formed by an east–west extension from the end of the pre-Tertiary to the beginning of the Tertiary (Darman and Sidi 2000). Tectonically, the structural features present in the Basin result from three main events (de Coster 1974).

They are the Middle-Miocene orogeny, Late Cretaceous-Eocene tectonism and a Plio-Pleistocene orogeny. The first and second of these tectonic processes produced the basement configuration. These are formations of half grabens, horsts and faults blocks (Adiwidjaja and de Coster 1973; Pulunggono and Cameron 1984). The third tectonic event contributed to the northwest–southeast trending structures and the northeast trending depression.

Locally, the Talang Jimar Field is one of the oil fields in the area bounded by Lematang Depression (South Palembang Depression) in the south, the Limau Graben in the north, the Ogan Low in the east and the Pendopo High in the west (Figure 2).

The general stratigraphy of the Field is shown in Figure 3. The Lahat or Lemat Formation is the oldest formation, consisting of a series of andesitic volcanic breccias, tuffs, lahar deposits and lava flows, with a quartz sandstone horizon in the middle. This formation is overlaid by Talang Akar Formation, which consists of sandstone, limestones and clay. The age of Talang Akar formation is Late Oligocene to Early Miocene. The Baturaja Formation lays conformably on the Talang Akar Formation. The oil in the Talang Jimar Field is produced from the Talang Akar Formation known as the F-sand. According to 2D seismic interpretation of the near Top F-sand, the Talang Jimar Field is characterized mainly by northeast–southwest trending normal faults.

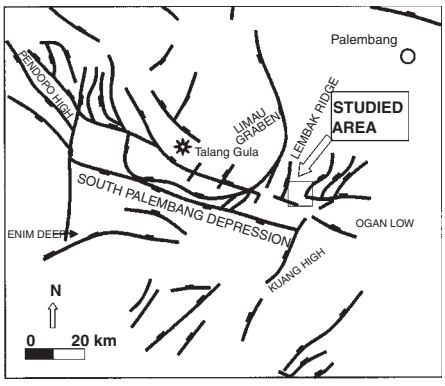


Fig. 2. Tectonic setting of Talang Jimar Field.

Djoko Santoso
dsantoso@itb.ac.id

Wawan Gunawan

Syarkowi
Geophysical Engineering Research Group, Bandung Institute of Technology, Indonesia

Adriansyah

Waluyo
Pertamina, Indonesia

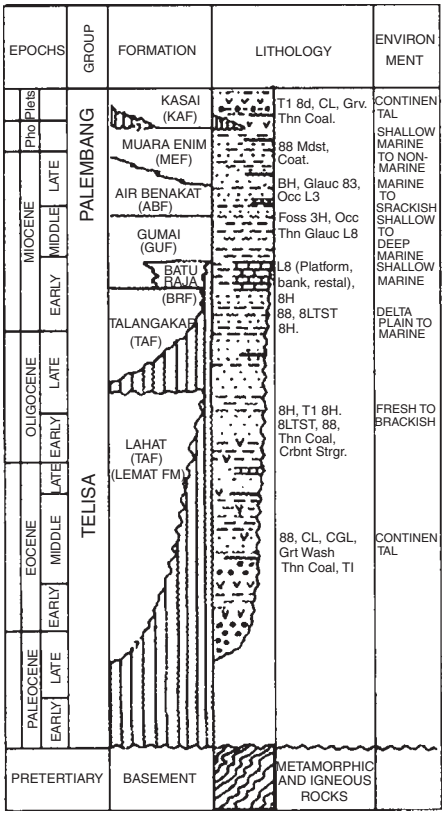


Fig. 3. General stratigraphy of South Sumatra Basin.

Microgravity observations, anomalies and time-lapse mapping

Time-lapse microgravity mapping is divided into stages. The first stage is the data acquisition, which was carried out at least twice at two different times. We assumed that all the corrections for normal gravity, Bouguer, free air, and terrain were constant throughout each of the surveys. Therefore, the anomaly, which is the difference between two measurements at the lapse-time, is mainly due to changes of the subsurface density and tidal effects. The tidal gravity values were observed using continuous gravity measurements in the area. Therefore, if we can measure the tidal gravity values, we can calculate the anomaly mainly caused by the change of the mass or change of density in the subsurface. An example of the tidal gravity value measurements in Talang Jimar area is shown in Figure 4.

An ideal model for a time-lapse microgravity anomaly and the change of the reservoir density due to water being injected into the reservoir can be seen in Figure 5. This figure shows the gravity measurement lines, the injection well and the distribution of the production wells (Figure 5a) at time t0 and after water injection. We can assume

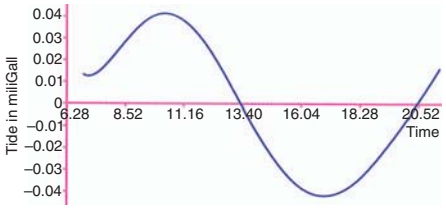


Fig. 4. Tidal observation in Talang Jimar Field in 24 January 2004.

that the water is flowing to all directions surrounding the injection well.

The injection of water means we add mass in the reservoir; therefore, it will increase the overall density values of the reservoir and result in an increased microgravity anomaly, because the density of water is higher than oil (Figure 5b).

The time-lapse microgravity anomaly map will show the distribution of the density mainly due to the change in the reservoir properties. If this information is supported by some geological and geophysical data, which is mainly related to the structure and the production history of the wells, we will be able to interpret the movement of the injected water.

Time-lapse microgravity mapping of the Talang Jimar Field

Time-lapse microgravity mapping in the Talang Jimar Field was carried out three times. The first measurements were carried out in January 2003, the second in May 2003 and the third in September 2003. The studied area is approximately 1500 m wide and 4500 m long. The distance of each line of observation is 100 m and the distance of each observation points is 50–60 m. Three instruments were used for detecting the tidal effect on gravity. Therefore, the time-lapse microgravity observation values can be calculated as:

$$\Delta g_{obs} = g_{obs(t1)} - g_{obs(t2)} \qquad (1)$$

where

$g_{obs(t1)}$ is the corrected gravity observation value measured at time $t1 = g_{obs(1)} - g_{tide(1)}$; $g_{obs(1)}$ = the gravity observation value measured at time $t1$; $g_{tide(1)}$ is the microgravity value caused by the tidal effect during the first measurement.
$g_{obs(t2)}$ is the corrected gravity observation value measured at time $t2 = g_{obs(2)} - g_{tide(2)}$; $g_{obs(2)}$ = the gravity observation value measured at time $t1$; $g_{tide(2)}$ is the microgravity value caused by tidal effect during the second measurement.

Figure 6 shows the time-lapse microgravity values between the measurements of January and May 2003. The time-lapse microgravity map between May and September 2003 is shown in Figure 7.

From those two maps we can obtain a density distribution map at depth of the reservoir. According to Kadir *et al.* (1996), Santoso (1997), Kadir (1999) and Kadir and Santoso (2000), we have the following relationship for the density distribution.

If we have a three dimensional body with the density $\rho = (\alpha,\beta,\gamma)$, the gravity response at point $P\ (x,y,z)$ at the lapse time (Δt) can be written as:

$$\Delta g(x,y,z,\Delta t) = G \int_0^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \times \frac{\Delta\rho(\alpha,\beta,\gamma,\Delta t)(z-y)}{[(x-\alpha)^2+(y-\beta)^2+(z-\gamma)^2]^{3/2}} \times d\alpha d\beta d\gamma \qquad (2)$$

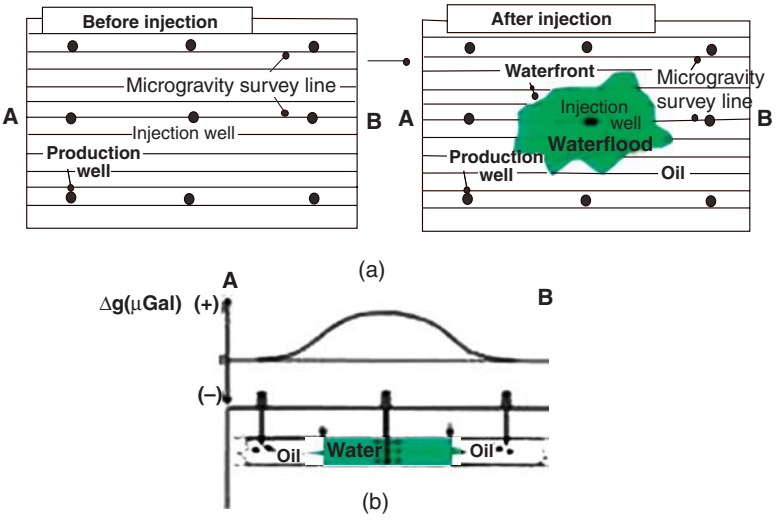


Fig. 5. Ideal model of microgravity anomaly caused by water injection. 5a shows a plan view of the model, before and after water injection. 5b shows the gravity anomaly due to the injected water.

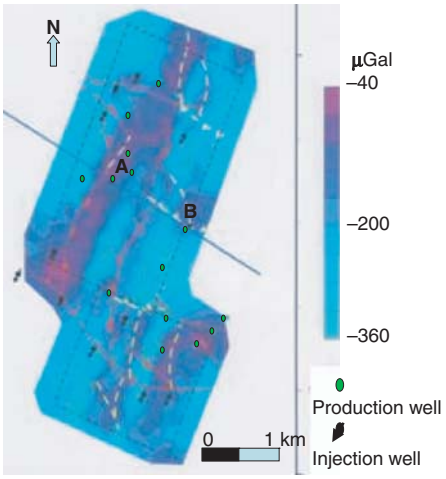


*Fig. 6. Time-lapse microgravity anomaly map of January–May 2003 of Talang Jimar Field. **A** and **B** indicate the location of the cross section shown in Fig. 9.*

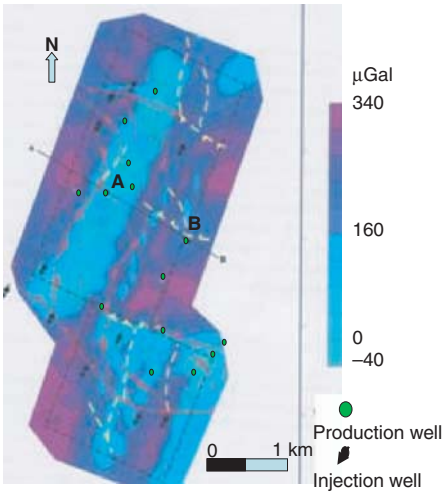


Fig. 7. Time-lapse microgravity anomaly map of May–September 2003.

where α, β, γ are defined as the location of the body, $P(x, y, z)$ is the location of the observation point, and Δt the time interval.

If there is no geometrical change and volume change of the body then Equation (2) can be approached as:

$$\Delta g(x,y,z,\Delta t) \cong K.\Delta\rho(x,y,z,\Delta t) \qquad (3)$$

$$\Delta g(x,y,z,\Delta t) = g(x,y,z,t2) - g(x,y,z,t2) \qquad (4)$$

where

$\Delta g(x,y,z,\Delta t)$ is time-lapse microgravity anomaly;
K is a constant value related to the geometry and volume of the body;
$g(x,y,z,t1)$ is microgravity at the first observation ($=g_{obs(t1)}$);
$g(x,y,z,t2)$ is microgravity at the second observation ($=g_{obs(t2)}$).

Equations (2) and (3) indicate that the time-lapse microgravity is directly proportional to the density change. This change could be due to the change of density caused by the addition or release of fluids inside the pore of the rock. During the water injection, there is a possibility that the reservoir pores were filled with water at the lapse time observation Δt. We write the density change ($\Delta\rho$) as:

$$\Delta\rho = \rho - \rho' \qquad (5)$$

where ρ is the density at the first observation and ρ' is the density at the second observation after time Δt.

The time-lapse density anomaly maps of Talang Jimar Field, which are derived from the maps of Figures 6 and 7, using the assumption of the section in Figure 8 and 9, are shown in Figures 10 and 11, respectively. These two maps are obtained using a deconvolution technique mentioned by Kadir *et al.* (1996). The two maps show the density distribution at two different times. The difference might be caused by water injection.

Figure 6 is the microgravity anomaly map showing the difference between two observations carried out in January and

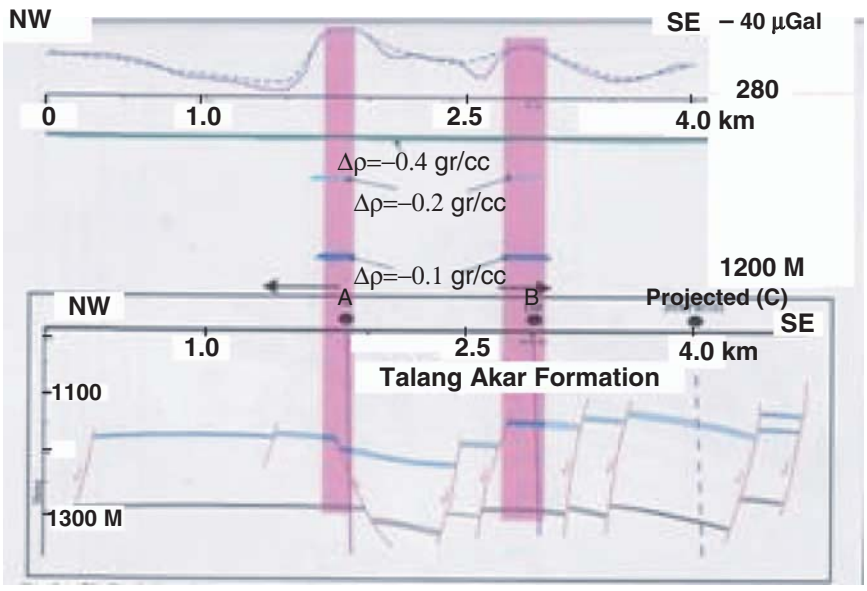


Fig. 8. Forward modelling as an approximation for calculating the time-lapse density distribution map of January–May 2003.

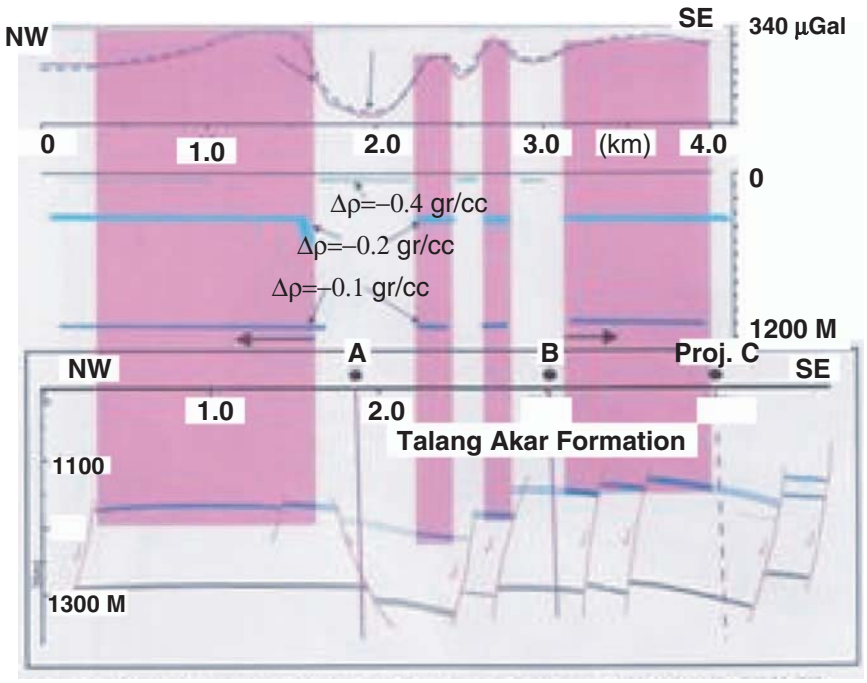


Fig. 9. Forward modelling as an approximation for calculating the time-lapse density map of May–September 2003.

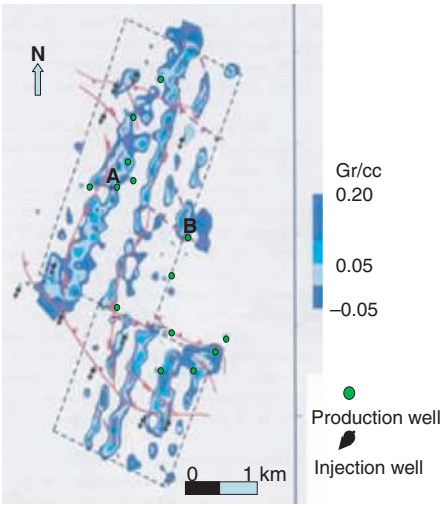


Fig. 10. Time-lapse density distribution map of January–May 2003.

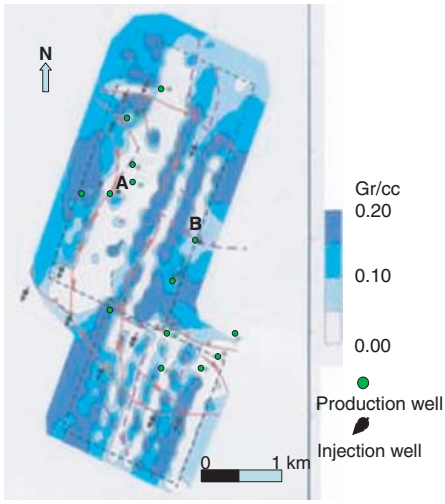


Fig. 11. Time-lapse density distribution map of May–September 2003.

May 2003. We considered that the change was caused by the change of density associated with the rainfall water in the upper subsurface layer, because we know that January 2003 was the rainy season while May 2003 was the dry season. This change should be corrected later. Another possibility is that the differences were caused by the additional water in the upper part of the reservoir and the increase of water injected into the reservoir itself. In order to prove this hypothesis the forward modelling technique was applied. The result shows that the best fit for the anomaly can be achieved by correcting the upper-part low-density value due to the lost of density contrast –0.4 g/cc, with the layer thickness of 10–20 m from the surface (Figures 6 and 8). Besides the upper surface layer, the best fit was also achieved by the additional density contrast of 0.2 g/cc in the depth range 350–400 m that was caused by the additional water above the reservoir. On the other hand, the density increase of 0.1 was found in the reservoir at the depth of 1100–1200 m, which is caused by water injection. The best fit section was through the Well A and B (see Figure 6). As mentioned before, using those assumptions, the density distribution map using a deconvolution method of time-lapse microgravity anomalies between January and May 2003 was obtained as shown in Figure 8.

A similar approach was made to map the time-lapse microgravity anomaly for May and September 2003. Some parameters were changed as the upper subsurface layer has a thickness of 15–20 m, the increase of the layer above the reservoir is around 350 m, and the same depth of 1100–1200 m is the depth of reservoir. This section is shown in Figure 9, and the density distribution map as the microgravity anomaly difference between May and September 2003 can be seen in Figure 11, respectively.

Analysis and interpretation of injection water monitoring

According to the geological information, the main Talang Jimar Field is a graben structure. The normal faults are trending approximately southeast–northwest. In the southern part we found the thrust faults directed about northeast–southwest. The geological data indicate that the productive zones are mainly sandstones of Talang Akar Formation. The locations of injection wells are close to the location of the faults. On the other hand, the production wells are located near the sides of the graben (Figures 6 and 7).

The time-lapse density anomaly maps in the Figures 10 and 11 show the distribution of high density material mostly located near the footwall. This is interpreted as being caused by the flow of the injected water only through the faults zone and being trapped towards hanging wall. This indicates that the fault is sealed at the hanging wall, as the sand reservoir allows the water to flow in any direction. Therefore, we can conclude that the fault pattern makes compartments of the reservoir in the oil field. Consequently, it becomes important to map these compartments accurately.

The result of this study suggests the relationship between the boundaries of the compartments and location of the injection wells and the production wells are crucial. It is better to place the injection well close to the middle part of the graben (as the main part of the field), and to make the water push the oil towards the west and east where we can locate the production wells.

Conclusions

The conclusions from this research are:

- The density distribution maps and their sections successfully monitor the flow of injected water in the area, as shown by the relatively high density anomaly found around the fault zones due to the location of the injection wells located in the fault zone area.
- The reservoir of the Talang Jimar Field is not a continuous sand formation but consists of several compartments as indicated by the blockage of the water flow towards the hanging wall.
- In order to increase the oil production, we suggest that the injection wells should be placed near the middle of the compartment (graben) and the production wells are located towards the boundary of the compartment.

References

Adiwidjaja, P., and de Coster, G.L., 1973, Pre-Tertiary paleotopography and related sedimentation in South Sumatra: Proceedings of Indonesian Petroleum Association 2nd Annual Convention, pp. 89–103.

de Coster, G.L., 1974, The geology of the Central and South Sumatra Basins: Proceedings Indonesian Petroleum Association Third Annual Convention, June, 1974, pp. 77–110.

Darman, H., and Sidi, F.H., 2000, An outline of the Geology of Indonesia: Indonesian Association of Geologists.

Kadir, W.G.A., 1999, The 4D gravity survey and its subsurface dynamics: a theoretical approach: Proceedings of the Indonesian Geophysical Society Annual Meeting.

Kadir, W.G.A., and Santoso, D., 2000, Porosity estimation of porous rock using 4D gravity survey: Proceedings of 2000 AAPG International Conference and Exhibition, Bali.

Kadir, W.G.A., Sukmono, S., Zen, M.T., Hendrajaya, L., Santoso, D., 1996, Gravity evidence for the thinning crust around the north Sumatra area: Proceedings of the Indonesia Petroleum Association 25th Annual Convention, Jakarta.

Pulunggono, A., and Cameron, N.R., 1984, Sumatran microplates, their characteristics and their role and their evolution of the Central and South Sumatra Basins: Proceedings of the Indonesian Petroleum Association Convention, Jakarta.

Santoso, D., 1997, Analysis of density distribution map of gravity data and resistivity study of Muaralaboh Geothermal Field: Proceedings ASCOPE'97, Jakarta.

Geological Surveys of Queensland, Western Australia, Northern Territory, Tasmania and Geoscience Australia

Update on Geophysical Survey Progress (Information current at 11 January 2007)

Table 1. Airborne Magnetic and Radiometric Surveys

Survey Name	Client	Project Management	Contractor	Start Flying	Line km	Spacing AGL Dir	Area (km^2)	End Flying	Final Data to GA	Locality Diagram (Preview)	GADDS release
Ashburton	GSWA	GA	UTS	4 Aug 06	105,840	400 m 60 m N/S	34,920	27 Dec 06	TBA	121 – Apr 06 (p. 35)	TBA
Southern Officer Basin	GSWA	GA	GPX	15 Aug 06	105,200	400 m 60 m N/S	37,330	91% complete @ 9 Jan 06	TBA	121 – Apr 06 (p. 35)	TBA
Musgrave	GSWA	GA	Fugro	15 Jun 06	83,950	400 m 60 m E/W;N/S	27,920	10 Oct 06	Expected @ end Jan 07	121 – Apr 06 (p. 35)	TBA
Isa South-West	GSQ	GA	Fugro	3 Apr 06	140,000	400 m 80 m E/W	50,100	2 Aug 06	TBA	118 – Oct 05 (p. 41)	TBA
Isa South-East	GSQ	GA	Fugro	8 Aug 06	101,200	400 m 80 m E/W	35,800	19 Nov 06	TBA	118 – Oct 05 (p. 41)	TBA
Tiwi Islands	NTGS	GA	Fugro	2 Oct 06	29,300	400 m 80 m N/S	10,200	19 Nov 06	TBA	123 – Aug 06 (p. 39)	TBA
North-East Tas	MRT	GA	GPX	Early Feb 07	52,000	200 m 90 m E/W	8,600	TBA	TBA	123 – Aug 06 (p. 39)	TBA
Flinders Island	MRT	GA	UTS	9 Jan 07	17,900	200 m 90 m E/W	2,900	TBA	TBA	123 – Aug 06 (p. 39)	TBA
East Isa North	GSQ	GA	UTS	31 Jan 07	113,000	400 m 80 m E/W	39,940	TBA	TBA	125 – Dec 06 (p. 32)	TBA
East Isa South	GSQ	GA	Fugro	31 Jan 07	145,900	400 m 80 m E/W	51,560	TBA	TBA	125 – Dec 06 (p. 31)	TBA
AWAGS2	GA	GA	UTS	End Jan 07	145,350	75 km 80 m N/S	7,659,861	TBA	TBA	124 – Oct 06 (p. 15)	TBA
Tanumbirini	NTGS	GA	TBA	Quotes closed 20 Dec 06	69,463	400 m 80 m E/W	24,047	TBA	TBA	126 Jan 07	TBA

TBA: To be advised

Notice that UTS Geophysics has been awarded the contract to cover the whole continent with a 75 km grid at a nominal flying height of 80 m. The map of the grid is shown in the October 2006 *Preview* on page 15. The survey is expected to take the whole year to complete.

Seismic Reflection Surveys

The ANSIR seismic crew completed the 2006 Mt Isa Seismic Transect Project on Wednesday 13th December. Although we were expecting rain to stop the survey early, it never came and the entire project was completed last year. The crew acquired a total of 900.7 km of deep seismic data along 6 seismic traverses located across the Mt Isa Inlier. The Mt Isa project involved the Geological Survey of Queensland – Queensland Department of Mines & Energy, Geoscience Australia, Zinifex Limited, the *pmd**CRC and ANSIR. TERREX Seismic, ANSIR's facility manager is thanked for their efforts in completing this task for ANSIR. The objectives of the project involved improving the understanding of the Mt Isa regions crustal architecture and its mineral systems.

Geoscience Australia and Geological Survey of Queensland have finished the first phase of planning a deep seismic transect from the Mt Isa Inlier to the Georgetown region, then southwards through Charters

Table 2. Gravity Surveys											
Survey Name	**Client**	**Project Management**	**Contractor**	**Start Survey**	**No. of Stations**	**Station Spacing (km)**	**Area (km²)**	**End Survey**	**Final Data to GA**	**Locality Diagram (Preview)**	**GADDS Release**
Isa Area B	GSQ	GA	Fugro	4 Jul 06	9,898	2 and 4 regular	78,000	10 Oct 06	TBA	118 – Oct 05 p. 41	Dec 06
Webb	GSWA	GA	Daishsat	14 Aug 06	4,100	2.5 regular	24,800	13 Sep 06	4 Oct 06	123 – Aug 06 p. 38	Dec 06
Isa Area C	GSQ	GA	Fugro	19 Oct 06	9,236	2 and 4 regular	68,500	71% complete @ 9 Jan 07	TBA	124 – Oct 06 p. 29	TBA
Murchison	GSWA	GA	Fugro	Feb 07	3,600	2.5 regular	24,800	TBA	TBA	123 – Aug 06 p. 39	TBA
Isa Area D	GSQ	GA	Daishsat	1 Feb 07	4,903	4 regular	75,460	TBA	TBA	125 – Dec 06 p. 32	TBA
Isa Area E	GSQ	GA	Daishsat	1 Feb 07	6,233	4 regular	97,420	TBA	TBA	125 – Dec 06 p. 32	TBA

TBA: To be advised

Towers to the Drummond Basin. This survey will commence in April this year and involve the collection of approximately 1100 km deep seismic reflection data, as well as coincident gravity data and magnetotelluric data. This survey is funded in part by the Commonwealths Onshore Energy Security Initiative and the Geological Survey of Queensland. Industry has already expressed interest in collaborating. An AuScope proposal (via Professor Bill Collins, JCU) to run a seismic traverse from the Georgetown region towards Cairns, crossing the Palmerville Fault and Tasman Line is being planned as part of this larger northern Queensland deep seismic project.

The ANSIR high frequency MiniVib completed a series of jobs in Western Australian with Curtin University. The MiniVib work included work near Leinster with Curtin and Newmont mapping local Archaean stratigraphy and structure that hosts nickel sulphide deposits in the Wiluna greenstone belt. The MiniVib's last job for 2006 was in the Perth Basin where it undertook a groundwater project involving the Western Australia Water Board.

For further info please contact Bruce Goleby +61 2 6249 9404 or bruce.goleby@ga.gov.au

Northern Territory

The Northern Territory Geological Survey has completed flying airborne magnetics and radiometrics over the Tiwi Islands, that is, Melville Island and Bathurst Island.

The first use of the data will be to explore for strands of heavy minerals on the deep sediments that cover the islands.

How deep? Is another question to be addressed from the Tiwi data. Very strong tides have applied considerable sorting round the islands, so it is hoped that more indications for minerals sands deposits will be given by the new information.

The NTGS has obtained funding to fly the Tanumbirini survey, mainly over the Tanumbirini sheet and half of the Hodgson Downs sheet, which we expect to fly in May. This survey is listed in Table 1 above and the location is shown in Figure 1.

Roger Clifton

GA identifies priority areas for new oil search program[1]

On 14 August 2006, the Prime Minister announced $134 million in additional funding for Geoscience Australia as part of the Australian Government's Energy Security Initiative (see October 2006 Preview, p. 14). This new funding, which will extend from 2007 until 2011, includes $75 million to continue Geoscience Australia's offshore frontier basin program to identify a new oil province. The program will support the annual offshore acreage releases for the next five years by providing precompetitive information, acquiring new geophysical (such as 2D seismic) and geological data, and improving data access for the exploration industry.

The initiative builds on the $61 million 2003–07 Big New Oil Program, but at an accelerated pace. In contrast to the 2003–07 program, which included $10 million for remastering of existing seismic data and $15 million for new data acquisition, the new program allocates over $60 million for new data acquisition, reprocessing, interpretation and access.

Geoscience Australia has prepared a portfolio of potential offshore frontier areas for discussion with industry (see Figure 2). Likely areas for inclusion in the new program are deepwater frontier areas, such as the Mentelle Basin and offshore northern Perth Basin, off southwestern Australia; the Capel, Faust, Fairway, Gower and Moore Basins of the southern Coral Sea; and the Sorell Basin/South Tasman Rise region off western Tasmania. Options for data acquisition in older, more complex basins in shallow waters of western and northern Australia are also being considered.

Meetings with national and international companies will take place over the next few months, and planning should be finalised by the end of March 2007.

Acquisition of new regional 2D seismic data in frontier basins has been the cornerstone of the 2003–07 program, augmented by reprocessing of previously

[1]Information obtained from an article by Clinton Foster in AusGeo News, December 2006, Issue No. 84.

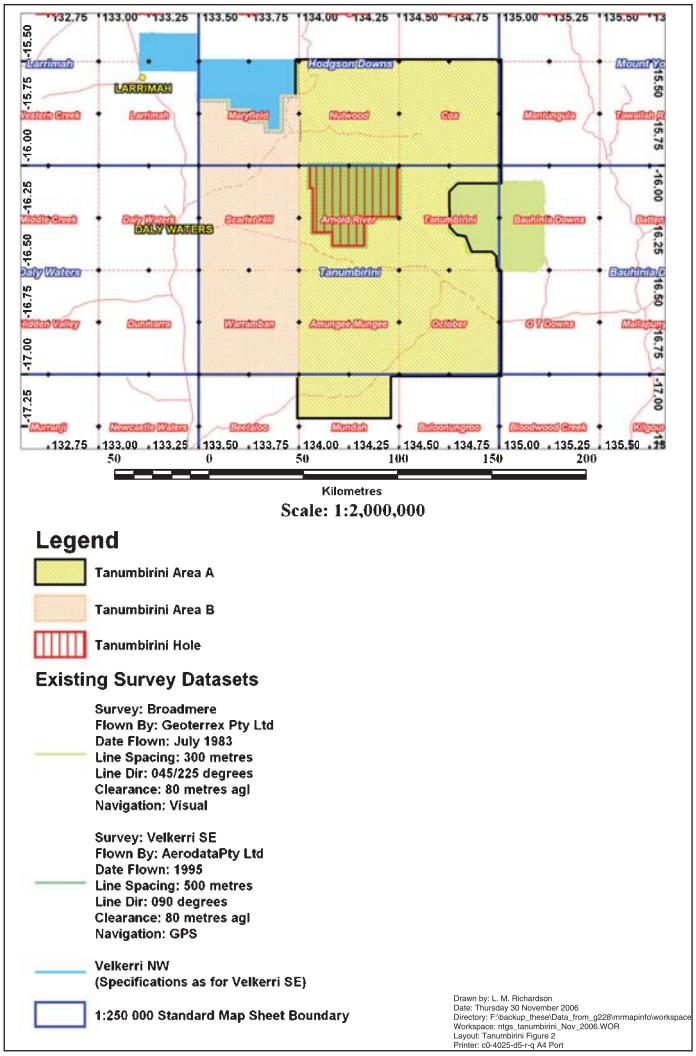


Fig. 1. Location of the Tanumbirini airborne survey scheduled for 2007 (see Table 2).

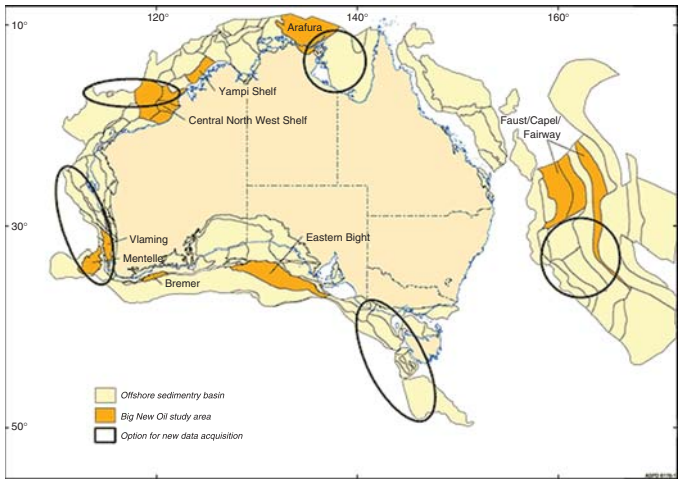


Fig. 2. Areas studied in current Big New Oil program and options for new data acquisition.

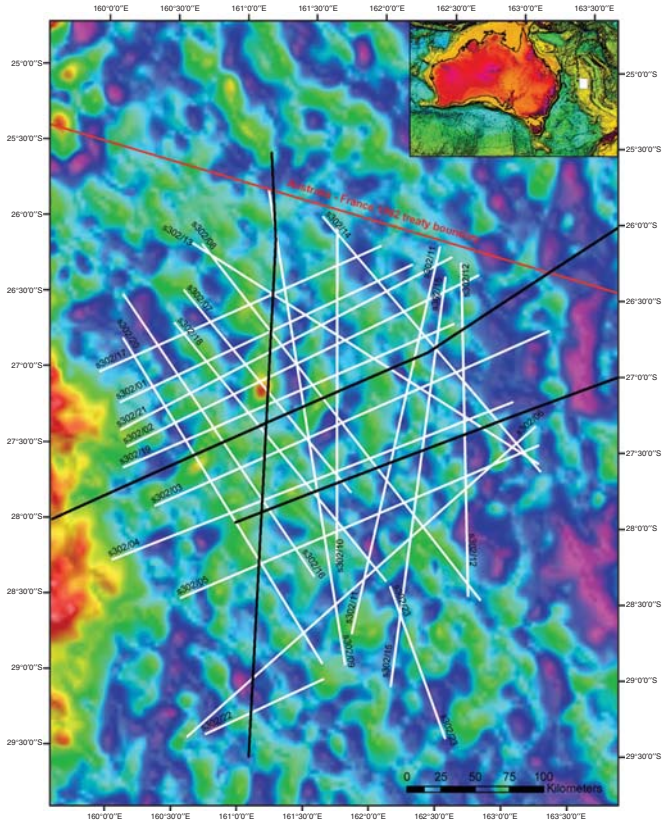


Fig. 3. Geoscience Australia Survey 302, Capel and Faust Basins Seismic Survey, November 2006 to January 2007.

acquired seismic data, geological sampling and natural hydrocarbon seep detection. For more information phone Clinton Foster on +61 2 6249 9447 or email on: clinton.foster@ga.gov.au

Capel and Faust Basins Seismic Survey completed

Geoscience Australia has completed a seismic survey in the Capel and Faust Basins, approximately 800 km due east of Brisbane, in the initial appraisal of the hydrocarbon potential of this area. These two remote deepwater offshore basins were identified in as part of the Australian Government's 2003–2007 New Oil initiative, to open up offshore frontier areas for exploration.

The Pacific Titan acquired a grid of approximately 5920 km of high quality 2D seismic data from 19th November 2006 to 7th January 2007 with a line spacing of approximately 30 km. The attached map shows the position of the seismic lines collected, overlayed on the satellite gravity data. Lines marked in white are from the new survey and those in black are from AGSO surveys collected in 1996 and 1998. The white square in the top right hand corner of the map shows the area in which the data was collected.

The vessel used an 8 km solid seismic streamer, and collected 12 seconds of data with a 12.5 m group interval and 37.5 m shotpoint interval resulting in 106 fold cmps.

Magnetic, gravity and long offset refraction and reflection data were also collected during the survey.

As with previous surveys in this program, all seismic data will be available at the cost of transfer from Geoscience Australia. The contact link is http://www.ga.gov.au/oceans/og_Rpstry.jsp

Fred Kroh and Paul Williamson

Mineral and Petroleum exploration surge in September quarter

Minerals

Exploration powers ahead

Figures released by the Australian Bureau of Statistics in December 2006 show that the trend estimate for total mineral exploration expenditure increased by 7.2% in the September quarter 2006. The trend estimate of $365.3 million is now 28.4% higher than the September quarter 2005 estimate. The level of expenditure is now only 12% less than the CPI adjusted peak of $289 million, reached in the June quarter 1997, and is the second highest on record.

Figure 1 shows the expenditure estimates from September 1998 through September 2006. Both the trend and the seasonally adjusted numbers are powering ahead.

Figure 2 shows the longer term trends from March 1986. It indicates that in real terms (CPI adjusted) the expenditure levels are approaching those of 1997.

The largest contributions to the increase this quarter were in Western Australia where the investment increased by $33.9 million or 22% to a massive $190.2 million. Most of the other states and the Northern Territory reported similar levels to those in the previous quarter. Western Australia attracted 48% of the nation's minerals exploration dollars, with Queensland being a distant second at $64.2 million.

The Greenfield investment is a healthy 35% of the total. It is now at $138.5 million, compared to the September quarter for 2005 (105.5 million).

Drilling activity also increased substantially in the September quarter with a total of 2251 km drilled in that period. This compares with a total of 1835 km for the September quarter of 2005.The total for September 2006 comprised of 1439 km on existing deposits and 812 km on new deposits.

No wonder everyone is flat out looking for new resources! How long can these trends continue?

Petroleum

Hugh increase to best ever

Not to be outdone, the petroleum sector turned in another very good performance. Exploration expenditure for the September quarter increased by $108.7 million (28.6%) to a record $488.6 million.

Expenditure on production leases increased by $22.0 million or 20.1%, while exploration on all other areas increased by $86.8 million or 32.1% during this quarter.

There was an increase of $96.4 million (33.9%) in offshore exploration, while onshore exploration expenditure increased by $12.4 million (13.0%).

Western Australian expenditure increased from $168.7 million to $289.9 million and now attracts about 60% of the total Australian exploration investment in this sector. The Northern Territory, had a slight fall from $114.3 million to $101.4 million, but is still a very good second.

Figure 3 shows a plot of the quarterly petroleum exploration expenditure from March 1986. Notice that in the last year there appears to have been a significant increase exploration expenditure. Clearly the government's Big New Oil program is having the desired effect.

2006 a good year for resources

Resource stocks do well

Resource stocks listed on the ASX performed very well during 2006. Figure 4 shows the total market capital of the resource companies listed on the ASX in the top 150 Australian companies. It also shows how the top two companies, BHP Billiton and Rio Tinto, have performed together with the All Ords Index. Notice that from 2000 until mid-2006 the resource stocks outperformed the All Ords. However, since mid-2006 the resource stocks have become more volatile.

By the end of 2006 there were 17 resource companies in the top 150 companies. BHP Billiton dominated the market and for a short period in May its capital value went up to more than $110 billion. However, the big winners were in the Zinc and Uranium businesses. Zinifex started 2006 at $3.39 billion and finished at $9.15 billion – not a bad gain. Paladin Resources was even more impressive. It started at about $1 billion (it was not even listed in the top 150 until March) and at the end of the year it had risen to $4.46 billion!

As usual there were takeovers and mergers to keep investors on their toes. Placer

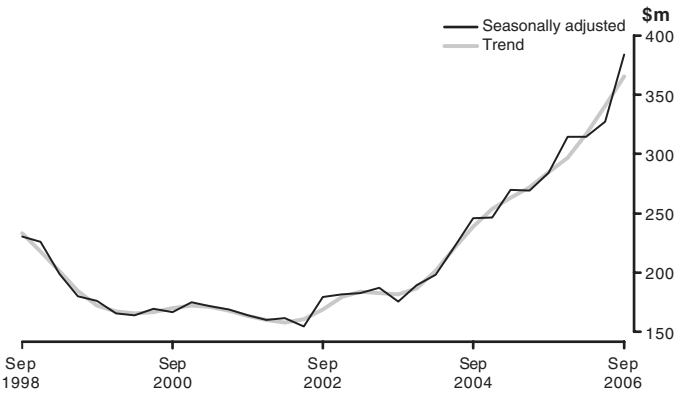


Fig. 1. Trend and seasonally adjusted quarterly mineral exploration expenditure from September 1998 through September 2006 (provided courtesy of the Australian Bureau of Statistics).

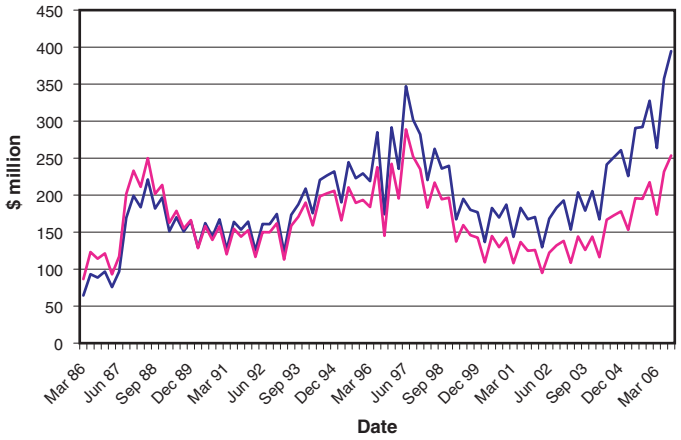


Fig. 2. Quarterly 'actual' mineral exploration expenditure from March 1986 through September 2006 (from ABS data). The blue curve represents actual dollars spent and the red curve shows the CPI adjusted number to 1998/99 levels (ABS data).

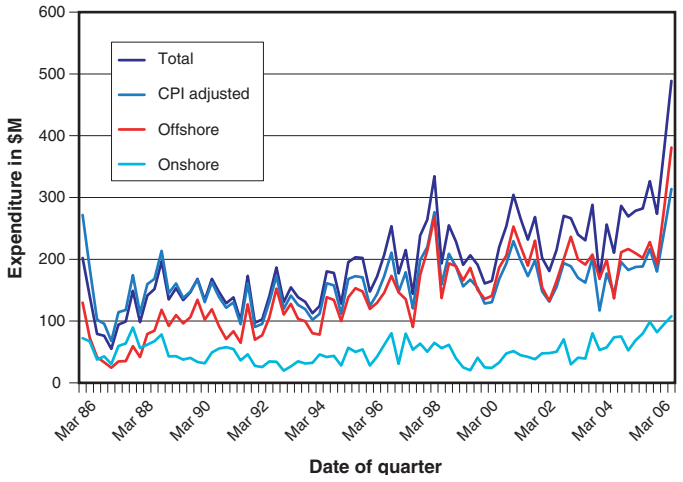


Fig. 3. Quarterly petroleum expenditure from March 1986 through September 2006. The individual offshore and onshore numbers are actual numbers spent at the time, not CPI adjusted. The dark blue graph shows the contemporary dollars spent and the blue curve shows the CPI adjusted number to 1989/90.

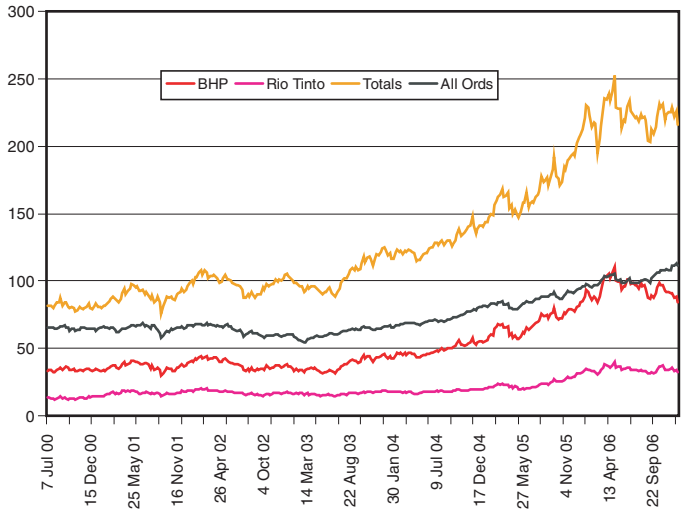


Fig. 4. Graph of the total market capital of the resource companies in the top 150 listed companies on the ASX, together with a history of the top two; BHP Billiton and Rio Tinto, and the All Ords. Notice that from 2000 until mid-2006 the resource stocks outperformed the All Ords index. However, since mid-2006 the resource stocks have become more volatile.

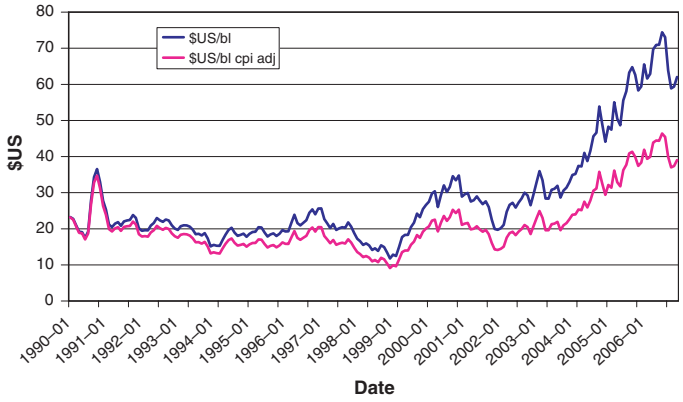


Fig. 5. Price of West Texas Crude from 1990 though 2006 in $US. The CPI adjustment is to 1989/90 $US values. In the first half of the 1980s (not plotted) the CPI adjusted price was over $50/barrel. Since the start of 1999 the price has steadily increased.

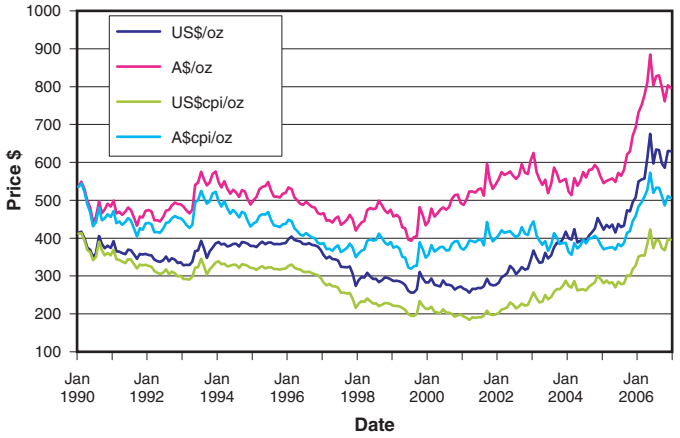


Fig. 6. Gold prices in $A and $US per oz, with and without CPI adjustments. The CPI adjustments are normalised to1989/90. Notice that the price in Australian dollars does not increase in real terms until mid-2005.

Dome was the biggest casualty. It was first listed in October 2002, at $5.8 billion, and in March 2006, when it was valued at $15.1 billion, it was taken over by Barrick Gold and delisted.

Excel Coal was delisted, when it was taken over by Peabody Energy in October 2006. However, it was only valued at $2 billion so the impact on the total resource market capital was marginal.

Commodity prices strong in 2006

Oil

Oil surged until the later part of the year. Figure 5 tells the story. However, although it is now at record highs for the last 15 years, the price has not reached the heady days in the early 1980s when it rose above $50/barrel in 1998/90 dollars.

Gold

Gold has performed soundly during 2006 but not increased as dramatically as oil. As shown in Figure 6 it is really only since mid-2005 that there has been any major increase. Gold prices are more complex than oil because there needs to be adjustments, not only for CPI increases, but also for the $A/$US conversion. This is because the costs of operating mines are mostly in $A for Australian gold mines, and the sale price for gold is in $US.

Other metal prices

Figure 7 shows the variation in a selection of other metal prices during 2006. These were taken from the London Metal Exchange website. Although most of the prices have increased during the year, there has been considerable volatility in the Copper price. This increased substantially from March through May and since then its price has followed a downward trend. Nickel, Tin and Zinc were the best performers with their prices approximately doubling in twelve months.

No wonder the mineral exploration investments have been very encouraging.

Offshore exploration acreage proposed for release in 2007

Minister Ian Macfarlane plans to announce the 2007 Acreage Release package on 16 April 2007 at the APPEA annual conference in Adelaide, South Australia.

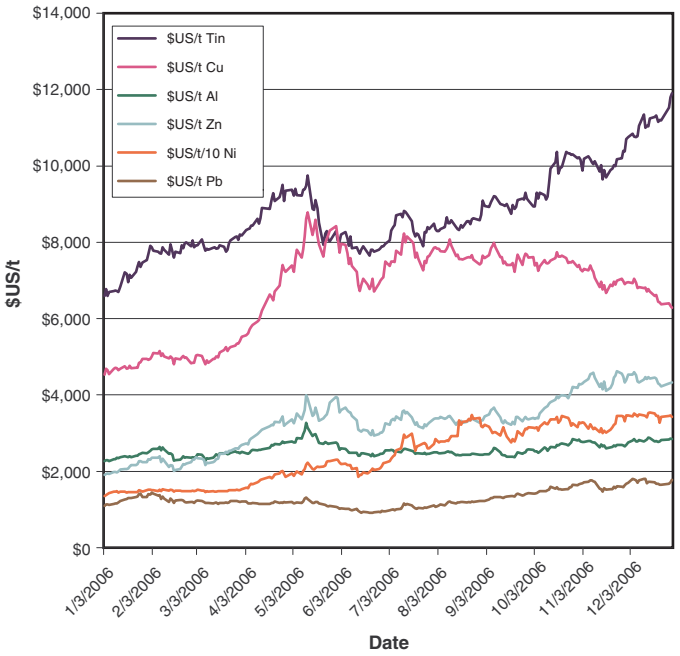


Fig. 7. Metal prices for Tin, Alumina, Zinc, Copper, Lead and Nickel in $US/tonne except for Nickel, where the price is ten times the plotted values. Notice the gradual decline in Copper prices since May 2006 and the doubling of prices for Ni, Zn and Tin.

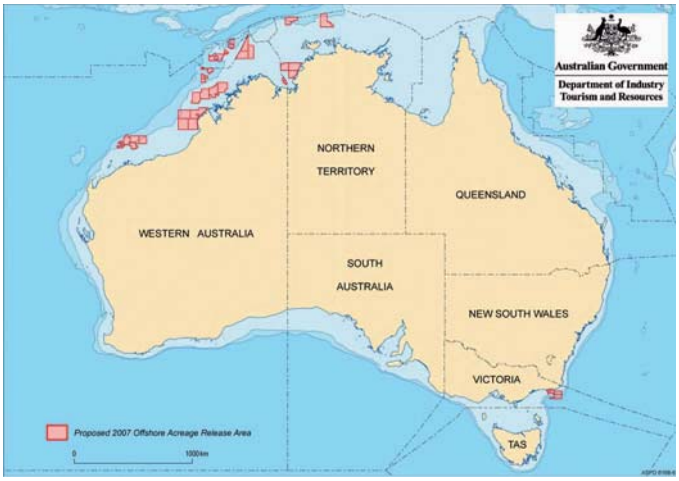


Fig. 8. Proposed 2007 Offshore Acreage Release areas. Notice how the North West Shelf areas dominate the release.

Summary of areas available for bidding from the 2006 rounds		
Release/round	**Areas**	**Bid Closing Date**
2006 Acreage Release, Second Closing Round [14 areas]	NT06-1 to 4 (Northern Arafura Basin) T06-5 (Northeast Bonaparte Basin) W06-1 to 5 (Northern Bonaparte Basin) W06-9 & 10 (Central Exmouth Plateau) and W19 & 20 (Perth Basin)	Thursday, 10 May 2007
Re-release of 2006 areas (from first close of bidding round) [2 Areas]	W06-13 (Barrow Sub-Basin) and V06-1 (Eastern Otway Basin)	Thursday, 10 May 2007

The map below (Figure 8) indicates the areas currently proposed for release in 2007. This preliminary advice is provided to allow industry greater lead time to assess areas and to facilitate acquisition of speculative seismic data.

In addition to the above areas, two areas that did not receive bids in the first bidding round of the 2006 Acreage Release have been re-released as well as 14 areas released in the 2nd bidding round of 2006. Bidding for all these areas will close on Thursday 10 May 2007. The areas are shown in the table below.

Further information on these areas and application requirements can be found by visiting this website: www.industry.gov.au/petexp or by requesting a free CD-ROM by email: petroleum.exploration@industry.gov.au

Jack Rayner and the Imperial Geophysical Experimental Survey

John Rayner[1]
Visiting Fellow,
National Centre for the Public Awareness of Science,
Australian National University
john.rayner@anu.edu.au

Introduction

The Imperial Geophysical Experimental Survey (IGES) of 1929 to 1931 arguably marks the beginning of exploration geophysics in Australia. The principal aim of the IGES was:

> 'To conduct thorough trials of the principal geophysical methods and to determine their practical value and limitations under a variety of geological conditions' (Edge and Laby 1931, p. 1).

Priority was to be given to areas where two or more techniques could be applied and compared, and also to areas where the results could be checked by other means, such as from the known geology or drilling. Barry Butcher (1984) has written an excellent article that places the IGES within the social and political context of the times. The technical work of the IGES is well documented in its formal report (Edge and Laby 1931), which for many years was used as a standard textbook in exploration geophysics.

A second major objective of the IGES was to provide:

> 'Instruction in the use of the instruments and the application of the methods in the field to be given to such Australian students and others who may be nominated for the purpose' (*ibid*).

The success of this objective can be measured by the number of people involved in it who were to have a major impact on the further development of geophysics in Australia, including: Bob Thyer, Norm Fisher, Lew Richardson, Neil ('Blue') Lewis, Eric Blazey, Joe Pawsey, and my father, Jack Rayner.

Jack Rayner joined the IGES is 1929 as the 'trainee geophysicist' on secondment from the NSW Mines Department. He had just completed a first class honours degree in mathematics and physics at Sydney University specialising in the production of ultra-short wavelength radio waves and working with Vic Bailey. At the time the only suitable texts in this area were in French (Mesney 1927) and its companion volume on triodes (Gutton 1925), which I still have in my library.

Figure 1 shows some of the IGES staff dressed for the field photographed at Regatta Point, Strahan, Tasmania. James Ferguson (later of the Southern Rhodesia Geological Survey) and Sydney Shaw (later of the Colonial Geological Survey) had joined the IGES from South Africa, where they had been working with the director of the IGES, Arthur Broughton Edge. Regrettably, Etienne Bieler, a Swiss born Canadian and the senior theoretician, contracted pneumonia and died in July 1929, leaving a major hole in the program, At the time of his death he had only made some very rough notes on electromagnetic techniques, and so it was left to Jack, the 'trainee geophysicist', to complete this section of the final report.

The experimental program of the IGES investigated a wide range of geophysical techniques including: surface electrical: (resistivity and spontaneous polarisation), electromagnetic, magnetic, gravity and seismic refraction. As shown in the map in Figure 2, field sites were scattered across Australia and included Gulgong (seismic, magnetic, electrical and gravity), Gippsland (gravity, electrical and magnetic), and Tasmania (electrical and magnetic). The distances were enormous and travel onerous for the staff. For example, Bob Thyer recalls how it took him two weeks and 15 changes of train to go from one field site at Northampton in WA to Chillagoe in far north Queensland (Wilkinson 1996, p. 23).

Fig. 1. Left to right: James Ferguson, Etienne Bieler, Jack Rayner and Sydney Shaw, taken at Regatta Point, Strahan, Tasmania, early 1929.

Techniques

Seismic

The refraction seismic program was very much of an experimental nature as there was little written on the subject and so the field techniques had to be developed on the spot, largely by trial and error. The 6-channel recording equipment consisted of

[1]In the 2007 Australia Day Honours, John was awarded an AM for service to education, particularly in the areas of electronics engineering and physics, and to the community through the development and delivery of science enrichment programs. We offer him our congratulations and hope he will be able to contribute further to *Preview* in the future.

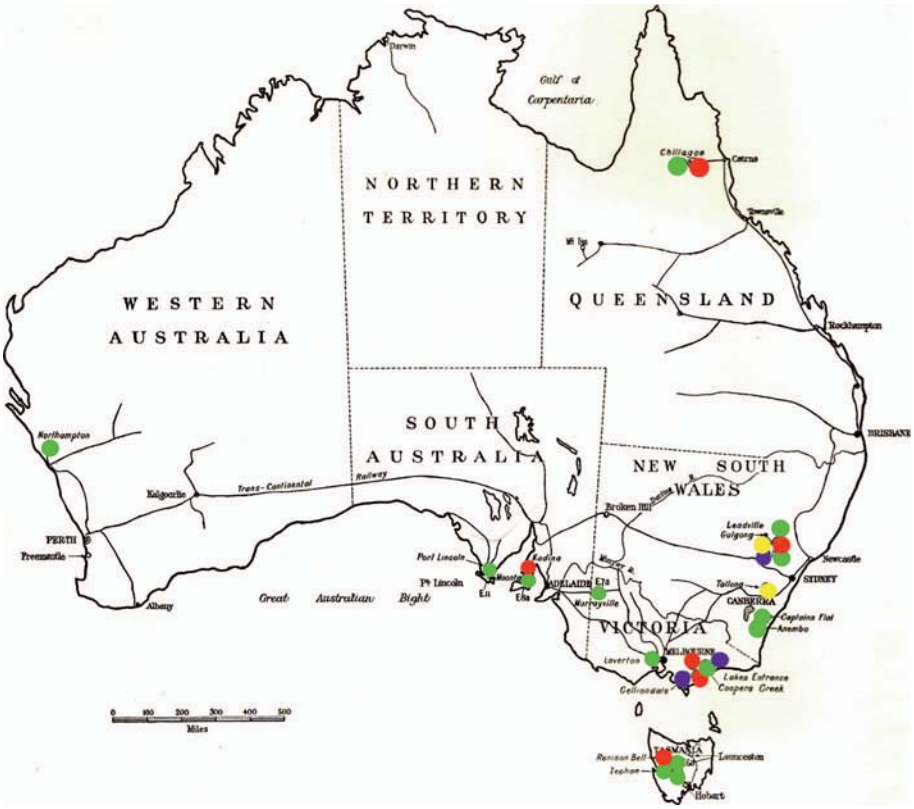


Fig. 2. Map showing sites used by the IGES for different types of survey: Yellow, Seismic; Blue, Gravity; Red, Magnetic; Green, Electrical (Edge and Laby 1931, Frontispiece).

Fig. 3. Exterior of the portable seismic hut, Home Rule near Gulgong, NSW.

an Einthoven string galvanometer with 6 strings arranged in a 'harp', and automatic photographic recording of the vibrations of the moving shadows of the strings. The equipment was purchased from the British War Office, where it had been used during the Great War to locate the position of the enemy's artillery based on the recoil thump of the big guns. It was housed in the portable hut shown in Figure 3.

Major Edgar Booth, of Sydney University's Physics Department, and co-author of a classic physics text with Phyllis Nicol (Booth and Nicol 1962), acted as consultant because of his familiarity with the equipment from his war years in France. The hut was highly portable and could be pulled down, moved and re-erected at a new site in about an hour. Figure 4 shows the inside of the hut with the light source for producing the shadows of the strings, and the galvanometer on the bench.

The photographic recording equipment is to the left, but out of the picture. Figure 5

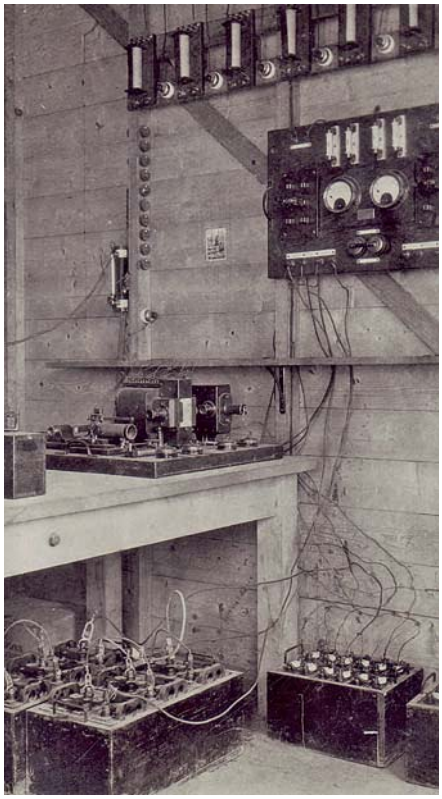


Fig. 4. Interior of the seismic hut showing the light source, the 6-string Einthoven galvanometer, and the power supplies.

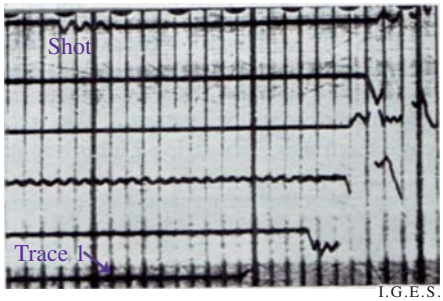


Fig. 5. Seismogram from 6-channel recorder. The top trace records the moment of the shot plus the most distant observation. Time markers 0.01 s produced by a spoked wheel controlled by a tuning fork (Edge and Laby 1931, p. 214).

is a typical seismogram taken from the Report (Edge and Laby 1931, p. 214) and shows on the top trace the shot point and also the most distant response, while trace 1 records the signal from the closest seismometer.

The source was an explosive charge of typically 25 lb[2] of blasting gelatine (nitroglycerine and guncotton) buried 12 ft down, while the geophones were essentially carbon microphones, mounted in a protective housing. Jack told me that

[2]I have used imperial units throughout in order to preserve something of the flavour of the times.

at the end of the Home Rule program near Gulgong they had a fair amount of explosive left so they decided on one last shot, augured a deeper hole than usual, back filled it with soil and the heavier pieces of unwanted camp equipment including several crowbars and fired. Apparently the crowbars were never seen again.

Gravity

The gravity survey of the Gelliondale brown coal deposit in Gippsland was undertaken using an Oertling torsion balance and a gravity gradiometer. The torsion balance stood more than 6 feet tall, and was housed in a hut consisting of a triple layer of aluminium and kapok to protect it against draughts and thermal effects, as in Figure 6. This was then placed inside a kapok-lined outer hut with a tarpaulin thrown over the top. Even with these precautions, measurements had to be taken at night.

The instrument took about an hour to set up, and another hour to stabilise. Readings were required at three different azimuths (0°, 120° and 240°) with a settling time of an hour between readings. Each station therefore required at least 4 hours for a complete observation. The balance and its hut were then transported on a home-made handcart to the next station. Jack reckoned that 14 stations per week was good progress, with the 325 stations of the Gelliondale survey taking about 6 months of laborious work to complete. Not surprisingly the Report concluded that 'The torsion balance…did not prove to be satisfactory under Australian climatic conditions' (*ibid*, p. 355). By comparison, the gravity gradiometer was much more reliable, was less susceptible to thermal effects, was very much faster to use (only one hour per station) and was reported to be highly portable: 'The instrument weighs only 65 lb. and can be carried by one man for 100 yards without undue stress' (*ibid*, p. 149).

I.G.E.S.

Fig. 6. Aluminium and kapok housing for the torsion balance with 'Blue' Lewis.

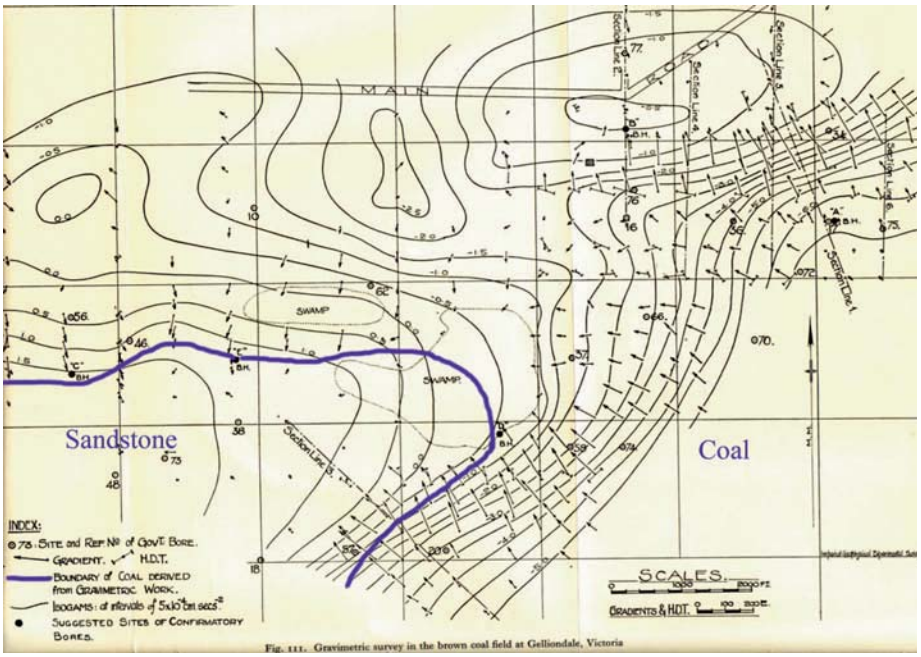


Fig. 7. Gravimetric survey of the brown coal field, Gelliondale, Victoria. The blue line represents the boundary of the coal derived from the survey. The arrows show the magnitude and direction of the gradients from which the contours of equal gravity anomaly were constructed (Edge and Laby 1931, p.156).

Figure 7 shows the gravity anomaly map resulting from the Gelliondale survey (*ibid*, p. 156). It shows the magnitude and direction of the gradients and also the contours of equal gravity anomaly derived from them. The blue line is the approximate boundary between the brown coal and the bedrock deduced from the survey. Bore-hole drilling confirmed the overall accuracy of the survey.

Gradiometers remained in service for many years with Jack undertaking one of the last surveys with such an instrument in 1939–40 to map the southern extension of the Broken Hill lode (Rayner 1939), prior to the introduction of gravity meters during the 1940s. He told me that data analysis by hand was extremely laborious as initially the gradient measurements had to be converted to gravity contours. You then assumed various sub-surface profiles from which you calculated their gravity profiles and compared them with the field data. You continued the process until a reasonable match was obtained, all with a slide rule and pencil and paper. Despite these difficulties, the Broken Hill survey was able to locate the presence of high-density mineralisation at a depth of 2400 ft (*ibid*).

Electrical and magnetic

The IGES conducted electrical and magnetic surveys over the heavy metal province of the west coast of Tasmania. Figure 8 shows Jack using a 'rapier' and back-pack amplifier to map the electrical equipotentials set up by a 500 Hz current injected into the ground by two fixed electrodes.

In the late 30s he undertook similar work around Broken Hill. One day in the field he was being helped by his newly arrived young wife, Phyllis, whose job it was to water the probes to improve their electrical contact with the very dry ground. A passing farmer stopped his truck and remarked casually: 'You'll never get 'em to grow out here love.'

Schmidt vertical magnetic balances were the main instruments used for the magnetic surveys. Jack recalled that on one occasion in Tasmania they turned up an old gun barrel. Being a miserable, cold, wet, west-coast evening they decided that they needed some mulled wine to cheer their spirits. They duly heated the gun barrel to red heat in the fire and plunged it into the claret. To their horror, the barrel

Fig. 8. Jack mapping equipotentials, west coast of Tasmania about 1929: rapier in hand, amplifier on his back and polished shoes ready for the bush.

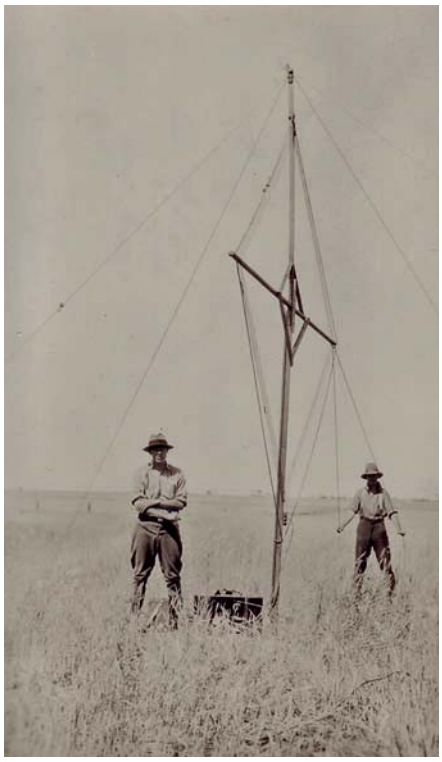


Fig. 9. Jack in the foreground and a field hand with the transmitting aerial for the high frequency electromagnetic survey.

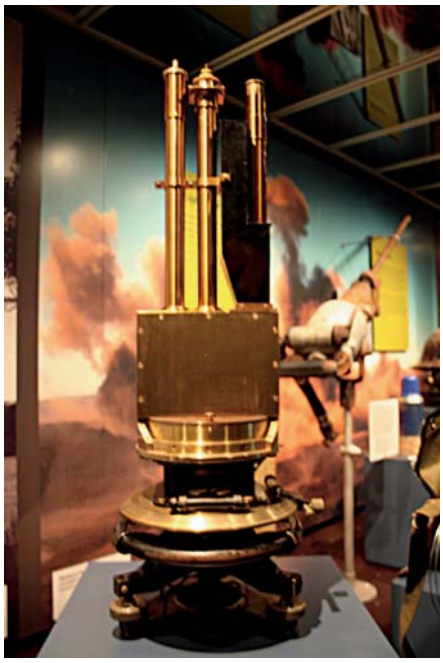


Fig. 10. Oertling gradiometer displayed in the National Museum of Australia.

discharged its accumulated debris of dirt, leaves, small sticks and charred spiders into their precious drop.

Jack always had a particular love of geomagnetism and magnetic techniques. Family history records that while with the North Australia Survey in the 1930s, he took Phyllis on some of his field trips. His bride had to ride in the open back of the truck while the precious magnetometer rode on the front seat alongside him.

Electromagnetics

The electromagnetic (EM) work was trialled at two different frequencies: a low frequency system at 500 Hz and a high frequency system at 60 kHz. For the low frequency measurements they laid out a primary loop with a side of 1000 to 1700 ft carrying a current ~3 Amp powered by a portable generator. The area inside the loop was then traversed by a double coil detector system and amplifier for which Jack remarked that '*La lampe à trois électrodes*' (Gutton 1925) proved extremely helpful. Around Renison Bell in Tasmania the system detected anomalies down to a depth of around 100 ft. A vertical antenna in the form of a triangle with a base 133 ft long and height of 45 ft was used for sharply dipping formations while the horizontal loop was more satisfactory for flat lying deposits.

Figure 9 shows the high frequency transmitting aerial, with the 25 watt, 60 kHz 'Hartley' oscillator at its base. The aerial with its 8-foot long booms was designed to be highly portable and could be folded away and readily re-erected. The detector coil was connected to a heterodyne receiver and the resulting audio tone was monitored by headphones as the plane of the coil was rotated until a null was obtained.

The Report concluded that electromagnetic methods worked well under dry conditions whereas the other electrical methods were more suited to wet conditions where skin-depth effects could be a problem for EM (Edge and Laby 1931, p. 353).

Conclusions

In discussions with Jack, and in reading the reports of the time, I have been struck by several things. The first is the skill and sheer effort required to obtain meaningful results under the most trying conditions. Lugging that torsion balance around must have caused endless swearing and frustration but also demonstrated enormous dedication to geophysics. The second is how the principles underlying the various techniques have changed so little over the years. The sophistication, sensitivity, portability and speed of the instrumentation have increased by orders of magnitude, while the use of computers for data analysis and modelling could not even have been imagined in those days. A difference in density, however, still produces a gravitational field gradient and an EM wave penetrating a conductor still induces a secondary signal with modern instrumentation relying on these same effects. In his days as the Director of the BMR in the 1960s Jack told me that in his view there were four main ages in the development of exploration geophysics: a heroic age, based largely on mechanical instrumentation, from the 1920s through to the outbreak of World War 2, a first electronic age through the war years and up to the early 1950s, a third age characterised by the rise of airborne based instrumentation and its miniaturisation, and a software age from the 1960s onwards. As a person of infinite curiosity, he would have been fascinated by the developments since those days and the prospects that the future holds.

Postscript

The Oertling gradiometer ended its life as part of a donation of equipment of historical interest to the National Museum of Australia in Canberra by Geoscience Australia. At the Museum it was cleaned, but otherwise left in its field condition,

Continued on p. 44

Reviewed by David Robinson
david.robinson@anu.edu.au

Top Resource Stocks 2007: an Australian investor's guide to 100 leading mining, energy and resource stocks

Allan Trench, Don Pridmore and Leonard Lau

Publisher: John Wiley & Sons Australia, 2006, 176 pp. (pbk)

RRP: $29.95, ISBN: 0731404890

Top Resource Stocks 2007 is an investment guide for the resource sector. It contains a concise analysis of the top 100 Australian Stock Exchange listed resource companies by market capitalisation. Market capitalisation is defined by the number of shares multiplied by the share price and it represents the nominal price that one would expect to pay to own the entire company.

The preface compares the resource sector with other market sectors and points to the importance of listing on the stock exchange. In the resource sector, the need to list is motivated by the level of funds required for a typical investment as well as the inability of individual investors to accept the high degree of risks.

The Preface is followed by an introduction which defines the selection process for the top 100. The primary criterion for selection was size. However, each of the selected companies needed to satisfy two further criteria. Their shares must have reasonable liquidity and hence be freely tradeable and they must have a significant mineral asset base, compliant with best practice reporting standards. Also covered in the Introduction is a definition of key terms as well as interesting statistics about the top 100. For example, the top 25 companies exceed $1 billion in market capitalisation, the top 50 exceed $400 million and the top 100 exceed $125 million. Of the 100 listed companies roughly half are yet to turn a profit and less than half are paying dividends.

Part I represents the core of the guide. It provides an alphabetically ordered one page analysis of each company in the top 100. Included in each analysis is a company outline, market and financial statistics, a list of key strengths and weaknesses, discussion of potential share price triggers and a table of key investments. The concise combination of statistics and author analysis facilitates an appreciation of the company, its recent performance and future potential.

Part II contains 8 tables. The first 7 of these are ordered lists of the companies by market capitalisation, shareholder return (1, 3, 5 and 10 year), dividend yield and price-earnings ratio. The final table categorises each company into a commodity-focused grouping. An appendix is included to describe the JORC code for reporting mineral resources and ore reserves and the guide concludes with a four page glossary covering commonly used terms and acronyms.

I recommend Top Resource Stocks 2007 to anyone who is investing in the minerals sector on the Australian Stock Exchange. Both seasoned and first-time investors will find the analysis useful. The template for a one page company description is well structured and allows the reader to cover areas of interest quickly. This guide may also appeal to those with a general interest in the mining sector and could be helpful for someone considering a career prospect in one of the top 100.

The Geology of Australia

David Johnson

Publisher: Cambridge University Press, 2005, 276 pp. (softback)

RRP: $69.95, ISBN: 0521601002

The Geology of Australia traces the fascinating story of Australia's formation and evolution. Two introductory chapters provide the necessary pre-requisites to enjoy the remainder of the text. The first of these chapters, "An Australian Perspective" discusses the main features of Australia including the climate, age and stability. The second chapter is a geological primer. It covers basic models of the Earth, rock types, minerals, erosion, plate tectonics, and mountain building.

Significant events in Australia's geological history are discussed in chronologically ordered chapters from Chapter 3 to 8. This historical account begins with a discussion of events prior to 545 Ma. An overview of the formation, age and heat loss of the Earth is provided and followed by a description of Archaean rocks and significant process of the Proterozoic including the formation of large orebodies and banded iron formations. The origins of life are covered and the supercontinents of Rodinia and Gondwana introduced.

Chapter 4 covers the "Warm Times" spanning from 354 to 545 Ma years ago when Australia formed part of Gondwana. Much of central and eastern Australia was overlain by warm seas during the early part of this period. Gradually, the seas retreated and cycles of sedimentation and deformation created the continental crust that now forms eastern Australia. Chapter 5 is set between 251 to 351 Ma years ago. Glaciation covered much of the country from 325 to 310 Ma and erosion by ice continued to around 295 Ma years ago. This was followed by the formation of large basins through crustal extension in north-eastern and eastern Australia which are now home to important coal resources. This time was also significant for flora as plants evolved to reproduce by seeds.

The period from 251 to 100 Ma years ago is discussed in Chapter 6. It describes how 251 to 140 Ma years ago the majority of Australia consisted of arid riverine plains with dinosaurs, reptiles and possibly even primitive mammals roaming freely. Roughly 154 Ma years ago the Western Australian coastline was formed as India broke away and began its journey towards China. Around 140 Ma years ago the seas began to rise reaching a maximum in 117 Ma where they covered much of the continent, before withdrawing again by 99 Ma years ago. It is postulated that some 100 000 cubic kilometres of volcanic debris was erupted along the eastern volcanic arc (north

Queensland to Tasmania) between 120-105 Ma ago.

Chapter 7 describes the "Birth of Modern Australia". It begins with an overview of the environment as Antarctica and Australia separated and discusses the cooling of Antarctica at 30 Ma and the subsequent formation of an Antarctic ice sheet 15 Ma ago. This led to increasing aridity in a northerly travelling Australia and ultimately the formation of sandy deserts and salty lakes. The chronological history of Australia's formation is completed in Chapter 8 which describes the volcanic activity in the eastern Highlands beginning 70 Ma and finishing roughly 4600 years ago. The basaltic volcanism is linked to gem formation and key features in the Great Dividing Range.

The building of Australia's continental shelf and coastline is the topic of Chapter 9. Types of coastlines, sea level, coastal erosion, tsunamis and the age of beach sand are all covered. A discussion of the formation, health and nature of the Great Barrier Reef is given in Chapter 10. Chapter 11 is used to relate what is observed in Australia to what we know about the planets, moons and meteorites and it describe how this information helps us learn about the earliest processes on Earth. The chapter also covers important meteorite (or comet?) impacts such as Chicxulub, which coincides with the 65 Ma extinction of dinosaurs. The final chapter summarises the key events in Australia's geological history in terms of "Cycles in a Continental Journey". It includes a discussion of global wandering, cycles of deformation, climate change, evolution and extinction.

I have no hesitation in recommending The Geology of Australia to anyone with an interest in Australian geology and landscape formation. It is written in an accessible manner that appeals to a wide audience. Johnson's writing is neither confined by excessive scientific jargon nor does it require a detailed understanding of geological processes. A copy of this book would be equally at home as an introductory text for first year university classes, on the coffee table of the amateur geologist or in the book shelf of someone researching Australian earth sciences.

Copies can be ordered directly from Cambridge University Press: Tel. (03) 9676 9955 or www.cambridge.edu.au

Continued from p. 42

and now, as shown in Figure 10 holds pride of place in an exhibition of early geophysical instruments including Geiger counters, magnetometers and gravimeters.

References

Booth, E.H., and Nicol, P.M., 1962, Physics: Fundamental Laws and Principles, with Problems and Worked Solutions, 16th ed: Australasian Medical Publishing Co., Sydney.

Butcher, B.W., 1984, Science and the Imperial Vision, The Imperial Geophysical Experimental Survey, 1928–1930: Historical Records of Australian Science 6(1), 31–43.

Edge, A.B., and Laby, T.H., 1931, The Principles and Practice of Geophysical Prospecting: Being the Final Report of the Imperial Geophysical Experimental Survey: Cambridge University Press.

Gutton, C., 1925, La lampe à trois électrodes, 2nd ed.: Les Presses universitaires de France, Paris.

Mesney, R., 1927, Les Ondes électriques courtes: Les Presses universitaires de France, Paris.

Rayner, J.M., 1939, Preliminary Geophysical Report, the Southern Extension of the main Line of Lode, Broken Hill: NSW Dept of Mines, Geological Reports, 1939–1945, 30–35.

Wilkinson, R., 1996, Rocks to Riches: The Story of Australia's National Geological Survey: Allen and Unwin.

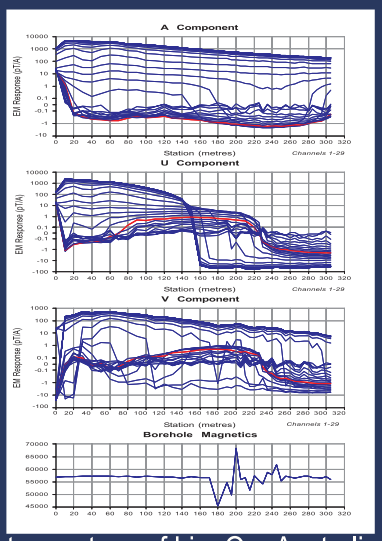
EMIT

ElectroMagnetic Imaging Technology Pty Ltd

Industry Standard Products for Mineral Exploration

Atlantis borehole system

- A low-noise 3-component magnetometer in a slim probe for TEM, MMR and geomagnetic surveys.
- Superior to dB/dt for detecting good conductors further from the borehole.
- The cross-hole components have the same noise level as the axial component.
- Automatically measures the rotation of the probe and the borehole orientation.
- Measures off-time and on-time response.
- Automated interface with SMARTem.
- The same sensor commonly used in surface EM.



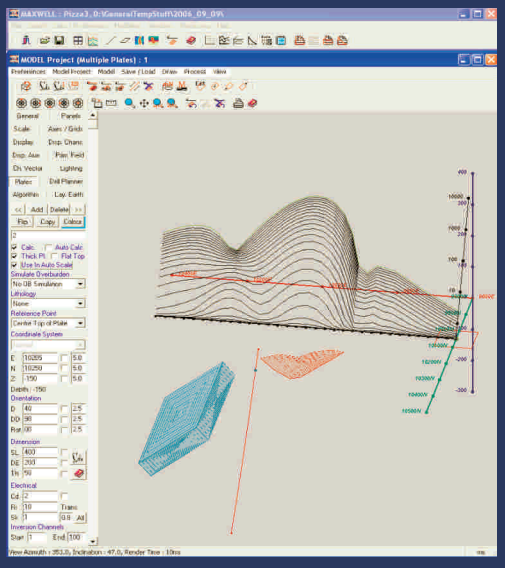
Data courtesy of LionOre Australia

SMARTem receiver system

- 8 Channel multi-purpose receiver system for EM, IP & other electrical geophysical techniques.
- PC-based system with hard disk, VGA graphics, QWERTY keypad, USB and Windows OS.
- User friendly QC software – display profile, decay, oscilloscope, spectrum analyzer, and more.
- Record and process full time series.
- Powerful signal processing for noise reduction.
- Use with any transmitter system and receiver antenna.
- Industry standard file formats.
- Optional transmitter controller with crystal sync.
- Comprehensive PC processing & display software.

Maxwell EM processing software

- Processing, visualisation, interpretation and plotting software for any type of EM geophysical data - ground, airborne, borehole, time and frequency domain.
- Constrained multiple plate inversion and approximate prism modeling.
- Display profile, decay, spectrum, plan, 3-D model and primary fields.
- Compute B-field and on-time response.
- Import/export industry-standard file formats for EM data and interface with Geosoft's OM6 and EMAX.
- Drill planning, decay analysis, MMR modeling, database of system configurations, gridding, contouring, extensive online help and many more features.



www.electromag.com.au

6/9 The Avenue, Midland W.A. 6056, AUSTRALIA. Ph (+61 8) 9250 8100. Fax (+61 8) 9250 7100. Email: sales@electromag.com.au