Preview

Australian Society of Exploration Geophysicists

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BHP Develops World's First Airborne Gravity Gradiometer for Mineral Exploration

see page 26

ASEG 2001 Conference Call for papers - see insert

Advances in Seismic Acquisition 1990-2000

see page 23

Seismic Focus

Contents

Advertiser's Index

2000 Corporate Plus Members

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Velseis Pty Ltd

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Anglo America Technical Services - AATS
Ashton Mining (WA) Pty Ltd
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Cover pictures:

'Veritas Viking' courtesy of Veritas DGC

and

'Airborne Gravity Gradiometer' courtesy of BHP.

This issue of Preview features the first of a series of three articles, contributed by staff from Veritas, reviewing the main advances in the acquisition, processing and interpretation of seismic data. The first, on data acquisition, is by Stuart Denny and I hope you find this and the two to follow of interest and value. We also have, a very topical article by Mark Dransfield on the airborne gradiometer being used by BHP Minerals Technology.

Airborne gravimetry carried out at the required accuracies has been somewhat of a holy grail in the last few years and the results shown by Mark indicate a very promising development, not just for regional studies. It is good to see such frontier work reported first in Preview.

We also have the abstracts of recent theses completed at Curtin University. The mainstream research of the future frequently originates from PhD studies, and the work described in this edition of Preview provides a flavour of what we may be in store for in the context of future research directions.

I invite other universities to send in their abstracts of geophysical theses so that we can all appreciate the main outcomes of contemporary research in exploration geophysics.

Earlier this month, with my FASTS hat on, I visited Warren Entsch MP Parliamentary Secretary in the Department of Industry Science and Resources, along with Sonia Cousins GSA, Mike Smith ASEG and Toss Gascoigne, CEO of FASTS. The purpose of the meeting was to express our concern for the future of the onshore resource industries in Australia.

It seems to many of us that the intellectual capital needed to underpin these industries is being degraded, and that the Federal Government is well placed to act and correct the situation.

We also raised the specific problems associated with:

- sustaining AGSO funding for onshore work,
- cuts in the CRC program,
- loss of geoscience expertise due to downsizing and,
- geoscience education and tourism.

As a result of these discussions, Mr Entsch issued a formal invitation to FASTS/AGC geoscience representatives to prepare a raft of proposals for consideration by his office in the context of the 2001/2002 Federal Budget.

He particularly requested input on AGSO's future programs and where they could make a significant input to increase national prosperity.

We will see what happens.

David Denham

David Denham, Editor

The ASEG - Changes on the horizon

I am constantly heartened and impressed by the dedication and hard work of individuals who comprise the ASEG. The ASEG is you - the members - and it is your energy and enthusiasm that make the society function. The ASEG has now been in existence for 30 years, and has an enviable reputation for excellence in exploration geophysics, both in its publications and conferences. But the challenges that face the industry today also challenge the Society. Our membership numbers are static, and action needs to be taken to improve the Society's finances and ensure its long-term viability and continued growth. Largely, this situation mirrors that of the industry itself, and it is in these times more than ever that the ASEG needs to be proactive to meet the needs of our membership, and through it, our geophysics profession.

The ASEG has operated for many years without full-time staff or a permanent Secretariat. To save on travel costs, the Federal Executive has rotated around capital cities - Sydney, then Adelaide, Perth, Melbourne, Brisbane and back to Sydney. This procedure invariably results in a steep learning curve for each new Executive, whose members have little 'corporate memory' and spend much of the first year learning the ropes all over again. This has been exacerbated by changing secretariats, auditors and publishers.

Last year, under the leadership of President Mike Smith, the Federal Executive developed strategies to put the Society under better financial and managerial control. The ASEG Business Plan, circulated to the State Branches for comment and presented at the ASEG General Meeting in Perth, highlights many of the changes and issues facing the Society, and the mechanisms for addressing the challenges.

The new Federal Executive will continue to address these themes during the coming year. In particular, the Executive will concentrate on several areas:

Annual Conferences

The possibility of reducing the time interval between our major conferences from 18 months to 12 has been raised at various forums during the last year, and there are good reasons for either option. Arguments against annual conferences include the possibility of reduced attendance and a lower level of financial support from the exhibitors and sponsors. Advantages of annual conferences include better continuity, more frequent updates and better networking, better functioning of committees and Council, and the possibility of joint conferences with other societies. The Conference Advisory Committee has been asked to assess the viability of an annual conference and make recommendations to the Federal Executive. In addition to the technical importance that is associated with ASEG conferences, they are also a major source of income for the Society.

Expanded Committees

The ASEG's most active committee is the Publications Committee, under the chairmanship of Andrew Mutton (the recipient of last year's ASEG Silver Medal). The effectiveness of this active committee is crucial to the well-being of the Society, and through its new initiatives the publications of the Society (see below) are on a much better technical and financial footing. The newest committees are the Internet Committee, chaired by David Howard, which is working to assist the Society to improve electronic communication and services to our members and the outside world, and the Revenue Committee, chaired by Steve Webster, which is overseeing broader aspects of the Society's revenues and expenditures. In addition, I am pleased to announce the appointment of Stewart Greenhalgh as the chairman of the Education Committee and David Pratt as chairman of the Technical Standards Committee. This year will see the formalisation of roles and responsibilities of the committees, expanded functions, and the publication of annual reports of the committees and the Society.

Publications

Many changes in ASEG's publications have taken place over the last year. Our new publisher, RESolutions, is providing a new standard of professionalism to Society publications. The most obvious change is the new-look Preview, which is evolving under the editorship of David Denham to reach a wider audience with more timely information. I am also pleased to announce the appointment of Shanti Rajagopalan as ASEG's new Managing Editor - Exploration Geophysics. Shanti's duties will include overall management and editorial responsibility for all issues of Exploration Geophysics. Thanks too, to John Denham for his fine stewardship of Exploration Geophysics over the past few years. As publications represent the single largest expense of the Society, colour page charges and page limits have been introduced to control costs. RESolutions is also working with the Publications Committee to phase in electronic publications for selected purposes.

Secretariat

Dellaraine Association Management Services have been the ASEG Secretariat for 12 months under a provisional contract, which is subject to ongoing review. Our long-term goal is to build a stable, professional Secretariat capable of taking on many of the day-to-day tasks currently undertaken by the Federal Executive, which will allow the Executive to focus on longer term strategic issues. In a related exercise, the Federal Executive will investigate the appointment of a permanent conference convenor or Executive Director to oversee long-term conference planning for the Society.

Constitution and Governance

The ASEG is evolving towards a society of a truly national Federal Executive, which, rather than being dominated by any one state, is representative of the entire membership

Continued On Page 5

On behalf of all delegates who attended the 14th ASEG Conference and Exhibition, I would like to say a big thank you to the co-chairmen, Kim Frankcombe and Mike Sayers, and to the Conference Committee for their well-organised conference. The conference attracted 560 full delegates and exhibitors sponsored over 110 exhibition booths.

Members will welcome the recent endorsement by the Federal Committee of an extra volume of Exploration Geophysics in 2000. The Publications Committee has approximately 60 papers at various stages of review including many late papers from the Perth Conference. It is proposed that Issue 3 and 4 will both be up to 80 pages in length. Congratulations to Shanti Rajagopalan on her appointment for a 3-year term as Managing Editor of Exploration Geophysics.

We congratulate Northern Territory on the formation of the NT Branch. In particular, we wish Branch President, Gary Humphreys, and Branch Secretary, David Johnson, all the best in organising their first year of activities. Recently, we were approached by a member to look at the possibility of establishing an ASEG branch in New Zealand. We are also currently looking at the possibility of a long-term cooperation with the SEG Japan (SEGJ) similar to that established between the SEGJ and the Korean SEG.

As the conference issues of both Exploration Geophysics - Hobart's and Perth's production cost were respectively $137,00 and $105,000 - the Publication Committee has recommended changes to the conference volumes. The Federal Committee has now endorsed a ~400page conference issue of Exploration Geophysics to contain expanded abstracts and to be available in both hardcopy and CDROM. The expanded abstracts would follow the current SEG guidelines in being no more than three to four pages in length and authors would submit their contribution in a prescribed electronic format. To help achieve this goal, we will seek assistance from our friend Bill Barkhouse, President of the SEG and his SEG team in formulating new guidelines.

To help promote further education of our members, the Federal Committee approved a $2500 contribution for the ESSO Distinguished Lecturer to visit Australia. The Web Committee is also adding educational information on the web with links to SEG and major educational institutions.

For the calculation of GST, our Federal Treasurer is now required to report our financial transactions every three months. He will give assistance to State Treasurers to ensure we complete our legal obligations.

On behalf of the Secretariat Glen Loughley, please note his address changes on page 7 of Preview.

David Robson, Honorary Federal Secretary
robsond@minerals.nsw.gov.au

Continued From Page 4

of the Society. Our 2nd Vice President Ray Shaw, assisted by three past-presidents of the Society, chairs a new ad-hoc Constitutional Committee charged with revamping the Society's constitution and by-laws in line with modern practice. This committee will also look at the role of the states and ASEG Council in governance of the Society. The proposed new constitution will be widely circulated for member's responses and input prior to seeking formal approval.

In all, the next year will be exciting and challenging. The Federal Executive will be looking at mechanisms to strengthen and grow the Society, so that it may better serve the needs of its members now, and into the future.

B. P Spies

Brian Spies
President

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Preview is published six times per year by the Australian Society of Exploration Geophysicists and is provided free to all members and subscribers of the ASEG, which is a non-profit company formed to promote the science of exploration geophysics in Australia.

Contents

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

Material published in *Preview* aims to contain new topical advances in geophysical techniques, easy-to-read reviews of interest to our members, opinions of members, and matters of general interest to our membership.

All contributions should be submitted to the Editor via email at pdenham@atrax.net.au. We reserve the right to edit all submissions; letters must contain your name and a contact address. Editorial style for technical articles should follow the guidelines outlined in *Exploration Geophysics* and on ASEG's website www.aseg.org.au. We encourage the use of colour in *Preview* but authors will be asked in most cases to pay a page charge of $400 per page 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.

Deadlines for contributions to Preview for 2000/2001

Preview is published bi-monthly, February, April, June, August, October and December. The deadlines for submission of all material to the Editor is as follows:

Preview Issue	Text & articles	Advertisements
87 Aug 2000	15 Jul 2000	22 Jul 2000
88 Oct 2000	15 Sept 2000	22 Sept 2000
89 Dec 2000	15 Nov 2000	22 Nov 2000
90 Feb 2001	15 Jan 2001	22 Jan 2001
91 Apr 2001	15 Mar 2001	22 Mar 2001
92 Jun 2001	15 May 2001	22 May 2001
93 Aug 2001*	15 Jul 2001	22 Jul 2001

* (Conf Edition)

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 the issue date. Therefore, the advertising copy deadline for the August 2000 edition is the 22nd of July.

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Events for 2000-2002

2000

July 10-11
Yandal Belt Symposium
Regolith, geology and mineralisation of the Yandal Greenstone Belt
AIG (WA Branch), PO Box 606, West Perth WA 6872
Tel: +61 8 9226 3997

August 6-11
Society of Exploration Geophysicists, International Exposition & 70th Annual Meeting, Calgary, Canada
Website: http://www.seg.org

September 19-22
Indonesian International Oil, Gas & Energy Conference & Exhibition 2000 (IIOGE)
Jakarta Convention Centre, Jakarta, Indonesia
Contact: Ramson Piter
Email: rpiter@ptrei.com
Website: http://www.ptrei.co.id

October 15-18
2000 AAPG International Conference & Exhibition
(joint meeting between AAPG & Indonesian Petroleum Association)
Bali, Indonesia
Theme: 'Energy for the new Millennium"
Contact: AAPG Convention Department
Tel: 918 560 2679
Fax: 918 560 2679
Email: convene@aapg.org
Website: http://www.aapg.org
or at IPA Secretariat
Tel: +62 21 527 3663
Fax: 62 21 520 7672
Email: ipa@cbn.net.id
Website: http://www.ipa.or.id

December 15-19
American Geophysical Union, 2000 Fall Meeting,
San Francisco, California, US.
Website: http://www.agu.org

2001

May 29-June 3
American Geophysical Union, 2001 Spring Meeting,
Boston, Mass., USA
Website: http://www.agu.org

June 11-15
63rd EAGE Conference & Technical Exhibition, Amsterdam, The Netherlands
Website: http://www.eage.nl

August 5-8
Australian Society of Exploration Geophysicists, 15th International Conference and Exhibition, Brisbane, Qld
Theme: '2001: A Geophysical Odyssey'
Website: http://www.aseg.org.au
Event Manager: Jacki Mole
Tel: +61 7 3858 5579 Email: aseg2001@aseg.org.au

September 9-14
SEG International Exposition & 71st Annual Meeting, San Antonio, Texas, USA
Website: http://www.seg.org

September 24-28
4th International Archaean Symposium
University of Western Australia, Perth
Convenor: Susan Ho
Tel: +61 8 9332 7350
Email: susanho@geol.uwa.edu.au

2002

May 27-30
64th EAGE Conference & Technical & Exhibition
Florence, Italy. Website: http://www.eage.nl

Sep 22-27
SEG International Exposition & 72nd Annual Meeting
Las Vegas, Nevada, USA. Website: http://www.seg.org

New South Wales - by Alan Willmore

In April the NSW Branch held it's AGM as a joint meeting with the Federal Executive. Presentations of the ASEG Silver Certificate were made to Graham Butt, Derecke Palmer and Phillip Schmidt for 25 years membership of the Society. After the AGM Dr Ken McCracken gave an interesting presentation of his views on "Science and Geophysics in the next 10 years". Ken's ideas on "high octane" geophysical methods provided keen interest from the audience, with more than ten questions being fielded on the topic.

The 2000-2001 NSW Branch Committee of Steve Webster (President), Phil Schmidt (Treasurer) and Alan Willmore (Secretary) convened its first meeting on 17th May. A good attendance of members heard Phil Schmidt outline the principles of magnetic petrophysics, explain how they can be used to unravel geological information and cite several case histories to illustrate application in the field.

The new Committee is yet to finalise a program of events for the year, however, a mid-year dinner is under consideration and a joint meeting with SMEDG is being planned for late July.

South Australia - by Michael Hatch

Somehow or other we have missed out on a few sets of Branch News here in SA, so will try to make some of it up right now. Fortunately nothing too major has happened so far this year, but we have quite a lot to look forward to. First things first.

The AGM was our first event of the year and was held on the 8th of March. We had our usual turnout of diehards (and those of us lucky enough not to be in the field at the time). A good night was had by all, and we even managed to shuffle a few executive positions around, and add a few new names to the committee. Our new president is Richard Hillis, and our new treasurer is Mark Tingay. The rest of the committee is made up of: Alan Appleton, Andrew Davids, Andrew Shearer (still our faithful secretary), Anna Dutkiewicz, Anthony Goodall, Glen McFadzean, Graham Heinson, Mike Hatch, Suzanne Roberts, Rod Lovibond, and Stephen Tomlin.

Our first talk of the year (sponsored by Petrosys) was on the 2nd of May, and featured Alistair R. Brown, of Dallas, Texas. His talk was titled *Let the Data Speak to You: How to improve your 3-D Seismic Interpretation.* This meeting was very well attended, and quite interesting.

Our second talk of the year will be given by Michael Schoenberg, ex of Schlumberger who is currently a visiting scientist at CSIRO. His talk is titled: *The 4-Component Ocean Bottom Seismometer/Hydrophone: How to Analyze Data Recorded by a Single Instrument*, and will discuss the use of a number of single receiver systems each connected to individual multicomponent arrays in order to optimise data recording in underwater seismic surveys. This talk will be sponsored by the CSIRO. Additionally, at this meeting we will be presenting this year's Silver Certificate winners from South Australia with their awards (see photo).

June looks to be a busy month here with two talks planned. On the 20th Richard Jones and Scott Mildren of the local NCPGG will be giving a talk titled: *Faults: Sealing or Non-Sealing?*. Then on the 22nd we will be kicking off the first talk in the "Millennium Series". The Millennium Series is a cross-society collaborative series of five talks (say that three times fast) given by prominent leaders in industry working for companies either in or related to the resources industries in Adelaide. This first talk will be given by Ian Lilly, Marketing Manager for Silicon Graphics, whose talk is titled *Computing in the New Millennium: Where are we headed?*. While only one of the five talks will be hosted by the local ASEG (this one will be hosted by AusIMM), we are very excited about this series and strongly encourage everyone to attend.

Silver Certificate winners from SA are from left to right: Chris Anderson, Ian Edwards, and Chris Porter.

Then on the 18th of July Craig Beasly will be coming to town and giving a talk titled *The Role of Geophysics in the Oilfield of the Future.* This will be a joint PESA/ASEG talk. More details on that later.

Much to look forward to here in SA over the next few months. See you all at the meetings.

Northern Territory - by Richard Brescianini

ASEG members based in the Northern Territory are pleased to announce the formation of the NT Branch of the Society.

The inaugural meeting was held in The Waterhole Bar of the Darwin Central Hotel on May 5th. Almost half of the membership was in attendance for this auspicious occasion. The following members were elected as office bearers:

President - Gary Humphreys (NT Department of Lands, Planning and Environment)
Secretary - Dave Johnson (Rio Tinto Exploration)
Treasurer - Jon Sumner (Stellar Exploration)

By default the remaining members, numbering a staggering 11, will make up the committee.

The first guest speaker of the NT Branch, scheduled for mid-June, will be Vern Wilson.

Victoria - by Trudi Hoogenboom

On May 23rd, David H Moore & Bruce A Simons spoke on: *Victoria revealed: stripping off the cover to show the basement features.*

The dates and speakers for the next couple of months are not quite finalised but the program will probably look like this:

June: Annual Dinner

July: Joint PESA meeting with Dr Craig Beasley, ESSO distinguished lecturer.

August: Bill Matthews, on topic to be announced.

October: Student night with Ashley Grant speaking on: *Downhole EM processing of Pasminco Pakistan data* and Julie Elders on *Geophysics/environmental concerns of wasterock acid mine leakage.*

November: Xmas Party

Meetings are usually held at the Kelvin Club, Melbourne, on the 3rd Tuesday of every month.

Queensland - by Kathlene Oliver

At the end of April the Queensland Branch held its Annual General Meeting. All nominations were unanimously acceptable with the following office bearers elected:

President - Troy Peters, Velseis Processing
Secretary - Kathlene Oliver, Veritas DGC Asia Pacific Ltd
Treasurer - Grant Asser, Oil Company of Australia

Committee Members -
Fiona Duncan, Velseis Processing
Gary Fallon, MIM Exploration
Mike Sharry, North Ltd
Natasha Hendrick, University of Queensland

The meeting was followed by a technical presentation by Ritchie Huber of the Department of Minerals and Energy, Queensland. Entitled *Prospectivity Plus - Prosperity From Information* the presentation focused on Government initiatives for exploration in both the minerals and petroleum sector.

With the fallout of papers from the Perth conference, the technical schedule for upcoming meetings is promising. In addition PESA and the ASEG QLD Branch are conducting a joint meeting in July. Dr Craig Beasley from Western Geophysical will be presenting his lecture *Geophysical Technology for the New Millennium*

The Queensland Branch has moved into full swing preparing for the Australian Society of Exploration Geophysicists' 15th Conference and Exhibition, which will be held in Brisbane during August 2001, at the Brisbane Convention and Exhibition Centre. Details of the conference and the organising committees can be found on the Queensland web page.

ASEG's Student Day

A Geophysics Information Day for upper school students was held on Tuesday 14th March 2000 during the ASEG conference. The aim of the day was to introduce students with an interest in physics, mathematics and/or geology to the wonderful world of geophysics, and to promote geophysics as a career option. Over 150 students and teachers attended.

John Mignone, the Education and Community Liaison Services Coordinator from PIRSA kicked off the day with an introduction to geophysics entitled 'Geophysics-Forensic for the Earth'. This was followed by demonstrations of the physics of minerals by Dr Charter Mathison from University of Western Australia - even the lighting technician was impressed!

We also managed to persuade Richard George from the Department of Agriculture to leave the special environmental session at the conference and present a quick insight into how geoscientists are contributing to the fight against Western Australia's salinity problem.

Following soft drinks and chips, the heavies of the industry geophysicists emerged -Audrey Leonard (Woodside Petroleum), Mike Smith (Geo Instruments), Tim Pippett (Alpha Geoscience) and the rock'n'roll presentation of Nick Sheard (MIM Exploration). What a lineup!! Everyone left convinced that Nick Sheard is paid to go camping, attend rugby finals in Wales, have tequila-drinking competitions and do it all to loud 70's & 80's music!!

Thanks go to all the speakers for contributing their time and enthusiasm.

A special effort was made this year to provide a good range of resource material for the teachers and students. Eye-catching green and gold backpacks were given out filled with an extensive range of CD-ROMs, videos, mineral identification kits, lists of websites, as well as other brochures. These ensured that we were on side right from the start of the day!!

To assist the teachers in utilising the resources provided to them, we ran a separate workshop for them during the morning. John Mignone ran another excellent session showing off his 'Resources - Working for the Right Balance' kit. Other speakers included Susan Ho, organiser of the Australian Student Mineral Venture scheme, and Georgina Edmondson who runs the WA Petroleum Club's Schools Information Program for APPEA.

After lunch we let the students loose in the trade exhibition at the Burswood Superdome, with each small group accompanied by a geophysicist. An hour was spent wandering around the exhibitions looking at the technologies available, collecting any (and as many) freebies and making regular stops at the ice-cream bars! Thanks to the willing guides who turned up and to the other people who were roped in as last minute 'volunteers'! Also thanks to the exhibitors who made a special effort to demonstrate things of interest to the students.

We received very positive feedback from the teachers, both from an interest point of view and relevance as career guidance. We may have even managed to convince a few students that geophysics is a worthy career path! Excess resource material and backpacks are being distributed to schools that were unable to attend.

Year 12 student David Goode from Morley High School, wearing a back pack GPS antenna, discusses the use of a portable conductivity meter with 1999-2000 ASEG President Mike Smith, during Students Day at the Perth Conference and Exhibition.

Thanks also to Dominic Howman from Curtin University for being co-organiser and getting 300 backpacks packed with all the resource material, and to Promaco Conventions for their assistance. Finally the day would not have been possible without the sponsorship of the following companies: Anglo American, Apache Energy, Ashton Mining, BHP Petroleum, Chevron Australia Pty Ltd, ExxonMobil, Fugro Airborne Surveys, Homestake Gold of Australia, Normandy Exploration, Faculty of Science - University of Western Australia and Woodside Energy Ltd.

Helen Anderson

More Awards From the Perth Conference

The list below contains the awards for the Perth Conference that were not published in Preview 85, congratulations to all the winners.

Best Exhibit:
Veritas DGC Inc.

Best Referee:
Helen Anderson

Referee Honourable Mentions:
N. Stoltz, A. Long and S. Greenhalgh

Best Published Paper:
- 'Current channelling in time-domain airborne electro-magnetic data' by J. Reid and J. MacNae.

Carl Davis from Veritas DGC's corporate headquarters receiving the 'Best Exhibit' award from Mike Smith ASEG's immediate Past President

Published Paper Honourable Mentions:
- 'The determination and application of vector gravity anomalies' by W. Featherstone, M. Dentith and J. Kirby.
- 'Acoustic wave velocity modelling in sedimentary sequences' by M. Wiltshire and Leslie Huggard.
- 'Travel-time computations for true-amplitude migration of constant-offset seismic data' by J. Gazdag.

Best Poster:

- 'Geophysical signatures of porphyry copper mineralisation in Victoria' by S. Rajagopalan and S. Haydon.

Poster Honourable Mentions:

- '3D fluid flow tomography' by J. McKenna, D. Sherlock, and B. Evans.
- 'A new multi-frequency AEM system for ground TEM' by R. Henderson and Z. Beldi.
- 'Practical Overview of HEM data processing' by N. Valleau.

Best Petroleum Geophysics Paper:

- 'Magnetic signatures produced by fluid flow in porous sediments' by M. Middleton, D. Winkler, M. Bick and T. Sahlin.

Best Petroleum Geophysics Paper Honourable Mentions:

- 'Calibrated wide angle 3D AVO processing for improved lithology classification', A. Strudley, T. Brice, and S. B. Reymond.
- 'Interactive seismic event recognition and its applications' by M. Li, and I. Mason.
- 'Reducing resource uncertainty using seismic amplitude analysis in the Southern Rankin Trend, North-West Australia' by M. McLerie, F. Herkenhoff, D. Criddle, J. Schrull and L. Clegg.
- 'A D I plus interpolation - accurate finite-difference solution of 3D wave - equation migration' by Y. Wang.
- 'Acoustic compression wave performance modelling in sedimentary sequences' by M. Wiltshire and L. Huggard.

Best Mining Geophysics Paper:

- 'Interpreting crustal scale features using wavelet-based multi-scale edge analysis of regional gravity datasets' by N. J. Archibald, D. Holden, F. Boschetti, F. Horowitz and P. Hornby.

Best Mining Geophysics Paper Honourable Mentions:

- 'Towards geophysical grade estimation via automated interpretation of borehole logs' by G. N. Fallon, P. K. Fullagar and B. Zhou.
- 'Wavelet estimation of a local long memory parameter' by B. Whicher.
- 'Imaging and identification of thick electrical conductors using conductance and differential conductivity parasections of TEM data' by M. Asten.
- 'Automatic merging of gridded airborne gamma-ray spectrometric surveys' by B. Minty.

Best Groundwater Geophysics Paper:

- 'Airborne geophysics improves the diagnosis, prognosis and treatment of dryland salinity in Australian landscapes' by R. J. George.

Best Groundwater Geophysics Paper Honourable Mentions:

- 'Parna petrophysics - implications for its detection using airborne geophysics and their potential application for land management in western NSW' by T. Munday, K. Lawrie, T. Scott, C. Chartres, J. Wilford and P. Wilkes.
- 'The use of ground EM systems to accurately assess salt store and help define land management options for salinity management' by D. L. Bennett R. George and B. Whitfield.
- 'Airborne geophysical surveys to assist planning for salinity control National Airborne Geophysics Project case studies' by G. Street, G. Pracilio, R. J. George, D. Heislers and I. Gordon.

Joint Societies' Millennium Series

The professional societies involved in the resources sector in South Australia are hosting a series of milestone talks entitled the Millennium Series. The Millennium Series comprises five talks, one hosted by each of the societies, that will take stock of trends and critical issues facing our industries. Members of all the societies and visitors are invited to the Millennium Series. Bookings are required for PESA & SPE talks, and would be appreciated from members of the other societies and visitors for ASEG, AusIMM and GSA talks.

Gold Mining in the New Millennium
Bruce Kay, Group Executive - Exploration, Normandy Mining
Host: Geological Society of Australia
Date/Time: Thursday 20 July, 5:30 for 6:15pm
Venue: Mawson Lecture Theatre, Geology and Geophysics, Adelaide University
Costs: $4 members & visitors (pre-talk drinks and nibbles)
GSA Bookings: Sandra McLaren
Ph: 8303 4868
Email: smclaren@geology.adelaide.edu.au

Energy For Our Future
Andrew Stock, General Manager, Major Industry and Power, Origin Energy
Host: Australian Society of Exploration Geophysicists
Date/Time: Wednesday 9 August, 5:30 for 6:15pm
Venue: Historian Hotel, Coromandel Place, Adelaide
Cost: $5 members & visitors, $2 students (pre-talk drinks and nibbles)
ASEG Bookings: Andrew Shearer
Ph: 8463 3045
Email: Shearer.Andrew@saugov.sa.gov.au

Extinctions, Past and Future
Dr. Tim Flannery, Director, South Australian Museum
Host: Petroleum Exploration Society of Australia
Date/Time: Thursday 21 September, 12:00 for 12:30 pm
Venue: Grosvenor Hotel, North Terrace, Adelaide
Cost: $25 members, $30 visitors & $15 students (lunch)
PESA Bookings: Jodie Lindsell
Ph: 8224 7740
Email: jodie.lindsell@santos.com.au

Environmental Challenges in the New Millennium
Don Henry, Executive Director, Australian Conservation Foundation
Host: Society of Petroleum Engineers
Date/Time: Tuesday 10 October, 12:00 for 12:30 pm
Venue: Novotel Adelaide on Hindley (formerly Hindley Parkroyal), Adelaide
Cost: $25 (+GST) members, $30 (+GST) visitors, $15 (+GST) students (lunch)
SPE Bookings: Lisa Hosking
Ph: 8224 7389
Email: Lisa.Hosking@santos.com.au

This month I focus on websites of professional organisations and societies that help promote our fields of work and study to the science community and general public, as well as providing publication, education and employment services for members. All of these sites can help keep us informed and up to date with our industry, and are well worth a visit.

Remember, if you have any favourite sights you'd like to share with our members please email me, Natasha (natasha@geoph.uq.edu.au).

Australian Society of Exploration Geophysicists (ASEG) - www.aseg.org.au

ASEG is a non-profit company founded in 1970. Its aims are to promote the science of geophysics, and specifically exploration geophysics, throughout Australia; to foster fellowship and co-operation between geophysicists; to encourage closer understanding and co-operation with other earth scientists; to assist in the design and teaching of courses in geophysics, and to sponsor student sections where appropriate.

This site you should ALL be familiar with! Here you'll find highlights of articles from the most recent editions of Preview and Exploration Geophysics (EG). Visitors can also view conference abstracts from the 2000 ASEG conference, and join our on-line discussion forum. And if your contact details are not up-to-date, let us know via the website.

Canadian Society of Exploration Geophysicists (CSEG) - www.cseg.org

The mandate of the Canadian Society of Exploration Geophysicists is to promote the science of geophysics, especially as it applies to exploration, and to promote fellowship and co-operation among those persons interested in geophysical prospecting.

The website provides an archive of abstracts from recent technical presentations, as well as access to an on-line corporate directory. The CSEG also has an informative on-line brochure introducing careers in geophysics.

Society of Exploration Geophysicists of Japan (SEGJ) - wwwsoc.nacsis.ac.jp/segj/index_e.html

The Society of Exploration Geophysicists of Japan was established in 1948 with the objectives to promote the science and technology of geophysical and geochemical exploration, as well as to encourage mutual communication among the members.

This site (in English!) provides an overview of the status of geophysical activities in Japan, gives details of the 2001 International Symposium on Imaging Technology (which is co-sponsored by many geophysical societies including ASEG), and provides a comprehensive list of Japanese and international professional organisations, institutions, universities and companies.

Society of Exploration Geophyscists (SEG) - www.seg.org

The Society of Exploration Geophysicists promotes the science of geophysics and the education of exploration geophysicists. The Society fosters the expert and ethical practice of geophysics in the exploration and develop- ment of natural resources, in characterising the near-surface, and in mitigating earth hazards.

Natasha Hendrick

The website provides visitors the opportunity to purchase SEG publications from the on-line book mart, and download abstracts from upcoming SEG meetings. The site also lists international geophysical consortia and promotes member services including continuing education courses and employment opportunities.

New Zealand Geophysical Society - www.rses.vuw.ac.nz/science.orgs/nzgs.html

The New Zealand Geophysical Society, founded in 1980, aims to encourage the advancement of geophysical sciences; to serve as a means of facilitating communication and co-operation among members, and with other bodies; and to investigate and report on matters of general interest to New Zealand geo-physicists.

This site enables access to abstracts from all volumes of the New Zealand Journal of Geology and Geophysics from 1994 to the present, as well as providing other general member services.

The Australasian Institute of Mining and Metallurgy (AusIMM) - www.ausimm.com.au

Founded in 1893, AusIMM is recognised as the principal and preferred professional society for all appropriately qualified personnel associated with the study and practice of the minerals and energy industries in Australasia.

From this website you can access the AusIMM Week in Review. Members and employers can take advantage of the new AusIMM on-line employment service. Visitors can also purchase AusIMM publications and merchandise, keep up to date with the Calendar of Events, and retrieve contact details of local AusIMM branches.

Australian Institute of Petroleum (AIP) - www.aip.com.au

Established in 1976, the Australian Institute of Petroleum has gained national and worldwide recognition as a key representative body of Australia's petroleum industry. AIP's mission is to promote and assist in the development of a strong internationally competitive Australian petroleum products industry, operating efficiently, economically and safely, and in harmony with the environment and community standards.

This site provides access to relevant media releases, and an up-to-date look at industry information, including petrol prices, environmental issues, and statistics associated with supply and demand of petroleum products. Visitors can also download a PDF file of recent AIP publications.

Continued On Page 14

Continued From Page 13

Geological Society of Australia (GSA) - www.gsa.org.au

The Geological Society of Australia was established in 1952 as a learned, non-profit organisation. The society's objectives are to promote, advance and support the earth sciences within the scientific and wider communities.

Information on local technical meetings is available, in addition to details on relevant Australian and Overseas conferences and events. GSA also runs and employment service, and has a page dedicated to geoscience education including a list of universities providing honours and postgraduate training in Australia.

Petroleum Exploration Society of Australia (PESA) - www.pesa.com.au

This site is still under construction, but it promises to be useful with the ability for visitors to submit and search for PESA News and Journal articles, links provided for relevant Australian Government Departments, and results from PESA surveys posted. Keep it in mind for the near future.

Environmental and Engineering Geophysical Society (EEGS) - www.eegs.org

The Environmental and Engineering Geophysical Society is a professional non-profit society chartered in 1992. It's goal is to promote the science of geophysics especially as it is applied to environmental and engineering problems; to foster common scientific interests of geophysicists and their colleagues in other related sciences and engineering; to maintain a high professional standing among its members; and to promote fellowship and cooperation among persons interested in the science.

Here you can browse and search for abstracts from the Journal of Environmental and Engineering Geophysics (1995-present) and the Symposium on the Application of Geophysics to Engineering and Environmental Problems (1988-present). Visitors can also preview an interactive CD-ROM introducing Applications of Geophysics in Environmental Investigations, and subscribe to the EEGS list server, aimed at promoting discussion among EEGS members.

European Association of Geoscientists and Engineers (EAGE) - www.eage.nl

Here the visitor will find notice of upcoming EAGE conferences, and other relevant events. However, no access to past or present abstracts of conference proceedings or publications is allowed. Employers can advertise positions vacant on the website. One of the more useful pieces of information on this site is the list of contact details for all associated geophysical and engineering societies in Europe (42 in total!).

The Geological Society of America (GSA) - www.geosociety.org

Established in 1888, The Geological Society of America provides access to elements that are essential to the professional growth of earth scientists at all levels of expertise and from all sectors: academic, government, business, and industry.

The website gives detailed information on activities of the Society, including meetings and conferences. This site also highlights geoscience initiatives (including educational resources), and provides information on GSA publications and employment services.

European Geophysical Society (EGS) - www.mpae.gwdg.de/EGS/EGS.html

The EGS, founded in 1971, is a dynamic, innovative and interdisciplinary learned society devoted to the promotion of the sciences of the Earth and its environment, and of planetary and space sciences; and cooperation between scientists.

This website really only provides announcements for the annual, international assemblies organised by the EGS, subscription details for the numerous EGS journals, and instructions for authors if any of you feel like publishing! If you look carefully, you'll be able to access abstracts from special issues of EGS Journals such as Nonlinear Processes in Geophysics, and Hydrology and Earth System Sciences.

Society for Sedimentary Geology (SEPM) - www.sepm.org/sepm.html

SEPM is a not-for-profit Society based in Tulsa, Okalahoma. SEPM, through its network of international members, is dedicated to the dissemination of scientific information on sedimentology, stratigraphy, palaeontology, environmental sciences, marine geology, hydrogeology, and many additional related specialties.

This site promotes upcoming SEPM events including technical meetings for research groups covering topics ranging from carbonates and evaporites, to hydrogeology and sequence stratigraphy. Abstracts with images are also available from the Journal of Sedimentary Research and Palaios, a relatively new journal focusing on the application of palaeontology.

American Geophysical Union (AGU) - www.agu.org

AGU, a nonprofit scientific organisation, was established in 1919 by the American National Research Council. AGU's mission is: to promote the scientific study of Earth and its environment in space and to disseminate the results to the public, to promote cooperation among scientific organisations involved in geophysics and related disciplines, to initiate and participate in geophysical research programs, and to advance the various geophysical disciplines through scientific discussion, publication, and dissemination of information.

This website provides access to on-line abstracts from the three most recent issues of each AGU journal. A complete index of all AGU journals, books, and other publications back to 1988 is also available to members. Visitors can also access results from a study undertaken by the AGU on the public attitude towards geophysical research.

Regional Geophysics in the Geological Survey of Western Australia

Western Australia is fortunate in the richness and extent of its mineral and petroleum resources. It is not surprising, therefore, that the State attracts very high levels of private exploration activity and expenditure relative to those in other States of Australia and many other parts of the world.

Whereas the others are focused on attempting to increase the level of private company exploration from what, in some cases, are very low levels, the concerns of the Geological Survey of Western Australia (GSWA) are, primarily, to:

- maintain the attractiveness of Western Australia as a focus for exploration;
- attract new global resource investment companies to the State; and
- ensure that the State and the exploration industry benefits from the work that has been and is being carried out by government and in the private sector.

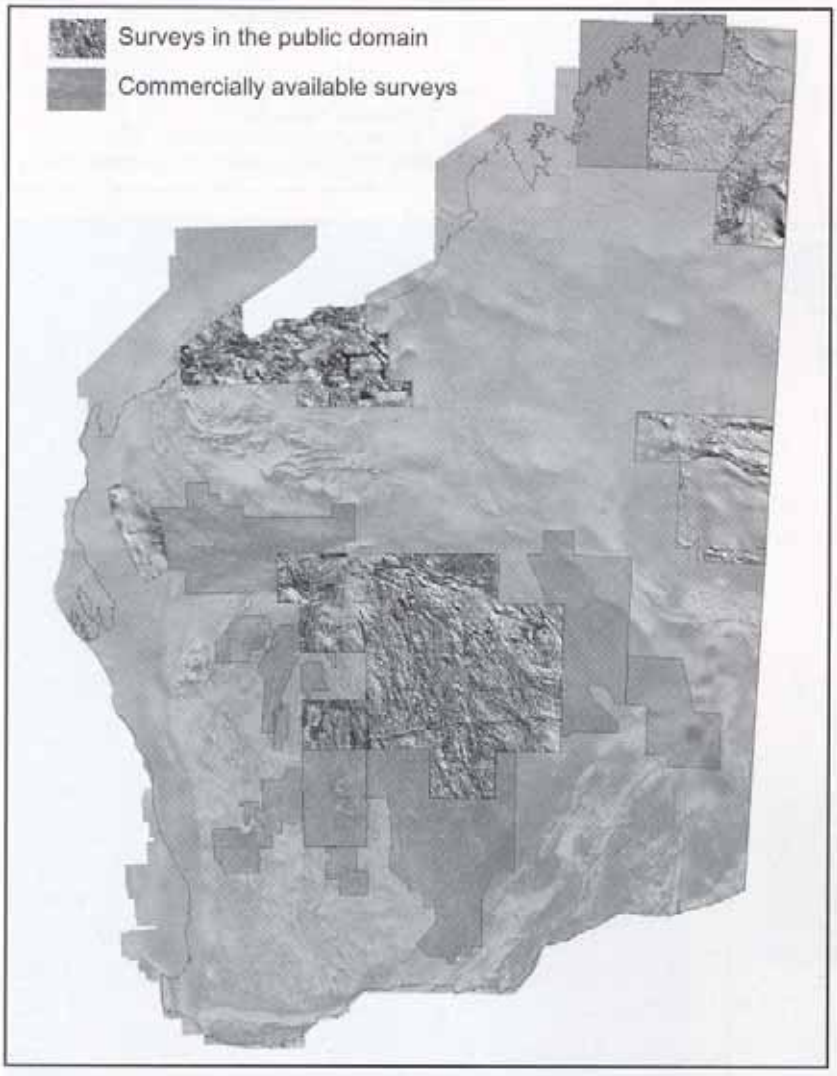

Fig. 1. Location of publicly available, moderate- to high resolution surveys in Western Australia.

It is for this reason that the regional geophysical data acquisition and distribution philosophy in the GSWA is somewhat different from those of the other Australian State Geological Surveys, although it has the same basic objectives to:

- support regional geological mapping projects;
- constrain tectonic and mineralisation models; and
- make regional geophysical data available to explorers.

Underlying philosophy

The funding for the GSWA covers a wide range of activities in a very large state. It must meet the competing, and sometimes conflicting, expectations of significant basic geoscience support from a large and diverse exploration sector that includes individual prospectors, service providers, and large corporations.

The philosophy behind the GSWA's regional geophysics program is based on taking full advantage of industry's attraction to the State's rich endowment, and has two main thrusts:

1. encouraging and facilitating wider use of the extensive regional geophysical data sets generated by the private sector; and

2. conducting new geophysical surveys to:
   - complement industry activity in active exploration areas; and
   - provide supplementary information to increase the attractiveness of relatively under-explored areas and encourage greater interest in these areas.

The GSWA has taken an allocentric view of regional geophysics data acquisition that places less importance on GSWA ownership of data and greater importance on increasing total, publicly available coverage. Through this approach the GSWA is able to minimize the duplication of effort and maximise the value obtained from government and industry expenditure.

Mainly for reasons of cost-effectiveness, the GSWA's regional geophysical data acquisition program concentrates on airborne magnetic and radiometric surveys and, increasingly, gravity surveys. The priorities for area selection are based on balancing the demands for data from GSWA geological mapping project teams with the broader objective of obtaining improved data resolution over less well mapped areas of the State.

Close ties are maintained with the airborne geophysics and gravimetry groups at the Australian Geological Survey Organisation (AGSO), and all GSWA geophysical data are incorporated into the national databases.

Airborne geophysics

The GSWA and AGSO work together closely to ensure that State and Federal government funds directed to regional

airborne surveys are used to maximum effect so that the greatest area is covered at the lowest cost. For most recent regional surveys, a line spacing of 400 m has been selected as providing the optimum coverage- resolution balance.

With the completion of the 400 m line surveys jointly funded by AGSO and GSWA over the Rawlinson 1:250 000 Sheet area in 1998, and the Webb and Wilson Sheet areas in 1999, there is complete broadscale aeromagnetic coverage over Western Australia.

Because much of this coverage is at low resolution (800 m- 3200 m line spacing), the focus now is to increase the degree of moderate-resolution coverage (200 m- 500 m line spacing).

As mentioned, an aspect of the GSWA strategy to increase airborne geophysical coverage over the State is to encourage and facilitate the availability of private sector regional surveys, of which there are two sources:

- speculative surveys commissioned by companies (generally airborne survey contractors themselves) for non-exclusive commercial sale; and
- exclusive, exploration surveys commissioned by mineral and petroleum exploration companies.

The former are commonly described as 'multiclient' surveys and are publicly available at a price that is governed by the age of the dataset, the location, and the prevailing cost of new data acquisition. The latter, often flown outside the boundaries of the commissioning company's exploration tenements, have tended to remain confidential because, under prevailing mining legislation, the company is not obliged to submit these data to the Department of Minerals and Energy (DME) for eventual 'open file' release. (This does not apply to petroleum exploration surveys that, under the State's Petroleum Act, must be released after three years.)

Recently, however, a number of exploration companies have decided to make some of their exclusive surveys publicly accessible on a commercial basis, and many others have agreed to publicly disclose the location and specifications of their surveys. The GSWA supports this trend and has implemented an initiative, discussed below, that encourages more companies to do the same.

The GSWA and AGSO have acquired a number of these datasets (both commercial multiclient and private company exclusive) for use by their geological mapping project teams and for eventual release into the public domain.

Figure 1 shows a grayscale magnetic anomaly map of Western Australia with areas of public domain moderate-resolution coverage shown in more detail (no distinction is made between AGSO and GSWA surveys). Also shown are the outlines of some of the large commercially available surveys (many smaller surveys exist).

MAGIX and reporting of company airborne surveys

The GSWA/AGSO program of regional airborne geophysical data acquisition is being complemented by a renewed thrust to encourage greater use of the very large quantities of detailed airborne survey data that are generated by private companies as part of their exploration activities.

Under the prevailing mining legislation in Western Australia, companies are not obliged to submit data from outside their tenement boundaries to DME. As a result, because surveys often extend well beyond tenement boundaries, data submissions have tended to be highly fragmented. Quite apart from the cost to the companies of sub-sectioning datasets and the cost to the GSWA of processing multiple fragmented datasets, the value of these data fragments to the GSWA or to other explorers is minimal.

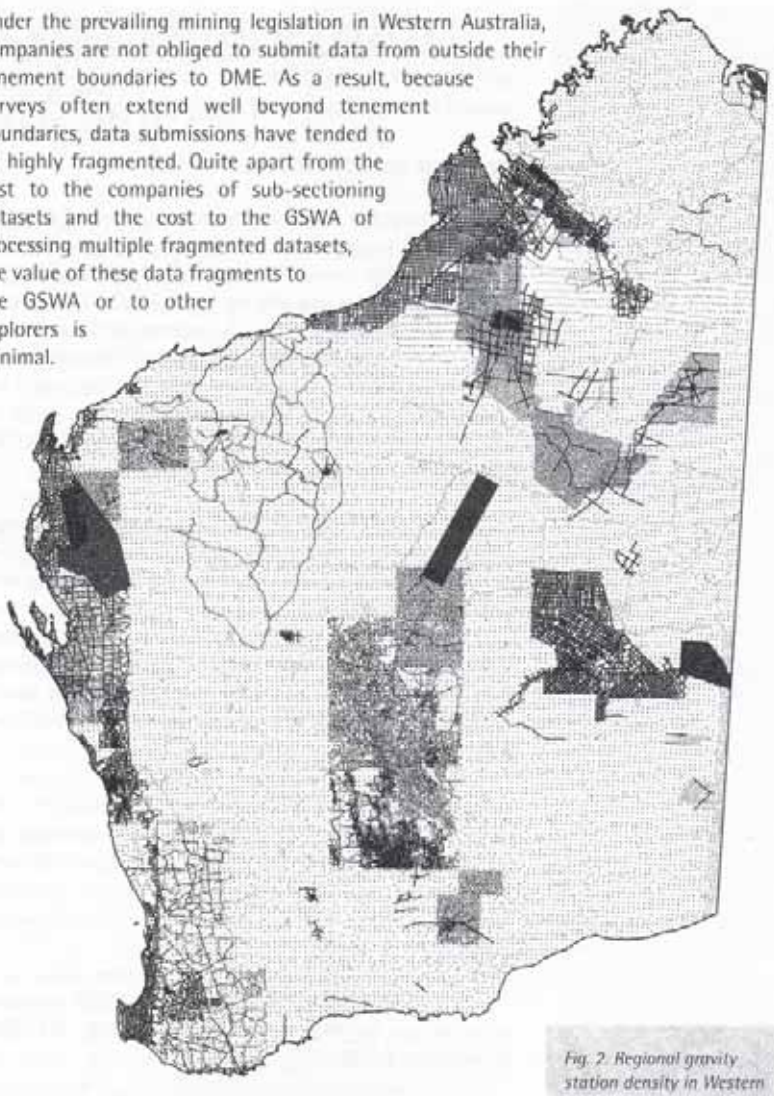

Fig. 2. Regional gravity station density in Western Australia

In 1998, the GSWA adopted a new policy for airborne survey reporting that made it more attractive for companies to submit complete survey datasets and to make these data available to others within a shorter period of time.

Under the provisions of this policy, data from any survey need only be submitted once. The data are not released to 'open file' by the GSWA if, within a period of five years, they are placed with a sales agent for unrestricted commercial sale at normal market prices.

A critical element of the policy is the MAGIX (Minerals and Energy Airborne Geophysical Information eXchange) airborne survey database and integrated GIS graphical interface. The database, which includes the location and basic specifications of airborne geophysical surveys in Western Australia, can be accessed from the DME website (see contact details below).

The success of this policy has been such that, from the situation that existed before 1998 when almost no data were submitted, almost 2 million line-km of survey data have been submitted since July 1998.

The airborne geophysics reporting policy is currently under reconsideration following a request from the Chamber of Minerals and Energy of Western Australia to review some aspects of the policy and the legislation.

Regional gravity surveys

With the resurgence of industry interest in gravity data, the GSWA has also stepped up its program of regional gravity data acquisition, complementing the work being done by AGSO to gradually upgrade the basic AGSO 11 km grid of gravity stations. Project-specific surveys, on 2 km x 3 km grids, were commissioned to support the GSWA's petroleum exploration initiative program over parts of the Savory and Officer Basins and the Merlinleigh Sub-basin in 1995-96, and in the Coolcalalaya (1996-97) and Waigen (1997-98) Sub-basins.

In 1998, a gravity data acquisition component was added to the GSWA's helicopter-assisted geochemical and regolith sampling surveys, with survey crews taking gravity readings at geochemical sampling sites on a nominal 4 km x 4 km grid. The technique has proved to be extremely cost-effective and a total of six surveys have been completed over the Wyloo, Ajana, Winning Pool, Kingston and Stanley 1:250 000 Sheet areas and an equivalent area in the Fraser Range region.

Data from all these surveys have been incorporated in the AGSO National Gravity Database. Figure 2 shows the current on-shore gravity station density in Western Australia.

Data access and pricing policy

Maps and hardcopy images of all GSWA regional geophysical datasets are available from the DME information Centre.

Digital data from wholly owned GSWA geophysical surveys have been placed with a number of data sales agents in Perth and Adelaide. Digital data from GSWA/AGSO shared airborne datasets are available from AGSO.

Current prices for airborne data are approximately 15 cents per km (equivalent to about 3% of exclusive new data acquisition cost) for GSWA data, and approximately 25 cents per km (about 5% of new data cost) for GSWA/AGSO data. The pricing policy for digital data and hardcopy products is presently under review. However, because most of the GSWA's regional geophysical datasets are also partly owned by AGSO, the pricing policy for these data involves consultation with AGSO. Open file company survey data is available on request from the GSWA's Statutory Information Reporting Group for a nominal data-copying fee.

Gridded data from all public domain (GSWA and AGSO) and open file company datasets are accessible for viewing and image processing with software provided by ER Mapper installed on a PC workstation that is located in the DME library in Perth. There is no charge for this service although a small media fee is charged for hard copy plots.

Further information and contact details

GSWA data and data products
DME Information Centre
www.dme.wa.gov.au
100 Plain Street, East Perth, WA 6004
Tel: 08 9222 3459
Fax: 08 9222 3444
DME on-line catalogue and shop
www2.dme.wa.gov.au/ebookshop

GSWA/AGSO data and data products
AGSO Sales Centre
www.agso.gov.au
GPO Box 378, Canberra ACT 2601
Tel: 02 6249 9519
Fax: 02 6249 9982
Email: sales@agso.gov.au

MAGIX and airborne survey reporting policy
Website: www.dme.wa.gov.au
(select "Computer databases")
John Watt: j.watt@dme.wa.gov.au
Tel: 08 9222 3154

General information on regional geophysics policy and program contact:
David Howard
Tel: 08 9222 3331
Email: d.howard@dme.wa.gov.au

For further reading, please see article in Products on page 27.

Budget 2000, A Missed Opportunity For Australian Science

At a time when many leading OECD countries are increasing their investment in Research and Development, the May 2000 Federal Budget essentially delivered a status quo financial package for Science and Technology, with no hint of any long term wealth generating strategies.

The Minister for Industry, Science and Resources, Senator Nick Minchin, was seemingly pleased by the budget and simply stated that "the Commonwealth Government has increased its already strong commitment to science and innovation by providing a record level of $4.5 B for major science and innovation programs in 2000-2001 and reported that the Government had increased by $167 M, or 1.1% in real terms, funding in this year's Science and Innovation Budget."

The Shadow Minister for Industry and Technology, Bob McMullan, was quick to respond and argued that total Commonwealth spending on science and innovation has not kept pace with economic growth, and it is now standing at a meagre 0.68 per cent of GDP, down from 0.77 per cent when the Labor was last in power.

So where do we stand when we look at the numbers?

The main items contributing to the increased budget of $167 M appear to be:

- $47 M for the IR&D Tax Concession taking it up to a Government contribution of $600 M;
- an additional $30.5M package of assistance for the National Biotechnology Strategy (with at least $10M to come from reductions elsewhere in the ISR budget);
- $70 M to Syntroleum Corporation to develop gas-to liquid fuel technology in Australia; and
- $43 M for a new nuclear reactor at Lucas Heights.

In the context of a total budget of $4.6 B these adjustments are small. It is worthwhile looking at the Agencies within ISR to see how they fared.

- CSIRO, according to Minchin's statement, receives $616M in 2000/2001, as against $623M in 19999/2000, but in the Portfolio Statement the figure for 2000/2001 is $610M. In any event the numbers show a reduction in appropriated monies. Furthermore, the organisation has to provide $23M to Government from the proceeds of the sale of six properties (in Perth, Canberra, Brisbane & Sydney), so that it can lease back those very same properties. In the following two years it is planned to sell more properties to raise $31M and $53M respectively - more of the farm sold off. If that were not enough to make Sir Malcolm turn in his grave provision has been made for a review of CSIRO's IT support functions as part of the Commonwealth IT Outsourcing Initiative.
- AIMS budget increases from $25M to $26M. This includes $3.5M of new money and $4.1M from AIMS's running costs to complete the construction of a new research vessel. It will also have to raise $5.5M in external earnings ($0.6M more than last year) to balance the books.
- ANSTO fares reasonably well in the budget. In addition to the $106M allocated as running costs (~$102M in 1999/2000) the first instalment ($43M) of the $326M approved to construct a replacement research reactor over the next nine years will be provided in 2000/2001.
- AUSLIG's numbers are buried in the ISR statements but it turns out its budget has been reduced from $26.8M to $26.1M.
- Cooperative Research Centres funding has been reduced from $143M to $134M, a significant reduction for a most successful program.
- Funding for the Australian Research Council, which provides significant research funding to universities stands at $239M for 2000/2001 (not $455M reported in Minchin's statement), similar to last year's allocation.
- For AGSO, the numbers are similar to last year ($62.1M to $62.4M), with no restoration of the cuts made to the Minerals Program last year.

However, there is a strange sleeper in the papers, relating to AGSO and the Mapping of the Australian Antarctic Territory extended Continental Shelf. According to the Budget Papers:

'The Government will undertake a program of mapping the limits of the Continental Shelf off the Australian Antarctic Territory beyond Australia's 200 nautical mile Exclusive Economic Zone, to preserve Australia's rights under the United Nations Convention on the Law of the Sea.

Resources will be provided to the Department of Finance and Administration to manage this project in consultation with the Antarctic Division of the Department of Environment and Heritage. The Department of Finance and Administration will contract out the services to collect and analyse data necessary to delineate the outer limits of the Antarctic continental shelf for submission to the Commission on the Limits of the Continental Shelf by November 2004.'

In 2000/2001 these funds amount to $15.8M, of which $0.8M comes from AGSO and $0.5M from the rest of ISR. Where the other $14.5M comes from is not clear. It is also not clear what expertise resides in DOFA to drive a mapping program in the Antarctic Ocean.

Furthermore, although anticipated that the bulk of the work will go to AGSO, it is not certain at this stage that AGSO will be given the job of completing the work on the Law of the Sea it has been undertaking for the last five years or more.

Apparently DOFA has not yet decided whether it will call for public tenders or not. If the black background of their website is any guide, don't expect any easy money.

For the record, according to ISR's publication 'Australian Science and Technology at a Glance 2000', Australia sat 13th in the international table of R & D performance, where this is assessed as the ratio of the total R&D expenditure over the Gross Domestic Product. The first five are Sweden, Finland, South Korea, Japan and the United States, in that order.

Clearly there is room for major improvement if we are to make real progress in the 21st Century.

The Editorial in the Australian on 10th May, when commenting on the budget, hit hard on this issue:

"But it is disgraceful that in education and science, both areas in which the Coalition has talked up expectations, the Budget fails to deliver. The Government stands condemned for its lack of commitment. It is unconscionable that a country that claims to be an important part of the increasingly global economy puts so little into tertiary education and fails to understand the need to stimulate scientific research."

Professor Sue Serjeantson, President of the Federation of Australian Scientific and Technological Societies (FASTS), made similar comments in her statement made after the budget when she said:

"national policy had failed to come to grips with the speed the world is moving. The rest of the world is investing in research and innovation while Australia considers reports. This Budget has not made the necessary investment decisions, and we are falling behind.

Australia is failing to keep up with the challenges of the knowledge-driven economy. The future lies in industries based on high technology, and this requires investment in research, development, innovation and industry links"

There may be hope for better things in the next budget, because by then the government will have input from the Innovation Summit Implementation Group, which is developing an Action Agenda and the Chief Scientist's Science Capability Review. However, don't hold your breath.

AGSO building sold for $152M

In keeping with Government policy of selling assets, the Commonwealth has now sold the Canberra headquarters of the Australian Geological Survey for $152M. The building, which cost ~$110M to construct has been bought by the Motor Trades Association Superannuation Fund, which also owns the Foreign Affairs building for which it paid $200M. AGSO will have to pay a base rental of about $13M per year over at least the next 10 years. CSIRO will have to go through the same process year with six of its buildings.

The benefits to the taxpayer of these deals have never been demonstrated, but the ACT government is laughing all the way to the bank. It pocketed about $8M in stamp duties on the AGSO sale.

Eristicus, Canberra May 2000

Geophysics Theses From Australian Universities

Abstracts of recently completed student Theses from the Department of Exploration Geophysics, Curtin University

Development and Application of Processing Techniques for Signal Enhancement Using Multisystem Resistivity Measurements

Abolghasem Kamkar-Rouhani PhD

DC electrical surveying involves the injection of current into the earth, and the measurement of the electrical potential differences this produces. A number of electrode configurations such as the Schlumberger and Wenner arrays, dipole-dipole and pole-pole geometries are in common use for electrical surveying. New acquisition systems enable the convenient collection of data with a number of common configurations at the same time. It is found however that while the recovery of layered structure from electrical surveys can be effective, the sensitivity and resolving power of such systems in detecting the presence of anomalous three-dimensional (3-D) bodies is poor. This mainly due to the dominance of conduction pathways through the layered earth compared to the influence of small 3-D conductivity anomalies.

Theoretical relationships between the responses of various survey geometries to the layered earth may be established as is shown in this thesis, but their response to 3-D targets differs strongly. This thesis introduces a new procedure for anomalous target detection by the computation of an apparent resistivity residual using multi-electrode configuration survey data. This procedure, applicable to a variety of electrode geometries, reduces the dominance of the layered earth response and enhances the signal from 3-D structures.

In the development and testing of this new apparent resistivity residual, numerically modelled data were used. In order to obtain suitable test data of high accuracy it was necessary to make improvements to modelling software. For this purpose, recently developed techniques in numerical modelling such as the biconjugate gradient method, new digital linear filters for computation of Hankel transforms, and spectral formalism were employed in an integral equation approach for the software developed in this thesis.

The computed apparent resistivity residual was found to depend on the array type and dimensions, the nature of the anomalous zone, depth of the anomalous zone, geological layer geometries, and resistivity contrasts of the layers involved. While the apparent resistivity residual signature requires some measure of interpretation, it is shown to enhance the resolution and detectability of 3-D targets in a layered environment.

The presence of random noise produces some degradation in the performance of the residual technique, but a normalisation procedure has been developed to alleviate the problem. A preliminary field trial showed that survey profiles of apparent resistivity residual were able to locate a subsurface conductive anomaly in an area in Western Australia.

A transitional zone is defined as a layer in the earth where resistivity varies as a continuous function of depth. A theoretical formulation for the electrical response of an earth structure composed of anomalous 3-D bodies in the presence of transitional layers is introduced. Tests on synthetic survey data showed that the apparent resistivity residual is an effective anomaly detector in transitional layer environments.

A multisystem method of computing an apparent resistivity residual has been developed theoretically and tested on both synthetic and field data. This new approach when applied to resistivity profiling is more sensitive to, and gives greater resolution of, localised anomalies than is possible using conventional profiling procedures.

Multiple Attenuation Via Wavefield Transformations

Matthew Lamont PhD

Seismic multiples are a serious hindrance to hydrocarbon exploration in Australia. In particular, water bottom multiples can be very difficult to attenuate. This is because there often exists a strongly reflective sea floor, which gives multiples large amplitudes when compared with the primary events they overlay, and secondly, because of a widely occurring velocity inversion, which seriously reduces the effectiveness of a very important class of multiple attenuation techniques.

Multiple attenuation techniques can be classified according to the characteristic of the data which is used to discriminate against the multiples in conjunction with the operation behind the demultiple process. Common multiple attenuation processes include FK demultiple, Radon Demultiple, predictive deconvolution, wave equation based demultiple procedures and the family of techniques which come under the umbrella of Surface Multiple Attenuation (SMA). All of these techniques, given the right conditions, can be very effective. They also vary in price from very cheap (FK demultiple) through to expensive (wave equation based demultiple procedures).

However, despite these procedures, and fifty odd years of research, there is no effective general solution to multiple problems off the coast of Western Australia and indeed in many regions around the world.

Two new wavefield transformations, Multiple MoveOut (MMO) and IsoStretch Radial Trace (ISR), have been developed in this research to precondition data prior to the removal of surface related multiples by existing techniques. These form the basis of a new multiple attenuating procedure.

MMO shifts the data so that the water bottom primary event is flattened and the simple water bottom multiples are also flat and periodic. Water bottom peg leg multiples are made approximately periodic.

To solve the stretch problem introduced by the MMO transform, ISR interpolates oblique traces of constant stretch, which also map constant shot emergence angles. The water bottom primary and multiple events form a stationary time series after MMO and ISR. They are then amenable to removal by autoconvolution and predictive deconvolution.

The results of the new procedure are demonstrated on two case studies from offshore Western Australia. It is shown to be more effective at removing both simple and peg leg water bottom multiples than traditional techniques. Finally, it is an inexpensive procedure, which does not require velocity analysis prior to its application.

Seismic Imaging of Sandbox Models

Don Sherlock PhD

Analogue sandbox models are important in the study of reservoir geology because they can offer insight into geological processes that we are rarely able to observe in nature. Seismic physical modelling is used to study the effects of seismic wave propagation in isotropic and anisotropic media and is particularly suited to isolating the effects of a single parameter independently from all others in an infinitely complex geological system. Seismic physical modelling has also been used for the testing of numerical processing algorithms, and to evaluate interpretations of field seismic sections with scaled representations of geological formations. For this project, I set about developing methods to combine these two independent modelling techniques for the first time. However, previous attempts to use sand as a seismic modelling material failed due mainly to problems with understanding and controlling the distribution of the grain packing.

This research has addressed a number of these problems through systematic laboratory experimentation that has provided new insight into the factors that affect unconsolidated sediment acoustics. An innovative technique of recording seismic physical modelling surveys has been developed so that it is now possible to successfully record ultrasonic reflections within analogue sandbox models in three-dimensions (3-D), providing benefits for both analogue sandbox and seismic modelling disciplines. For sandbox modelling, the recording of seismic images allows more detailed analyses of the structures than previously possible. For seismic modelling, more geologically realistic settings can be modelled at a fraction of the cost and construction time of conventional models. However, the greatest benefit of this new technology is that it is now possible to build seismic physical models from porous media, rather than solid, non-porous materials that are conventionally used. This scientific advance allows different fluids to be incorporated into physical models for the first time.

Time-lapse 3-D seismic is becoming increasingly important in the management of hydrocarbon production, yet there is a lack of model data to support some of the conclusions being deduced. The controlled physical modelling laboratory environment combined with the ability to consistently repeat the 3-D seismic survey process now allows time-lapse seismic experiments to be performed without the need for the costly and time consuming data processing that is necessary to match legacy 3-D field data. This subsequently avoids any pitfalls that may be associated with the process, such as the masking of true fluid flow anomalies or the generation of false anomalies from data acquisition footprints.

A series of time-lapse models are presented where the three-dimensional movement of fluids through the models is remotely monitored using time-lapse 3-D seismic data. These models demonstrate the true seismic response that comes from recording real data from models that undergo real changes representative of reservoir environments. Such models are inexpensive and allow rapid data turn around in a matter of days. The techniques developed here provide a new research tool that can be used to improve our understanding of the dynamics of fluid flow within porous sediments, or to study the seismic response of reservoirs as they change with time.

(Preview will be publishing information on recently completed geophysical theses from Australian Universities, next issue we will provide Abstracts of the Masters and Honours studies from Curtin University. Ed.)

[1]Advances in Seismic Acquisition 1990 - 2000

Stuart Denny
Veritas DGC Inc.

Introduction

In the last ten years, the field of seismic data acquisition has seen many significant changes in equipment and techniques, as well as an evolution in the relationship between contractors and their oil company clients. These changes have benefited both contractor and client through improved safety, higher data quality, and better efficiency, all of which has led to a dramatic reduction in the cost of seismic data. In the following paragraphs, I examine the most important advances in acquisition technology, as well as some aspects of the changing relationship between contractors and clients.

Source Technology

Over the last ten years, marine seismic sources have evolved steadily in terms of output and tuning. Deepwater sources of 100 bar-m are now standard equipment, representing an improvement of more than two-fold since the beginning of the decade. Source tuning has seen a similar margin of improvement in terms of peak to bubble ratios, spectral smoothness, and bandwidth. At the heart of this are the introduction of more reliable, more efficient sources and the adoption of clustering.

Land seismic source technology now features high fidelity vibrator recording and techniques allowing the simultaneous utilisation of vibrators at multiple source points. These techniques, Sei-Fi™ and slip-sweep, are improving both the bandwidth and the efficiency of land seismic sources.

Positioning

The Global Positioning System (GPS) has come into its own in the last decade. In 1990, GPS was just emerging into the public sector, but suffered from a limited constellation and skepticism on the part of both contractors and clients. Its use was limited to supplementing the Transit satellite system and placing base stations. Today, GPS is a key part of every seismic survey conducted on land or marine. Improvements in survey accuracy brought about by GPS technology have made a dramatic improvement in the overall quality of seismic surveys. In marine surveys, with the aid of differential corrections, it is used for absolute vessel positioning to an accuracy of better than 5 m. This accuracy is available to distances of greater than 1,000 km offshore, which has greatly facilitated deepwater exploration. The need to deploy and calibrate chains of radio navigation beacons has disappeared, thereby improving the efficiency and reducing the cost of marine seismic. On land, in open areas, GPS has reduced the size and improved the efficiency of survey crews.

Another major advance in marine seismic positioning has been the advent of least-squares network adjustment solutions in Integrated Navigation Systems. This mathematical approach has allowed the real time integration of the array of satellite, laser, acoustic and magnetic sensor measurements used to position multiple streamer/multiple source spreads.

Instrumentation

The words *smaller, higher capacity and greater reliability* summarise the advances in instrumentation.

On land, recent advances in digital sensors promise to greatly reduce the size of field gear in land acquisition, greatly reducing layout and move-up costs. The number of channels that can be deployed in the field has increased by a factor of 10, further contributing to efficiencies. Land systems with radio telemetry or radio control and local data storage have found a significant niche, especially in harsh, obstructed, or limited access areas, thereby enabling once impossible surveys or reducing the cost of acquisition on difficult surveys. Some crews are realising the advantages of using radio systems in easy access, open areas instead of having to deploy and maintain telemetry cabling. Steady improvements in battery technology, the design and construction of connectors and cabling, and the use of more highly integrated electronic chips have improved reliability.

In marine surveys, solid streamer technology promises a host of advantages including improved noise performance, better depth control, and no environmental risks. Marine recording systems have also seen a large increase in the number of deployed channels. The overhead time, or dead time between shots for instrument reset is also being continuously trimmed, allowing vessels to either shoot faster or extend data record lengths.

24 bit Delta Sigma Analog-Digital converters have brought improved reliability and resolution to both land and marine acquisition. Similarly, in both areas, ready access to satellite communications is enabling greater flexibility in the acquisition, processing, and quality control of both reflection and positioning.

Techniques

Contractors and interpreters have a larger 'toolkit' today due to the advent of a variety of new data acquisition techniques.

4D or time lapse seismic is emerging as a production tool. The first solid footsteps towards the permanent instrumentation of producing fields have been taken. This is an area of the industry that can be expected to expand.

Multi-component recording is now helping unravel complicated lithology. While this technique may not yet prove cost-effective in all settings, in areas of strong velocity contrasts or significant anisotropy, it will likely be the tool of choice.

[1] *This is the first of a series of three articles reviewing the advances that have been made in* ***Seismic Data Acquisition, Data Processing, and Interpretation****, during the last ten years. Previews 87 & 88 will contain parts two & three. Ed.*

Helicopters were once used only where absolutely needed, in places where no other means of access was possible, or where environmental issues prohibited other means. Today, land crews are using helicopter operations for access in areas traditionally thought of as surface access. Despite the cost of the aircraft, helicopters equipped with advanced guidance systems and devices for automatically dropping off and retrieving bags of equipment, have substantially improved operating efficiencies and safety, while lowering environmental impact.

At sea, ten years ago 6,000 m streamers were the longest available, but from only a few contractors. Today streamers up to 12,000 m have been used, although not widely. Single vessel recording with ultra-long streamers has opened up sub-basalt areas to investigation and promises similar benefits in other areas where the sedimentary section is interrupted by high velocity layers.

Multi-streamer acquisition, just coming into its own at the beginning of the decade, is now a proven tool. The use of synthetic ropes, high efficiency deflectors, mechanised handling, and state of the art bend restrictors and towing gear have increased the scope and efficiency of the technique and reduced the unit price of marine seismic data for clients.

In 1990, aside from a few experiments with full data processing in the field, all work in this arena was focused on quality control processing. Today, especially offshore, full data processing in the field, or at least substantial pre-processing of data, continues to reduce the turnaround time between field acquisition and delivery of interpretable data.

HSE Management

Many of the advances mentioned above have collateral benefits in the arena of Health, Safety and the Environment (HSE). Smaller equipment lowers the risk of back and other injuries. More reliable equipment and mechanised handling reduces the exposure of the crews. Satellite positioning has eliminated much of the need for field personnel to be deployed on coastal base stations, which in turn eliminates the hazards associated with surveying, establishing and operating these stations. In addition, the way the seismic industry manages safety has undergone a fundamental change. Contractors have elevated the importance of safe operations, adopting comprehensive HSE management systems as a standard business practice. Compared with the dawn of the decade, HSE is now organised, documented and reported on. It is an integral part of everything we do.

Data Library

At the beginning of the decade, Data Library was an attempt by contractors to realise better value from under-utilised assets. Now, at the end of the decade of innovation, the value of libraries of non-exclusive seismic data to the industry as a whole is well understood. Clients have access to larger volumes of data at lower cost, while contractors own an asset with the potential for multiple sales, as well as more predictable and efficient utilisation of crews.

In a sense, seismic data has become a commodity, which is changing the fundamental business relationship between geophysical contractors and their clients. Many of the proprietary surveys bid on today have a data library component. This trend will continue to grow into the next decade.

Technology Outsourcing

In 1990, many oil companies still operated their own seismic crews and data processing centres. During the last decade this disappeared, leaving data acquisition and processing to contractors. There is now a trend for other facets of exploration technology to come under the umbrella of the contractor. Data interpretation, modelling, advanced studies, visualisation and other exploration services are now offered by many contractors. As oil companies continue to restructure and downsize, the role of the geophysical contractor as a technology partner in the exploration process will continue to grow.

Schlumberger Provides Lateral Streamer Steering Technology

Schlumberger Oilfield Services has just introduced a radical new system that provides lateral steering of towed seismic hydrophone streamers. The new system makes it possible to steer several degrees laterally from the natural streamer feather angle. This ability is integrated with a new accurate positioning system that uses a fully braced acoustic network from the front to the tail of the streamers. The new system will enable streamers to be towed closer together than has been operationally achievable to date.

Closer streamers will provide finer spatial sampling of the seismic wavefield, and controlled positioning will ensure consistent coverage and offset distribution. Constant streamer separation and more accurate receiver positioning will reduce errors in processing and advanced

Geco Eagle, which will arrive in Australian waters early July.

binning techniques, leading to a more accurate and reliable reservoir model.

"Using the new system, streamers can be steered to match the positioning of previous survey vintages for time-lapse (4D) studies", said Terje Nikolaysen, Vice President Marine Seismic, Schlumberger. Improved high-resolution seismic and 4D repeatability will enhance our ability to monitor reservoir changes and detect flow barriers and areas of untapped hydrocarbons."

The system will also improve the safety and efficiency of streamer deployment and retrieval and provide the control to tow streamers closer to surface obstacles such as platforms while keeping the vessel at a safe distance, thereby reducing gaps in coverage.

Streamer Control Advantages:

- *Shorter Linechange Time*
- *Constant Separation Control*
- *Reduced Risk of Streamer Entanglement*
- *Line Up with Bin Grid*

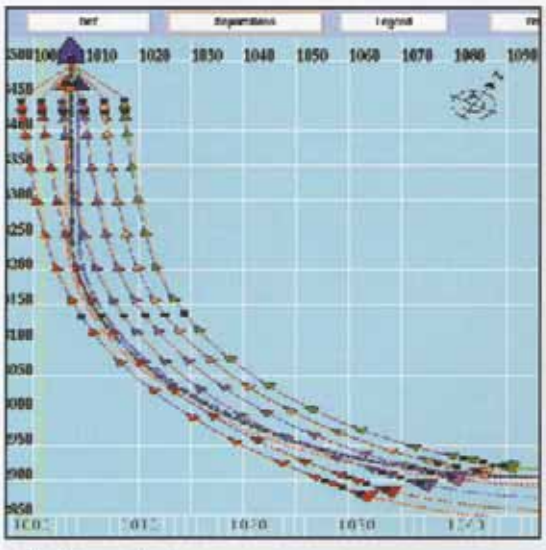

Fig. 1. Conventional

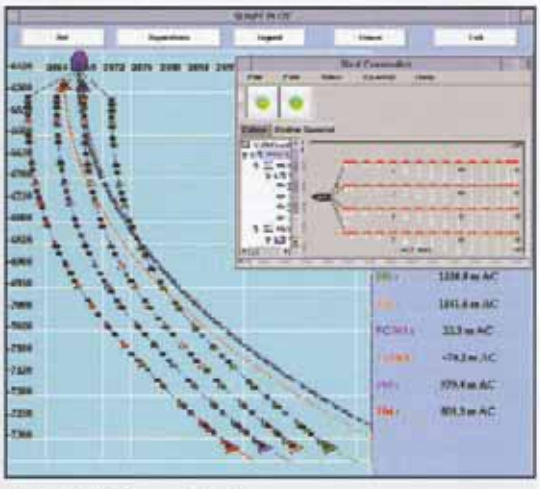

Fig. 2. With Streamer Control

The first plot (Fig. 1.) shows the tails of each streamer following a similar track to the vessel's track. This is what would normally happen with conventional streamers during a line change.

On the second plot (Fig. 2.) steerable streamers are in operation. In this example it is possible to straighten the streamers much sooner when coming out of the turn. Therefore less run-in distance is required and therefore line change can be carried out in a shorter time.

The plots pictured below show examples of the degree of control that can be obtained with the new system.

In Figure 3 the tail of the streamers is splayed so that there is increased separation between each streamer. Control like this could be very beneficial when acquiring infill or when undertaking in-sea maintenance on streamers using a small work boat.

Figure 4 shows how it is possible to move the two inner streamers to the starboard. Once again, this degree of streamer control could be beneficial when undertaking in-sea streamer maintenance.

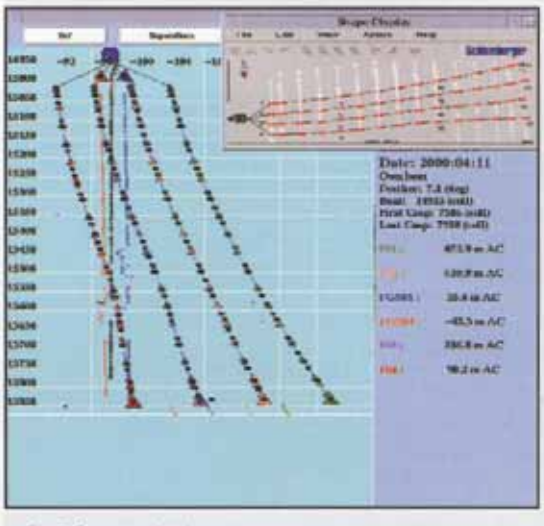

Fig. 3. Streamer steering

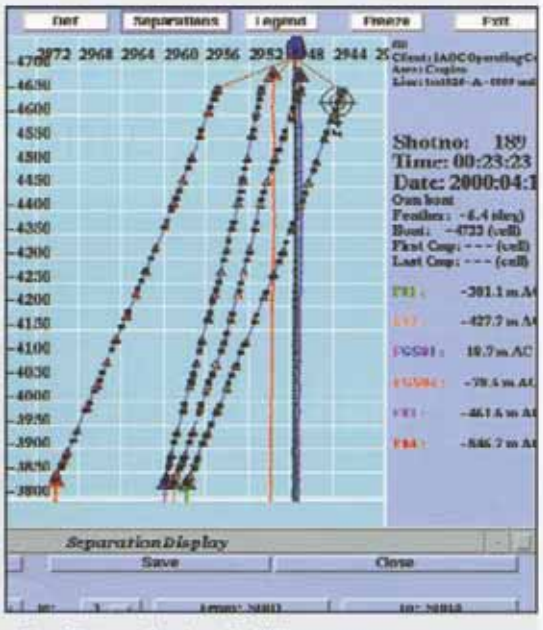

Fig. 4. Streamer Steering - Flexibility

Magnet Attracts Majors

Australia's resources exploration industry is poised to receive an injection of nearly five million line kilometres of previously confidential airborne geophysical data. The data will be released through MAGNet Database Services, which is operating a data broking service for company-funded airborne geophysical surveys. Both minerals and petroleum companies will benefit from the release of these vast amounts of information.

Three of Australia's largest mineral exploration companies have now signed as data contributors to MAGNet Database Services. BHP Minerals Ltd, Rio Tinto Australia Ltd and Stockdale Prospecting Ltd have acquired millions of line kilometres of aeromagnetic and radiometric data over the last 20 years, much of which will be released for public sale. The agreements make MAGNet easily the largest repository of multi-client airborne geophysical data in Australia.

MAGNet is jointly operated by Pitt Research Pty Ltd and Geoimage Pty Ltd, two Australian companies with a long history of service and innovation in airborne geophysics and remote-sensed data. With offices in Brisbane, Sydney, Perth, Adelaide and Darwin, the two companies are able to provide a truly national service.

One of the major attractions of MAGNet is the opportunity for contributing companies to use past exploration data as a springboard for future exploration. Benefits will flow back to the contributors in the form of cash royalties or as credits to be used in future data purchases.

Unlocking these vast amounts of company-funded airborne data will present new exploration vistas to oil exploration companies, who will find existing survey data available in many hydrocarbon-prospective areas of Australia. Many mineral-specific surveys overlap the margins of sedimentary basins, and some types of exploration activity, for example mineral sands and diamond exploration, are conducted in geological terrains also conducive to hydrocarbon formation. Airborne data is now being used by some petroleum companies as an inexpensive way of quickly evaluating the huge areas of Australia still relatively unexplored for hydrocarbons, and there are ample opportunities for sharing and exchange of data between the petroleum and minerals sectors.

The MAGNet surveys supplement the substantial airborne coverage of sedimentary basins available from State Government sources. During the 1990s many States including NSW, Vic, Qld and the NT targetted their basins with airborne geophysics, and the combined coverage is now almost continuous in many areas of Australia.

MAGNet has its greatest scope and benefits in Western Australia. All WA company-funded surveys flown prior to 1995 are eligible for contribution to the Database, as are certain types of post-1995 surveys. These include 'open-range' surveys, which were flown without any tenement cover, and multiple-tenement surveys. The current WA Government policy on these post-1995 airborne surveys is that they will revert to 'open-file' status after a period of 5 years, thereby losing all commercial value, unless they are contributed to a commercial database. This policy encourages companies to pass custodianship of these surveys to an independent agency such as MAGNet Database Services.

Some surveys flown in the NT, Qld and NSW are also eligible for contribution to MAGNet. These include all NT company-funded surveys not previously released under the NTGS Airborne Programme, and open-range surveys in all States.

Graphic indexes and survey meta-data will shortly be available on the Internet; see http://www.magnetdata.com.au for details. An important benefit of this facility will be a rationalisation of survey coverage due to a better inventory of existing data. Knowledge of existing survey coverage and access to the data will ensure that companies make best use of the existing information and direct more of their exploration budgets to interpretation and analysis tasks.

MAGNet surveys are available at a price which is approximately 1/3 the cost of new data acquisition. The price covers a licence to use the data within a purchaser company or bona-fides joint venture, but does not allow further commercial use of the data.

A data reprocessing service is offered by MAGNet for surveys flown prior to some of the latest developments in processing methods. Both aeromagnetic and radiometric datasets can be significantly upgraded and in most cases will merge satisfactorily with surveys flown at modern specifications. Both Pitt Research and Geoimage are also able to provide a full interpretation and analysis service from airborne data.

MAGNet is actively seeking further contributors to its database, especially from the petroleum sector. Please contact Mark Deuter at Pitt Research, Adelaide (08 8152 0422) or Max Bye at Geoimage, Perth (08 9383 9555) for further information.

During the shake-up caused by the mining bust of the late 1990's, a quiet revolution took place in the attitudes of Australia's largest mining companies. Most went through an extensive process of questioning established business practices to determine their real costs and benefits, and a new open policy of doing business has now emerged. The majors are increasingly involving smaller 'lean and mean' exploration companies in tiered and commodity-specific joint venture arrangements in order to maximise their probability of finding world-class mineral deposits.

Nowhere is this change more evident than in the willingness of the majors to share and trade information with other companies, especially geophysical and geological data. Once regarded as a meta-commodity to be jealously guarded, exploration companies are now viewing their extensive archives of airborne geophysical data as an under-utilised resource.

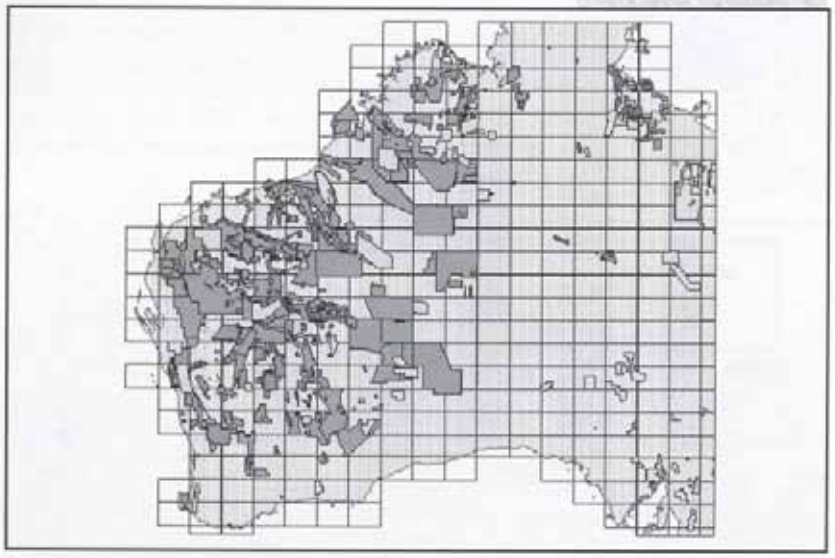

Fig. 1. Airborne survey coverage from current MAGNet contributors - April 2000.

BHP Develops World's First Airborne Gravity Gradiometer For Mineral Exploration

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Abstract

BHP has successfully developed the world's first airborne gravity gradiometer (AGG) system for exploration. The AGG was developed in conjunction with Lockheed Martin by a dedicated team operating in a "skunk works" environment and delivered under budget at 200% better than specifications.

Two AGG systems are currently being flown by Sander Geophysics. Results from the first surveys are very pleasing and demonstrate a sensitivity and resolution equivalent to ground gravity sampled at 200 m spacing and upward continued to the survey altitude which is typically about 100 m.

Introduction

BHP's Project Falcon has succeeded in turning the exploration geophysicists' vision of airborne gravity into reality with two fully operational airborne gravity gradiometer (AGG) systems.

These AGG systems are capable of sensitive, high-resolution detection of small variations in the Earth's gravity at the level required in exploration for mineral and hydrocarbon resources.

Airborne geophysics allows rapid, low cost surveying of large areas without the variety of access problems that can make ground surveys slow, difficult and expensive. With magnetic, radiometric, spectral scanning and electromagnetic methods all available from airborne platforms, gravity was the missing element. This was not for want of effort. Nettleton tried and failed in the 1950s. Carson flew the world's first working airborne gravimeter in the 1980's. Other companies have followed this success but these airborne gravimeters have all been limited in sensitivity and resolution. The GPS revolution improved the performance of airborne gravimeter systems to about 1mGal sensitivity over 2 km wavelengths but it was always clear that this technology could never deliver the performance required for exploration needs, particularly in the minerals industry.

The comparative weakness of the gravitational force and the extreme difficulty of measuring the tiny variations in that force in the presence of the large accelerations experienced in an aircraft meant that the successful development of an AGG system required an exceptionally focused and dedicated team. The Falcon team is pleased to announce their success.

Development

The Falcon project is a high risk, high reward development and research project directed at building the world's first airborne gravity gradiometer system. The project was the result of a strategic vision of a small group of research and exploration staff in the early 1990's. The AGG technology was to provide BHP with an international competitive advantage in mineral exploration and also possibly to address hydrocarbon opportunities.

To achieve this strategic vision, BHP assembled a small group of high calibre technology-development people from its corporate technology laboratories. This team operated under intense focus, and pressure, in a manner similar to the "Skunk Works" operation used by several companies to achieve exceptional breakthroughs in technology. The magnitude of the technical task that confronted BHP in the mid-1990s was significant

Following a worldwide search for suitable gravity technologies in the early 1990's, BHP initiated a feasibility study into the most appropriate technology in 1993. The manufacture of two operational systems commenced in 1995 and the first airborne gravity mapping system entered operational service in October 1999 with BHP's Minerals Discovery Group. The second AGG system followed in April 2000. The core technology comprises a custom-designed gravity gradient instrument, incorporated into an inertially stabilized platform built by Lockheed-Martin. The gradiometer BHP adopted was much more sensitive than the original one built for the US Navy. This new gradiometer had not been designed for use on a moving platform. In mid-November 1997, the new gradiometer under went detailed tests on a 6 degree of freedom shaker,

designed and built by BHP, to determine whether there would be adequate suppression of the spurious responses to aircraft accelerations. After many months of testing the Falcon team began to see test data which indicated that the gradiometer noise level could be significantly reduced in an airborne platform, but the final solution was still 18 months and a lot of hard work away.

In parallel to the system build, BHP also commenced a significant technical effort to develop computer algorithms to analyze the data from the AGG system. This was another complex non-trivial exercise, which taxed the group to the limit. Data processing algorithms were not limited to post mission compensation. The resulting code was subsequently integrated into a prototype software package for conversion of raw signals into interpretable map-products. After three years of intensive work the system hardware and software were finally mated and the entire system tested.

The first clear "gravity" pictures exhibited were of Bulgary Ridge, a prominent hill in up-state New York in mid-1998. It was to be another year before the AGG system passed all its performance tests and BHP was confident it had a superior new exploration tool for measuring gravity gradients.
Despite the fact that they were doing something that had never been done before, and despite the need to overcome previously unknown and severe technical problems the Falcon project (Fig. 1) was successfully delivered, exceeding all its technical specifications and under budget.

System Performance

The Falcon gravity sensor is extremely sensitive. We seldom think of the fact that we all exert an extremely small gravitational force on the people around us. Each of us is about 10^{-22} times less massive than the Earth, so that this personal gravitational force is much smaller than that due to the Earth. There are very few instruments in the world that can measure this force. The BHP instrument is so sensitive that it can measure the gravitational effect of a 3 year old child standing a metre away from it and yet, the system has been built in such a way that it is almost

Fig. 1. One of the airborne gravity gradiometer (AGG) systems pictured in Lockheed Martin's Buffalo facility.

completely insensitive to the effects of aircraft turbulence. Without that, the effects of the turbulence would be a thousand million times bigger than the signal from an ore body. The minute nature of the gravity signal from an orebody means that BHP had to develop extremely sophisticated software to process the signals from the instrument.

One of the key operational advantages of this excellent rejection of turbulence is that the AGG can successfully map the Earth's gravity to the required accuracy in all flying conditions, restricted only by considerations of crew safety. This has a dramatic effect on productivity and on keeping survey costs down. The AGG system productivity is frequently in excess of 1000 line-km per day with data being available the "next day". This data is of high quality, up to 0.1g aircraft accelerations. BHP has also commenced on an aggressive path to upgrade the system in the near

Continued On Page 30

Fig. 2. The Cessna Grand Caravan containing system Einstein on survey in South Australia. The support equipment is visible in the foreground.

Continued From Page 29

future to be operatorless. The fact that the system has been built to strict military manufacturing standard and tolerances will allow future systems to be easily manufactured and maintenance and repairs to be undertaken.

BHP has also negotiated a significant period of exclusivity, which provides unique business opportunities in developing joint ventures and deals.

Acquisition

Sander Geophysics Ltd. is flying the AGGs for BHP in single-engine Cessna Grand Caravans (Fig. 2). The aerodynamic and load-carrying characteristics of this aircraft make it ideal for AGG survey work.

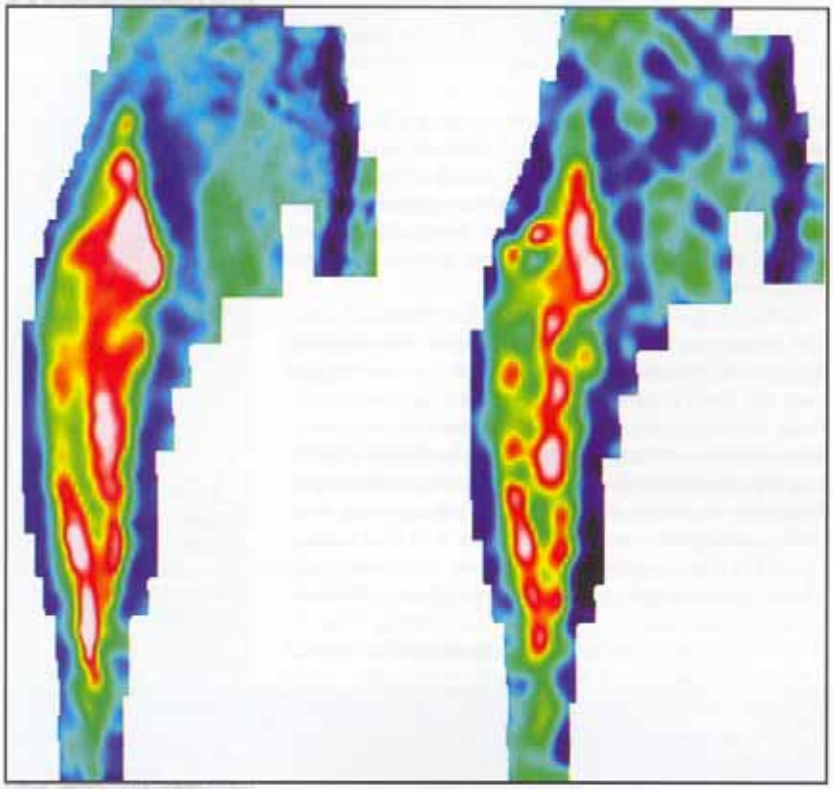

Fig. 3. A comparison of the AGG data with ground gravity. On the right is an image of the fully terrain-corrected vertical gravity gradient map over the survey area, flown at 120 m terrain clearance with Einstein. This is to be compared with the first vertical derivative of the ground gravity, also fully terrain-corrected, after upward continuing to the same altitude shown on the right. The comparison is striking, with not only the major anomalies in the high-density western geological formations clearly mapped, but much more subtle anomalies in other areas also detectable by the AGG. The mapped area is approximately 18 km from north to sout

The gravity data from the AGGs are comparable with ground gravity collected on a 200 m grid after upward continuation to the flying height, typically about 100 m ground clearance. This excellent performance means that the AGG is valuable for geological mapping as well as directed detection of targets.

To further aid the identification of mineral resources, several other sensing technologies are flown on the aircraft with the gravity system. A stinger-mounted caesium vapour magnetometer and scintillation spectrometer enables the collection of aeromagnetics and radiometrics. In addition, the aircraft carries the latest in LASER scanner systems, which, in combination with excellent differential GPS navigation, provides very detailed and accurate terrain mapping.

Test Results

Since October 1999, the first BHP airborne gravity system, called Einstein, has completed eight surveys and presently both systems are flying large areas. Einstein is flying in Australia while the other, Newton, is in North America. The first surveys included tests over areas where detailed ground gravity survey data were already held, providing verification of the quality of the airborne data.

Figure 3 shows results from one of these test areas in southern Australia and clearly demonstrates the excellent quality of the airborne gravity data.

Deployment Strategy

A deployment program is being developed by BHP's Mineral Discovery Group and is aligned to the Discovery strategy that considers both brownfield and greenfield exploration opportunities. There are some exciting possibilities. The program is evolving, as we get familiar with the system capabilities but is well determined over the next year. In the future, the use of airborne gravity will become a part of the normal Discovery planning process, as have other similar projects.

Conclusion

The Falcon group were very much a can-do team of development engineers and technologists, who worked round the clock for months at a time, sifting through performance data and checking that the AGG system was hitting the design specification. Ultimately we managed to come in 200% better than our original specifications, a truly remarkable feat. The relentless pace of the work continued year in year out until in October 1999 when we were confident that we had an airborne system, which would give superior results. It was a magnificent team effort between BHP and Lockheed Martin to develop the AGG technology and with Sander Geophysics to integrate the AGG system into an appropriate survey aircraft.

The Falcon build, system processing and deployment processing teams were managed by the author and comprised, Graham Creer, Peter Diorio, Mark Dransfield, Nick Fitton, Gary Hooper, Jim Lee, Ken McCracken AO, Tim Monks (dec.), Graeme O'Keefe, Peter Stone, Bob Turner, Ken Witherley, Maurice Craig, Mark Downey, Xiong Li, Guimin Liu, and Marion Rose.

Imaging Ahead of the Working Face With Seismic Reflection Tomography

By David Neil and Bob Whiteley

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Abstract

Economic and safe rock excavation is critically dependent on a detailed understanding of rock conditions beyond the working face. The latest advance has come in the area of seismic reflection tomographic imaging implemented from the opening during operations. The new technology allows three-dimensional (3D) images of rock structure and condition to be rapidly obtained ahead of the excavation. The method is called True Reflection Tomography (TRT™) and is analogous to shining a torch beam into the rock ahead of the working face. Since its introduction last year TRT™ has proved to be an effective and non-intrusive tool for imaging ground features along and adjacent to tunnels and mine developments in complex geological settings. Currently, TRT™ has a detection range of 50 m to 120 m along the alignment, and a peripheral range of 20 m to 30 m either side of the opening. The technology uses readily available acquisition equipment and a portable computer with specialist processing software, and represents a breakthrough in tomographic imaging for the mining and tunnelling industry.

Introduction

The dream of all underground miners and tunnellers is to know the geology ahead of the working face, to mine towards the rich lode and to avoid the poor ground. Likewise, their nightmare is encountering unexpected and possibly life-threatening geological hazards. In truth, economic and safe rock excavation is critically dependent on a detailed understanding of rock conditions beyond the face. While there have been dramatic developments in tunnelling technologies in recent years and modern Tunnel Boring Machines (TBMs) can now tolerate a wide range of conditions, unexpected faults and broken rock are still the major problems.

Early experiments in the application of seismic reflection methods to map the conditions ahead of TBMs were carried out in Europe in the mid-1980's and most geophysicists were made aware of this application in 1992, when the results of a pilot project in Switzerland were published in *First Break* (Sattel et al., 1992). Since that time development has continued mainly in Europe (Bruckl et al., 1997).

The latest advance, which is the subject of this brief article, has come from the USA in the area of seismic tomography or seismic tomographic imaging (STI, Neil et al., 1999). STI may be implemented during underground excavation to allow a rapid, accurate, 3D investigation of rock structure and condition ahead of excavation. For this purpose, NSA Engineering, Inc. of Golden, Colorado, which retained the core technologies from the now defunct US Bureau of Mines has developed True Reflection Tomography (TRT™).

TRT™ uses a seismic source such as the cutting action of a TBM cutter, shearer, drill or impulsive sources such as an impact breaker, explosive charge or hammer blow on the tunnel. The resulting seismic signals are detected by an array of accelerometers within the tunnel after reflection from structures up to 150 m ahead of the face.

Since its introduction in early last year, TRT™ has been used on multiple faces in more than 10 tunnelling projects on three continents including Australia. Rock types have included, fractured and jointed andesites, karstic limestones, greywackes, a melange sequence of fissile shale, sandstone and shale, slate and chert, and hard basal granites and schists.

Description of TRT™Technology

TRT™ employs a three-dimensional array of detectors in an Omni-directional Tube Array (OTA) installed around the tunnel at some distance behind the tunnel face. Placement of the OTA is controlled by the tunnel geometry and site constraints. Initially, an OTA using two NSA-designed probes was installed in 3 m-long by 50mm-diameter holes some 15 to 20 m behind the face (Fig. 1). This has now been replaced with up to 10 pre-amplified accelerometers, which are placed in a pre-determined pattern and bolted to the rock of the tunnel wall.

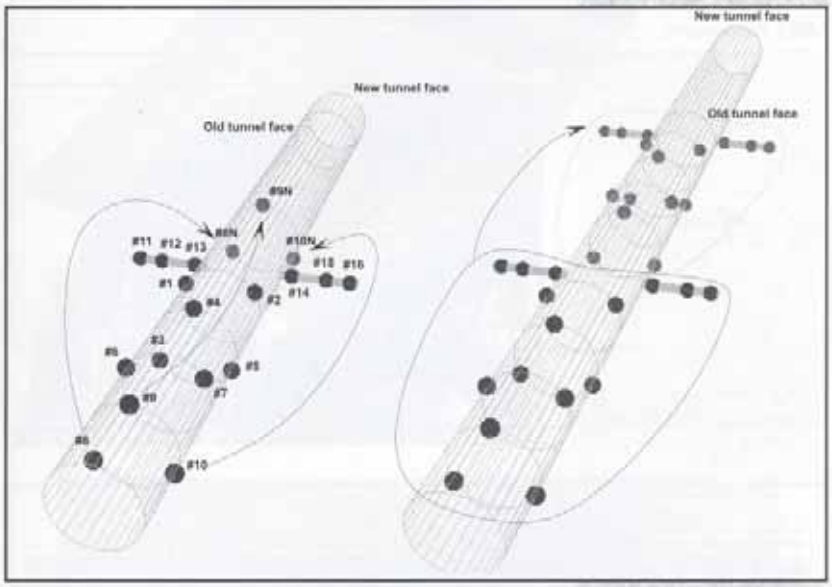

Fig. 1. Schematic of Omni-directional Tube Array (OTA)

Rock breaking activities associated with a tunnelling operation can generate seismic waves at a number of source points at and adjacent to the tunnel face, and the signals are ideal for reflection requirements. These signals, or those produced from an impact source, are collected on a standard digital seismograph during the normal tunnelling or mining cycle. Installation and data acquisition can normally be completed during one shift. Once collected the data are then transferred to the surface and processed at the site on a high-speed laptop computer.

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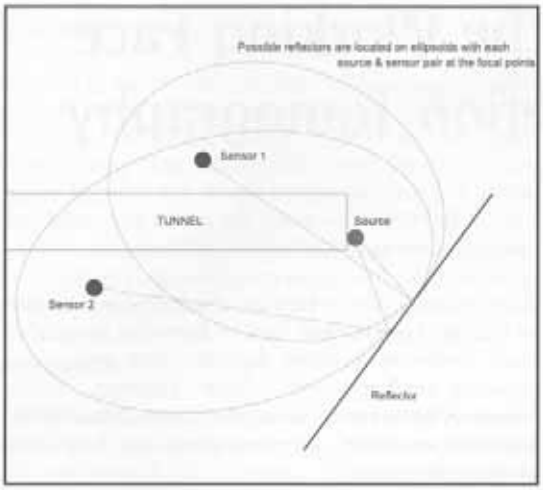


Fig. 2. Principal concepts of True Reflection Tomography (TRT™). ➤

Fig. 3. Geology as mapped in the main and pilot tunnels. ▼

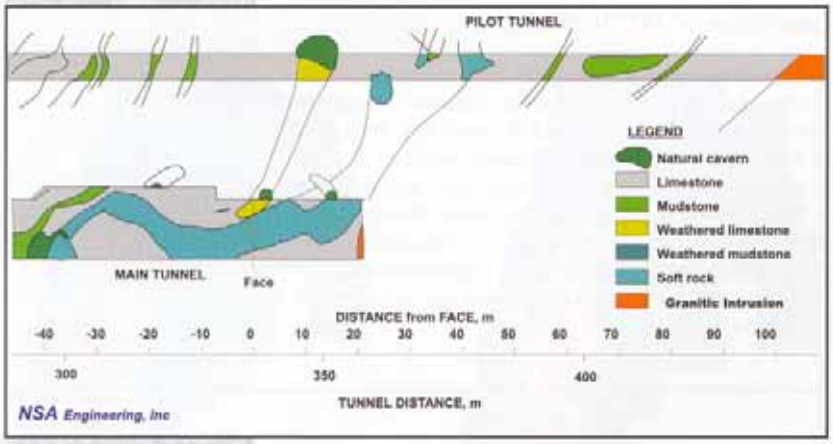


Fig. 4. Main Tunnel face at the time of TRT™ imaging. ➤

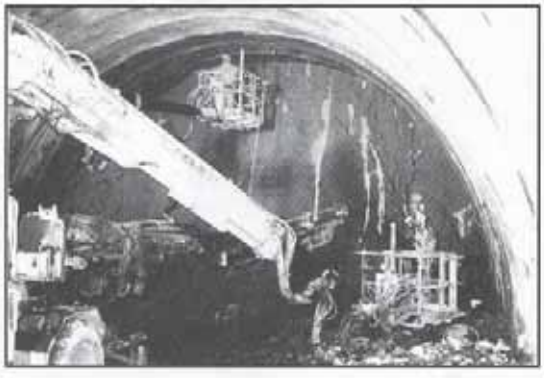
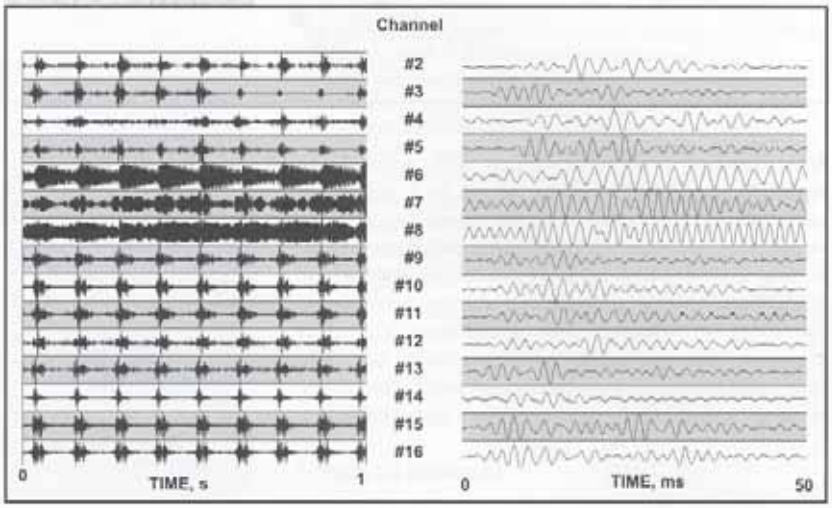


Fig. 5. Seismic signals obtained with Rock Breaker Source. ▼



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A 3D reflection tomographic image of conditions ahead of the tunnel face is produced, typically during the next shift. As the tunnel excavation advances, the OTA may be re-installed, and data acquired during the next selected active mining cycle. The entire data collection process is typically conducted every 80 to 100 m of tunnel advance to maintain a complete coverage of the driveage. Geological and geotechnical mapping as the development advances is used to calibrate the seismic images and to refine them.

Both direct and reflected seismic waves ahead of and around the tunnel are detected by the OTA and used to determine a velocity model for the earth and to image geological features. The velocity model is established within a rectangular block chosen to include regions of importance. Normally, each rectangular block is oriented parallel to the tunnel axis and orthogonal to this, usually in the vertical direction if the tunnel is horizontal. The velocity model is then used by the TRT™ software, that incorporates NSA's fast RockVision3D™ tomographic programs, to generate an image of weaker and stronger regions ahead of and adjacent to the tunnel.

The principal concepts embodied in the software for the use of seismic reflection to image ground conditions in 3D space are illustrated in Fig. 2 with a 2D slice. For each source and receiver of known location in a homogeneous medium, the locus of all possible reflector positions with a given two-way travel time defines an ellipsoid in 3D space. For a sufficient number of sources and receivers forming a three-dimensional array, each boundary reflecting seismic waves can be identified as an area where a majority of ellipsoids for individual source-receiver pairs intersect.

Example of TRT™ Application

The following example, from Japan, illustrates the use of TRT™ to create a hologram depicting the expected conditions ahead of a tunnel excavation. Subsequent ground truthing by excavation of the tunnel has been performed and the accuracy of the images has been verified by the project owner and contractor involved. The information obtained has also been used satisfactorily to manage the risks at this site posed by unforeseen geological conditions.

A twin gallery highway tunnel is being excavated near Kamaishi, Japan using the NATM (New Austrian Tunnelling Method). The left gallery is being excavated as a pilot tunnel with reduced dimensions to examine ground conditions along the tunnel path. The galleries are on 30 m centres with the pilot tunnel carried some 200 m in advance of the main tunnel. Both tunnels cut through fractured, weathered, karstic limestone with inserts of mudstone with occasional granitic dikes. The karst cavities are of various sizes and many carry water or mud. Fig. 3 shows the geology as mapped in the tunnels, which included a large cavity encountered in the pilot tunnel and an additional 20 m of mapping in the main tunnel which was completed after the first seismic imaging run (0 to 20 m in the main tunnel).

The main tunnel at the location where the seismic imaging was first performed (0 m) is shown in Fig. 4 and the seismic

signals obtained with the tractor mounted impact breaker (on the left in Fig. 4) are shown in Fig. 5. Typical frequencies are ~500 Hz.

Fig. 6 is a 2D longitudinal TRT™ S-wave image in a horizontal plane through the base of the tunnels built from signals generated by the impact breaker operating at the face (0 m) in the main tunnel. This source produces predominantly S-waves at average S-wave velocity through the material of 1960 m/s. This is represented by the green colour on the seismic image. Lower velocities, indicating weaker or softer materials are represented by the bluer colours and any higher velocities would be represented by yellow to red colours. The geology was overlain on the image after further excavation for comparison with imaged conditions. In the main tunnel the mudstone shows as a low velocity zone in blue, bound by limestone. This image also shows the location of reflection elements, which have been constructed where the ellipsoids from each source-receiver pair intersect in the image space. These are either yellow or purple representing higher or lower acoustic impedance contrasts respectively. The dimensions of the individual reflection elements are a measure of the spatial error in location and the significance of the "hit". A strong reflective region can be observed by the region of dense reflection elements along the tunnel alignment about 85 m ahead of the main tunnel, which extends to the pilot tunnel. This represents a granitic dyke which has been mapped in the pilot tunnel at about 100m.

This TRT™ image in any defined plane can be rotated with NSA's RockVision3DTM software and geophysicists and engineers can proceed to examine the face at interesting locations anywhere along the alignment within the range (Fig. 7). In this figure, the lower velocity zone mudstone is readily apparent in the face. Both higher velocity rock contacts and lower velocity water-bearing regions can seen in this image, analogous to the beam of a flashlight shining along the tunnel alignment to about 100m ahead of the face with peripheral vision some 30 m to either side. The image can also be viewed in selected intervals along the tunnel from the working face using NSA's TunnelViewTM software, in much the same way as the tunneller or miner would see the earth as it was excavated. Features around the tunnel are also imaged which cannot be observed at the tunnel margin but can be probed if desired. Fig. 8 shows a TunnelViewTM image, much as a tunneller or miner would see it looking along and around the opening. These views can be produced at any distance from the OTA within the imaged block. In this image the simulated face is 42 m ahead of the main face and is shown by the red dot in the tunnel to the right. Low velocity regions can be observed to the left and entering from the upper right of the tunnel alignment.

Conclusions

True Reflection Tomography is the latest non-intrusive tool for imaging ground features in three dimensions along and adjacent to tunnels and mine developments in complex geologic settings. This technology currently has accurate detection range of 50 m to 150 m along the alignment, and a peripheral vision range of 20 m to 30 m. The system provides timely information and flexible viewing using

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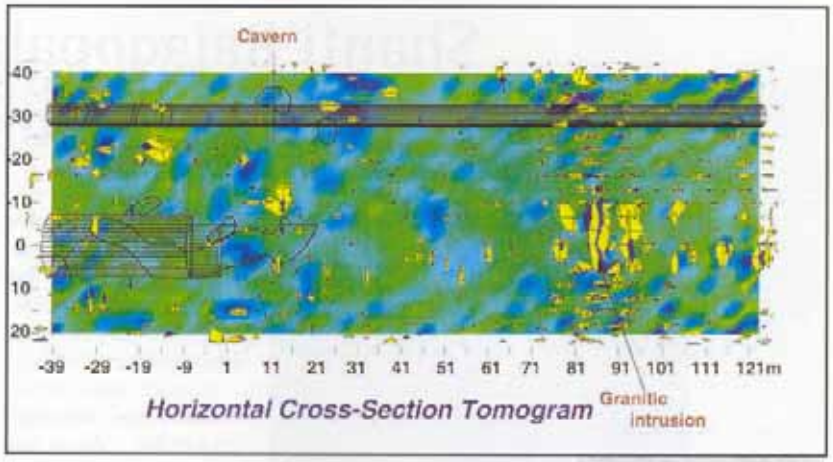

Figure 6 Horizontal S-wave TRT™ image through the base of the Main Tunnel.

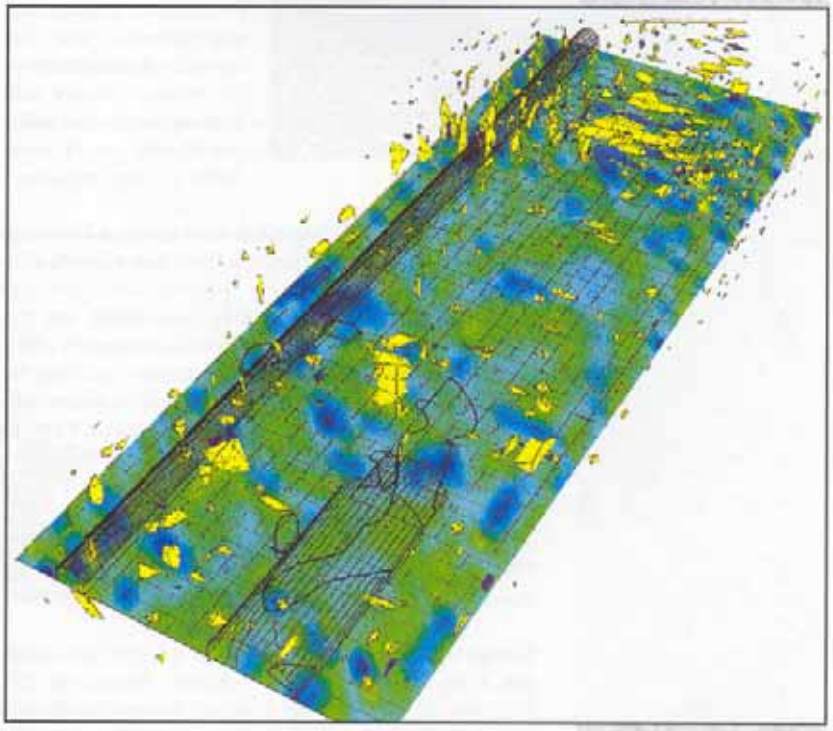

Fig. 7. Isometric projection of the TRT™ image in Fig. 6.

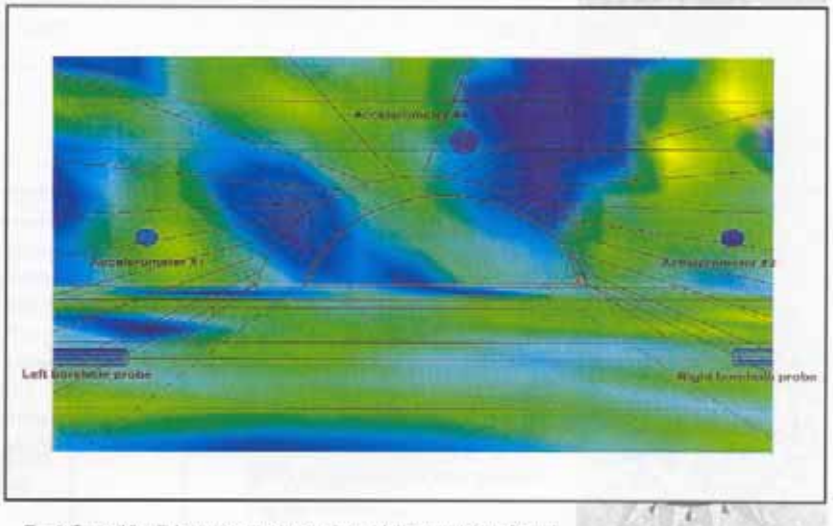

Fig. 8. TunnelView™ image 42 m ahead of the Main tunnel Face (42 m).

Shanti Rajagopalan: New Managing Editor of Exploration Geophysics

Shanti Rajagopalan

As Brian Spies announced in his 'President's Piece', Shanti Rajagopalan has been appointed as ASEG's new Managing Editor - Exploration Geophysics.

Shanti has excellent credentials for this position. She has worked in universities, the exploration industry and government, and is currently a consultant to the mineral industry with Earth Bytes Pty Ltd, which she started in February 1998.

Shanti has an MSc in Geophysics from Osmania University and a PhD in geophysics from the University of Adelaide.

In 1991/92 she worked at the BMR (now AGSO). This was followed by three years at the University of Adelaide, where she was a lecturer in exploration geophysics, teaching the entire non-seismic geophysical course (gravity, magnetism, radioactivity, and electrical and electromagnetic methods with an emphasis on mineral exploration) to undergraduate and Honours students.

She moved into the exploration industry proper in January 1995 when she joined Rio Tinto Exploration, where she stayed until she entered the consulting field in early 1998.

She has been involved in ASEG Branch activities and was at one time President of the Victorian Branch. As Co-Chairman of the Technical Program Committee for the 13th ASEG Conference held in November 1998, she had her first taste of editing through assisting John Denham with the Conference edition of Exploration Geophysics. Shanti is currently Associate Editor (Mining Geophysics) of the SEG journal Geophysics, and well placed to lead Exploration *Geophysics* in these challenging times.

We wish her well in her new role in the Society, where she is waiting for a series of quality articles across her desk.

New Members

We would like to welcome the following 10 new Members to the ASEG. Their membership was approved at the Federal Executive meeting on 16th May 2000

NAME	AFFILIATION	STATE
Jamie Dousset	Monash Univ	Vic
Myra Keep	Uni WA	WA
Miranda Mayle	Monash Univ	Vic
Irwan Djamaludin	Santos	QLD
Robert Lawrence	Santos	SA
Christopher Gilbert	Santos	QLD
Marcel Rive	CGG	WA
Sarah Vanderwoude	Adelaide Uni	SA
Mattew Hutchens	Adelaide Uni	SA
WMC Exploration	Corporate member	WA

Missing Members

Any member who knows the current contacts of the following members please contact the Secretariat (Tel: (07) 3855 8144 ; Email: **secretary@aseg.org.au**).

NAME	LAST KNOWN ADDRESS
Mark Beeson	Subiaco, WA
Matthias Densley	Adelaide, SA

Continued From Page 33

"Tunnel View" capabilities. When used by an experienced site tunnel geologist or engineer, the ability to interpret expected conditions and anticipate ground control measures is greatly enhanced over any other available method currently in use. TRT™ uses the latest portable computer technology to produce images using existing off-the-shelf geophysical equipment during the active mining cycle with minimal interruption to operations. The technology represents a breakthrough in tomographic imaging software technology, which is now available to the mining and tunnelling industry.

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Neil, D., Haramy, K., Descour, J., and Hanson, D., 1999, Imaging Ground Conditions Ahead of the Face. World Tunnelling Nov. 1999, 425-429.

Sattel, G., Frey, P., and Amberg, R., 1992, Prediction ahead of the tunnel face by seismic methods-a pilot project in Centovalli Tunnel, Locarno, Switzerland, First Break, 10, 19-25.

US Stops Degrading GPS Signals

From midnight on 1st May 2000, the United States stopped the intentional degrading of the Global Positioning System (GPS) signals available to the public, by deactivating the Selective Availability (SA) feature.

Selective Availability (SA) was the deliberate introduction of error to the precise timekeeping of the GPS satellites, thereby reducing both positioning and timing accuracy for civilian users. It was designed to provide U.S. and Allied military forces with a navigational advantage in times of crisis or conflict. With SA activated, civilians were only guaranteed to be within a 100 m radius of where their GPS receivers said they were. The removal of SA provides civilian users a positional accuracy of approximately 20 m.

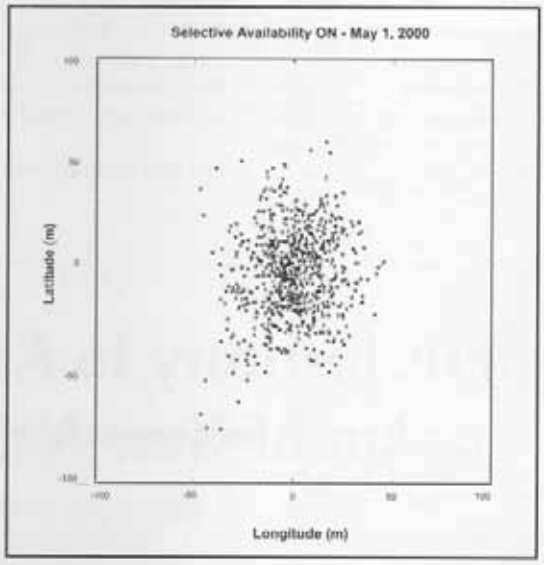
The decision to discontinue SA was made in response to the needs of civil and commercial users, as well as the US's capability to selectively deny GPS signals on a regional basis when 'national security is threatened'. In fact the US plans to launch up to 18 additional satellites to improve the GSP service.

Currently, it is estimated that there are more than four million users worldwide and the market for GPS applications is expected to double over the next three years to over US$6 billion.

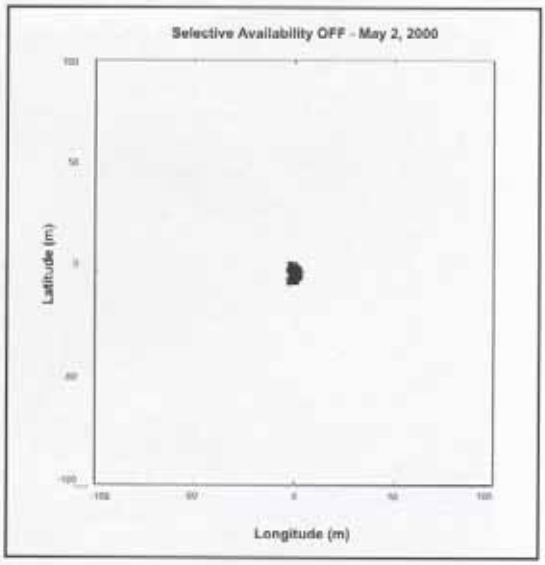
GPS is essentially the global navigation and positioning standard throughout the world and is widely used throughout the mineral and petroleum exploration industries. The increased accuracy obtainable from the GPS will eliminate, in many cases, the need for costly differential correction equipment and services.

The improvements obtained following the US decision are dramatic. The diagrams obtained by the US National Geodetic Survey, compare the before and after readings at one of the Continuously Operating Reference Stations operated by the U.S. Coast Guard at Hartsville, Tennessee. The images compare the accuracy of GPS with and without selective availa-bility (SA). Each plot shows the positional scatter of 6.5 hours of data (0730 to 1400 UTC). The plots show that SA causes 95% of the points to fall within a radius of 43 m. On May 2nd, 2000, and with SA was no longer present, 95% of the points fall within a radius of 4 m.

(The information from this item was obtained from the web site of the Interagency GPS Executive Board at ***www.igeb.gov,*** Ed)



May 1, 2000



May 2, 2000

$17 Million for Australian Institute of Marine Science

The Minister for Industry, Science and Resources, Senator Nick Minchin, announced in early May the go-ahead for $17 million to be spent on the refurbishment of the Cape Ferguson laboratories and the design and construction of a new vessel for the Australian Institute of Marine Science (AIMS) near Townsville.

Senator Minchin's announcement at the Aquarium and Southbank Convention Centre in Townsville was made following consideration of the Chief Scientist's, Dr Robin Batterham, recent review of marine science infrastructure in the Townsville region.

The Minister said:
"The Commonwealth Government's decision to proceed with the Cape Ferguson laboratories refurbishment program and the design and construction of a new research vessel highlights our commitment to marine science research in the Townsville region. It gives certainty to AIMS and those who seek to collaborate, further enhancing the Institute's research capability.

"It is particularly fitting that this announcement is made during National Science Week as the Cape Ferguson site is ideal for marine research support into the sustainable use and protection of the marine environment.

"As an integral and indispensable part of Australia's marine science effort, AIMS' Cape Ferguson facilities are optimal for access to the Great Barrier Reef. The collaborative nature of much of AIMS' research and strategic planning results means it has the capacity to deliver world-class tropical reef research.

"This research provides an essential resource for James Cook University, the Cooperative Research Centre for the Great Barrier Reef World Heritage Area and the Great Barrier Reef Marine Park Authority.

"The decision to proceed with the refurbishment program of the new wing and existing main building will further enhance the Institute's research capability and independence."

The design and construction of the new wing and the refurbishment of existing facilities at Cape Ferguson, is estimated to cost about $12.5 million. Up to 150 people would be directly employed on the project during the design, construction and refurbishment phases. A total of $4.15 million has been dedicated to the new vessel and the refurbishment of AIMS' second vessel, the *Lady Basten*.

(see also Eristicus's budget comments in this issue. Ed)

Northern Territory to Acquire 347 000 line-km of New Airborne Data

Richard Brescianini, the Chief Geophysicist of the Northern Territory Geological Survey, announced (on 16th May) the awarding of five contracts to acquire 347 000 km of new airborne geophysical data in the NT during 2000.

The five surveys are as follows:

1. Amadeus Central survey: Tesla Airborne Geoscience (400 m line spacing N-S, 83 500 line-km)
2. Wiso survey: Fugro Airborne Surveys (400 m line spacing N-S, 113 000 line-km)
3. Bauhinia survey: Tesla Airborne Geoscience (400 m line spacing E-W, 45 500 line-km)
4. Mary River survey: Kevron Geophysics (400 m line spacing E-W, 47 500 line-km)
5. West Arnhem survey: UTS (400 m line spacing N-S, 50 litre crystal capacity, 57 500 line-km)

Survey flying is planned to start during the May-July period and the digital data releases are planned for the final quarter of 2000.

These surveys will be a shot in the arm for Australian service industries and will hopefully lead to an increase in exploration effort in the Northern Territory.