Preview

Australian Society of Exploration Geophysicists

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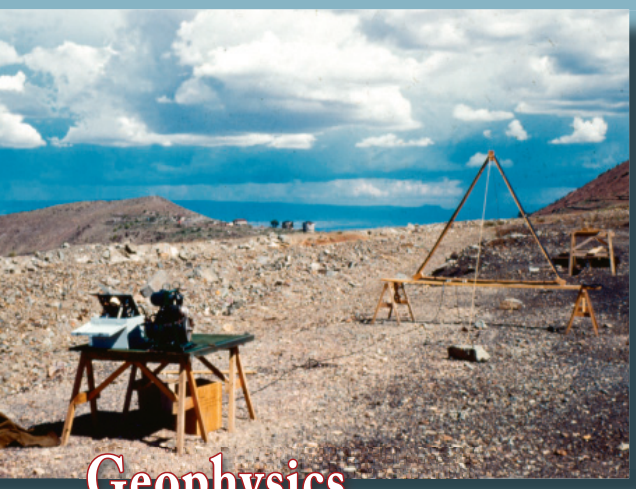

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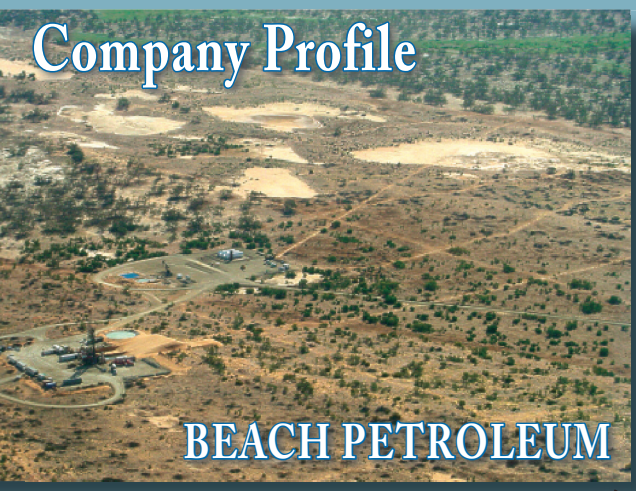

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Sumatran earthquake affects the whole world

Apart from wars and global pandemics, like the 1918 Spanish flu, the 2004 Boxing Day earthquake, that took place off the west coast of northern Sumatra, had a more widespread impact than any other disaster in the last 200 years.

The death toll to date is over 280,000, of which more than 200,000 were from Indonesia, 30,000 from Sri Lanka and 16,000 from India. In addition nearly 9000 foreign tourists from 39 countries have been reported as either dead or missing. The tourists came from all the six habitable continents. They were visiting the area from Argentina to Iceland, from South Korea to South Africa and from Australia to Canada. In Europe, for example, Germany and Sweden each lost nearly 1000 of their citizens.

Previous natural disasters have killed more people. Chinese floods in 1887, 1931, 1938/9 and 1959 reportedly killed nearly 7 million people, but these events only appeared to have affected China. The phenomena of globalisation, cheap travel and multi-national interdependence did not really predominate until the end of the 20th century. At present the world in which we live is home to 6.4 billion people, an increase of about 70 percent in the last 40 years, and these people are rapidly spreading to cover more and more of the land area. So it is not surprising that natural hazards have the potential now to cause catastrophic global effects.

So what do we know about the earthquake? Firstly, although it was a giant earthquake, it was only the fifth largest to have occurred since 1900, when the first global seismographic networks were being established. However, the 2004 event was the largest earthquake known to have occurred outside of the Pacific Basin.

The table below shows the top five.

We also know that all these top five earthquakes were associated with shallow thrust faulting at subduction zone plate boundaries. The faulted areas extended over thousands of square kilometres for each event. They also caused significant damaging tsunamis.

Faulting mechanism

The complete faulting mechanism for the main Boxing Day 2004 earthquake has not been finally determined. However, it appears (see 'Preliminary Rupture Model by Chen Ji, Caltech at http://neic.usgs.gov/neis/bulletin/neic_slav_ff.html) that the rupture, which generated the tsunami, had almost a pure thrust mechanism. The strike of the fault was ~274° with a dip of ~13° and a slip direction of ~55°. The epicentre was situated at the south-eastern end of the main fault, which propagated northwest for up to 400 km. The total rupture duration was estimated at ~200s with a maximum slip of ~20 m. The aftershock sequence extended over 1300 km along the plate boundary (see Figure 1) and in the first 12 hours after the main event ~55 earthquakes with magnitudes of 5 or greater were located by USGS. The largest had a magnitude of 8.8 and seven were larger than 6.0.

The cause of the earthquake is due to the interaction of the India Plate, which moves northeast at a rate of about 6 cm/year relative to the Burma Plate. This results in oblique convergence at the Sunda Trench. The oblique motion is partitioned into thrust-faulting, which occurs on the plate-interface, involving slip directed perpendicular to the trench, and strike-slip faulting, which occurs several hundred kilometres to the east of the trench and involves slip directed parallel to the trench (see USGS website). The December 26 earthquake occurred as the result of thrust-faulting at the trench.

The Tsunami

The tsunami generated by the earthquake caused death and destruction all around the Indian Ocean (even in East Africa where 137 people were reported killed). One of the key questions is: Given the occurrence of a giant earthquake, what sort of tsunami will it generate and where and when will it strike?

Fortunately, a modelling package is now available to address these questions (see Figures 2, 3 & 4 and Titov, V.V., and F.I. Gonzalez (1997): Implementation and testing of the Method of Splitting Tsunami (MOST)

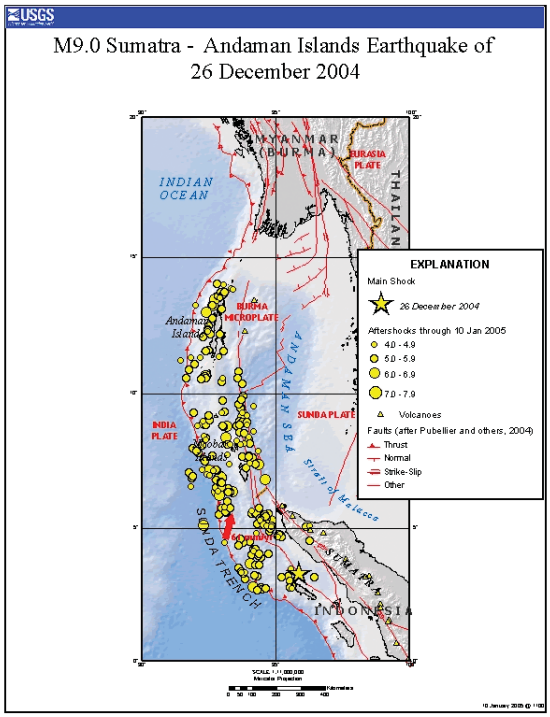

Fig. 1. Aftershock distribution and tectonic setting of the Boxing Day 2004 earthquake. Note the direction of the interaction, between the India and Burma Plates, which does not coincide with the direction of faulting from the earthquake (55°). The diagram was sourced from: http://earthquake.usgs.gov/eqinthenews/2004/usslav/tect_lg.gif.

Location	Date	Magnitude	Co-ordinates
Chile	22 May 1960	9.5	38.24 S, 73.05 W
Prince William Sound, Alaska	28 Mar 1964	9.2	61.02 N, 147.65 W
Andreanof Islands, Alaska	9 Mar 1957	9.1	51.56 N, 175.39 W
Kamchatka	4 Nov 1952	9.0	52.76 N, 160.06 E
Off west coast of Northern Sumatra	26 Dec 2004	9.0	3.30 N, 95.78 E

model NOAA Technical Memorandum ERL PMEL-112, 11; and Cummins, P., 2004, Small threat, but warning sounded for tsunami research: AUSGEO news, Issue 75, September 2004, www.ga.gov.au).

These models are clearly only first approximations to what actually happened but they provide excellent material on which to design improved warning systems.

The Future

The main focus now is to rebuild the tsunami-affected areas as rapidly as possible from the devastation and destruction they experienced. The next step is to investigate what can be done to minimize the damage from future events. As can be seen from Figure 2 the travel-times to the main populated areas in the region are mostly less than two hours. In that time the earthquake has to be located and its size determined to estimate whether or not it might generate a tsunami. And if the answer is yes, then all those likely to be threatened have to be warned. A big ask.

The location problem is the easiest to solve. With current technology seismic signals can be transmitted in real time to regional centres, where there will be a seismologist on duty 24 hours a day every day to determine the source parameters. Not easy but it can be done, and is already in place for parts of the globe right now.

The next task is harder because appropriate pressure sensitive tide-gauges have to be acquired, installed and maintained. At present there are none in the Indian Ocean. Even the Pacific Ocean is poorly served.

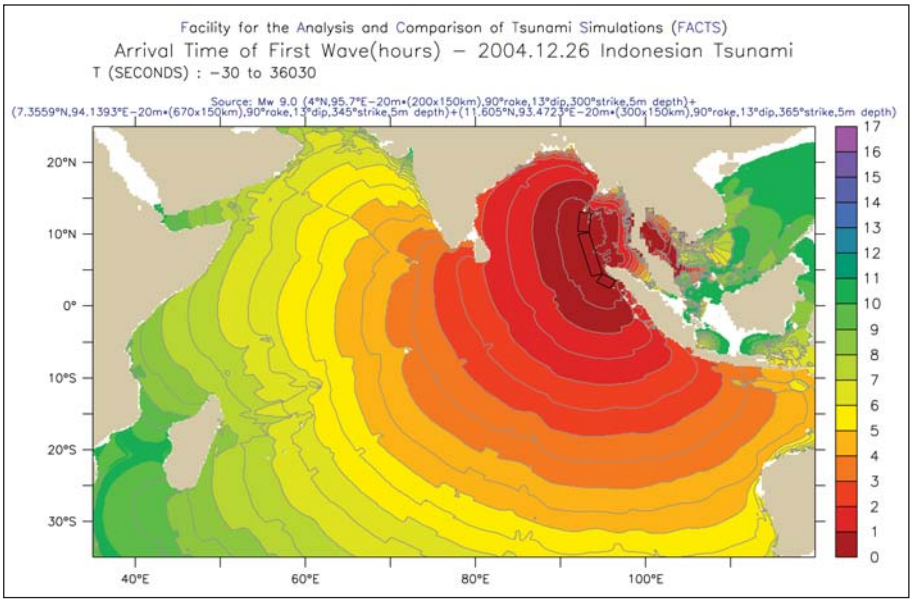

Fig. 2. Travel-times in 30 minute intervals from a modelled source comprising three fault segments. From http://www.pmel.noaa.gov/tsunami/indo20041226/TT.pdf. Notice that there is only a two hour period from the earthquake taking place and the tsunami arriving in India and Sri Lanka.

Finally, there needs to be more effective regional warning systems using the local Emergency Service Agencies. A simple phone call to the Maldives, for example, could have reduced the death toll there from 82 down to zero, but no system was in place, and nobody called.

In any case more than a phone call would be needed for Thailand, Indonesia, India and Sri Lanka. And even if a system is set up within the next six months, what are the chances of it working when the return period of these earthquakes is over a hundred years? By the time the next giant earthquake occurs at this plate boundary again there will be no one alive who remembers the last tsunami.

And of course the irony of the earthquake is that without Plate Tectonics there would be no crustal recycling, no oceans, very little atmosphere and the continents would all be flat and eroded. Plate Tectonics builds mountains, enriches soils, regulates the planet's temperature, concentrates gold, petroleum and other resources, and maintains the sea's chemical balance. Without it there would be no humans on planet Earth to be at risk from earthquakes, tsunamis and volcanoes.

I would like to thank Phil Cummins of Geoscience Australia for assistance in compiling this contribution.

David Denham

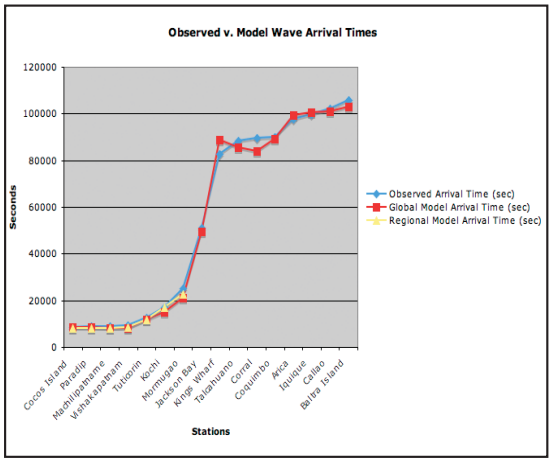

Fig. 3. Observed and calculated travel-times for the tsunami. From http://www.pmel.noaa.gov/tsunami/indo20041226/obs_vs_model.png.

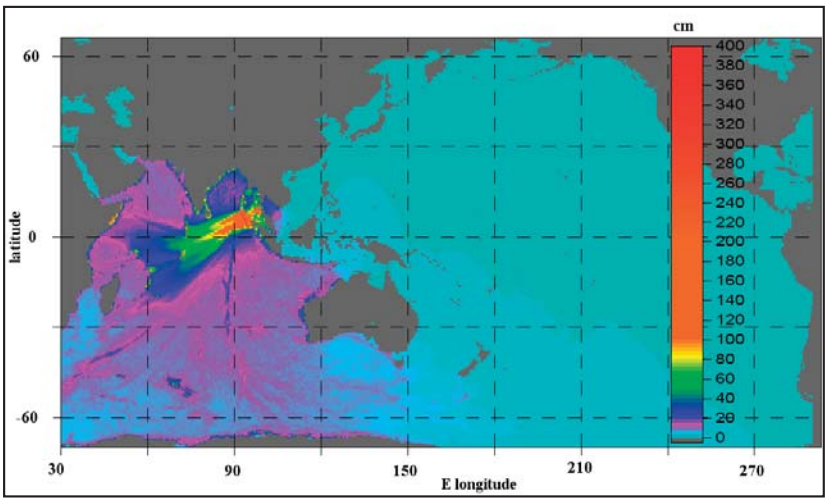

Fig. 4. Predicted amplitudes as the waves proceed across the Indian Ocean. From http://www.pmel.noaa.gov/tsunami/indo20041226/max.pdf.

The Tsunami Aftermath

I write this piece barely two weeks after the tsunami in the Indian Ocean. Most everything that can be written or said about the extent of the horror and devastation caused by the earthquake and subsequent tidal wave has already been read or heard. All the statistics relating to the magnitude of the tremor, the still escalating death toll, the size and speed of the wave, and a myriad more have by now pretty much been discussed by talking heads on every network worldwide.

From the narrow perspective of a geophysicist, one interesting aspect I noticed was the rush to find geoscientists to quote, interview, even blame in the days after the event. This is often the case on a smaller scale after every newsworthy earthquake, but this time the interest in geophysicists, cross-sections, plate boundaries, even genuine map symbols showing reverse faulting were prominent in every media I picked up.

The public's memory is notoriously short, and few will remember that the quake that initiated the tsunami was at the Indian – Burmese plate boundary, and many of the readers still haven't grasped the order of magnitude difference between an 8.0 and 9.0 seismic event.

But perhaps this is an opportunity to take advantage of the fact that the public worldwide has been reintroduced to the work of geoscientists. Maybe this is a prime time to write to our legislators and push your barrow, be it flow-trough shares for mineral leases, increased funding for government funded geoscientific research, Petroleum Regulation, native title issues, etc. Or why not spend a day at your daughter or son's school explaining what you do at work?

The mineral and petroleum sectors are booming now, but the cycle will eventually roll around, and what we do now will ensure that government and private efforts to support the geosciences continue during the down times. As well, acting now will ensure that we attract high calibre students to the profession. In fact, any geoscience related issue you care to name – yes, even tsunami prediction and warning systems – will stand a better chance of being influenced, even funded, now than at any time in recent history.

I've already heard quotes from NGO workers indicating that the challenge in tsunami ravaged areas is not just to rebuild them but to ultimately emerge with a better place for people to live. In the same vein, this just might be a time, with the world's eyes on earth issues and geoscience, to ultimately emerge with a better place in which to practice geophysics. I am assuming that ASEG members made contributions to the tsunami relief effort. I urge you also to contribute to making a difference in the role of geoscience in the community.

Howard Golden

Aims and Scope

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

Contents

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Contributions

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

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

References

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

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

Abbreviations and units

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

Deadlines

Preview is published bi-monthly, February, April, June, August, October and December. The deadline for submission of all material to the Editor is the 15th of the month prior to the issue date. Therefore the deadline for the April 2005 issue is 15 March 2005.

Advertisers

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

Advertising copy deadline is the 22nd of the month prior to issue date. Therefore the advertising copy deadline for the April 2005 issue will be 22 March 2005. A summary of the deadlines is shown below:

Preview Issue	Text & articles	Adverts Copy In
115 Apr 2005	***15 Mar 2005***	***22 Mar 2005***
116 Jun 2005	15 May 2005	22 May 2005
117 Aug 2005	15 July 2005	22 July 2005
118 Oct 2005	15 Sep 2005	22 Sep 2005

Executive Brief

The ASEG needs your input at the AGM

By the time you read this Executive Brief (I hope that people actually do read the Executive Brief) Christmas and New Year celebrations will possibly be a distant memory. After all, since Christmas there have been tsunamis, bushfires and Federal politics (Feral politics?) to occupy our thoughts, not to mention the day-to-day of our work and families. But, if you can still recall the festive season, I hope it was an enjoyable one.

I thought I would take the opportunity here to talk about the ASEG Annual General Meeting (AGM). "Boring…" – I can hear your thoughts already. Stop yawning there! This is important stuff! The Constitution of the ASEG states that AGMs shall be held at least once each calendar year and that any member shall be 'entitled' to attend the AGM. Therefore, you have a Constitutional **right** to attend the AGM (the Constitution is on the website, if you don't believe me…).

Now that you have (hopefully) stopped yawnig, you are probably wondering why you would want to attend the AGM. Well, lots of valuable business is transacted there. This includes, but is not limited to, reports from the Federal Executive on the activities of the society during the past year, financial accounting and auditing reports and finalising the election of new office bearers in the Federal Executive (hold that thought – I will come back to it later). General business, such as the presentation of 25 year membership certificates, may also be on the agenda.

I know what you are thinking…long, boring meeting. Wrong. Last year's AGM lasted about one hour. The business was transacted efficiently and we were soon enjoying drinks and nibbles.

Why would you want to attend? Because this is your Society. If you would like to be familiar with the goings on in your society or if you would like to have some input, attending the AGM is a great way to do this. Back to the election of office bearers... nominating some capable person as office bearer (or having yourself nominated) is also a very good way of having a say in what happens in your society.

When you see the notices, in the not-too-distant future, of the AGM and the election of office bearers, I strongly encourage you to participate in this process if you can and help to make the ASEG a better society. At the very least, you are welcome to come along and enjoy drinks, nibbles and the conversation of colleagues.

Lisa Vella
Federal Secretary

AUSTRALIAN SOCIETY OFEXPLORATION GEOPHYSICISTS

INVITATION
FOR CANDIDATES FOR THE FEDERAL EXECUTIVE

In accordance with Art. 14.1.12 of the ASEG Constitution, any Member may lodge the name of any other eligible Member for any of the following elected offices:

• President • President-elect • Secretary • Treasurer

by forwarding the name of the nominated candidate to the Secretary

Lisa Vella
c/- of the ASEG Secretariat
PO Box 8463
Perth Business Centre WA 6849
Australia
Fax: 08 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 COB 05 March 2005 WST. Positions for which there are multiple nominations will then be determined by postal ballot of Members and results declared at the AGM on 02 May 2005 in accordance with the Constitution.

Lisa Vella
Secretary, ASEG

2005

8-9 March
Science Meets Parliament
Venue: Parliament House Canberra
Organiser: TFASTS
Contact: http://www.fasts.org

15-16 March
SEE GRID II: Implementing interoperability for an Australian solid earth and environmental sciences grid
Venue: CSIRO Discovery Centre, Canberra
Contact: michele.quigley@csiro.au
Website: https://www.seegrid.csiro.au/twiki/bin/view/Main/WebHome

4-7 April
SAGEEP
Venue: Atlanta Airport Hilton Hotel, Atlanta, USA

5 April
Promoting Professional Women: Conference and Mentoring Program
Venue: Sofitel Wentworth, Sydney, NSW
Sponsor Australian Government
Website: www.apesma.asn.au
Email: conference@apesma.asn.au

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

19-21 April
12th annual Cultural Heritage and Native Title Conference
Theme: relationship building, negotiation, sustainable development and cultural heritage management
Venue: Novotel Langley, Perth WA
Email: info@iir.com.au
Website: www.iir.com.au/resources
See notice on this page.

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

6-7 June
11th Annual South East Asia Australian Offshore Conference
Venue: Darwin, NT
Email: rreilly@iir.com.au
Website: www.seaaoc.com

13-16 June
67th EAGE Conference & Exhibition
Madrid, Spain
Website: http://www.eage.nl/conferences/

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

19-23 September
22nd International Geochemical Exploration Symposium
Sponsors: The Association of Exploration Geochemists
Theme: From Tropics to Tundra
Venue: Sheraton Hotel, Perth, WA
Website: www.promaco.com.au/conference/2005/iges

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

2006

2-7 July
The Australian Earth Sciences Convention 2006
ASEG, in collaboration with GSA; ASEG's 18th International Conference and Exhibition, and GSA's 18th Australian Geological Convention
Venue: Melbourne, Vic.
Website: www.earth2006.org.au

2007

18-22 November
ASEG's 19th International Conference and Exhibition
Venue: Perth, WA
Contact: Brian Evans
Email: Brian.Evans@geophy.curtin.edu.au

Society of Exploration Geophysicists of Japan 7th International Symposium on Imaging Technology

Sendai, 24-26 November, 2004

Koya Suto

Terra Australia Geophysics Pty Ltd, koya@terra-au.com

John A. McDonald

Curtin University of Technology

Late November in northern Japan can be cold and miserable; however the weather during the SEGJ Symposium, which was held in Sendai, was fine and pleasantly cool. A taxi driver remarked that it was the temperature to be expected in early October. The venue, at the Aoba Memorial Hall at Tohoku University, was on the hillside of the old Sendai Castle site overlooking the City and the Hirose River. The hill is now mostly developed as a university campus.

The symposium was attended by 180 delegates from 17 countries: including 95 from Japan; 27 from Korea; 13 from China; 6 from Malaysia; 6 from Indonesia; 13 from North America; and 9 from Europe. Although we were the only two delegates from Australia, two graduates of Curtin University of Technology, currently working in Japan as Post Doctoral Fellows, gave papers.

Sixty-four oral presentations and 23 posters were presented in a variety of disciplines. The numbers of papers by discipline (oral–poster) were: Reservoir Geophysics (5-6); Borehole Geophysics (5-1); Seismic Data Analysis (7-0); Fracture Geophysics (3-1); Resistivity and Electromagnetics I (11-4); Ground Penetrating Radar (5-1); Integrated and Interdisciplinary Methods (5-2); Near-Surface and Hazard Geophysics I (13-7); Environmental Geophysics I (6-1); Laboratory Experiments and Numerical Modelling (3-0). In addition, there were eight invited papers by world experts in imaging technology.

Professor Keiiti. Aki (of Aki and Richards fame) gave a fascinating account of the possibilities of predicting earthquakes using the whole earthquake coda and not just the phase arrival times. Aki is living in Reunion, a remote volcanic island off Madagascar, which he uses as his laboratory. Aki's research has become all the more pertinent to the Indian Ocean following the Boxing Day Disaster of 2004.

Fig.2. John McDonald addresses a session at the same meeting.

Imaging technology is a broad term, and most geophysical techniques fall in this category. As seen in the number of papers presented, this symposium was unique in that majority of the presentation was on non-resource application of geophysics. Engineering and environmental application accounted for more than half of the presentation.

It is often said that SEGJ meetings do not provide information relevant to the interests of Australian SEG members. As can be seen from the list above the range of topics covered is broad. More specifically, the three papers addressing carbon dioxide disposal, which should have been of interest to persons in the CRC for Greenhouse Gas Sequestration.

We feel that unless the ASEG and its members participate in regional meetings our local society is in danger of being marginalised, and being left out of regional planning.

This Symposium was co-sponsored by SEG, ASEG, EAGE, KSEG and EEGS.

At the end of the meeting it was suggested to hold the 8th SEGJ International Symposium in Kyoto, and perhaps the 9th in Korea. Also, tentative plans were made with Craig Beasley, President of SEG, to hold a joint HAGI-SEGJ meeting in Bali in 2007. It is hoped that the ASEG will actively participate in all these meetings.

Fig. 1. Koya Suto and John McDonald at the 7th International Symposium on Imaging Technology, held at Sendai, November, 2004.

Curtin Reservoir Geophysics Consortium receives SEG's Distinguished Achievement Award at Denver 2004 meeting

Fig. 1. John McDonald receiving the Award from SEG President Peter Duncan at the SEG's 74th annual meeting at Denver, in October 2004.

SEG's Distinguished Achievement Award is given from time to time to a company, institution, or other organization for a specific technical contribution or contributions that have, in the opinion of the SEG's Honours and Awards Committee and the Executive Committee, substantially advanced the science of exploration geophysics.

The citation by William S. French, reads as follows:

The Curtin Reservoir Geophysics Consortium (CRGC) was initially funded in 1998 by forward looking companies in the petroleum exploration industry with help from national and state government entities in Australia. Since inception, CRGC has been the driving force for industry research in the Department of Exploration Geophysics, Curtin University of Technology in Perth, Australia.

In CRGC's short lifetime, 13 students and two members of the academic staff have received petroleum-related PhD degrees; only two were awarded prior to CRGC. This distinction, combined with the many BSc, honours, and master's degrees awarded by the department, allows CRGC's monthly newsletter to proudly carry the motto: Curtin Geophysics—producing the largest number of petroleum geophysicists in the Southern Hemisphere. Another statistic of significance is that postgraduate students have come from over 25 different countries.

CRGC's young age belies its rich history. In the 1980s, Norm Uren (now recently retired as head of the department) and Brian Evans (now a professor in the department) actively promoted the concept of a petroleum industry and government-sponsored research consortium in Australia, but the concept was not accepted at the time.

In 1994, funding by the Australian Petroleum Cooperative Research Centre permitted Norm Uren to invite John McDonald on a six-month sabbatical. McDonald was then the Director of the Allied Geophysical Laboratories (AGL) of the University of Houston so he brought to the department a wealth of knowledge of consortium and research management as well as industry visibility.

Joint research projects had taken place between Curtin Geophysics and AGL since the early 1980s. Virtually the whole research program on the Curtin side was carried out by Norm Uren and Brian Evans. The tireless efforts of Brian Evans in field work and fund raising were a key to early success.

McDonald was recruited by Uren on a permanent basis in 1995 to specifically launch CRGC. Industry initially said it could not be done in Australia, but they did it!

The research strengths of the department were submitted to about 70 industry experts to vote on their preferred ranking of the topics. The top six were selected and written into the initial CRGC proposal.

Simultaneously and synergistically, a two-semester postgraduate course in reservoir geophysics was started. In addition, Curtin's vice-chancellor pledged to build a research wing onto the upcoming Australian Resources Research Centre to house the resource sciences: exploration geophysics, petroleum geology, and petroleum engineering. This is now complete.

The critical mass was in place. The State of Western Australia under its Centre of Excellence program funded the Centre for Exploration and Production Geophysics. This enabled the hiring of a world-class theoretical rock physicist, Boris Gurevich, in a joint appointment with CSIRO Petroleum. This appointment brought immediate and deserved attention to CRGC.

In addition to the research activities listed in the preamble, physical modelling technology was developed to study two-phase fluid movement in unconsolidated sand reservoirs using time-lapse 3D techniques. Innovations in 3D signal processing, multiple suppression, wavelet transformation, and time-reversed acoustics were also developed. These research activities have led to the founding of a closely associated Interactive Virtual Environment Centre (IVEC), which has applications in other disciplines in addition to imaging in the geosciences.

CRGC holds a two-day annual meeting for sponsors each year where research results and related software are presented and distributed. Staff and students contribute worldwide to SEG and other professional meetings, workshops, and journals; the current average is some 30 papers and presentations per year.

The Curtin Reservoir Geophysics Consortium of Curtin University of Technology is conducting research in areas that are highly beneficial to the exploration geophysics industry and thus is very deserving of SEG's Distinguished Achievement Award. The research areas include signal processing, multicomponent processing, and rock physics. The consortium also helps to train geophysicists for later careers in industry and academia. A few examples of recent work on anisotropy and mode conversions include: a 3C VSP analysis, recovery of anisotropic parameters, and attribute analysis; anisotropic processing (NMO and velocity analysis for which CRGC has developed a new implementation of anisotropic moveout that is accurate to all offsets; isotropic and anisotropic P-wave imaging of VSP and surface seismic data; isotropic and anisotropic converted-wave imaging; characterisation of reservoir rock properties using seismic anisotropy; and anisotropic AVO analysis.

Congratulations to a great organization!

ASEG Officers

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[1] Members and chairpeople of ASEG's Standing and ad hoc Committees can be found on the ASEG website.

ASEG welcomes three new Corporate Members

Three new Corporate Members have joined the ASEG for 2005. They are Eni, Oil Search Ltd and Seismic Asia Pacific Pty Ltd. For members not familiar with these companies a thumbnail sketch of each is provided below:

Eni

Eni is a major international company operating in the oil and natural gas, electricity generation, engineering and construction sectors, and in the petrochemical business: The three main business areas are: Exploration & Production, Gas & Power and Refining & Marketing. The company is active in around 70 countries with a staff of more than 76,000 employees.

Eni's 2003 consolidated revenues, of around €51.5 billion, generated a net profit of €5.6 billion and a return on capital employed of 15.6%.

The company is listed on the Milan and the New York stock exchanges.

In Australia it operates in the exploration and production of hydrocarbons and in oilfield services, construction and engineering.

In September 2001, Eni discovered an important gas field in the offshore Bonaparte Basin, about 300 km southwest of Darwin. The finding was made through the Blacktip - 1 exploration well located in the WA - 279 - P Block. Eni is present in the WA - 279 P Block (Eni's interest 30%) together with Woodside Petroleum Ltd and Shell. It is also present in the development of the Bayu - Undan Gas Field and in the Wollybutt Oil Field.

In February 2004 Eni started the production of the Bayu-Undan field. In the first phase, the total production of the Bayu-Udan field will be 115,000 barrels per day of condensates and LPG. The second phase of the development will start in 2006 and will regard the production of gas, too. The gas will be sent through a 550 km pipeline to Darwin's LNG plant, which build-up works have already started. The plant will have a capacity of 3.52 million tonnes per year.

Australian office contact: David Hearty
Eni Australia
Level 3, 40 Kings Park Road, West Perth, 6005
david.hearty@eniaustralia.com.au

Oil Search Limited

Oil Search is an oil and gas exploration and development company that has been operating in Papua New Guinea since 1929. It has a market capitalisation of approximately US$1.5 billion and is publicly listed on the Australian and Port Moresby Stock Exchanges.

Oil Search is incorporated in Papua New Guinea (where the State holds an 18% equity in the Company) and owns approximately 70% of PNG's oil reserves and over 50% of gas reserves dedicated to the PNG Gas Project. It took over as operator of the country's producing oil fields in October 2003 from incumbent Chevron Niugini.

Oil Search is one of PNG's largest companies, and one of the largest investors, spending almost K1 billion in PNG in 2004. It is responsible for around 14% of PNG's G DP and 20% of its export revenue and has approximately 900 employees in PNG, Australia, Yemen and United Arab Emirates.

In PNG it has seven Petroleum Exploration Licences, five as operator; five Production Licences; eight Gas Retention Licences and three Pipeline Licences.

It also has three concession areas in Yemen (two as operator) and a concession area in Egypt.

Australian office contact: Keiran Wulff
Oil Search Ltd
GPO Box 2442, Sydney NSW 2001
Email: administrator@osl.com.au

Seismic Asia Pacific Pty Ltd

Seismic Asia Pacific Pty Ltd, supply Geophysical and Hydrographic and Navigation data acquisition systems to the Australasian and Pacific Rim countries. Product fields include, Acoustic positioning, Geophones, Hydrophones, GPS, DGPS, Heave compensators, Attitude sensors, Hydrographic, Oceanographic, Magnetometers, Tide and Current meters, ROV's, Side Scan sonar, Sub bottom profilers, Echo sounders and Transducers.

From its modest beginnings in 1959, as a company supplying consumables and services to Australia's fledgling seismic and fast growing oil and mining industries, the company has grown to become the largest supply and service company in its field. Seismic Asia Pacific is a publicly owned Australian subsidiary of Nautronix Pty Ltd.

Mining consumables are now available through the Company's Seismic Supply Kaltex Division.

Seismic Asia Pacific (SAP) is now the largest organisation of its type in the Pacific Rim. It provides equipment, consumables, systems integration, engineering hardware and software maintenance support services to the Geophysical, Hydrographic, Oceanographic Environment and defence Industries throughout the region. It also maintains a pool of rental equipment and has skilled technicians available for technical support.

It provides a range of products and services for offshore applications to Government, Defence and Resource related clients and has established a worldwide reputation as a supplier of robust reliable equipment and systems. This is through our long term and close associations with many of the leading manufactures of the equipment used in these activities, and through our in-house expertise and innovative methods of integrating, adapting and developing the base manufactures' equipment to accommodate individual users needs.

SAP provides standalone, integrated systems and engineering support equipment, hardware and software.

As a result of our ongoing commitment to investing in the best facilities, equipment and staff, SAP has developed an excellent, proven range of high quality equipment and systems to suit a variety of offshore applications.

Head Office
Seismic Asia Pacific Pty Ltd
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Queensland 4076

A snapshot of the members of the first ASEG Federal Executive 35 years later

compiled by Roger Henderson
rogah@optusnet.com.au

The first Executive Committee of the ASEG in 1970/71 consisted of:

President: R A McQueen
1st Vice-President: L V Hawkins
2nd Vice-President: M G Parsons
Secretary: J E Sundquist and later J Wardell
Treasurer: V L R Furlong
Editor: E R Crain
Committee Members: J E Bordelon & L N Ingall

The following is a very brief summary of their activities since 1970 and their present whereabouts.

Robin McQueen spent an adventurous career in both soft and hard rock exploration, alternating between big company posts and entrepreneurial endeavours. His work took him beyond his native Australia to Africa, Asia and North America. One entrepreneurial foray in Canada gained NASDAQ listing. Another, in Thailand, led to a discovery that spawned the country's largest gold mine. He has settled near Brisbane.

Laric Hawkins started in the BMR and later joined the University of NSW where he became Assoc. Professor. His main interests were in seismic refraction interpretation and plate tectonics. He was the first, of only 4 persons to date, to be awarded the ASEG Gold Medal, in 1985. Laric died prematurely in 1985 and his memory is honoured through the Laric Hawkins Award, inaugurated in 1986 and given at every conference.

Mal Parsons continued as 2nd V P in 1971/72. He was a Senior Geophysicist with Esso and it is believed that he returned to his roots in Canada some time ago. Mal was with Esso at the same time as Ken Richards who was the Editor in 1972-3. Ken was also involved in the foundation of the ASEG and was the first recipient of Honorary Membership in 1977. His memory is perpetuated by the Earth Resources Foundation at Sydney University where a bequest from his estate provides scholarships each year to worthy students.

Jim Sundquist was site manager with GSI and was recalled to USA after only a few months as Secretary. He later left GSI and became a consultant, living in Evergreen, Colorado.

John Wardell took over as Secretary from Sundquist and held the position until 1974. He received Honorary Membership in 1991 and is still a member of ASEG. John spent most of his career with GSI, spending 2 years each in Houston and Calgary before returning to Sydney in 1979. He retired in 1989 and is now living in Castle Hill, Sydney.

Lee Furlong became 2nd V P in 1972/73, 1st V P in 1973/74 and President in 1974 –75 and is still a member. Lee remained in geophysics through to the mid '80s, consulted to the IAEA for 5 years, co-authored two IAEA publications on borehole geophysics, and subsequently became president of several small public exploration companies. Lee is still very active in a number of applied science ventures.

Ross Crain continued as Editor in 1971/72 after which he returned to Alberta where he still lives. Ross is a well-known petrophysicist and has published extensively on well-log analysis including the textbook; The Log Analysis Handbook, first published in 1986, which contains 7 chapters on seismic petrophysics. He was awarded Honorary Membership of the Canadian Well Logging Society in 1994.

J H Bordelon served on the first committee for a short time, responsible for publicity. It is believed that he left Sydney in mid-1971 to become Senior Geophysicist with Esso in Kuala Lumpur. He is last known to be a consultant in New York in 1989.

Lindsay Ingall became the second President in 1971/72 and again in 1979, was awarded Honorary Membership in 1988, and was the first recipient of the Service Medal in 1998 recognising an almost continuous involvement in the Society over 28 years. After a full career leading to managing a successful contracting company, Wongela Geophysical, Lindsay died in May 1999. His great contribution to the ASEG and other societies is recognised by the inauguration, in 2000, of the Lindsay Ingall Memorial Award.

Should anyone wish to contact some of the above, their email addresses are:

Robin McQueen: omview@bigpond.com,

John Wardell: WardellJandC@bigpond.com,

Lee Furlong: lee.furlong@bigpond.com,

Ross Crain: ross@spec2000.net.

Branch News

South Australia – by Tania Dhu

The SA Branch held the Annual Student Night in early December. Lesja Mitrovic (Flinders University), Luke Gardiner (Australian School of Petroleum) and Clarke Petrick (University of Adelaide) gave presentations on a wide range of topics, including geophysics for investigation of saline intrusion, structural analysis of part of the Warburton Basin and the use of magnetotellurics for onshore petroleum exploration. Over 50 members attended the evening with Lesja Mitrovic receiving the award for best presentation and Clarke Petrick for best paper. The year ended with the Christmas Party held at Past president Richard Hillis's home. Twenty eight people attended and a good time was had by all.

Sadly Graham Heinson's tenure as President has come to an end although he will continue to serve on the Committee. We would like to thank him for his time and effort as President over the last two years and also as Secretary before that. His time as President has been extremely successful, especially at increasing student involvement both within the Committee, the South Australian Branch and the Society as a whole.

The AGM of the South Australian Branch will be held on 16 February 2005 at which a new President and committee will be elected. We wish the new President well in following the footsteps of Graham Heinson and stewardship of the branch.

Finally we would like to thank our sponsors who have made all these events possible. In 2004 the ASEG SA Branch was sponsored by PIRSA, Schlumberger, Santos, Cooper Energy, Australian School of Petroleum, Minotaur Resources, Petrosys, Zonge Engineering, Beach Petroleum and Stuart Petroleum. We look forward to their continued support in 2005 for the betterment of the geophysical industry and the resources industry in general.

Western Australia – by Anita Heath

The WA Branch held their AGM in December. A new committee was formed and President Don Sherlock gave a presentation of events during the year. Treasurer Levin Lee gave a presentation on finances and Best Student Papers. The best presentation was awarded to Jill Slater and the best technical content was awarded to Mike Whitford.

The 2007 ASEG Provisional-Conference Committee has been formed and is in the process of selecting a Professional Conference Organiser (PCO). A decision is expected to be announced in early February. Two optional venues presently booked are the Perth Convention Centre in the city, and the new Holiday Inn convention centre at Burswood. A decision on the venue will be announced in July.

Present committee:

Brian Evans	Co-Chair
Howard Golden	Co-Chair
Kim Frankcombe	Technical Papers
Andre Gerhardt	Technical Papers
Norm Uren	Technical Papers
Bill Peters	Treasurer
Megan Evans	Exhibition
Greg Street	Courses
Mike McLerie	Publicity
Laurence Hansen	Sponsorship
Levin Lee	Sponsorship and publicity
Richard Haines	TBA
Gigi Ewing	Provisional social events
Dom Howman	Students day

We are on the lookout for new committee members so if there are any volunteers out there, please call Brian Evans on 9266 7092 or email evans@geophy.curtin.edu.au.

Observing Earth from space

Today, images of our planet from orbit are acquired continuously. They have become powerful scientific tools to enable better understanding and improved management of the constantly changing Earth and its environment. Prior to the advent of space-borne observations, changes to the Earth and the environment were monitored and inferred from data gathered at widely disparate points on the Earth's surface. Large scale systems, processes and trends are more easily and reliably observable from space. With the current explosion in information technology, these data have been made readily accessible to everyone.

We need to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable an improved assessment, prediction and mitigation of environmental changes, climate, weather, and help us to understand the cause and effect of natural hazards for present and future generations.

The recent Tsunami that caused widespread damage and human loss has been observed and reported on a scale that no other natural disaster has ever been before. High resolution satellite imagery has captured the event before, during and after the wave struck, highlighting the actual wave, and the destruction it caused from space. This edition of Webwaves looks at websites dedicated to the observation of Earth from space. Satellite images such as that of the Tsunami can be found on most of the following sites.

NASA Earth Observatory ★★★★1/2

http://earthobservatory.nasa.gov/

earth observatory

The NASA's Earth Observatory site provides freely accessible up-to-date satellite imagery and scientific information about our home planet. The main focus is on Earth's climate, environmental change and natural hazards. The website shows high resolution satellite imagery of various environmental phenomena including droughts, dust, smoke, fires, floods, tsunamis, storms and volcanoes. Worthy of note, the satellite imagery of the January fires which affected Perth (the flames are captured from space) and the breaking tsunami waves along the east coast of India, captured on December 26th 2004.

Be sure to check out the Visible Earth, a searchable directory of images, visualizations and animations of the Earth.

National Oceanic and Atmospheric Administration ★★★

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

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration is an American organization which conducts research and gathers data about the global oceans, atmosphere, climate, space and the sun. NOAA provides weather forecasts, charts the seas and skies, and conducts research to improve our understanding of the environment.

NOAA provides its services through five major organizations: the National Weather Service, the National Ocean Service, the National Marine Fisheries Service, the National Environmental Satellite, Data and Information Service, and NOAA Research. The National Environmental Satellite, Data and Information Service provides global environmental data, which I found most relevant and interesting.

Australian Government IPS Radio & Space Services ★★★★1/2

http://www.ips.gov.au

Australian Government IPS Radio and Space Services

The Ionospheric Prediction Service (IPS) acts as the Australian Space Weather Agency, providing a support for a wide range of systems and technologies affected by space weather: HF radio systems (communications and surveillance systems), geophysical exploration, power systems protection and satellite and spacecraft operations. It provides services to various industry and government bodies, including Boeing Australia Limited, Telstra, the Department of Defence, the Australian Customs Service, Airservices Australia, the Bureau of Meteorology and the Australian Communications Authority (ACA). Their extensive network of monitoring stations and observatories gather space weather information which is then made available on their website. Up-to-date forecasts on solar, geophysical and high-frequency propagation conditions are a feature on this site. Other interesting topics include solar activity, space debris, eclipses and radio communications.

Committee on Earth Observation Satellites ★★★1/2

http://www.ceos.org/

CEOS

The Committee on Earth Observation Satellites membership encompasses the world's government agencies responsible for civil earth observation satellite programs, along with agencies that receive and process data acquired remotely from space. The committee coordinates international civil spaceborne missions designed to observe and study planet Earth.

Under Subsidary Groups, there are links to the ad hoc Group on Earth Observations (GEO) and the ad hoc Disaster Management Support Groups, both of which have informative websites.

Integrated Global Observing Strategy ★★★1/2

IGOS Integrated Global Observing Strategy

http://ioc.unesco.org/igospartners/index.htm

The Integrated Global Observing Strategy (IGOS) seeks to harmonize the common interests of the major space-based and in-situ systems for global observation of the Earth. Information relating to climate and atmosphere, oceans, coasts and coral reefs, the land surface and the Earth's interior is provided on this website. Of particular interest was the Geohazards theme, which aims to map, monitor, mitigate and predict earthquakes, volcanoes, landslides and subsidence. A link to the website can be found under Themes>Geohazards.

EarthSat – Earth Satellite Corporation ★★★★

EARTHSAT Earth Satellite Corporation

http://www.earthsat.com/default.html

Earth Satellite Corporation (EarthSat) is an international professional services firm

which specializes in the development and application of remote sensing and geographic information technologies (GIS). Projects focus on the exploration, sustainable development and management of the Earth's resources and the monitoring of the environment. Have a look at the remote sensing services which can be applied to oil and gas, water and minerals exploration.

European Space Agency – Observing the earth ★★★★★

http://www.esa.int/export/esaEO/index.html

The Observing the Earth website is managed by the European Space Agency. This very informative site has fantastic satellite imagery of a wide range of environmental occurrences. Examples include images of the Tsunami disaster and the collision course of the largest floating object, the B-15A iceberg, recorded from space. There are many interesting news articles on applications of earth observation via satellite. Earth Observation satellites can highlight environmental changes occurring gradually, thus satellite data can map the steady clearing of rainforests, and the apparent annual rise in sea level. Very interesting and informative. I highly recommend this site. For all the space nuts, the ESA website is also well worth a look.

ACRES - Australian Centre for Remote Sensing: Geoscience Australia ★★★★

http://www.ga.gov.au/acres/

The Australian Centre for Remote Sensing (ACRES) is Australia's major satellite remote sensing organisation, which was established as the Australian Landsat Station in 1979. ACRES goal is to maintain a comprehensive archive of satellite remotely sensed data over Australia to help ensure that fundamental geographic information is available for the benefit of the Australian community. Satellite data can be ordered and delivered online, and some data is available to download for free. The Geoscience Australia website also includes a range of geohazard factsheets, as well as up-to-date geomagnetic forecasts.

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

ARC provides $381million for 1387 new research projects

In November 2004 the Minister for Education, Science and Technology, Brendan Nelson announced that the Australian Government will allocate $381 M over five years for 1,387 new research projects from 2005.

The projects will be funded through Australian Research Council's (ARC) *Discovery Projects, Discovery Indigenous Researchers Development, Linkage Projects, Linkage International*, and *Linkage Infrastructure Equipment and Facilities* grants.

ARC *Linkage Projects* grants encourage the formation of long-term strategic alliances between university researchers and their collaborating partner organisations, including from within industry. In this round, the ARC will provide $55.5 M to new collaborative research projects. Industry and other partner organisations will contribute $80.4 M, investing $1.45 for every dollar of Government funding.

ARC *Discovery Projects* grants support fundamental or basic research. The number of these grants awarded has increased from 875 in 2004 to 1,051 in 2005.

The new grants were awarded under the umbrella of the National Competitive Grants Program, an initiative of *Backing Australia's Ability*.

Linkage Projects better bet than Discovery Projects

Those researchers looking to develop grant applications for the 2006 round should be aware that bids for Linkage Projects have a much higher success rate (51.2%) than for Discovery Projects (30.8%).

Table 1 summarises the outcomes for new funding by discipline group for ***Linkage Projects***:

Three points are noteworthy.

1. The industry contributions amount to $80,364,264, so the total amount available over the five year period will be ~$137 million.

2. The Physics, Chemistry and Geosciences discipline group had the highest success rate – 61%

3. The top five universities, in the context of dollars awarded by the Commonwealth were:
   - The University of Queensland, $7.2 M
   - The University of New South Wales, $4.9 M
   - The University of Melbourne, $4.3 M
   - Monash University, $3.7 M
   - The University of Sydney, $3.6 M

There were only five Linkage projects approved in the geosciences. These totalled $1.5 M, with the largest being a grant to Adelaide University ($420 k) *to decipher the tectonic history of the Musgrave Block to assist mineral explorers and regional synthesis programs*.

For the Discovery Projects the nearest equivalent table is as shown in Table 2.

The overall success rate was only 30.8% for the Discovery Projects. However, a total of $295.5 M was awarded, so the size of the pie is much larger.

The most successful universities were:

- The University of Melbourne, $37,953,748
- The Australian National University, $37,640,751
- The University of Sydney, $34,336,283
- The University of New South Wales, $34,254,172
- The University of Queensland, $25,392,296

In the Geosciences, 44 projects were funded for a total of $13.2 M, which is equivalent to 4.5% of the sum allocated. The ANU was awarded 14 grants for a total of $4.15 M over the duration of the projects, followed by Melbourne, which awarded 6 grants for a total of $2.15 M.

The largest geoscience Discovery grant was $965 k, which was awarded to Mike Sandiford at Melbourne University for a five

Table 1

Discipline Group	Applications received	Applications funded	Success rate (%)	Requested funds over project life (all applications 2005-2009)	Funds awarded over project life (all funded applications, 2005-2009)
BSB	82	39	47.6	$21,838,518	$11,059,443
EE	103	51	49.5	$22,286,746	$12,141,684
HCA	59	27	45.8	$11,512,484	$5,860,298
MIC	45	22	48.9	$14,392,486	$6,522,689
PCG	41	25	61.0	$14,186,128	$7,016,249
SBE	133	73	54.9	$24,890,313	$12,909,189
Total	463	237	51.2	$109,106,675	$55,509,552

BSB: Biological Sciences and Biotechnology
EE: Engineering and Environmental Sciences
HCA: Humanities and Creative Arts
MIC: Mathematics, Information and Communications
PCG: Physics, Chemistry and Geosciences
SBE: Social, Behavioural and Economic Sciences

Table 2

Discipline	Average amount requested by funded applications for 2005	Average funding awarded to successful applicants	Average funding awarded as a proportion of average funding requested (%)
BSB	$142,596	$104,993	73.6
EE	$147,928	$110,951	75.0
HCA	$91,525	$70,071	76.6
MIC	$135,220	$92,075	68.1
PCG	$169,330	$121,590	71.8
SBE	$102,216	$71,632	70.1
Total	$130,003	$94,204	72.5

year study of the Neotectonics of the Indo-Australian Plate.

Geochemists score well for new infrastructure

The ARC is also providing $28.3 M under the *Linkage Infrastructure Equipment and Facilities Program*. The geochemists did very well with five projects totalling $1.54 M being approved. The two largest were $552 k for a consortium headed by the ANU to build a stable isotope ion microprobe (SHRIMP SI) to examine extraterrestrial and terrestrial systems, and $495 k to a Macquarie led group to install a ThermoFinnigan Triton high-sensitivity thermal ionisation mass spectrometer for constraining geoscience rates and environmental processes via Ra and Os analysis (we geophysicists probably need some enlightenment on this one!).

Overall, the geoscience disciplines obtained 4.2% of the $381 M distributed, so there are clearly opportunities to increase this by developing more, good project proposals during 2005.

For more detailed information visit the arc website: http://www.arc.gov.au/arc_home/default.htm.

Government invests $407 million in CRC Program

In December 2004, Minister Nelson announced grants of $407 M for research and innovation under the Australian Government's Cooperative Research Centres (CRC) Program.

The CRC Program brings together universities, research organisations, government agencies and industry. The latest round of funding will support five new CRCs with an additional nine to be developed from existing CRCs. Supplementary funding will go to two existing CRCs. Each CRC is scheduled to last for seven years.

The successful CRCs will undertake research in manufacturing, information and communications technology, mining and energy, agriculture and rural-based manufacturing, the environment and medical science.

The only successful applicant in the resource/energy sector was the Parker CRC for Integrated Hydrometallurgy Solutions, which was developed from an existing CRC. It will receive program funds of $20 M over seven years (i.e. funds from the government).

The application process was very competitive, with only 14 Centres being funded out of the 58 that were invited to make applications on the basis of their Expressions of Interest.

The five new CRCs are:

1. Advanced Automotive Technology Manufacturing, Technology Sector – Victoria; CRC Program funding: $38.35 M;

2. An Internationally Competitive Pork Industry, Agriculture and Rural Based Manufacturing Sector – SA; CRC Program funding: $25.75 M;

3. Biomedical Imaging Development, Medical Science and Technology Sector – Victoria; CRC Program funding: $21.47 M;

4. Contamination Assessment and Remediation of the Environment, Environment Sector – SA; CRC Program funding: $30 M; and

5. National Plant Biosecurity, Agriculture and Rural Based Manufacturing Sector – ACT; CRC Program funding: $20.5 M.

Several major CRC's dealing with emerging technologies lost their funding, such as the CRC for Microtechnology and significantly, the CRC for Clean Power from Lignite. This has sparked criticism from some quarters regarding the government's priorities. The Clean Power CRC had been in existence since 1994, with about 100 scientists associated with its work. Victorian Energy minister Theo Theophanous has called for the decision to be overturned.

Details of the successful applicants, including funding and contact information, can be found at http://www.crc.gov.au/ or http://www.dest.gov.au/ministers/nelson/dec_04/n1038211204.pdf.

Expert Advisory Group to oversee development of the Research Quality Framework for publicly funded research

Just when we all thought we could go home to prepare for Christmas, Minister Nelson announced on 21 December 2004, the membership of an Expert Advisory Group he has appointed to oversee the development of the Research Quality Framework for publicly funded research.

The members are:

- Sir Gareth Roberts (International representative - UK), President of Wolfson College, Oxford – CHAIR,
- Paul Callaghan (International representative - NZ), Victoria University of Wellington, New Zealand,
- Michael Barber (representing the CSIRO) is Executive Director, Science Planning, CSIRO,
- Ian Chubb (representing the Group of Eight),
- Peter Høj (representing the ARC),
- Ian O Smith (representing ANSTO),
- Robin Batterham, Chief Scientist of Australia,
- Peter Sheehan (representing the AVCC) VC of the Australian Catholic University,
- Phil Clark (representing the BCA),
- Ross Milbourne (representing the ATN) VC of UTS,
- Anne Edwards (representing the Innovative Research Universities Australia (IRUA)) VC of Flinders University,
- Alan Pettigrew (representing the NHMRC), and
- Evan Arthur (representing DEST).

Terms of Reference

The Expert Advisory Group will support the development of the Research Quality Framework through provision of advice on processes and measures to assess the quality and impact of research in Australia's universities and Publicly Funded Research Agencies (PFRA's) including:

- International experiences of implementing research assessments and options for international benchmarking;
- Options to improve the comparability of quality assessment mechanisms across discipline areas;
- Cost effective approaches to undertaking research quality assessment processes;
- Advantages and drawbacks to linking quality assessment in universities and PRFA's to research funds allocation; and
- Appropriate processes for consultation with universities and PFRA's and other key stakeholders to progress consideration of a Research Quality Framework.

More information can be obtained from DEST's web site: www.dest.gov.au/resqual.

This is a huge committee with no representation from practicing researchers, and representation of 4 VC groups. Why all the VCs are needed is not clear neither are the words in the Terms of Reference. Don Watson of Death Sentence fame would not be amused.

Project Results

The ASEG Research Foundation provided a total of $3650 to the School of Earth Sciences, University of Tasmania in 2003, to support fieldwork costs for two Honours projects in northwest Tasmania. Project supervisors were James Reid and Michael Roach. Both students were awarded first class Honours, and are currently employed as geophysicists with G-Tek, where they have worked on UXO and utility detection projects in Australia and the USA.

Student: Ian Wilson
Honours title: HEM data levelling – The Clump, NW Tasmania.

Project Summary

This project involved interpretation of an 8 km^2 subset of Hummingbird helicopter electromagnetic (HEM) data collected for the Western Tasmanian Regional Minerals Program (WTRMP). The study area included known copper mineralisation at The Clump, approximately 10 km north of the historical mining centre of Balfour. A particular focus of the project was on re-levelling of the HEM data based on ground-truth geophysical measurements. The HEM data had already been processed to correct for drift, by removal of high altitude zero levels, and to remove obvious 'line busts'. Apparent resistivity grids produced from the data showed very good correspondence to mapped geology. However, the 'non-geological' nature of EMFlow conductivity-depth images (CDI's) computed from the data suggested the likely presence of levelling or calibration errors.

Re-levelling of the data was undertaken by comparing the HEM data with the results of ground truth geophysical surveys. Ground truth data were acquired at a number of points on the HEM survey lines, in areas of uniform HEM response. These areas tended to be resistive, and DC resistivity soundings were found to be the most appropriate geophysical technique. Resistivity sounding data were interpreted in terms of layered-earth models, which were then used to predict the HEM response at survey altitude. For all ground truth points, the largest absolute error between the observed and calculated HEM data was 56 ppm (in comparison with a measured response of 66 ppm). The misfit between the observed and predicted data yielded levelling corrections for the inphase and quadrature components at each frequency. Misfits varied widely between ground control points, and a number of different methods for applying the levelling corrections were trialled. However, simple interpolation of the levelling corrections between the ground truth points was found to be an effective approach.

Levelling of the data in this manner produced significant along-line improvements in data quality, expressed as improvements in the quality of EMFlow CDI's (Figure 1). Cross-sections of the mapped geology and a surface TEM profile were used to independently verify CDI's generated from the re-levelled data. Post-levelling CDI's showed better correspondence to the inferred geology than those produced from the 'raw' data. Plan maps of inphase-quadrature apparent resistivity generated from the re-levelled data also showed some improvement, with increased stability of the algorithm leading to fewer null points in the post-levelling plots.

Student: Jhana Hale
Honours title: Geophysical investigation and interpretation of the Temma area, NW Tasmania

Project Summary

The Temma area in northwest Tasmania has long been the subject of minor exploration interest due to the presence of quartz – sulfide lodes of unknown size and extent that show anomalous levels of Cu, Pb, Ag and Au. This project involved ground-truthing and interpretation of regional magnetic, radiometric and HEM data from Temma, and HEM anomaly picking to identify any bedrock conductors potentially associated with sulfide mineralisation.

The major lithologies in the area have distinct physical characteristics, which allowed them to be successfully mapped using airborne geophysics. Apparent resistivity grids produced from Hummingbird HEM data were effective in delineating conductive Tertiary basalts as well as resistive quartzites and siltstones of the Proterozoic Rocky Cape Group. Magnetic and radiometric data have provided further constraints on interpretation.

A numerical modelling study was carried out in order to assess the depth of investigation of the HEM system in areas of conductive basalt cover. Model parameters were constrained by the results of surface TEM and DC resistivity surveys, and by extensive magnetic susceptibility measurements on both basalt and basement outcrop. The basalt was found to have a relatively low magnetic susceptibility (2.4×10^{-3} SI), and to have conductivities in the range 0.02 – 0.055 S/m. The high conductivity of the basalt results

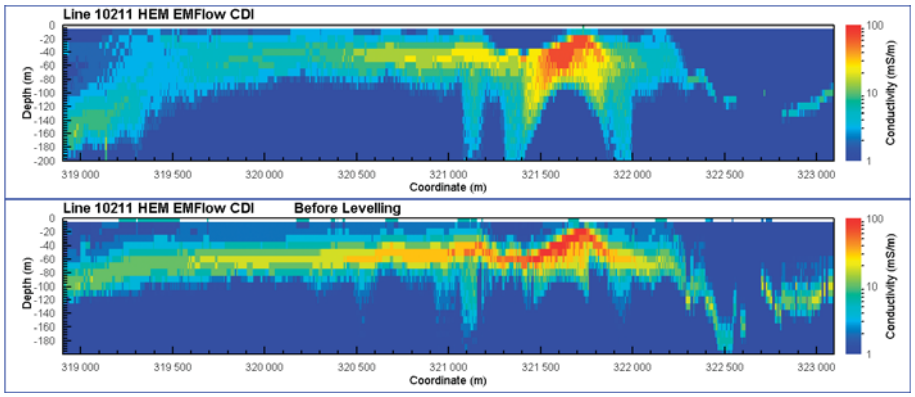

Fig. 1. EMFlow CDI's from Line 10211 over 'The Clump'. The lower CDI was generated from the 'raw' HEM data, and the upper CDI from data which has been re-levelled based on ground-truth data. The unlevelled CDI contains a geologically implausible continuous conductive horizon between 319 000 E and 322 250 E. This artefact has been suppressed in the levelled CDI. The strong conductor between 321 400 E and 321 900 E in the levelled CDI is a black shale unit. The discontinuities in the levelled CDI at 319 400E and 322 250 E correspond to mapped fault contacts.

from clays produced by weathering, and because the flows are extensively fractured and jointed. The model study indicated a maximum depth of investigation of only 28 m for typical basalt conductivities and susceptibilities, due to the relatively high frequencies used by the Hummingbird system. The high conductivity was found to be the main factor limiting the depth of investigation. Drilling results indicate clay + weathered/fractured basalt thicknesses of up to 60 m. As a result, little exploration significance was assigned to HEM anomalies occurring in areas of Tertiary basalt cover, which were considered most likely to be due to variations in thickness or conductivity of the basalt.

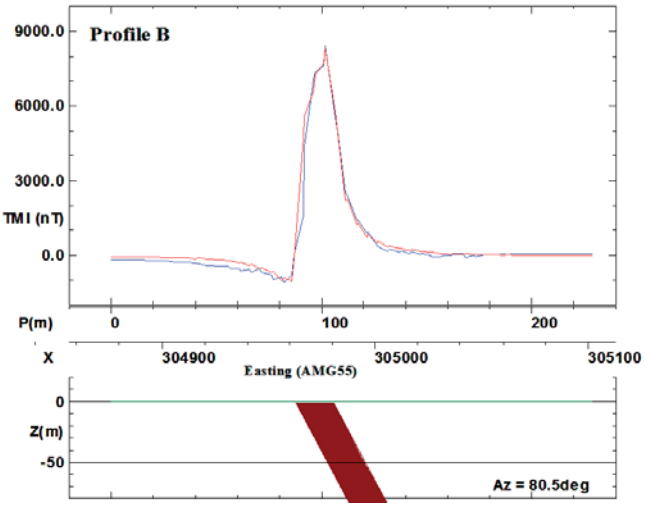

Fig. 2. Observed (blue) and modelled (red) ground TMI responses from Couta Rocks, north of Temma. The dyke-like causative body has width 18 m, depth to top 3 m, magnetic susceptibility 0.309 (SI), strike 350° and dip 73°E.

Aeromagnetic data show numerous northwest trending lineaments transecting the Temma district. These lenticular magnetic units are associated with known sulfide mineralisation in the area. However, the patchy vein style of mineralisation did not produce large EM responses and anomalies associated with known mineralisation were not apparent in the HEM data. Ground-based investigation of aeromagnetic anomalies in the north of the survey area revealed shallow magnetite-bearing bodies hosted in the laminated siltstones of the Rocky Cape Group. Quantitative modelling of ground magnetic data indicated that these bodies are of dyke-like form and steeply dipping, clearly crosscutting the shallowly east-dipping host rocks (Figure 2). Orientation of these bodies is locally parallel to the cleavage of D_4 and on a regional scale to the northwest trending faults of D_3.

70 Years Ago

The 'Southern Cross' and some geophysical reconnaissance

Fig. 2. The 'Southern Cross'. 19th April 1935. Courtesy Queensland Air Museum 136/2 via Jack Petersen.

In late June 1934 the first executive committee meeting of the Aerial, Geological and Geophysical Survey of Northern Australia (AGGSNA) chaired by Sir Herbert Gepp (Figure 1) recommended that the technical members of the committee should make a preliminary aerial reconnaissance of the Survey's proposed exploration regions, so tenders were called for the supply of an aircraft and crew. The Sydney based Kingsford Smith Air Service Limited were the successful bidders.

The AGGSNA, it should be mentioned, was a pioneering and jointly funded minerals exploration program between the Commonwealth and the governments of Queensland and Western Australia instigated by the mover-shaker Sir Herbert Gepp, a dominating character and considered by some the 'father of exploration geophysics in Australia'. Gepp had earlier established the joint UK and Australian government Imperial Geophysical Experimental Survey (IGES), which had run from 1927-30. The IGES published a report (and distributed it worldwide) describing their field geophysical experiments in Australia and the AGGSNA was to put some of these IGES methods to the test.

On the 19th September 1934 the famous (and then aging) tri-motor Fokker FVIIB-3 m VH-USU *Southern Cross* (Figure 2), piloted by O. B. (Pat) Hall with co-pilot and engineer Harry Purvis, departed from Sydney for Brisbane (and parts north) with passengers Dr. W. G. Woolnough, the Commonwealth Geological Advisor; P. B. Nye (later to become Director of the BMR in 1951), the Executive Officer of the AGGSNA; F. G. Forman, the Government Geologist of Western Australia and the radio operator/ meteorologist Alan Hooper. The aircraft was specially fitted out for the survey. The normal longitudinal leather seating being removed and replaced with cane chairs (!) for each of the scientists.

Fig. 1. Sir Herbert Gepp (1877-1954)

The *Southern Cross* stopped over at Brisbane to pick up L. C. Ball the Chief Government Geologist for Queensland.

The reconnaissance extended as far north as Darwin, as far west as Roebourne and as remote as The Granites and Tanami with the actual route being recorded in the AGGSNA Parliamentary Report June 1935. A map of the route is shown (Figure 3). The *Southern Cross* returned to Sydney on the 20th October 1934 after 12,000 miles and 143 hours of flying, a very full month! The AGGSNA financial report for the period lists the cost of 'aerial services' at £1,583/9/4.

The regions inspected were primarily gold mining areas and all members of the party made independent reports at the completion of the reconnaissance and at the following (the second) AGGSNA executive meeting they made recommendations on the way the survey was to proceed over the following years. The recommendations for the first year included a plan to carry out aerial photography over the following specific areas, Cloncurry (Bower Bird and Soldiers Cap), Palmer River, Mount Oxide, Pine Creek, East MacDonnell Ranges, Marble Bar (Warrawoona) and Nullagine (Mosquito Creek). This photography, in itself historic, was flown by the Royal Australian Air Force in 1935 following a decision that commercial bids were far too expensive.

Cloncurry was selected as the headquarters for the AGGSNA's first year of operations and the first geological work commenced nearby in April 1935 followed by the first ground geophysics at the Mount Freda mine on 12th May 1935. The geophysics, performed in conjunction with the contracted Electrical Prospecting Company of Sweden (represented by Sepp Horvath) included electrical, electromagnetic and magnetic methods.

Harry Purvis and his 'Outback Airman'

The use of the *Southern Cross* on this and other mineral exploration related flights in the era is very significant in the history of aviation in Australia and it is quite fortuitous that the co-pilot on the AGGSNA reconnaissance, Harry Purvis, devoted a chapter to some of these survey flying operations in his 1979 book *Outback Airman* where he included some interesting side comments regarding the work - stuff that did not make the official reports.

Harry Purvis was a co-pilot on a number of pioneering flights (e.g., the post-war transpacific flight Australia – Chile with P. G. Taylor in the Catalina *Frigate Bird II*) and many explorationists involved with remote

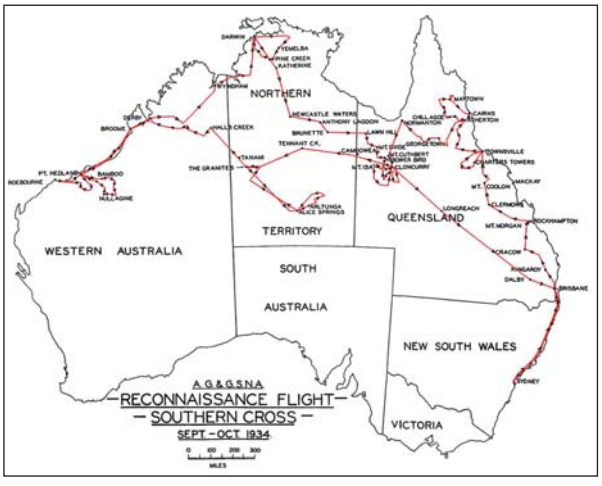

Fig. 3. The AGGSNA 'Southern Cross' reconnaissance route of 1934.

Fig. 4. A signed AGGSNA philatelic cover carried by the 'Southern Cross' postmarked Longreach 18th October 1934. Author's files.

survey work in the 1960s, may recall Harry when based from Alice Springs, Uluru etc., Harry piloted many charter flights for oil and mineral exploration companies with aviation companies SAATAS and Connellan Airways. He was also a part owner of the pub at Ayers Rock and the Inland Motel at Alice – a haunt for many a survey crew. Harry was a legend even then. The Survey's pilot Pat Hall, as well as being Kingsford Smith's partner, was also a pioneer aviator, having flown the first airmail from Sydney – Melbourne in 1929 for instance.

Harry's 1934 recollections

In 1934 the *Southern Cross* was nearing the end of it's working life – in fact it had been stationary for some time prior to the AGGSNA contract and Harry Purvis was worried the old Wright J5 engines would struggle with flying for a month or two of continuous operations and he was not wrong; some frustrating magneto problems also occurred throughout the operations but he recalled the scientists were an uncomplaining lot although their patience was stretched at times.

The normal procedure throughout the survey was to plan in the evening the survey flight plan for the following day and according to Harry, Pat Hall had a very good eye for visual navigation and rarely missed locating the previous nights defined targets – although he does say that neither pilots nor geologists could locate Soldiers Cap from the air.

Harry wrote that each of the scientists in the cabin wore leather flying helmets and each had attached speaking tubes so they could communicate with each other over the engine noise – he also wrote that as a result they all looked like creatures from another planet! Camping under the stars (and under the wing of the *Southern Cross*) did occur during the tour and it gave Prof Woolnough the opportunity to show his expertise as a great camp cook. Everyone respected Prof Woolnough – and he was affectionately known to all as 'Dad'. Eating at the remote pubs in those days was an experience, one, unidentified by Harry, served a menu of goat (for regulars) or galah (for others)!

The days were long and to make it easier for the pilots they changed roles every half hour (no auto-pilot in those days). Despite the long, noisy, turbulent and tiresome days the tour went well with the scientists continuously attentive to the scene below – Harry recalled the scientists were particularly excited when viewing the geology of the East Kimberleys.

The exorbitant cost of fuel at Tennant Creek at 6/- (six shillings) a gallon appalled Hall and Purvis, compared to Sydney prices of 1/2 (one shilling and two pence) it was enough to remove all the profits from the work, in fact there was even trouble by the company paying the pilots salaries at the completion of the survey.

It may be interesting to some readers that a number of 'By Airmail' philatelic covers were carried on the flight as a commemoration of the survey and some of the covers were signed by participants and postmarked 'LONGREACH 18th OCT 34'. An example is shown (Figure 4).

The historic crew meeting with Smithy at Cloncurry

On landing at Cloncurry on the 29th September 1934, the AGGSNA scientists, Pat Hall and Harry Purvis were absolutely amazed to see waiting for them 'Smithy' (Sir Charles Kingsford Smith) and P. G. Taylor in their single engine Altair 8D Special, the *Lady Southern Cross* (Figure 5). Smithy and Taylor were enroute to London for the start of the Melbourne Centennial Air Race – they had been flying Sydney to Darwin but winds had forced them to stop and overnight at Cloncurry. Smithy instructed Harry Purvis to check over the Altair which did not please Harry too much as he had just done a long day's flying and everyone was heading for the pub (Millers Post Office Hotel). A good night was being had by all until Harry arrived and announced he found a number of extensive cracks in the *Lady Southern Cross*'s engine cowling – this was serious enough for Smithy to call off his ferry to London. Smithy and Taylor returned to Sydney the following day, where they were to receive some extremely unpleasant newspaper comments regarding their failure to continue to London. Within a few weeks, as an alternative project to the air race, Smithy and Taylor flew the *Lady Southern Cross* to California across the Pacific Ocean - the historic first aerial west to east crossing!

Smithy and his engineer Tommy Pethybridge were to go missing in the *Lady Southern Cross* in the early hours of the 8th November 1935 near Aye Island, Burma – they were never found.

In 1935 the Commonwealth of Australia purchased the Southern Cross.

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Fig. 5. Historic photograph of the trans-Pacific pioneering aircraft the 'Southern Cross' and the 'Lady Southern Cross' together at Cloncurry during the AGGSNA survey. Note the wide vision available from both sides of the cabin. 29th September 1934. Courtesy Queensland Air Museum 158/7 via Charles Fotherington.

Geophysics at Newmont – a history of innovation and development

(Part 1, 1946-1975)

Introduction

Newmont's geophysical department has a long history of innovation and development since 1946. Essentially there were four major eras in its history so far:

1. **Jerome, Arizona** (1949-1957): This was the amazing post-war period under Doc Brant that led to the development of IP and time-domain EM.

2. **Danbury, Connecticut** (1957-1975): This period was difficult with low metal prices, small budgets and the breakup of the Jerome group. Significant developments were primarily with computing and the first gridding and contouring routines in collaboration with IBM.

3. **Tucson, Arizona** (1975-1989): A large portion of this period was spent developing and utilizing the ground-based high-power, deep-penetrating time-domain EM system (EMP). After the advent of the PC, portable imaging workstations were developed and sent out to the field offices, a major change in the way computing was done.

4. **Denver, Colorado** (1989-Present): In downtown Denver and later at the Malozemoff Technical Facility, significant developments were with rugged airborne and ground data acquisition systems aided significantly by the advent of GPS navigation. Important in the late 1990s were the collaborative Newmont/ Normandy NewTEM/HoistEM helicopter-borne EM systems and modelling and inversion of IP and EM data.

In the first of a two part review we will be covering the period from 1946-1975. In the April 2005 Preview we will be covering the period from 1975 to the Present.

The story starts at the end of World War II, which brought a period of growth, discovery and evolution in geophysical techniques. At this time a concerted effort was undertaken to sieve war-time technological developments for their exploration potential.

Radio Frequency Laboratory of Boonton, New Jersey, a developer of near-shore underwater mine detection devices, drew Newmont's attention in early 1946 to the phenomenon whereby metal samples in a water tank gave rise to a discharge of considerable magnitude and duration when a pulse of direct current was applied. At this time Arthur Brant, from the University of Toronto, began to consult for Newmont and recommended an investigation of this phenomenon be undertaken by RFL. Following positive tank tests on sulphide ore samples in 1946, equipment was built and mounted in an Army 6 x 4 truck and used for field tests at Tintic, Utah, and Ely, Nevada, in 1947. This was followed by further field tests in 1948 at San Manuel, Arizona, where Magma Copper, a Newmont affiliate, was developing a new, large copper deposit. Directed by Harry Siegel (see June 2004 Preview, p. 8), these tests demonstrated that disseminated sulphide mineralization could be detected even under considerable depths of cover using this overvoltage, or induced polarization, phenomenon.

Jerome, Arizona 1949 – 1957

In 1949, Dr. Brant joined Newmont and a geophysical group was established at Jerome, Arizona, in the porphyry copper country of the southwestern United States. 'Doc' Brant always felt that the requisites for the successful development of geophysical exploration technology were good theoretical work, good instrumentation, solid rock property studies and modelling. He assembled an exceptional group of scientists and technicians at Jerome in 1949, all Canadians, including his top students at the University of Toronto: Harry Siegel, Jim Wait, Len Collett, Ken Ruddock, Robert Baldwin, Don Wagg, Ken Hunter, John Dowsett, and Ewart Blanchard. Others followed in later years.

Brant credited the genius of Jim Wait for almost single-handedly laying the mathematical foundations for time and frequency domain electromagnetic prospecting while at Jerome. And Harry Siegel developed the first mathematical expressions indicating the overvoltage anomalies to be expected across mineralized bodies of geometric form charged by the application of a square-wave direct current pulse. Len Collett carried out model and physical property tests on particle size, mineral response, surrounding media, fracture orientation, suppression

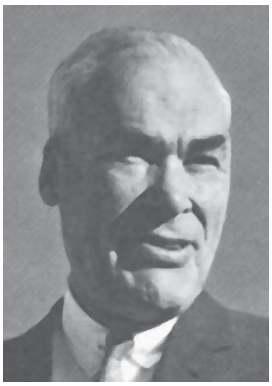

Fig. 1. Arthur Brant (Director 1949-1975) assembled the first significant research group in the history of mining geophysics in America.

Fig. 2. The home of the geophysical group at Jerome, Arizona, from 1949- 1957.

Fig. 3. The first Induced Polarisation tests at Johnson Camp, Arizona. ~1947.

Fig. 4. Magnetometer and EM receiver coil on Newmont Aero Service frequency-domain EM system ~1956.

Fig.5. Transmitter coil on Newmont Aero Service EM system mounted on a Sikorsky S-55 helicopter ~1956.

by oxidation, and frequency versus time domain. Ken Ruddock proved exceptional in electronics and was the chief designer of the early field equipment. Elwood Bratnober was a human computer and did much of the numerical computation for the Siegel and Wait theory.

Under Brant's leadership, the Jerome laboratory developed several innovative geophysical techniques, marking the beginning of a coherent and continuous geophysical effort by Newmont that continues to this day. In all, the Jerome group holds 25 patents in geophysical techniques. Patents were sought, as a matter of policy, for defensive purposes to ensure Newmont's right to work and apply these techniques. Although Conrad Schlumberger was the first to recognize the phenomenon of induced polarization in 1912, it was the post-war work by the Radio Frequency Laboratory and Arthur Brant's team at Newmont that significantly advanced the method to commercial use. By the late 1940s and early 1950s, overvoltage exploration was being carried out around Jerome; Leadville, Colorado, and later over many of the copper showings in southern Peru.

Other major contributions to the development of IP in the 1950s were made by Ralph Holmer and George Rogers at Kennecott, Ed McAllister at Anaconda, John Sumner and Sal Gaytan at Phelps Dodge, and Vic Mayper, Ted Madden, Phil Hallof and Keeva Vozoff at MIT. The latter's development of the dipole-dipole surveying technique and pseudo-section presentations are now in general use, and IP is routinely applied by mining companies and geophysical contractors worldwide.

The development of electromagnetics had two main contributors in the 1950s: McPhar Engineering of Toronto, primarily in instrumentation and field procedures, and Jim Wait in quantitative theory and evaluation at Newmont. Under sponsorship from Sherritt Gordon Mines, a Newmont affiliate, and later Inco, McPhar developed the first helicopter-borne EM system in 1955. This was a rigid-beam coaxial-coil pair system in a 20 ft towed bird, credited with the discovery of the Heath Steele massive sulphide ore bodies in New Brunswick, Canada. As a result, mining concerns, including Newmont, rushed into EM exploration.

Fig. 6. Early EM tests at Jerome, Arizona ~1955. The triangle shaped transmitter coil was a prototype for the airborne EM system.

In 1956, Ken Ruddock built the Newmont Aero Service frequency-domain EM system mounted on a large Sikorsky S-55 with coaxial transmitter and receiver coils mounted fore and aft resulting in a coil separation three times that of towed-beam systems. The system was capable of measuring in- and out-of- phase of the primary field to about 5 ppm and allowed excellent interpretation of conductivity-width product and depth to source. In 1959, Texas Gulf Sulphur introduced a similar system, but with a rigid 15 m coil-carrying boom mounted on a light Bell 47G2 helicopter. This system resulted in the discovery of the giant Kidd Creek copper-zinc-silver deposit, one of the most successful applications ever of airborne EM. At the same time, Newmont also developed and applied a borehole EM system, a 400 Hz in-phase out- of-phase system with coils 30 m apart. Chuck Elliot joined Newmont in 1955 and spent time using the equipment at Newmont's O'okiep and Tsumeb copper operations in southern Africa in the late 1950s and at Lynn Lake in Manitoba, Canada, in 3,000 ft horizontal holes the early 1960s.

Danbury, Connecticut 1957 - 1975

In 1957, Newmont built a new research facility at Danbury, Connecticut, and focused on interpretive techniques and the development of special methods in geophysics. Innovators like George McLaughlin, who joined Newmont from McPhar in 1959, developed a portable IP receiver that could be operated without being connected to the transmitter for timing, thereby allowing several receivers to be used simultaneously. George had a remarkable ability to build equipment that worked. He and Bill Dolan also worked on the theory, modelling and design of a high current, low voltage, large loop pulsed electromagnetic system originally conceived by Jim Wait in 1952. In the early 1960s Dolan operated this system in Cyprus.

Maurie Davidson and Misac Nabighian joined the Danbury group in 1966 and 1967, respectively, both from the Lamont-Doherty Earth Observatory at Columbia University.

Newmont had one of the first in-house computers in the mining industry, an IBM 1130. The first gridding and contouring routines were developed in collaboration with IBM staff from their nearby White Plains research facility.

Arthur Brant retired from Newmont in 1975 and in 1977 moved to Tucson to become an adjunct professor at the University of Arizona and the Krumb School of Mines at Columbia.

Beach Petroleum – focusing on Australian oil and gas production and exploration

Beach Petroleum Ltd is a public company based in Adelaide and listed on the Australian Stock Exchange. It has a market capitalisation of around A$140 million, putting it in the top tier of Australia's oil and gas producers and explorers.

Beach was established in the early 1960s by the late Dr. Reg Sprigg, an outstanding Australian oilman, geologist, explorer and conservationist. In recent years its exploration program has expanded considerably. Currently it holds interests in tenements throughout Australia and in Papua New Guinea. The company's activities are mainly focused upon the Cooper/Eromanga Basin of South Australia and Queensland, where it holds interests in nine exploration areas and four oil production joint ventures.

However, in recent years it has diversified to include investments in the offshore Gippsland Basin (Vic.), the offshore and onshore Otway Basin (SA and Vic.), the offshore Browse and Carnarvon Basins (WA) and the Gulf of Papua (PNG).

Beach's share of production during the 2003/04 financial year totalled ~1.0 million barrels of oil equivalent (Mboe), or approximately 3200 boe per day. This number is about six times the amount produced in 2001/02, with a corresponding improvement in cash-flows.

The company has a reserves/annual-production ratio of about 10:1 and an active exploration program to boost its reserves.

The main objectives of the company's exploration and development program are:

- As a first priority, participate in sufficient low risk exploration and development activity, primarily in the onshore Cooper/Eromanga and Otway Basins, to maintain or improve the company's reserves base; and

Managing Director – Reg Nelson

- As a second priority, participate in exploration activities, primarily in prospective offshore regions on the northwest margin of Australia, with the potential to make substantial additions to the company's reserve base, albeit at a higher level of risk.

Key Personnel
Chairman – Bob Kennedy
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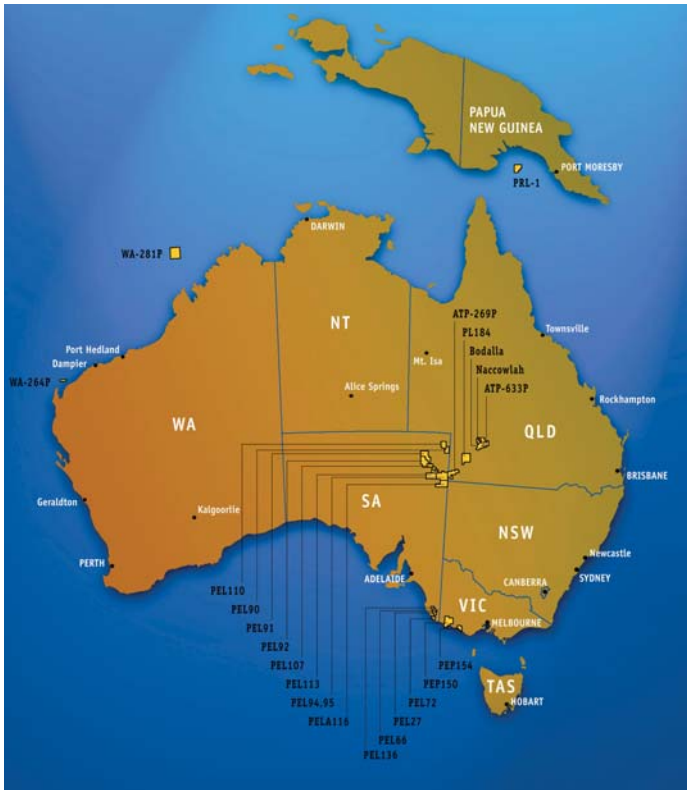

Fig. 1. Locations of tenements where Beach has an interest. Details of the Gippsland holdings postdate this map; refer to the website: http://www.beachpetroleum.com.au/files/exploration_VIC_RL06_09_10.htm for details of the 2004/2005 exploration programs

Fig 2. Discovery well Christies No 2 in PEL 92, SA.

Passive Seismic: what, where and why

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Summary

The practice of passive seismic, listening without active surface sources, is hardly new. Yet the application to resource exploration and development has lagged behind the use of more conventional 2D and 3D seismic techniques. The need to explore in more difficult frontier terrains and the current 'smart oilfield' initiatives have led to renewed interest in passive seismic. This paper will review the various methodologies currently employed with several real field examples from applications around the world.

Introduction

3D seismic is generally accepted as the most significant technical development in the E and P business in the last 15 years. Seismic imaging as an exploration and development tool has changed radically over the last 80 years and become a billion dollar business. Recording systems that can handle thousands of channels of data, fleets of vibrators operating in tandem and helicopter supported field ops are commonplace. But there are environments where such modern systems are too expensive to operate, or where environmental or community concerns obviate the use of heavy machinery. There are also problems in today's oilfield that reflection seismic cannot address.

Enter passive seismic.

What is passive seismic? It is seismic imaging without sources. Wait a moment. That seems a silly statement.

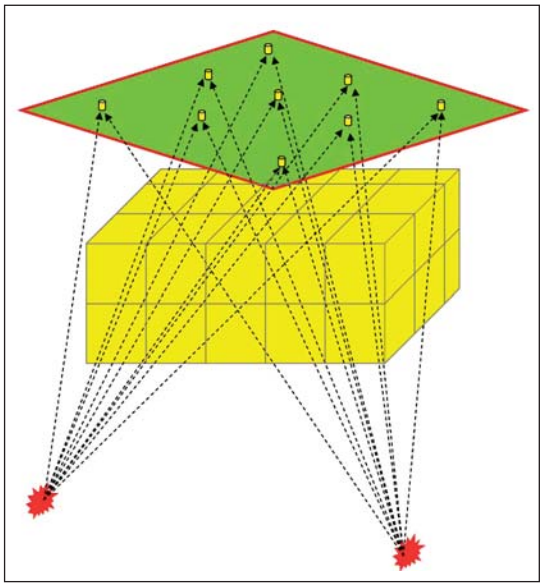

Fig. 1. In passive seismic transmission tomography, micro-earthquakes occurring below the target, illustrated here as the yellow cube, serve as seismic sources. 3-component geophones on the surface record the arrival times of P and S waves from these tremors. Travel-time inversion is used to estimate the P and S velocity distribution in the target. As more events are observed, the velocity distribution can be estimated to a finer resolution.

Surely, one has to have some sort of energy source. Rather let us say that it is seismic imaging using sources of opportunity rather than the standard airguns, vibrators or dynamite that a crew usually puts to good use. A passive seismic crew merely lays out an array of receivers and……listens. They are listening for earthquakes and microseisms, some produced naturally and some the result of production activity, but all useful to create an image of what's going on down under.

There are two distinct branches of passive seismic. The first I will call transmission tomography. This branch uses micro-earthquakes located below the target area to create a 3-D image of the target using travel-time tomography. The second branch I will call emission tomography. In this technique, one listens for the seismic events occurring at or near the target to image the dynamics of the target. One is listening for the noise created by creeping faults, or opening fractures or the movement of fluid through porous rocks.

Let us deal with each of these branches in turn.

Passive Seismic Transmission Tomography

Passive seismic transmission tomography creates 3D images of the target volume using the observed travel-time of seismic signals originating from micro-earthquakes occurring below the target. The field setup is illustrated in Figure 1. A sparse array of independent seismographs is established above the target volume. The array usually consists of 20 to 100 observation stations each recording the output of a 3-component geophone. Typical imaging areas for such an array are 300 to 1500 km^2. The 3-component phones are typically placed 10 to 30 m below the surface to get away from the noisy surface environment. The stations may store their data locally, but often are linked to the processing centre by some form of telemetry.

Once the array is established the survey proceeds by simply listening. Assuming a starting velocity model, the observed micro-earthquakes are located in time and space using standard location algorithms dependent upon picks of the arrival times of the p and s phases at each observation station. Once a number of events has been located one flips the process, assumes the origin time and hypocentre of the events are known, and uses some form of travel time inversion to estimate a new velocity model for the target volume. The 3-component nature of the observations allows for estimation of

the Vp and the Vs velocity structures. Over time, as more events are added to the dataset, ever finer estimates of the velocity structure can be achieved. The process proceeds in this boot-strapping fashion until the desired resolution is reached. The length of time needed will depend upon the level of seismic activity in the area and the number of stations deployed. Since the processing of the data proceeds in near real time, it is possible to monitor the effectiveness of the survey and cease field operations when the particular needs of the survey have been met. Survey times of 6 to 12 months are typical.

Most of us are surprised to find that there are enough micro-earthquakes occurring to make this a viable tool. We are conditioned by media and government publications to only think of earthquakes in terms of life threatening, concrete crushing events that thankfully happen only rarely. Such events have a local magnitude (m_L) of 3 or greater. Earthquakes are observed to be log-normally distributed as to their magnitude. This means that there will be, on a statistical basis, 10 times as many magnitude 2 earthquakes as magnitude 3, and 10 times as many magnitude 1 as 2, and so on. The micro-earthquakes used for passive seismic transmission tomography are typically all those down to magnitude 0 or even smaller depending on the local ambient noise environment. Given the frequency of occurrence of these smaller events, one begins to appreciate how passive seismic imaging can be possible. It is often useful to deploy a few stations in the project area prior to mobilizing a full suite in order to assess the noise environment and the level of micro-seismicity. This enables a reasonable estimate of time-to-resolution for a given number of observation stations.

Where and when does such an approach to imaging become cost effective? Certainly in flat, open country a more conventional survey using reflection 3D is probably a better solution. But in mountainous terrain where it's difficult and expensive to carry on conventional operations, passive can be as much as an order of magnitude less expensive. In environmentally sensitive areas, where permitting of conventional surveys is becoming next to impossible, the benign environmental impact of passive means that a survey that might otherwise never get shot becomes possible. In highly cultured areas, the low impact presence of passive again makes the likelihood of obtaining permits much higher.

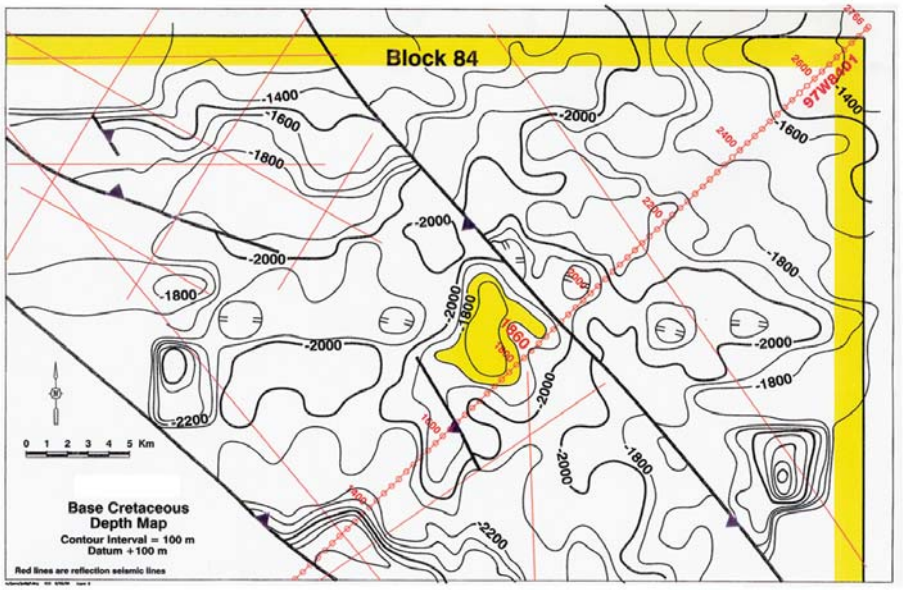

Fig. 2. Depth map to the Base Cretaceous created by integrating a 2D seismic line (indicated by the red line with circles) with the results of a 3D passive survey (used with permission).

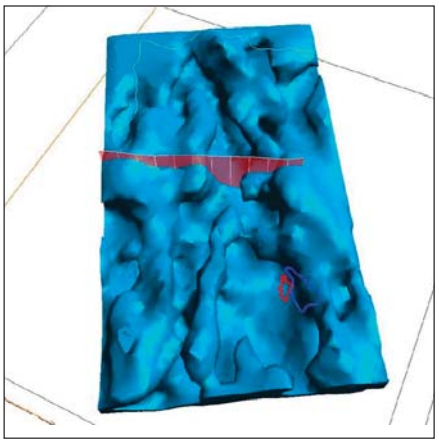

Fig. 3: Common Vp value volume extraction from a 3000 km2 passive 3D representing distribution of carbonates in the subsurface (courtesy of LandTech Enterprises).

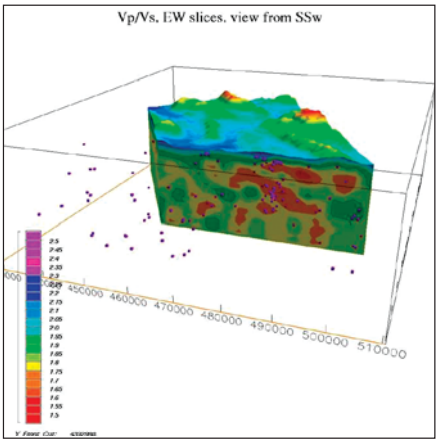

Fig. 4. Portion of 3D cube showing Vp/Vs distribution extracted from a 3000 km2 passive 3D (courtesy of LandTech Enterprises).

There is not a great abundance of case history to report for passive seismic transmission tomography. One example that has been reported was a project in the Ucayali Basin of Peru conducted by Technology Research Associates Corporation on behalf of Anadarko in 1997 (*The use of earthquake energy for structure tomography in the northern Ucayali Basin, B. Mallick and J. Drummond, Anadarko Peru Co., Houston, TX USA, INGEPET* '99). The project area is in the headwaters of the Amazon, in triple canopy jungle. Quotes for conventional 3-D ran as high as $150,000 per km^2, and it was not certain that the survey could be permitted. Anadarko elected to shoot a 2D line across the prospect and then extend the 2D to 3D using passive data. Twenty stations were deployed for 5 months. About 4000 events were located of which about 1000 were used for inversion. Figure 2 shows a structure contour map made by combining the 2D and passive 3D data. The cost for the 3D data was on the order of $1000/km^2. Attained resolution was on the order of 300 m in the survey centre.

Another example was published in December 2003 (*Case study in NW Greece of passive seismic tomography: a new tool for hydrocarbon exploration, S. Kapotas, G-A Tselentis and N. Martakis, First Break Volume 21, Dec 2003*). This survey was performed by LandTech Enterprises. The driving force was again cost. 2D dynamite

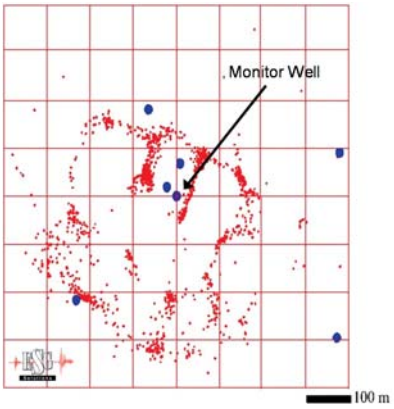

Fig. 5. Distribution of event epicentres observed by monitor well in Ekofisk Field. Events are interpreted to be caused by compaction-related faulting associated with hydrocarbon withdrawal (image courtesy of ESG Solutions).

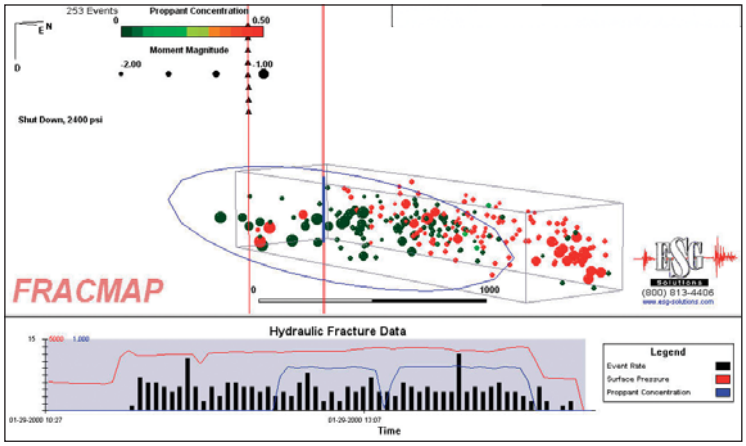

Fig. 6. Presentation of event hypocentre distribution observed during a hydraulic fracturing of a well. The red vertical line with the thicker blue section represents the frac well and the frac interval respectively. The black triangles on the other well line represent the monitor 3D geophones. The hypocenter locations are represented in 3 dimensions as spheres, with larger size representing greater magnitude and the colour representing the level of proppant concentration in the frac well. The lower diagram shows the event count over time as a bar chart. The red curve presents the pumping pressure. The blue curve shows proppant concentration (image courtesy ESG Solutions).

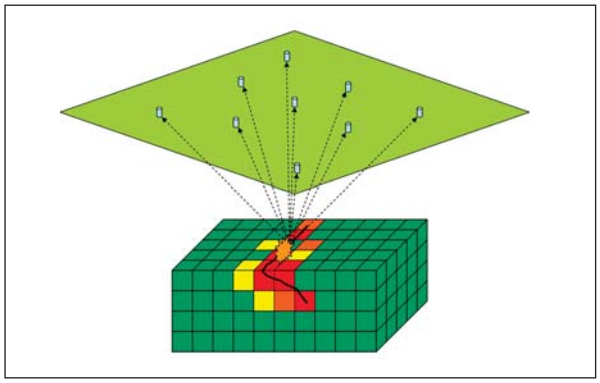

Fig. 7. Illustration of the surface method of emission tomography. Movement on the fault causes a seismic signal that is recorded on the surface array. The array is beam-steered sequentially at each cell in the subsurface. The seismic energy recorded by the array over a period of observation time is displayed as colours in the cube, hotter colours representing higher energy levels. The areas of high energy will delineate where dynamic activity is taking place in the subsurface.

seismic was costing £30,000 per line-km. Vibrator 2D was £6000/line-km. 3000 km^2 of passive 3D with a resolution of about 500 m was acquired for around £500,000. Forty recording stations were deployed for about 10 months and 4000 events were captured and used in the inversion. Figure 3 presents a structure map of a key marker derived from the data. Figure 4 shows a Vp/Vs section derived from the data highlighting the multi-component aspect of passive seismic.

In summary, passive seismic transmission tomography offers an opportunity to obtain cost effective structural images (velocity structure not impedance structure). It competes with conventional seismic in rugged terrains, in environmentally sensitive areas and in culturally difficult areas. Most areas of the world experience enough seismicity for the approach to 'work' given enough time. The issue of resolution is largely an economic one of trading off time in the field with number of stations deployed.

Passive Seismic Emission Tomography

When we move to emission tomography we move from using micro-seismic activity as a convenient source of energy with which to image the subsurface, to considering the micro-seismic activity itself as the target. By mapping the distribution and character of this activity we intend to gain some insight into the dynamic processes occurring in and around the imaging target.

The most straightforward approach to such a task is to observe and record the direct arrival of the seismic waves from theses events and to locate and map the distribution of hypocentre locations using the same mathematics as the first step in the transmission tomography application. For the most part, the events being considered here are small, with local magnitudes in the -1 to -3 range. Such small events are rarely discernable as clean first breaks on surface recordings. Consequently, much of the work in this domain has been executed with receivers placed near the target activity in a nearby borehole.

Figure 5 shows one of the earliest and most published of such an emission tomography application. The data plotted are the epicentres of the events observed in a monitor well in the Ekofisk Field. The objective was to observe seismic activity associated with compaction faulting contributing to ocean floor subsidence in the area of the field probably as a result of hydrocarbon withdrawal. The locus of hypocentre locations clearly shows the fault pattern controlling the compaction and suggests a certain compartmentalisation of the reservoir. The scale of the figure illustrates one of the limitations on such downhole observations. Attenuation of the signal limits the area of investigation to perhaps no more than 1 km from the observation well.

One of the more common applications of emission tomography in use today is the monitoring of well stimulation through hydraulic fracturing. Typically an array of 8 to 12 3-component geophones is clamped at or just above the reservoir level in a wellbore near the frac well. First break picks are made of the events observed by the array and used to estimate events' hypocentres. Mapping the hypercentres over time, mirrors the development of fracturing as pumping proceeds. Figure 6 illustrates the results of such a survey. Often these results are presented as movies, which much better reflect the dynamic nature of the process.

The availability of observation wells and the limitations of observation distance are serious impediments to the widespread usefulness of this downhole technique. A different approach to emission tomography

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Fabienne d'Hautefeuille

3D geophysical processing, visualisation and interpretation of rice irrigation impacts

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Abstract

The National Centre for Groundwater Management at the University of Technology, Sydney has completed a three stage research project at a field site near Griffith NSW, which included an examination of the dynamics of groundwater levels and salinisation adjacent to an irrigated rice paddock. The site had 22 piezometers and was instrumented with 16 data loggers from October 1999 to September 2001. Ten resistivity imaging and EM34 surveys were conducted during the period October 1998 to June 2001 – before, during and after irrigation. Each imaging survey comprised 15 lines (during winter) or 10 lines (during irrigation) each of about 200 m long. The lines were generally 10 m apart (sometimes 5 m). The results from each survey have been assembled into a movie (using SURFER and SLICER software), which shows the 3-D heterogeneity in resistivity across the site. A couple of movies have been produced showing the variation with time along representative sections. Snapshots of the differential apparent resistivity between surveys before and after irrigation show definite incremental salinisation in the fallow paddock adjacent to the irrigated rice paddock.

Introduction

Resistivity imaging allows a good approach to investigations of the level of salinity in groundwater and spatial variability in plan and section. 3D animations

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[1] No longer at UTS, contact now via Email: hautefeuille@yahoo.com

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is illustrated in Figure 7. In this method an array of geophones is deployed on the surface much as in the transmission tomography case, but the array is denser, typically with 40 to 100 stations distributed over a few km^2. The array is sequentially beam steered at all points in the subsurface and a 3D map is made of the acoustic energy being emitted over a given time from each subsurface location. In this way it is not necessary to 'see' each individual event, but rather we map the cumulative energy released by the sum of events over a period of time. We are using the same principle as the hyperbolic microphone or the dish antennae. The approach effectively extends the lower limit of signal that can be seen from the surface. Of course, this method can incorporate borehole observations as well, if such are available.

Figure 8 presents the results of a frac monitor conducted with a surface array as just described. The array consisted of 100 3D phones spaced on a regular grid above the well to be frac'ed. The well is a horizontal well with the depth of the horizontal segment at about 2500 m. The horizontal reach is about 1000 m. The figure clearly shows the concentration of acoustic energy extending away from the well parallel to the direction of maximum principle stress as expected.

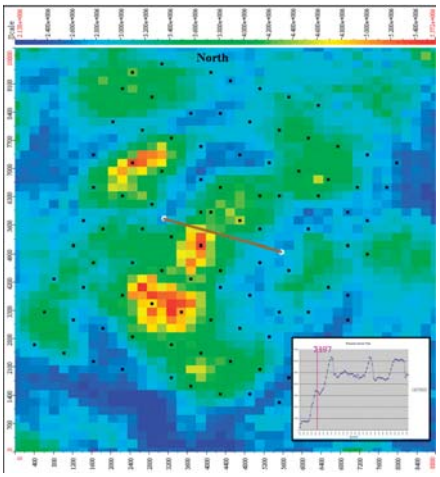

Fig. 8. Depth slice at the reservoir level through an emission energy cube derived from one minute of observation time, during a hydraulic fracture stimulation of a horizontal well. The black dots are the locations of the observation stations. The brown line terminated by the white dots represents the location of the horizontal portion of the well. The hotter colours represent areas of higher energy acoustic emission. The inset shows the frac pressure history with the vertical lilac line being the time of this observation. The distances along the axes are in feet. The energy distribution is consistent with fractures being set up in 2 directions, one parallel to the direction of maximum principal stress (thought to be perpendicular to the well), and a conjugate set at right angles to this direction.

The ability to monitor dynamic processes in real time from the surface presents many opportunities for useful application. These include frac monitoring, mapping of fault creep and compaction, and tracking of injected fluids. In a very real way we are putting a stethoscope on the chest of the earth and listening for the internal dynamics. It is a continuous 4D seismic survey, if you like, and represents a unique direct detection of subsurface activity. The challenge is that we don't have a lot of experience to draw upon with which to interpret these sounds.

Conclusion

Passive seismic in my terminology encompasses two complimentary applications. In the first, micro-earthquakes below the target are used as seismic sources with which to create an image using travel time tomography. In the second application, the micro-earthquakes themselves are the target to the extent they reveal in real time something about the dynamic processes taking place in the subsurface. Neither of these technologies is particularly new theoretically, but the application to the resource industry on a practical basis is new. It remains for a body of case history to be developed for us to gain better insight into the range of problems that can be usefully and economically attacked with a passive approach.

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through space or time enable an even better understanding of the apparent resistivity variations at a site. Watching the evolution of the salinity in the ground over a period of time provides an insight into the dynamics of the groundwater processes.

This work is part of a project concerning the salinity at an irrigated field site. A field investigation of the dynamics of groundwater level and salinity adjacent to a rice paddock before, during and after a growing season was completed by Mclachlan (2000), and a model of groundwater flow and solute transport at paddock scale and at short time scale was developed on this site by Hodson (2000).

The site is located in the New South Wales Riverina (Australia), 30 km south east of Griffith at Whitton. Fieldwork, including resistivity imaging surveys, was done at different dates over a two-year period.

The water table is generally less than 2 m below ground surface. Field apparent resistivities vary over a narrow range (generally 4-12 m); consistent with a clay lithology and groundwater salinity in the range 1500-3000 mg/L. Formation resistivity is a bulk physical property that has source ambiguity. It is determined by a number of more fundamental factors, the more important of which are soil texture (e.g. clay, sand), salinity and moisture content. Without other controls, the method will be ambiguous in its interpretation of the causative factors. Time-lapse imaging can differentiate between these if the electrode array is properly focused. As soil texture is time-invariant, the difference between repeated images can highlight changes in either salinity or moisture, by focussing the depth of investigation to the saturated or unsaturated zones, respectively.

In this way, we ensure that the survey depth of investigation starts under the water table, so that any observed changes between surveys are caused by salinity variations.

Using a defined methodology and different software packages, animated movies showing the salinity variations were created.

Method and Results

Characteristics of the field site

The field site is 360 m x 200 m in size, located in a very flat rice-growing area where irrigation takes place every year between October and April. Ground slope is 1:4000 towards the west, established by laser planing. In this operation, about 0.15-0.2 m of top soil was removed from the site. The site is organised into three blocks (Figure 1):

- Line 45E to 5E: Eastern section (rice paddock)
- Line 5W to 35W: Central section (middle paddock, fallow)
- Line 45W to 80W: Western section (western paddock, fallow)

The Central and Western sections are fallow paddocks, surrounded by rice paddocks in the south and in the Eastern section. Rice had been planted for the first time in 1998 in the paddock after a few years of fallow. The drain to the west of the fallow paddocks is filled by overflow from the flooded rice paddocks and drains into the main drain at the northwest corner of the site. The rice paddocks are supplied with gravity-fed water at the south-eastern corner of each paddock. In October 2001, rice was reintroduced in the fallow and thus the whole field site was irrigated.

The site is located on the Dallas Clay Plain and is characterised by extensive level plains of dense clay, classified as grey-brown soils of heavy texture. The identified soil associations at the site are: Mundiwa clay loam (Eastern section), and Gogeldrie clay (Central and Western sections). Hodson (2000) conducted a soil survey by taking samples at 0.25 m intervals down two representative profiles to a depth of 1 m. The Mundiwa clay loam is strongly alkaline (ph 9.0), has uniform soil moisture of about 23 percent (23.1-23.9%), and has soil salinity averaging 840 mg/L (577-1130 mg/L). The Gogeldrie clay is also strongly alkaline (ph 8.5-9.0), has similar soil moisture of about 21 percent (21.0-21.7%), but has considerably lower soil salinity averaging 450 mg/L (352-546 mg/L). Infiltration tests indicate that the infiltration rate under ponding conditions is expected to be higher for the Gogeldrie clay.

On a broader scale, the clay at the site is part of the Shepparton Formation, at the top of the Cainozoic Murray Basin sequence. The Formation consists of fluvio-lacustrine sediments (clay, silt, sand) with vertical and lateral heterogeneity. The regional hydraulic conductivity is of order 1-3 m/d, but sandier lenses can be an order of magnitude higher. Hydraulically, the formation is an unconfined aquifer, overlying an extensive semi-confined sand-gravel aquifer (Calivil Formation) at a depth of about 30 m.

Data acquisition

Resistivity data were collected using the Sting Memory Earth Resistivity Meter and the Swift multi-electrode accessory developed by advanced Geosciences, Inc. (Austin, Texas). Data were acquired with two cables of fourteen electrodes each attached at the Sting/Swift system, and then one cable leapfrogs the other for another acquisition using two cables. Roll-along command

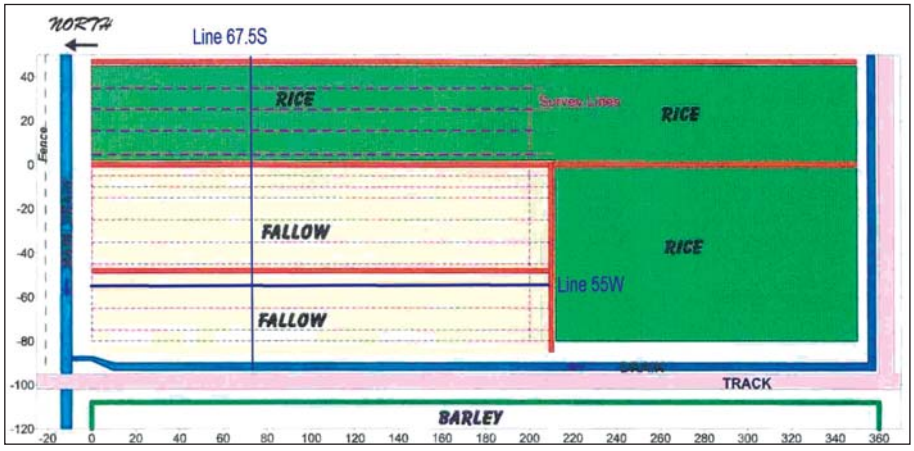

Fig. 1. Rice irrigation field site. Survey lines are represented by parallel dash lines. Each line is 200 m long. Lines are defined from their Y axis, if below zero, they are west, if above they are east lines.

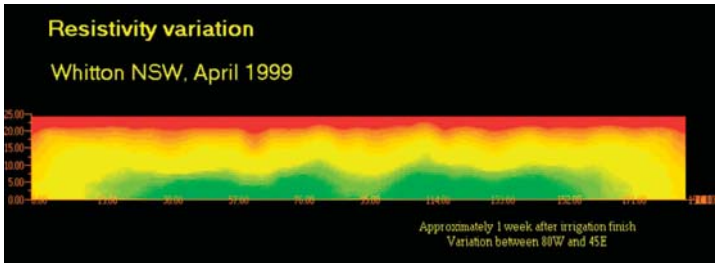

Fig. 2. Linear and homogeneous pattern in the variation of the resistivity. April 1999, line 55W. Lower values of resistivity are in red, then yellow, green and blue (highest values of resistivity). Looking east (left towards north).

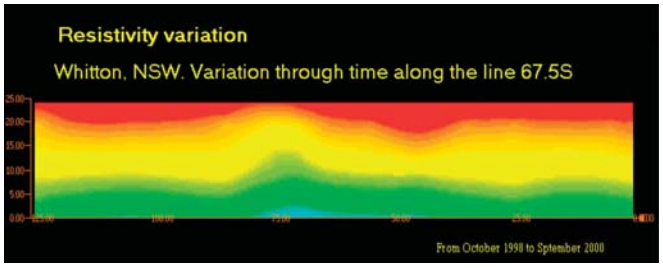

Fig. 3. Heterogeneity created by the drain between rice and fallow bays. September 2000, line 67.5S. Transversal section, looking south (left towards east). Linear pattern once more observed here; it is interrupted by a decrease of the salinity near the drain between the rice and fallow paddocks (left of centre). This section was created from the 3D resistivity data at each survey.

files (WL051, WL052) avoid repetition of overlapping readings. The June 2001 survey used three cables, so no leapfrogging was required. The data are stored in the internal memory and downloaded to a laptop computer each night.

Ten surveys were conducted between October 1998 and June 2001. These were completed before, during and after two irrigation seasons in order to monitor the dynamic variations in groundwater level and salinity.

The field contains 15 lines spaced every 10 m (sometimes 5 m), but only 10 lines were accessible during the irrigation season due to ponding of the Eastern section. The Schlumberger configuration was used for all the surveys except the first one (October 1998 with Wenner configuration). With electrodes at 5 m spacing, resistivity is measured to an effective depth of about 25 m. The first survey was documented by Merrick and Williams (1998).

The apparent resistivity data vary between 3.6 and 19.6 Ωm, the main range being from 4 to 12 Ωm. The initial survey identified substantial spatial variability, with a higher resistivity area in the south-eastern corner of the field and a lower resistivity area in the northern part and in the fallow paddocks.

Creation of animated movies[2]

The Slicer3D (Version 1.1) software, developed by Fortner Research LLC Company, was used to create animation movies. The scale used to represent the range of apparent resistivity is the same for all the movies.

As a first view of the data, movies are created for field apparent resistivity data, not inverted true resistivities. In this area there are no dramatic contrasts in resistivity, only smooth variations. It is considered that the apparent resistivity images give an adequate indication of the spatial variations in true resistivity, sufficient as a basis for understanding groundwater processes.

Two types of movies were created:

- Movies showing spatial variation of the resistivity. Ten movies, one per survey.
- Movies showing variation of the resistivity through time. Two movies along the North-South axis (lines 65W and 10W) and one movie in the transversal section (line 67.5S).

Observations

It is observed that generally, the resistivity increases with depth in a linear and homogeneous pattern (Figure 2). This is most likely to reflect a variation in salinity with depth, as groundwater salinity sampled in multi-level piezometers is generally 200 mg/L higher near the surface (2 m) than at greater depth (7 m). Some discordance and anomalies are observed during the irrigation period especially for the first irrigation event (October 1998). Eastern and Central sections have a lower resistivity in the northern half of the field in the upper part of the profile. The south-eastern corner is always slightly more resistive than the rest of the site in the upper layers. Drains or water supply channels are elements of disturbance on the homogeneous pattern (Figure 3). There is a clear permanent increase in resistivity at the junction between the rice and fallow paddocks, as this coincides with the toe drain that is permanently wet during summer and is the receptacle for runoff during winter rain events.

During irrigation, the resistivity tends to increase with a time delay, especially in the upper layers. After irrigation stops, resistivity stays constant for a while before decreasing a little at the end of winter. In the movies we can see an increase of the salinity in the upper part of the profile with time especially in the observation bay (fallow paddocks). There is as well an up and down movement of the horizontal pattern with time.

Interpretation

Changes in the resistivity values can be due to three main factors: clay content, moisture content and salinity variation. Clay content will remain the same from one survey to another and the effective depth for the smallest electrode spacing is beneath the shallow water table. Hence, changes in resistivity correspond to salinity variations.

The rise of the resistivity in the southeastern corner or along the drain between the fallow and the rice paddocks can be due to an introduction of some fresh water in the aquifer by infiltration. In the drain the fresh water comes from the excess water from irrigation. The south-eastern corner is a water feeding point for the rice bay.

Irrigation causes an increase in the resistivity of the soil beneath the fallow paddocks. This is not observed as soon as irrigation starts but with a certain time delay. When irrigation stops, a decrease in the resistivity is observed following another delay. This can be accounted for by the fresh water brought by the irrigation. When some fresh water gets into the ground, the salinity decreases. During this supply, the salts migrate up under the fallow paddocks. When irrigation stops, there is no fresh water supply and the salts are more concentrated than they were

[2] To view the movies please contact Fabienne d'Hautefeuille or Noel Merrick.

before as groundwater evapotranspiration occurs from a high watertable. Therefore, an increase of the conductivity is observed in the movies between irrigation events. This phenomenon amplifies over time and hence the salt concentration increases beneath the fallow paddocks.

The delay time with which the variations of the salinity are observed cannot be quantified by data from only two irrigation seasons, with sampling at 2-3 month intervals.

The rainfall quantity is not as important as irrigation and, being much lower than evapotranspiration, is an unlikely factor for the variations. However, greater rainfall and a lower evapotranspiration in winter may be the cause of the time delay between the end of the irrigation and the increase of the conductivity.

Differential maps of the apparent resistivity between October 1998 and September 2000 at 2.5 m and at 13 m effective depths illustrate the spatial evolution of the apparent resistivity in the field site (Figure 4, Figure 5). At shallow depth, there is a clear freshening below the irrigated bay and a clear increase in salinity beneath the fallow paddocks. At greater depth, there are some fresher patches but on the whole there is a perceptible increase in salinity. The fresher zones could be due to preferential recharge of fresh water.

Conclusions

Three-dimensional resistivity movies show the variations of the salinity in a field site in an irrigated area in space and through time.

Resistivity increases with depth in a quite linear and homogeneous pattern. Irregularities are connected to fresh water supply from irrigation and drainage through the drains system. Annual variations and also seasonal variations have been captured by imaging. Over the years, there is a global increase of the salinity in the ground, especially for the upper parts of the profile.

A simple model (Figure 6) can be drawn to explain the salinity variation in the fallow paddocks. During irrigation, the fresh water infiltrates the aquifer and raises the water table in the fallow bays. This gives an increase of the resistivity in the fallow bays, in particular near the rice bay. The higher evapotranspiration due to the higher water table results in an increase of the salinity with salts mobilisation and migration to the top of the aquifer. During winter, the level of the water table goes down, evapotranspiration is lower, and the resistivity increases slightly, the salts being partly washed away with the groundwater flow. On the whole, however, there is an inexorable increase in salinity.

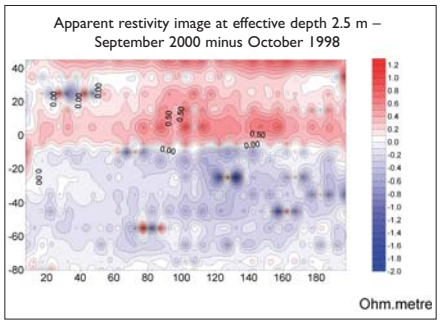

Fig. 4. Differential apparent resistivity image at effective depth 2.5 m; September 2000 minus October 1998. Negative values (blue) correspond to an increase in salinity. An increase in the salinity is obvious under the fallow paddock (lower two-thirds). The soil beneath the irrigated paddock is fresher.

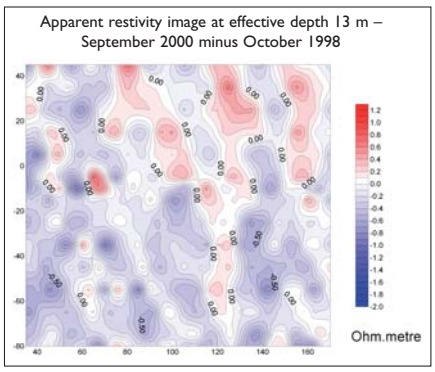

Fig. 5. Differential apparent resistivity image at effective depth 13m; September 2000 minus October 1998. Negative values (blue) correspond to an increase in salinity. Generally, salinity has increased at this depth. The red zones beneath the irrigated paddock might be due to preferential recharge of fresh water.

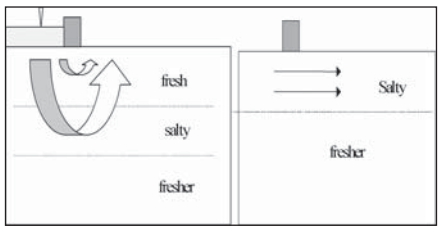

Fig. 6. Conceptual model of resistivity variation during irrigation and between irrigation seasons: during irrigation, the fresh water infiltrates the aquifer and raises the water table in the fallow bays, the resistivity increases in the fallow bay, in particular near the rice bay. A high water table results in high evapotranspiration which causes an increase of the salinity. During winter, the level of the water table drops, evapotranspiration is lower, and the resistivity increases slightly, the salts being partly washed away with the groundwater flow.

Slicer3D software has been used to create the movies. Its use is simple but the version used isn't the ideal software: annotations can't be animated, real values on the axis and colour scale can't be shown, and animation scripts have to be rewritten for each movie. Other limitations include importing base map and information on the screen.

Three-dimensional resistivity movies are a good instrument to visualise resistivity evolution, and are a complement to more traditional surface map and cross section presentations.

Acknowledgments

The Cooperative Research Centre (CRC) for Sustainable Rice Production financed the whole project and Peter and Lorraine Stott kindly allowed use of their farm for research. The Department of Land and Water Conservation (DLWC NSW) supplied the equipment. Eric Gordon ran many of the field surveys.

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Geoscience Australia

GA's Southwest Frontiers Geophysical Survey

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As part of the Australian Government's 'New Oil' initiative, Geoscience Australia completed the Southwest Frontiers Geophysical Survey over the southwestern Australian continental margin between October 20th and November 25th 2004. Geophysical data collected during the survey will be used to understand the petroleum potential of basins on the southwest margin that are not currently held under permit, with a view to promoting new exploration opportunities.

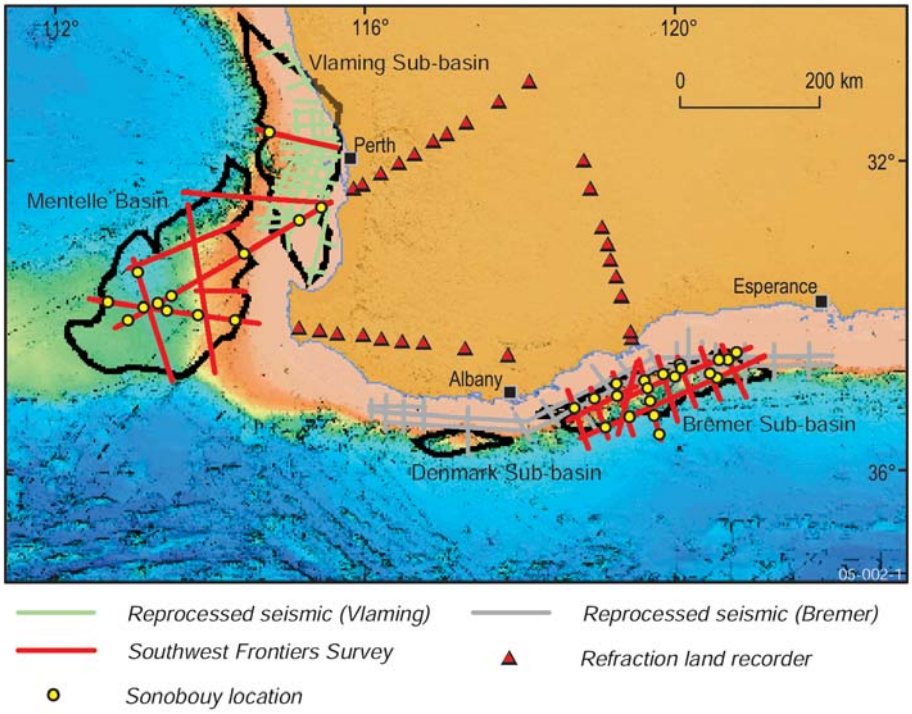

Fig. 1. Map showing locations of new seismic lines and refraction recording stations from the Southwest Frontiers Survey. Also shown are locations of reprocessed seismic lines in the Vlaming and Bremer Sub-basins, which are currently available from Geoscience Australia.

These include the frontier Mentelle Basin and Bremer Sub-basin (western Bight Basin), and the previously explored Vlaming Sub-basin (Perth Basin). This is a very challenging area to acquire seismic data, with shallow carbonate hard-grounds in the Vlaming Sub-basin, deep water conditions (200–4000 m) in the Mentelle Basin and Bremer Sub-basin, and a system of submarine canyons throughout the Bremer Sub-basin. Veritas DGC were contracted to undertake the Southwest Frontiers Survey for Geoscience Australia using the M/V Pacific Sword. The survey acquired 2700 km of industry-standard, 106-fold seismic reflection data recorded to 12 seconds two-way time using a 6–8 km digital streamer and 4900 cubic inch air gun array. Seismic data collected includes 11 lines (1300 km) in the Bremer Sub-basin, 7 lines (1100 km) in the Mentelle Basin, and 3 lines (300 km) in the Vlaming Sub-basin (Figure 1). These are the first seismic reflection data to be acquired in the Mentelle Basin and Bremer Sub-basin in almost 30 years, and from the Vlaming Sub-basin in over a decade. The new seismic reflection data provide a regional coverage of the Bremer Sub-basin and Mentelle Basin, and will help determine if suitable geological conditions exist for generation and trapping of hydrocarbons in these frontier basins. It will also provide the first deep seismic reflection data (> 6 seconds two-way time) in the Vlaming Sub-basin, which will be integrated with a 2000 km grid of recently reprocessed data to develop an improved understanding of the geology and petroleum prospectivity of the Vlaming Sub-basin.

During the seismic acquisition, sonobuoys were also deployed and land recording stations placed along the onshore continuation of three key survey lines (Figure 1) to record refractions from the seismic vessel's energy source. The objectives of this refraction work are to: estimate seismic velocities to better constrain conversion of reflection time to true depth; estimate sediment thickness; constrain gravity modelling; and investigate the nature of basement and crust in this part of Australia. Twenty-nine sonobuoys (nineteen of these in the Bremer Sub-basin) recorded data to maximum offsets of 23 km. The onshore refraction survey deployed nineteen stations in line with two survey lines in the Mentelle-Vlaming area, and 9 stations collinear with one line in the Bremer Sub-basin (Figure 1). The new refraction seismic data collected during the Southwest Frontiers Survey will add substantially to existing onshore and offshore refraction data sets in this region.

All seismic reflection data acquired during the Southwest Frontiers Survey (including field tapes) with basic on-board processing (Radon de-multiple, DMO, Stack, Migration) will be available at the cost-of-transfer from April 2005. Three lines acquired in the Vlaming Sub-basin will be made available from February 2005 for use by explorers interested in the 2004 acreage release permit W04-17 from this area. Further processing (SRME, XRmult, Pre Stack time and/or depth migration, full stacks, near, middle and far offset stacks) will be undertaken on seismic data acquired from the Bremer Sub-basin, and will also be available at cost-of-transfer in April 2005. Reprocessed seismic data sets from previous industry surveys in the Vlaming Sub-basin and Bremer Sub-basin are currently accessible through the Geoscience Australia Data Repository. Further information can be obtained from Barry Bradshaw at Geoscience Australia (phone +61 2 6249 9035, fax +61 2 6249 9980, email barry.bradshaw@ga.gov.au).

Deep seismic surveys focus on mineral exploration

Geoscience Australia, in conjunction with the Geological Survey of Western Australia, the Northern Territory Geological Survey and local gold explorers, are well advanced in their planning for the 2005 Tanami Seismic Research Project. The results from this project will help understand both the crustal architecture and mineral systems that operated in the Tanami region by using an integrated geological and geophysical investigation. The Tanami Project will include the acquisition of seismic reflection data and gravity data along four traverses (Figure 1, though it is anticipated that only parts of each traverse shown will actually be acquired) within the Tanami region of northern Australia to test our understanding of the 3D architecture by imaging the regional geology and key regional structures. Some of these key structures are related to gold mineralisation. This deep seismic refection survey will use the facilities of ANSIR, Australia's Major National Research Facility in seismic imaging. Geoscience Australia, in conjunction with Adelaide University, is also investigating undertaking a coincident Magnetotelluric survey to determine conductivity variations along the seismic profile. Geoscience Australia, in conjunction with RSES and the NTGS, is also investigating the feasibility of a longer-term teleseismic study of the Tanami region and the possibility of undertaking a wide-angle seismic experiment during the acquisition of the reflection data.

The 2003 Gawler Craton seismic survey results were presented at the *Gawler Craton: State of Play 2004 and Seismic Workshop*, held in Adelaide in August 2004. These results were described in the last issue of *Preview*.

The Curnamona Province seismic survey, undertaken as a collaborative project involving the Office of Minerals and Energy Resources, South Australia, the Predictive Mineral Discovery Cooperative Research Centre and Geoscience Australia was completed in 2004 after it was postponed due to rain in 2003. The seismic data are currently being processed. Results from this survey will be presented in 2005, after the dataset has been interpreted.

Future work being discussed includes extending the Curnamona seismic traverses into the Gawler Craton and a seismic program within the Paterson Province of Western Australia.

Airborne magnetic and radiometric survey over Paterson Province WA

Planning is underway for the second large regional survey project of the West Australian government's four-year, $12 million program to increase airborne magnetic and radiometric coverage of Western Australia. The survey is planned to start in April 2005.

A call for tenders has been issued to provide magnetic and radiometric coverage of an area approximately 28 000 km^2 in the Paterson-Rudall region (Paterson Central in Figure 2). Depending on analyses of coverage priorities, availability of private company data and new data acquisition costs, the survey may be extended to the southeast and northwest in a region of 69 000 km2 extending from Mandora to Tabletop 1:250 000 Sheet areas. When completed, the project will produce a total of between 90 000 and 200 000 line-km of magnetic and radiometric data for public access.

The new data will be acquired on lines spaced 400 m apart with a ground clearance of 60 m above ground level. Geoscience Australia will be managing the flying program.

For further details, contact David Howard by telephone on 08 9222 3331 or by e-mail at david.howard@doir.wa.gov.au.

Absolute Gravity Measurements at Fundamental Gravity Base Stations

Geoscience Australia has conducted absolute gravity measurements at selected Fundamental Gravity Base Stations using an A10 Portable Absolute Gravimeter to determine the accuracy and precision of the current Australian Gravity Datum, Isogal84. Measurements were made at sites in NSW and Victoria during 2003 with sites in Queensland, the Northern Territory, Western Australia and South Australia visited in

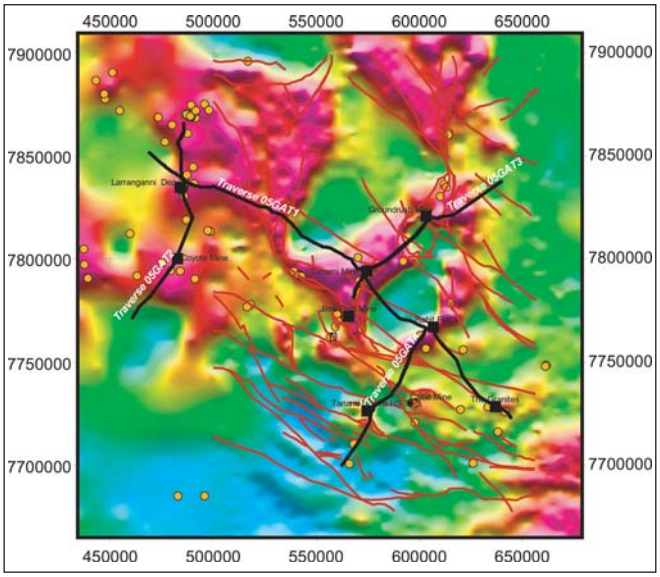

Fig. 1. Location of all proposed Tanami Seismic traverses (black lines with traverse name) on regional Tanami gravity image. It is anticipated that only part of the proposed traverses will actually be acquired. Also shown are the main faults (red) and main mineral deposits (yellow dots).

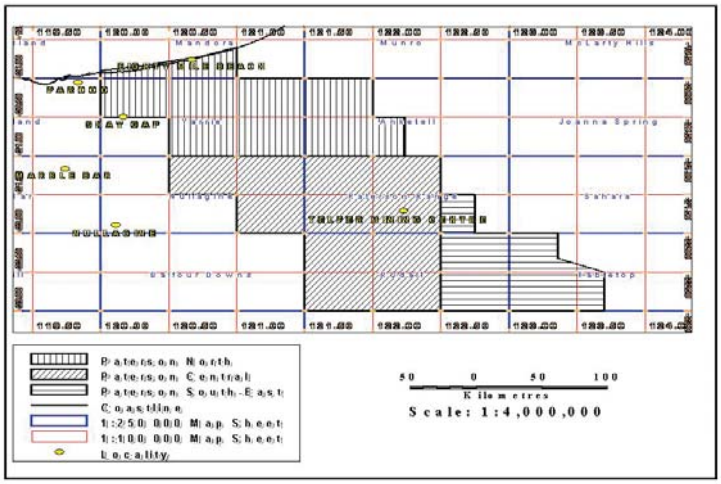

Fig. 2. Location of areas to be covered by the 2005 airborne geophysical survey over the Paterson Province, WA.

2004. The locations of the 48 base stations occupied are shown in Figure 3.

Isogal84 is based on a network of some 900 stations established using relative gravimeters from the 1950's to the present. This network is tied to absolute gravity measurements made at Sydney, Hobart, Perth, Alice Springs and Darwin by a Soviet absolute gravimeter in 1979. The errors in this relative network have been distributed throughout by least squares adjustments of the network. The absolute measurements made by Geoscience Australia will indicate the magnitude and distribution of these errors and provide accuracy estimates for all of the Fundamental Gravity Base Stations. Analysis of the differences between the Isogal84 values and the absolute measurements is currently underway.

For further information about these absolute gravity measurements, contact Ray Tracey: Ray.Tracey@ga.gov.au

Fig. 3. Absolute gravity station locations occupied in 2003 and 2004.

Geothermal energy exploration takes off in SA

Concern over greenhouse gas emissions, and the resulting global warming and climate changes, have heightened the need to generate 'clean' energy to replace those sources that rely on the burning of fossil fuels.

One option being explored involves the use of the heat from hot dry rock to generate electricity. In practice, this means exploring under sedimentary cover to find high temperature basement rocks that can be fractured. Water is then circulated through the fractures via deep injector wells to drive heat exchangers and generate electricity.

Based on the results of recent heat flow analysis (see Figure 1) there are some attractive prospects in South Australia, and the State Government has been pro-active to encourage geothermal exploration there.

The legislative framework for companies wishing to explore has been established and at end-December 2004, 22 Geothermal Exploration Licences (GELs) have been issued to 7 companies, with another 7 applications still being considered (GELAs). This commitment translates into an exploration investment of ~$325 million – a very significant amount.

Companies or individuals wishing to apply for a GEL (see Alexander, 2004) need to provide:

1. A map of the application area (at present the area must be <500 km^2),
2. A proposed five-year work program to evaluate the prospectivity of the licence area (including the expected annual cost of operations),
3. Evidence of technical and financial resources, and

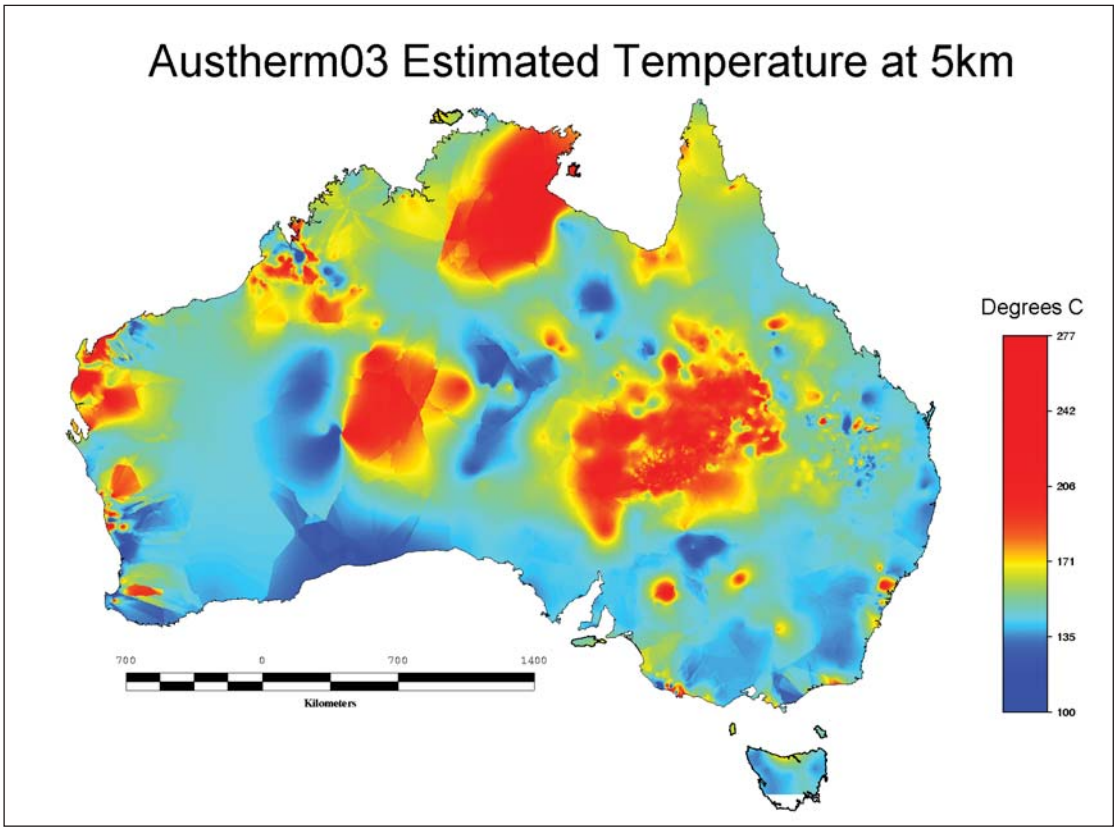

Fig. 1. Estimated crustal temperature at 5 km depth, based on the austherm03 data base (see Holgate and Chopra, 2004). Note the large anomaly near the Queensland South Australia border.

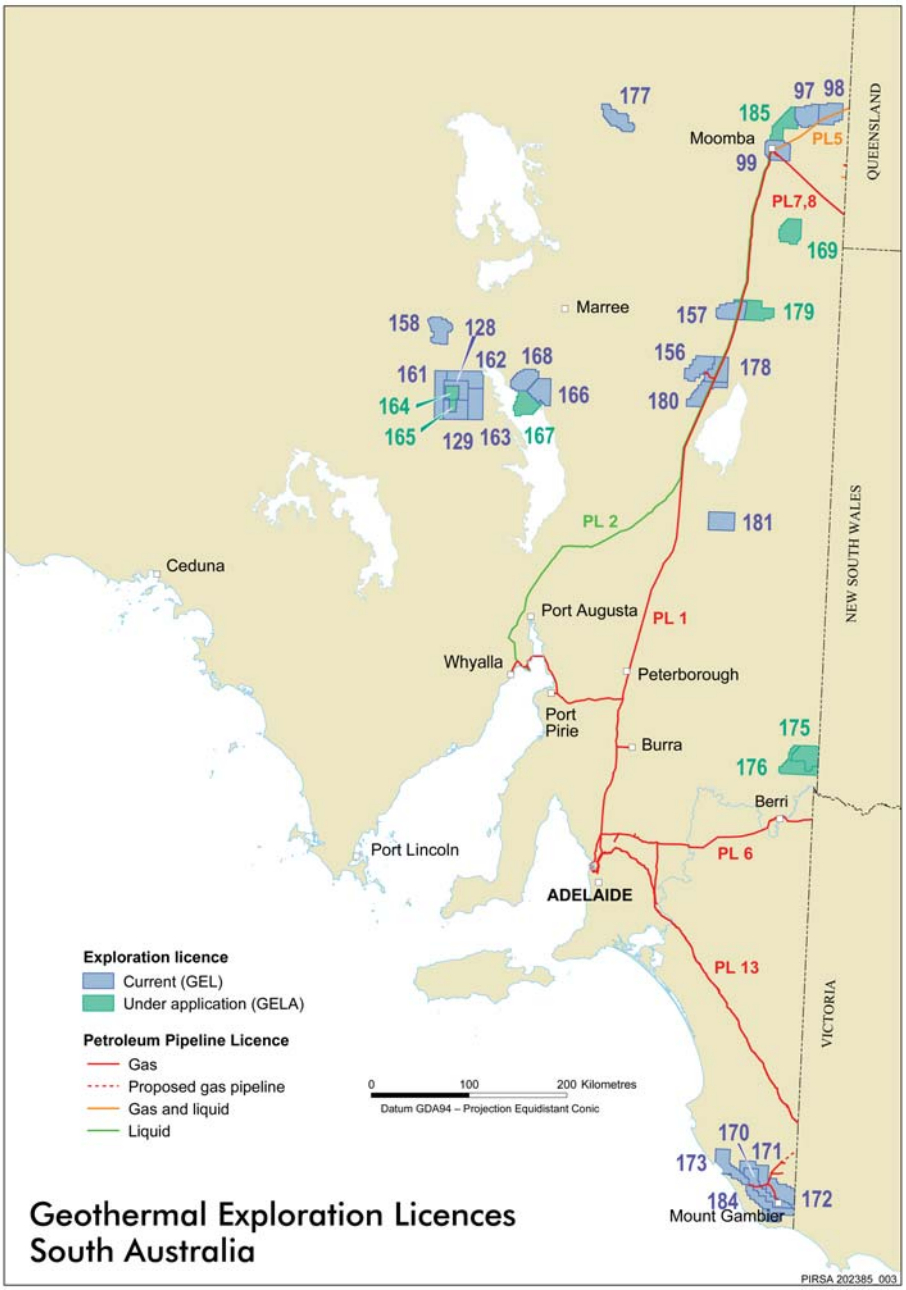

Fig. 2. Locations of the current GELs and those presently under consideration. Refer to the Table to identify the operators.

Fig. 3. Habanero #2 well – Cooper Basin HFR Project. First geothermal steam produced during fish recovery operations on 21 November 2004.

4. Pay an application fee of A$2736.

Companies currently active in the state and their current interests are shown in the Table below (see also Figure 2).

Company	GEL	GELA
Eden Energy Pty Ltd (Tasman Resources)	166, 168, 177	167, 169, 175, 176, 185
Geodynamics Ltd	97, 98	
Green Rock Energy Pty Ltd	128, 129, 161, 162, 163	
Havilah Resources NL	181	
MNGI Pty Ltd (Petratherm)	156, 157, 158, 178, 180	179
Perilya Ltd	128, 129, 161, 162, 163	164, 165
Scopenergy Limited	99, 170, 171, 172, 173, 184	

The Geodynamics prospect is currently the most advanced. This is in the Cooper Basin in the north east of the state (GELs 97 & 98). To date, a 4.4 km well (Habanero 1) was drilled in 2003 and Habanero 2, which is 500 m away, was completed in late December 2004 to a depth of 4.3 km (see Figure 3). Drilling targets of this scale are not cheap. It is expected that the company will have to spend ~$10 million to complete the drilling program just for these two holes.

However, if the technology is proven then the payoffs will be very worthwhile for both the companies involved and the environment.

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2004 good year for resource stocks

Whatever anyone may say about the happenings during 2004, the performance of resource industry shares on the ASX was quite remarkable.

Figure 1 shows how the total market capital of the resource companies listed in the top 150 companies of the ASX tracks against the All Ordinaries Index. During the last 18 months it is clear that resource stocks have out performed the AO Index. This is in spite of Newmont, which had a market capital of $4.5 billion in September 2004, transferring its stock to the New York Stock Exchange. In fact, apart from the 9/11 blip, the resource stocks have done very well since 2000.

One interesting change in the five year period is that the cut-off for the 150 top companies has risen from about $550M to $1billion. Everything has grown!

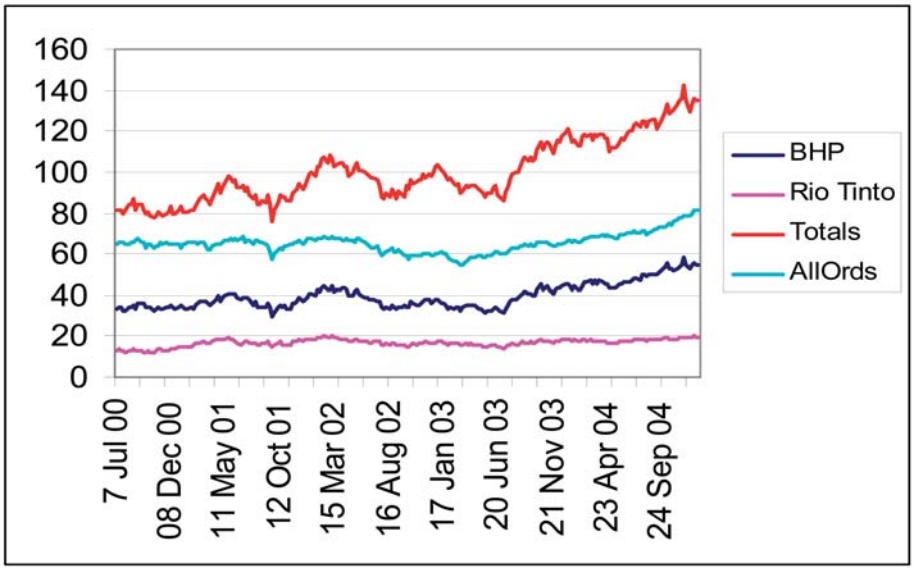

*Fig.1. Total market capitalisation, in $billion, of resource companies listed in the top 150 of the ASX (top graph); All Ords Index *20 for the same period (2nd graph), and the two largest companies, BHP-Billiton and Rio Tinto (lower two graphs).*

Concern over future oil supplies

At the start of 2005, the Association for the Study of Peak Oil and Gas (ASPO) has put a real dampener on the prospects for future petroleum supplies.

ASPO comprises a group of European institutions and universities formed "to determine the date and impact of the peak and decline of the world's production of oil and gas, due to resource constraints". In their January 2005 Newsletter (http://www.peakoil.net/Newsletter/NL49/newsletter49.pdf) this group estimated that the peak would come in at 2008. Figure 2 shows the main results of their study.

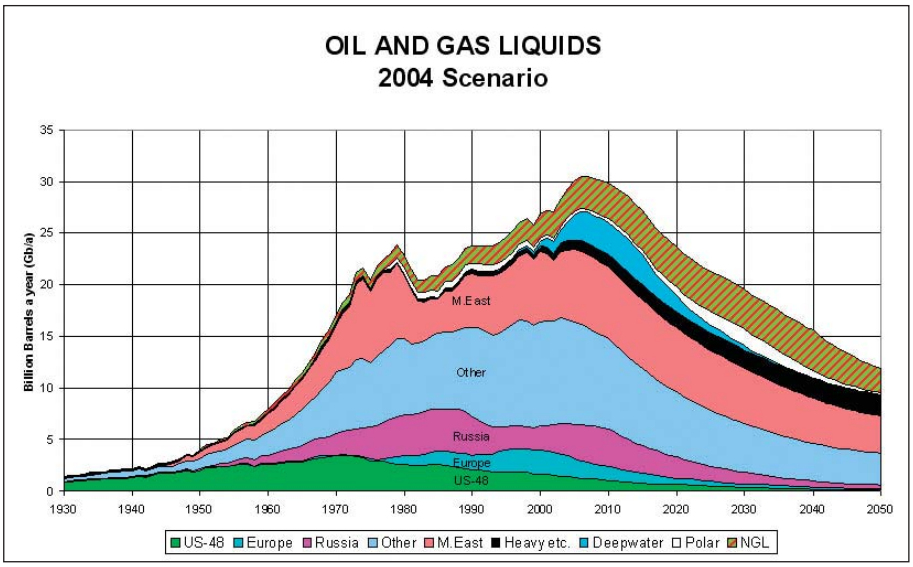

Fig.2. Global oil and gas resources, 1930-2050. Note how US production has already peaked in about 1970.

Of course, this result was predicted long ago by King Hubbert, but is seems that more notice will have to be taken of the situation now. The main problem is that oil and gas are being burnt much faster than new resources are being discovered. Figure 3 shows the growing gap.

The world now uses about 82M barrels a day, so it is a big ask to find replacement sources. Even if new fields with the capacity to produce ~100,000 barrels a day

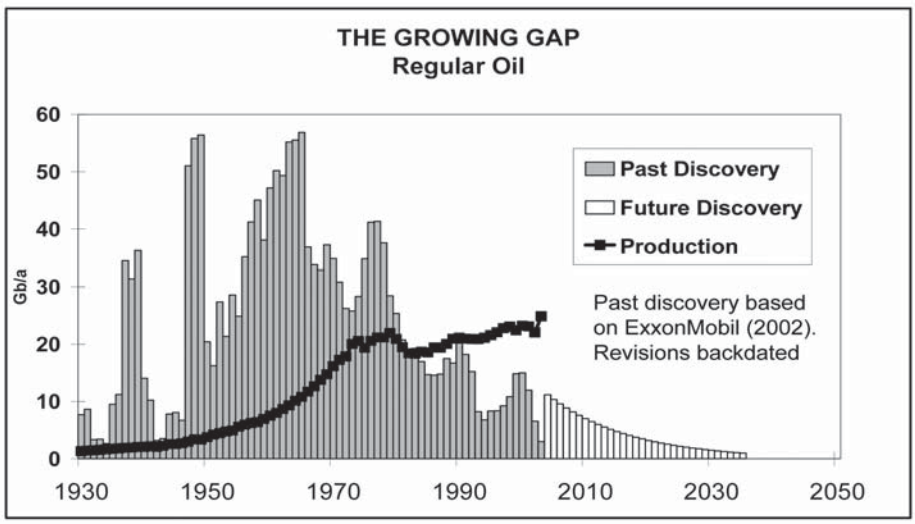

Fig. 3. Growing gap between production and discovery of oil and gas.

are discovered, they are really very small in the global context. The world's largest field, Ghawar in Saudi Arabia, is currently producing almost 5M barrels a day, but this was discovered way back in 1948 and its future is somewhat uncertain.

To put these numbers into perspective, it is worth noting that many of the wells in the Cooper/Eromanga Basins only produce ~500 barrels a day.

Scary stuff.

WMC announces 30% resource upgrade at Olympic Dam

In the midst of a takeover war with Xtrata, WMC Resources announced a 30% increase in its resource estimates for Olympic Dam at 31 October 2004. Total mineral resources there are now estimated to be 3.81 billion tonnes up from the 2.95 billion tones estimate made in 2003.

These results were based on an analysis of 113 deep holes around the southern end of the orebody. Of these, 97 deep holes hit mineralisation, with the best (RD1399) intersecting, 458 m of 1.2% Cu, 0.5 kg/t U_3O_8, 0.6 g/t Au and 1.4 g/t Ag.

The overall grades have been re-estimated as 1.1% Cu, 0.4kg/t U_3O_8 and 0.5 g/t gold. These translate into 41.9Mt, Cu; 1.52Mt, U_3O_8 and 1900 t, Au.

This resource upgrade was based on the following price assumptions: uranium at A$30/lb, gold at $500/ounce and Cu at $1.42/pound.

Already the largest known uranium resource, Olympic Dam now contains 38% of the total global economic uranium resource base, up from 33%.

The announcement of the upgrade came several days after Xstrata made a $6.35 a share offer for WMC. This resulted in WMC shares rising from $4.99 at the end of October to $7.26 a month later in November 2004. Since then the share price has plateaued and at the time of writing (15/1) was still close to this value, at $7.21 a share.

The future is uncertain with BHP Billiton, Rio Tinto, Anglo American and of course the Treasurer, Peter Costello all reported as showing a keen interest in proceedings.

ABARE forecasts commodity exports to reach $95 billion in 2004-05

In a media release of 13 December, ABARE has forecast that earnings from Australia's commodity exports will increase by 15 per cent to a record of $95 billion in 2004-05.

"This forecast increase mainly reflects higher minerals and energy prices on world markets and increased export shipments in response to global economic growth," Dr Fisher said.

"The value of Australia's minerals and energy exports is forecast to be $65.1 billion in 2004-05, a rise of 23 per cent from $53.0 billion in 2003-04.

Dr Fisher noted that export earnings from coal are forecast to increase by 48 per cent to $16.1 billion in 2004-05. Reflecting higher world prices, the value of crude oil exports is expected to increase by 34 per cent to $6.8 billion in 2004-05. For base metal (copper, lead and zinc), export earnings are forecast to reach a total of around $5.1 billion in the year, a rise of 23 per cent from last year.

Unit returns for energy exports are forecast to increase by 33 per cent in 2004-05, after a decline of 11 per cent in 2003-04. World oil prices are forecast to average around US$41 a barrel for West Texas Intermediate crude in 2005, compared with an estimated average of US$42 a barrel in 2004. Unit export returns for metallic minerals and metals are forecast to rise by 15 per cent in 2004-05, following a fall of 2.0 per cent in 2003-04.

Earnings from farm exports are forecast to be $26.8 billion in 2004-05, an increase of 2.6 per cent from $26.1 billion in 2003-04. Crop exports are forecast to rise by 3.0 per cent to $13.7 billion and livestock product exports to increase by 2.1 per cent to $13.0 billion in 2004-05."

It is interesting that, in spite of these good numbers, the Trade Deficit continues to get worse.

Drilling Begins at Paralana for hot rocks

Hot rocks are in the news again with the start of drilling at Petratherm Ltd's first geothermal evaluation well, Paralana 1 in the far north of South Australia. This well will be used to evaluate the hot rock potential of the Paralana Plains Area east of the Mount Painter Ranges where exceptionally high heat producing granites are known to occur.

CEO of Petratherm Peter Reid said: "Recently acquired down hole temperature readings from shallow mineral exploration drill holes (170m to 200m) in the adjacent area indicate a highly elevated temperature gradient in the shallow sedimentary sequence. This is encouraging for the prospect of finding elevated subsurface temperatures in Paralana 1.

Cont'd on page 39

AGC proposes research directions for mineral exploration in CSIRO

The Australian Geoscience Council (AGC) has been asked to provide input to CSIRO, for the current review of research directions being carried out in the Exploration and Mining Division.

CSIRO is the leading research agency in Australia it is important that its research programs are focused on high priority activities.

The challenge is to discover, extract and process mineral resources so that Australia can maintain and improve its global position as an attractive place to explore and invest in new resources. In recent years it has been harder to find world class deposits, particularly in Australia where the easy-to-find targets have already been discovered.

The AGC has identified four main research directions. These are listed below together with the collaborating publicly funded agencies. Members are invited to consider these proposals, and of course, to suggest improvements.

Mike Smith (President of the AGC) would welcome feedback via:
mike_rpgeo@optusnet.com.au

Research Direction	Collaborating agencies	Suggested CSIRO areas for research
Provide tools for efficient processing of geoscience information	GA & State and Territory Geol. Surveys	Develop better ways to use the data sets that are now available, through better software. In other words ***more effective system integration***.
Develop new concepts of ore-body formation, and predictive modelling of ore distributions	GA, CRCs & Universities	Research into ore formation and ore body models. Develop models that ***improve the search for attractive prospects.***
Develop new and better techniques to hunt for resources, particularly at greater depth, thereby restoring Australia's very high rating as a preferred destination for mineral exploration investment.	CRCs	More powerful or more sensitive methods to '***see through' the cover***. Development of ***cheaper and more efficient methods for drilling*** as this essential activity is the greatest single cost of exploration. ***Better interpretation techniques*** to distinguish potential ore from other geological features. Aid interpretation by establishing a better handle on the ***physical properties of rocks and ore mineral assemblages***. This will also aid the development of more sophisticated in-hole logging systems.
Develop new ways to extract and process resources, so that more ore bodies can be economically exploited.	CRCs	***Improve extraction processes*** to make them more efficient with negligible environmental impact (producing waste streams which are either useful or benign).

Cont'd from page 38

Paralana 1 will be drilled through the artesian aquifer which is estimated to be located at 500 m, and into underlying rock sequence. A total depth of around 600m is projected for the first phase of drilling of Paralana 1.

On completion the hole will be cased and projections of the temperature gradient will be made to the target depth of around 3.5 km."

We will watch with interest.

Nexans introduces Seismic Cables

In response to increased exploration investment in Australia, Nexans Australia has added Seismic cables to its range of services/ products. Nexans is a multinational company specialising in cables and cabling systems. It was formed in 2000 (Formerly Alcatel Cables) and has offices in 41 countries and five continents with the group headquarters situated in Paris. Its annual sales amount to ~€4 billion and it employs some 17,000 people.

In a world of hi-tech facilities, cables are now an essential part of modern life. Nexans is cabling the 555-seater A380 Airbus, the Transrapid magnetic levitation train in Shanghai, and has cabled the Petronas Towers in Malaysia and Daydream Island in Australia.

So it is not surprising that it is aiming to expand its activities in the geosciences where lightweight reliable cables are essential in many parts of exploration activities.

It currently has projects with Velseis and Tyco/Greenspan and is looking to increase its activity in this area, and also with offshore, umbilical, submarine, petrochemical and specialised sensor & instrumentation cables.

For more information, contact
Chris Armstrong at:
chris.armstrong@nexans.com.

Petrophysics: Theory and Practice of Measuring Reservoir Rock and Fluid Transport Properties

D.Tiab and E.C. Donaldson
Gulf Professional Publishing an imprint of Elsevier pp. 850
ISBN: 07506771 12
Price: $AUD 205

"Petrophysics is the study of rock properties and their interactions with fluids." Herein lies the essence of this book. The aim of which is to provide the reader with a basic understanding of the physical properties of porous rocks and the interactions with fluids filling the pores. Despite an author dedication that includes "Last but not least, to my ex-wives: brainy Teresa, beautiful Twylah, and Salima for giving me the best years of their lives", this book can be taken very seriously.

The book is well structured taking the reader through various levels of knowledge and techniques starting with Geology 101 in the first chapter. Even the second chapter would not hold much mystery to experienced petroleum geoscientists but rock and fluid properties get introduced at first principles.

Subsequent chapters lead on to the essential aspects of porous rock properties including:

- Porosity and permeability (Chapter 3),
- Formation resistivity and water saturation (Chapter 4),
- Capillary pressure (Chapter 5),
- Wettability (Chapter 6),
- Applications of Darcy's Law (Chapter 7),
- Naturally fractured reservoirs (Chapter 8),
- Effect of stress on reservoir rock properties (Chapter 9), and,
- Fluid-rock interactions (Chapter 10).

The porosity and permeability chapter runs for 116 pages alone. Besides dealing with the basic concepts of these two extremely important properties, the chapter also introduces the important concepts of flow units and reservoir heterogeneity.

The following chapter starts to look at the formation fluids and their properties. The formulae become more complex here but again they are well demonstrated with useful and relevant examples. Capillary pressure leads onto a discussion of water saturation and the determination of the free water level; not just hydrocarbon-water contacts.

One of the better known physical laws for fluid motion is Darcy's Law. Rocks by their very nature do not allow for simple straight flow paths but the permeability of a rock is an important property to determine as relates directly to the hydrocarbon producibility. The formulae in this chapter are more complex, as the authors attempt to mathematically describe flow through real rocks. Altered zones around boreholes also get treatment in this chapter.

Fracture porosity gets a chapter of its own with a detailed description of fracture types.

The following chapter on stress should appeal to drilling engineers if they want to avoid drilling expensive wells due to hole instability. The production of hydrocarbons also produces near-bore stress and strain changes that need to be taken into consideration when designing production programs.

The fluid-rock interaction chapter primarily deals with rock alteration or damage associated with field operations; there is unlikely to be any operation that does not in some way affect the rock properties. Any damage is likely to reduce the near-bore permeability thus affecting production rates. This zone of reduced permeability is referred to as the 'skin' and it is important to be able to reduce this effect. Other formation damage concepts are also dealt with.

In all of this there are many formulae shown but this daunting prospect is very well balanced by many realistic worked examples. The text is liberally illustrated with schematics, graphs and the occasional photograph, all of which are designed to explain the text. Each chapter contains a very extensive reference list.

In the Appendices a series of nineteen experiments are outlined illustrating the procedures to determine the physical rock properties. Some examples include the determination of surface tension, viscosity, permeability and porosity plus other properties that are essential for the petroleum industry to do its work properly.

It is very difficult to adequately review this book in such a short space. It is so full of useful information to help professionals better understand their rocks and the fluids in them. The chapters cover the important subjects and the content is well designed to assist in solving problems. You would have to be a hard reader to satisfy if there was not something of use within this book that could make a positive difference to your work.

This book is highly recommended for professionals in the upstream petroleum industry who have a need for a comprehensive reference on petrophysics. It sticks very closely to the definition in its title. At a cost of $205, this book is not likely to be on everyone's shelves although it deserves to be. It will certainly form an important reference in company and organisation libraries.

This book, however, should come with a safety warning – at more than 850 pages one would not want to drop it on one's foot.

I wonder if later editions will come with dedications to even more wives!

Copies can be purchased directly from Elsevier Australia Customer Service on Tel. 1800 263 951, fax (02) 9517 2249 or email service@elsevier.com.au