Preview

Australian Society of Exploration Geophysicists

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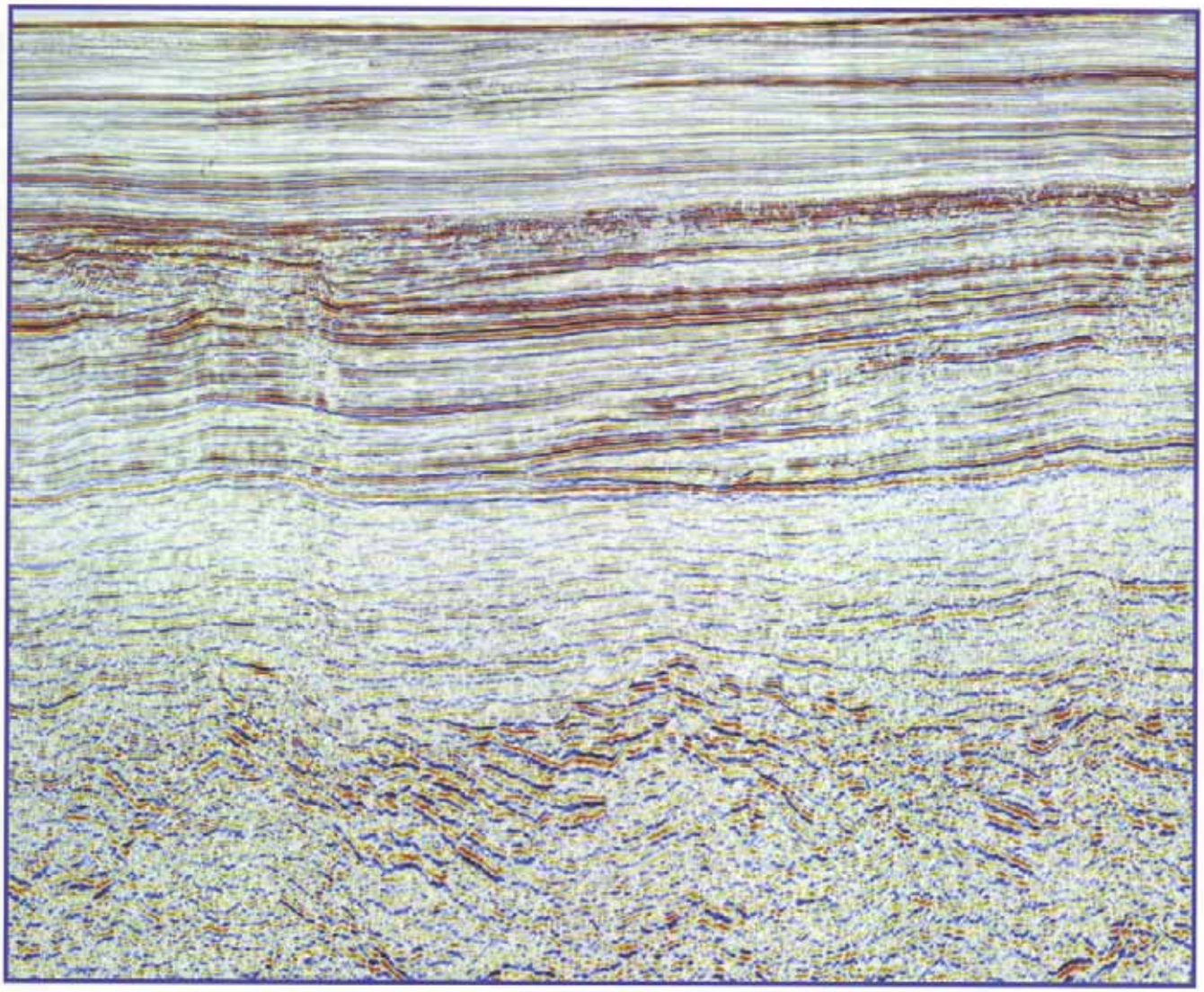

Seismic Focus- Part II

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Front cover:

The front cover image is from the North Browse TQ3D undertaken by Schlumberger Geco-Prakla and Seismic Australia.

New prospects can be defined through the improvements possible with modern acquisition and processing techniques.

Migration in 3D allows the rifted sequence to be accurately imaged with improved lateral resolution. Improved frequency content allows important unconformities and reservoirs to be defined with confidence.

Sneak Preview

Preview No. 88 will include the following feature articles:

- *Airborne EM with Helicopters*
- *Geophysics and Groundwater*
- *Geophysics in AGSO*
- *Seismic Interpretation*

After the rigours of London traffic and UK petrol prices its good to be back at my desk in Canberra. When we left Heathrow in mid-July petrol prices in the London area were about €0.859/l. This translates to close to A$2.25/l, which is now the most expensive petrol in Europe. Unfortunately for the petroleum exploration industry, something like 80% of the price at the pump is taken by government in tax, so the incentive to explore for more petroleum is still not very high. Naturally most people were complaining bitterly, but the price will obviously have to rise much higher if it is going to deter drivers from using their cars and clogging up the roads.

It was also good to open the mail to find my copy of the June Preview, and I would like to thank Henk van Paridon for finalising the material for that issue with Brian Wickins, and guiding the production process while I was away.

The current issue contains articles on a number of topics. Carl Notfors reviews seismic processing advances, Don Emerson introduces a novel approach to using magnetic susceptibility measurements in sediments, Tim Mackey outlines AGSO's approach to mapping geology in areas of no outcrop, and Mick Micenko and Tim Brice make interesting contributions to seismic interpretation. We also have Koya Suto's comparative analysis of Australian and Japanese geophysical Societies. In the October issue we hope to have articles by Robert Hobbs on seismic interpretation, Barry Drummond on Geophysics in AGSO and Geoff Pettifer on geophysics and ground water.

Eristicus, in this issue, discusses the challenges facing the Government in boosting the Science & Technology/Research & Development Sectors in Australia. He also shows in some detail FASTS' proposals for investing $1 billion. It may be of interest to consider some improvements to this wish list, and come-up with alternative proposals. I am therefore inviting members to submit new proposals on where the Government should invest taxpayers' dollars for Science & Innovation. We will publish an analysis of the results in a subsequent Preview.

I mentioned in my last Editor's Desk that Warren Entsch had requested a raft of proposals for consideration by his office in the 2001/2002 Budget. A copy of the letter sent to Mr Entsch is contained in the letter section of this issue.

We will see what happens.

David Denham

David Denham, Editor

President's Piece

Reaching out

As geophysicists, we are constantly in touch with other professional and technical people, ranging from geologists and geochemists, to engineers, accountants, statisticians and computer programmers. Increasingly, many of these people refer to themselves as geoscientists, to reflect the broad range of skills and experience they may have. These professionals have 'reached out' - embraced other fields of endeavor through education, training, work experience and networking. Doing so enhances one's employability and greatly expands the opportunities for career advancement and security of employment.

Similarly, it is important for a professional society such as the ASEG to 'reach out', in order to maintain its health and increase its relevance to its members and the profession. This can be done in several ways, including formal and informal links with other societies, and through education programs, workshops and conferences targeted at specific groups that may be users of geophysics.

The ASEG has historically always had strong links with the SEG and, as an Associated Society of the SEG, is granted representation on its governing body, the SEG Council. The ASEG also has strong links with the EAGE, with respective presidents invited to speak at the opening ceremony of the other Society's conferences. The SEG's Global Affairs Committee also has good representation from Australia, thanks to efforts last year by Mike Smith.

Recently, the Federal Executive of the ASEG has begun building links with the Japanese SEG, and Koya Suto and Mike Smith are preparing an agreement of cooperation and association to be signed by both organisations. This will enhance the ASEG's relevance in the southeast Asian region.

Within Australia, the ASEG is a member of the Australian Geoscience Council (AGC), which is composed of eight major geoscientific societies. Through the AGC, the ASEG is also represented on the Federation of Australian Scientific and Technical Societies, (FASTS) a significant voice for scientists and technologists in Australia with influence on Federal policy and budgets. Our own Preview editor, David Denham, is currently Vice President of FASTS.

At the grass-roots level, it is encouraging to see members of the ASEG reaching out to users of geophysics, in fields traditionally dominated by other technologies. The ASEG Federal Executive recently gave its support for a workshop on dryland salinity, proposed by an ad-hoc committee chaired by Greg Street, which is targeted at the land management community in Victoria. In Greg's words, "the workshop is designed to break down the barriers between the mystical geophysics and the users in land management." The Federal Executive sees this as an exciting opportunity to reach out to a specific group of users of geophysics, and is hoping that the workshop might be expanded to a form where it could be given in other states as well.

I encourage other groups and individuals to organise specialist workshops along the same lines, with the support of the ASEG where appropriate. In this way, the ASEG could grow from being a society of geophysicists for geophysicists, to a more robust society that promotes geophysics and its uses in a diverse range of applications.

Waving the flag

The ASEG will be well represented at the upcoming SEG meeting in Calgary, with the ASEG booth staffed by Dave Robson and other volunteers. ASEG members also hold key roles in several SEG committees that will meet during the conference, including technical standards, publications, research, and global affairs. A number of Australian technological organisations will also be highlighted at the ASEG booth. A report on the SEG conference will be given in the next issue of Preview.

B. P Spies

Brian Spies
President

Committee Reviews

The Brisbane Conference Committee has all of the important arrangements for the 15th ASEG Conference & Exhibition in place for 5th-8th August 2001. The committee is co-chaired by Jenny Bauer of Origin Energy Resources and Nick Sheard of MIM. On behalf of the Federal and Conference Committees, I remind all potential presenters for this conference, of the end of October deadline for an Expression of Interest. The venue in Brisbane has been described as "the best in Australasia".

With any ASEG conference, the publication costs for both the Conference Preview and Conference Exploration Geophysics are substantial - generally close to $150 000. To help keep a lid on costs and the enormous editorial time associated with producing these volumes, the Executive has ratified a new model for publication of the Conference technical proceedings as proposed by the Publications Committee for Brisbane 2001 Conference. Details are included elsewhere in this issue of Preview (see Publications News). While there will be no formal hardcopy edition of the papers presented, it is planned that the best 60 papers or so from the Brisbane Conference would be edited and refereed and form the 'Best of Conference' *Exploration Geophysics* volume. The responsibility for editing this volume will rest with Brisbane Technical Program Committee and the Managing Editor of *Exploration Geophysics*, Shanti Rajagopalan. This new structure of conference publications could result in potential savings of about $50 000 on previous conference publication costs.

In following the 1999 / 2000 Business Plan, I am very pleased to inform all members that the costs of Preview publications are near cost neutral. For instance, Preview 85 (April) gave a cost reconciliation of $2000 (includes postage of $2000) with only a moderate level of advertising. Congratulations to the Publications Committee, the Publicity Committee and to RESolutions (Publisher) in obtaining enough advertising for offsetting costs.

The 1999 accounts have now been audited. The final Profit & Loss accounts show a small loss of $3239.59, which is a reasonable result considering that 1999 is a non-conference year. From a cash perspective, and as a result of the receipt of both Hobart and AEM conference income during 1999, the Society's cash position improved in 1999 by approximately $15 373. Given the solid surplus forecast from the Perth conference and assuming advertising income performs as forecast, we are hopeful of presenting a surplus in 2000.

The September edition of Exploration Geophysics is set to be a significant volume with a total of 14 papers. Nine of the papers relate to seismic processing on oil and gas applications with another on a coal application. The remaining four papers describe mineral case studies.

Membership is now close to 1300 financial members with 83 library members. Unfortunately, nearly 200 members and 30 libraries have not renewed their 2000 subscriptions. The Calgary SEG conference will see a major overseas membership and sponsor drive. A more attractive membership form and a special 'media kit' has been organised by the Revenue Committee.

The ASEG is to part sponsor a workshop on 'Salinity Land Management and New Technologies' which is planned for Bendigo from 18th-21st February 2001. This workshop will focus on emerging technologies with emphasis on airborne EM. It will be the forum where catchment managers can be informed on the important role of geophysics in land care issues. Greg Street is the chairman of the organising committee with most presenters being invited by the committee.

Just a reminder that members planning to present at the Brisbane 2001 Conference, must have their Expression of Interest to Intermedia Convention & Event Management in Brisbane by the end of October.

David Robson
Honorary Secretary

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
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*	29 June 2001	13 July 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 October 2000 edition is the 22nd of September.

Print Post Approved – PP3272687 / 0052.

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.

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New Members

We would like to welcome the following new members to the ASEG. Their membership was approved at the June 2000 Federal Executive meeting.

NAME	AFFILIATION	STATE
Simon Sturrock	Strat Trap	WA
Fiona Gillian Alexander		SA
Brian Charles Wickins	Oilfield Publications	WA
Robert John Galvin	Curtin University	WA
Matthew Levinson	Sydney University	NSW

Interested in membership of ASEG (or know someone who is)? Application form for new memberships is available on www.aseg.org.au or contact ASEG Secretariat at ph 07 3855 8144 or fax 07 3855 8177.

Obituaries

Eric Lloyd Blazey, 1906-2000

Eric Blazey, who died on 7 July 2000, aged 94 was the last surviving member of the Imperial Geophysical Experimental Survey (IGES) Group, which pioneered exploration geophysics in Australia in the late 1920's and early 1930's.

He was a member of the Gravimetric Section, which used the Eötvös torsion balance and the Vertling gradiometer. Later he was responsible for defining, with electrical methods, the (since famous) 'Footprint Anomaly' at Mount Lyell, Tasmania.

The IGES was the initial training-ground fro other past well-known geophysicists such as Jack Rayner, Lou Richardson and Bob Thyer.

Written by: Bill Langron

Dave Dekker, 1951-2000

At about midnight on 16 July 2000, after watching the eclipse of the moon, Dr Dave Dekker, Chief Research Scientist and Mining Science Co-ordinator in CSIRO Exploration and Mining, died suddenly. It is some comfort to know that as a physicist and a keen amateur astronomer, Dave was doing one of the things he truly loved when he died. Dave was born on 1 July 1951 and came to Exploration and Mining in 1995 from Mount Isa Mines where he was the Engineering Research Manager. He was a member of the ASEG since 1977. In his regrettably brief career with CSIRO, Dave successfully managed a significant research leadership role in Exploration and Mining and the Minerals Exploration and Mining and Energy Sectors. In fact, because of the broad depth of his vision and his clear logical thinking Dave was asked to be the Co-ordinator for the Minerals Exploration and Mining Sector in March this year. Dave was also actively involved in a number of research projects in mining automation and the study of far-sited potential to mine or benefit from deep-sea ore bodies. This culminated in him being one of the lead scientists on a CSIRO multi-divisional research cruise on RV Franklin in April 2000. Dave's main interest was in hyperthermophilic microbes which reside in submarine hydrothermal vents and which have great potential to assist in the extraction of metals from ores. He also supervised the evaluation of the feasibility and potential of a series of geophysical measurement systems to locate and estimate the quality of now inactive vents known to be very rich in base metals. One of the tested systems was a new instrument designed by Dave last year for the measurement of perturbation of the Earth's electric field by conducting mineral ore bodies, a significant new research initiative. The cruise received widespread publicity in both the print and electronic media in Australia and overseas. Dave was a warm and supportive colleague, mentor to staff and well respected throughout the mining and mineral industry. In recognition of his exceptional leadership skills and active research role, Dave was reclassified to Chief Research Scientist the week before he died. His wife Cathy, and son Andrew survive him.

This obituary is based on material supplied by Sharyn Dawson of CSIRO.

Events for 2000-2001

2000

September 3-7
6th Meeting Environmental and Engineering Geophysical Society, European Section
Theme: Explore Tomorrow's Fundaments
Secretariat c/o Unikontakt - Dr. Budach Ruhr-Universitaet Bochum, D-44780 Bochum, Germany.
E-mail: wolfg.budach@ ruhr-uni-bochum.de
Website: http://www.ruhr-uni-bochum.de/eegs-es-2000/

September 19-22
Indonesian International Oil, Gas & Energy Conference & Exhibition 2000 (IIOGE)
Jakarta Convention Centre, Jakarta, Indonesia
Theme: Secure the Future
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
Email: convene@aapg.org
Website: http://www.aapg.org
or at IPA Secretariat
Tel: +62 21 527 3663
Email: ipa@cbn.net.id
Website: http://www.ipa.or.id

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

2001

January 24-26
The Society of Exploration Geophysicists of Japan, 5th International Symposium, Tokyo, Japan
Theme: Subsurface imaging technology and Underground Heterogeneity
Website:
http://segjsvc.geosys.t.u-okyo.ac.jp/segj/meeting/
Email: segj5th@segjsvc.geosys.t.u-tokyo.ac.jp

March 4-7
The Annual Meeting of The Environmental and Engineering Geophysical Society
Doubletree Hotel, Denver Colorado, USA.
Theme: Geophysics: Reducing Risk in Environmental and Geotechnical Engineering
Email: lcramer@expomasters.com
Website: http://www.sageep.com/

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: A Geophysical Odyssey
Theme: '2001: A Geophysical Odyssey'
Website: http://www.aseg.org.au
Event Manager: Jacki Mole
Tel: +61 7 3858 5579; Email: aseg2001@im.com.au

September 2-6
7th Environmental & Engineering Geophysical Society, European Section, Birmingham, U.K.
Theme: Better and faster solutions
Email: conference@geolsoc.org.wk
Website: www.geolsoc.org.uk/eegs2001/

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

ASEG 2001 on Track... The Odyssey Continues

Written by:
Henk van Paridon

Preparations for the ASEG 15th Geophysical Conference and Exhibition are well in hand. Readers should take time to look at the ASEG web site www.aseg.org.au for the latest details.

The organising committee welcomes Nick Sheard as co-Chairman to provide the yang to Jenny Bauer's yin. Wayne Stasinowsky has resigned due to his other commitments and we thank him for his past contributions.

The SEG has confirmed its intention to co-host the conference continuing a format that has been used for the last three conferences. Members of the ASEG, COC and the FE will represent the Society at the SEG conference in Calgary and our posters and publications will be distributed widely. Invitations to the EAGE and SEGJ have also been issued.

The Technical Papers Committee distributed the initial Call for Papers in the June Preview. This conference will be slightly different from the past with the proceedings from the conference to be published on CDROM. This will alleviate the recurring problems associated getting the conference volume of Exploration Geophysics out on time. More information and a detailed Extended Abstract Information Kit will be available to download from August 1st. The Committee is especially looking for petroleum case histories.

The workshop committee has been collating suggestions for pre and post conference workshops. Up to 10 workshops will be considered. The three-day conference format means that workshops can be run on the Thursday and Friday following the conference so that you can keep your weekends free for Queensland's other attractions.

Sponsorship opportunities are now available and several companies have been contacted for Gold Sponsorship. Those companies interested should contact Jacqui Mole of Intermedia at the address below.

The weather in Brisbane at this time of year can only be regarded as halcyon. Cool to cold nights perfect for sleeping and warm cloud-less days. Even the whales like it.

ASEG 15th Geophysical Conference & Exhibition
Brisbane Queensland
5th - 8th August 2001
Tel: 61 7 3858 5579
Fax: 61 7 3858 5510
Email aseg2001@aseg.org.au
www.aseg.org.au

Changes to ASEG Conference Proceedings

Written by:
Andrew Mutton
ASEG Publications Committee Chairman

Following an extensive review of costs and several publishing options, the Federal Executive has approved a recommendation by the ASEG Publications Sub-committee for a major change to the publication of future ASEG conference proceedings.

Commencing with the Brisbane 2001 Conference, the conference proceedings will change from the previous fully refereed conference edition of Exploration Geophysics, to a non-refereed Expanded Abstract issue. The following model has been specifically adopted for Brisbane 2001:

- a Conference Preview similar to Perth 2000 Conference, containing short summaries of all papers and other information on the conference program and exhibition;
- a supplementary CD-ROM containing searchable full Expanded Abstracts, each of about four pages length including figures. Submission of the Expanded Abstracts will be fully electronic via a prescribed template, which will be available from the ASEG website from August 2000.

No hardcopy of the Expanded Abstracts will be available, but delegates at the conference will have access to print stations at which hardcopy of selected papers can be printed. Selected conference papers will also be available subsequently in hardcopy format in a 'Best of Conference' edition of Exploration Geophysics, planned for the second half of 2001 following the Brisbane conference. Authors of the best Expanded Abstracts, as judged by the Technical Papers committee, will be invited to submit their paper for peer review and publication in Exploration Geophysics.

The need for these changes has come about due to the increasingly large cost, time and editorial effort involved in producing the conference edition of Exploration Geophysics, which has been one of the largest expense items for the ASEG. The changes should not only result in much needed cost savings, but also should lead to a more uniform and regular publication of Exploration Geophysics throughout the year, without the need to tie the publishing schedule into conference deadlines.

New South Wales - by Alan Willmore

Technical meetings with the NSW Branch are generally held on the 3rd Wednesday of the month at the Rugby Club. The June meeting was a joint SMEDG meeting with a presentation by Bruce Hooper of Straits Resources on the Nifty Copper deposit in W.A.

July provided another two joint technical meetings, this time with PESA. The ESSO distinguished lecturer, Dr Craig Beasley (Vice President - Worldwide Data Processing at Western Geophysical) gave a short course on the 10th July, titled *The Connection between Acquisition Geometry and Illumination*. PESA, ASEG and ESSO jointly sponsored the course, which was attended by 12 members who were suitably impressed by the style and content.

This was followed the next day by a joint PESA/ASEG lunchtime presentation by Dr Beasley, titled *The Role of Geophysics in the Oil Field of the Future*. The presentation was well attended by 50 members of the two societies. Dr Beasley discussed the integration of geophysical well-logging (vertical extent) with seismic data (lateral extent) to monitor oil resources. He showed some nice comparisons of pre-stack depth migration verses post-stack time migration. Dr Beasley lamented the loss of key personnel within the industry with the downturn in exploration, yet remained optimistic that we should see increased exploration toward the end of the year as continued high oil prices swell production figures.

The annual dinner is planned for the 28th July, once again at the Different Drummer restaurant in Glebe. Last year's dinner at the same venue proved very popular with those who attended, and more of the same can be expected this year.

South Australia - by Michael Hatch

Regular readers will not be surprised to hear that things are pretty active here in SA (ASEG-wise, at least).

June (especially the third week) was busy, with two talks presented during that week. On the 20th, Richard Jones and Scott Mildren of the NCPGG gave a talk titled: *Faults: Sealing or Non-Sealing?* While not a strictly geophysically oriented talk, it was interesting and useful for our members. Then on the 22nd June we had our first talk in the 'Millennium Series' (actually hosted by AusIMM). The Millennium Series is a cross-society collaborative series of five talks given by prominent leaders working for companies either in or related to the resources industries in Adelaide. This first talk was given by Ian Lilly, Marketing Manager for Silicon Graphics, and was titled *Computing in the New Millennium: Where Are We Headed?* He had some very interesting ideas as to what we can look forward to in the computing arts.

Then on the 17th and 18th July Craig Beasley came to Adelaide and gave a series of Esso Distinguished Lecturer talks for PESA. His final talk on the 18th was a joint PESA/ASEG event titled *The Role of Geophysics in the Oilfield of the Future*. Craig provided a good overview of what some of us can expect in our futures.

Then on the 20th July the local GSA sponsored the second talk in the Millennium Series. This talk was titled *Gold Mining in the New Millennium*, and was delivered by Bruce Kay. Bruce is the Group Executive for Exploration at Normandy Mining. He provided us all with a good idea of what some of the rest of us can look forward to in the gold industry.

On to the future. You will be amazed to hear that there is a lot to look forward to in SA for our local members. On the 9th August we are expecting the fourth talk in the Millennium series. This one will be hosted by the ASEG and is titled: *Energy for our Future*. Andrew Stock, General Manager, Major Industry and Power, Origin Energy will present this talk.

Then in September we are looking forward to our annual Industry Night. This is an enjoyable evening where some of our local companies get a chance to tell the rest of us about some of the interesting things that they are doing. The talks are generally short, informal, and informative. We have this event pencilled in for 19th September (more details later).

We are also looking forward to participating in Resources Week 2000, a weeklong celebration of the mining industry in South Australia, running from the 6th through the 12th of August. This event is organised by Primary Industries and Resources SA, and the South Australian Chamber of Mines and Industry. The local ASEG will be sharing a booth at the Career Expo at Resources Week, along with a number of other earth sciences-oriented professional societies here in Adelaide.

We are also looking forward to the evening that so many on the local committee dread, the onerous task of choosing the red and white wines that will have the honour of being distributed to ASEG members throughout the country in October and November in our wine offer. Look out for the order forms in the next Preview issue.

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

Victoria - by Trudi Hoogenboom

On 20th June Geoff Pettifer & Paul McDonald spoke on: *High-resolution gravity and EM grid surveys for mapping of fire-hole overburden hazards in open-cut brown coal deposits.*

The gala dinner was held on 11th July when George Mallory spoke on the Mt Everest trek and Silver Certificate presentations for 25 years of ASEG membership were made. The Victorian ASEG branch was also invited to attend the PESA ESSO Distinguished lecture. This year's speaker was Dr Craig Beasley of Western Geophysical.

Upcoming Meetings are planned for:

- 15th August when Bill Mathews will speak on: *On-stream and bulk analysis based on nuclear techniques for the mineral industry*, and
- 19th September when Julie Elders will talk on: *A comparison of receiver technologies in down hole MMR surveys.*

Queensland - by Kathlene Oliver

The Queensland Branch is actively organising the next ASEG Conference and Exhibition, which will be held at the Brisbane Exhibition and Convention Centre during August 2001. We are currently calling for interested parties for major sponsorship of the event and are receiving encouraging feedback. Please contact Kathlene Oliver if you are interested but have not received the sponsorship prospectus.

At the end of June we held a technical meeting providing 'dry-run' opportunities for two of our members who will be part of the Australian contingent at the SEG Conference in Calgary. Andrea Rutley (MIM Exploration) and Binzhong Zhou (CSIRO) enthusiastically presented their work for the well attended meeting. Everyone enjoyed the presentations and we wish them our best at the SEG Conference.

The Queensland Branch is planning a number of events in the upcoming months including a beer tasting evening and technical meetings. We hope to see a large portion of our members at these events, the details of which will be available on our web page. If any of our members have suggestions for social events please contact the Branch President Troy Peters.

Western Australia - by Mark Russell

Technical Meetings are held at the *Celtic Club*, 48 Ord Street, West Perth (5:30pm drinks and nibbles, 6:00pm meeting commences; for members admission is free, for non-members admission is $10.00).

Recent meetings have included:

- 17th May: *Pre-Stack Imaging in Time or Depth*, by John Cant Veritas DGC Australia Pty Ltd and *Quadrio Lake: we have found the barite, where are the sulphides?*, by Franco Pirajno Dept. Minerals and Energy. Veritas DGC Australia Pty Ltd sponsored the meeting and after the presentations Veritas DGC invited us back to their office for a tour of their new Visualisation Centre.
- 19th July: *Fault on Reservoir Geometry, Central Uthmaniyah, Saudi Arabia*; an Interpretation by Dogan Perincek, Kuwait University-Perincek & Associates and, *Geophysics in the Exploration for Diamonds in the North Kimberley Region of Western Australia* by Paul Wilkes, Curtin University.
- 20th July: The Esso Distinguished Lecturer Short Course (at Novotel Langley, Perth WA), *The Connection between Acquisition Geometry and Illumination: designing, acquiring and processing 3D data*, was presented by Craig J. Beasley, Vice President - Worldwide Data Processing, Western Geophysical. Lecture Tour. The meeting was sponsored by ESSO, PESA and ASEG.

Future Program:

- 11th October: FESWA & ASEG one-day seminar *'From Logs to Waves - value added seismic analysis using petrophysical attributes'*. More details are on the Website www.aseg.org.au/wa. If your company would like to present a paper and/or sponsor at future meetings please contact Kevin Dodds (9464 5005) or Guy Holmes (9321 1788) about speakers and sponsorship possibilities.
- 9th-10th & 12th-13th October: *the George Bertram Course - Seismic and Sequence Stratigraphy for Play Prediction and Basin Analysis*. A series of courses presented by Dr. George Bertram. Places are limited to a maximum of twenty participants. For more information and a registration form please contact Jim Dirstein dirstein@iinet.net.au
- 24th November: *Golf Day at Meadow Springs*. Details for the PESA/ASEG 2000 Golf Classic are on WA website. Contact is Robert Iasky: r.iasky@dme.wa.gov.au

Employment Service

Our Employment Service is running on the WA website. This service is available to WA members to facilitate initial contact between employers and those seeking employment. To see who is available right now, or the register, go to the Employment Section. At www.aseg.org.au/wa

Decision Time Close for Government on Science Funding

As we all know, when a government is confronted with a big issue that is not considered politically urgent, the standard action plan is to conduct a review.

In the case of Science and Technology it called for two major reviews. The first was the review of Australia's science base by the Chief Scientist, Dr Robin Batterham and the second was the *Innovation Summit* that took place in February this year.

The Chief Scientist produced his interim report *Investing in Knowledge Generation for the Twenty First Century* at the Innovation Summit in February 2000. After the Summit, as reported in the April Preview (p 10), Senator Minchin appointed an 'Innovation Summit Implementation Group' to develop the 'strategies to create a culture of innovation in Australia'.

This Group presented an Interim Report to the Prime Minister's Science, Engineering and Innovation Council on 2 June 2000, and is scheduled to present its final report to the PMSEIC Council of Ministers by 30 August 2000.

- Review the R&D tax concession, considering options to obtain the best benefit/cost ratio
- Encourage development of private research capacity
- Develop innovation awareness across all sectors of the community
- Encourage philanthropic investment in R&D by reducing red tape and providing tax incentives
- Improve the legislative framework and administration of the intellectual property system and improve awareness of the importance of intellectual property and its management
- Develop a framework for getting intellectual capital and associated 'intangibles' on balance sheets

I don't think anyone would argue with these but the difficult bit is clearly going to come when the dollars have to be allocated to make them happen.

FASTS had one solution and simply suggested that an additional $1 billion should be allocated to the R & D/S & T Sector as listed below:

Double funds to the Australian Research Council large grants	$100 M
Improve laboratories and libraries in universities	$100 M
New scheme to provide major national research facilities	$60 M
Retraining, HECS relief for new science and maths teachers	$20 M
Assist libraries with electronic subscriptions to journals	$10 M
Measures to stimulate careers for younger scientists	$50 M
Tax credits to stimulate innovative companies	$250 M
Additional funding for the CRC Program	$50 M
Priority environmental projects	$40 M
Boost funding to science agencies (CSIRO, AIMS, AGSO etc)	$70 M
New commercialisation stimulants	$20 M
Increase funding to awareness programs, particularly in industry	$20 M
University salary equivalence for NHMRC and ARC fellowships	$10 M
Overdue university salary increases (scientists' share)	$200 M

So far the Group has progressed by consolidating the more than 120 recommendations of the Summit into 34 solid recommendations and some 16 of these are already being addressed by actions in place.

It is understood that the Government aims to have an agreed action agenda on Innovation by the end of the year - presumably in time for the 2001/2002 Budget deliberations.

I won't go into the details of all the priority recommendations (these can be found on the website of the Department of ISR, http://www.isr.gov.au/), but to give you a flavour of the outputs, I have listed eight key recommendations below:

- Establish and strengthen international linkages to build innovation partnerships and alliances
- Streamline delivery, alignment and coordination of government innovation support grant programs

Not to be outdone Senator George Campbell (ALP NSW) commissioned a report on the state of the Australian Manufacturing Industry in the New Economy. This report was released in July this year. In essence it concluded that there is currently a "Knowledge deficit" in Australia compared to other similar OECD countries that will take an injection of $135 billion over the next ten years to rectify.

Basically this amount was estimated as necessary to 1) lift our investment in the national education system to 5% (compared to 4.3% today), 2) implement policies aimed at raising investment in R & D and training to reach average OECD levels, and 3) raise Commonwealth support for Science & Innovation to at least 1% of GDP from the 0.7% level of today.

All this adds up to substantial dollars. It will be interesting to see how the Government responds.

Eristicus, Canberra, July 2000

Inversion: Publications and Software Related Web Sites

Written by:
Natasha Hendrick

Geophysical data are typically interpreted via inversion methods. Geophysicists use observed data to measure causative parameters, such as depth, orientation, velocity or density of a target body. This month's Web Waves takes a look at some of the information, publications and software related to inversion that are available on the World Wide Web.

Remember, if you have any favourite sites you'd like to share with our members please email me, Natasha (natasha@geoph.uq.edu.au). An ASEG Favourites list will be published sometime in the near future.

The Rice Inversion Project (TRIP)
www.trip.caam.rice.edu/

This site provides large quantities of information through project reports and other publications. Abstracts are available on-line. A number of full papers can be downloaded as PDF and/or PostScript files. Topics covered include semi-recursive Kirchoff migration, joint inversion using the convolutional model, coherent noise suppression in velocity inversion, adaptive finite-difference methods for traveltimes and amplitudes, and many others. Comprehensive lecture notes (86 pages) are also available on the 'Mathematical Foundations of Reflection Seismology'.

Consortium for Electromagnetic Modelling and Inversion (CEMI)
www.mines.utah.edu/~wmcemi/

Past and current research projects of this consortium are detailed on-line. Projects include Electromagnetic Matlab, 3D inversion of magnetotelleric data, 3D forward modelling and inversion of IP data, and 2D magnetotelluric focusing inversion. The site also gives details of the 35 software algorithms developed through CEMI, with relevant references and authors names.

University of British Columbia: Geophysical Inversion Facility (UBCGIF)
www.geop.ubc.ca/ubcgif/

UBCGIF has an on-line Outreach Program to facilitate understanding and application of inversion technologies. The program provides web-based case-histories of inversion applications (eg. DC resistivity, IP, magnetics and gravity); tutorials (eg. 2D forward modelling and inversion of DC resistivity and IP data); and, occasionally, unpublished technical notes are posted. The site also provides a comprehensive list of publications (1990-1999). Most abstracts are available directly on-line, and a large number of papers can be downloaded in PDF/PostScript format.

Inverse Methods for Wave Propagation Applications in Time Domains (IMPACT)
www.arttic.com/projects/IMPACT

IMPACT is a parallel implementation of an inverse scattering method. It is used to determine unknown physical properties of a given object by analysing its response to the emission of radiated signal. Applications include Electromagnetics, Acoustics and Ultrasound Imaging. A brief overview of the software is available in PDF format. A complete description of the IMPACT method is available on registration (no charge). Contact details for organising access to code are also given.

Northeastern University Wavefield Inversion and Image Restoration Lab (NUWIIRL)
claudius.ece.neu.edu/nuwiirl

WIIRL focuses on the solutions to inverse problems arising in a variety of applied geophysical fields. A comprehensive publications list is given, including work from PhD and Masters Theses, and conference and journal publications. Published material covers adaptive filtering, linear reconstruction tech-niques, statistical signal restoration and regularisation of linear inverse problems. A majority of the abstracts are available on-line. This site also contains links to WIIRL collaborators and other useful websites.

Automatic Differentiation of Fortran 77 Programs
www-unix.mcs.anl.gov/autodiff/ADIFOR/

Given Fortran 77 source code and user's specification of dependent and independent variables, ADIFOR will generate an augmented derivative program that computes the partial derivatives of all specified dependent variables with respect to specified independent variables. ADIFOR is available for educational and non-profit research, and for commercial evaluation. The software is supported on Sun, HP, IBM and Intel X86 platforms.

G.A. Ryzhikov's Home Page
www.fi.uib.no/~antonych/invG.html#Also

A personal collection of inversion references. Topics include 3D non-linear inversion, Born inversion, regularised global approximation algorithms, imaging of reflectors, multiple attenuation, and more. Papers available on-line, and in PDF and PostScript format.

Iterative Methods for Linear and Non-Linear Equations: Matlab Code
www.siam.org/books/kelley/kelltode.htm

Matlab M-files for conjugate gradient methods, finite-difference methods using Newton's iterative approach, fast Poisson solvers, Newton-Krylov-Armijo algorithms, locally convergent Broyden solvers, and more.

Regularisation Tools V3: Matlab Code
serv1.imm.dtu.dk/~pch/Regutools/regutools.html

On-line Matlab package for analysis and solution of discrete, ill-posed problems. All software, and the users' manual, can be downloaded directly from the web.

Netlib www.netlib.org/

Comprehensive on-line collection of mathematical software, papers and databases. LAPACK is available from this site. It provides routines for solving systems of simultaneous equations, least-squares solution to linear systems, eigenvalue problems and singular value problems. LAPACK is available for Fortran 77, Fortran 90 and C++ compilers.

Report from the Web Committee Chairman

Written by:
David Howard

A draft web plan has been put to the Federal Executive Committee for comment. The proposed plan is based on the website design of a number of similar organisations.

The plan proposes a relatively flat, hierarchical structure with major and minor elements as shown in the Table. Administration will be highly automated, with content presentation being almost totally database driven. A significant degree of interactivity is envisaged. Site sponsorship will be actively sought to defray or cover the costs of development and maintenance; and a clear distinction is drawn between sponsorship and classified advertising.

Site management issues are still under consideration.

Major category	*Subordinate content*
Home	Introductory page with permanent frame containing shortcuts to all sections and news items; Special announcements; Site search form; member login; shortcuts; feedback.
About ASEG	Current office bearers; Federal Committees; ASEG Foundation; State Branches; Corporate members
Events/Meetings	Meeting details; Conference calendar; Administration form
Member services	How to join (+On-line application form); Member search form; Change of members' details; Job search; Mailing lists/discussion forums
Professional development	Training (Details of selected course; Course admin form); Scholarships and grants; ?Internships; ?Mentor opportunities
Publications	Publications index; On line journals; Information for authors; Technical standards; Slide sets/presentations
Classifieds	Classified service ads; Classified jobs ads; Advertising information
Education & Public interest	Society news flashes (+Media relations/releases);General geophysics news (?links, ?media monitor; Policy and government affairs/issues; Occupational health, safety & welfare issues); Geophysical Education (Teaching resources); Careers information; Related links

Advances in Seismic Processing 1990 - 2000

Written by:

Carl Notfors, Veritas DGC Asia Pacific Ltd

Introduction

Many advances took place in the area of seismic processing during the 1990's. Some of these changes came about because developments in computer technology increased the computational speed by at least an order of magnitude during the decade. Although the acquired seismic data volumes have also increased, the faster computers have allowed algorithms that were previously too computer intensive to be used in the regular processing sequence. Genuine algorithmic advances also took place during the decade. In the following sections I present the significant advances as seen through the eyes of a (particular) seismic contractor during the 90s decade and have grouped seismic processing into areas of trace interpolation, multiple attenuation and imaging.

Trace interpolation

There was an increasing awareness of the effect of irregular sampling and under sampling in acquisition, which has lead to increasing use of interpolation algorithms both to regularise data and reduce aliasing effects. In our view, interpolation is a key interface between the inherent non-uniformity and sparseness of acquisition, and the implicit assumptions of regularity and optimum sampling in our processing algorithms.

Some of the specific developments in this area were:

The f-x interpolation method of Spitz (1991), which was a large step toward allowing aliased data to be interpolated with confidence. Spitz's technique is based on spatial prediction filtering and the observation, that for linear events, the prediction coefficients for a particular frequency at half the trace spacing are the same as the prediction coefficients at half the frequency of the original trace spacing. The prediction coefficients are then used to find the amplitudes of the interpolated traces using a least squares inversion scheme. Figure 1 shows a cross-line from a 3-D seismic survey before and after interpolation. Note how the technique has been able to interpolate the steeply dipping aliased diffractions.

Another area where interpolation has made a difference is to fill in empty bins for marine 3-D surveys. Marine 3-D data typically suffers from incomplete offset distributions in some bins; this has traditionally been remedied by the use of flex-binning, where the spatial extent of empty bins is expanded to ensure a full complement of offsets. This 'borrowing' of traces is typically done without any structural considerations and in areas with dipping geology this is not appropriate. An alternative, and better, approach is to organize the data into common offset cubes and perform trace interpolation using traces on both sides of the empty bins. Figure 2 compares the two methods of empty bin filling; note the dipping events in the lower left-hand corner.

Fig. 1. Cross-line before and after f-x-interpolation with Spitz's technique.

Modern marine 3-D data are often acquired with coarse shot spacings giving low fold and aliased gathers which can present multiple elimination techniques (see below) with problems. Interpolation in both the receiver and the mid-point domains (see Jakubowicz, 1994) help in reducing this problem.

Multiple attenuation

The improvement of our understanding of multiples was probably the biggest advance in the 90s, although we are some way from realising all the attendant benefits. Maybe the most significant development has been the realisation that, as decendants of primaries, multiples can be predicted directly from the data, without a subsurface model, as used in the free surface multiple attenuation technique. It is now also realised that sampling is an issue for multiple removal, particularly in the CMP domain, and that interpolation can make otherwise modest algorithms perform to their full potential.

Multiple attenuation based on the discrete parabolic *Radon Transform* (Hampson, 1986) became the de facto standard technique. This has better primary-multiple separation characteristics than the F-K technique used earlier. A common use of the parabolic multiple attenuation technique is to transform the data to the

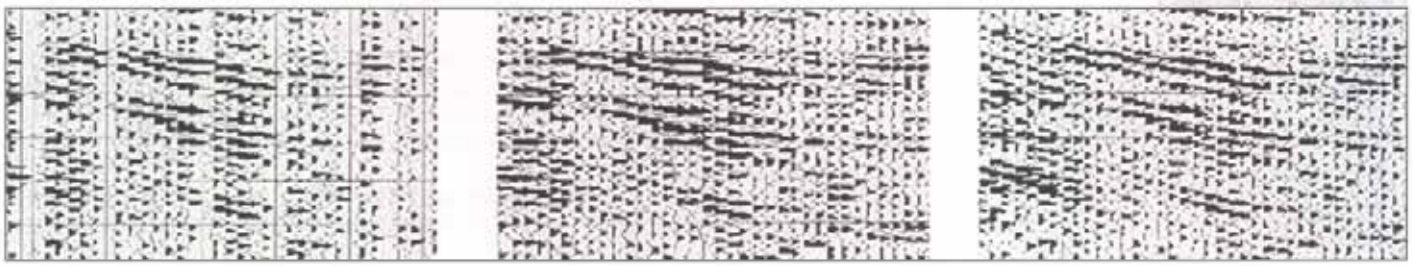


Fig. 2. Cross-line with empty bins, with empty bins filled with flex-binning, and bins filled with interpolation.

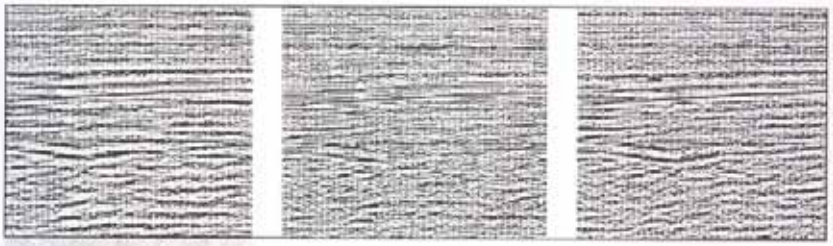


Fig. 3. Comparison of multiple elimination techniques. On the left is a stack without multiple elimination. In the middle is a stack with the F-K multiple elimination method and on the right is a stack with the parabolic multiple elimination method applied.

parabolic 'Tau-q' (where q is a measure of the curvature) domain, blank the primary data, transform back, and subtract from the original data. This has proved to be a robust and effective way of attenuating multiples where the multiples exhibit different curvature from the primaries. Figure 3 compares sections with no multiple attenuation, with F-K and radon transform methods. The radon section (far right) shows better attenuation of multiples and less degradation of primaries compared to the F-K section in the middle.

The *free surface multiple attenuation (SMA)* technique, first developed in a 1-D formulation by Riley and Claerbout (1976), has been extended to 2-D and heavily researched since the late 80s (e.g. Verschuur et al., 1988). The principle of the SMA technique is that multiples can be predicted directly from the data without the need for a subsurface model and there is furthermore no requirement of primary-multiple separability as in the Radon Transform technique. The theory of the SMA technique is very elegant and provides for the attenuation of all multiples with more than one reflection at the water-air interface. However, a practical and robust implementation has proven to be more troublesome, and as such SMA is not yet a mainstream production technique.

Imaging

In general, the 90s saw a gradual trend towards more comprehensive (prestack) imaging methods, partly because computational costs became less of a consideration, and partly because of the intrinsic linkage between imaging and velocity estimation. Thus, because velocities are inherently obtained from prestack data, imaging is increasingly performed prestack (or at least partially so). Furthermore, the progression from NMO or NMO+DMO to NMO+DMO+prestack migration, or simply prestack migration (time or depth), is also dictated by the types of velocity variations we encounter, and this has in turn been dictated by the types of targets we have moved towards (e.g. subsalt plays).

Dip Move-Out (DMO) saw some improvements, mainly to do with sampling and its effects on the amplitudes after DMO-stack. Beasley's (1992) technique of Equalised DMO gives better amplitudes by taking into account the acquisition sampling while his 'Fat DMO' technique (1997) handles the output binning of the DMO-operator in a more optimum way. The requirements and problems in application of DMO for land data and single cross-spread gathers in particular was studied and highlighted by Vermeer et al. (1995). Several solutions to this problem were suggested, see for example Cooper et al. (1996).

Pre-stack time migration (PSTM) became more prevalent during the decade, initially, mainly, for 2-D data and later also for 3-D data. The cascade of NMO+DMO+Zero Offset Migration(ZOM) is an efficient way to apply PSTM (Marcoux et. al., 1987) and could at the later part of the decade be used for very large 3-D surveys. The cascaded implementation above of PSTM is strictly valid only for constant velocity (but works reasonably well in practice for mild velocity variations). As computational speed increased the more accurate, but much more compute intensive, full pre-stack Kirchhoff time migration technique came into production use at the end of the decade.

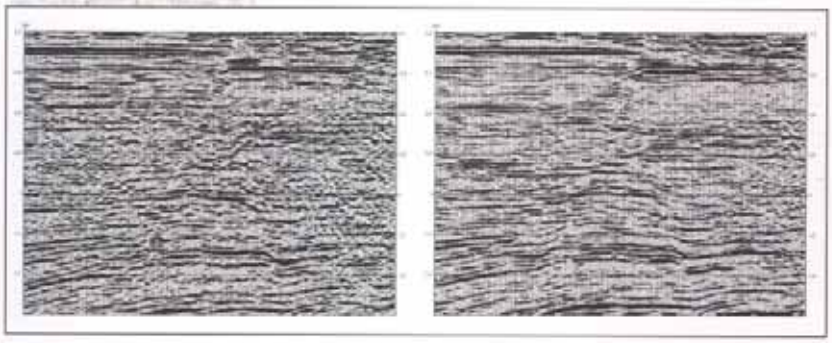
Before the early 90s *3-D post-stack migration* was carried out as a 2-pass operation, where standard 2-D migration was first performed along one direction and then in the other. The main reason for this implementation was limited computer disk and memory storage space. The 2-pass technique is an approximation strictly valid only for constant velocity. With more abundant disk and memory space available the one-pass technique became the preferred option. The first 1-pass migration implementations used a splitting technique allowing 2-D downward continuation algorithms to be used. 1-pass 3-D migration using the splitting technique can be implemented very efficiently but results in an azimuthally anisotropic, migration operator but later, 'true' one-pass algorithms were developed (e.g. Hale, 1991 and Notfors, 1995). Figure 5 compares impulse responses from algorithms using the splitting approximation and a true one-pass implementation.

Pre-stack depth migration (PSDM), 'the ultimate' imaging tool came into main stream use during the 90s. PSDM for 2-D data was already in use by the early to mid 80s using wave-equation downward continuation algorithms. The wave-equation algorithms perform implicit mixing across the offset axis, this means that these algorithms are very sensitive to errors in the velocity model used for the migration. Mainly because of this fact and the development of fast travel-time computation algorithms, like the Vidale (1989) finite difference method or Gray's ray-tracing technique (1986), common offset methods using ray-trace based Kirchhoff algorithms came into use. Later, as 3-D PSDM came into widespread use, the Kirchhoff based algorithms became even more important as they were the only ones that could be used economically.

The ray-tracing algorithms used for the Kirchhoff migrations saw developments from the Vidale first arrival to the more correct (for migration use) maximum energy and shortest path algorithms. Other variations of Kirchhoff migration that use all the branches of the traveltime field, such as Gaussian beam migration, have been in limited use for some time.

Velocity model building for depth migration was mainly performed with the vertical updating technique also

Fig. 4. Comparison of pre-stack migration methods. Left shows the stack after migration with the cascaded method (NMO+DMO+ZOM). Right shows the stack after Kirchhoff full pre-stack time migration. Note less noisy appearance and better lateral resolution off the latter.



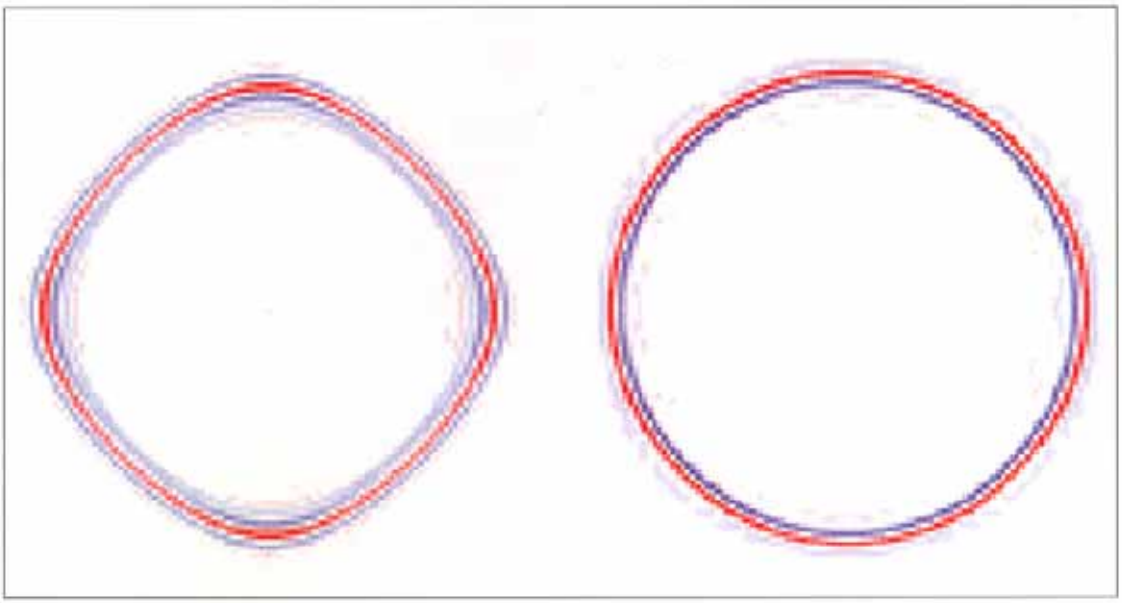


Fig. 5. Impulse responses from algorithms using the splitting approximation and a true one-pass implementation. Note azimuthal anisotropy introduced by the splitting approximation while the more accurate "true" one pass algorithm is closer to the ideal, circular response.

known as the Deregowski loop (1992). In the vertical updating technique, PSDM is performed with the common offset approach using an initial velocity model. The resulting depth migrated gathers are then analysed for residual curvature and the velocity model updated accordingly at the *vertical location of that gather*. The technique is often applied in a top-down fashion, starting with shallow layers, keeping these constant as successively deeper layers were analysed. The vertical updating technique is an approximation (that works reasonably well in practice), and a more accurate method using the tomographic approach came into some use by the end of the decade. The principle of tomography is to compare travel-times picked from the data with travel-times obtained by ray-tracing through the velocity model. The velocity model is then updated, based on the errors between these travel-times, and the procedure repeated until a close match is found, see Bishop et al., (1985) and Whiting (1998).

Figure 6 compares time and depth migration for the same data-set as of Figure 4, with the depth migration section stretched back to time. The velocity model for the depth migration was constructed using a tomographic technique. The depth migration section shows better continuity for several events, note for example the event at 0.8 s on the right hand side.

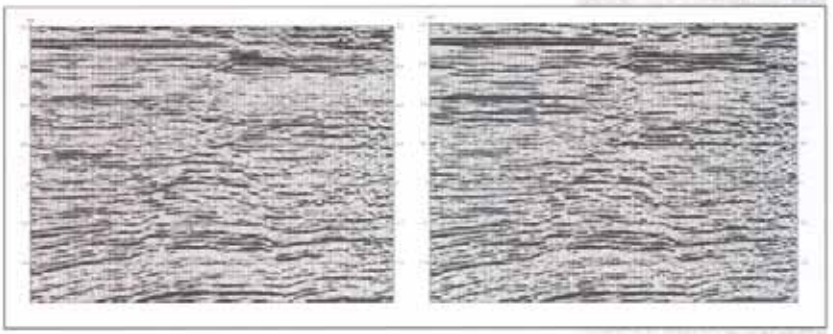


Fig. 6. Pre-stack time (left) and depth migration comparison. The velocity model for the depth migration was built using a tomographic approach.

Other advances

The above-mentioned areas of improvements have been used in production processing on large volumes of data. Of course, there has been much development that has not seen main stream production usage. Here I mention some of these developments.

4-D seismic is a term used to describe the procedure where 3-D surveys are repeatedly acquired and processed over the same area. By analyzing the differences between two of the surveys information regarding reservoir depletion can be gained.

Towards the end of the decade there has been an increase in the interest of acquiring and processing *converted wave seismic* over areas where conventional p-wave seismic have problems with penetration, such as in gas-cloud areas.

Seismic processing has generally assumed the Earth is isotropic, i.e. the speed of seismic waves is independent of propagation direction. It is well known that in the 'real Earth' this is not the case. Much research into imaging algorithms that handle anisotropy was conducted during the decade, and at the end of it some of this research was making its way into limited quantities of production processing.

Processing tools

The tools available for processing geophysicists have improved dramatically. In the early 90s most processing geophysicists had only alpha-numeric terminals available and had to use paper-plots for analysis and quality control (QC) purposes. With the availability of inexpensive and powerful graphic workstations, having powerful interactive analysis software, the processing procedures have been much simplified and have improved the efficiency of processing personnel. Velocity picking and QC of large 3-D surveys is now, typically, performed interactively on a workstation. Large 3-Ds can now also be displayed in vision centres, with very powerful graphics computers, on cinema size screens allowing rapid scrolling through data-cubes.

Acknowledgements

I acknowledge input and constructive criticism from several of my colleagues at Veritas.

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Acquisition and Processing of Single Sensor Seismic Data

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Abstract

Surface seismic data are normally acquired using arrays of receivers, each array forms a group, which is recorded into a single seismic channel. Two of the main drawbacks of conventional analog arrays are that the outputs of each receiver element are simply summed without any pre-processing and that the spatial sampling is fixed at the survey design stage. A new acquisition system has been developed which can record up to 30,000 channels so each component of the array can be digitised and recorded individually, this is called single sensor recording. The system consists of the acquisition hardware and a suite of software tools for processing the data. Single sensor data will yield improved data quality as improved noise attenuation results from the process of digital group forming (DGF). In addition, eliminating intra-array static variations retains high frequencies lost when statics are averaged in conventional analog arrays. DGF also allows greater flexibility in the processing centre. Output sampling may be varied during processing so different processing schemes can be employed for different temporal and spatial parts of the survey. In a single survey, shot to image multiple targets, the workflow can be optimised for each target. The new system moves us a step closer to decoupling the geophysics of the imaging process from the acquisition hardware and reduces the levels of noise and distortion, which limit the bandwidth of seismic data.

Introduction

The current method of acquiring seismic data involves the deployment of groups of hydrophones or geophones. In the case of land acquisition, receivers are laid out in a regular pattern over the survey area; in marine acquisition they are towed behind the recording vessel. Normal practice has been to form receiver groups by connecting the outputs of individual receiver elements, however there are drawbacks associated with the nature of the analog array. The outputs of these elements are simply summed without any processing applied, as the group forming is hard-wired in the acquisition system. The ideal would be to record each individual receiver element into its own seismic channel (single sensor recording) so that a dense grid of receivers samples the entire wavefield alias free, however, this has been prohibited by cost and equipment limitations. The Q-Land seismic acquisition and processing system recently launched by Schlumberger has increased the number of channels which can be recorded by an order of magnitude, so making it possible to record up to 30,000 channels. The concept and potential advantages of single sensor recording are not new, as limited acquisition experiments using single sensors have been carried out in the past. However, the use of this technique has previously been prohibitively expensive, and impossible for the large areal layouts common in modern 3D surveys.

The system capable of acquiring single sensor data not only consists of the acquisition hardware but also of a toolbox of geophysical software for pre-processing of the data. This allows sophisticated methods of group forming that offer the potential to deliver higher quality data than was previously available. The principles behind the group forming processes and the advantages of recording individual receivers are the subject of this article.

Concepts

Some of the main advantages and processes involved in single sensor recording are specific to the land acquisition situation, while others cover both marine and land environments. The recording and digitising of single sensor data remove some of the inadequacies in conventional methods of recording and processing:

Wavenumber response:

Receiver arrays are used as wavenumber filters to remove unwanted energy such as surface waves in land acquisition. As these surface waves generally have much lower measured velocities than reflection events at any frequency, the noise wavelengths must be shorter and their wavenumbers greater. So, in theory, for any desired frequency, noise may be suppressed by the application of an appropriate wavenumber filter. It is a simple case of shooting some noise spreads to determine the velocity and dominant wavelength of the noise and group the detectors into linear arrays of length equal to this wavelength. The array will then have a rejection notch at the noise wavelength, leaving a signal only shot record. In reality the situation is not as simple as this: although signal and noise are separable at any given frequency, over the entire seismic bandwidth signal and noise wavenumbers overlap, therefore an unwanted effect is that we may notch signal at higher frequencies. This may become severe where dipping reflectors are present and depends on whether shooting is updip or downdip (Ongkichong and Askin, 1987). Small errors in geophone coupling and positioning will also compromise the performance of the array (Newman and Mahony, 1973). In addition, arrays have a sinc-type wavenumber response, which has side lobes and does not have a desirable passband shape.

The new generation of acquisition systems will enable improvement on the conventional array by digital group forming (DGF). Assuming the wavefield is adequately sampled, any time and/or frequency dependent wavenumber response can be applied. This will allow better separation of signal and noise and the removal of noise without adversely affecting the signal.

Perturbations:

Land seismic data may contain a significant component of intra-array statics as individual geophones in the array can have different elevations, coupling and residual moveout (see Figure 1). A simple sum of all the geophones in the array gives an averaged static value, however, with single sensor data each trace can be corrected individually.

Higher frequencies are usually lost within a conventional array due to the smearing effect of the perturbations; therefore single sensor recording retains the higher frequencies in the data.

Output sampling:

In conventional recording the output sampling is fixed at the point of survey design, thus limiting the options at the processing stage. In single sensor recording grouping is variable and may even be varied during processing. Schemes, which include space and time variant binning, become available to the processor.

Group forming

At some stage in the acquisition and processing chain the volume of single sensor data will be reduced by digital group forming (DGF). The type and complexity of the pre-processing of the raw data will depend on where in the chain the DGF occurs. Figure 2 shows a comparison between a conventional field system and one where DGF occurs in the field. Group forming may be achieved using different options:

- Receiver outputs are grouped in a field station unit/digitising unit. This has the advantage of reduced data rates over the field network but lacks flexibility as it assumes prior knowledge of group forming parameters.

- Group forming in the recording truck/instrument room. All single sensor data are transmitted to the central acquisition system. The group forming may not necessarily be done in real time, but as an offline process when parameters and field conditions have been established. This is more flexible than the previous case as parameters may be changed to allow for varying conditions affecting data quality, such as weather or terrain.

- Group forming in the data processing centre. This is the most flexible of all applications as it is one channel per receiver – the logical ultimate goal (Ongkiehong, 1988). Bin size parameters can be varied during processing to deliver multiple datasets, each optimised for a different target depth. The price paid for the increase in flexibility is a large increase in the amount of data being handled in the field and the processing centre.

Data examples

In Figure 3 the left hand shot gather is recorded at 30 m intervals with a fairly large analog array, whereas the right hand shot gather is recorded at 5 m intervals, with one single geophone every 5 m. There are two small sand dunes on the spread, which cannot really be seen on the analog gather. In addition, the ground roll is aliased on the left but well sampled on the right, which enables better attenuation. Figure 4 shows data recorded using analog arrays (left), which shows aliased groundroll. The groundroll has been attenuated using DGF (right).

Conclusions

The new generation of seismic acquisition systems offers the potential to improve data quality dramatically,

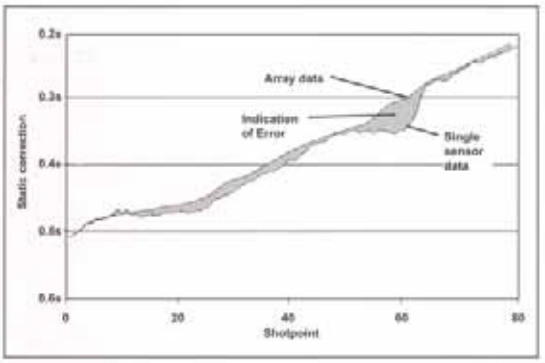

Fig. 1. Static errors cannot be deconvolved when data are summed before static corrections are applied. Single-sensor data can be corrected before processing.

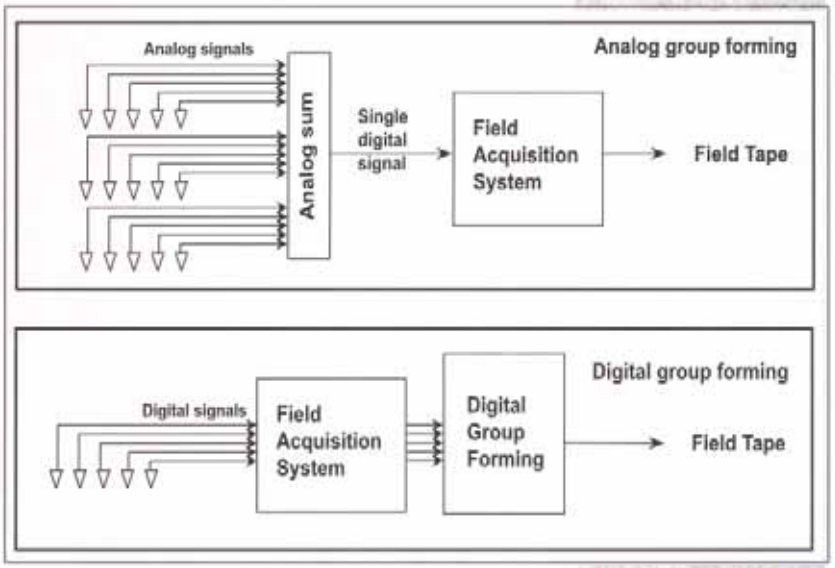

Fig. 2. A comparison between the conventional and point receiver acquisition techniques. Top: The conventional way of seismic acquisition, with analog group forming applied in the field using geophone arrays. Bottom: The proposed method of acquiring point receiver data, with group forming applied by a Digital Group Forming process.

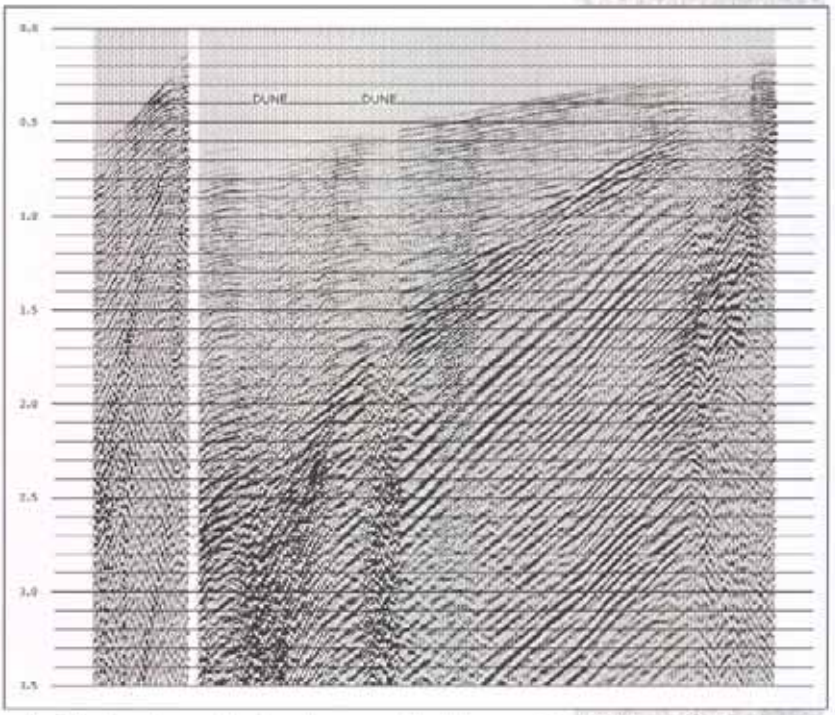

Fig. 3. Shot records recorded with analog arrays with a 30 m group interval (left) and with single sensors spaced at 5 m (right).

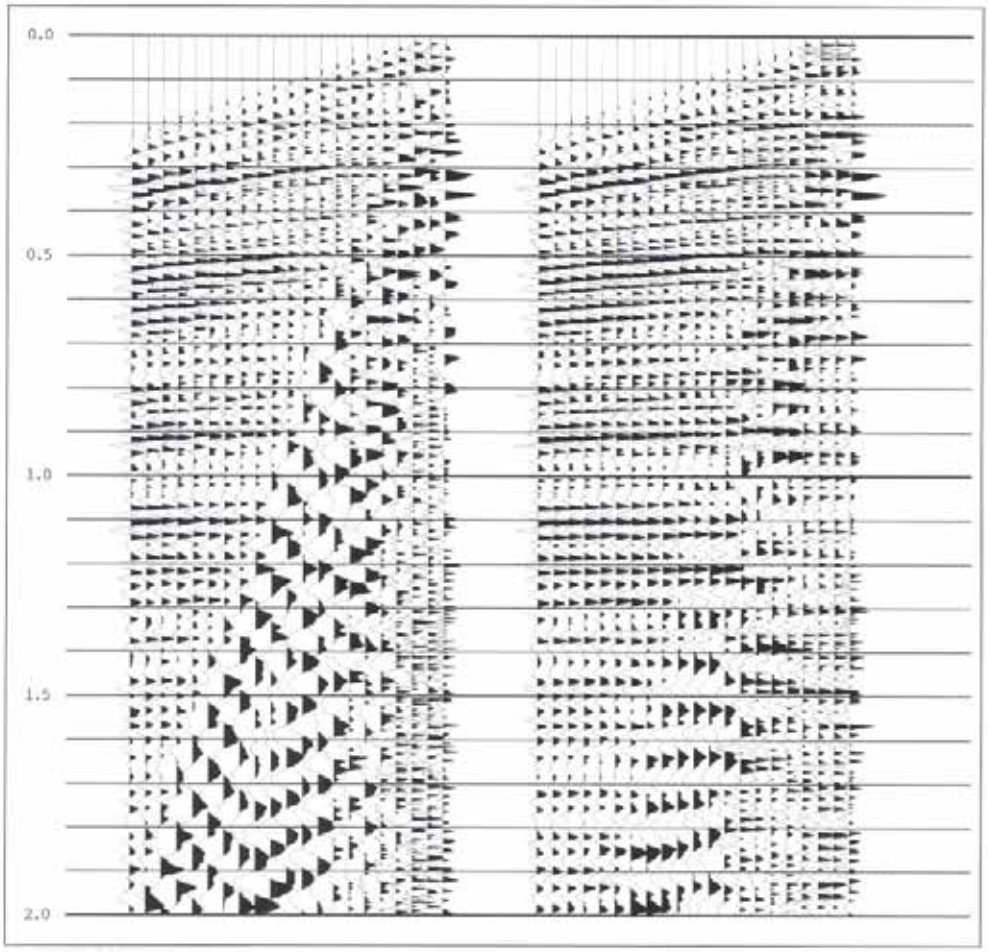

Fig. 4. Shot record recorded using analog arrays (left) and using single sensors (right). DGF has been carried out to attenuate groundroll.

particularly in traditionally poor data areas. The digital group forming process and the flexibility it provides offers many advantages over conventional hard-wired group forming. An example of this is in areas where extreme statics variations degrade data quality. In marine acquisition there is the potential to increase production rates by being able to shoot when weather conditions would have previously stopped operations.

If group forming is done in the data processing centre and one channel per receiver is recorded on field tapes, the resolution of the processed image can be varied to improve S/N and enhance resolution as required. This means that the geophysics of the imaging process has effectively been de-coupled from the acquisition hardware - the acquisition system does not dictate the sampling interval. Using this technology it is now possible to record 'uncommitted' data to tape. Another potential bonus of single sensor recording is improved repeatability due to more accurate recording of the wavefield. This will aid in the use of 4D (time-lapse) seismic data to map fluid movement within the reservoir over time.

The ideal land recording pattern would consist of sources and receivers arranged in a dense areal pattern across the whole survey area, which would result in alias free recording of the entire wavefield. This is likely to remain impossible due to logistical and cost constraints; however, single sensor recording permits the recording of a 'compromise geometry': alias-free recording of cross-spreads using orthogonal geometry (Vermeer, 1990, 1998). In this way it is possible to reduce the perennial problems of seismic data - noise and distortion, which limit the seismic bandwidth. The actual level of improvement in data quality remains to be seen as projects using the new technology are just commencing. However, the technology is certain to make an impact on the market and is likely to be the way that most seismic acquisition systems will go in the future.

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Using Seismic Attributes

Written by:
Mick Micenko

The basic seismic attributes such as amplitude, frequency and phase and their many derivatives are useful tools for defining the extent of hydrocarbon reservoirs. In the early life of a field there is very little well control and it is easy to produce a straight line function linking a seismic attribute to a particular reservoir property. For instance, a seismic amplitude map is often translated directly into a nett pay map and this is then used to model the reservoir or plan further development. But is this correct?

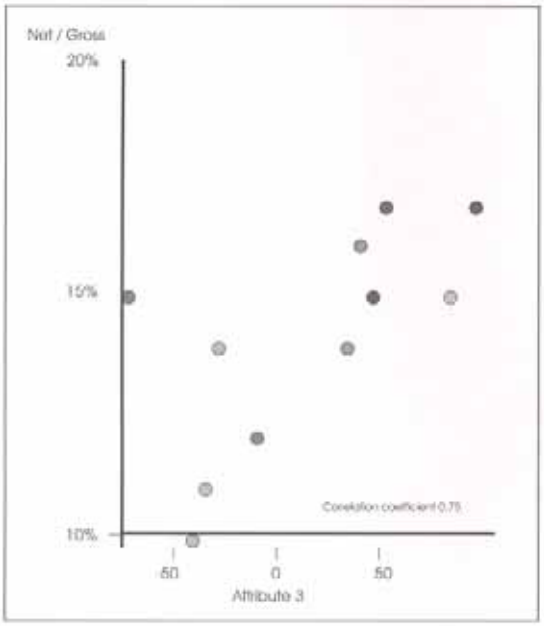

Fig.1. Cross plot of reservoir net/gross versus seismic attribute 3. A number of attributes can be calculated from seismic data with varying correlation to the reservoir attribute of interest. Often no obvious correlation exists. The small discs represent the locations of production wells in the same field.

Figure 1 shows a plot of reservoir net sand/gross reservoir thickness versus a seismic attribute (average instantaneous phase) for a small field with 11 wells in the vicinity. The instantaneous phase of a seismic trace is calculated at each sample point and the average value is calculated for all points within a window that straddles the reservoir.

The data points show a general linear trend and a linear function could be derived to describe the general trend. Figure 2 is a map of the seismic attribute over the field and surrounding area and could be used to describe the net/gross distribution of the reservoir.

The coefficient of correlation between the well and seismic data is reasonably high at 0.75. If I remember my statistics correctly, this means that the net/gross calculated using this seismic attribute has only a 55% (0.75 x 0.75) chance of being correct. From my experience, this is a good correlation.

It is not uncommon to have correlation coefficients of 0.6 (36% probability of being correct) or less. A low correlation could be due to noisy seismic data, variations in geology around the reservoir interval of interest, a poor selection of seismic or reservoir attributes or some other reason. With such a low correlation between seismic and reservoir attributes a different way to model the reservoir is needed that takes into account some of the uncertainty. Stochastic reservoir modelling based on seismic attribute information and well data is a useful tool for dealing with this uncertainty.

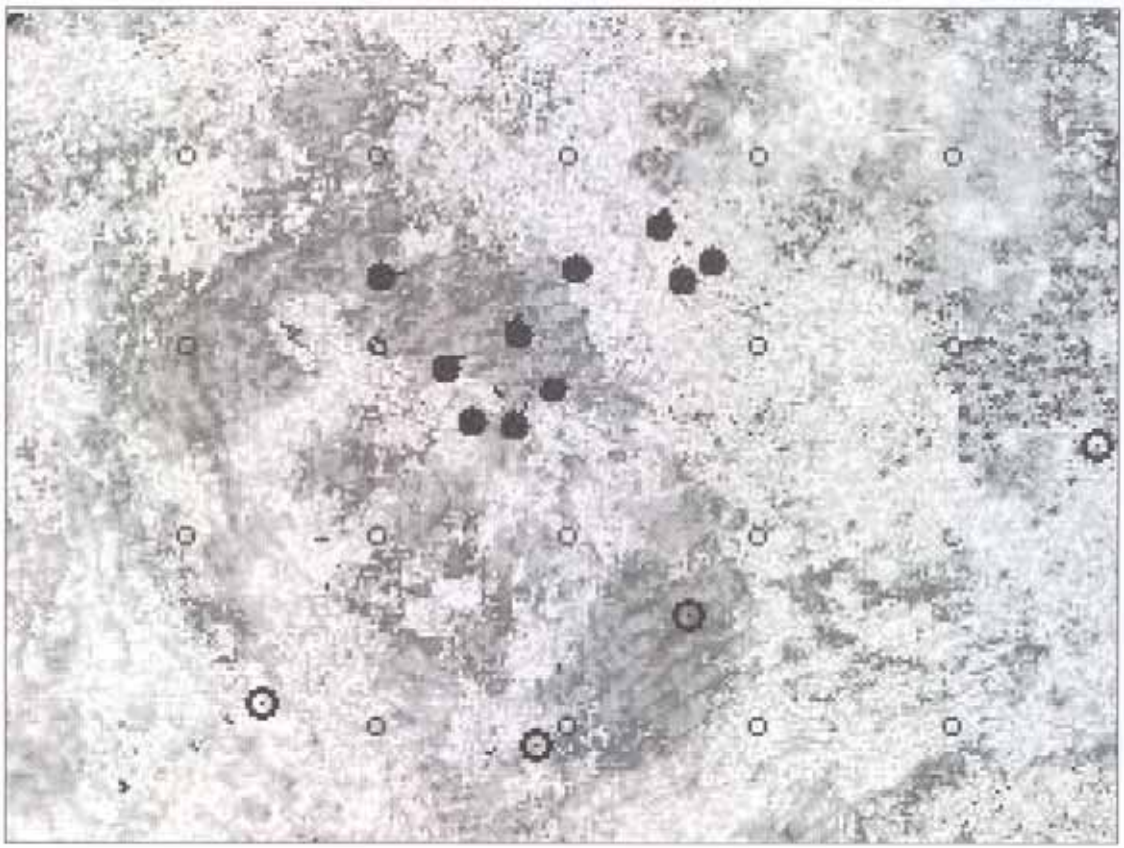

Fig. 2. Seismic attribute 3 derived from 3D seismic across of producing field area. Low amplitude areas (light) correlate with poor reservoir net/gross while dark areas correlate with good reservoir net/gross ratio. The image is about 10 km across.

Mapping Australian Geology Under Cover: a Case Study Applied to the Boulia and Springvale 1:250 000 Map Sheets, Queensland

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Keywords

Boulia, Springvale, Mount Isa Inlier, Georgina Basin, aeromagnetic, gravity, interpretation

This paper is based on a presention at the 13th International Geophysics Conference and Exhibition of the ASEG, Hobart, November 1998.

Abstract

An interpretation of aeromagnetic, gravity, outcrop geology and drill hole information for the Boulia and Springvale 1:250 000 Sheet areas, Queensland, maps out units of the prospective Mount Isa Inlier, where they plunge southward beneath the flat lying Georgina Basin. Over 95% of the Proterozoic Mount Isa Inlier in the area is under the Cambrian Georgina Basin sediments.

A methodology was developed for geological interpretation of airborne geophysical data, which could be used as a basis for other regional geological studies. The methodology makes use of GIS and image processing software to integrate all available geoscientific information into a single environment. It significantly reduces the time required to analyse and interpret regional geoscience data-sets.

Calculations of depth to magnetic basement show that much of the prospective Mount Isa Inlier in the north of the area is less than 300 m below the surface, while the thickness of the covering Georgina Basin is as much as 3400 m in the south. Prospectivity for both mineral and hydrocarbon resources is high in the study area.

Previously unknown volcanic units were identified within the Georgina Basin sediments. In addition, the interpretation identified a series of intrusive features that appear to have traversed the Georgina Basin section so that their tops are close to the present day land surface. These intrusions have dimensions and characteristics similar to kimberlite pipes.

Introduction

This study aimed to map the continuation of the Early to Middle Proterozoic Mt Isa Inlier southwards under the cover of subhorizontal sedimentary rocks of the Cambrian Georgina Basin. The study area (~150 x 200 km) is in western Queensland, south of Mt Isa (Figure 1). It contains the southern-most outcrops of the Mt Isa Inlier in its northern-most 10 km. Cambrian and younger rocks overlie the continuation along strike of the Proterozoic rocks south of this.

The Australian Geological Survey Organisation (AGSO) carried out an airborne geophysical survey of the Boulia and Springvale 1:250 000 Map Sheet areas, during 1996. The survey was flown on east-west flight lines, spaced 400 m apart and flown 80 m above ground level. Magnetic, radiometric and digital elevation model data were acquired (Brodie, 1999), with the magnetic data being the primary data used in the interpretation.

Other data used in the interpretation included:

- Bouguer gravity data from the "Gravity Anomaly Map of the Australian Region" (2.5 km grid cell size, based on 11 km station spacing) (Murray, et al., 1997).
- Digital geology - the 1:500 000 scale "Geology of The Mt Isa Inlier and Environs" (Blake, 1987) had been digitised by AGSO. A 1:250 000 scale "Geology of the Duchess-Urandangi Region" (Blake, 1983) map was also used.
- Water bore drill logs (BMR, 1960).

The rocks of the Mt Isa Inlier are folded and faulted sedimentary and igneous units, intruded by several mafic and granitic bodies, with a dominant north-south structural trend. Metamorphism has occurred regionally to greenschist through amphibolite levels, generally increasing in grade to the east. Most units dip steeply to the east. The study area contains the continuation, along strike, of three major tectonic divisions of the Inlier: the Western Fold Belt, the Kalkadoon-Leichhardt Belt and the Eastern Fold Belt (Figure 1). Currently known gold and base metal mineralisation occur mainly in the Western and Eastern Fold Belts (Blake, et al., 1990).

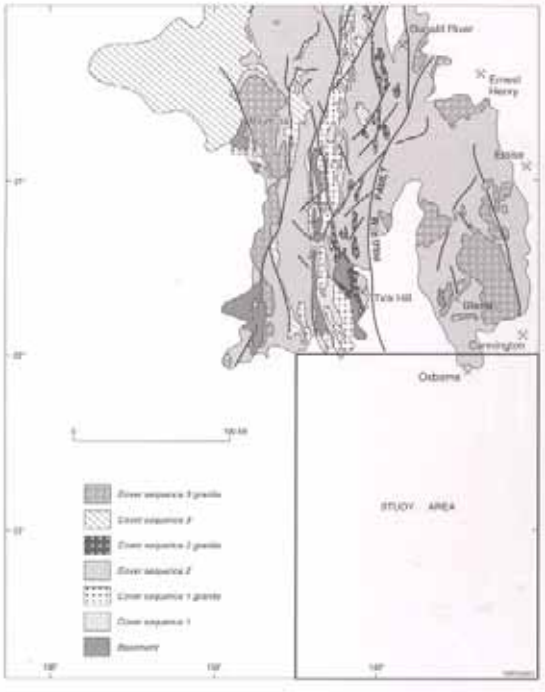

Fig. 1. Regional geological setting.

The Western Fold Belt is subdivided into the Lawn Hill Platform, Leichhardt River Fault Trough, Myally Shelf and Ewen Block. In the study area, rocks of the Leichhardt River Fault Trough dominate the stratigraphy of this Belt. The Kalkadoon-Leichhardt Belt comprises the Kalkadoon-Leichhardt Block and the Blockdale Block. The Eastern Fold Belt contains the Mary Kathleen, Quamby-Malbon and Cloncurry-Selwyn zones (Blake, 1987). Parts of all of these three zones are found in the study area.

As well as being subdivided spatially, the Mt Isa Inlier can be subdivided stratigraphically. The oldest rocks in the sequence are known as the basement and were deformed and metamorphosed before the oldest cover rocks were laid down. The basement rocks are older than 1875 Ma; the only unit in the interpretation from this group is the Plum Mountain Gneiss. The oldest cover sequence is cover sequence 1, which comprises the Leichhardt Volcanics and parts of the Tewinga Group. Cover sequence 1 is only found in the Kalkadoon-Leichhardt Block in the study area. The next oldest sequence is cover sequence 2, which is far more widespread. It occurs in all three tectonic divisions and consists of the majority of the units interpreted in the study area, excluding those listed as parts of the other sequences. Cover sequence 3 contains the youngest Proterozoic rocks of the Inlier. It includes the Mt Isa Group, which outcrops just to the north of (but is interpreted to not continue into) the study area. The cover sequences and their relationship to the broad tectonic divisions described above are illustrated in Figure 1.

The only current mining operation in the study area is the Osborne Cu-Au deposit (Davidson, et al., 1990), located in the northeast corner. The Mt Isa Inlier immediately north of the study area contains numerous world-class copper, lead, zinc and silver deposits. It has also produced substantial amounts of gold, uranium and cobalt (Blake, 1987). In the Georgina Basin, phosphate deposits have been mined and it is also a target for petroleum exploration.

Interpretation Methodology

A methodology for the routine geological interpretation of airborne geophysical datasets was developed (see Figure 2). After a literature review and collation of all relevant datasets, the interpretation was carried out digitally using a geographic information system (GIS). In this case, the GIS used was ArcInfo. The GIS was used primarily as a digital 'light table' to easily overlay datasets to quickly and accurately test for correlations between datasets. Interpretation lines and polygons were drawn directly into the GIS. Geophysical transformations were made in *Intrepid*, while *ER Mapper* was used for the image processing. The hardware used was a Unix workstation with dual head monitors.

Several enhancements (Milligan & Gunn, 1997) of the geophysical and geological data were prepared for inclusion in the GIS. Those images produced for this study include:

- *TMI (RTP), colour.* To compare the amplitude of anomalies, without any asymmetry introduced by sun angle enhancements.
- *First vertical derivative of TMI (RTP), greyscale.* To define high-frequency anomalies in the dataset.
- *First vertical derivative of TMI (RTP), with northeast illumination, colour.* Also used to define high-frequency anomalies in the dataset. It also provided clear definition of separate bodies that produced single broad TMI anomalies.
- *Total magnetic intensity (TMI) reduced to the pole (RTP), with east-west illumination of its first vertical derivative,* colour (Figure 3). To present an overall view of the magnetic data, with an acceptable compromise between displaying long and short wavelength information.
- *Automatic gain control of first vertical derivative of TMI (RTP), greyscale.* To present the short wavelength anomalies in the magnetic data; especially the circular bullseye anomalies interpreted as intrusive pipes.

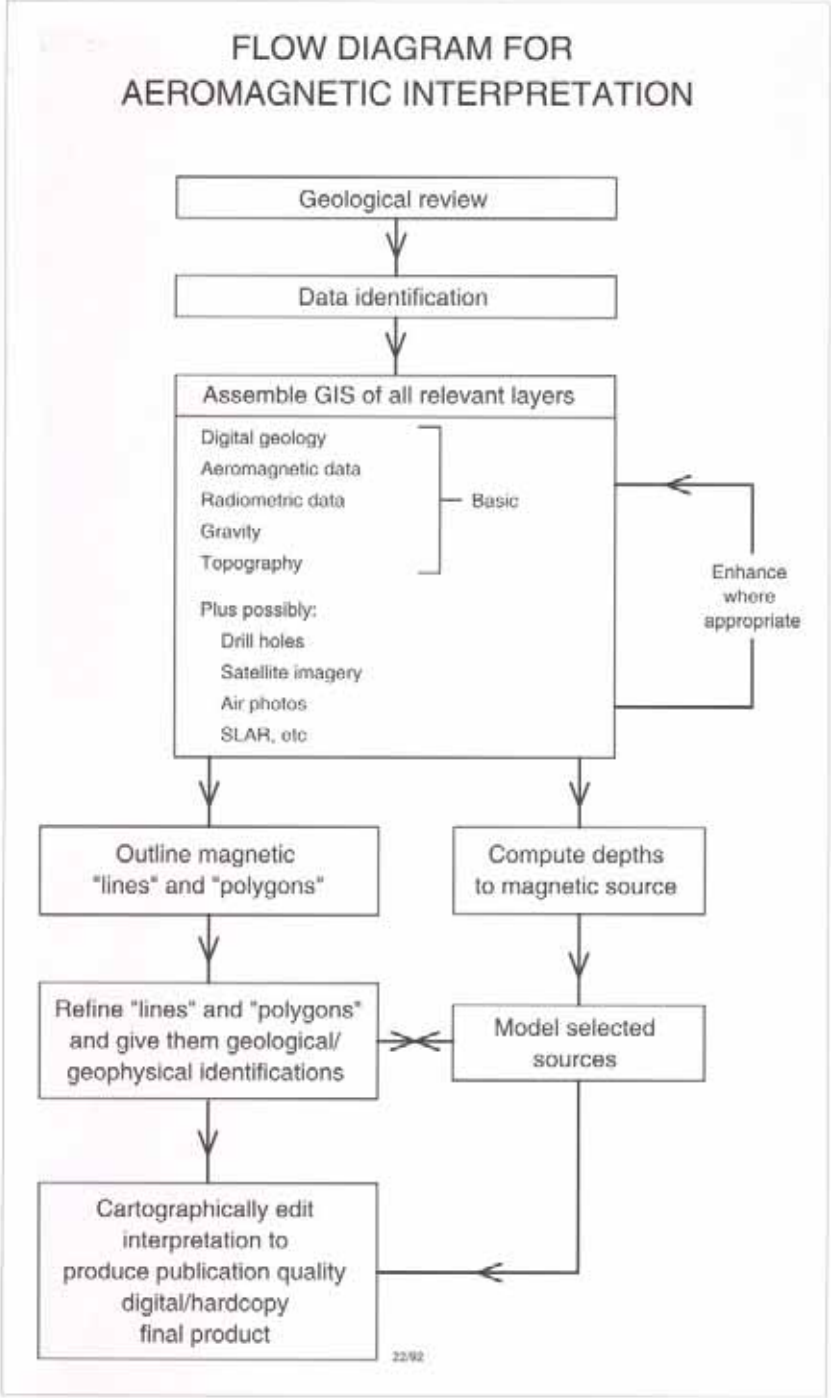

Fig. 2: Flow diagram for aeromagnetic interpretation.

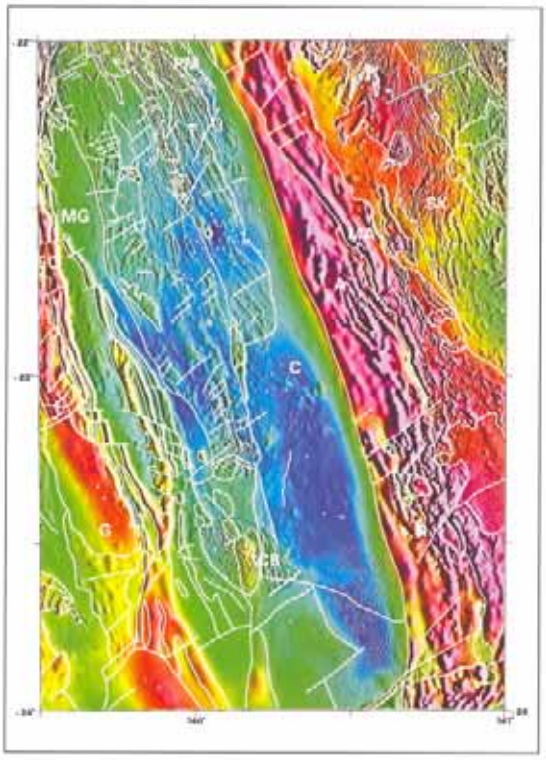

Fig. 3. Total magnetic intensity, reduced to the pole with east-west illumination. Magenta high, blue low colour palette.

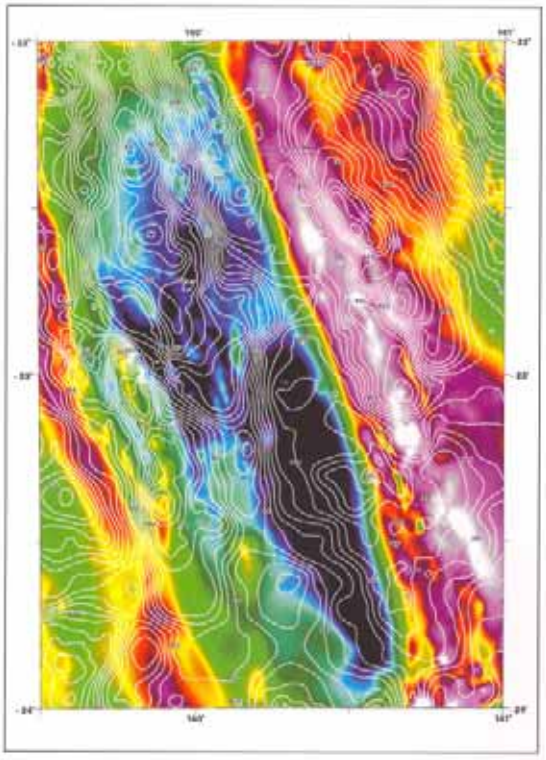

Fig. 4. Total magnetic intensity, upward continued 1000 m, with 20 μms⁻² gravity contours. Magenta high, blue low colour palette.

- *TMI (RTP) upward continued 1000 m, colour.* To present the long wavelength anomalies in the magnetic data. This image is shown in Figure 4, with 20μms⁻² gravity contours superimposed.
- *Potassium (red), Thorium (green), Uranium (blue) RGB colour composite of gamma-ray spectrometric data.* The thickness of cover prevented any response from the Proterozoic basement. Most radiometric anomalies appeared to be caused by alluvial sediments.
- *Digital Elevation Model, with easterly illumination, colour.* To check the topographic controls on the radiometric anomalies.
- *Bouguer gravity, colour.* Used, with gravity contours (Figure 4) to assess the gravity data.

The interpretation started by producing a "magnetic source map" based on the aeromagnetic survey data. The outlines of magnetic sources were estimated using the known shapes of anomalies arising from simple model (e.g. dipping dyke, vertical cylinder) sources. Geological identifications were assigned, where possible, to the magnetic sources and structure and distribution of non-magnetic units was inferred. Ancillary information such as outcrop geology, drill information and gravity data, plus geological reasoning based on the texture and amplitudes of the magnetic anomalies was used. Structural information (faults, folds, etc.) was deduced from the geometric shapes and relationships of sources and known deformation of correlated units to the north.

Depth to magnetic basement

As approximately 95% of the Proterozoic rocks in the area are under cover, it is important for mineral exploration to know the thickness of this cover. The overlying Cambrian Georgina Basin sediments are prospective for hydrocarbon resources, so knowledge of the thickness of these sediments is important for hydrocarbon exploration. Depth to magnetic source maps for the area, generated as part of this project, were published by Meixner, (1997a, 1997b).

Encom Technology's Automag, software was used to calculate depth to magnetic sources. This is based on Naudy's (1971) method as modified by Shi (1991), and operates on magnetic profile data. A window is moved along the profile and a comparison is made of the calculated anomaly from a dipping tabular source for a range of physical properties with the measured magnetic field. Solutions with sufficiently close comparisons are kept.

The method makes some assumptions, which must be catered for. The modelled body is assumed to have an infinite strike extent, which is valid when the body has a large strike extent in relation to its depth. The profile is also assumed to pass over the centre - and be perpendicular to - the strike of the body. Solutions are then forward-modelled. This forward model is compared with the profile to check the reliability of the solution. Poor solutions are rejected and a strike correction is applied for bodies that do not strike perpendicular to the profile. The final solutions are then gridded to produce a continuous surface. In the case of local discontinuities in depth to source (e.g. displacement across a fault), this surface may be inaccurate. It should be noted that this surface is the depth to magnetic sources, which is interpreted to approximate the thickness of the overlying non-magnetic Cambrian sediments.

Significant areas were calculated as having less than 300 m of cover rocks over the Proterozoic basement. The thickness of the Georgina Basin sediments in the south of the area was greater than 3400 m. Comparison of the solutions with petroleum and water bore drilling results was extremely favourable - the calculated solutions were within 10% of the drilling results where these intersected crystalline basement.

Overview of Geophysical Data

The magnetic data for the study area (Figure 3) can be divided into three broad north-south oriented regions. Two high magnetic intensity regions flank a central region of generally lower total magnetic intensity. This central area is the Kalkadoon-Leichhardt Belt, and the two higher magnetic intensity regions are the Western and Eastern Fold Belts. As shown in Figure 4, the Kalkadoon-Leichhardt Belt is generally associated with low amplitude gravity values.

Interpreted Geology

A simplified view of the interpreted geology is shown in Figure 5. More detailed maps were published by Mackey et al. (1999a, 1999b).

Western Fold Belt

The Western Fold Belt consists mainly of linear, strongly magnetised steeply dipping bodies, which are interpreted as continuations of Jaya Creek Meta-basalt and Eastern Creek Volcanics (labelled EC on figure 3). The Eastern Creek Volcanics also produce high-amplitude gravity anomalies and, 150 km to the north, host the world class Mt Isa Cu-Pb-Zn-Ag deposit.

A region of generally featureless magnetic texture is interpreted as part of the Mt Guide Quartzite (MG). A large oval-shaped region of moderate magnetic amplitude and smooth magnetic texture in the south of the area coincides with a gravity low anomaly (G). This is inter-preted as granite, possibly a correlative of the Sybella Granite in the Duchess area.

Kalkadoon-Leichhardt Block

The Kalkadoon-Leichhardt Block consists of east dipping generally non-magnetic Proterozoic granite and volcanics. The western part is a region with a strongly lineated magnetic texture, interpreted as arising from a mixture of granite, felsic gneiss and felsic and mafic schist of the Tewinga Group (T). Further to the east, volcanics from the same formations are more magnetically intense. To the east of this is a region of smooth magnetic texture, interpreted as the Plumb Mountain Gneiss (PM). At the eastern edge of the block is a region of extremely low magnetic intensity, smooth magnetic texture and a gravity high, which is interpreted as part of the Corella Formation (C), containing amphibolite, marble and calc-silicates. Late Proterozoic gabbroic intru-sions are also evident.

The contact between the Kalkadoon-Leichhardt Block and the Eastern Fold Belt is the Pilgrim Fault. This is clearly shown in the magnetic data as a dramatic change in amplitude on either side of the fault.

Eastern Fold Belt

The western portion of the Eastern Fold Belt coincides with a large, high-amplitude magnetic anomaly. The area covered by this anomaly can be subdivided on gravity measurements: the eastern section has a high-amplitude gravity anomaly and the western section a low-amplitude gravity anomaly. The western part is interpreted as a continuation of the Argylla Formation (part of the Tewinga Group), consisting of felsic volcanics (A). The eastern part is interpreted as a continuation of combined Marraba Volcanics and Answer Slate (MA). The package consists of meta-basalt, meta-siltstone, slate, phyllite and schist.

To the east of the large magnetic anomaly is a region containing the Staveley and Kuridala Formations (SK), which consist of meta-siltstone, slate, schist, phyllite and meta-arkose. This region contains three significant features:

- Narrow, linear, extremely intense magnetic anomalies, which arise from banded iron formations within the Staveley Formation, which hosts the Osborne Cu-Au deposit.

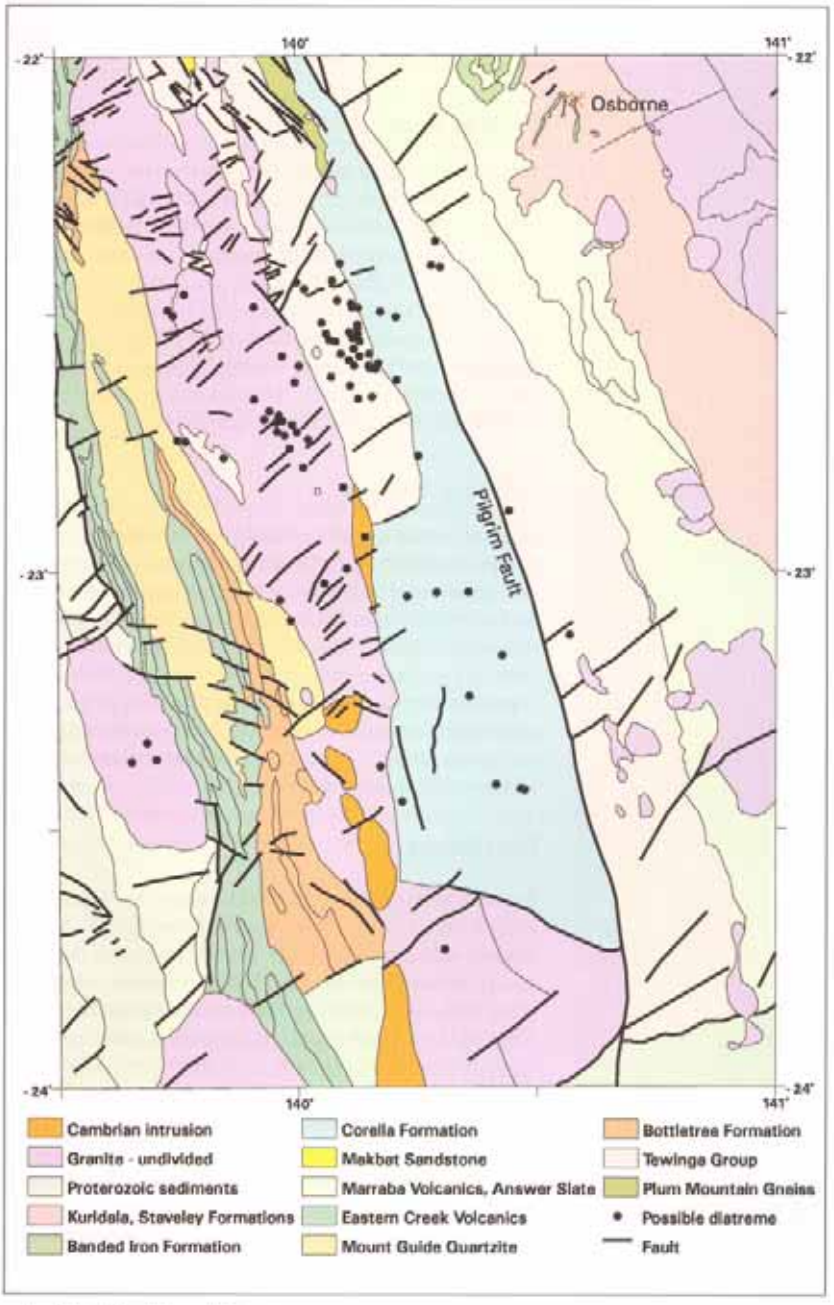

Fig. 5. Simplified interpretation map.

- Circular magnetic anomalies interpreted as late Proterozoic granites, with some possible correlatives of the Williams Batholith.
- A linear, magnetic body, interpreted as a dolerite dyke trends northeast across the Belt.

A large circular high-amplitude magnetic anomaly underlies the Osborne deposit, particularly apparent in Figure 4. This has been interpreted as a late Proterozoic intrusion, underlying the Staveley Formation.

Several areas in the south of the Belt are characterised by very low-amplitude magnetic anomalies (R). The amplitude of these anomalies is too great for them to be the result of demagnetisation or a dipolar effect from neighboring positive anomalies. In addition, positive anomalies can be observed in the analytic signal (Roest et al., 1992) of the TMI data. Therefore, it is interpreted that these are remnantly magnetised bodies. These bodies are adjacent to a granitoid, probably late Proterozoic, which has apparent zoning and intrudes the Argylla Formation.

Cambrian basalt

Two extensive zones of high frequency magnetic anomalies occur in the south of the survey area (CB). These are interpreted as Cambrian volcanics within the Georgina Basin. The textural character of the anomalies indicates that they are thin, near surface, horizontal sill-like bodies. Forward modelling of the magnetic data produced depth estimates of around 200 m whereas neighboring depths are around 1900 m (Meixner, 1997a; Meixner 1997b). To the west of the study area, in the Georgina Basin, Cambrian basalt crops out, which correlates of the Antrim Plateau volcanics.

Cylindrical intrusives

Numerous small circular anomalies are interpreted as being caused by cylindrical intrusive bodies and can be seen in the first vertical derivative of the total magnetic intensity data. Most of these anomalies cannot be correlated with any known cultural features. They were forward-modelled from the magnetic data as being vertical cylinders with tops between 40 and 60 m below ground level and with diameters of approximately 200 m. These characteristics are similar to those of igneous intrusive bodies such as Kimberlite or Lamproite pipes.

Conclusions

A methodology has been developed for geological interpretation of airborne geophysical data. The use of modern software to integrate all relevant spatial data into a single environment significantly reduces the time required for interpretation. This procedure could be used as a template for other regional geological studies.

The continuation of several prospective units of the Proterozoic Mt Isa Inlier has been mapped under cover through the Boulia and Springvale 1:250 000 map sheets. Much of the region is under less than 300 m of the overlying Georgina Basin. The identification of several "bullseye" anomalies within the Georgina Basin section provides targets for diamond exploration. The thickness of the sediments of the Georgina Basin (in the southern part of the study area) is also of interest from a hydrocarbon exploration perspective. Hopefully, this interpretation will enable exploration companies to apply area selection processes to regions previously considered either too deep or not containing favourable rock types.

Acknowledgements

The authors thank members of the Geological Survey of Queensland for their contributions to this interpretation. This paper is published with the permission of the Chief Executive Officer, Australian Geological Survey Organisation.

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More than a Numbers Game: A Geophysical Comparison between Australia and Japan

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There is a common tactic in comparing Australia and Japan in statistics: divide by population if you want to show Australia large; or divide by area if you want to show Japan large. As seen in Table 1, there are vast differences in area and population. Any statistical figure has to be different by the factor of 130 to overcome this tactic.

	Australia	Japan	Ratio
Area (km^2)	7 682 300	377 819	20.3:1
Population	18 943 000	126 680 000	1:6.7

Table 1. Area and population (Encyclopaedia Britannica, 2000).

For example, Australia's consumption of electricity in 1994 was 167 151 million kW-hr and that of Japan was 964,382 million kW-hr. In a simple comparison, Japan consumes nearly six times more electricity than Australia. However, if it is examined in terms of population, Australia's electricity consumption per capita is 8824 kW-hr while that of Japan is only 7613 kW-hr. Therefore an average Australian consumes 16% more electricity than an average Japanese. If we consider electric consumption per unit area, it is 21 758 kW-hr/km^2 for Australia and 2 552 497 kW-hr/ km^2 for Japan. This means that Japan uses 117 times more electricity than Australia per unit area.

The Australian Society of Exploration Geophysicists (ASEG) has 1385 members (ASEG, 2000), while membership of the Society of Exploration Geophysicists of Japan (SEGJ) numbers 1641 (SEGJ, 2000). The numbers include Active, Associate, Honorary and Student members. Despite the difference in the area and population, the number of membership differs only slightly. How can we compare and interpret these figures? Is the figure for Australia large or small? One may say, "Australia has so many geophysicists compared with Japan," or "Geophysics is a popular profession in Australia," and others may say, "To cover the vast land, the number of Australian geophysicists is so small." Table 2 illustrates this comparison.

	Australia	Japan
No. of geophysicist	1385	1641
Geophysicist : population	1:13 700	1:77 200
Geophysicist : area	1:5550 km^2	1:230 km^2

Table 2. Density of Geophysicists.

Perhaps it may be more appropriate to use economic indicators to find a meaningful comparison. Table 3 compares the GNP and GDP between the two countries. In this instance, even dividing by population does not give an advantage to Australia. Japan is often called an "economic superpower". Examining the difference between GNP and GDP, it is noted that half of Japan's wealth comes from overseas as return of foreign investment. On the other hand Australia's GNP is mostly accounted for by GDP. If divided by area, representing "productivity of land", Australia looks miserable.

	Australia	Japan
GNP (US$$10^6$) (1997) *	382 705	4 812 103
GDP (US$$10^6$) (1996) #	354 600	2 668 750
GNP/capita (US$) (1997) *	20 650	38 160
GDP/capita (US$) (1996) #	19 700	21 350
GDP/area (US$$10^3$/$km^2$) (1996)	46	7 060

Table 3. Economic Indicators (Encyclopædia Britannica, 2000; # O'Connor ed., 1997).*

Another comparison is the countries' mining and energy production and exports, where geophysicists are (conceivably) working (Table 4).

	Australia	Japan
Production (US$$10^6$) (1995)	14 150	10 047
Exports (US$$10^6$) (1995)	14 129	875
Against National Export (%)	16.8	0.6
Export/Geophysicist (US$$10^3$)	10 200	530

Table 4. Mining and Energy Production and Export (Encyclopædia Britannica, 2000).

To avoid misunderstanding, it should be made clear that "energy production" is petroleum and coal production and does not include generation of electricity. This table clearly shows the importance of the resource industry to Australia's economy, and geophysicists should be proud of themselves for participating in it.

Readers may query if the production figures are correct. Through the school geography, we were taught that Australia is a resource-rich country, and Japan is poor in resources. But Table 4 shows Japan's mining and energy production is more than two-thirds that of Australia. It is not bad. This was a surprise to me, too!

Here is another trick in statistics! The figures are compared in US dollars. These figures are severely influenced by the price of commodities; and it is not the price on the international market but the local price. For example, price of coal at an Australian port is about $25/t (US$15/t), while coal at a Japanese mine site costs 20 000 Yen/t (US$200/t). The difference is as large as 13 times! In fact, Australia's 1995 coal production of 176 078 000 t is 25 times larger than Japan's 6 949 000 t. Perhaps similar unfair comparisons in US dollars of other commodities resulted in the close production values shown in Table 4.

The membership directories of both ASEG and SEGJ display the distribution of areas of specialties of the respective members (Figures 1 and 2). For several reasons a direct comparison is rather awkward: the classified categories are

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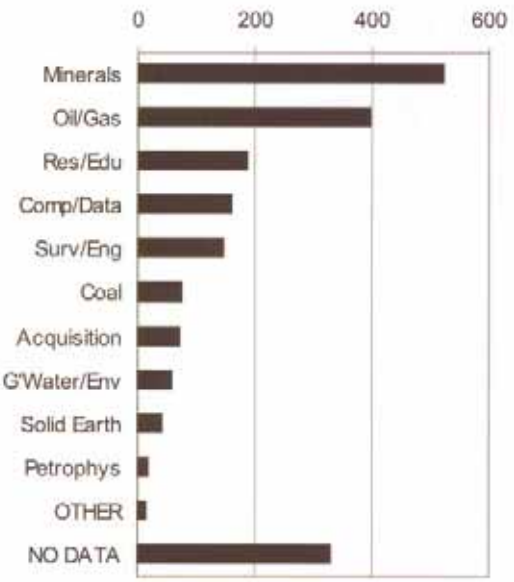

Fig. 1. Fields of interest - ASEG (from ASEG, 2000).

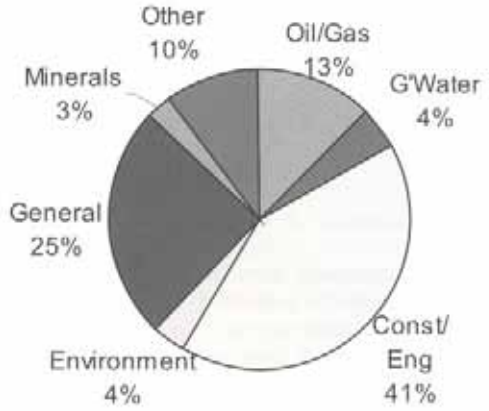

Fig. 2. Fields of interest - SEGJ (from SEGJ, 1998).

different between the two societies; there are a significant number of ASEG members with "no data"; and SEGJ asks for single answer while ASEG allows multiple responses.

Even with this comparison, a difference between them is apparent: a majority of the ASEG members are resource-oriented geophysicists, whereas amongst Japanese geophysicists resource explorationists are minority and close to half of the SEGJ members are concerned with civil engineering and the environmental application of geophysics. This clearly reflects the difference of the area, population and economic development of the countries.

This difference is somewhat mutually complementary. Both societies have different strengths, and the number of papers published in the journals and presented at the respective conferences reflects it.

A discussion has started between ASEG and SEGJ towards a general agreement of cooperation and friendship to encourage interaction between the societies and their members. ASEG is co-sponsoring the SEGJ's 5th International Symposium in Tokyo in January 2001 and ASEG is negotiating with SEGJ to co-host our 15th Conference and Exhibition in Brisbane in August 2001.

Magnetic Susceptibility in Sedimentary Basin Studies - some Features of the Hawkesbury Sandstone

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Introduction

Magnetic volume susceptibility (k) is a useful physical property in the study of soft rock sedimentary basin sequences, but preferably it needs to be measured with a sensitive high resolution instrument that is accurate to $1x10^{-5}$ SI or better, and that generally means a careful laboratory study of subsamples from drillcores or outcrop faces. When viewed in a drillhole log format magnetic susceptibility data can show similarities to a natural gamma log. Accordingly mag k may be used for lithological interpretation, zone delineation, and correlation, provided that there is a reasonable degree of geological control.

The sediment mag k response may arise from paramagnetic minerals such as Fe bearing biotite, illite and siderite, or antiferromagnetic minerals such as hematite and ferrichydroxide mineraloids (collectively limonite), or ferrimagnetic minerals such as magnetite (or combinations of these) occurring authigenically &/or diagenetically in shaley, silty and sandy sequences of continental or marine origin. Thompson & Oldfield (1986) have discussed magnetic mineralogy and some sedimentary processes; Clark & Emerson (1991) have reviewed the ranges of magnetic susceptibility values in minerals and rocks, and also pointed out the possible contribution from paramagnetics; and Ellwood et al (1999) analysed susceptibility records for chronostratigraphic markers in correlating Devonian marine beds.

The Hawkesbury Sandstone

The Triassic Hawkesbury Sandstone is a massive formation, up to ~270 m thick, comprising mainly fine to medium grained argillaceous quartz sandstone with a few percent interbedded mudstone. This porous (~13%) rock forms distinctive outcrops in and around Sydney, but it has by no means been extensively studied except geotechnically and as a building sandstone. The sandstone beds are lenticular, up to 10 m thick and 500 m lateral extent. Individual beds lack persistence as would be expected from the Hawkesbury Sandstone's interpreted origins as an arid area braided river system possibly akin to the modern Cooper Creek or Diamantina River in Queensland or to alluviation in a much wetter region such as the modern Brahmaputra River in Assam and Bangledesh (Branagan, 2000).

Standard (1969) has discussed the Hawkesbury Sandstone and its mineralogy. The approximate solid mineralogy is (by volume): 60% quartz, 20% pellet and matrix clay (kaolinite: illite: mix layer ~12:7:1), 10% secondary silica and carbonate cement (incl. siderite), and a 10% melange of biotite (degrading or degraded to Fe oxides, muscovite, sericite), graphite & carbonaceous material, weathering

Table 1. Mesoscale Physical Properties (lab.) Selected Samples Eveleigh DH Central Sydney Basin (Redfern Area)

category	sample #	depth m	mag k $5x10^{-5}$ (average of sub samples)	laboratory gamma ray spectrometry (CSIRO,DEM) total count c/m/g uncal. (500-2810 keV)	K %	eU ppm	eTh ppm	calculated grain density SGGA g/cm³	apparent porosity P_a %	galvanic resistivity 1 kHz (vac. sat. ρ_w 10 Ωm 25°C) ρ_a ⊥ bed. ohm m	elec aniso. as $\rho_\perp / \rho_{//}$
1. white kaolinitic Hawkesbury Sandstone medium grainsize	9	45.43	5	0.36	0.37	0.58	3.11	2.64	15.6	95	1.08
	62	204.63	2	0.33	0.40	0.35	3.07	2.65	10.4	227	1.18
(strong qtz framework)	70	227.45	2	0.85	0.41	0.93	10.71	2.68	11.6	269	1.14
2. carbonaceous laminated H.Ss medium / fine grainsize	45	158.33	5	0.77	0.93	1.76	5.53	2.63	9.3	111	1.25
3. dusty off-white H.Ss fine grainsize	38	138.42	14	0.66	1.40	0.83	4.45	2.70	10.9	57	1.24
grainsize decreasing ↓	21	86.84	18	0.67	1.33	0.80	4.89	2.70	13.2	65	1.33
	84	279.21	10	1.07	1.70	1.31	9.66	2.71	13.1	53	1.10
(quite graphitic)	37	135.67	30	1.22	1.50	2.12	10.84	2.77	6.6	72	1.89
	77	252.27	22	1.34	1.76	1.54	12.71	2.76	9.3	83	1.46
4. dark mudstone in H.Ss	58	194.00	33	4.37	6.40	8.48	32.30	2.82	8.3	80	1.86

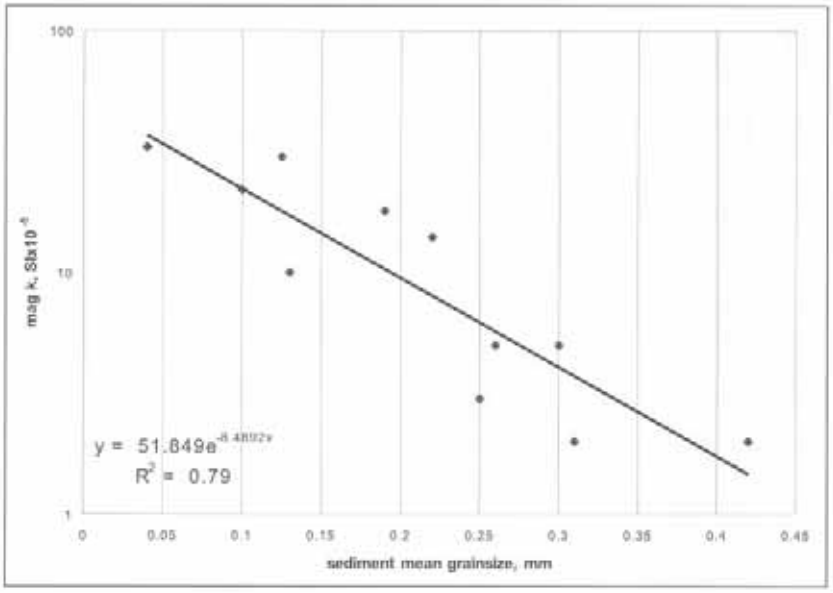

Fig. 1. A plot of magnetic susceptibility against mean grainsize for 11 Hawkesbury Sandstone sediment samples from Eveleigh, NSW.

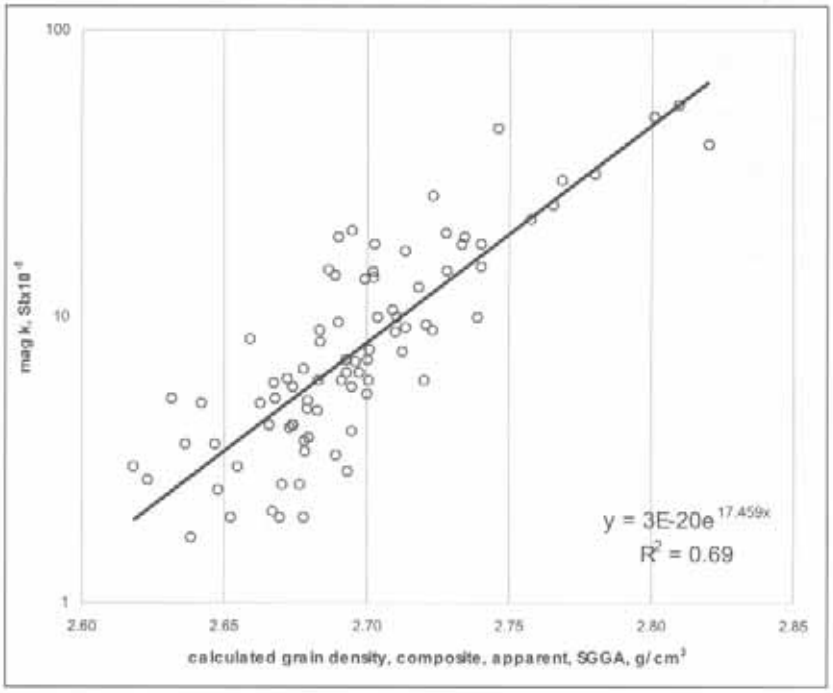

Fig. 2. A plot of magnetic susceptibility against grain density (from mass property measurements) for 84 Hawkesbury Sandstone sediment samples from Eveleigh, NSW (78 sandstones, 6 mudstones).

and alteration dependent limonite, and heavy minerals such as zircon, monazite, tourmaline, rutile, ilmenite. These heavy minerals can be found, usually sparsely, in sandstones of all grainsizes. Magnetite may occur but only in minute amounts, subordinate to paramagnetic (if pure) ilmenite. Analyses show the magnetite often appears to be absent (Ward & Taylor, 2000). Fe mica, siderite, limonite, Fe illite and ilmenite/magnetite would be expected to contribute to magnetic susceptibility. The K content of illite and mica, the scavenged U content of carbonaceous material, and the U, Th content of zircon, monozite and tourmaline would be expected to contribute to natural gamma emissions.

Petrophysics

Physical property studies have been carried out in the laboratory by Robson (1978) from a geotechnical viewpoint (summarised by Pells, 1985), and by Emerson (2000) whose data have been used in this article. This latter program investigated 104 sandstone and associated mudstone samples from a nearly complete Hawkesbury Sandstone section (263 m) in Pacific Power's Eveleigh borehole near Redfern railway station about 3 km south of the Sydney CBD. A few samples from the Sydney suburbs were also measured. Table 1 summarises some physical properties of selected samples measured at mesoscale. Four sediment categories are listed in Table 1: medium grained (0.25 to 0.50 mm) relatively clean, white, quartz sandstone with kaolinite, ~0.25 mm grainsize carbonaceous (laminated) kaolinitic quartz sandstone, fine grained (0.13 to 0.25 mm) dusty, darker, clayey sandstone, and a gritty mudstone in the medium-coarse silt (~0.03 mm) grainsize range.

The four coarser sandstones have quartz/kaolinite grain densities, relatively low mag k's, relatively high resistivities (less clay), and natural gamma emissions that vary with K bearing clay and mica content and heavy mineral content (e.g. monazite → high Th, carbonaceous → high U). The two lowest mag k samples (2×10^{-6}) are strong, quartz-rich, high velocity (Vp > 4000 m/s) materials. Despite being similarly sandy their U, Th gamma emissions differ. The finer grained materials have higher grain densities, relatively high mag k's, relatively low resistivities (more clay) and gamma emissions that increase progressively as grainsize decreases, as is to be expected in the absence of erratic heavy mineral occurrences. However, the gamma response cannot be relied upon here to provide an unambiguous indication of grainsize or clayiness or shaliness as is sometimes erroneously assumed (see Ellis, 1987, on the uses and limitations of the gamma log in sediments).

Rubey (1933) noted that in aqueous sedimentation abrasion and sorting tend to concentrate the denser minerals in the finer grained portions of sandstone beds irrespective of the sandstone being predominantly coarse or fine grained. Young & Olhoeft (1976) have shown that grain densities increase significantly as the felsic-mafic mineral ratio decreases. General data on the average chemical compositions of sandstones and shales (Garrels & McKenzie, 1971) also imply higher grain densities in finer grained rocks. In a *broad and relative* sense then it is considered that mag k should be inversely related to sediment grainsize and that mag k should be directly related to sediment grain density.

A plot of magnetic susceptibility against sediment grainsize is given in Figure 1 where an inverse relationship ($R^2 = 0.79$) is apparent for the ten samples from Table 1 and for one other for which a grainsize measurement was also available. The trend for this quite limited data set can also be discerned in Robson's (1978) measurements on 38 samples ($R^2 = 0.65$).

A plot of mag k against grain density is given in Figure 2 for 78 sandstones and 6 mudstones from the Eveleigh core set. A direct relationship ($R^2 = 0.69$) can be seen in this plot.

In this discussion the issue of the actual nature of the magnetic fractions and their grainsizes has not been addressed; rather, a quite empirical approach has been employed. Further study may lend to a refining of the technique suggested herein. Three other points are worthy of note. Firstly, in very quartz-rich low clay sandstone ("sparkling" Hawkesbury Sandstone, due to silica overgrowths) mag k's may be negative owing to the dominance of diamagnetic quartz. This is a useful lithological indicator, but it is not present in the data set cited herein. Secondly, the galvanic resistivities display anisotropy that increases considerably as grainsize decreases. It is thought that the magnetic susceptibilities are probably anisotropic too and that this would be useful in sedimentation studies. The Eveleigh magnetic susceptibilities in the plots are bulk values averaged from several subsamples from each depth specimen and rounded off to $1x10^{-5}$ SI. Thirdly, remanence responses from five samples were extremely low (≤0.1 mA/m) and in fact were really in the noise level of the spinner magnetometer used. Paramagnetics have no remanence.

Depth-Logged Data

The laboratory data are depth-plotted in Figure 3 together with uncorrected gamma log readings from the Eveleigh borehole. Four subsurface zones are shown and are summarised in Table 2. The sampling is sparse (of the order of the average individual Hawkesbury Sandstone bed thickness), the sequence embraces many alluvial cut and fill and upward and downward coarsening subcycles, and fine detail could be distorted or missing, so the interpreted zones are broad. Nevertheless, they do agree with visual inspection of the core. A feature of the interpretation is the reliance on mag k where the amplitude variation of the readings imparts a good dynamic range to the data. The magnetic data are corroborated by the grain densities and resistivities. The gamma log shows excellent local agreement with the mag k information but lacks a cohesive character from top to bottom of the sequence. The interpretation is in accord with the hydrogeological subdivision of the Hawkesbury Sandstone: sandy top and bottom sections separated by a silty central part (McKibbin & Smith, 2000).

The 37 m thick bottom zone may be the Gosford Formation (upper Narrabeen Group) and not the Hawkesbury Sandstone as this bottom unit has relatively low porosity and low resistivity, which seems to be a consequence of porosity texture and saltier groundwater. The zone is mainly sandy and is (overall) upward fining. The position of the base of the Hawkesbury Sandstone has always been debateable; perhaps mag k information can shed some light.

The 112 m thick sandy lower mid zone has quartz rich sections and mudstone lenses (lithified billabongs in Branagan's Cooper Creek analogue). These are easily recognised in the mag k and gamma data. Resistivities are generally high as clay, overall, is diminished. The average mag k in Table 2 would be halved if the high mudstone values were omitted. Rock clast sections of sandstone also give higher readings.

The 60 m thick finer grained upper mid zone is differentiated from the others by an overall increase in susceptibility, a decrease in resistivity, and interesting correspondences in the mag k, grain density and gamma trends.

Zone (thickness)	depth m	no. samples n	mag k SIx10-5 (mean)	grain dens. g/cm3 (mean)	galv. resist. ⊥ ohm m (mean)	comments
1. TOP (54 m)	26-80	17	9	2.68	75	seds upward coarsening mag k overall decrease with decrease in depth
2t. MID-FINER (60 m)	80-140	19	14	2.72	66	seds upward fining, mag k overall increase with decrease in depth
2b.MID-SANDY (112 m)	140-252	38	11	2.69	125	massive sandy seds mag k's low except for mudstone intercalations
3. BOTTOM (37 m)	252-289	10	9	2.70	79	seds upward fining may be top of Gosford Formation (not H.Ss)

Table 2. Interpreted Physical Zones, Hawkesbury Sandstone, Eveleigh Broad zones only, sedimentation subcycles present, large sampling interval so much detail missing, averages include high readings on mudstones and samples with rock clasts.

The 54 m thick top zone represents a younging change to sandier conditions culminating in a very clean sandstone section in its uppermost part. In this top zone the mag k and gamma data are in good agreement and corroborated by the grain density and resistivity data.

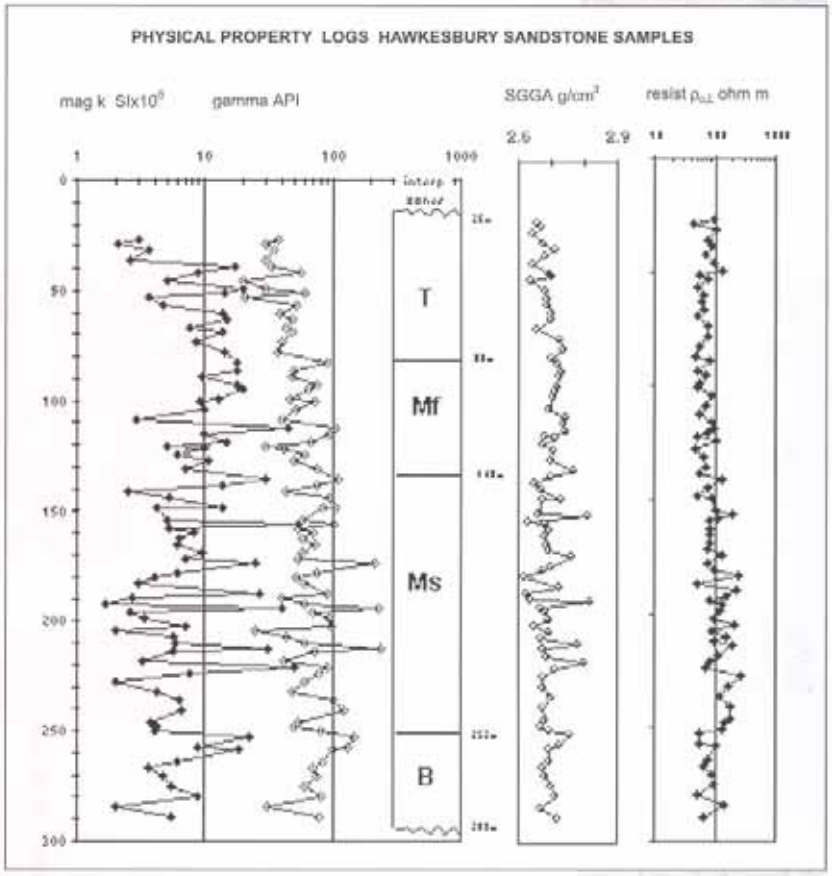

Fig. 3. Physical property values measured in the laboratory (except the borehole gamma) plotted against depth. Samples (n=84) are from the awkesbury Sandstone sequence in Pacific Power's Eveleigh drillhole near Redern 3 km south of the Sydney CBD. Interpreted zones are shown; T is top, B is bottom, M is middle, f is finer grained, s is sandier and coarser grained (see Table 2).

Conclusions

Accurate determinations of mag k have a place in petrophysics studies of sedimentary sequences. Mag k information can supplement gamma data and complement other physical property measurements. Depth-plotted and cross-plotted mag k data should contribute to a better understanding of lithological and environmental features.

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Acknowledgements

This article contains some data previously published in the Geological Society of Australia's Monograph No.5, Sandstone City; the data are used here with the permission of the GSA Environmental, Engineering & Hydrogeology Specialist Group Editor, G H McNally. Dr B Dickson, CSIRODEM, carried out the spectral gamma work on the ten selected samples.

Footnote

A reviewer of this article commented:

"This article demonstrates that magnetic susceptibility could have wide-spread application as a supplement to traditional lithology indicators such as the Gamma Ray observations, especially in areas where so-called 'hot sands' occur. I am not aware of a down-hole device sufficiently accurate to match the results of this study and would be pleased to hear from any readers with experience in this matter." Ed.

4th Australian Geomagnetism Workshop

Written by:
Adrian Hitchman

On 26th-27th April, 50 delegates gathered in Canberra for the 4th Australian Geomagnetism Workshop. Convened by Charlie Barton (AGSO) and Ted Lilley (ANU), the workshop provided a focus for scientists and others who have a common interest in Earth's magnetic field and its applications. It drew Australian and international participants from universities, government agencies, private companies and consultants.

Delegates enjoyed stimulating presentations and lively discussions on a range of geomagnetic topics including developments in modelling the geodynamo, measuring the field near Earth's surface using observatory, ship, aircraft and satellite, and interactions of the geomagnetic field with the solar wind. Intriguing talks on the role of the geomagnetic field in bird migration and 18th century Chinese culture were also presented, as was a study of chemical proxies from ice cores interpreted as evidence of historical solar activity.

A number of presentations addressed the issue of diurnal corrections for magnetic surveys. In particular, speakers described how natural-source EM induction can modify diurnals near electrical conductivity anomalies. Such conductivity anomalies can significantly change temporal variations in different parts of a survey area. Consequently, the diurnal recorded by a base station is commonly an incomplete representation of the actual diurnals occurring over the entire survey area. This modification is frequency dependent and can affect variations with frequencies higher than those resolvable using the tie-line method of diurnal correction. Speakers described significant high-frequency EM induction effects associated with coastlines and with known continental conductivity anomalies. Research into a risk map that identifies areas of high EM induction hazard in Australia is continuing.

In a presentation describing the measurement of magnetic signals of moving seawater, delegates learned of data from floating total-field magnetometers which indicate that, at the sea surface, the magnetic signal from ocean swell (period: say 15 s) can be of the order of 1-1.5 nT/m of swell. These results support theoretical calculations which further suggest that, at an altitude of 100 m, this effect reduces to about 0.2-0.3 nT/m of swell. These signals can be significant sources of noise for aeromagnetic surveys over the continental shelf, particularly above swell which may be 4-5 m high.

Presentations on the origins and properties of magnetic-field activity highlighted recent developments in understanding the nature of pulsations. Some discussion centred on developing methods which provide indices of magnetic activity in real time so that they could be available for planning survey work.

This fourth in the series of Australian Geomagnetism Workshops again afforded delegates an invaluable opportunity to renew contacts, to be appraised of recent developments in diverse geomagnetism topics, to participate in a creative cross-pollination of ideas, and to advance cooperative research efforts. Delegates benefited significantly from the organisational efforts of convenors Charlie Barton and Ted Lilley, and of co-organiser Heather McCreadie (AGSO).

Participants in the 4th Australian Geomagnetism Workshop held in Canberra on 26th-27th April 2000. From the left of the picture, participants are Ted Lilley, Heather McCreadie, Patrick Phelan, Adrian Hitchman, Stewart Bennie, Andrew Lewis, Ray Morris, Bruce Sibson, Jim Heirtzler, Peter Hopgood, David Ivers, Peter Crosthwaite, Graham Heinson, Ron Merrill, Gillian Turner, Mark Lackie, Colin Phillips, Robert Kusi, Francois Chamalaun, Richard Marshall, Jim Dooley, Charlie Barton, Fred Menk, Peter McGregor, Stewart Dennis, Malcolm Gamlen, Dudley Parkinson, Ken McCracken, Anton Hales, Andrew McEwin, Mark Gordon, Denis Winch, Malcolm Kirton, Robert Stening, John Brock, Kari Anderson, Alan Willocks, Andrew Bailey, Ursula Munro, Peter Milligan, Liejun Wang, Ian Dunn.

Proposals for Geoscience Initiatives in the 2001 Budget

The Hon Warren Entsch MP
Parliamentary Secretary
PARLIAMENT HOUSE
CANBERRA ACT 0200

22 June 2000

Dear Mr Entsch,

Thank you for meeting with us as representatives of the Australian Geoscience Council (AGC) and FASTS on 11 May this year. In response to your invitation at that meeting, to provide input to the 2001 Budget, the geosciences sector of FASTS proposes the following initiatives in the context of ISR's Portfolio aims:

1. increasing the international competitiveness of Australia's resource industries; and
2. developing Australia's science and technology capabilities and infrastructure.

1. Develop a 'National Geoscience Online' facility

The Commonwealth Government has recognised that the development of more and better online information services is one of the keys to future knowledge-based economies. It has outlined its strategy on this issue in the 'Government Online' publication released in April 2000.

FASTS recommends that funds be provided in the 2001/2002 budget to develop a National Geoscience Online facility within AGSO. Resource exploration is akin to detective work. Evidence for mineral and petroleum deposits exist in disparate data sets housed by a multitude of industry and government sources. Principal data sets are currently housed in AGSO, CSIRO and the State and Territory Geological Surveys. The National Geoscience Online would be used to encourage mineral and petroleum exploration and to improve the development of strategies for agricultural and urban land management and land degradation issues.

We envisage that this information will be used to boost tourism and provide much needed information on the geology of National Parks and other tourist attractions. The information should also be made available to researchers at universities and other research institutions as well as secondary schools throughout Australia.

The key to this proposal, in the budgetary context, is to ensure that the data sets are provided free or at minimal charge to the clients. From a Commonwealth viewpoint this would mean supplementing AGSO for the loss of external revenue. We believe this would be more than made-up by the boost the facility would bring from resource development and commercialisation of research products in Australia.

2. Increased funding to improve the continental coverage of geoscience data sets

The geophysical (magnetic, radiometric & gravity) and geochemical data sets are most important in the context of understanding the geology of the continent and increasing the success of mineral and petroleum exploration. There are at present significant gaps in these regional datasets. FASTS recommends that the Commonwealth, in cooperation with the States, embarks on a 10 year program to complete the airborne geophysical coverage so that it is complete to at

least 400m line-spaced surveys. At the same time the gravity coverage should be improved in selected key areas. Resources should also be allocated to systematic airborne electromagnetic mapping to map salt storage in regions such as the Murray Darling Basin where dryland salinity is threatening agricultural productivity.

3. Funding joint AGSO studies with the States/Territories and Universities

Funding should be maintained for AGSO to continue special regional studies, such as the very successful Broken Hill Exploration Initiative. AGSO cannot be relegated simply to maintaining a database repository of information relevant to resource exploration and development. It needs to maintain a good working stock of intellectual capital to be effective in supporting the resource industries. This outcome can only be achieved with AGSO being seriously engaged in generating new science. An archiving role is not sufficient. Funds should also be allocated to ensure the continuity of high quality earth science teaching and research at Universities.

4. Establish specialist national geoscience research facilities

Some impressive recent advances in our understanding of the geology and economic potential of the Australian continent have resulted from using advanced ion-probe and accelerator-based techniques for dating geological and environmental materials. Such techniques have been developed at the ANU, CSIRO, and ANSTO and require sophisticated equipment costing several millions of dollars. The current demand from industry, universities, and geological surveys far exceeds the available capacity for both sample preparation and analysis. FASTS proposes that AGSO takes the lead in co-ordinating a national consortium of members from these organisations to manage the dating effort nationally. Funding to achieve this should be considered in the Science Portfolio budget for 2001/2002.

Similarly, the user community has demonstrated a strong need for a national palaeomagnetic facility based either in Sydney or Canberra, yet the futures of both CSIRO's and AGSO's palaeomagnetic facilities are uncertain. To remedy this crucial impasse, we propose an initial injection of $0.5M to establish a national palaeomagnetic centre that will amalgamate both existing laboratories plus ongoing annual funding for at least one professional staff member to run the facility.

5. Cooperative Research Centres

Cooperative Research Centres have been very successful in the context of involving Government, Industry and University resources to tackle research programs of national significance. Ralph Slatyer, a founder of the CRC program, said at the recent CRC Association conference in Brisbane that the amount of government funds available to the CRC program are now insufficient to meet the national need, and should be increased by 50% to be as effective as they were 10 years ago when the scheme was introduced. CRC funds were cut in the 2000/2001 Budget. These need to be increased in 2001/2002 so that worthy proposals are not unsuccessful.

Conclusion

FASTS and the AGC considers that these five proposals are essential in contributing to increasing the international competitiveness of Australia's resource industries, and developing Australia's science and technology capabilities. We have not undertaken detailed costings at this stage; these are probably better developed by the agencies involved in implementation of any new policy proposals, and we would be happy to discuss the issues in more detail in consultation with these. We would also be pleased to expand on any of these items wherever this would be helpful.

We thank you for the opportunity to present these proposals in the context of developing specific strategies of national importance and of immediate relevance to the 2001/2002 Federal Budget. The AGC and FASTS looks forward to a continuing dialogue with you.

Yours sincerely,

Mike Smith
Australian Society of Exploration Geophysicists

Sonia Cousins
Geological Society of Australia

On behalf of David Denham
Vice President, FASTS

The Editor
Preview

Dear Sir,

The article 'BHP develops World's first airborne gravity gradiometer' by Dr Edwin van Leeuwen (Preview no. 86) rightly claims to be a world first, and the Falcon team deserves full credit for a magnificent success.

In the credits at the end of the article, the author omits the names of several ASEG members who played significant roles in accessing the technology and guiding it into the mineral exploration environment. For the record, these include Michael Asten (initiated the feasibility studies prior to the construction contract with Lockheed Martin), Wayne Stasinowsky and Doug Price (represented the Exploration Department on the Falcon team over the period 1997-2000), plus other current BHP employees who were part of what was then the Exploration Department.

I am delighted to see that what was our hope and dream of 1992 is now an outstanding reality in 2000.

Yours sincerely,

Michael Asten
3rd August 2000

Exploration Expenditure Declines Again

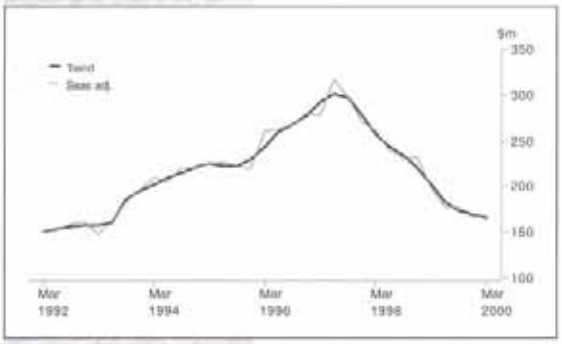


Fig. 1. Mineral Exploration Expenditure, March 1992 to March 2000.

The release of exploration expenditure statistics, for the first quarter of 2000 by the Australian Bureau of Statistics, showed that mineral exploration activity continued to decline for the 11th consecutive quarter. It is now at the lowest level since June 1993 but there are clear indications that the trend is about to be reversed (see Figure 1).

The 'trend' estimate for mineral exploration expenditure fell $3M to $166M. This was 18% lower than the estimate of $201M for the same quarter in 1999.

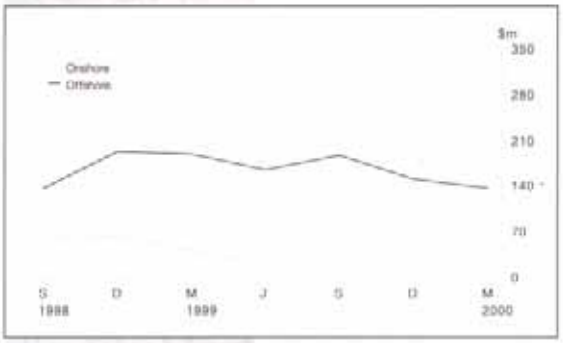


Fig. 2. Petroleum Exploration Expenditure, Sept. 1998 to March 2000.

Although the 'trend' estimate reduction was quite small, the total mineral exploration expenditure was 18% ($31M) lower than for the same quarter in 1999.

Clearly we are still experiencing the flow on effects of low world commodity prices and lack of capital.

The number of metres drilled is even more disturbing. At 1.06 km it is less than half the number for the equivalent 1998 quarter and is now at its lowest level since the ABS first collected these data in the June quarter of 1987.

The expenditures by State and Territory make interesting reading. In order, these are: WA $85.0M, Qld 17.1M, NT $8.8M, Vic $7.5M, SA $3.8M and Tas $2.4M. Once more WA accounts for more than 50% of the nation's total mineral exploration budget, but it is surprising that Victoria outspent South Australia given their comparative surface areas.

Petroleum exploration expenditure also declined in the March 2000 quarter. At $161M it was $30M lower than the December 1999 quarter. However, as shown in Figure 2 the decline is not as dramatic as that experienced by the mineral industry over the equivalent period. The offshore expenditure of $136M dominates the total, and the drilling component of this at $103.1M represents the bulk of investment.

In the expenditure by State and Territory, WA domi-nates expenditure with a total of $121M. Evidently the upward trend in crude oil prices has not yet impacted on exploration activity in the Australian region. (Charts provided with permission of the Australian Bureau of Statistics).

Takeovers Grab the Headlines

Ever since John D Rockefeller developed well-practised techniques to eliminate his rivals, takeovers have been part and parcel of the resource industries. A hundred years on, and this side of the business has not changed, as North and Woodside are finding out.

North with a market capital of some $3.3 billion and one of the top 40 Australian companies and been subject to takeover attacks from both Rio Tinto and the South African-based giant Anglo-American. Anglo is one of the world's largest mining and natural resource groups and is a leader in gold, platinum group metals, diamonds, and has significant interests in coal, base and ferrous metals, industrial minerals and forest products.

One of the consequences of this battle has been the spectacular rise in North's shares from a low of about $2.50 in May to a whopping $4.75 in early August, when Rio Tinto beat Anglo in the takeover battle. We essentially had an auction with only three bids. Rio started with $3.80 a share, Anglo upped the stakes to $4.20 and Rio's final bid of $4.75 was deemed by Anglo to be beyond their valuation estimates. No doubt very good for the shareholders, but not so good for the Australian resource sector, with another major asset likely to be foreign owned.

Meanwhile De Beers has made a bid for Ashton Mining, whose share value has now more than doubled in the last year, and it is reported that WMC and Anaconda are also being chased as valuable resource acquisitions.

In the oil sector Woodside is having similar problems with the Dutch giant Shell. Woodside is currently Australia's 16th listed company with a market capital of about $8.3 billion. Shell currently has a stake of 34% and is trying to raise this to 60% under a merger proposal, in exchange for upstream assets and projects estimated at $7.9 billion.

The Woodside directors rejected this proposal, but don't expect it to go away.

In a less confrontational takeover Anglo-American that it will purchase Shell Coal Holdings Limited for the sum of around $1.5 billion. This purchase follows last year's announcement by Shell of its intention to invite tenders for its coal business and the deal was presumably a win-win situation for both parties. It was certainly supported by the Minister for Industry, Science and Resources, Senator Nick Minchin, who stated that: "Anglo American's purchase of Shell Coal reinforces the position that Australia's mining sector is entrepreneurial, innovative and successful. It is internationally competitive and has a global outlook.

"Anglo American has confirmed that with respect to the long life of the mines, Australia is in a similar position to what has been achieved in South Africa and is currently being planned for Colombia. There is no doubt that Anglo American's announcement is great news."

So clearly we can all now relax.

Minister opens New Petroleum Research and Training Centre for University of Adelaide

Minister for Minerals & Energy, The Honourable Wayne Matthew

A major new facility for petroleum technology research and training, was opened on 26th May at the University of Adelaide's Thebarton campus, by Minister for Minerals and Energy, Wayne Matthew. The state of the art facility, at the University of Adelaide's National Centre for Petroleum Geology and Geophysics (NCPGG) is a joint initiative with Schlumberger, NCPGG and the State Government.

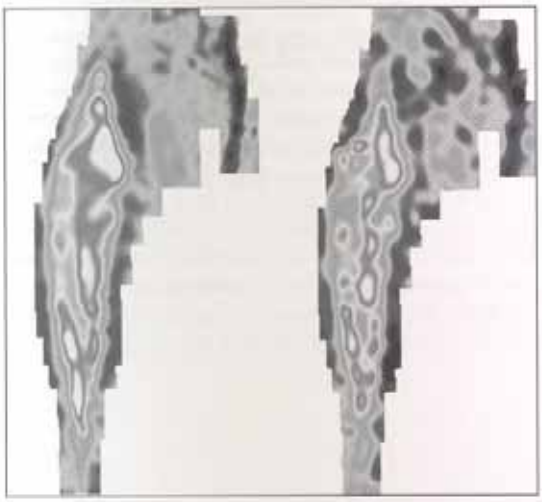
The South Australian Government is supporting the new centre with $150 000 of seed funding and training commitments. The Department of Industry and Trade have contributed $100 000 over three years and PIRSA have pre-committed $50 000 in training. Local oil and gas companies have also strongly supported the centre by subscribing to the training.

The Training Centre is one of only two such facilities in Australia, the other is located at Curtin University in Perth. The role of the facility is to provide a venue for conducting training courses for oil and gas companies, government agencies, service companies and consultants as well as students and academics. The facility will employ trainers and administrators in SA and will also attract interstate Australian and overseas graduates to study and research in SA.

The training facility consists of six Sun Microsystem's high performance unix workstations and a complete suite of Schlumberger's Geoquest exploration and production software for the oil and gas industry. This system is specifically designed to better enable efficient petroleum exploration and production through very sophisticated data manipulation, analysis and visualisation. The hardware and software represents a $9M investment by Schlumberger and is a demonstration of the strong links that exist between government, industry and universities in South Australia.

This facility will consolidate South Australia as the key player in petroleum technology in Australia, by strengthening collaborative links between industry, government and our academic institutions.

Correction To Preview No. 86 New Technology



The Caption for Figure 3 on page 30 in Preview 86 was incorrect. It should have read:

'Fig. 3. A comparison of the AGG data with ground gravity. On the right is an image of the fully terrain-corrected vertical 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 left. 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 south.'

In addition, the final paragraph was not corrected. Here is the corrected paragraph.

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

Paleomagnetism: Continents and Oceans

Written by:

Michael W. McElhinny and Phillip L. McFadden
Academic Press

ISBN 0-12-483355-1
Hardback, 382 pp.
ARP A$130

Reviewer:

David Clark, CSIRO Exploration and Mining

The discipline of palaeomagnetism has been well served by textbooks since the publication of Irving's classic *Paleomagnetism and its Application to Geological and Geophysical Problems*, which is still worth reading nearly four decades since its publication in 1964. That book preceded the full flowering of the plate tectonic revolution, creating a need for a text that covered not only covered basic principles of palaeomagnetism and rock magnetism, but fitted paleomagnetic results into the framework of the then new global tectonics. This need was amply met by McElhinny's *Palaeomagnetism and Plate Tectonics*, first published in 1973. Much more recently, an excellent introduction to the principles of palaeomagnetism was published by Butler *(Paleomagnetism: Magnetic Domains to Geologic Terranes)* in 1992.

Over the ensuing years the palaeomagnetic data set has grown prodigiously and been incorporated into a Global Palaeomagnetic Database (files available from the World Data Center A in Boulder, Colorado, at http://www.ngdc.noaa.gov, or can be queried directly from the internet site at the Norwegian Geological Survey: http://www.dragon.ngu.no/Palmag/paleomag.htm). Understanding of magnetisation processes in rocks, which underpins the interpretation of palaeomagnetic data, has progressed steadily, magnetic survey coverage of the oceans has greatly increased, and geological and geophysical data relevant to continental reconstructions, displaced terranes, Precambrian plate tectonics, Precambrian climatic paradoxes, and palaeomagnetic dating of mineralising and tectonic events have greatly increased. An updated treatment of the subject and analysis of the implications of the enhanced data set are therefore very timely.

Paleomagnetism: Continents and Oceans is the sequel to McElhinny (1973) and retains the virtues of the earlier book, but with significantly updated treatment of traditional topics, supplemented by much new material, reflecting the great advances in the subject. New material abounds in the sections on rock magnetism, statistical analysis, marine magnetic anomalies, apparent polar wander paths for major blocks and palaeogeographic reconstructions. The authors have strived to pitch the book at a level that can be understood by undergraduates at about the second year level. Mathematical treatment has therefore been limited to aspects that are essential for understanding, without significantly sacrificing utility. I suspect that only the better undergraduate students can gain maximum benefit from this book, because an average undergraduate geology student may struggle to understand all the material. However, the clarity of the writing and the quality of presentation may ensure that the authors' hopes are not too optimistic.

Chapters 1-3 cover the foundations of the subject: geomagnetism, rock magnetism and palaeomagnetic methods. Chapter 4 covers magnetic reversals, with thorough coverage of the greatly improved information on the geomagnetic polarity time scale and polarity transitions. Chapter 5 on oceanic palaeomagnetism covers marine magnetic anomalies and the magnetisation of the oceanic crust, magnetisation of seamounts and palaeopoles derived therefrom, the hotspot reference frame and evolution of the purely oceanic Pacific plate. Chapter 6 on continental palaeomagnetism starts with fairly standard treatments of data selection and reliability criteria, testing the axial geocentric dipole hypothesis (which underpins all of palaeomagnetism), palaeointensity variations, comparison of paleomagnetically derived latitudes with palaeoclimatological data, apparent polar wander paths, and relationships between magnetic blocking temperatures and isotopic ages. A significant new aspect is the discussion of the global palaeomagnetic database. The second part of Chapter 6 comprises detailed discussions of palaeomagnetic data and apparent polar wander paths for the major continental blocks. After discussing methods for combining Euler and palaeomagnetic poles and making reconstructions from palaeomagnetism, Chapter 7 builds on Chapter 6, providing an invaluable synthesis of the data from the various blocks to evaluate reconstructions of the Phanerozoic supercontinents (Gondwana, Laurussia and Pangaea), the assembly of the various continental fragments that comprise Asia, displaced terranes in western North America, rotations in the western Mediterranean and the recently recognised Neoproterozoic continent of Rodinia, amongst other topics. Both this chapter, and the book, conclude with discussion of non-plate tectonic hypotheses: true polar wander and Earth expansion.

The book can also serve as a valuable resource for postgraduate courses. However, perhaps its greatest utility will be as a ready reference for working palaeomagnetists and for geologists interested in palaeomagnetic applications to local and global tectonics. In the latter role, I expect this book could act as a steadying hand over the next decade or so, restraining some of the over-excitable misuses that can be made of the global palaeomagnetic database, which contains a very large number of results of very variable quality. I also feel the book contains much of interest to exploration geophysicists who wish to know more about Earth history as revealed by palaeomagnetism, as well as topics that are crucial for better interpretation of magnetic anomalies: magnetisation of rocks and the behaviour of the geomagnetic field through time.