Preview

Australian Society of Exploration Geophysicists

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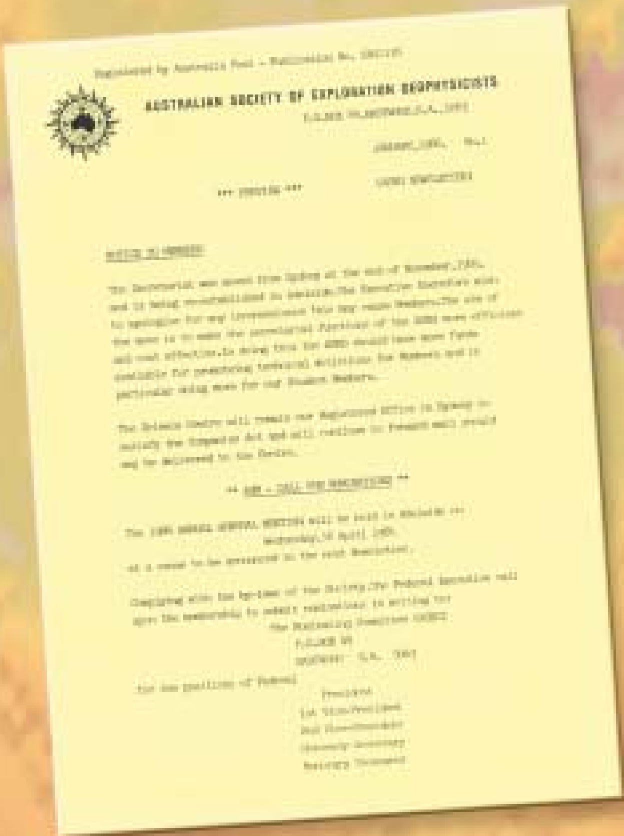
October 2002 Issue No.100

100th Commemorative Issue

Reminiscing the past... ...looking to the future



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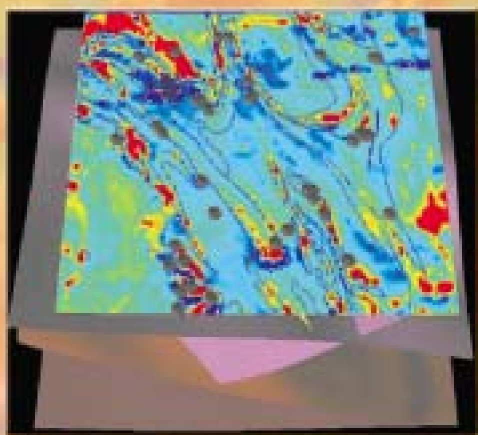

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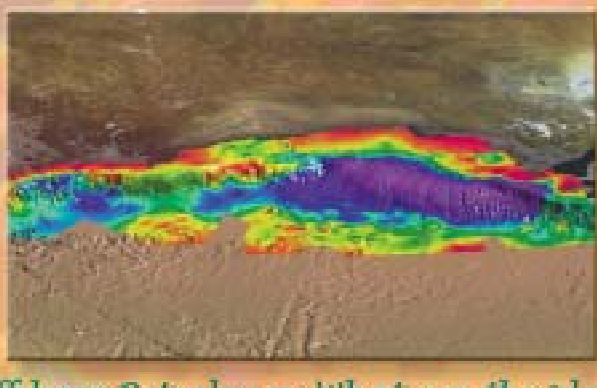

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Deadlines

Preview is published bi-monthly, February, April, June, August, October and December. The deadline for submission of all material to the Editor is the 15th of the month prior to issue date. Therefore, the deadline for editorial material for the **December 2002 edition is 15th November 2002.**

Advertisers

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

Advertising copy deadline is the 22nd of the month prior to issue date. Therefore, the advertising copy deadline for the December 2002 edition is 22nd November 2002. A summary of the deadlines is shown below:

Preview Issue	Text & articles	Advertisements
101 Dec 2002	15 Nov 2002	22 Nov 2002
102 Feb 2003*	**20 Dec 2002**	**22 Jan 2002**
103 Apr 2003	15 Mar 2003	22 Mar 2003
104 Jun 2003	15 May 2003	22 May 2003
105 Aug 2003	15 Jul 2003	22 Jul 2003

Conference Edition, abstracts of papers to be submitted by 2nd December 2002

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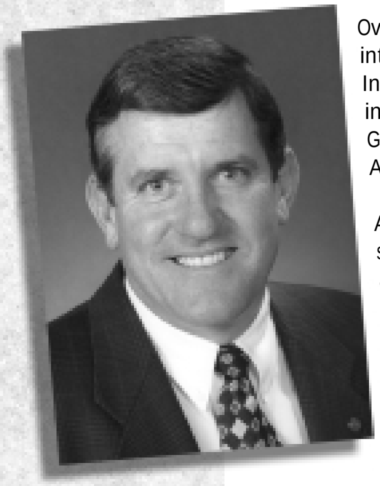
Role of Mineral and Petroleum Exploration in Australia



Guest Editorial by Ian Macfarlane, Minister for Industry, Tourism and Resources

Over the last 100 years, Australia has developed into one of the world's leading mining nations. In 2000-01, the minerals and petroleum industries produced nearly 9% of Australia's GDP of A$640 billion and earned 36% of Australia's total exports of goods and services.

Australia's exploration and mining success is supported by quality geoscientific databases and information systems, and an investment environment conducive to exploration and development. This is reflected in Australia's consistent top ranking in international investment surveys, and success in attracting the highest individual country share of global exploration budgets.

Importance of geophysics to resource exploration

Geophysics and geophysicists have played, and continue to play, an important role in the discovery of Australia's mineral and petroleum resources. National and regional geophysical datasets acquired under Government geophysical mapping programs by Geoscience Australia, its predecessors and the various State and Northern Territory geological surveys provide a framework for exploration which has directly contributed to a number of major discoveries.

Australia was the first continent to have complete coverage of regional magnetic and gravity data. Pioneering developments in aeromagnetic and radiometric data acquisition, processing and visualisation by Australian researchers and companies in the 1980s and 1990s demonstrated the value of high-resolution airborne surveys to geoscientific mapping, and in detecting anomalies due to mineralisation and/or petroleum accumulation.

These developments formed the basis of a major program of geoscientific mapping by the Commonwealth and States/NT over the past decade under the National Geoscience Mapping Accord and the National Geoscience Agreement. These have seen the acquisition of 3 million line kilometres of new airborne magnetic and gamma-ray data and a significantly upgraded the national gravity database.

Much of Australia's prospective ground lies under cover and, as acknowledged in the report on Mineral Exploration to the Prime Minister's Science, Engineering and Innovation Council last year, geophysics is therefore bound to play an even larger role in future discoveries.

Government actions in supporting resource exploration

The Commonwealth Government appreciates the importance of pre-competitive geoscientific information in attracting capital for exploration through reducing exploration risk. Geoscience Australia aims to improve the geoscientific knowledge base available to the mineral and petroleum exploration industry. New geophysical surveys — including seismic surveys — continue to be important in the development of a comprehensive model of the Australian continent and offshore areas. For example, deep crustal seismic reflection surveys provide a 3 dimensional view of the crust. In many cases — as in Broken Hill and the Eastern Goldfields — results of such surveys have rekindled exploration in a number of important historical mineral provinces.

Access to data

In recognition of the importance of access to information for the entire sector, the Government implemented the Spatial Data Access and Pricing Policy last year to provide ready access to Commonwealth spatial data. Under this policy fundamental spatial data, including geophysical survey data, are made available at the cost of transfer or free over the Internet to all. The merger last year of AGSO and AUSLIG to form Geoscience Australia brings together major providers of spatial data and will provide a 'one-stop shop' for Commonwealth spatial information.

Inquiries into resource exploration

In response to the continuing low levels of mineral exploration expenditure and increased industry concern, the government initiated an inquiry by the House of Representatives Standing Committee on Industry and Resources.

In May 2002, I requested that the committee inquire into and report on, any impediments to increasing investment in mineral and petroleum exploration in Australia, including:

- An assessment of Australia's resource endowment and the rates at which it is being drawn down;
- Impediments to accessing capital, particularly by small companies; and
- Access to land including Native Title and Cultural Heritage issues.

Around 80 submissions were received from industry, government and private sector organisations, with the findings of the inquiry expected early 2003.

In September this year I was pleased to launch the Mineral Exploration Action Agenda, receiving strong support from industry. Key issues to be addressed include:

- Access to land for mineral exploration;
- Access to investment capital to facilitate exploration; and
- Availability and public provision of precompetitive geoscience data.

It is hoped that in conjunction with the findings of the House of Representatives Committee, the Action Agenda will provide means of focussing attention on key areas leading to positive change for the minerals industry.

Cont'd on page 4

This anniversary issue will remind you of the contributions the Society has made to the profession during its life. The robustness of the Society is due in no small part to the vision of the founding members (see the website Memorandum of Association for the names). Within this vision they identified the guiding principles of the Society that have defined our charter and have contributed to the success we see today.

It is appropriate to remind members of these goals:

- To promote the science of geophysics;
- To promote and strengthen the profession of geophysics;
- To promote fellowship amongst practitioners;
- To promote cooperation with other professional groups;
- To facilitate Australia-wide involvement; and
- To encourage safe practice.

These principles have motivated some of the recent activities. The Society has worked with the SEG and SEGJ through translation editorship and intervention to publish a geophysical monograph on microseismics. We are underwriting a volume of geophysical signatures for South Australia. The Society has also recently published a high quality special issue of Exploration Geophysics on Salinity and Land Management, which highlights the role of geophysics to issues of national interest. We are participative in submissions to government committees on geoscience matters. We are very active at State levels, and we are interactive with our sister societies.

It is important to note that our membership of 1288 claims roughly equal numbers from both the minerals (36%) and petroleum sectors (31%). This means that we need to involve and collaborate with other societies in each of these areas to promote integration of techniques and usage. To that end we have convened discussions for forward planning and collaboration for conferences with both minerals and petroleum societies, to ensure communication and optimisation of interaction with our industry partners. I encourage you to look at the content planned for the Adelaide Conference "Growth Through Innovation" and note the special events and forums with particular focus on petroleum issues.

Lastly I would like to urge all members to look around at the contributions of your fellow geophysicists and come up with nominations for the Honours and Awards Committee. Look in the 2002 Membership Directory and on page 9 in this issue of Preview to see the award categories and to help identify potential nominees. It is an opportunity for their contributions to be acknowledged, and the only way for us to do that is through the acclaim of the membership.

I congratulate the ASEG on behalf of its members on reaching this milestone in such a healthy state in terms of living up to its principles and its ability to deliver its benefits.

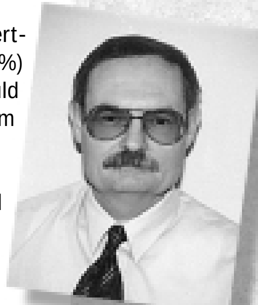
Kevin Dodds

Cont'd from page 2

Future

Geophysics is set to continue to play a major role in the exploration for and discovery of new mineral and petroleum deposits. Advances in geophysical methods allowing higher resolution discrimination of bodies and structures at depth, coupled with the ongoing advances in data processing and visualisation, mean that exploration will be increasingly dependent on geophysical techniques. Australia's mining industry continually proves itself to be highly adaptive and innovative. I hope this flexibility combined with rapidly evolving and improving geophysical techniques, and a Government commitment to providing the industry with every opportunity to move forward will underpin Australia's reputation as one of the world's leading mining nations.

Preview 100 – A Milestone or a Millstone for the ASEG?



On behalf of the ASEG Publications Committee, I wish to pass on my hearty congratulations to all those who have contributed or have been involved in the production of *Preview* for the past 16 years. I would like to thank in particular the Editors, who I know (from the close encounters I have had in recent years) put in an enormous amount of their time and effort to produce what must be one of the best publications of its kind in the geophysical arena.

Especially I acknowledge the substantial contributions of the current Editor David Denham and the publisher, RESolutions Resource and Energy Services, for which this 100th issue represents the 19th that David and RESolutions together have produced.

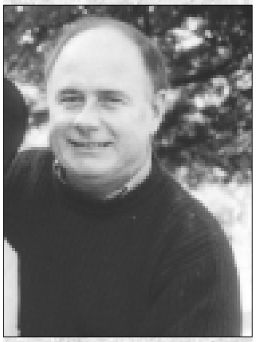
From the gestation of the idea in 1985 for a regular Newsletter service to members, *Preview* has grown from humble photocopied beginnings to the glossy full print publication of today. Advertising revenue has always been the foundation upon which *Preview* could be provided regularly to members at minimal cost to the ASEG. Due to industry pressures and other means for companies to promote their products, advertising support in recent years has declined, while the desire to make the publication more colourful and more appealing to both members and advertisers alike has resulted in increased production and distribution costs. *Preview* now costs the ASEG about $20 000 to $30 000 per year after receipts from advertising. This represents a substantial proportion (about 25%) of membership subscription income. Clearly this could not be sustained without the income ASEG receives from conference surpluses.

The question is whether ASEG can continue to afford such an outlay as a service to members, or whether the funds used to produce *Preview* should be invested elsewhere? Advertising is less likely to meet the income expectations previously anticipated, so serious changes to the style, content or frequency of *Preview* may be necessary in the future.

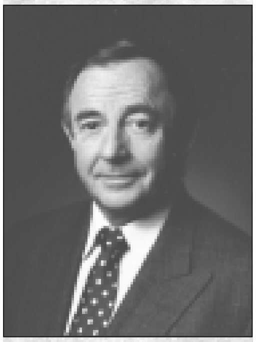
The answer to what the future holds for *Preview* ultimately lies in the feedback from members to determine if *Preview* remains a desirable and important benefit of membership. Members must use the opportunity to contribute to *Preview*, and to voice their opinions on the value of such a publication to themselves and the ASEG in general, by way of letters to the Editor, or direct submissions to the Federal Executive. *Preview* started as, and should always be, a service to members – does it still fulfil this role, or is it time for a change?

Andrew Mutton
ASEG Publications Chairman

The History of Preview through the eyes, and pens of all the Editors



Peter Elliott



Reg Nelson

Peter Elliott (SA):
January 1986 to June 1986, Issues 1-4

Early History of Preview

As a special request I was asked to write an editorial piece on the inception and establishment of *Preview* as a publication. It is difficult to do this without putting it in the context of ASEG activities at that time. During the Brisbane hosted ASEG Conference in November 1983, the various State Branches jointly pushed for rotation of the Federal Executive through the Branches instead of always being located in Sydney. Reg Nelson (then with SADME in Adelaide) was nominated as the President Elect to oversee the first transition of the Executive from Sydney to Adelaide. In April 1984, Reg Nelson was elected as President assisted by Peter Gidley (1st VP), Heather Lemaire (2nd VP), Steven Greaves (Treasurer), Adam Wheatley (Honorary Secretary) and Don Emerson (Editor-ASEG Bulletin), except for Reg, the Executive was still mostly Sydney based. Members of the "Shadow" Executive at that time included Terry Crabb and myself (Adelaide based). In April 1985 the move of the Federal Executive to Adelaide was completed. Reg Nelson still maintained the Presidential post assisted by Mike Middleton (1st VP), Eric Firmin (2nd VP), Terry Crabb (Honorary Treasurer) and myself, as Honorary Secretary.

The first transition of the ASEG Federal Executive to a Capital City other than Sydney was complete, but the Secretariat was still maintained at the Science Centre in Sydney. As the new Honorary Secretary I found that communication with the Secretariat in Sydney was difficult due to the tyranny of distance and lack of familiarity with the individuals working there. A review of the ASEG accounts at that time also showed the Science Centre as requiring a fair proportion of the Annual Budget. Rather than lift membership fees we (the Executive) decided to look at ways of cutting costs. Up until 1985, the "ASEG Newsletter" had been produced as an A4 multiple sheet format. Each newsletter had to be folded and inserted into envelopes, and then stamped with the fully franked postage amount. This process was time consuming, heavy on material usage, and therefore costly.

The Newsletter up to that point was prepared and distributed from Sydney. The Newsletter was the "clarion" for the ASEG and the only effective means of keeping members updated on monthly events. It fell within the Secretary's responsibility every month to ensure that it was prepared and distributed. As Honorary Secretary, I persevered with the existing system for the first couple of months in office and then made an independent decision to take over the preparation of the final version of the Newsletter and distribute it from Adelaide. As part of that decision I decided to do away with the envelopes and prepare a booklet style version of the Newsletter that could be folded and stapled. This more than halved the cost of producing and distributing the Newsletter. The first issue in this format was sent out in August 1985.

I investigated other ways to cut the costs of Newsletter production and discovered, after some enquiry, that publications attracted a lower postage charge than ordinary mail. As part of the decision to register the Newsletter as a publication, it was necessary to come up with an appropriate name. *Preview* was a name that sprung readily to mind. The main function of the Newsletter was to inform members of events to come. I put the name before the Federal Executive Committee in November 1985 and it was accepted unanimously. January 1986 saw the first official issue of *Preview* (No. 1). It was a fairly austere publication still in a booklet form and printed on coloured paper. The booklet now had included on the front page:

Registered by Australia Post-Publication No. SBG1116

****************PREVIEW******************

The first subject covered on the front page, of the first issue, was the removal of the ASEG Secretariat from Sydney to Adelaide. This move basically was the finalisation of cost cutting measures initiated in 1985 and with it was born a new ASEG Publication called *Preview*, which has now become a very polished magazine. *Preview* currently competes in lustre and presentation along side the SEG equivalent (The Leading Edge).

I edited and produced the first four issues of *Preview* and then handed the publication over to Reg Nelson (immediate Past President) in June 1986, who was ably assisted by Terry Crabb (Head of the Publications Committee and Honorary Secretary). Reg took the "baton" and improved greatly on my early efforts, as have other Editors that followed him. We are now up to the 100th issue of *Preview*.

I wish all the best for ensuing Editors and I hope that *Preview* continues to serve the ASEG as a trusted "clarion" well into the future.

Peter Elliott

Reg Nelson (SA):
July 1986 to June 1988, Issues 5-14

My memory is not the most reliable, but I think the genesis of Preview was around the time I became President.

It was the first time that the ASEG Committee had moved from Sydney and for that first year all the committee except for me were still based in Sydney (Steve Greaves was still Secretary). My concern was that we needed to set up a parallel group in Adelaide to build up knowledge and who would then be able to take up the reins in the following year when the Committee and Secretariat made the full move to Adelaide and began the process of rotating between the States. Peter and Terry Crabb were stalwarts during this process. Peter is very organised and I accept his assertion that I was Editor for the period mentioned. I recall that there was some considerable debate about the name of the newsletter. I believe that Peter came up with "*Preview*". I believe that I suggested the seismic signature border that was used initially.

Our aim was to provide something akin to SEG's "The Leading Edge" to give timely information to members. There were a number of issues in the ASEG at that time: viz. the question of members' liabilities for what was then an unincorporated body, whether ASEG should provide accreditation for Stock Exchange reporting (thankfully it declined) and the status of the ASEG Bulletin as a professional journal (the necessity for establishing credentials and a referee process was a strong factor that led to "*Preview*" so that the Bulletin could then focus more on its scientific credibility and authority - until then it had been somewhat of a hybrid, with a mix of serious scientific articles and more general society information). There was also debate about whether ASEG was a subsidiary of the SEG or an independent group similar to the EAEG (our views were strongly for independence).

Well, well: *Preview* is now approaching its 100th edition. It's good to hear that. I send my very best wishes for the next 100 editions.

Reg Nelson

Anita Heath (WA): August 1988 to February 1992, Issues 15-36

Anita Heath

I was invited to become *Preview* Editor when the secretariat moved to Perth in 1988. My expertise was in the petroleum industry and I had been secretary of the WA Branch for a couple of years. I was well aware of the difference of interest between petroleum and mining geophysicists, which was reflected in participation in society events and publications. The oil industry seemed to want lunch at a city hotel compared with the mining industry evening beer in a suburban pub. Also different was their appearance, being either of the suit and tie brigade or the woolly jumper and beard brigade. Favoured topics were either, seismic imaging, 3D acquisition and processing with a few case histories thrown in, or improved magnetic imaging, tomography and GPS. Hard rock versus soft rock geology. It was always a challenge to keep both parties interested at the same time. This is not necessarily true today when both parties seem interested in improved imaging whatever the technique.

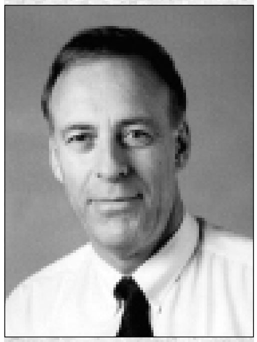
An advantage of being *Preview* Editor is that there is plenty of room for innovation and creativity in the newsletter. Editorial standards are not nearly as rigid as for Exploration Geophysics making less work for the Editor who will need his/her time to canvass articles. Preview has developed a long way since my days as Editor and is progressing towards becoming a magazine that we hope will one day be compared with the PESA newsletter or even the Leading Edge.

The aim of my job as editor was to promote the society to its membership and their contacts. I was also aware that the AusIMM outstripped us for members in WA and the same could probably be said for PESA. I also learned to give more consideration to the long-standing members of the ASEG who are still active in the society today.

During the late 80s we were facing such issues as the ASEGRF and whether or not a joint conference should be held with the SEG. At that time the appearance of *Preview* was greatly enhanced by Paula Sinclair, our secretariat from the Chamber of Mines of WA who produced the first issue using Microsoft Publisher. She also set up a new members listing and a forthcoming events calendar. The invisible co-author was Andre Lebel who was a constant source of mining articles and book reviews making up for my shortcomings in this area. Committee meetings were usually informal and were held in a member's home along with a good bottle of red wine.

Anita Heath

Geoff Pettifer (Vic): April 1992-February 1996, Issues 37-60

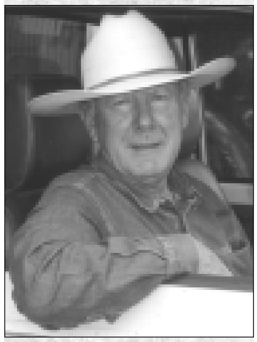


Geoff Pettifer

My period as *Preview* Editor was a rewarding one, where with the support of the then Melbourne based ASEG Secretariat (under Presidents Hugh Rutter and Kathy Hill and Publications Chairman Mike Asten), and sub-editors and advertising sponsors, a conscious effort was made to bring *Preview* closer to the technical / education article standards and colour format of Leading Edge and First Break, in terms of the place that the ASEG's equivalent magazine *Preview* took in the publication spectrum and life of the Society. *Preview* as the Conference Handbook and the Membership Directory were two changes introduced that also gained support of ASEG members. The encouragement received from ASEG members and contributing authors who could see a role for an improved *Preview* in lifting the image of the Society, spurred on our efforts. The effort to produce a higher standard magazine using volunteer people, was substantial and for my part, and I believe subsequent Editor Henk Van Paridon, the strategy was always to get *Preview*, to the point where professional production for *Preview*, such as we now enjoy with RESolutions under the Editorship of David Denham, was endorsed, by the ASEG. We can all be rightfully proud of *Preview* today and congratulate the Society on the 100th Edition milestone.

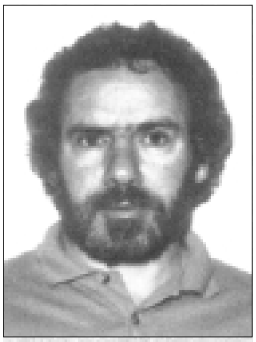
Geoff Pettifer

Mike Shalley (Qld): April 1996-April 1997, Issues 61-67



Mike Shalley

Taking over the editing of *Preview* from Geoff Pettifer in April '96 was no picnic because Geoff had recently created a seismic shift in the quality of the magazine, helped to a considerable extent by the professionalism of the printing service provided by Jenkin Buxton of Melbourne, our printers at the time. The one downside was that the editing was a time consuming business and issues were coming out well behind schedule to the distress of both our readers and our advertisers. I made it my task to gradually bring the remaining issues of 1996 back to a timely distribution while still aiming for the quality levels set by Geoff. A few minor improvements were also made to the presentation, such as the inclusion of an Advertisers' Index and a short preview of coming events.



Henk van Paridon

David Denham

In those days the Conference Handbook, distributed at ASEG conferences, was an issue of *Preview* and putting that together was an awesome task. It contained all of the abstracts, a conference programme, lists of stall holders and a summary of their offerings, maps of the stall layouts etc. etc. The Sydney conference of 1997 was my task and very nearly proved my undoing as I under-estimated the time involved and was almost in panic mode as the deadline approached. But with the help of our president of the day, Henk van Paridon, we got it all together and the show went on.

I congratulate the current *Preview* team on another upward shift in quality and wish them and the ASEG the best in continuing development and prosperity.

Henk van Paridon (Qld): June 1997 - August 1999, Issues 68-81

My editorship started at the same time as my employer offered me a career as a consultant. I promised myself some time to smell the roses, but instead found myself knee deep in fertilizer as *Preview* went through the first of two convulsions (more than evolution but not really revolution) under my watch.

It was clear that the Society needed to change the relationship between the editor and the printers. It would be too hard to match the efforts of Geoff Pettifer and Mike Shalley. Firstly the role of the printer changed to publisher/printer responsible for layout and advertising. Most of the artwork at that time was still in hardcopy and I learnt not to be concerned when bromides arrived in envelopes. The second major change followed an extensive tender process where the publisher/printer became the publisher (RESolutions) who managed the printing rather than did it. The use of Digital to Plate technology certainly made life easier.

I tried a few things including a crossword and student abstracts with mixed success. The magazine had limited success in attracting petroleum articles although most of my petroleum colleagues are members and avid readers.

I have always believed in *Preview* as a quality magazine containing interesting and current articles. I still look forward to every issue although I'm glad to say I no longer read every word as I did when I was editing.

Andrew Mutton supported me throughout my period as editor and he continues give to the ASEG. Congratulations to all those who have nurtured and supported *Preview*. I hope that we can continue to support.

Henk van Paridon

David Denham (ACT): from October 1999, Issue 82

By now you will all have gathered that this is Issue 100 of *Preview*. We have tried to include a little bit of history but most of the invited feature articles are reviews of the main sectors of interest to our members. We therefore have papers on Petroleum and Mineral Exploration, Coal, Airborne EM, Environmental Geophysics and the National Geophysical Data Sets. We have also included a ***Quo Vadis Explorator***? contribution. This poses challenges to what we do and what we should be doing. It would be interesting to have feed back on these issues.

Finally, I would like to reinforce Henk's comments on Andrew Mutton. As Chairman of the Publications Committee Andrew's contributions have been invaluable. His counsel is always wise and his support and encouragement are always strong.

Editors can only do so much chained to their computers. It needs a robust and active Society, and enthusiastic authors who are prepared to give of their time and talents, to succeed. So a big thanks to Andrew, ASEG Executives and all those who have contributed words to *Preview* over the last sixteen years. Let us look forward to the next 100 issues.

David Denham

Australian Society of Exploration Geophysicists: Honours And Awards

During the 16th ASEG Conference to be held in Adelaide in February 2003, several categories of Honours and Awards will be presented to members who merit recognition for distinguished service to the Society and to Exploration Geophysics. ASEG Members are invited to submit nominations for the following awards:

1. **ASEG Gold Medal: for Distinguished Service to Geophysics.**
   This is the ASEG's highest award.

2. **Honorary Membership: for Distinguished Contributions to the Profession of Exploration Geophysics.**

3. **Grahame Sands Award: for Innovation in Applied Geophysics.**
   It is made to a person or persons who has or have been responsible for a significant practical development of benefit to Australian applied geoscience. This could be in the field of instrumentation, data acquisition, interpretation or theory.

4. **Lindsay Ingall Memorial Award: for the Promotion of Geophysics within the Wider Community.**
   This award is for an Australian resident or former resident for the promotion of geophysics, (including but not necessarily limited to applications, technologies or education), within the non-geophysical community, including geologists, geochemists, engineers, managers, politicians, the media or the general public. The candidate need not be a geophysicist, or a member of the ASEG.

5. **ASEG Service Medal**
   In recognition of extraordinary and outstanding service to the ASEG over many years, through involvement in and contribution to state branch or federal committees, ASEG publications or conferences.

6. **ASEG Service Certificates:**
   In recognition of outstanding service to the ASEG through involvement in and contribution to State Branch or Federal Committees, ASEG Publications or Conferences.

For the first four award categories any member of the society may nominate applicants. These nominations are to be supported by a seconder, and in the case of the Lindsay Ingall Memorial Award by at least four geoscientists who are members of an Australian Geoscience Body (e.g. GSA, AusIMM, AIG, IAH, ASEG or similar). The ASEG Service Awards are to be nominated by the state and federal executives.

Nominations including digital copies of all relevant supporting documentation are to be sent to:

Bill Peters
Chairman, ASEG Honours and Awards Committee,
8 Kearns Crescent
Ardross WA 6153

Email: bill@sgc.com.au
Tel: 08 93162814
Fax: 08 93161624

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

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

Petrophysics: Don Emerson
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ASEG Head Office & Secretariat:
Glenn Loughrey
AMCO Management Pty Ltd
PO Box 42, Everton Park Qld 4053
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Federal Executive 2002

President: Kevin Dodds
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Email: klaas.koster@woodside.com.au

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

Honorary Treasurer: Robert White.
Tel: (02) 9450 2237
Email: rwhite@tooronga.com

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

Past President and International Affairs:
Timothy Pippett
Tel: (02) 9542 5266
Email: tpippett@alpha-geo.com

Publications Committee: Andrew Mutton
Tel: (07) 3374 1666
Email: andrew.mutton@bigpond.com

Conference Advisory Committee:
Kim Frankcombe
Tel: (08) 9316 2074
Email: kim@sgc.com.au

Membership Committee: Koya Suto
Tel: (07) 3858 0612
Email: koya.suto@upstream.
originenergy.com.au

Education Committee: Stewart Greenhalgh
Tel: (08) 8303 4960
Email: stewart.greenhalgh@adelaide.edu.au

Publicity Committee: Mark Russell
Tel: (08) 9389 8722
Email: mrussell@micromine.com.au

Internet Committee and Web Master:
Voya Kissitch
Tel: 0419 651 737
Email: vkissitch@falconbridge.com

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

Continuing Education and ad-hoc
Committee for Constitution: Ray Shaw
Tel: (02) 9969 3223
Email: vanibe@bigpond.com

Committee

Helen Anderson
Tel: (08) 9366 3232
Email: opa@cygnus.uwa.edu.au

Jim Dirstein
Tel: (08) 9382 4307
Email: jim@td.iinet.net.au

Howard Golden
Tel: (08) 9479 8576
Email: howard.golden@wmc.com

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

John McDonald
Tel: (08) 9266 7194
Email: mcdonald@geophy.curtin.edu.au

Koya Suto
Tel: (07) 3858 0612
Email: koya.suto@upstream.
originenergy.com.au

Paul Wilkes
Tel: (08) 9266 2330
Email: wilkes@geophy.curtin.edu.au

ASEG Branches

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

Secretary: Nick Rawlinson
Tel: (02) 6125 0339
Email: nick@rses.anu.edu.au

New South Wales
President: Stephen Webster
Tel: (02) 9858 5559
Email: swebster@sneaker.net.au

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

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

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

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

Secretary: Kathlene Oliver
Tel: 0411 046 104
Email: ksoliver@optusnet.com.au

South Australia
President: Andrew Shearer
Tel: (08) 8463 3045
Email: shearer.andrew@saugov.sa.gov.au

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

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

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

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

Secretary: Ashley Grant
Tel: (03) 9412 5099
Email: ashley.grant@nre.vic.gov.au

Western Australia
President: Kirsty Beckett
Email: aseg@uts.com.au

Secretary: Guy Holmes
Tel: (08) 9321 1788
Email: guy@encom.com.au

Leading Geophysicist Retires

There is no way to measure Norm Uren's contribution to Curtin University's Geophysical Department, or to the advancement of the discipline both nationally and worldwide. But his dedication and countless hours of hard work have been recognised in a series of presentations since he retired on 1st September 2002.

In the early days, Uren was a high school physics and mathematics teacher before he moved to Leederville Technical College. There he heard of plans for a new technical college in the undeveloped pine plantations southeast of Perth.

"I thought I wouldn't mind a job out there eventually", Uren said. A short time later he was promoted to a physics position at Perth Technical College (PTC), which later became the West Australian Institution of Technology (WAIT).

"While I was at PTC, I first developed an interest in geophysics", he explained. "Originally I was planning to be a nuclear physicist. I was studying a postgraduate diploma and I needed a project to finish it. Stewart Gunson, the Department's geophysicist, offered to supervise my project on the gravity of Victoria, and I was hooked on geophysics after that."

During the mid-70s, Uren and Gunson would meet regularly with fellow ASEG members Joe Williams, Des Rouston and Hugh Doyle at Perth's Federal Hotel. Together they formed the first State Branch of the ASEG. Des Rouston became the first President of the WA Branch, and Uren was the first Vice-President.

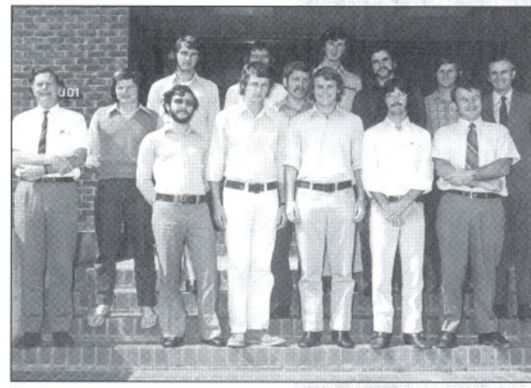
In 1978, as the pace of the local oil industry picked up, the Geophysics Department realised with some dismay that its staff were all focused on nickel and minerals. So in 1979, Norm took study leave. He worked at Getty Oil for six months, and then another six months at Shell, where he worked in the Processing Centre. This was followed by a year of long service leave when he established his own consultancy.

"Then WAIT asked if I was ever coming back", laughed Uren. "So I went back to teach and, started up a post-graduate petroleum geophysics program."

In the busy days of the mid 80s Brian Evans and Uren initiated research into multi- dimensional seismology and, despite some setbacks with the equipment and criticism from the traditionalists who didn't think the new technology would make any difference, acquired the first 3D land seismic equipment in Western Australia. "We worked with some pretty old gear. We had a donated DFS4 that had been decommissioned off a ship. Then we got cables and geophones that had faults in them, but we made it all work and acquired the 3D over the Woodada Gas Field."

Uren then, headed to the USA to further his studies, adding to his 1974 MSc with a PhD in anisotropy and seismic processing from the University of Houston.

"I was supervised by John McDonald. When I returned to Curtin I hired John, and now he's the new head of the Exploration Geophysics Department."



The First Geophysics Degree Class, 1973, Geophysics Third Year.
L-R (Back Row): Christopher Webster, Eric Mills, Kim Greenham, John Platt, Ken Foster, Dr. John deLaeter (Head, Department of Applied Physics)
(Front Row): Mr. Stewart Gunson (First Founding Senior Lecturer), Graham Elliott, John Daniels, Mike Sayers, Steve Baggot, Paul Carter, Trevor Wilson, Mr. Norman Uren (Lecturer)

During his time in the USA, Uren met GiGi in a Houston bar. In the introductory small talk he mentioned he was a geophysicist and, expecting the usual Australian response of "what's that?" asked if she knew what that meant. "Oh, you're unemployed", replied GiGi, who had been surrounded by the oil and gas industry all her life.

The two married in the same bar a year later, beneath a neon sign that said 'Gas'.

Uren said the 1980s also saw the foundations laid for the Department of Exploration Geophysics. "It wasn't formally established until I returned from study leave in 1990, when I became the first head, but it was during the 80s that it really got going."

Uren refers to the 90s as the kaleidoscope years, because so much happened. He became President of the ASEG in 1991, an ASEG Honorary Member in 1996/97 and the first Australian to be on the Executive of the SEG, when he became Vice President in 1996. Curtin also awarded him a personal Chair in Exploration Geophysics.

Norm Uren making a speech at his farewell party.

Department of Exploration Geophysics was booming and undergraduate enrolments were at their highest ever: 150 in 1998.

The research program of the Department saw it involved in a National Key Centre for Resource Exploration, the AMET, LEME and Australian Petroleum CRCs and the Centre for Mining Technology and Equipment. Its research income was five times its teaching budget. Over the last twenty years, Curtin has produced more than 300 geophysics graduates, more than half of the Australian output.

But then something happened. Student intakes began to slow, then dropped dramatically. In 1999 the School took in 40 first year students, in 2000 it was 22 and in 2001 it was 12. This year just four new students enrolled in the geophysics degree course. Uren predicts that there will be severe shortages of new graduates within two to three years.

Luckily Curtin University has shown commitment to the resource sector. A new Division of Resources and

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(Adapted from PESA News October/ November 2002)

Gordon West Receives Maurice Ewing Medal

Gordon F. West

Gordon F. West, known to many in the ASEG, was awarded the Maurice Ewing Medal, the highest award given by the SEG, at its 2002 Annual Meeting in Salt Lake City, Utah. West's selection was due to "important contributions to the science of geophysics, both personally and through his supervision of generations of graduate and undergraduate students...for co-developing with Yves Lamontagne the UTEM method which has been credited for the discovery of several important base-metal deposits, and as co-author with Fraser Grant of the classic text book "Interpretation Theory in Applied Geophysics", which has been used to teach thousands of geophysics students over the past 37 years."

He has spent virtually his entire professional career at the University of Toronto. He received a bachelor's degree in engineering physics from Toronto in 1955 and a doctorate in geophysics in 1960. He has been on the Toronto faculty ever since, advancing from lecturer to professor and ultimately to professor emeritus in 1998.

West has regularly published important articles in professional journals on a very wide range of subjects—electromagnetic methods of exploration, rock magnetism, tectonics and geodynamics, potential fields, crustal seismology, and cross-hole tomography. He played a major role in Canada's Project Lithoprobe, a multidisciplinary study in the 1980s, which investigated the composition, evolution, and structure of the Canadian continental crust.

In 1990 he was awarded the J. Tuzo Wilson Medal of the Canadian Geophysical Union.

Obituary: Stanley H Ward, 1923-2002

Stan and late wife Shirley 10 years ago in Anacortes, courtesy Bob Smith.

Stanley H. Ward passed away on July 23, 2002, in Anacortes, Washington, USA. He was 79. Stan was born in Vancouver, BC, and received a PhD from the University of Toronto in 1952. For the next 7 years, he pursued mine exploration geophysics with the McPhar Group and played a key role in several major discoveries using some of the first airborne EM methods. Stan entered academia, leading internationally recognized education and research programs at the University of California at Berkeley (1959-1970) and the University of Utah (1970-1989). He chaired 23 PhD. and 42 MS degrees, including myself. In 1977, he also started the multi-disciplinary Earth Science Laboratory at the University of Utah, now part of the Energy & Geoscience Institute, leading the U.S. Dept of Energy's geothermal exploration research effort. Stan Ward also served as Editor of Geophysics for two years, and became an honorary member of the SEG in 1982. To perhaps cap it all, he won the distinguished Ewing Medal from the SEG in 2000. I thought he would go on forever.

Article provided by Phil Wannamaker.

Nick Direen Moves To Adelaide

Nick Direen has moved from Geoscience Australia in Canberra, to Adelaide University, where he has been appointed as a lecturer in the Department of Geology and Geophysics.

Nick will be undertaking a mix of teaching, postgraduate supervision and research through the Co-operative Research Centre for Landscapes, Environments and Mineral Exploration (CRC-LEME).

Nick has been President of the ACT Branch for over two years and he will be really missed in Canberra. David Robinson is the new President of the ACT Branch, and his contact details are in the ASEG Officer's segment.

Nick's new email is: nick.direen@adelaide.edu.au.

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Environment has been created, bringing together exploration mining and agriculture. The WA Government has sponsored the creation of the Australian Resources Research Centre on the Technology Park adjoining Curtin, bringing together two CSIRO Divisions - Exploration and Mining, and Petroleum Resources - with Curtin's Departments of Exploration Geophysics and Petroleum Engineering. This is expected to develop into Australia's premier research centre in the resource sciences.

During his career, Uren has seen some monumental changes in the industry, the most important being the evolving relationship of technology and processing.

"In the 60s digital computing wasn't very common at all. Handheld calculators hadn't been invented! As part of my thesis for my MSc on processing magnetic data, I predicted that one day, every geophysicist would have a computer on their desk, and the methods I was developing for processing magnetic data would be used by people as a routine procedure", Uren said.

Although the enormous computers of the 70s caused people to scoff at his ideas, by the mid-70s digital processing had taken hold, and now, a computer on every desk is the only way to do business.

"The first computer we had on campus had all of 28k available for processing. We all thought it was wonderful, but now, the machines that sit on our desks are all more powerful than the machine that used to fill a room."

After retiring, Norm will still have an office at Curtin, where he will supervise his research students on a voluntary basis. He plans to remain active in the ASEG and do "some consulting if it comes around." But, he stipulated, he will only consult if there's a shortage. He doesn't want to compete with those who consult for their livelihood.

We wish Norm and GiGi a long and happy retirement.

New Members

We welcome the following new members to the ASEG. Membership was approved by the Federal Executive at its meetings on 31 July, 28 August and 25 September 2002.

Name	Organisation	State/Country
Tony Almond	Woodside Energy Ltd	WA
Torill Andersen	Woodside Energy Ltd	WA
Kila John Bale	ChevronTexaco	WA
Patrick Euan Boss	Woodside Energy Ltd	WA
Grant Couston	Tesla	WA
Richard John Dry	Santos Limited	SA
Susannah Elvey	Santos Limited	Qld
Catherine Farmer		NT
Charles Mark Faulkner	Phillips Petroleum Ltd	WA
Simon Jenkin Grope	ESSO Australia	VIC
Zsolt Hamerli	Santos Ltd	Qld
Brian Alec Harris	PGS	WA
Colin Michael Hawke	Woodside Energy Ltd	WA
Michael J. Holzapfel	Geoscience Australia	ACT
Natasha Yun-May Hui	Santos Ltd	Qld
Douglas James Knowles	Santos Ltd	Qld
Kate Lawson	Woodside Energy Ltd	WA
Min Li	Paradigm Geophysical	Qld
Paul John Lyon	NCPGG, University of Adelaide	SA
Keith C. Maynard	Conoco Indonesia Inc.	Indonesia
Patrick Grant McEffer	Santos Ltd	Qld
Gerard Michael McNeill	GPX Services Pty Ltd	WA
Karalee O'Brien	Santos Ltd	SA
Alex Pauli	Origin Energy Resources	Qld
Mark Livingstone Sloan	Phillipi Petroleum	WA
Daryn Voss	Velseis Processing	Qld
Jasi Anne Watson	University of Queensland	Qld
Sandy Watters	Santos Ltd	SA
Matthew Zengerer	CGG	WA

2002

November 19-21
First International Technical Conference and General Assembly: Angolan Geophysical Society (SGfA)
Theme: Key Challenges for Geophysics in Angola
Sponsors: SEG, EAGE, EGS, AAPG, IUGG and SGfA
Venue: Hotel Tropico, Luanda
Contact: sgfa@netangola.com

December 6-10
2002 AGU Fall Meeting
Venue: San Francisco, California, USA
Contact: AGU Meetings
Email: meetinginfo@agu.org
Website: www.agu.org/meetings

2003

January 6-10
Deep seismic profiling of the continents and their margins (10th International Symposium)
Venue: Taupo, New Zealand
Organised by Institute of Geological and Nuclear Sciences, Victoria University of Wellington and Geoscience Australia
Website: http://www.gns.cri.nz/news/conferences/seismix2003/
Email: seismix2003@gns.cri.nz

January 20-23
International Conference On Soil and Groundwater Contamination and Cleanup in Arid Countries
Venue: Sultan Qaboos University, Muscat, Sultanate of Oman
Contact: Anvar Kacimov, Department of Soil & Water Sciences
Email: anvar@squ.edu.om, arkasimov@yahoo.com
Website: www.squ.edu.om

January 22-24
6th Society of Exploration Geophysicists of Japan's International Symposium on Imaging Technology
Themes: Solutions for Resource Exploration and Environmental Preservation
Organised by SEGJ and co-sponsored by the (SEG), (ASEG), (EAGE) and the Korean SEG
Venue: Nihon-Daigaku-Kaikan, Tokyo, Japan
Website: http://www.segj.org/committee/sympo/is6/index.html

February 16-19
Australian Society of Exploration Geophysicists 16th International Conference and Exhibition
Venue: Adelaide, SA
Theme: Growth through Innovation
Contact: Rob Bulfield
Tel: (08) 8227 0252
Email: rob@sapro.com.au
Website: www.aseg.org.au

April 6-10
Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP)
Venue: San Antonio, Texas, US
Organised by Environmental and Engineering Geophysical Society
Website: http://www.eegs.org

April 7-11
Joint Meeting: European Geophysical Society (EGS) XXVIII General Assembly and the American Geophysical Union (AGU) Spring 2003 Meeting
Venue: Nice, FRANCE
Contact: EGS office
Email: egs@copernicus.org;
Website: www.copernicus.org/EGS

June 2-6
65th EAGE Conference and Exhibition
Venue: Stavanger, Norway
Website: www.eage.nl

August 31-September 4
EAGE/SEG Summer Research Workshop, Trieste
Theme: The role of velocity models in seismic processing and imaging
Website: www.eage.nl

September 1-4
EAGE Workshop on Fault and Top Seals: What do we know and where do we go?
Venue: La Grande Motte (France)
Website: www.eage.nl

October 6-9
1st North Africa/Mediterranean Petroleum & Geosciences Conference and Exhibition
Venue: Tunis, Tunisia
Website: www.eage.nl

October 13-15
Water in Mining 2003
Theme: The role of water in a sustainable minerals industry
Venue: The Sheraton Brisbane Hotel and Towers
Sponsor: The AusIMM
Website: www.ausimm.com
Email: Conference@ausimm.com.au

October 26-31
SEG International Exposition & 73rd Annual Meeting
Venue: Dallas, Texas, USA
Email: meetings@seg.org

ASEG 16th Conference & Exhibition
Growth Through Innovation

16-19 February 2003
Adelaide Convention Centre
www.aseg.org.au/conference/Adelaide/

It's hard for us not to keep getting more excited about the upcoming Conference in Adelaide. Of course we are a bit prejudiced as a) we do live in Adelaide (and have two teams still in the AFL finals!), and b) we know about all of the new things that are being added to this event as they happen. A quick overview of what is new will hopefully perk your interest too.

Program Highlights

The Program Committee under the leadership of Stewart Greenhalgh has been hard at work organising the 215 paper submissions that were received. Our hearty thanks to all contributors; the quality of submissions was outstanding, covering much of the geophysical spectrum. This huge number of papers has left the Committee with no choice (don't we all wish that we had such problems) but to open the Conference out to five parallel streams per day. This still leaves a healthy number of posters for you to enjoy at your "leisure". The Committee has gone to great lengths to minimise potential conflicts between sessions and papers so that attendees will miss as few as possible within their interest areas. So while there are a significant number of talks in the usual petroleum and minerals areas, there will be more talks than ever on environmental topics, forensic/archaeological topics and other less common areas of geophysics. Our two mainstays will be well represented with more than 60 specifically petroleum oriented papers and more than 70 specifically minerals oriented papers - there will be many quality presentations to choose from. There will also be three Keynote Sessions each day covering subjects that we feel will be of special interests to attendees - so keep your eye out for those. The petroleum Keynotes will be especially interesting to our oil oriented members, as these have been organised as "challenges". As such they will have a less structured feel to them, allowing the specially invited speakers to say what they really think about the state of geophysics in their specialty areas. Each of these will culminate in a panel discussion, which promises to be at least occasionally hot.

Workshop Highlights

Our workshops committee has been working hard to put together a worthwhile program for you, both before and after the Conference. At this time we have plans to put on four Petroleum Short Courses and six Minerals Short Courses. Prices are, of course, reasonable: ranging from $375 to $900 depending on course length and materials needed. On the minerals side of life, courses include Chris Anderson and Geoff McConachy's course titled "Responses of Fe-Oxide Cu-Au Deposits", and Bruce Goleby and Leonie Jones' course titled "Seismic Applications in Minerals". On the Petroleum side Fred Hilterman is offering his acclaimed course titled "Seismic Amplitude Interpretation" and Marnix Vermaas is offering his course titled "Analysis and Interpretation of Impedance Data - Workflows for Quantitative Reservoir Characterisation". If you are interested in furthering your geophysical knowledge through one (or more) of these short courses, we strongly encourage you to sign up as soon as possible, as each course will need sufficient numbers, well ahead of time, to ensure their viability.

Sponsorship

Most of the opportunities for "big time" sponsorship were taken quite early, with Santos snapping up the Platinum, and Newmont Australia and Schlumberger/WesternGeco taking the Gold. We are pleased that the number of Silver and Bronze sponsorships is progressing well and feel that the variety of companies in these top groups reflect the overall coverage that we expect from the Conference as a whole. We thank these companies and the rest of our sponsors for their support, as without their help, these conferences would be impossible.

There are still opportunities to get your company suitable exposure at this event. There are still happy hours, ice cream breaks and student events that need sponsoring. If any of these opportunities are of interest to you or your company do not hesitate to contact John Hughes (john.hughes@santos.com.au) or Mike Sexton (mike. sexton@newmont.com.au).

Exhibition

Booth sales are also progressing well. The exhibition area is second to none, with more than 100 potential sites. If you haven't already arranged booth space at this event, please do it soon as the best spaces are going fast. The people to contact are Doug Roberts (dcrgeo@tpg.com.au) and Chris Anderson (euroex@bigpond.com.au).

3DEM Symposium

We are pleased that the Third International Symposium of Three-Dimensional Electromagnetics will be held in Adelaide immediately after the Conference. This biannual

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ASEG 16th Conference & Exhibition
Growth through Innovation

Schlumberger WesternGeco NEWMONT The Gold Company Santos

New Issues for Geophysics in Salinity and Land Management

Ann-Marie Anderson-Mayes
5 Arbery Ave
Sorrento WA 6020
Phone: 08 9203 7231
Email: ama.mayes@bigpond.com

Greg Street
Phone: 08 9268 9672
Email: Gstreet@skm.com.au

The second Salinity, Land Management and New Technology Conference was held in Katanning, Western Australia on July 29, 2002. Eleven speakers presented papers on a range of topics including discussions of the role for geophysics in land management, case studies, improvements in interpretation, and the need to link outcomes of geophysical surveys to farm profitability. The overwhelming message to emerge from the conference was that there are some critical issues affecting the use of geophysics for salinity and land management studies. It is now widely accepted that geophysical information provides unparalleled insights into the subsurface processes that are directly relevant to both local and catchment scale land management. However, this is not resulting in widespread application of geophysical techniques, especially airborne surveys, to these problems.

The award for best paper presented at the conference went to Dr Richard George, for a paper based on George and Woodgate (2002). Dr George presented a controversial paper designed to stimulate discussion of the critical issues that are hindering the uptake of geophysics for salinity and land management studies. Based on outcomes of the National Airborne Geophysics Project (George et al., 1998), Dr George asserted that geophysical data (in conjunction with other data sets) could yield very useful products such as maps of soils, salt hazards, geology, regolith materials, salt storage, and groundwater resources. However, he identified several impediments to the uptake of geophysics for salinity and land management. These included awareness of the technology amongst potential users; the cost of surveying (especially the cost of airborne surveys); functionality in the sense that a significant interpretation process is required to convert geophysical data into useful information; reliability in the sense that AEM can be difficult interpret precisely as conductivity-depth information; and culture because there is a degree of resistance to using this unfamiliar, computer-based technology. Dr George asserted that "To be accepted, airborne geophysics must be shown to provide concise information that leads directly to produce solutions to specific salinity problems."

The runner-up for best paper was Simon Abbott for a presentation based on Abbott (2002). Ironically, this paper demonstrated exactly why the issues raised by George and Woodgate (2002) are so critical. Mr Abbott's paper discussed a case study from the Upper Kent catchment in the south-west of Western Australia. The study involved revisiting the complete data suite for the Upper Kent catchment which has been collected over the last 1-2 decades. Using the spatial analysis capabilities of a GIS, Mr Abbott showed that the geophysical data, in conjunction with other data sets, identifies a significant palaeo-drainage system that is not considered in existing management strategies for the Upper Kent. The current strategy of encouraging revegetation on the uplands is likely to have the counterproductive effect of raising the salt concentration of discharge from the Upper Kent catchment.

Other papers covered a range of topics including conceptual models of salinity, results from Toolibin Lake catchment, a practical overview of ground electromagnetic techniques, adding regolith and bedrock information to hydrogeological frameworks, a discussion of radiometrics from an ecological viewpoint, computer-assisted interpretation for large data suites, site characterisation for a water storage pond and an overview of planning for a geophysical survey. The final presentation by Marty Ladyman gave a farmer's perspective discussing whether degradation reversal is a good investment and the role that geophysics should play in land management activities.

A discussion session at the end of the day concluded that essentially, the geophysicists have done an excellent job in developing geophysical techniques for salinity and land management applications. There is always research and development than can be pursued to improve on these techniques, but the technology exists now to provide valuable information for land management. However, a

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event has already attracted a number of internationally known speakers in this subject area. Most of the attendees to the 3DEM symposium will be attending the ASEG conference, with quite a few presenting papers also. This sort of synergy between the ASEG Conference and the 3DEM symposium can only make each more interesting. We encourage you to take advantage of the fact that this event will also be in Adelaide and attend both.

Social

What would an ASEG Conference be without a veritable plethora of opportunities to rekindle old friendships in comfortable settings? The ice breaking opening drinks session will be held in the spectacular foyer of the Exhibition Centre overlooking the Torrens River; and there will be happy hours each day in the exhibition area. The Conference Dinner will be held at the Adelaide Oval where we are looking forward to serving you some of the best that South Australia has to offer.

For more information on ASEG 2003 please visit our website www.aseg.org.au/conference/adelaide or contact the Conference Co-chairs, Richard Hillis (rhillis@ncpgg.adelaide.edu.au) and Mike Hatch (zongeaus@ozemail.com.au), or the Conference Organiser, Rob Bulfield of SAPRO (aseg2003@aseg.org.au).

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significant multidisciplinary effort is now required to ensure that the potential of those geophysical applications are realised. Several avenues for development were suggested.

Two farmers (Bernie Doak and Marty Ladyman) gave strong support for the developments that have been made with geophysics in the last decade, but stressed that we now need to explore avenues for making the technology work. Bernie Doak suggested that positive, practical applications need to be demonstrated to instil confidence in the agricultural community; whilst Marty Ladyman stressed that clear links need to be made between commissioning a geophysical survey and farm profitability. Richard George asked how the resources of CRC-LEME could be used to address these aims. Paul Wilkes responded that CRC-LEME represented an excellent research resource, within which a small multidisciplinary team might be coordinated to liaise directly with all relevant parties in developing geophysics for land management to the next level.

A number of the papers from this conference can be found in the recently published Exploration Geophysics, Volume 33, No. 2. This special issue on salinity and salinity management draws mostly on presentations from this conference and the first Salinity, Land Management and New Technology Conference held in Bendigo in 2001.

Speakers at the 2nd Salinity, Land Management and New Technology Conference in Katanning on July 29, 2002. Standing from L to R: Justin Anning, Simon Abbott, Ann-Marie Anderson-Mayes, Richard George, Adrian Peck, Marty Ladyman and William Verboom. In front from L to R: Greg Street, Kirsty Beckett and Ken Lawrie. Not shown: Graham Jenke. (Photo courtesy of Great Southern Herald, Katanning).

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George, R. J., Beasley, R., Gordon, I., Heislers, D., Speed, R., Brodie, R., McConnell, C. and Woodgate, P., 1998, The National Airborne Geophysics Project - National Report: Evaluation of Airborne Geophysics for Catchment Management, (see www.ndsp.gov.au), (unpublished).

George, R., and Woodgate, P., 2002, Critical Factors Affecting the Adoption of Airborne Geophysics for Management of Dryland Salinity: Expl. Geophys., 33, 84-89.

Networking at the Trots.

Western Australia - by Kirsty Beckett and Kim Cook

Technical Meetings

The August meeting for the WA Branch had the theme of seismic challenges. This huge topic was extremely well covered by Jack Dvorkin from Rock Solid Images, and Birgit Cropp from Woodside Petroleum. As Jack explained it seems geophysics is not just a science anymore, but an art as well. He then demonstrated how data mining techniques can be applied to the reservoir characterisation to improve the understanding of trends and petrophysical properties in seismic data. Jack demonstrated through the use of 3D cross-plots that while the scale of the characteristics being measured differs enormously, trends within larger scale data sets (such as seismic) can be extrapolated to identify small-scale properties (such as well logs) to improve reservoir definition.

Birgit Cropp from Woodside Petroleum then demonstrated how the art of negotiation is required in order to run a successful 3D seismic survey. Exploring off the coast of the Islamic Republic of Mauritania, Birgit showed how Woodside not only kept to their very stringent safety standards, but also passed these standards on to locals in Mauritania.

The ASEG WA was also proud to support the retirement party held on Friday 30th August in honour of Norm Uren, now former head of school for Exploration Geophysics at Curtin University, to celebrate 36 years of service to the local geophysical community. With the largest collection of local geophysicists in attendances since the Perth ASEG Conference of 2000, Norm's true character was highlighted through a series of tales and poems presented by fellow colleagues and students. The night was enjoyed by all, with plenty of stories, laughs and even a few tears. Norm leaves some big shoes to fill and we wish him well with his woodworking endeavors in retirement.

ASEG WA Mid-Year Event: Christmas Reduced to the Pole - August 2nd Gloucester Park or a Night at the Trots.

The Night at the Trots was a fantastic night for the geophysical community of WA. From the 42 people who came along (apologies to those who didn't respond fast enough to get a ticket), few people walked away with more cash than they started with; but for the most, it was a great value, enjoyable night out.

Some of the winners we heard about were Megan Evans who won enough to cover her dinner bill, and also a taxi home. Greg Street put a bet on one of his friend's horses - and had a big win. Greg also walked away easily covering the dinner costs for both himself and his wife Nola. Jeremy Cook won a couple of trifectas and scooped up. Meanwhile Don Sherlock tells us he was "this close" to winning a trifecta.

Because of our final numbers, the planned cocktail-style food evolved into a full seafood buffet at the Beau Rivage Restaurant in Gloucester Park, which was absolutely yummy.

The general consensus by all in attendance was to do it all again next year. That being the case, keep the end of July/early August in the back of your mind for next year. The aim being to make it even bigger and better.

Once again, thanks to our sponsors UTS, AurionGold and WesternGeco. Without them, this night would not have been possible.

Making Waves with Open Source

There is a growing community of scientists committed to changing the IT game ... and it's starting to make waves in the seismic industry. The open source revolution provides a way out of high-cost, proprietary software and expensive software maintenance charges. It also provides opportunity for organisations to take advantage of in-house expertise, and modify or create programs to trial new ideas efficiently within the production environment. Furthermore, open source provides the flexibility to use the software throughout any organisation without worrying about seat licenses or node locks. No doubt you are aware of the power of GNU-Linux cluster technology and the impact it's having on seismic processing (see April 2002 Web Waves for more information on Linux). Here I take a brief look at some of the open source software available for seismic processing and signal analysis.

If you have any of your own favourite open source sites you'd like to share with your fellow ASEG members, please contact me (natasha@velseis.com.au) and I'll include them in future editions of Preview. Here's to a growing seismic open-source development community.

FreeUSP
www.freeusp.org

This is the official download site for FreeUSP (Unix Seismic Processing), a collection of signal analysis and seismic processing routines written at Amoco Production Company's Tulsa Research Centre over the last 40 years. Since 2001 this open source software has been offered by BP America Inc., in the hope that it may foster education, understanding and collaboration amongst the worldwide signal analysis community. In addition to the latest source download, this site provides access to the online FreeUSP support website. Online support is in the form of basic tutorials, answers to FAQ, hints for avoiding the most common newbie pitfalls and a FreeUSP Mail List. If you're a little nervous about being responsible for your own processing software, you'll find links to professional support companies. Note that there are a number of organisations that supply software or hold copyrights for software utilised in FreeUSP — you may require a license and/or written permis-sion to use these products if you're planning a commercial venture based on FreeUSP.

Seismic Unix
www.cwp.mines.edu/cwpcodes/index.html

The CWP/SU (Seismic Unix) package is an instant, easy-to-use seismic processing and research environment developed at the Center for Wave Phenomena (CWP), Colorado School of Mines. Available online since 1993, the SU package is distributed free, with full source code. In addition to contributions received from the global seismic processing community, SU continues to evolve through support from SEG and CWP. Online help is available through the SU home page (in addition to the documentation and demonstrations included with the source code). The SU website also includes links to a simple interactive version of SU (integrating a TCL/Tk graphical front end), BHP's SU modules for random reading and writing of seismic data cubes, and INT's BHP-Viewer, a powerful platform-independent graphical tool for viewing slices through SU data volumes. For those of you still operating under Windows there are commercial versions of SUNT and Visual_SUNT available. However, it is recommended that instead you simply repartition your disk and install some form of the Linux OS on your PC to operate SU. Note that Radar Unix, a complete add-on to SU for the processing of GPR data, is available at www.iamg.org (select "ftp access to programs published in Computers & Geosciences" and search for the Radar Unix article in Vol 25 (No 2) — both DOS and Unix versions available).

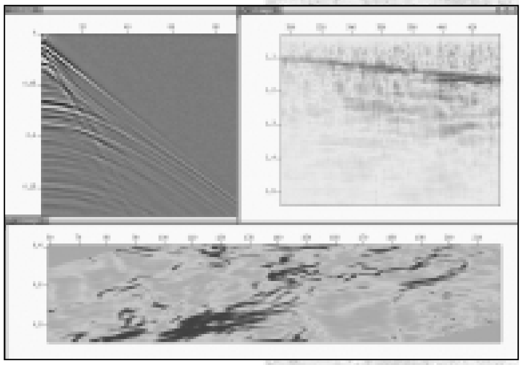
Natasha Hendrick

If you have any of your own favourite sites you'd like to share with your fellow ASEG members, please contact me (natasha.hendrick @mim.com.au) and I'll include them in future editions of Preview.

GNU Octave
www.octave.org

GNU Octave is a high-level language, primarily intended for numerical computations. It provides a convenient command-line interface for solving linear and nonlinear problems numerically, and for performing other numerical experiments using a language that is mostly compatible with Matlab. In addition to providing tools for solving common numerical linear algebra problems, Octave has 2D and 3D plotting capabilities (caveat — I haven't tested this using the Windows OS). It is easily extensible and customisable via user-defined functions written in Octave's own language, or using dynamically loaded modules written in C++, C, Fortran or other languages. It is simple to port Matlab programs to Octave. GNU Octave is freely redistributable software. Source binaries are available for both Windows and Linux. The latest development source code is also available for those interested in modifying/improving Octave for the future. You may redistribute it and/or modify it under the terms of the GNU General Public License.

SEPlib
sepwww.stanford.edu/software/seplib



SEPlib is a complete and freely distributed seismic data processing software package created and used for research by the Stanford Exploration Project. SEPlib offers a collection of basic seismic processing routines, such as modelling, filtering, and migration, that to date have been tested on Linux, IRIX and Solaris platforms. Installation instructions can be found on the SEPlib home page — both source RPMs and source code are available. Once installed, every routine prints its own documentation when executed without any argument. Help is also available through the online SEPlib documentation and a downloadable PDF version of the SEPlib manual. The simple database concept that underlies the original SEPlib package assumes the data to be regularly sampled in all dimensions. Recently, SEP3d added support for irregular data to assist with the manipulation of 3D seismic volumes. Graphics displays are handled through Vplot, a graphics library for Unix systems that is fully integrated into the SEPlib framework.

New Action Agenda for Mineral Exploration announced

Ian Macfarlane, the Federal Minister for Industry, Tourism and Resources announced, on 12 September, a new Whole of Government Action Agenda to cover the issue of Mineral Exploration. The Action Agenda will explore all impediments and incentives for this key driver of growth in Australia's mining industry. The process will build on the outputs from a House of Representatives Committee that is currently examining impediments to resource exploration (see Preview 99, p2).

"Australia is consistently ranked in the top five for international companies seeking to invest in mineral exploration. But since 1997 the industry has been suffering from a world-wide decline in exploration activity," the Minister said in his media release.

"The Mineral Exploration Action Agenda is a concentrated government and business effort to make sure Australia leads a revival of interest and investment in exploration."

"It will address all the tough issues including investment incentives, Native Title rulings, land access and environmental regulation to develop a set of realistic and achievable strategies for the industry to encourage further investment," he said.

"Action Agendas, of which there are almost 30, are a cornerstone of the Federal Government's industry policy. They bring together industry and government leaders to work on long-term strategies."

"The final framework usually sets production and export goals as well as providing a game plan for industry to turn potential opportunities into practical achievements. The Mineral Exploration Action Agenda will develop a clearly defined strategy for increasing exploration activity to underpin the future growth of Australia's mining industry."

"Our resources sector currently attracts the largest single country share of global mineral exploration budgets and we've proved mining can be an adaptable, high technology industry. In fact software used at 60 percent of the world's mines is Australian-designed," said Mr Macfarlane.

"I know industry will welcome this announcement and I encourage all those interested to participate in this important industry-specific Action Agenda," he said. Those wishing to provide input should contact Jeff Harris, Resources Division ITR, 02 6213 7520.

The AusIMM and the Australian Geoscience Council have been lobbying for this development for several months and it is a most welcome step to address the recent decline in mineral exploration investment that has taken place in Australia during the last few years (see Industry News in this Preview).

'Science meets Parliament' Day: 12-13 November 2002

FASTS' 2002 Science meets Parliament Day will be on 12-13 November. The event is a wonderful opportunity for scientists and technologists to put the case for science to their MPs.

Among the science and research issues Parliament will be considering are the Higher Education Review, priority research areas and triennium funding for Government-funded research agencies. These are all matters where the science community has well-considered views.

FASTS is arranging for scientists to meet directly with Parliamentarians. In this unique event, pairs of scientists will visit MPs and Senators at Parliament House in Canberra to press the importance of the national investment in science and technology.

"Science meets Parliament" Day runs over two days. The first day is devoted to discussions on strategy, tactics and ideas and is based at the National Press Club; and on the second day, participating scientists will meet their Parliamentary representatives.

Science-industry dinner - new feature

A new feature this year is a special dinner on Wednesday 13 November, in the dignified and atmospheric Members' Dining Room at Old Parliament House. Guests will be drawn from three groups: from participating scientists, from business and industry, and from selected Parliamentarians. The after-dinner speaker is Bob Herbert of the AIG.

This dinner is an optional extra for participants who would like to build dialogue with MPs and industry.

The good features remain. A high-profile speaker will deliver a keynote address at the National Press Club on Tuesday's Briefing Day. This year is Keith Williams; CEO of Proteome Systems will be delivering the lunchtime address. His company has rapidly expanded to be one of the world forces in proteomics, and employs about 60 PhD graduates.

A cocktail reception has been arranged at Parliament House on the evening of Tuesday 12 November. The Speaker of the House, the President of the Senate and the Minister for Education, Science and Training have been invited to address this event, an important opportunity for scientists, sponsors and Parliamentarians to meet informally.

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Articulate scientists needed

Articulate scientists and technologists from around Australia to come to Canberra to give first hand accounts to Parliamentarians of good science, the opportunities this work creates, and how more of the benefits of research could be captured. The event has been a success in previous years because of the involvement of our Member Societies.

FASTS is looking for enthusiastic and personable people who can present persuasive arguments to Parliamentarians. Ideally they will represent a cross-section of Australian science by gender, age and discipline.

More information is available on FASTS" website: http://www.fasts.org.

External Earnings Targets Removed for CSIRO, AIMS and ANSTO

In more good news from Canberra, the Federal Science Minister Peter McGauran announced on 13 September that external earnings targets currently applying to the CSIRO, the Australian Nuclear Science and Technology Organisation (ANSTO) and the Australian Institute of Marine Science (AIMS) will be removed.

This announcement was the Government's response to a *Review of the External Earnings Targets Policy Applying to CSIRO, ANSTO and AIMS* by the Chief Scientist, Robin Batterham.

The Report was submitted to the Government in May this year and it articulated the detrimental effects of the policy of external targets in research organisations.

Perhaps the key argument in the report is:

> "The external earnings targets policy has become a *de facto* priority setting mechanism, and if left in place will continue to bias research in terms of its capacity for financial return to the science authorities themselves. An environment needs to be re-established in which research planning can be based on more objective assessments of optimal financial and non-financial benefit to the nation generally."

In his media statement the Minister said:

"The external earnings targets policy was introduced to forge closer relations between the science agencies and industry, and to ensure that the continuing health and growth of these relationships became part of the culture of the organisations. Our aim is to encourage greater collaboration among research providers and to improve the opportunity for the commercialisation of research."

However, as he pointed out, "All three science agencies have been achieving external earnings around the target levels for several years and, the Chief Scientist's report shows the targets policy to be inflexible and to have unduly constrained the agencies in pursuing their business relationships."

"The removal of the external earnings targets will allow greater flexibility in the research and commercial decisions made by the three agencies, and new performance measures will focus on the social, economic and environmental impact of their research," Mr McGauran said.

FASTS, the Australian Geoscience Council and many other scientific groups have been arguing against setting external earnings targets as performance indicators for several years, and the Government's decision is very welcome. The next step is to apply these principles to all government scientific agencies, such as Geoscience Australia, the Bureau of Meteorology and ABARE.

The report and submissions to his Review are available on the Department of Education, Science and Training website at: http://www.dest.gov.au/chiefscientist/.

National Priorities and Higher Education reviews gather momentum

Priorities

An Expert Advisory Committee to advise the Federal Government on the selection of national research priorities was announced in August by the Federal Science Minister Peter McGauran.

The Committee, which includes people with a wide range of skills and expertise, will be chaired by Jim Peacock, Chief of CSIRO Plant Industry and President of the Australian Academy of Science, and comprises 12-members including the Chief Scientist, Robin Batterham. Other members are:

John Boshier,
  CEO, Institution of Engineers, Australia;
Sharon Brown,
  Strategic Business Manager, Alphawest;
Suzanne Cory,
  Director of The Walter and Eliza Hall Institute, Melbourne;
Chris Fell,
  President, FASTS;
Malcolm Gillies,
  Deputy Vice-Chancellor (Education), ANU;
Terry Hughes,
  Director, Centre for Coral Reef Biodiversity,
  James Cook University;
Leon Mann,
  President of the Australian Academy of Social Sciences;
Sue O'Reilly,
  Director, ARC National Key Centre for Geochemical
  Evolution and Metallogeny of Continents;
Helmut Pekarek,
  Chairman of the Board and Managing Director,
  Siemens Ltd; and
Michelle Simmons,
  Director of the Atomic Fabrication Facility, University
  of NSW.

"The key role of this committee will be to assess the written submissions for national research priorities and prepare a shortlist of these priorities for the Government's consideration," Mr McGauran said.

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AEM: Surviving In A Changing Environment

Andy Green
OTBC Pty. Ltd.
greenaa@ozemail.com.au

Introduction

The fascinating thing about the AEM development business is that it seems that it can't be stopped. Just when you think that there couldn't be anyone else willing to put up the required several million dollars, yet another AEM system appears. Why? Well, it surely can't be because the developers expect a huge return on their investment; the history of the business, littered with commercial failures as it is, can't be ignored. It must be because it's fun. I think that it's the combination of dramatic low altitude operation and some really fascinating technical challenges that appeals to the technically minded cowboy in us all. Nevertheless, having acknowledged our true motivation, it's worth trying to understand the application drivers and technical constraints that (probably) determine the way the technology develops.

The AEM Menagerie

David Fountain's excellent discussion of 50 years of evolution of AEM technology (Fountain, 1998) illustrates the complex nature of technical development. In this time there were many new concepts, many new "body shapes" were tested and there were almost as many evolutionary "dead ends". By the mid-1990's, survival of the fittest had narrowed the AEM kingdom down to two basic phyla:

Fixed wing, INPUT-style, high transmitter power time domain systems for detecting deep conductive targets (e.g. GEOTEM) and
Helicopter, multi-coil, multi frequency, high resolution, towed beam systems (e.g. DIGHEM).

Within each phylum there was still variation and an individual species could easily sport different transmitter waveforms or different transmit-receive coil geometries. However, these two major groups clearly did not interbreed and had differentiated themselves sufficiently to occupy distinct niches in the geophysical world. The fixed wing systems did not compete in the environmental, diamond exploration and geological mapping market and the HEM systems did not try to find deep conductive targets under conductive cover.

However, just about the time David wrote his history, things began to change. Firstly Tempest, a fixed wing time domain system with pretensions in the deep conductor market, also staked a claim in the environmental market. It could do this because it had a square-wave transmitter and much a wider bandwidth than previous time-domain systems. Secondly, and more revolutionary, was the re-emergence of a living fossil thought to have become extinct decades before; the time domain helicopter system (TDHEM). At least four species of this third phylum have appeared in the last few years. One, HOISTEM, is Australian, and the rest are North American.

Because the transmitter and the receiver are slung below the helicopter in these systems, they have the great advantage of being lower-cost, "button-on" systems. In general the transmitter is a largish (20 m diameter) loop about 30 m off the ground and the receiver is either on the transmitter superstructure or displaced above or behind it. I suspect the development of these systems was motivated by the base metals market but, as we shall see they also offer exciting possibilities in the environmental/mapping niche.

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The Committee will have to move quickly so that its recommendations can be incorporated in the 2003/2004 Budget process that starts at the end of this year.

Higher Education

Meanwhile in the same Department the Higher Education Review is also advancing. The five discussion papers have been produced and the closing date for submissions has now passed. As stated in Preview 99, one of the crucial issues for ASEG is an appropriate funding model for tertiary institutions, so that science based courses are not discriminated against.

The HE Review will have to report to Cabinet well before Christmas if it is to have any impact on the 2003/2004 Budget.

New Physics of the Earth Course at the ANU

In the doom and gloom following the closure of the Earth Science Department at Latrobe, it is good to see that the ANU will be launching new Honours and MSc degree courses in 2003.

It will offer a full range of courses in seismology, geodynamics, geophysical fluid dynamics, geomagnetism, geodesy and mineral physics.

For more details contact Jean Braun or visit the web page at: http://rses.anu.edu.au/physearth/.

VNG closes

After about 38 years of service, radio VNG, Australia's Standards Frequency and Time Signal Service, closed on 1 July 2002. For those of you old enough to be involved in the seismic probing of the continent in the 1970s and 1980s, the time signals from VNG were essential to obtain accurate timing on the rather primitive recorders that used at the time.

It was an excellent service, but, with the GPS now reigning supreme, it has unfortunately had its day. The equipment is still housed at Lyndhurst, Victoria and the National Standards Commission is looking for a permanent home for these facilities. Any suggestions?

Eristicus
27 September 2002

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They are exciting because they combine some of the most attractive features of the other systems.

Like the FDHEM systems, they usually have symmetrical Tx-Rx geometries making interpretation of anomalies on adjacent flight-lines much simpler than the asymmetric fixed wing data.
They put the transmitter close to the target giving high spatial resolution and increased transmitter-target coupling efficiency.
Like the fixed wing systems, they have the advantage of high-power, low base-frequency operation. This, combined with the strong target coupling, means that they have the potential to match, and even outperform, the fixed wing systems for conductive target detection in the top 100 m (As the targets become deeper than this, the much greater transmitter moment of the fixed wing systems overcomes the coupling advantage and should enable the fixed wing systems to retain the market for very deep targets).

However, these systems are still new and largely unproven in the long-term battle for survival. One important area of major uncertainty is their noise levels. They mostly operate with the receiver quite close to the transmitter. This induces all sorts of difficulties, especially at early times, when the receiver is seeing the complex transient current systems circulating in the transmitter superstructure (and the helicopter) immediately after the turn-off. The close coupling of the transmitter and the receiver also means that it is much more difficult to record the full waveform data that is so useful in subsequent deconvolution and transformation to step response.

The other big area of uncertainty is their performance in turbulence. We know that even the sleek FDHEM birds and the tight, high-drag birds on fixed wing platforms suffer as atmospheric conditions degrade. These TDHEM systems, with their flexible, dangling transmitters seem as though they will be unwieldy and liable to instability that will dramatically degrade their data quality as atmospheric conditions deteriorate. It remains to be seen if these apparent limitations cause weather delays that make the operation of TDHEM systems uneconomic. Table 1 summarizes the pros and cons of the three types of system.

An overview of hardware developments does not, however, provide the complete picture of the way the AEM world has evolved. There have also been changes in the market place, the environment in which these species must survive. I think we are now seeing applications that demand AEM data of three distinct types. I characterize them as: (i) Detection, (ii) Mapping and (iii) Measurement.

Some of the AEM platforms available in Australia.

Top:
Skyvan' - TEMPEST platform - minerals (Fugro Airborne Surveys).

Above:
HOISTEM helicopter TDEM system (Newmont Geophysics).

Detection

Direct detection of ore deposits was the application that started it all. Over the years it has focussed on a variety of targets but now the market is really dominated by just two: conductive base metals and kimberlites. In detection applications the objective is to configure your AEM system so that it will produce some kind of unique response when it passes over a target. This might be a bump in a late-time window that is otherwise unaffected by near-surface conductivity variations. Or, it might be a characteristic double peaked response in a vertical-coaxial channel over

	Fixed Wing TD	Helicopter FD	Helicopter TD
Tx Power	Outstanding	Weak	Good
Low Frequency Information	Very Good (12.5 Hz)	Performing to the limit of ability (>100 Hz)	Good (25 Hz)
Bandwidth	Fair to Good	Excellent	Good
Target Coupling	Fair	Very Good	Very Good
Symmetric anomalies	Poor	Good	Good
Spectral resolution	Good	Fair	Good
Calibration	Good to Very Good	Room for improvement	Improving
Flexible Tx - Rx	Fair (3 comp Rx) combinations	Excellent	Poor to Fair
Geometric Stability	Good	Very Good	Needs to prove its-self.

Table 1. AEM Technical Report Card

Sydney' - DIGHEM helicopter, Sydney Harbour - bathymetry (Fugro Airborne Surveys).

a kimberlite. In these circumstances, as long as the background geology does not introduce false alarms, we are not much interested in its response. We also don't care greatly if our system is miss-calibrated: a 20 ppm anomaly in 1 ppm noise is just as good as a 200 ppm anomaly in 10 ppm noise. It is only when we attempt to invert the data that calibration becomes an issue and, until recently, this was rarely attempted when in detection mode.

The advent of Conductivity Depth Imaging (CDI) (Macnae *et al.*, 1991) placed the first real pressures on system calibration. The necessary conversion to step response meant that, for the fixed wing data, the high altitude reference measurement had to be made reliably and system timing, and waveform accurately controlled. Once done, this enabled the approximate inversion of the data, based on a 1-D layered earth model that was later stitched laterally to produce a sectional image of conductivity along the profile. When a similar process was attempted for the FDHEM data a raft of inter-frequency calibration issues emerged because, previously, there had been little pressure to make sure that all frequencies could be interpreted in the context of the same conductivity structure.

When applied to the base metal detection problem CDI has provided a useful way of enhancing and presenting the data. Because of the 1-D assumption, only horizontal conductors are well characterized, but nevertheless, even vertical targets are detected, and although one can't be very confident of the estimated depths and conductivities, the method focuses the interpreter's attention in the right place.

Although base metal exploration is somewhat unfashionable at the moment, there is nevertheless, continuing interest in using AEM data for this application. In resistive environments, such as the Musgrave Block or the Canadian Shield, there has been substantial investment in AEM with some success. However, the application of AEM areas of conductive cover, such as the Mt Isa Block or the Andean porphyry terranes, has yet to yield an important discovery. This failure in conductive environments has continued to stimulate the development of the fixed wing systems and we are seeing a move towards even lower base frequencies and higher transmitter power. Thus, in regions with 50 Hz mains frequency, the traditional base frequencies of 75 Hz and 25 Hz are being pushed down to 12.5 Hz and even 6.25 Hz. These developments require extraordinarily soft receiver coil suspension systems to suppress the noise due to turbulence-induced rotation of the coil set in the Earth's magnetic field.

Diamond exploration has maintained a steady demand for FDHEM data to add an extra discrimination capability to airborne magnetics. It has worked quite well in resistive Canadian environments where it seems to be possible to discriminate ordinary lake sediments from more conductive weathered kimberlitic material that is also under lakes. In more complex conductive environments (e.g. Africa) the target selection problem is much more difficult because of the abundance of false alarms. In this context it is somewhat surprising the there has not been more evolution in FDHEM system design to overcome these limitations.

There's not much doubt that detection applications will continue to be the mainstay of AEM for some time to come. This because it's really only the high-value prize that can justify the cost involved of flying AEM data. But exploration is getting harder, discovery rates (we are told) are falling, and AEM, like every other exploration technique, is being applied in more difficult terrains where targets are no longer obvious bumps on otherwise flat backgrounds. AEM technologists are attempting to meet these challenges by improving S/N performance, widening bandwidth and providing new geometries but, unfortunately, there is a limit to what can be done and it is time for interpretation technology to play its part in separating target signals from the background "geological noise" that is unavoidable in these environments. We are only just coming to terms with this problem and there is enormous scope for intelligent use of other data types to help constrain the interpretation of AEM data.

Mapping

Whereas target detection cares not at all about the background geology, in mapping applications, it is important to be able to detect and map all the subtle lateral changes in conductivity structure. This means we are usually interested in mapping a wide range of conductivities and would like to have a system with a wide bandwidth, ideally with three orders of magnitude in frequency. The FDHEM systems usually meet this criterion easily and so, somewhat less easily, do TEMPEST and HOISTEM.

There is, however, an important sense in which the frequency-domain systems are weaker than the time-domain systems. This is in terms of spectral resolution. In general we should measure at enough frequencies to fully characterize the response function of the ground. Usually, the EM modellers consider that this is about five frequencies per decade. This implies that we should be measuring at fifteen frequencies over our three decades of range; far fewer than conventional FDHEM systems. In contrast, the time-domain systems indulge in overkill, effectively measuring at every odd harmonic of the base frequency up to their Nyquist sampling rate. Of course this is compressed down when the data are windowed and, in general, the fifteen to twenty windows typical of airborne time-domain systems summarize the available information quite well.

In mapping, as in detection, it is the spatial pattern that has been important rather than the absolute values. Thus, FDHEM systems, the main mapping tools, relied on the production of apparent resistivity maps, with a separate one for each frequency. Until recently there has been little pressure to ensure that these maps related to each other in a rigorous way. But, once again, the pressure to invert the data is driving changes and much more effort is being put into ensuring high-quality inter-frequency calibration on these systems.

Where the time-domain systems (e.g. Tempest) are used for mapping CDI has again proved a useful display and enhancement tool. Even so, it is clear that this application has not demanded anything more that *semi-quantitative* results from this inversion process. Thus, mappers have usually been happy with being able to say things like "the weathering is deeper here than over there" or "the cover is highly conductive in the east and becomes resistive to the west". Thus even though the AEM systems are mapping subtle changes in conductivity structure with great sensitivity it has not been necessary to label each area with exact physical properties.

All this is changing as AEM is applied to problems that are demanding accurate, *quantitative* results.

Measurement

It is the environmental problems that are increasingly making demands of AEM systems and stretch their performance to the limit. The essential difference between the requirements of these emerging environmental problems and those of more traditional applications of AEM is that the former require absolute *quantitative* measurements while the latter have been essentially *qualitative* or *semi-quantitative* applications.

Casa' - TEMPEST/GEOTEM platform - salinity/minerals (Fugro Airborne Surveys).

Salinity is the big environmental application of AEM in Australia at the moment. Here, the traditional exploration priorities are inverted. A few examples:

- Instead of detecting deep conductors, accurate shallow measurements are very important. When a saline water table reaches the root zone crops start to die and thus differences of 1 m in the top 10 m can be critical.
- Instead of mapping the regolith thickness and average conductivity, as we have in the past, there is now a need to know the *shape* of the conductivity profile down through the regolith. When most of the conductivity is in a bulge at the bottom it implies different recharge conditions to when it is uniformly distributed down the profile.
- Mapping thin, near-surface clay layers has become important. These can act as aquatards that inhibit the infiltration of irrigation water to the water table.
- In the long term it would also be useful to be able to use AEM to *monitor* changes in depth to the water table over periods of years. This implies accurate systems with very stable calibration.

These applications and others like them demand wide-bandwidth, high-precision, low-noise AEM measurements measured at enough frequencies to fully characterize the EM response function. Stable, accurately located measurement platforms are also vital; each meter of error in aircraft altitude is a meter error in depth to the water table.

In these applications inversion is an essential processing step. It is feasible because, for many problems, simple 1-D assumptions are often quite valid, especially if high-resolution helicopter data are available. Moreover, because we often have large amounts of ancillary information on the survey area, constrained inversion, where one or more well-understood parameters are fixed or limited in range, is likely to greatly improve the accuracy and stability of the

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inversion process. Nevertheless, in spite of these advantages, the subtle conductivity differences we would like to extract from the inversion process mean that the data must be very precise, especially at high-frequency/early-time.

At the moment these requirements are not really well met by either the fixed wing or the FDHEM systems. While Tempest has good, wide bandwidth, low noise performance the transmitter is 100 m away from the surface and the receiver separation does not help either. With this geometry, resolution is degraded and seemingly small errors in system geometry (e.g. 1%) are still important.

On the other hand, while the FDHEM systems have great geometry and good high frequency performance, their restricted number of frequencies, continuing difficulties with inter-frequency calibration and their poorer performance at very low frequency (<100 Hz), mean that inversion results are less reliable than we would like.

Here, then, is a potential niche for the TDHEM systems. Their low altitude time domain operation means that they are not plagued by many of the above limitations. However, they will have to have good early time performance and a well-controlled geometry, and these are not sufficiently proven as yet.

There is one other aspect of AEM operation that must be addressed before it can take a major role in environmental (and especially salinity) problems: COST. At the moment the way we are using AEM is just too expensive to contemplate its application over large areas. We need to bring the per-hectare cost down by at least a factor of 10 and preferably 100. This need not be a disaster for the contractors, the areas to be flown are huge (e.g. the whole Murray Darling Basin) and the amount of flying will still be substantial. What must happen is that we interpreters must find new ways to use AEM that don't rely on close flight-line spacing.

This is not unreasonable. Our existing survey strategy, with closely spaced flight lines, has been developed so that we don't miss the occasional isolated orebody. In the process we have become hooked on the beautiful imagery that results from these dense measurements. However, in many in salinity management problems, it is likely that blanket coverage will be unnecessary.

Rather, it is possible to envision using AEM as a precision tool in a sampling strategy to provide vertical conductivity sections along critical profiles or traverses that have been selected on the basis of other knowledge of the area. There are many occasions when hydrologists will drill a fence of holes to provide critical information for modelling or monitoring. Perhaps we should we start to see AEM in this non-imaging mode and be prepared to sacrifice the boardroom artworks to which be have become so accustomed. Perhaps we will see some projects where AEM is only flown along the drainage lines or with only one line in every third order drainage basin.

If this is to happen, AEM will have to be integrated much more closely into the process of environmental management. It will no longer be a matter of contracting a survey and seeing what shows up. Each flight line will have to be planned and as part of other, larger investigations. Moreover, data quality will have to spot on. What has been lost in terms of data density will have to be made up in data quality.

Conclusion

Like many exploration geophysicists AEM is in a period of uncertainty. Will exploration budgets revive sufficiently to motivate expensive geophysics? How should technology be managed to meet the demands of the new ways in which exploration is being managed? Will there be enough business in the environmental market to replace lost exploration dollars? The reader probably has a better chance of answering these questions correctly than the author, but assuming there is light at the end of the exploration and environmental tunnels I would make the following comments:

The challenges for the detection of orebodies lie not in improving the hardware but in recognizing the targets in the presence of complex background "geological noise".

The challenges for environmental applications lie in improving the calibration and precision of the measurements and in integrating AEM into the fabric of management practices, in a way that enable costs to be contained.

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Mineral Exploration: What should we look for, where should we look for new deposits, and what should we use in the search?

C J Pigram
Geoscience Australia
Chris.Pigram@ga.gov.au

A L Jaques
Geoscience Australia
Lynton.Jaques@ga.gov.au

I B Lambert
Geoscience Australia
Ian.Lambert@ga.gov.au

ABSTRACT

Major advances have been made in the past decade in the use of regional high quality magnetic, gamma ray and gravity datasets in mineral exploration, especially at the conceptual terrane-scale stage when prospective areas are selected for detailed exploration. However, unlocking Australia's full mineral potential under cover and at depth requires new advances - specifically the development of robust three-dimensional geological models of prospective terranes that maximise use of the sub-surface information contained within seismic, potential field and AEM datasets, and integrate this with geological and other information.

WHAT SHOULD WE LOOK FOR?

Australia's Mineral Endowment

Australia is one of the world's leading mineral resource nations. It is a major producer for a wide range of mineral commodities, and exports over 20 commodities to world markets. Australia is among the top three producers of ten of the most valued mineral commodities, including gold, diamond, zinc, tantalum and nickel.

Australian mineral production has grown enormously in the past 20 years. In 2001-2002 mineral and energy exports were worth $54.7 billion (ABARE, 2002). Production of many mineral commodities reached record levels in 2001-2002[1], and overall mine production is projected by ABARE to rise by around 8% over the five years to 2005 06 (Hogan *et al*., 2002). ABARE predicts significant growth in mine output over this period for nickel, copper, zinc, bauxite and alumina, and iron ore.

There are currently approximately 300 operating mines in Australia, but Australia's mineral production is underpinned by a relatively small number of major deposits that have sustained the bulk of production and contain most of the known resources. These 'world-class deposits' include the Olympic Dam copper-gold; Mount Isa copper and lead-zinc; Broken Hill silver-lead-zinc (which is nearing the end of production); the Kalgoorlie gold; and the Argyle diamond mines; the Weipa, Gove and Darling Range bauxite deposits; as well as the Hamersley Province iron ore mines, and the Bowen and Sydney Basin coal mines.

Australia has the world's largest economic demonstrated resources (EDR)[2] of cadmium, lead, mineral sands, nickel, tantalum, uranium and zinc. In addition, its EDR is in the top six worldwide for bauxite, bismuth, black coal, brown coal, cobalt, copper, gold, iron ore, lithium, manganese ore, rare earth oxides, silver and diamond.

Australia's long-term future as a major mineral producer depends on the discovery and mining of world-class deposits that are both profitable and have a long mine life.

Long term trends in Australia's resource base

Over three decades of systematic assessment by Geoscience Australia and its predecessors, Australia's EDR for all major mineral commodities have, on average, either increased or been maintained despite substantial levels of production; none have decreased significantly (Geoscience Australia, 2001). Much of the success in maintaining EDR is due to the sustained exploration activity that Australia has enjoyed until recently, which has revealed the natural mineral endowment of the continent.

The EDR to production ratios provide an indication of average resource life. It is an imprecise and dynamic indicator because it can be changed by:

- Further discoveries of economic mineralisation, especially those lower on the cost curve;
- Upgrading of resources through ongoing evaluation of lower category resources, commodity price increases, cost decreases or technology advances;
- Downgrading of resources from EDR through ongoing evaluation of resources, commodity price decreases or cost increases; and
- Changes in production rates.

Table 1 provides rounded EDR/production ratios as assessed at 5-yearly intervals since 1975. Even with the above qualifications, it is clear from these figures that Australia has major resources of the bulk commodities: coal, bauxite, and iron ore. In addition, there are other substantial known resources for the bulk commodities that could become EDR. However, the markedly lower EDR/production figure for iron ore in 2000 indicates how rapid changes can result from major increases in production, coupled with reassessment of resources following the introduction of new industry guidelines. The situation for gold, some base metals (especially zinc) and diamonds is much less secure. Significantly, the EDR/production ratio for gold has remained relatively constant despite major addition to the resource base. This has been achieved by successful exploration defining new resources.

Commodity	1975	1980	1985	1990	1995	2000
Coal	255	270	210	250	205	140
Bauxite	145	100	90	135	60	80
Iron Ore	180	155	175	135	125	80
Nickel	25	30	20	45	35	120
Copper	30	25	60	20	65	30
Zinc	40	45	30	20	40	25
Gold	10	20	15	10	15	15

Table 1. Years of economic demonstrated resources at the production level for the year (data from Geoscience Australia and rounded to nearest 5 years).

1 Gold production declined by 8% in 2001-2002 compared to the previous year.

2 The EDR/production ratio is a national level parameter that is based on an overall assessment. Commercial decisions are made on the basis of companies' estimates of reserves for individual deposits rather than national EDR. The reserves/production ratio is always lower than the EDR/production, which is an average resource life for a commodity at the time the ratio was calculated.

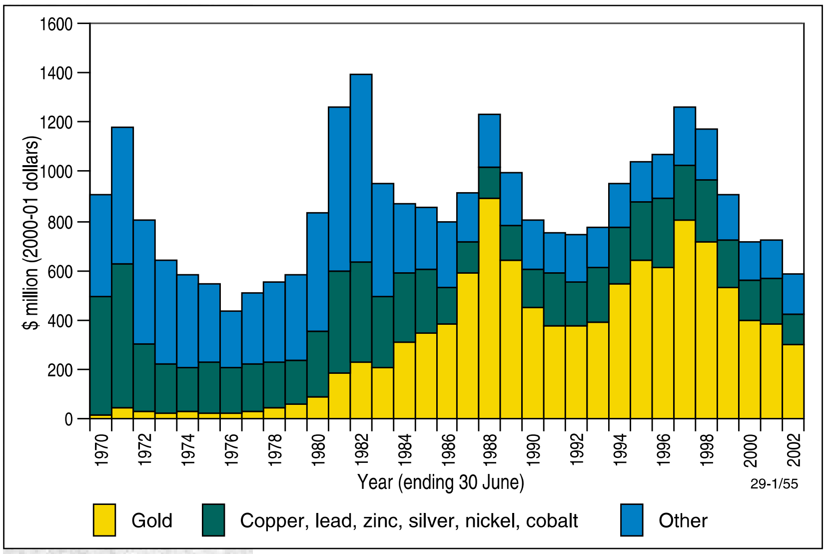


Fig. 1. Australian mineral exploration expenditure from 1970 to 2002 (in 2000-2001 dollars). Derived from ABS quarterly survey of mineral and petroleum exploration expenditure. Figures for 2002 are ABS estimates.

Exploration: current drivers

Resource exploration patterns vary considerably with economic cycles. Despite the very healthy state of Australia's mineral production (even allowing for the current downturn in gold), mineral exploration expenditure in Australia is presently at a 20 year low in real terms having fallen by more than half since peaking in 1996/97 (Figure 1). The decline mirrors a global downturn in mineral exploration and was accompanied by a major reduction in the number of companies engaged in mineral exploration. The reasons for the decline are primarily low world metal prices caused by oversupply, poor rates of return on investment, intense competition for risk capital, land access difficulties, and industry consolidation (Jaques and Huleatt, 2002a).

Australia has maintained its position as the world's leading country for mineral exploration with 17-20% of global expenditure over the past decade (Jaques and Huleatt, 2002a). It has an investment climate that is stable and financially competitive and an enviable record in successful discovery of new resources, due in no small part to a strong collaborative research and development effort between industry and government (PMSEIC, 2001).

The primary driver of exploration activity in Australia since the late 1980s has been the search for gold. Throughout the nineties and into this century around 60% of all exploration dollars have been spent in search of gold. Gold has become Australia's third most important resources commodity after coal and petroleum.

There is every reason to believe that gold will continue to dominate Australian exploration. Gold prices are expected to remain near current levels in the short-medium term. ABARE (2002) reported that Australian gold production in 2001-2002 was 271t, down 14% on the peak of 316t in 1997-1998[3]. Australia is a highly attractive country for gold exploration and mining in view of the highly favourable discovery costs (Jaques and Huleatt, 2002b) and low cost of production[4] .

The bulk commodities have not been an important/significant proportion of Australian exploration expenditure for over 20 years. Australian Bureau of Statistics (ABS) quarterly surveys of expenditure indicate that the base metals (copper, lead, zinc, nickel) have for the past 25 years consistently constituted ~ 20 - 30% of total exploration effort (average $200 - $240 million in 2001 dollars) apart from 1987-1989.

The demand for the bulk commodities and base metals is tied to global economic conditions. The very large reserves, world-class status of many of its mines, and Australia's competitive position in world markets should ensure that the bulk commodities will continue to play a key role in Australia's exports for several decades. ABARE predicts demand to strengthen as global economic activity and industrial production recover in 2003.

Substantial growth in metal demand in the next 10 years, mostly from China and the former Eastern bloc countries, has been predicted and significant price rises for base metals forecast in 2003-2004 (Lennon, 2002; Maurer *et al.*, 2002). However, ABARE expects also that the projected firmer prices will encourage new developments that will raise capacity and dampen prices beyond 2003-2004 (Berry and Haine, 2002).

ABS quarterly survey data indicate that 'other' commodities typically constitute ~20-25% of total exploration spending. Exploration for mineral sands has increased markedly in recent years and reached a record $29 million, 5% of total exploration in 2001. Diamond exploration comprises about 5% of total exploration. Uranium exploration has fallen significantly in recent years.

Given these economic drivers, Australia's EDR, favourable discovery costs, and mineral endowment Australia is likely to be highly attractive to gold exploration and also of interest in the short and medium term to zinc, nickel, lead, copper, diamond, mineral sands, coal and iron ore exploration.

Diversity of deposit types

Australia owes its mineral endowment to its diverse geology with over 70 types of mineral deposits of economic significance occurring in rocks ranging in age from very old (Archaean, ~ 3 billion years) to very young (< 5 million years), and over a wide range of geological settings. This diversity offers enormous exploration opportunities for many commodities. The high endowment and globally competitive discovery costs make Australia an attractive exploration destination (Jaques and Huleatt, 2002b). The following deposit types are given as selected examples of mineralisation known to contain world-class deposits and where the existence of major deposits underpins Australia's prospectivity.

Gold

About 80% of both Australia's current production and known gold resources are contained in orogenic (lode) gold deposits mostly of Archaean age (Jaques *et al.*, 2002). Of the approximately 30 world-class gold deposits known in Australia, ~80% are of this type.

[3] ABARE predicts that Australian gold production will increase to 294t in 2003 (Maurer *et al.*, 2002)

[4] Gold Fields Mineral Services (cited in Maurer *et al.*, 2002) claimed Australia's average gold production cash cost in 2001 was the lowest in the world at an average of US$175 per oz

Most of Australia's gold exploration is devoted to the search for Archaean gold deposits, mostly in the Yilgarn Craton. The high endowment, low discovery costs (<$20 per ounce), and the potential for highly attractive production costs provide strong incentives for continued exploration. Proterozoic orogenic gold systems are also highly attractive and have grown in importance in recent years with Callie in the Tanami Province Australia's second largest producer in 2001. Gold resources in the Tanami Province have nearly doubled in the past 5 years. Many areas of Proterozoic have not been subjected to modern exploration and are under explored (see *Where should we look?* below).

Australia is also highly prospective for other types of gold deposits. For example, large low-grade porphyry associated gold (-copper) deposits such as Cadia are an increasingly important deposit type with ~10% of current production and resources. Significant gold resources are also contained in the Proterozoic Fe-oxide gold copper deposits such as Olympic Dam and Ernest Henry, and there is also potential for more discoveries of smaller but high-grade epithermal systems such as those in the Drummond Basin.

Nickel

Australia's very large nickel EDR is mostly as lateritic ore. The development of the pressure acid leach (PAL) nickel operations at Murrin Murrin, Cawse and Bulong in WA refocussed attention on nickel laterite deposits, and exploration has resulted in enormous growth of Australia's lateritic nickel EDR. Significant new discoveries of nickel sulphide have also been found, some of very high grade, associated primarily with Archaean komatiites in the Yilgarn. Nickel ± copper sulphide deposits have also been found associated with Proterozoic layered mafic-ultramafic bodies in the Kimberley and Musgrave Ranges, highlighting potential for the basal sulphide (including Voisey's Bay type) deposits (Hoatson and Blake, 2000).

Copper

Australia's large copper production and resources are dominated by two deposit types and two major deposits — Olympic Dam and Mt Isa. The recent discovery of Cu-Au±U mineralisation at Prominent Hill has prompted a reappraisal of Australia's copper potential and, in particular, the potential of the northeast Gawler to host further economic Proterozoic Fe-oxide Cu-Au systems. Porphyry gold-copper deposits in central western NSW are also significant and suggest potential in other accreted arc systems of the Tasman Fold Belt System.

Although historically very significant in Australia, volcanic-associated massive sulphide (VMS) deposits have declined in importance in recent years. The recent high-grade intersections in the Yilgarn Craton (e.g. Teutonic Bore) suggest remaining potential for high-grade base metal deposits of this type.

Zinc and Lead

Australia is well endowed in zinc and lead deposits. Proterozoic sediment-hosted, stratiform Ag-Pb-Zn deposits dominate production and resources (Jaques *et al.*, 2002). Sediment-hosted stratiform deposits (commonly referred to as SEDEX) deposits are attractive targets in view of their disproportionately large size, large reserves and increasing importance in production (Allen, 2000). The McArthur — Mt Isa — Cloncurry mineral province or 'Carpentaria Zinc Belt' is one of the most endowed zinc and lead provinces in the world (QDME *et al.*, 2000). However, large areas of Australia s former Proterozoic basins remain under-explored. There is also potential for zinc and lead in Mississippi Valley type (MVT), VMS and Cobar-type deposits: collectively these constitute ~ 25% of current production and resources.

Mineral Sands

Australia has the world's largest EDR of ilmenite, rutile and zircon. The discovery in the past 5 years of over 200 coarse-grained ilmenite, rutile and zircon strandline deposits in the Murray Basin has seen the province become recognised as a world-class mineral sand province. Discoveries continue to be made in former beach systems on both the east coast and west coast (e.g. Dongara).

Diamond

Australia is the world's largest producer of diamond (by weight) with production almost entirely from the world-class Argyle mine in WA. There is limited production from the Merlin (NT) and Ellendale (WA) pipes. Much of Australia — notably the large shield area — is potentially prospective for diamond. Much of the Northern Territory is under title for diamonds following the recent release by the Northern Territory Geological Survey of new aeromagnetic data covering large areas.

WHERE SHOULD WE LOOK?

Australia has been subjected to an intense exploration effort throughout the 20th Century. This has resulted in the discovery and development of some of the world's leading mines and mineral provinces. The question of Australia's remaining mineral potential depends partly on the opportunities for the continued discovery of major new resources in existing mineral provinces and, more importantly, whether or not the major metallogenic provinces in Australia have been identified. In most mineral provinces — as in petroleum basins — the largest deposits tend to be found first because of their larger footprint. Given the extent of exploration in Australia are there as yet undiscovered provinces with world-class ore deposits? Or is Australia approaching maturity from an exploration point of view?

Frontier terranes

We believe that the answer to the former question is yes: there are still large tracts of Australia that have not been effectively explored for minerals. Reasons for this vary but include the remoteness of some regions (eg Tanami Province), difficult access (e.g., the Central Australia terranes such as the Musgrave Block, Arunta and Eastern Arnhem Land), and the barrier posed by deep weathering and transported cover (e.g., Gawler Craton, Olary region of the Curnamona Craton, eastern Mt Isa — Georgetown). Lines and Kay (2002) discussed these issues in relation to the Tanami region where modern exploration did not start until the mid-1980s. They estimated that as little as 20%

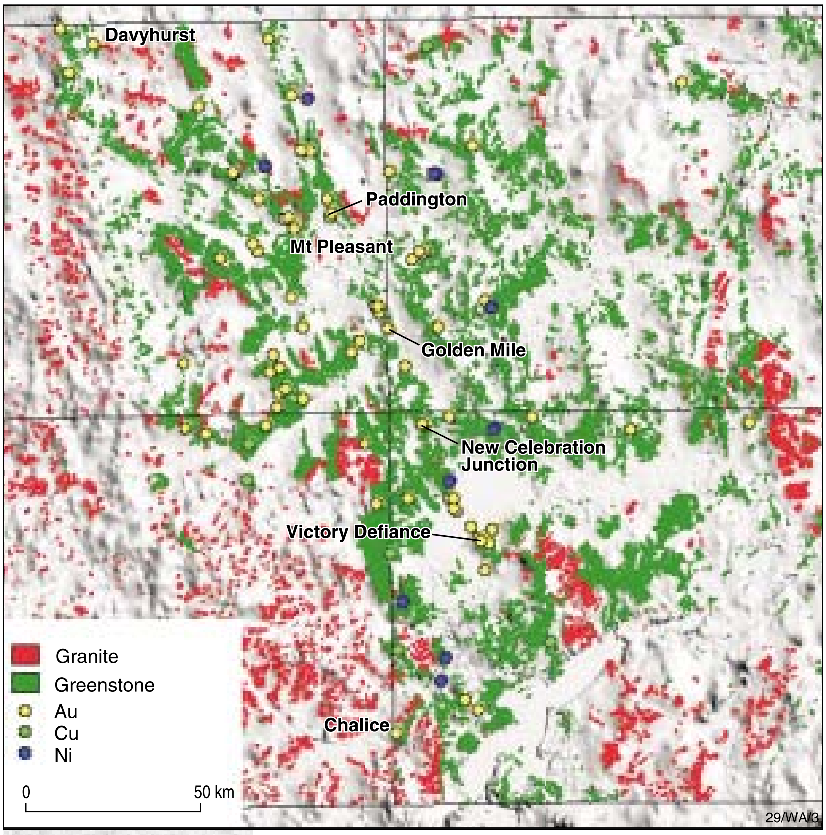


Fig. 2. Outcrop map of Kalgoorlie region of the Eastern Goldfields showing the distribution of mineral deposits in relation to the simplified geology and digital elevation model (DEM).

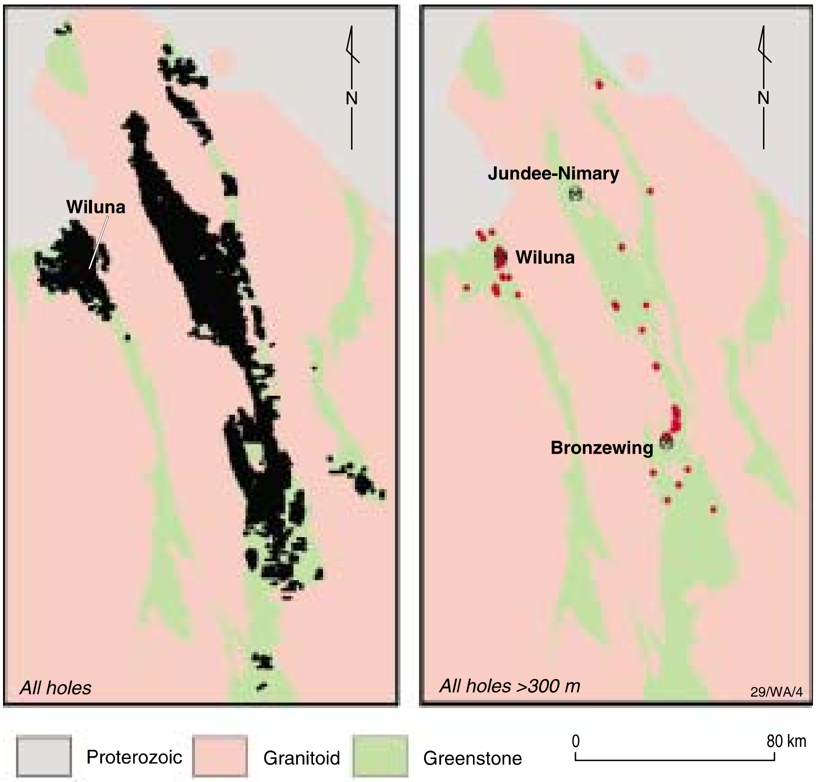


Fig. 3. Map showing the Yandal Greenstone Belt of the Yilgarn Craton comparing total drilling (a) with drill holes that have penetrated beyond 300m (b), after Champion de Crespigny (2002). The figure illustrates the untested potential at depth beneath one of Australia's premier gold-producing districts.

of the prospective covered areas of the Tanami region might have been subjected to modern exploration. Similarly, large areas of the Musgrave Ranges have not been explored since the nickel boom in the early 1970s. As a result of recent discoveries the Ashburton Province is emerging as a new gold province. Recent discoveries of gold grains have also sparked interest in the North Kimberley as a potential gold province. Each of these examples of under-explored frontier terranes provides considerable exploration opportunity.

Under cover and at depth in proven mineral provinces

In addition to these more obvious frontiers there are considerable tracts of prospective terranes beneath cover in the well-explored provinces such as the Eastern Goldfields of WA. Figure 2 is an outcrop map of the Kalgoorlie region of the Eastern Goldfields showing known deposits in relation to simplified geology and draped on a digital elevation model. The plot clearly shows that most deposits are located in areas of outcrop: they are thus likely to have been found by surface prospecting or to have had a surface expression of some form. The continued discovery of new deposits in the Eastern Goldfields — in some cases within 25 km of Kalgoorlie — indicates that the belt cannot be regarded as mature in terms of exploration.

In addition to the areas of thin cover within a mineral province or district, the outer limits for provinces as they plunge under sedimentary basins must be of interest. For example, the area to the east of Laverton, which was recently investigated by Geoscience Australia, the Geological Survey of WA, and the Predictive Mineral Discovery CRC using both potential field data and a deep crustal seismic reflection survey. The results show the Yarmana Greenstone Belt (which is largely covered) has a similar structural style, including the existence of a major east-dipping, deep crustal structure, to the greenstone belts further west implying the belt may have potential to host orogenic gold deposits (Goleby and Korsch, 2002).

The other great opportunity in so-called 'well explored' or 'mature' terranes is beneath the thin rind that has been drilled and exploited. This frontier is well illustrated in Figure 3 that compares the amount of deep drilling (holes greater than 300m) with coverage of conventional drilling in the Yandal Belt near Wiluna in the northern Eastern Goldfields of WA. This belt, which produces 10% of Australia's gold and has three world class mines, has not been explored at depth (Champion de Crespigny, 2002). This point is reinforced by the fact that, even in intensely explored regions, deep extensions to near-surface deposits continue to be made (e.g. Kanowna Belle).

Conceptual frontiers

The remaining frontier outside the geographically remote or covered terrane is one that could be referred to as a 'conceptual frontier'. By this we mean those aspects of mineral systems or terranes where new insights rapidly change perceptions of prospectivity. Despite the many years of research and exploration there are still fundamental gaps in knowledge of the geology of even many of our best-endowed and explored mineral terranes. For example, the results from the 1991 BMR Kalgoorlie deep crustal seismic reflection survey caused a major re-evaluation of the regional structure and the distribution and shape of greenstone belts (Drummond *et al.*, 2000). Similarly, new age data can significantly change understanding of geological events and prospectivity. For example, new precise U-Pb zircon dating has correlated Palaeoproterozoic sedimentary successions in the Curnamona Craton with contemporaneous sedimentary rocks in the western and eastern fold belts of the Mt Isa Inlier (Page *et al.*, 2000). To a large degree the WMC Ltd discovery of nickel-copper (± PGE) mineralisation at their West Musgrave project is an example of bridging conceptual frontiers through the application of a 'new' exploration model.

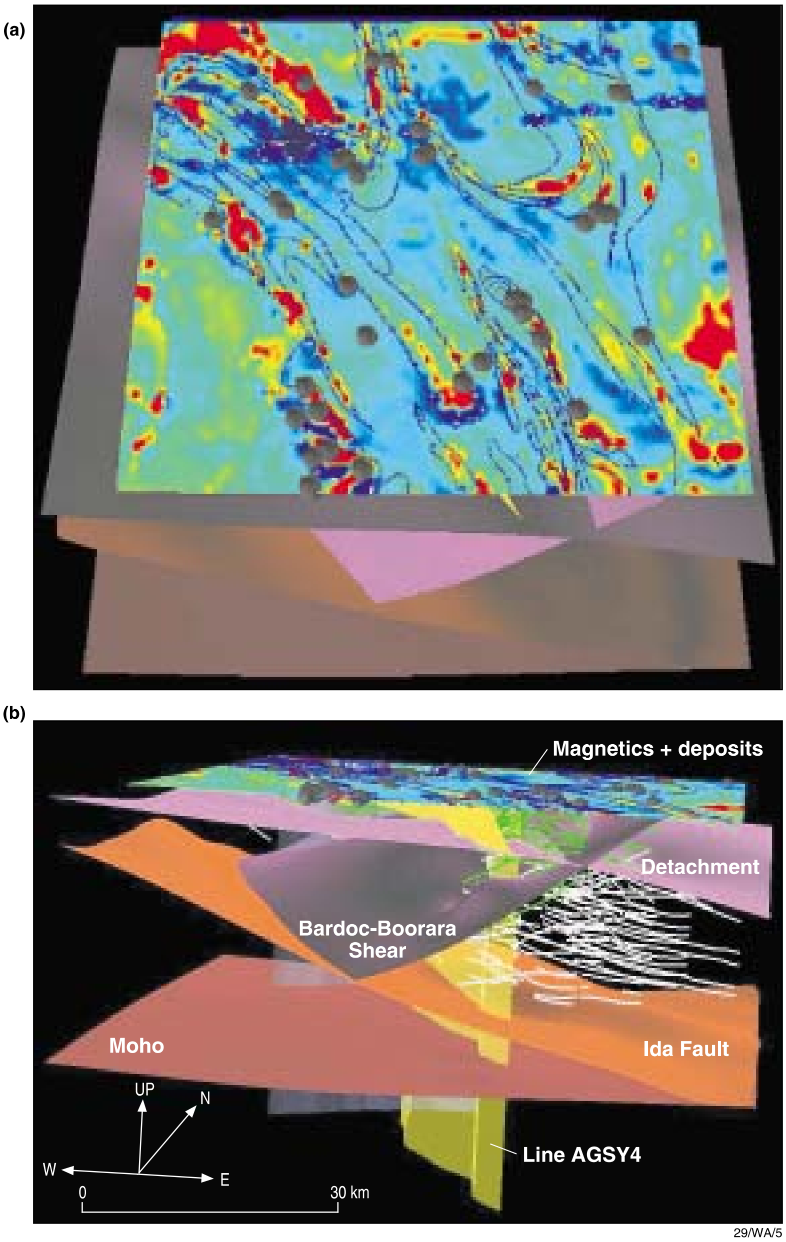
We have avoided identifying a 'shopping list' of prospective terranes because the issue is not where to explore in the next few months or years but rather recognising that Australia has an excellent endowment that can sustain a vibrant explo-ration and mining industry throughout the 21st century if we can develop the tools to explore the frontiers.

With regard to the question of where we should look then, there are two answers. The first is everywhere we have looked before, but with new tools, ideas and concepts so we can explore the layer beneath that which we have exploited to date. The second is in those provinces that, for one reason or another, have either been ignored or not yet fully tested, again using new tools and concepts.

WHAT SHOULD WE USE IN THE SEARCH?

Before answering this question, we need to define what it is that we will have to achieve to be able to successfully explore the frontiers outlined above. From a government perspective the key objective is to provide a knowledge framework sufficient to reveal prospectivity at the regional scale and provide a sound conceptual basis for area selection for detailed exploration. The challenge then is to develop 3D and 4D geological models of the crust at the terrane scale ('prediction' scale of Golden, 2001) that provide information on the geometry and lithology of prospective terranes. The application of high-resolution aeromag-netic mapping in the late 1980s revolutionised mineral exploration through more robust conceptual geological targeting (Isles *et al.*, 1989; McCuaig and Hronsky, 2000). High-resolution aeromagnetic surveys are now an essential component of both modern geological mapping and mineral exploration in almost all terranes. Robust terrane-scale 3D geological models will extend our ability to appraise the potential of terranes to host large mineralising systems and form a framework for the development of appropriate exploration programs to detect the mineralisation.

In short, this requires a better predictive capability. This approach is not new, and it has been articu-lated in many forms; for example, it



Top: Fig. 4. (a) Image map showing simplified interpreted geological boundaries and gold deposits (black dots) draped on total magnetic intensity; and (b) view of the three-dimensional model of the Kalgoorlie-Ora Banda region of the Eastern Goldfields, WA based on (after Goleby et al., 2002).

Right: Fig. 5. Australian National Seismic Imaging Resource (ANSIR) seismic acquisition system enroute to field survey. The four vibroseis trucks provide up to 30 tonnes (60,000 lbs) peak force and have been particularly successful in imaging a number of hard-rock terranes.

was the basis of the ambitious programs for two Cooperative Research Centres including the current Predictive Mineral Discovery CRC and the CSIRO's 'Glass Earth' initiative. It was highlighted as the 'tyranny of depth' issue in a presentation to the Prime Minister's Science, Engineering and Innovation Council (PMSEIC, 2001) among others. McCuaig and Hronsky (2000) stress that the relative effectiveness of prediction is greatest at the province and region scale, whereas detection becomes more important at the prospect and mine scale.

The great challenge in this, the first part of the 21st century, is to generate three dimensional physical property maps of a volume of the upper crust that contain sufficient information to enable reliable geological interpretation and prediction of mineral potential. Achievement of this will require a sound understanding of the structure and 3D evolution of the crust such that the surface geological map will remain vital as the factual layer from which to build the third dimension. An example of this is shown in Figure 4, which shows the 3D model developed by Goleby *et al.*, (2002) for the Kalgoorlie region of the Eastern Goldfields based on deep seismic reflection and potential field data. The model highlights the east-dipping Ida Fault, the west-dipping Bardoc-Boorara Sheer and the regional detachment.

Many of the tools exist for the rapid (and often remote) acquisition of the physical property data that are required, e.g. magnetic susceptibility, density, conductivity, seismic velocity, etc: others (e.g. tensor magnetometry and gravity) are under development. The major limitations are our ability to extract the information contained in these datasets and to interpret the data to full effect. The high quality regional aeromagnetic, radiometric, and gravity datasets that cover large parts of the continent and were acquired through combined Commonwealth-State/NT programs under the National Geoscience Agreement (formerly National Geoscience Mapping Accord) and individual State/NT exploration initiatives provide a basis for developing 3D models. Large areas of prospective ground remain to be flown to modern standards, however. The new airborne electromagnetic systems suitable for Australian conditions (e.g. Nabighian and Asten, 2002), the development of gravity gradiometry (e.g. Lee, 2001), and the application of the seismic reflection method to 'hard rock terranes' (Figure 5) have, over the last decade, added significant breadth to our toolkit for gathering/covering substantial areas rapidly and at high resolution. Quantitative modelling of these datasets, coupled with sophisticated geological interpretation, will form the basis of the 3D models.

This approach will also require a paradigm shift in the way we manipulate geoscientific data and indeed how we understand and extract the information contained within the data. New tools to assist with the forward modelling and inversion of geophysical data in three dimensions are essential, as is software for the interactive visualisation of the volume of rock that is being examined. Such software is becoming increasingly available and can be expected to have a major impact on the way in which exploration is conducted in future. Hobbs *et al.* (2000) extended this 3D geological modelling to include geological, geophysical and geochemical data with the objective of building holistic, integrated and quantitative models of ore formation.

In summary, geophysics has played a major role in the discovery of Australia's mineral resources in the past, both directly through detection of physical property anomalies and indirectly through the insights into the geology provided by potential field data, especially high-resolution aeromagnetic image maps. Modern exploration employs a multidisciplinary approach. Geophysics, integrated with geological and other datasets, will underpin the discovery of the next generation of ore deposits through an enhanced ability to better 'map' and image 3D volumes of the crust and predict the location and size of mineral deposits.

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Australia's Offshore Petroleum Industry: what are the plays, where are we heading?

Andrew Barrett
Geoscience Australia
andrew.barrett@ga.gov.au

Marita Bradshaw
Geoscience Australia
marita.bradshaw@ga.gov.au

Introduction

The Australian offshore petroleum industry has come along way since the drilling of the first offshore well in 1964, but by world standards, Australia is still relatively unexplored.

In this article we would like to address:
- Where have we come from?
- Where are we at?
- Where are we going?

Where have we come from?

There are now many narratives of the early days of the petroleum industry in Australia and of these, Rick Wilkinson's *A Thirst for Burning* (1988) has the most detail. Robertson (1988) has described many of the early aspects of petroleum exploration in Australia, including a history of resource assessment. How different things have turned out compared to some of the rather dismal early assessments. Will we see the same misjudgments become apparent in the next hundred years, especially in our frontier areas?

The discovery of gas in a water bore at Roma in 1900 is generally accepted as our first hydrocarbon discovery, albeit serendipitous. At various times during the twentieth century, state and federal governments have offered prizes and subsidies to encourage exploration but it was the discovery of oil in Rough Range 1 (spudded in 1953) in the onshore Carnarvon Basin that really pushed the exploration game to a new level, showing that oil would flow to the surface in Australia. Exploration activity increased with the results of Rough Range 1 but activity soon diminished (Figure 1).

The Commonwealth's Petroleum Search Subsidy Act 1957 provided important encouragement to explorers. By 1964 discoveries of oil and gas had been made in the onshore Amadeus, Adavale, Perth, Cooper, Surat and Carnarvon Basins (Bradshaw *et al,* 1999, Table 1). It was the step offshore that found the largest oil fields and the pre-conditions for this adventure were brought together in the Gippsland Basin. Oil recovered from Lake Bunga 1 in 1924 and the exploitation of the oil sands during World War II demonstrated that here was an active petroleum system (to use today's jargon). This observation was married with Bureau of Mineral Resources (a forerunner of Geoscience Australia) aeromagnetic data showing there was a thick basin offshore, and seismic showing large structures. In 1965 the first well, Barracouta, found a giant gas field, quickly followed by the discovery of the giant Halibut and Kingfish Oil Fields.

The production of oil from the Gippsland Fields has sustained Australia's domestic petroleum supply for the last 30 years, with additions from a larger number of smaller fields in the Carnarvon and Bonaparte Basins growing in importance through the 1990's until today they represent more than half of the production (Figure 2). By 1972 almost all of Australia's currently producing basins had had discoveries and the only new hydrocarbon-producing basins that have been added to that list were the Eromanga Basin, overlying the previously discovered Cooper Basin, and the Otway Basin, if the 1966 discovery of CO_2 at Caroline 1 is discounted.

Where are our resources?

Figure 3 shows Australia's developed reserves of oil, condensate and gas in their proportional volumes by basin. Both the volumes currently developed and those remaining to be developed as at the end of 1999 are depicted. In total there are 8.9 billion barrels of oil and condensate, with about 1.9 billion barrels yet to be developed; and 133 trillion cubic feet of gas, with 84 trillion cubic feet yet to be developed. Although significant volumes have been discovered onshore, the figure shows a very strong bias towards the offshore where the Gippsland and Carnarvon Basins dominate.

Australia is currently 84% self-sufficient for petroleum (Petrie *et al.*, in press) with local production of around 600 000 barrels/day. This self-sufficiency is now dependent upon the production of many small oil fields with relatively short life spans (Figure 2) and additional liquids from the condensate produced from gas fields such as North Rankin.

When Australia's undeveloped and estimated undiscovered resources (*from producing basins only*) are considered (Figure 4) the dominance of the large gas resources on the North West Shelf becomes apparent. Despite the growing export trade of liquefied natural gas (LNG) and liquefied petroleum gas (LPG) to Asia, there are still large stranded volumes of gas in the Carnarvon, Browse and Bonaparte Basins. Powell (2001) drew attention to the increasing reliance of Australia on condensate associated with these undeveloped giant gas accumulations. Condensate now represents 61% of our estimated future liquid reserves (Petrie *et al.*, in press). A key challenge for Australia is to monetise the gas resources and gain access to the condensate in a regime of declining oil production.

Australian offshore basins are vastly under-explored. By area, 80% of the offshore sedimentary basins are classed as frontier or immature with none or only a handful of exploration wells having been drilled in them. For Australia

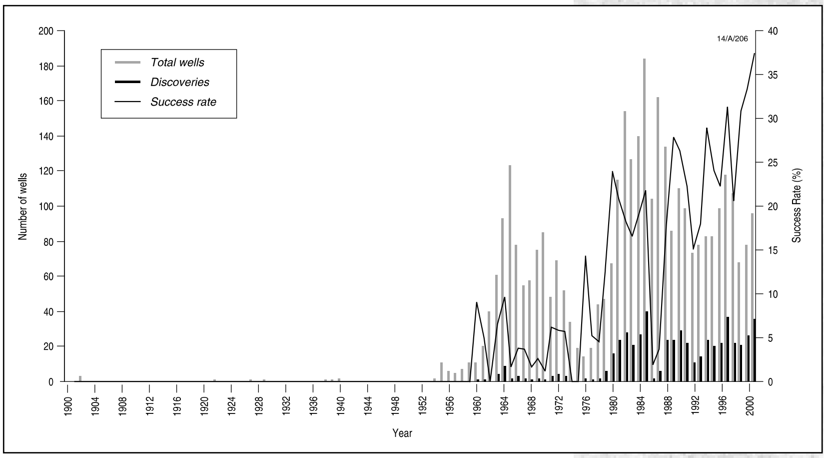
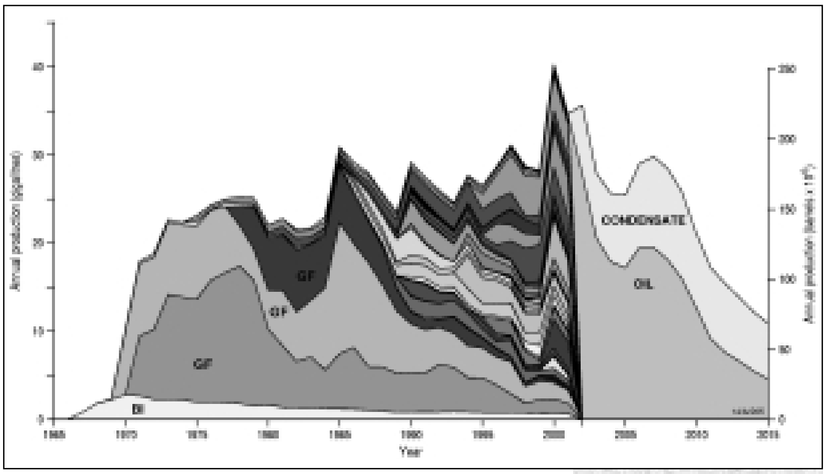
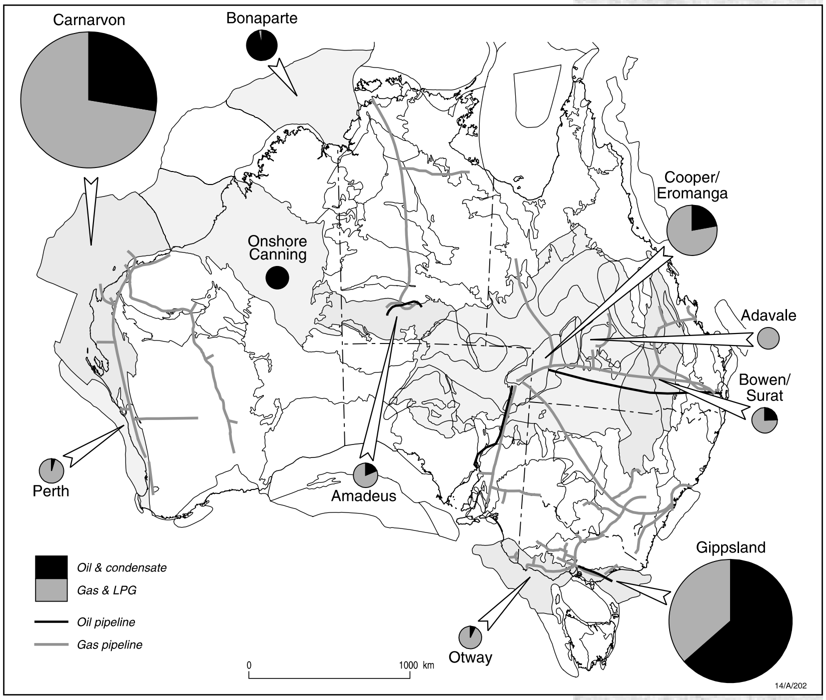
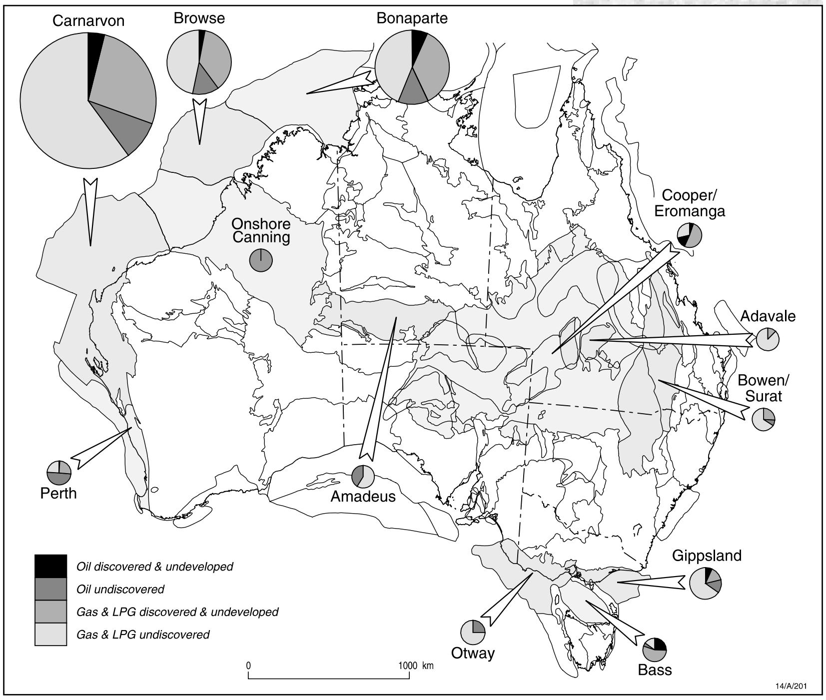


Fig. 1. Australian exploration history 1990-2001 showing exploration wells, hydrocarbon discoveries and success rate by year. A discovery is defined as a well from which any measurable amount of oil or gas has been recovered and makes no assumptions as to its commerciality. Data from Geoscience Australia's PEDIN database.







to retain its self-sufficiency, new productive basins will need to be brought in to play. High hopes are held for success in the Great Australian Bight where Woodside and its Joint Venture partners are due to drill in deep water early in 2003.

Proven basins

The term 'mature basins' is commonly used to describe the state of exploration in the Gippsland and Carnarvon basins but on the world scale, these basins are very much still at the immature stage of exploration. To date only about 8300 petroleum wells have been drilled in Australia of which about 2000 have been drilled offshore. Compare this with data from the Minerals Management Service (http://www.mms.gov/homepg/fastfacts/WaterDepth/WaterDepth.html) in the United States, which has approved over 2200 applications to drill wells in water depths greater than 1000 m in the Gulf of Mexico alone! More than 3 000 000 wells have been drilled in North America.

In Australia in 2000, 97 exploration wells were drilled with 61 of these drilled offshore. The Gulf of Mexico region sees about 1000 wells drilled per year.

The first offshore well in Australia was drilled in the Gippsland Basin in 1964; this well discovered the Barracouta field. By the end of 1999, 3.4 billion barrels of oil and 5.1 trillion cubic feet of gas had been produced from the Basin. Though it is acknowledged that most of the obvious traps in the major play type, "the top Latrobe", have been drilled, there is still significant remaining potential in the Gippsland Basin. There is active exploration for intra-Latrobe reservoirs and the recently acquired 3800 km^2 3D seismic survey by Exxon-Mobil in the northern part of the Basin should enhance development of this and other play types. With the arrival of several new explorers in the Basin, including OMV and EnCana, exploration has also moved from the main basin area to the northern terrace and onshore, as well as to the deepwater.

By the end of 1999, the Carnarvon Basin had pro-duced about 750 million barrels of oil and almost 6 trillion cubic feet of gas. The major oil reserves are in Late Jurassic and Early Cretaceous sands in anticlinal traps in the central Barrow and Dampier Sub-Basins, while the giant gas accumulations are typically in Triassic horst blocks, along the western edge of these sub-basins. Significant developments in the last ten years include the development of the eastern basin margin play fairway (Delfos, 1994; Ballesteros, 1994, 1998), the resurgence of the Exmouth Sub-basin as a potential oil producer (Polomka *et al.*, 1999) and the discovery of new giant gas accumulations in new play types - Perseus (Taylor *et al.*, 1998) and Jansz. Extensive 3D surveys acquired during the 1990s have provided the launching pad for many of these discoveries (Kingsley and Tilbury, 1999).

Top: Fig. 2. Production profiles of individual Australian fields and cumulative production forecast at 50 per cent probability, derived from industry data. BI denotes Barrow Island Field; GF denotes giant Gippsland Basin Fields.

Middle: Fig. 3. Australia's developed hydrocarbon resources and oil and gas pipelines.

Bottom: Fig. 4. Australia's undeveloped and estimated undiscovered hydrocarbon resources.

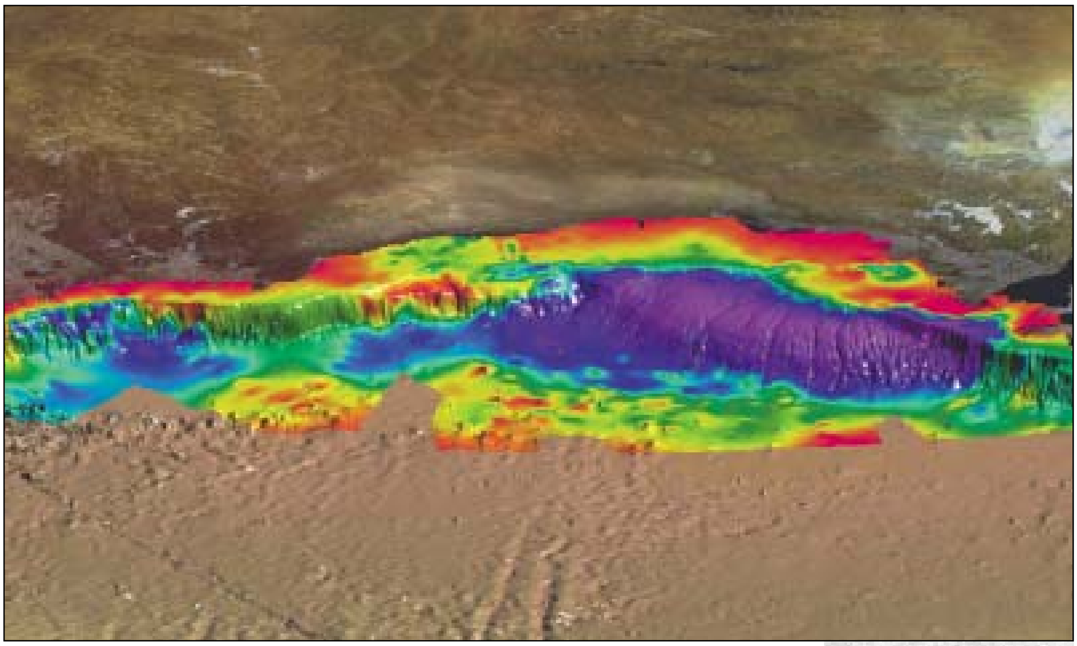


Fig. 5. Total resolvable sediment thickness grid for the Bight Basin in seconds (two-way time), draped over the 1km Bathymetry Grid of Australia and clipped at the coastline. The onshore image is a LandsatTM image draped over the 9 second digital elevation model of Australia. The thickness grid is based on the seismic identification of top basement, red is thin and purple thick; in areas where the base of the basin-fill could not be seismically imaged, the deepest resolvable reflections were used to estimate total thickness.

In terms of offshore production, the Bonaparte Basin ranks a distant third to the Gippsland and Carnar-von, having produced 196 million barrels of oil and 77 billion cubic feet of gas. However, the Bonaparte has proven petroleum accumulations from a greater diversity of petroleum systems than seen in the more prolific basins, with both Mesozoic and Palaeozoic sources (Edwards *et al.*, 1997) and a great variety of play types. The bulk of the drilling in the 1990s focussed in the Mesozoic Vulcan Sub-basin but with low success rates in part due to lack of trap integrity (O'Brien and Woods, 1995). However, the largest oil field found in Australia since the 1960s, Laminaria is in the Sahul Syncline of the Bonaparte Basin. Though drilled in 1994, Laminaria in one sense is a left-over from the government subsidy era and the first cycle of exploration success (1960-72). The structure was identified in the initial exploration phase (Smith *et al.*, 1996) as a deeper water look-alike of Flamingo 1, which was drilled in 1971 with oil shows. From late 1975, border issues effectively quarantined the area and delayed drilling of the prospect for nearly 20 years.

The exploration history of the Browse Basin in the 1990s has been dramatic. The 1997 Cornea oil discovery on the eastern basin margin proved not to herald the expected bonanza due to reservoir problems (Ingram *et al.*, 2000). The giant gas condensate discoveries by Inpex at Dinichthys, Gorgonichthys and Titanichthys (Tinapple, 2001) add further significant volumes to those already discovered at Scott Reef and Brecknock, but there is yet to be production from the Browse Basin.

The discovery of oil at Cliff Head 1 in the offshore Perth Basin in early 2002 by Roc Oil and partners has sparked a resurgence of exploration interest in the Basin. An extensive follow-up drilling campaign is planned and a number of new permits have been awarded. Cliff Head is an extension of the same Permian/Triassic petroleum system that is productive in the onshore Perth Basin and may prove to be the first com-mercial oil discovery in the offshore part of the Basin.

Intensified exploration in the offshore Otway Basin has also been stimulated by recent discoveries, but in this case gas at Thylacine and Geographe, and most recently (*as we go to press*) at Casino 1, following on from the earlier more inboard finds at Minerva and La Bella. All the areas in the offshore Otway Basin offered for release in the 2001 Commonwealth acreage gazettal were taken up by explorers in a competitive bidding round.

A major advancement in explora-tion in these basins has been the extensive use of 3D seismic data. 3D seismic data are now being used for the exploration phase offshore whereas as little as ten years ago, 3D was primarily used for the development phase only.

The change to 3D exploration has not only seen an increase in the number of surveys but also their size. Development 3D surveys were very much focussed on individual fields and rarely were more than 200 km^2 in size, whereas there are now a number of exploration 3D datasets in excess of 3000 km^2 each. What is also different is that many of these surveys are acquired as multi-client speculative surveys with the seismic contractor now having the ability to sell multiple copies of the data.

The large 3D surveys have been aided by the development of the multi-streamer seismic boats that can tow up to ten streamers with dual source arrays, allowing the acquisition of as many as twenty lines of data in one pass. These large surveys acquire massive amounts of data with some recording as much as 20 terabytes of data. Although 3D seismic has helped find new oil and gas fields in our proven basins and contributed to a considerable increase in success rates (Figure 1), it is not the tool to find the new petroleum province required to maintain Australia's self-sufficiency.

Frontier basins

And there is no shortage of frontier basins in Australia in which to look for a new petroleum province. The roll-call of potentially prospective basins around Australia that have yet to have a single exploration well drilled include the Gower, Capel and Fairway Basins on the Lord Howe Rise, the Ninene Basin on the South Tasman Rise, the Recherche and Bremer Sub-basins in the western Bight Basin and the Mentelle Basin to the east of the Naturaliste Plateau.

Rather than issuing highly speculative volumetric assessments for frontier basins, Geoscience Australia focuses its efforts on building the information base for these vastly under-explored regions. What is far more useful to explorers than unconstrained numerical estimates, is the demonstration of active petroleum systems. To achieve this, regional studies are undertaken using a combination of regional seismic and potential field datasets combined with remote sensing techniques such as Synthetic Aperture Radar (SAR).

	P_{95}	Mean	P_{05}
Crude oil (million barrels)	1577	5030	9846
Condensate (million barrels)	1740	6035	11870
Gas (trillion cubic feet)	33	114	228

Table 1. US Geological Survey assessment of undiscovered resources in Australia's major offshore basins (USGS, 2000).

Geoscience Australia's long history of geophysical data acquisition is bearing fruit in the development of regional grids of topography, bathymetry, gravity and magnetic anomalies including both onshore Australia as well as much of its offshore territories. These detailed grids provide fundamental layers in the compilation of regional information systems, in which modern image processing and modelling techniques are brought together with other data and allow a more integrated approach to geological interpretation. This data integration allows Geoscience Australia's scientists to develop fresh insights into the evolution, structure and tectonic setting of our continent while engaged in regional basement and crustal studies, petroleum prospectivity studies and definition of Australia's territorial boundaries.

SAR images are now regularly used to detect hydrocarbon slicks on the sea surface. In certain weather conditions, the presence of hydrocarbons on the surface can dampen the wave activity and the dampening effect can be seen on the images. It is important, however, to be able to distinguish slicks resulting from seeps from those produced by pollution or by biological activity. Repeat scenes are one way of discriminating. Corroborative evidence from other sources is also useful although groundtruthing of imaged slicks has not yet been achieved. A good example of this type of work is that of O'Brien *et al.*, (2000).

The Great Australia Bight is one area where Geoscience Australia has recently undertaken this type of regional work (Struckmeyer, 2002). This area has had very little exploration drilling. A regional seismic grid was acquired and detailed work has defined very large untested stacked Cretaceous-aged deltas are clearly imaged by bathymetry (see Figure 5, where sediment thickness has been draped over bathymetry).

Resource assessment

BMR/AGSO/Geoscience Australia has undertaken resource assessment for undiscovered hydrocarbons for many years. The reason for the assessments is:

"Government needs to know not only the petroleum resources that occur in identified oil and gas fields but also the resources in fields that remain to be discovered, so that decisions can be made on energy policy, energy management, and land use." Forman *et al.*, (1992)

The methodology employed by Geoscience Australia is a discovery process model where there is an attempt to model the petroleum explorers' ability to find the large fields early. The results from this type of model allow a discovery sequence to be fed into a production forecast.

An updated assessment of the undiscovered potential of the Bonaparte Basin will be released later this year in the *Oil and Gas Resources of Australia 2001* (Petrie, et al 2002) with more detail being presented at the Timor Sea Geoscience Symposium to be held in Darwin in June 2003. Geoscience Australia has been reviewing its assessment methodology and has adopted the internationally benchmarked US Geological Survey (USGS) World Petroleum Assessment (2000) to represent the ultimate potential volumes from Australia's major offshore hydrocarbon bearing basins. This assessment is shown in Table 1, left.

It is interesting to note that condensate is expected to be of greater volume than oil. This means that for the condensate to be exploited, a market has to be found for the gas. Currently, Australia has in excess of 100 trillion cubic feet of stranded gas resources although the recent signing by Woodside of an LNG contract with China has shown that there are potential markets for this gas.

New technologies

Increased computing power has probably been the most important driver of innovation within the petroleum industry over the last 15 years. This holds for the Australian industry as much as the rest of the world. This increased power has primarily enabled geoscientists to manipulate and interpret greater volumes of data than previously possible. Increased ability to manage this data has been the key.

Interpretation workstations are now standard allowing the rapid interpretation of both geological and geophysical data. Even more advanced are the various visualisation technologies available that allow the interpreter to view data in 3D rather than as a series of 2D representations.

Data management has been revolutionised by the development of relational databases that can be readily integrated with the interpretation process. GIS is now extensively used to view data in its correct geographical position and not just as a list of data points in a table. Data for different applications can also be stored in a single place thus ensuring that duplicates do not breed.

The Internet is also playing an important role with users now able to access vast amounts of data from their own desks. An example of this is the Geoscience Australia databases of organic geochemistry, biozonal, facies and reservoir data freely available on the Internet (http://www.ga.gov.au/oracle/apcrc/). Access to these types of data allows users to make decisions at a much earlier stage of their work.

One very important aspect of the Internet is that it removes the application link from the data. Previously, to get some datasets, the user also had to purchase the application but the Internet has allowed this link to be broken.

The way business is being done

There has been a fundamental change in the way the petroleum industry works in Australia in the last ten to fifteen years. Along with the advent of increased computing power there has been a change in the structure of companies.

In the early to mid 1980's, the major companies were fully self-contained units with their own research laboratories producing not only science but also the software being used. Service companies were primarily used to do the seismic acquisition and drilling. Today, most companies use off-the-shelf software and outsource many of the functions they previously held in-house. These functions include well-site geology, environmental evaluations and petroleum engineering. There has been a very large increase in the number and type of service companies.

There has also been the development of asset teams within companies that have crossed the previously insur-mountable barriers that used to exist between such professions as geoscience and engineering. The team approach has seen improvements in the speed in which decisions can be made with much of this due to constant communication on similar software between the various professions.

Where to from here?

Petroleum remains a vital part of Australia's energy mix, providing 71% of end use energy (Kantsler, 2002); and even with the advent of the hydrogen economy, hydrocarbons will continue to fuel the nation for decades to come. Although the industry continues to make large gas discoveries, the largest oil discovery in the last ten years is only about 150 million barrels in size. We need to discover one of these every year to just stay where we are. For Australia to remain reliant upon a local source for most of our hydrocarbon requirements we will need to discover new petroleum provinces. Unlike most other countries, Australia has the advantage of several untested frontier basins that have the potential to contain a new petroleum province of global significance. What is required is the exploration investment to discover where this new province will be, and the Ceduna Sub-basin in the Great Australian Bight (Figure 5) seems a likely candidate.

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Quo Vadis Explorator?

Don Emerson
Email: systems @lisp.com.au

The well-known question from John's Gospel Quo Vadis? (Where are you going?) is a timely one to ask now of those engaged in the exploration industry. It is also very appropriate on the occasion of the 100th issue of Preview, which together with Exploration Geophysics, caters well to the scientific publication and information dissemination needs of the 1202 geophysics devotees who currently belong to the ASEG. Just where we are going and how we are doing as professionals are topics that are rarely posed for formal discussion, which shall now be essayed, in a limited way and from a personal and admittedly idiosyncratic perspective (with headings from Matthew's Gospel).

"By their fruits you shall know them"

There are about 7000 geoscience professionals in Australia, and the numbers are in decline. It is a small profession compared to engineers (~62 000), chartered accountants (~15 000) or solicitors (~15 000 in NSW alone). Geophysicists are a minority part of the geoscience scene, but they are expected to provide vital input in exploration and exploitation activities at a time of declining discoveries (effected at relatively high cost), stringent environmental and access requirements, activists' agendas, and political and public indifference. Exercising influence in public policy these days, besides stridency, requires relevant and excellent scientific achievement that demonstrably augments Australia's well being. If not, geophysics may find itself ignored in matters that should be its concern, e.g. ponder the lack of reported geophysical input in the recent selection of a site for the low-level radioactive waste repository site at Woomera (DEST and PPK, 2002). Geophysics could find itself eventually in the position of geography and the Latin and Greek classics i.e. as a valid academic discipline but with few employment prospects.

Employment opportunities, or what should be employment opportunities for Australian applied geophysicists in-field, on-site, and in-mine, are given in Figure 1. These are extensive, and one could be pardoned for thinking that they would provide interesting and expanding employment for many. Australia is a big landmass (sixth largest country in the world), with a significant economic ranking (thirteenth in the world), and an important mineral resource base with considerable future potential. Vast parts of Australia are groundwater dependent. The whole of Australia is subject to environmental concerns or interests of varying types. Geoscience should be involved deeply in all of this. Australia's marine areas are enormous and geophysics is indispensable in their monitoring. Yet essential government geoscience departments, research institutions, and academic training schools are understaffed, underfunded, and in decline. Australian private enterprise is disinterested (or moved offshore). It is hard to be confident of a continuing rationale to underpin geophysics as a profession in the future unless it is to be as a tolerated adjunct to imported personnel and technology.

It seems to this writer that contributing factors to these states of affairs are the less than outstanding performance and some lack of relevance in geophysics practice. Lack of relevance will always be with us. Muddled modelling, tortuous mathematical formulations that are so naive that

Australian Geophysics: Employment Opportunities and Fields of Endeavour

MINERAL DEPOSIT

	operating	undeveloped
NSW/VIC	18	31
TAS	6	4
NT	12	13
SA	14	16
QLD	22	61
WA	75	58
	147	183

330 (of which WA has 40%)

COAL

NSW: 53 mines	WA: 3 mines
Qld: 34 mines	Vic: 5 mines
Victoria: 5 mines	Tas: 1 mine
SA: 1 mine	

PETROLEUM

Timor, NW Shelf, Perth, Amadeus, Cooper-Eromanga, Surat, Gippsland; et al basins

HYDROGEOLOGY

80% of Aust area dependent
500 000 water bores

54 Aquifers: 31 west; 54 Aquifers - ; 15 central [major aquifers]

Fract Rock: 8 eastern

Surficial: Fract Rock: 4 provinces (W, N, E, ctrl)
Surficial: Tertiary, Quaternary

ENGINEERING/GEOTECH
site studies

NON-METALLICS/AGGREGATES
quarries
pits

ENVIRONMENTAL
UXO
Waste Sites
Pollution
Planning
Archaeology
Salination

MINERAL PROCESSING
physics of materials

GOVERNMENT
understaffed

RESEARCH
low levels

ACADEMIA
decline

Fig. 1. Employment opportunities for geophysicists in Australia, compiled mainly from AGSO/MCA Mineral Deposit Map 2nd ed. April 2000; and from BMR Bulletin 227 Hydrogeology of Australia, 1987.

any significance is purely numerical rather than geological, has always been tolerated in geophysics, indeed such arcana are often the means of preferment in various jobs. It is quite good fun, for some, and all pretty harmless as long as the tail does not start wagging the dog. The muddlers should be confined to the cages of theory and nourished humanely with symbol soup. So what about performance and real geophysics?

Geophysics deals with the location, definition, enhancement, and evaluation of anomalies in the solution of geological problems. The location, definition and enhancement tasks are carried out very well in geophysical mapping, which depicts environments in filtered physical terms. Maps constructed by modern techniques are geophysics strengths. They are a timeless resource, useful for a very long time even if every part is not studied immediately. However, the evaluation task is often not a geophysical strength, especially when attempted in detail. The mapped-imaged-imagined-interpreted-proved/explained sequence is often incomplete.

Applied geophysics successes in petroleum reservoir work, minerals discoveries, and engineering site studies are rightly trumpeted, savoured, and published. However, what fails or disappoints has just as many lessons for the thinking professional. These are rarely addressed in the literature.

We deal with complex systems and work with dependent variables that are influenced by many more independent variables. We simplify, but often the desirables are in the detail. A famous physicist[1] once commented: '... a complex system is exactly that; there are many things going on simultaneously. If you search carefully you can find your favourite toy; fractals, chaos, self-organised criticality, ... in some corner, in a relatively well-developed and isolated way. But do not expect any single, simple insight to explain it all.'

"Seek and you shall find"

The efficacy of geophysics in environmental studies has been questioned by skilled practitioners (Whiteley and Jewel, 1992), who remarked on the need for improved interpretations. Consider the case of the quite important field of unexploded ordnance (UXO). The US Army Environmental Center conducted an evaluation of individual demonstrator (i.e. contractor) performance in an UXO advanced technology demonstration at Jefferson Proving Ground (US Army, 1995). A 40-acre site was prepared for ground systems, and 80 acres for airborne. The sites were realistic, i.e. noisy, with 76 anomalies due to pre-existing debris and ordnance delineated prior to emplacement of the test targets. In the ground tests the best performance was a 41% overall detection rate for non-plastic emplaced items. In the airborne tests none of the target declarations by any of the demonstrators was attributable with any confidence to any emplaced item. These are very sobering results of a type rarely, if ever, published in prominent journals that actually give the opposite impression from the implicit or explicit claims contained in the publications and publicity of the protagonists. The criticisms here relate not to the genuine efforts of dedicated geophysicists in a difficult field but to the unwarranted notions and expectations about imperfect methods however technically impressive. In the long run such attitudes are deleterious scientifically, and commercially, to our profession.

Modern seismic reflection techniques are highly developed and the results often outstanding. Nevertheless, the method is not without its deficiencies. An eminent practitioner of petroleum seismic geophysics[2] has pointed out the problems of plenty of data producing deficient results in the absence of geological understanding. He cited examples of: not being able to define boundaries properly with different data sets or not being able to define boundaries at all; P and S wave sections over the same geology being quite different (and the differences left unresolved); even small changes in P wave data sets from the same area (e.g. slight frequency band shift) producing quite different interpretations. Such problems are rarely addressed in public fora.

In Australian hard rock geophysics there is an admirable tradition of publishing documented case histories. Not so long ago two such excellent compilations (Dentith *et al.*, 1994, Willocks *et al.*, 1999) appeared with some interesting information on geophysics performance, which is summarised in Figure 2. These "signature" volumes are perhaps unfortunately named. A signature is a distinctive mark, characteristic or identifier. Not many of the ore bodies cited are actually tagged with these. Rather these volumes mainly document the geophysical responses of ore environments, and they do so very well. The two volumes treated a total of 34 deposits in a wide variety of geological settings. Geophysics was responsible for four discoveries (12%), it was very useful in an indicative sense or with hindsight in six cases (17%), and it was useful qualitatively as a local or regional environment indicator in all other cases (71%). This is about the same performance as that achieved by Broughton Edge & Laby (1931) in the Imperial Geophysical Experimental Survey in their study of nine Australian deposits sixty years earlier. If two other published case histories from former times are added to the list (Elura: Emerson, 1980, and Woodlawn: Whiteley, 1980) the overall percentages do not change dramatically.

It is acknowledged: that there may be some geophysical successes (unpublished or published elsewhere) not included in Figure 2; that ore bodies may be more difficult to find because likely targets are significantly fewer and deeper (debateable points); that one particular geophysical success may bring economic benefits eclipsing the cost of all hard rock geophysics expenditures; and that often geophysics has an indispensable supporting role in programs that are primarily geochemical and geological. Nevertheless, in Australia at least, hard rock geophysics gauged by published best-practice performance would seem not to have improved much in over half a century. It would also seem that in the evaluation phase there is much scope for improvement both in definitive interpretation and in the realisation of the reasonable limits of geophysics performance. Geophysics, like medicine, is an imperfect science; aetiology does not always match the technology.

"Let your light shine before people that they may see your good work"

Where are we going? At the moment nowhere in particular, perhaps just marking time. What is very clear is that any improvement in our overall situation as a profession will only come from within, by more scientific effort to match or complement advances in technology, and to carry out such work at various centres that are adequately supported by industry and government in the belief that general and

[1] *Landauer, R., Times Literary Supplement, June 1999.*

[2] *N Neidell, AAPG Explorer, October 2000*

specific benefits will result for Australia. That is the path, and the challenge. Based on an admiration for the unfortunately now defunct geophysics oriented CRC's this writer's preference is for the stimulus and dynamic of two quinquennially funded Co-operative Research Centres, one on the west coast, and one on the east/south coast. Both should be funded indefinitely, subject to satisfactory performance. Both should be open to the geophysics community and both should publish comprehensibly and comprehensively for that community. Research thrusts should be decided by a polled consensus of the Australian geophysical personnel and the financial sponsors. Locations and about half the staffing should change every five years. Staffing should be wide ranging: geophysicists working with geologists, geochemists, physicists, mathematicians, engineers. The set-up should be attractive to local and overseas honours and postgraduate students. As for funding for such a wish list? Now, that is the question. Some private enterprise support is possible, but the bulk of it should come from mineral and petroleum royalties collected by governments. It is fair that some of these monies be directed back to the professions that are involved in the discovery, maintenance and stewardship of such resources. And how is this to be arranged? Find someone with the rhetoric of a Cicero and the mind of a Machiavelli, and act quickly. In the absence of such handy qualities in an Australian geo-person perhaps all that can be done is to seek higher guidance as to the way: "Quo Vadis Domine?"

Hard Rock Geophysics Performance: Success Rate in Australia

Dentith *et al.*, 1994,
Geophys. Signatures in WA Min. Deps.
(mainly Archaean)

26 case histories / 3 discoveries (Pb/Cu, Cu/Zn, U)

2 diamond pipes
1 min. sands
1 paleaochannels
2 VMS
3 BIF gold
3 Kom. Ni
1 MV Pb Zn
2 Felsic gold
1 Ti mtt gabbro
1 Ni met.
6 m'Sed gold
1 Fe ore
1 uranium.
1 Pb-Cu clastics

Willocks *et al.*, 1999
Geophys. Signatures Vic Base Metal Deps.
(Phanerozoic)

8 case histories / 1 discovery (Cu/Zn)

3 VMS
1 Pal Met.
2 porphyry
1 skarn
1 rift lst

	deposits	discoveries	hindsight indicative	useful qual. local/reg.
WA	26	3	5	18
Vic	8	1	1	6
	34	4 (12%)	6 (17%)	24 (71%)

also -> ELURA WOODLAWN

Compare with Edge & Laby (1931)

9 case histories / 1 discovery (Cu)

1 NSW Pb-Zn m'sed
3 Tas Pb-Cu-Zn VMS et al
1 SA Cu porphyry
1 SA graphite/schist
1 WA Pb/Cu gneiss
1 Qld Cu/Pb m'sed
1 NSW Au leads

9	1 (11%)	3 (33%)	5 (56%)

Fig. 2. Geophysical success rates for mineral deposits in Australia, mainly from Dentith et al., 1994 and Willocks et al., 1999.

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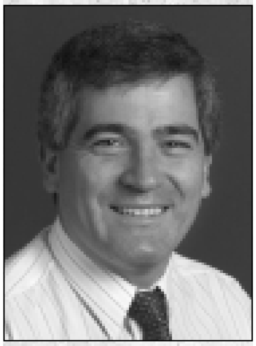
Geophysical methods in the coal mining industry



Peter Hatherly
CSIRO Exploration & Mining
Peter.Hatherly@csiro.au

Introduction

At the end of World War II, production in the Australian black coal industry was about 14.5 million tones (1947 figures). In the year 2001/2002, it is estimated that the output will be 272 million tones with over 200 million tonnes being exported. The export earnings from the trade in black coal for the year were $13.3 billion.

This huge growth in the industry has not been without significant advances in coal geology, mining engineering and even geophysics. New reserves have needed to be identified and mining techniques developed. The scale of the open pit dragline and underground longwall operations, that dominate current coal mining, was unimaginable in the 1950's. In support of these, mine planning procedures were developed whereby accurate maps of coal seams, their quality and the geotechnical conditions could be provided. To quote from the from *Technology in Australia 1788-1988*, available at the web site of the Australian Academy of Technological Sciences and Engineering[1]:

"(In 1947) for instance, the colliery manager planning a new mine would have been confronted with a mine plan outlining the lease boundaries and little more, except for some surface contours and possibly seam contours derived from bore-holes spaced about one and a half kilometres apart, and thus subject to considerable interpolation.

According to Jeffrey[2] 'The basic aim of mine planning is to design mine layout and schedules that allow operations to be optimised, costs minimised and so the recovery of the resource maximised'. The mine planner of today, thanks to improvements in exploration techniques, has a substantial input technique included in his initial plan. Seismic surveys over the proposed development area will show the position of major faulting and intrusions and other geologically disturbed areas can be indicated that may call for further drilling.

The geotechnical testing of bore cores can reveal important information on rock types from the surface to the seam which indicate what strata are competent and to what extent; where fracturing exists; what rocks are susceptible to rapid breakdown on exposure and, among other things the most important of all, the likely behaviour of the mine roof under working conditions. Within the seam, in-seam seismic is in process of development to the stage where minor dislocations of the seam can be detected in front of the advancing face -a major consideration in longwall operations.

Although all these measures have not reached the stage where they can be considered completely satisfactory their use is proving to be an invaluable assistance in the planning and operation of both underground and open-cut mines and their refinement seems only a matter of time."

A sense for the emerging role of geophysics that has occurred in coal mining is conveyed by these words. This role has also more or less developed over the life span of the ASEG.

The introduction of geophysics

One of the earliest ASEG papers on geophysics in coal exploration was by Packham and Emerson (1975) who give useful earlier references including one to an honours thesis on seismic reflection surveying for coal seam mapping by a certain P. G. Harman in 1971. Agostini (1977) describes the use of density logging for coal ash determination. Another luminary, D. King (1979), introduced the Mini-SOSIE method into seismic surveying. By the time of the first ASEG Conference in 1979, coal geophysics had an established role in both the geophysics profession and the coal mining industry. Papers concerning coal geophysics at that conference were provided by Rutter and Harman, King and Greenhalgh, and Haigh and Henderson.

In part, the impetus for the growth of the coal industry was provided by the oil shocks of the 1970's but it is interesting to note the coal production figures for the past 50 years shown in Figure 1. Clearly the growth began earlier, independently of the looming crisis in the petroleum industry. Part of the growth is due to the gradual increase in domestic consumption but it has mainly been in response to export demand that coal production has continued to grow through to the present day.

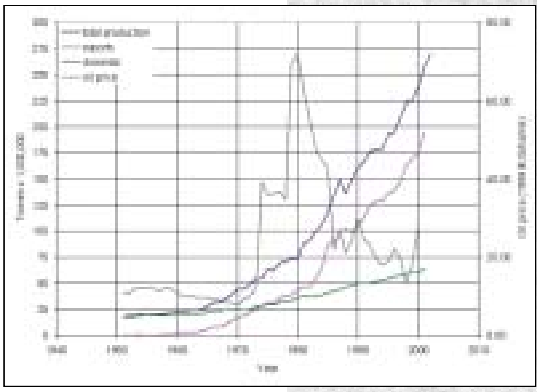


Fig. 1. The boom in Australian coal exports started before the oil shocks of the 1970's. It has also continued unabated to the present time. (Data from various sources.)

In the 1960's and 1970's, when the export business was taking hold, major international miners such as Utah Development Corporation were dominant. One consequence of this was the establishment by the Australian Government of the National Energy Research Demonstration and Development Program (NERDDP) in 1978. This had the role of supporting Australian capabilities in coal mining through research funded by a levy imposed on coal production. Over the intervening years NERRDP and more recently the Australian Coal Association Research Program (ACARP), which took over the role in 1992, have funded many geophysical developments for use in coal mining. ACARP is run by the coal producers. The levy is currently set at 5 cents per tonne and over $13 million p.a. is therefore available for coal mining research each year. While this supports many issues across the spectrum from exploration to greenhouse gas emissions, the availability of this fund has allowed a relatively ordered development of geophysics over the years. Mining companies such as BHP Billiton (Poole et al 1998) and contractors such as Velseis and Reeves Wireline have also taken a long-term view towards the development and application of geophysical techniques.

The present situation

Leaping to the present, the current situation is that geophysical techniques are routinely applied and underpin

1 *http://www.austehc.unimelb.edu.au/tia/767.html*

2 *Jeffrey, J. G., Australasian Coal Mining Practice, Australian Institute of Mining and Metallurgy, Monograph 12, 1986, p. 174.*

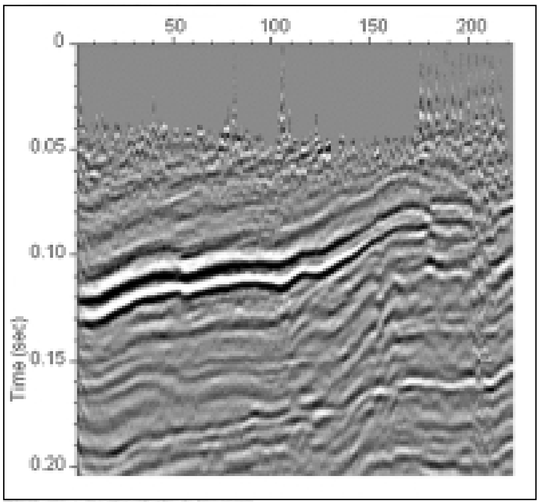


Fig. 2. A section from a 3D seismic survey showing coal seams dipping down from their subcrop. A seam split and various styles of structures are also evident (from Zhou & Hatherly, 1999).

most programs for coal exploration. Rarely are boreholes not geophysically logged. Airborne and land based magnetic surveys are routinely flown for the detection of igneous intrusions. High-resolution seismic reflection surveys are commonly undertaken across the coalfields and increasingly, 3D methods are used when ground surface conditions permit (see Figure 2 for an example of a section from a recent 3D seismic survey). To monitor the response of the strata surrounding a mine to the extraction of the coal, microseismic monitoring techniques are now available. In all cases there is a strong drive to integrate the geophysical findings with geological and geotechnical data. The industry is served by numerous contractors, consultants and researchers.

Results of current work do not always find their way into the geophysical literature. There are numerous research reports available from ACARP[3] . Proceedings from meetings of coal industry geologists such as the Bowen Basin Symposia (for the most recent proceedings see Beeston, 2000) and the Coalfield Geology Council of NSW (Doyle and Moloney, 2001) also contain many interesting papers. The proceedings of the 2001 ASEG Conference in Brisbane, where there were sessions on coal geophysics and high resolution seismic, also provide a measure of the work that is being undertaken.

Challenges for the future

Returning to the last paragraph of the quote from the *Technology in Australia 1788-1988* reference, given at the start of this article, it is clear that the on-going refinement of geophysical techniques suitable for use in coal mining has occurred. However, it is a moot point as to whether the results will ever be completely satisfactory. With every improvement to the resolution of geophysical results, geologists and mining engineers will necessarily look for more. Why stop at resolving 2 m throw coal seam faults with seismic surveys conducted 200 m above at the ground surface? Yes, such faults can cause serious disruption to underground mining but so can the fractured zone associated with a strike-slip fault. The nature of mining is such that any piece of advance knowledge of the geological conditions, properly incorporated into a mine plan can save lives and dollars.

Drawing up a list of issues in coal mining needing attention by geophysicists is a risky business. However, in no particular order, it could include the following:

- Measurement-while-drilling and seam guidance tools for use in the drilling of surface to in-seam and fully in-seam drill holes.
- Guidance techniques for longwall shearers, continuous miners, tunnel borers and other forms of mining equipment.
- Inversion of seismic data to reveal properties of coal seams — thickness, ash content etc.
- Solving the difficulties in shooting seismic surveys over areas of volcanic cover.
- Development of techniques for better assessing the geotechnical properties of rock masses.
- Means of remotely sensing and mapping anomalies within coal seams — old workings, silling dykes, sheared zones associated with faults, etc.
- Methods of assessing and providing continuous monitoring of roof conditions in underground workings.
- Techniques for determining the potential for coal measure strata to release seam gases for gas production, pre-drainage of coal seams and greenhouse gas abatement.
- Improved procedures for integrating geophysical results into mine planning processes.

As well as observing the changes in the coal mining industry in response to on-going social, economic and technological changes, it will be interesting to see if these issues are addressed before the time of Preview's 200th edition.

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3 *http://www.acarp.com.au*

Agriculture, Geophysics and Environmental Sustainability

Agriculture and Sustainability

The necessity to feed the rapidly expanding world population places great pressure on the agricultural sector to be effi-cient. However, throughout the world, the gradual degradation of agricultural land due to salinity, sodicity, erosion and other effects is the manifes-tation of this pressure. Early civilisations developed because they gained the ability to feed and clothe a larger population than that needed to generate the raw materials. Unfortunately, these civilisations did not recognise the stress they placed on the landscape. There is substantial evidence to indi-cate that many early civilisa-tions failed due to land degradation, particularly sali-nity (Boyden, 1987).

Today we appear no wiser, and the impending salinisation of some 30% of Australia's productive agricultural lands is viewed by an urbanised public as someone else's problem. Governments with policies that extend to only 3 or 4-year terms also lack the will to commit the kind of funds and effort needed to deal with the long-term solutions to the problem. Far too much money has been spent trying to put a finger in the dyke by planting trees with little understanding of their possible benefits.

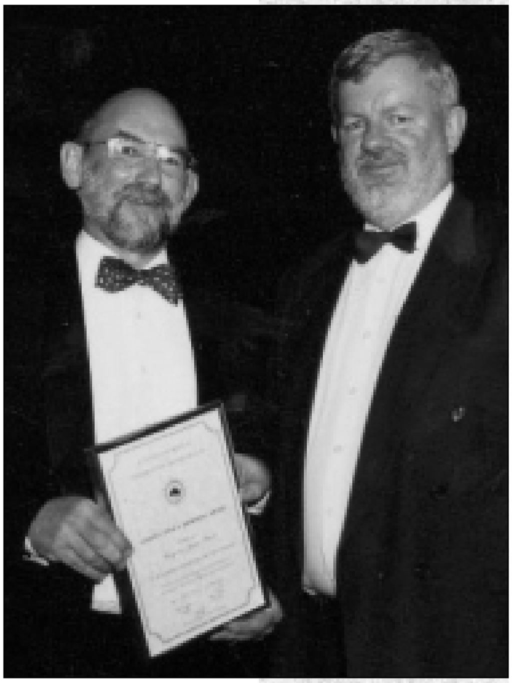
The spread of land degradation will reduce Australia's export trade but will not prevent us from feeding the Australian public. Thus the urban public remains at best a concerned observer. Planting trees has been widely promoted as the solution, but some research now suggests that we might have to totally replant the landscape to make any appreciable difference (George *et al*., 2001). Far too much publicity-hype from governments is attached to potential solutions without any effective review of whether they will work.

In a time when all activities must secure environmental approvals, agriculture alone appears to be immune. Farming continues to mine a resource that we should probably recognise as finite as any mineral mining activity. Those who have worked at the extraction end of the mining and petroleum industries know how many hurdles have to be crossed between discovery and production. Agriculture remains a protected industry in which small businesses commanding inordinate political clout can continue to do as they please. In the past, land use efficiency in Australia has been low and so we can afford to disregard the losses due to salinity.

Irrespective of political will, the production of food from the paddock to the table must be more environmentally accountable for the long-term sustainability of the population. Eventually we will run out of land and a sustainable agricultural industry is essential for Australia's long-term welfare.

Unfortunately farmers have not had access to good biophysical data on which to make their decisions (Nulsen, *et al*., 1996). Decisions in agricultural development have been driven by a perceived need for development rather than on sound scientific data. Despite the history of failures, it is only recently that science has been able to explain the long-term processes of land degradation. In Australia, farmers have imposed a northern hemisphere style of agriculture on a deeply weathered, fragile landscape. While this has been adapted over the last century, the general trend is still towards increasing degradation of the land. A lack of understanding of how landscapes evolve and operate is a key to practices that are continuing to degrade the agricultural areas.

Salinity is the greatest threat facing the nation and far greater than any perceived threats of terrorism or weapons of mass destruction that command such political debate at present. We desperately need to understand the landscape processes that lead to salinity so we can be pro-active in reducing its spread and, if possible, reversing the extent of presently saline land. Geophysical survey methods have shown they can provide this information (Street and Anderson-Mayes, 2002) and also provide better information for farmers to efficiently manage their soils (Taylor *et al*, 2002).



Author Greg Street (left), receiving his Lindsay Ingall Memorial Award for the promotion of Geophysics within the wider community from Tim Pippett (ASEG President) at the 2001 Brisbane Convention

G. J. Street
Curtin University of Technology,
Bentley WA 6845
gstreet@skm.com.au

Geophysics in Agriculture

Geophysical methods in agriculture began with the use of resistivity for water exploration in the early 20th century. But it is not until recent times that geophysics has been used to guide other land management decisions. Bennet and Ramsay (1979) showed that frequency domain EM instruments could be used to measure terrain conductivity with reasonable confidence. A workshop in Tatura in 1988 was devoted to the use of new technology in salinity studies. One day was spent on satellite imagery and the second discussed geophysical techniques with particular focus on EM.

Electromagnetics

In early applications in agriculture, geophysics was used as a measuring tool rather than a mapping tool. During the 1980s the availability of GPS location signals escalated a revolution that had already commenced in using geophysics for mapping. Aerodata showed what could be achieved with high-resolution airborne magnetic data in the Western Australia's Eastern Goldfields (Isles *et al*., 1989). In 1987 airborne magnetic surveys were used in catchment studies in the West Australian wheatbelt at Yornaning and Cartmeticup. While magnetic data could show the structure that controlled groundwater movement, a map of the salt in the ground was missing.

Trial airborne EM surveys had already been conducted by Geoterrex in Victoria and Western Australia with the analogue INPUT system, but whilst the results showed promise, the system specifications lacked the resolution required to obtain a good understanding of landscape processes. The competition was from satellite data that was widely promoted as providing solutions to salinity and was the target of much government spending. Geophysics mapping beneath the surface showed promise in being able to define the causes rather than the symptoms of salinity.

Over the last decade there has been a massive investment in new technology, particularly in new airborne EM systems by World Geoscience Corporation (WGC). The aim, as expressed in an early grant application to the National Dryland salinity Program in 1987, was 'to develop a low cost airborne EM system for environmental applications'. QUESTEM followed by SALTMAP and TEMPEST were the results. These systems, flown at line spacings of 200 m or less, are able to map salt in the ground in three dimensions. These data can then be related to other geographical, geological, geophysical and hydrogeological datasets to determine the causes of local salinity outbreaks (Street *et al.*, 2002). Unfortunately, the 'low cost' system remains elusive, despite research developing and consistently improving the airborne electromagnetic technology. However, the cost of good scientific data (geophysical or otherwise) remains a very small part of the total money needed to reverse the effects of salinity.

The inability to position the receiver for minimal asymmetry remains a problem in all the fixed wing systems when converting the data to 3-dimensional conductivity images. Parallax corrections are often empirically derived and do not take into account the lateral movement of the smoke ring with time. The environmental industry is less accepting of such asymmetry problems than professional geophysicists. Future airborne EM use in the agricultural sector will be with systems or processing that can eliminate the asymmetry such as HOISTEM or a fixed wing system with receiver on the aircraft. Possibly we would be better off with a two-frequency EM system mounted on a lower cost aircraft proposed by Geoinstruments at the last Perth ASEG Conference.

The comments of the previous paragraphs should be tempered with the track record. The National Airborne Geophysics Project conducted by AFFA in 1998 showed conclusively that airborne geophysics can be used to understand the causes of dryland salinity irrespective of the systems used. The focus on improving airborne EM systems is driven mostly by the geophysicists knowing they can do better. Abbott (2002) showed that information about salinity could be easily extracted from older datasets, such as a QUESTEM survey over the Kent catchment in 1993. The focus for EM development for salinity applications in the immediate future should remain on delivery of information rather than technological beauty.

Radiometrics

One exciting application for geophysics is the development of airborne radiometrics for soil mapping. Taylor *et al.* (2002) showed how radiometrics could map soil properties building on research such as Cook *et al.* (1996), Bierwirth *et al.* (1997), and Wong and Harper (1999). Soil mapping is a logical adaptation of geophysical technology in much the same way as magnetics is used for geological mapping. Also, with four or more variables from radiometrics plus one or two from a digital terrain model, the data lend themselves well to classification techniques. Thus predictive maps of soil types can be prepared from sand through to clays (Cook, pers. comm., 2001). Such a map showing the probability of soil type can be used effectively to make decisions about land use.

Good information about soil properties then allows for decisions on fertiliser application or potential yield, given a prediction of climate for the next growing season. For example, a low radiometric count on all channels located high in the landscape with low slope is most likely a deep residual sand plain. These areas are well drained. In a wet year they do not retain fertiliser and in a dry year they do not retain moisture. One could consider not using them for cropping, but many farmers do manage to get high yields from such areas, given the right spread of rainfall during the growing season and careful management of fertiliser. Too often this is by accident rather than design, or restricted to farmers with a long knowledge of the property. Radiometric data can allow more farmers to make the correct decisions.

Ground Surveys

Ground based EM surveys are being used in rice irrigation areas to predict seepage rates from rice ponds. Low conductivity equates to high seepage rates in a well-drained, sandier soil. These soils are also less sodic and more neutral in pH. So, EM conductivity for specific areas can be correlated with soil sodicity and/or pH, and thus decisions on irrigation practices can be made based on EM data.

Seepage from irrigation channels costs considerable money in lost water as well as potential land degradation due to rising groundwater tables. EM and resistivity surveys have been trialed as a technique for detecting seepage from irrigation canals. The challenge is to relate the conductivity and/or resistivity data to the amount of seepage so that the water managers can decide on the most cost-effective solutions. Information extraction leading to new knowledge is critical.

Information Extraction

The greatest challenge for geophysicists working in the agricultural and environmental sectors is delivering the information content from the data rather than a dataset of incomprehensible numbers. If the geophysics can add knowledge and lead to simple decisions it will become accepted. A technology push will result in rejection. During the 1980s and 1990s increased specialisation in geophysics courses at universities has produced high quality graduates with sound mathematics and physics backgrounds and a good understanding of geology. Perhaps the future is in degrees in geophysics with soil science agriculture as a third stream rather than geology.

Although many cringed when Wilson Tuckey, the Federal Minister for Forests, dubbed geophysics the 'Ultrasound of The Earth', the analogy has some merit. Geophysics is an aid for examining symptoms, just as ultrasound is used on the human body. It then takes expert analysis for diagnosis (information extraction) and to develop remedial strategies. The National Airborne Geophysics Project was a success in that it showed how geophysics could define the causes of salinity but was also a failure because there was no provision in the project to also a failure because there was no provision in the project to use the data to design remedial actions (Anderson *et al.*, 2001). The National Airborne Geophysics Project did however finally attract government attention to airborne geophysics as a tool in salinity with some $100 million 'promised' by the government for future surveys under the National Action Plan.

Conclusion

So where are we going? Agriculture must become more sustainable for the long-term future of our civilisation. To achieve this land management will require the backing of good biophysical data, part of which will be supplied by geophysics and thus we will see greater utilisation of our geophysical skills into this new application for land management. It will be a slow process with many hurdles, and geophysics still retains the stigma of the black box. However, it is not a panacea, and collection of geophysical data cannot possibly change the trajectory of salinity (George and Woodgate, 2002). At the launch of the Broomehill project where the SALTMAP airborne EM system was first tried David Chadwick a farmer in the project likened the geophysics to a two-way radio. He said something like "it will not put out the fire but will allow you to be directed to the points where you can."

Large-scale airborne geophysical surveys have been subsidised by both state and federal governments for some time as an aid to mineral exploration. In the meantime society has been mining its agricultural areas of their long-term sustainability (Flanerry, 1994; White, 1997). It is now time to look at the benefit of airborne geophysical surveys providing the basic framework for agricultural management. These surveys must be done with resolution suitable for the purpose. A typical farm in southwest Australia is around 1000 hectares. A survey with 100 m line-spacing (grided at 1/3 line spacing) will give around 9000 pixel of data or 9 per hectare. This is about the minimum level farmers need to make land management decisions in broad acres farming. We need such surveys collecting magnetics, radiometrics and EM data over the agricultural areas of Victoria, Tasmania, southwest WA, NSW and southern Queensland.

This year we will see the effect a widespread drought has on Australia's export income. The effects of land degradation from salinity and other effects will be greater, will not change with the season, and will affect all Australians. Good regional scientific data using airborne geophysics as a base will help prevent what appears inevitable.

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Footnote

A quote from Robert Townsend appeared recently in "The Australian" newspaper. It said "It's a poor bureaucrat who can't stall a good idea until even its sponsor is relieved to see it dead and buried" and indeed it would seem that the National Action Plan, a plan that seeks to address salinity hazard management, has become bogged down in bureaucracy.

Almost 18 months after flying the NAP geophysical surveys, the data remains unavailable for development of remedial actions by Catchment Management Authorities. Various reasons including fear of legal action have been advanced but it appears there is no plan in place for data release. Geoscience Australia and most geological surveys have a policy of releasing data as soon as possible to maximise its effective life and for maximum community benefit. We urgently need to collect geophysics over all Australia's agricultural areas but we also need get the data into the community and to harness Australia's vast geoscientific expertise and direct it towards Australia's number one environmental problem.

L. Murray Richardson*
Murray.Richardson@ga.gov.au

Phillip Wynne*
Phill.Wynne@ga.gov.au

Ian Hone*
Ian.Hone@ga.gov.au

* Geoscience Australia
PO Box 378
Canberra, ACT 2601

Geophysical Data Sets Over Continental Australia

Introduction

Magnetic, gamma-ray and gravity data sets provide vital information for mineral and petroleum explorers as well as for researchers studying the geology of the Australian continent and for those involved in environmental management issues. Commonwealth, State and Territory governments have devoted considerable resources to acquiring these data sets and making them available to encourage exploration. Geoscience Australia's (GA) geophysical databases contain data acquired by governments, private industry and universities; this report summarises coverages over Australia of these data.

On the occasion of the hundredth issue of Preview, it is worth considering the advances in the coverage of publicly available magnetic, gamma-ray and gravity data over Australia since the first edition of Preview in January 1986. Since then the areas and resolution of the coverages have increased dramatically. Quality of the data, through better acquisition and processing techniques, has also improved, and new types of data sets added to the explorers' supplies.

Magnetic data

Figure 1 shows the present state of coverage of airborne magnetic data over Australia at various line spacings, and Figure 2 the situation in January 1986. The most noticeable difference is the improvement in coverage of 400/500 m line-spaced data. However, even though coverage is now complete, large areas have only substandard coverage.

The tables below, showing the percentage cover of magnetic data over onshore Australia, and the distances surveyed onshore and offshore by 2002 and 1986, quantify the situation.

Far right: Table 1. Line spacing of airborne magnetic data over onshore Australia, 2002 and 1986.

Coverage (%)[1]		
Line spacing (m)	2002	1986
<= 500	53.4	3.7
501 - 1600	34.7	48.6
3000 - 3200	12.8	29.6
>3200	7.6	11.7
No coverage		6.4

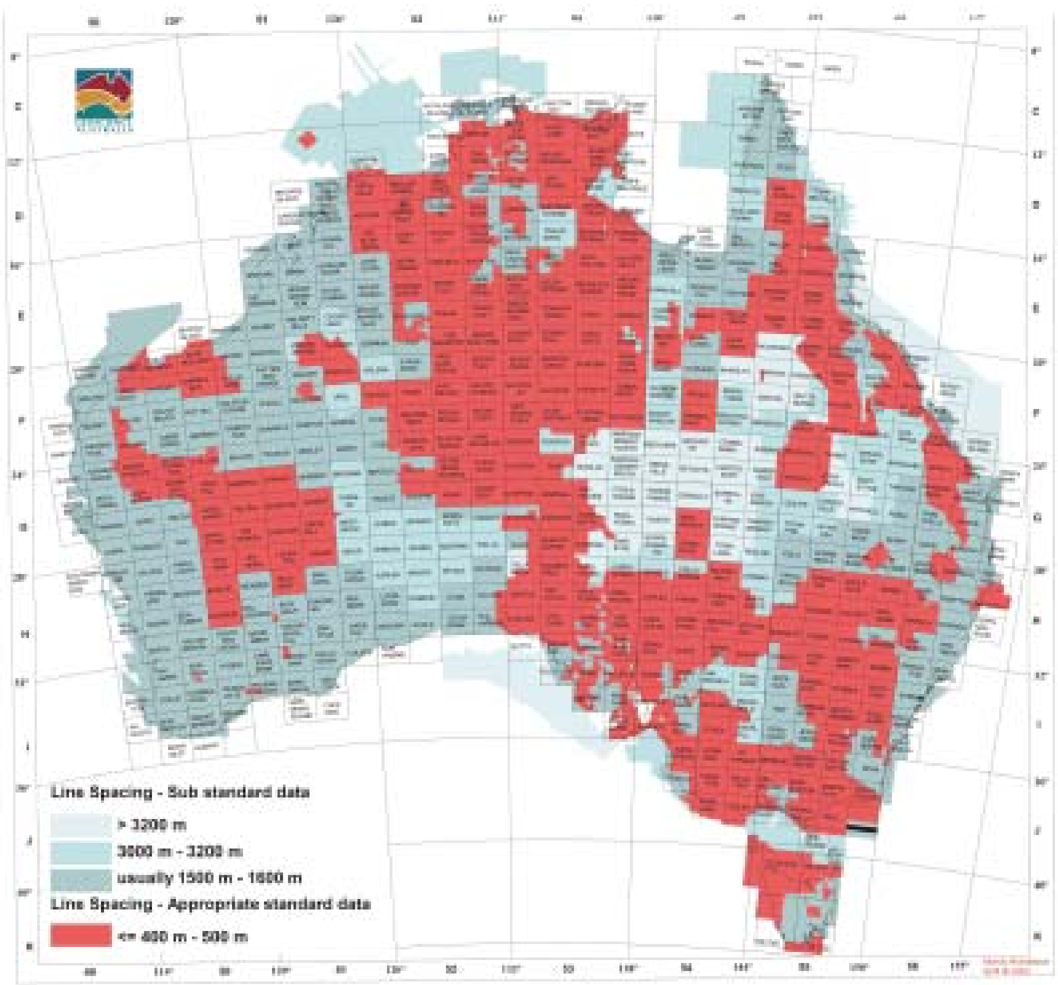


Fig. 1. Airborne magnetic coverage and line-spacing over Australia, April 2002.

[1] *The coverage numbers for 2002 in Table 1 add up to more than 100%, as some survey areas have been reflown at a higher resolution than that used when data were first acquired in the area.*

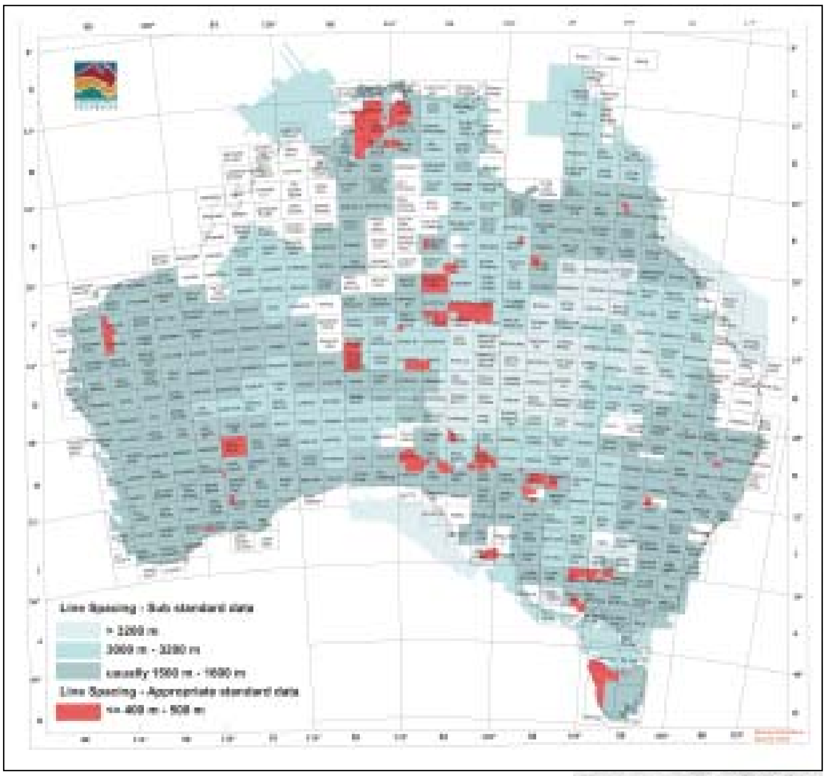
	Distance (km)[2]	
Line spacing (m)	2002	1986
<= 500	10 888 482	622 988
501 - 1600	4 170 909	2 736 756
3000 - 3200	1 182 317	861 941
>3200	212 909	176 838
Total	16 454 617	4 398 523

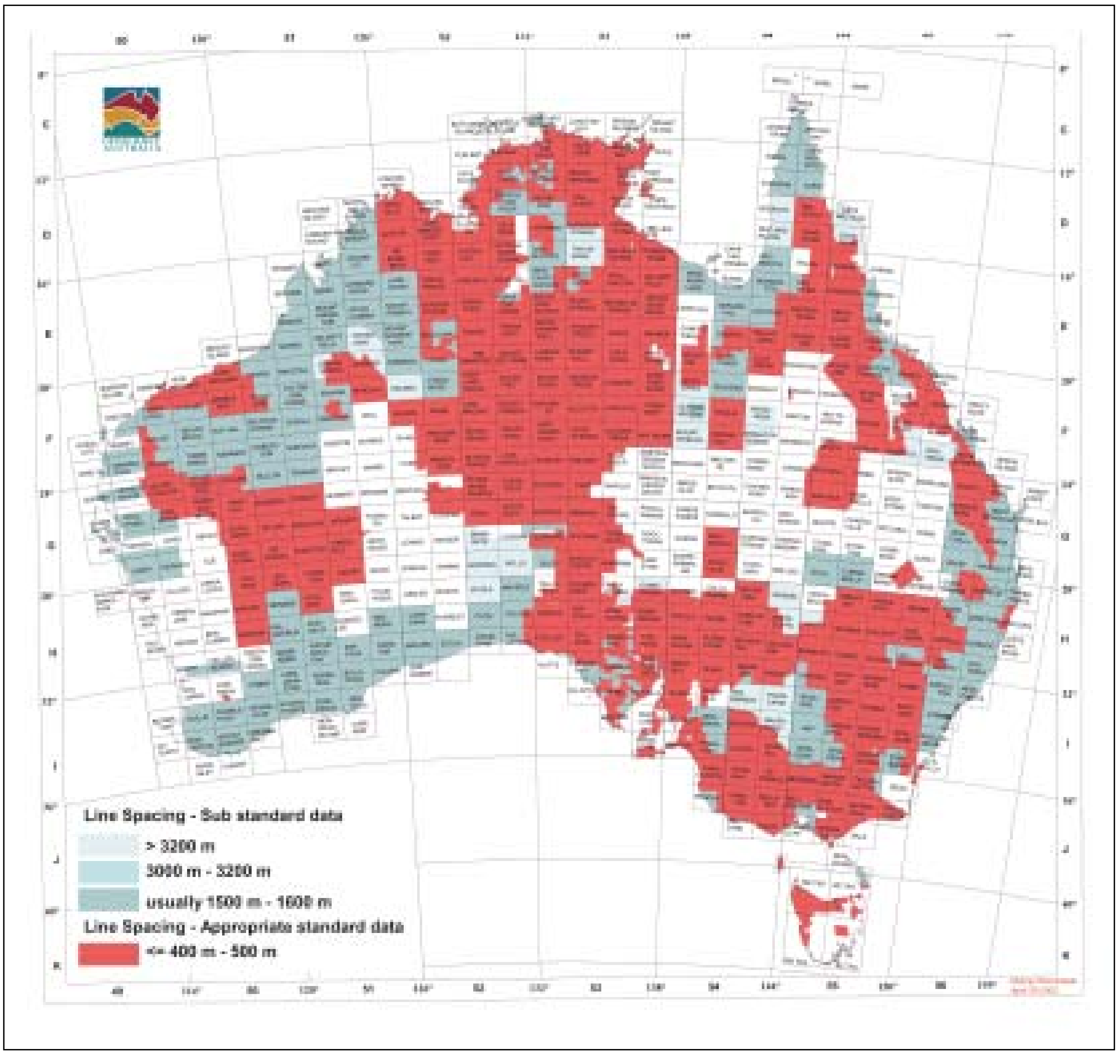
Table 2. Distances of airborne magnetic data over Australia, 2002 and 1986.

Gamma-ray data

Figure 3 shows the present state of coverage of airborne gamma-ray data over Australia at various line spacings, and Figure 4 the situation in January 1986. As with the magnetics, the most noticeable difference is the improvement in coverage of 400/500 m line-spaced data. However, the gamma-ray coverage is not complete.

The tables below show the percent coverages of gamma-ray data over onshore Australia, and the distances surveyed by 2002 and 1986.

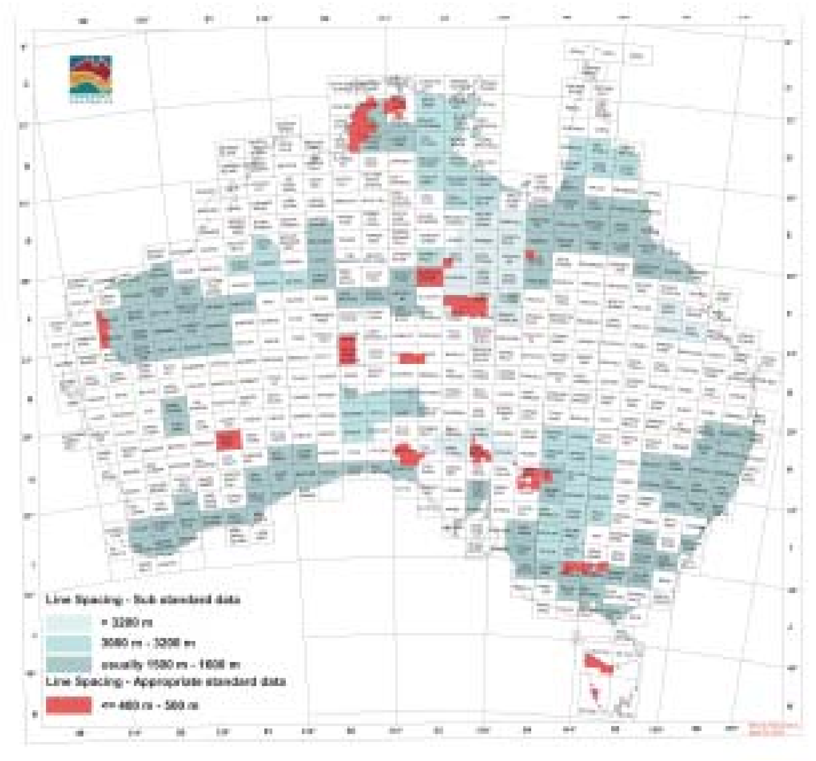




Above: Fig. 2. Airborne magnetic coverage and line-spacing over Australia, January 1986.

Right: Fig. 3. Airborne gamma-ray coverage of Australia and line spacing, April 2002.

[2] *The database holds a small percentage of surveys with undefined line distances, which have not been included: these are estimated to total 300 000 line-km.*



Coverage (%)		
Line spacing (m)	2002	1986
<= 500	52.5	2.8
501 - 1600	24.2	22.8
3000 - 3200	3.8	9.7
>3200	1.2	4.5
No coverage	18.3	60.2

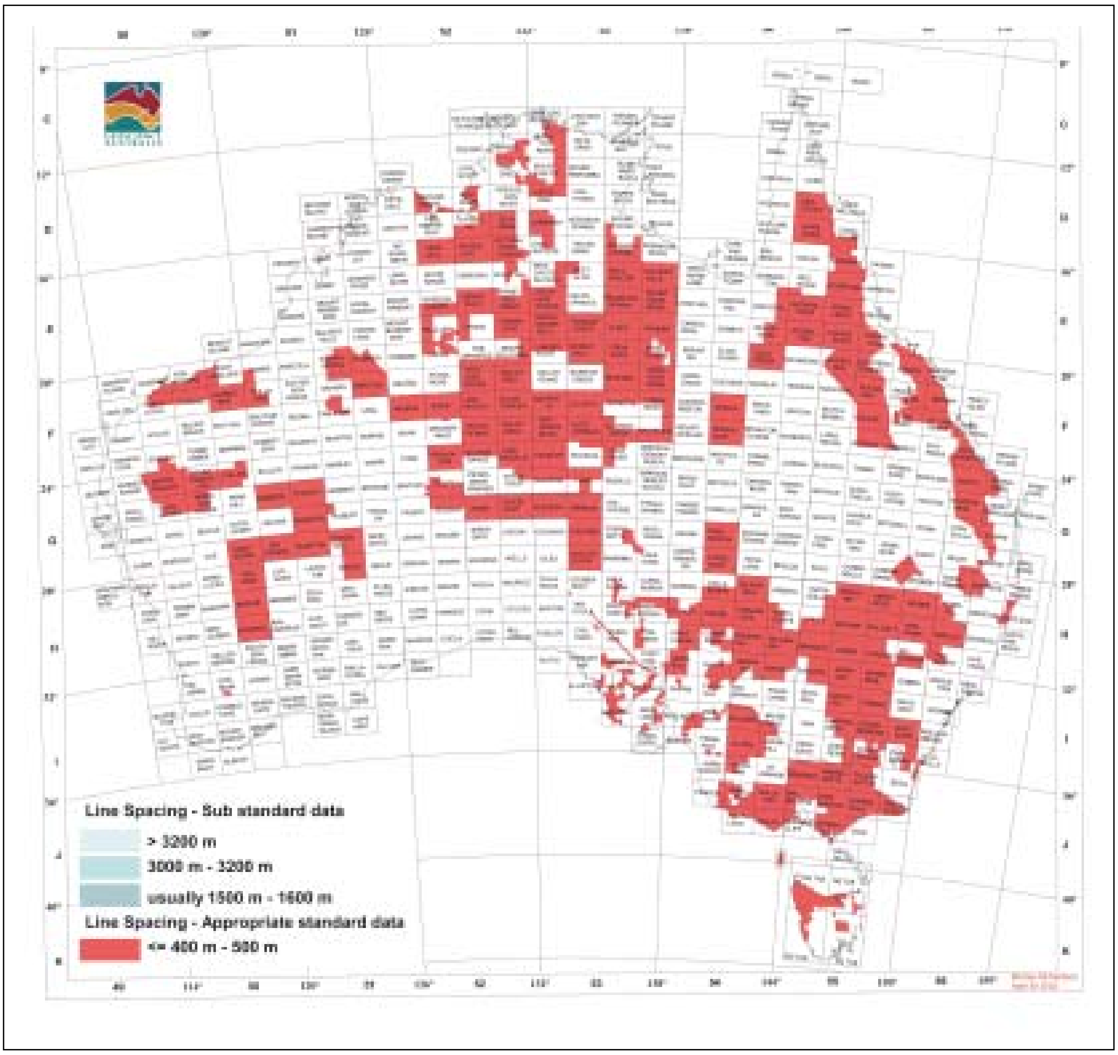
Table 3. Line spacing of airborne gamma-ray data over onshore Australia, 2002 and 1986.

Distance (km)[3]		
Line spacing (m)	2002	1986
<= 500	10 456 686	536 018
501 - 1 600	2 464 124	1 724 051
3 000 - 3 200	347 421	319 125
>3 200	43 117	43 117
Total	13 311 348	2 622 311

Table 4. Distances of airborne gamma-ray data over Australia, 2002 and 1986.

Above: Fig 4. Airborne gamma-ray coverage of Australia and line spacing, January 1986.

Left: Fig. 5. Airborne elevation coverage of Australia and line spacing, April 2002.



[3] *The database holds a small percentage of surveys with undefined line distances, which have not been included: these are estimated to total 150 000 line-km.*

Elevation

As a consequence of using GPS for flight path recovery, elevation of the Earth's surface above sea-level is now easy to calculate from data collected during airborne geophysical surveys. Elevation data are now a standard product from airborne geophysical surveys. In 1986, the GA databases held practically no elevation data. In June 2002 the coverage was as tabulated below, and as shown in Figure 5.

Line spacing (m)	Coverage (%)	Distance (km)
<= 500	34.9	7 094 873
501 - 1600	0.4	22 970

Table 5: Coverage of elevation data from airborne surveys over Australia, 2002.

A 250-m grid of elevations over all of onshore Australia derived from point elevations (spot heights), gravity survey station elevations and airborne geophysical survey elevation data is available from GA.

Accumulation of data into airborne geophysical databases

Figure 6 shows the yearly and cumulative acquisitions of airborne geophysical data into GA's airborne geophysical databases from 1951 to the present. The rapid accumulation of data, which occurred over the 1990s due to Commonwealth and State/Territory Government exploration initiatives, appears to be tapering off.

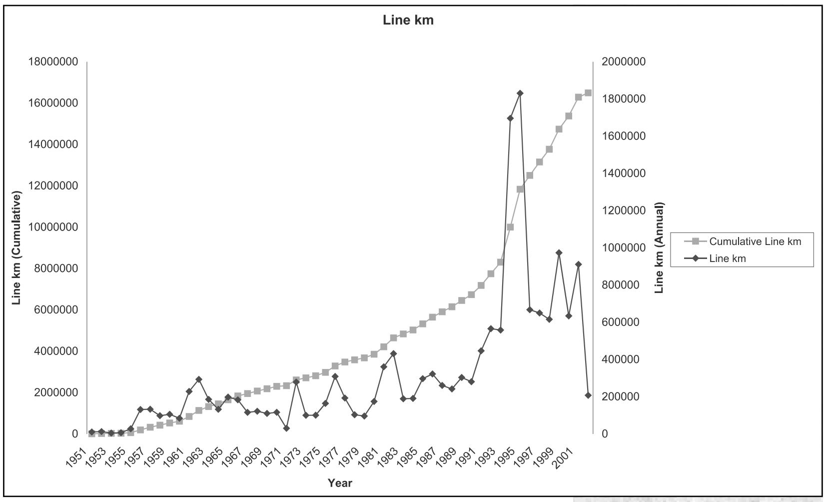


Fig. 6. Accumulation of data from State/Northern Territory, Commonwealth Government and Private Company airborne geophysical surveys into the National Airborne Geophysical Database from 1951 to the present.

Gravity

Figure 7 shows the present state of coverage of gravity data over onshore Australia at various station spacings, and Figure 8 the situation in January 1986. The table below quantifies the situation.

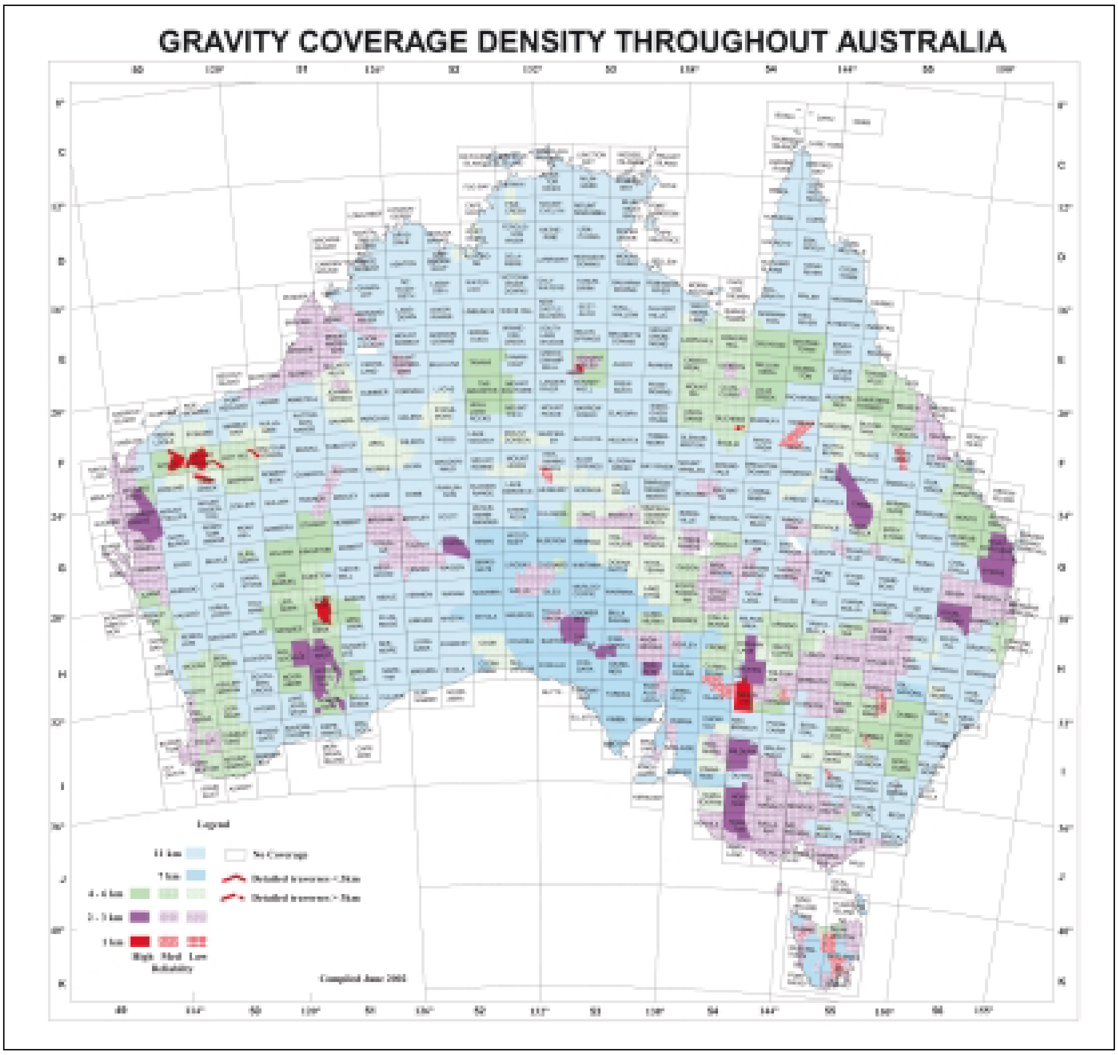


Fig. 7. Gravity Station Coverage of Australia, April 2002.

	2002		1986	
Station spacing	Coverage (%)	Stations	Coverage (%)	Stations
<= 1 km	0.9	8 688	0.3	1 436
2 - 3 km	14.2	135 197	7.6	44 351
4 - 6 km	25.6	244 783	9.7	56 778
7 km	11.0	105 331	10.8	63 076
11 km	48.3	461 673	71.7	419 259
Total		955 672		584 900

Table 6: Coverage of gravity data over Australia, 2002 and 1986.

Fig. 8. Gravity Station Coverage of Australia, February 1986.

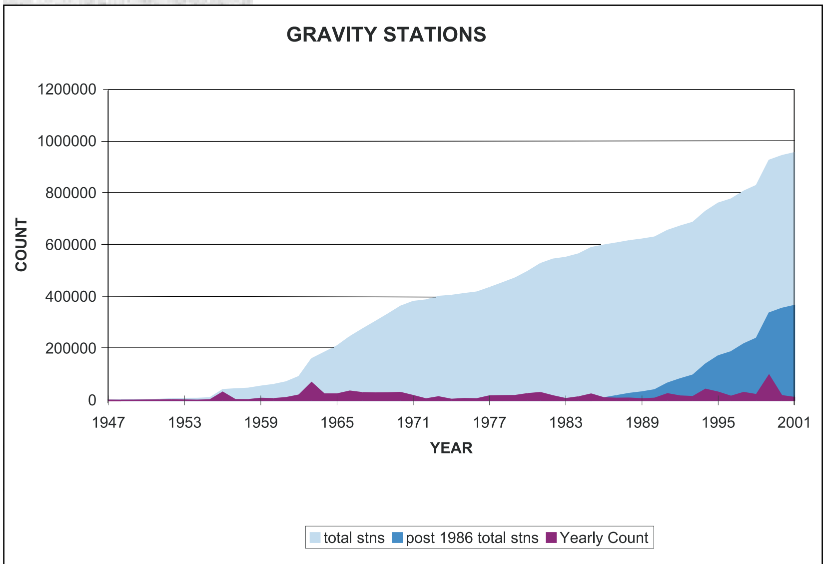


Fig. 9. Accumulation of data from State/Northern Territory, Commonwealth Government, Private Company and University gravity surveys into the National Gravity Database from 1947 to the present.

Although there is essentially full gravity coverage over onshore Australia, most is at a very coarse station spacing and much of the data are aliased. There are no airborne gravity or gravity gradiometry data in the GA databases.

Figure 9 shows the acquisitions of gravity data into GA's gravity database from 1947 to the present. Although accumulation of data accelerated in the 1990s, the increase of gravity data was not as dramatic as the increase in airborne geophysical data.

Data availability

Data owned by the Commonwealth in the National Airborne Geophysical Databases are available at cost of transfer from GA. Data owned solely by State and Territory governments are available from the relevant State or Territory Departments.

New Commonwealth policy on data pricing and access

Publicly available digital data from Geoscience Australia's airborne geophysics and gravity databases are now available under the Commonwealth Government's new spatial data pricing and access policy. Some data, such as the Gravity database and the gravity and magnetic grids of Australia, are available for free download from GA's website (www.ga.gov.au). Almost all released data are available on CDs at a cost of A$99 per CD (including GST).

Data from most semi-detailed airborne geophysical surveys are provided on one CD per survey. For surveys larger than 69 000 line-km (at say 400 m line-spacing) the data are contained on two or more CDs for each survey (up to a maximum of 7 CDs). Data from several 1500 m line spaced surveys fit on one CD. The GA website has a list of available airborne geophysics data by survey. The grid of the Magnetic Map of Australia (at 15 s ~ 400 m cell size) is on a single CD. The gravity database and the gravity grid (at 30 s ~ 800 m cell size) of Australia are on a single CD.

The Commonwealth's new policy on access to data relaxes previous restrictions on reprocessing and distribution of the data by third parties.

Improvements in quality of data

As well as improvements in the coverage of data since 1986, data quality has markedly improved from advances in acquisition and processing techniques. Some of these are described below.

Location of measurement points

In 1986 most airborne geophysical surveys used a combination of aerial photographs with Doppler navigation systems for aircraft navigation and flight path recovery. In the late 1980s radio-navigation systems were introduced and in the early 1990s Global Positioning System (GPS) navigation systems were beginning to provide navigation and flight path recovery information. Today, GPS navigation systems are the standard for airborne geophysical survey navigation and flight path recovery. Flight lines are straighter and more precisely located than in 1986. Positions are to within 5 m, compared to typically 70 m or more from aerial photographs.

GPS has improved the accuracy of gravity surveys. In 1986 many regional gravity survey stations were levelled using barometers and horizontally located using aerial photographs because the alternative of surveying was too costly and slow. Height data recorded with barometers typically had errors of 1 m for digital barometers to 10 m or more for aneroid barometers, resulting in uncertainties of 3 to 30 μms^{-2}. Appropriate GPS height data now gives heights to better than 5 cm. Locations from aerial photographs could have had uncertainties of 200 m (equivalent to 1 μms^{-2}).

Magnetometers

Proton precession magnetometers were the standard sensor in 1986. These measured the total magnetic field to a resolution of 0.1 nT. Magnetic data were recorded at 1 s intervals with a noise envelope of 1 nT. Currently, caesium and helium vapour magnetometers are the industry standard. Both types of magnetometer can be sampled at 0.1 s intervals or closer, with resolutions of 0.001 nT, and noise envelopes of less than 0.01 nT.

Improvements in base station magnetometer instrumentation have followed a similar pattern to developments with the airborne magnetic sensor. Progress has seen the standard base station magnetometers change from a proton precession magnetometer in 1986 to high sensitivity alkali vapour base stations in 2002.

Compensation

In 1986 the effects of airborne magnetic survey aircraft were compensated by adjusting the currents flowing through three mutually orthogonal coils. This procedure was time consuming at the best of times and often took one - two days before a satisfactory result was obtained. Typically, manoeuvre noise was up to ±0.5 nT with a heading error of up to ±1 nT. The Automatic Aeromagnetic Digital Compensator (AADC) revolutionised the magnetic compensation procedure. The whole procedure could be completed in one - two hours with manoeuvre noise less than ±0.15 nT and a heading error less than ±0.25 nT.

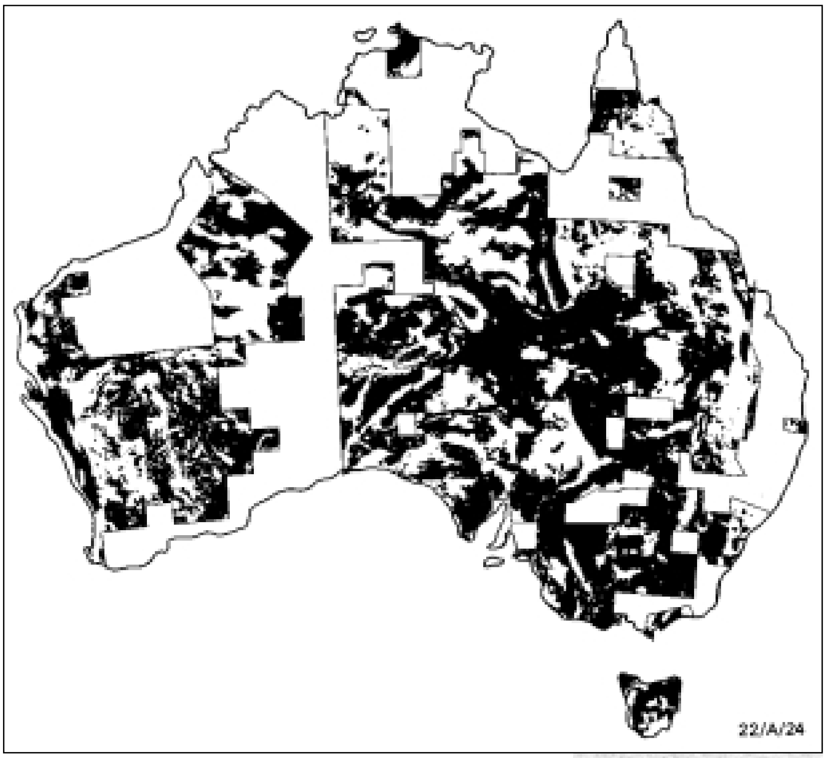
Gamma-ray spectrometer systems and processing

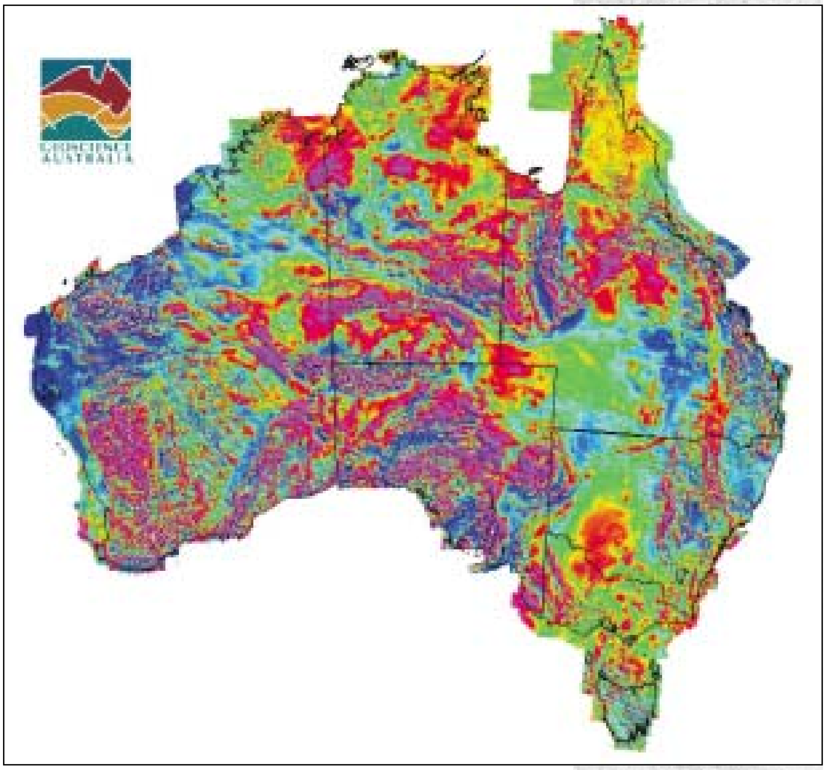
In 1986 the standard crystal volume in the aircraft was typically16.8 l, sometimes with 4.2 l of upward crystal. Now 33 l is standard, giving a $\sqrt{2}$ improvement in noise levels.

Spectrometer calibration was difficult in 1986. The crystal packs and photomultiplier tubes (PMT) had to be maintained at a constant temperature to achieve thermal stability. The spectrometer system required regular calibration to maintain the resolution of the data. Drift was common, degrading data. Spectrometers are now self-calibrating spectrometers that don't require temperature stabilisation of crystal packs or PMTs.

Whereas 4 channels of data were typically recorded in 1986, a minimum of 256 channels are now recorded. The increase in the number of recorded channels has enabled improved background estimation, and noise adjusted singular value decomposition (NASVD) or minimum noise fraction (MNF) processing to reduce noise. Systems are now regularly calibrated over calibration ranges so that final results are expressed as apparent ground concentrations, or dose rate. In 1986 results were usually expressed in counts per second, and easy comparison of results from different systems was not possible.

Cont'd on page 56





Top: Fig. 10. The Magnetic Anomaly Map of Australia, 1986 edition.

Above: Fig. 11. The Magnetic Anomaly Map of Australia, 1999 edition.

Acknowledgements

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Gravity Meters

There are now several meters such as the Scintrex CG-5 and LaCoste and Romberg Graviton-EG meters that take readings automatically and store the data for downloading direct to a computer, decreasing the problems of reading and input errors. One factor often overlooked for the LaCoste and Romberg G meters is that they can become more stable over time, thus a meter from the seventies or eighties may give better results because of better drift characteristics than newer more automated instruments.

Improvements in gravity meters in recent years have made taking gravity observations easier and less prone to operator error. These improvements mean that less time is spent taking observations resulting in increased production.

Concluding remarks

Considerable improvements have occurred in geophysical coverages of Australia since 1986, both in the extent and quality of data. State and Commonwealth initiatives fuelled rapid increases in magnetic, gamma-ray and elevation data during the 1990s. The completion of first pass magnetic coverage and the introduction of GPS systems have encouraged the reduction in line spacing of the airborne coverages. Quality of airborne geophysical data has improved due to GPS, better magnetometers and compensation systems, multi-channel gamma-ray data acquisition, and improved processing. In 1986, over a quarter of Australia was covered by analogue magnetic data. These have now been digitised or reflown and included in the national database. Coverage of gravity data has steadily improved, and data quality have improved, largely due to the introduction of GPS. Presentation of data has also improved with the now routine use of image processing, and the use of derivatives and other manipulations of data. Maps can now be generated much easier and faster than in 1986.

Figures 10 and 11 demonstrate some of the improvements in coverage for magnetic data from 1986 to now. Figure 10 shows the Magnetic Map of Australia, which was available in 1986 as a contour map generated by BMR in 1976. Figure 11 shows the 1999 edition of the Magnetic Map of Australia (Milligan and Tarlowski, 1999) which is available as a pixel image map. Not only has the area of data coverage increased markedly, but also the quality of presentation of the map has improved, making it far more interpretable. Due to improvements in processing and visualisation techniques GA has released three editions of the Magnetic Anomaly Map of Australia dur ring the 1990s whereas before 1990 only one edition of this map had been published.

Despite the recent improvements, large areas of Australia have poor quality of coverage. About 45% of onshore Australia has airborne magnetic coverage with line spacings of 1 500 m or more, and 18% has no coverage of gamma-ray data. Almost half of onshore Australia has gravity data at 11 km station spacings; only 15% has coverage at 3 km or closer station spacings.

Geophysical character of the Shoemaker Impact Structure

Franco Pirajno
Geological Survey of Western Australia
franco.pirajno@mpr.wa.gov.au

Phil Hawke
The University of Western Australia
phawke@geol.uwa.edu.au

Introduction

The Shoemaker Impact Structure is named in honour of Gene Shoemaker, and was previously referred to as the Teague Ring. Gene was about to start cooperative work with scientists from the Geological Survey of Western Australia (GSWA) on the structure in 1997, when he was tragically killed in a car accident in northern Australia. The GSWA recently published a Report on the geology, geochemistry and geophysics of the structure (Pirajno, 2002). Study of the structure also forms part of an ASEG-RF funded PhD project at the University of Western Australia.

Shoemaker is located on the southern margin of the Paleoproterozoic Earaheedy Basin, 110 km to the northwest of the township of Wiluna. Shatter cones and shocked quartz grains confirm that the structure is the result of a meteorite impact. The precise age of the impact is not known, but preliminary radiometric age dating suggests that it occurred sometime between 1000 and 600 Ma. The structure is 30 km in diameter and consists of a collar of upturned sedimentary rocks of the Earaheedy Group surrounding a core of centrally uplifted Archaean basement. The rocks of the central uplift were subjected to post-impact high-temperature hydrothermal alteration, resulting in pervasive alkali metasomatism. The resulting rock of generally syenitic composition is collectively named the Teague Granite. Since its formation, Shoemaker has been eroded to a depth of about 3 km.

Remote sensing

Shoemaker is most easily recognised by the deformation of the erosion resistant ironstones of the Frere Formation, which is clearly visible in satellite imagery. Figure 1 shows an RGB image of principal components 1, 2 and 3 overlain on a 3D terrain model (vertical exaggeration is 1500).
An arc of Frere Formation delineates the southern extent of the Shoemaker structure. A faint circular pattern can also be observed to the north of the structure in the overlying sediment of the Chiall Formation. An inner ring of Frere Formation forms one limb of the ring syncline encircling the central uplift. A ring syncline, also known as the "crater moat", is a common feature of large impact structures and defines the lowest structural position within the crater. The Teague Granite may be observed where it outcrops on the eastern flank of the structural uplift.

The strong red-magenta pattern is related to the highly saline waters of Lake Nabberu and Lake Teague. Low-lying areas around the Shoemaker structure are concealed beneath lacustrine, alluvial and aeolian sediment associated with this playa lake system.

Aeromagnetics

Aeromagnetic data were collected over the Shoemaker structure by Geoscience Australia as part of the Nabberu 1:250 000 Sheet Survey. Data were collected on east-west lines spaced 400 m apart at a nominal flying height of 80 m. The Shoemaker impact structure can be identified in the TMI image from this survey (Figure 2). The aeromagnetic data shows two circular patterns: an outer circular feature characterized by negative magnetic anomalies, and an inner trend of magnetic highs, particularly along the eastern and southeastern rims. These patterns largely reflect the bedding of the ironstones of the Frere Formation.

The high magnetic intensity in the eastern parts of the structure is spatially associated with extensive quartz veining and hydrothermal alteration of the Frere Formation. The high magnetic intensity is interpreted to reflect a secondary production of magnetite in the iron formation units by the circulation of impact-generated hot fluids. Enhanced susceptibility and the resulting magnetic anomalies is a common feature of many hydrothermal processes.

A pluton of hornblende-bearing monzogranite forms a prominent magnetic feature to the southwest of Shoemaker. Within the central uplift, the Teague Granite on the eastern half of the structure exhibits a moderate magnetic response. This suggests that the magnetic pluton to the south of Shoemaker was a likely contributor to the composition of the Teague Granite. Other magnetic features include numerous dykes, fractures and/or faults. Dykes trending north and northeast cut the circular structures. Fractures in the vicinity of the Shoemaker impact structure trend northeast, southeast and east. The northeast trending Lockeridge Fault system to the southwest of the structure is also clearly displayed.

Gravity

Large impact structures are characterised by negative gravity anomalies due to the lower density of fractured

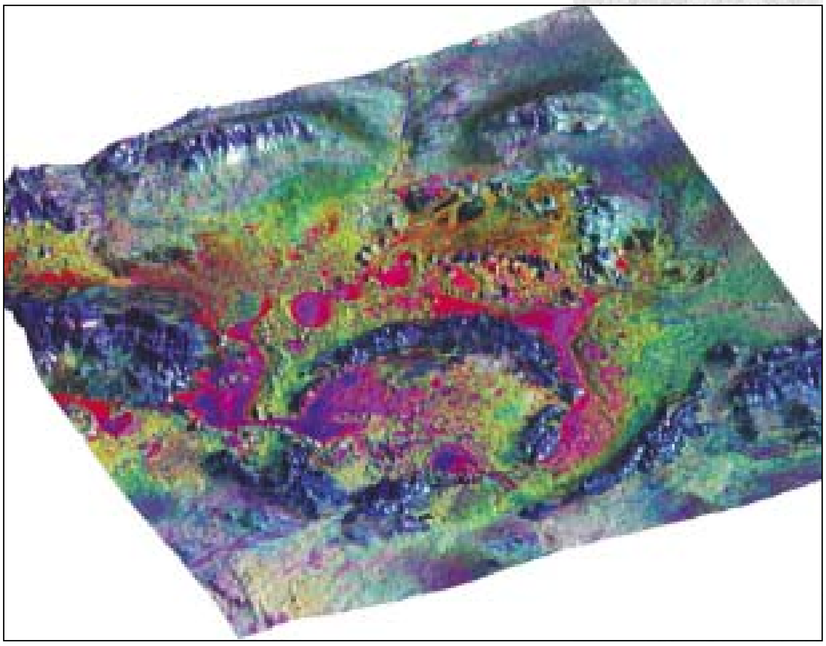
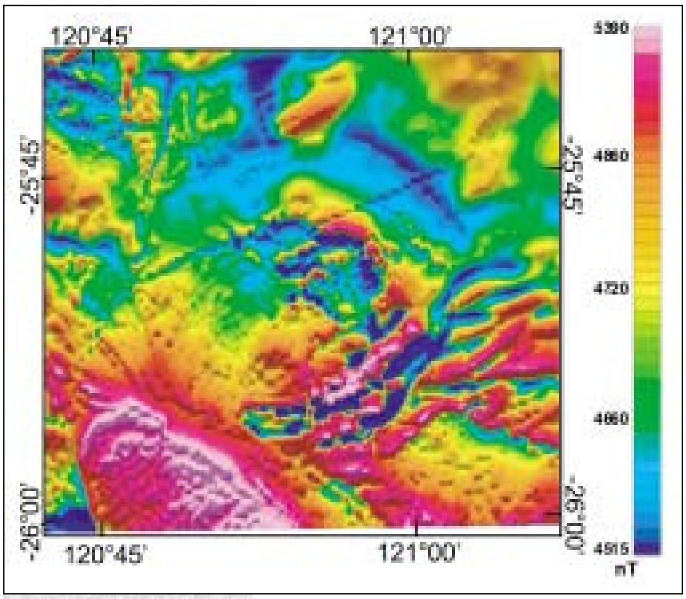
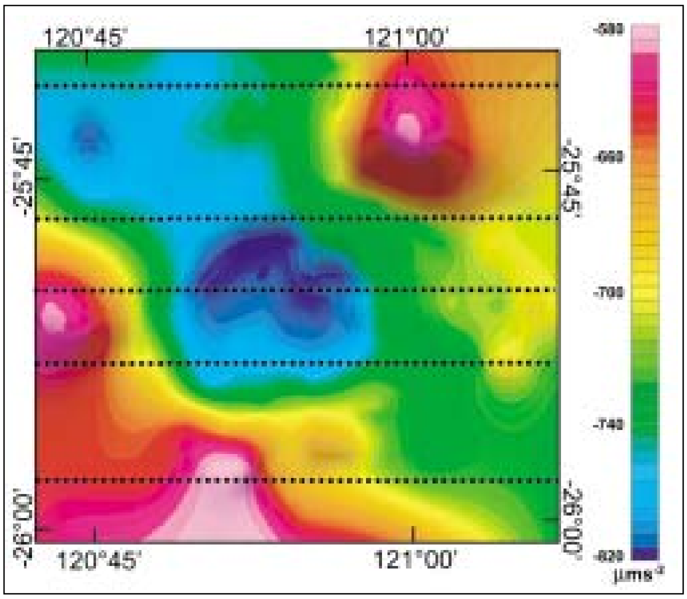
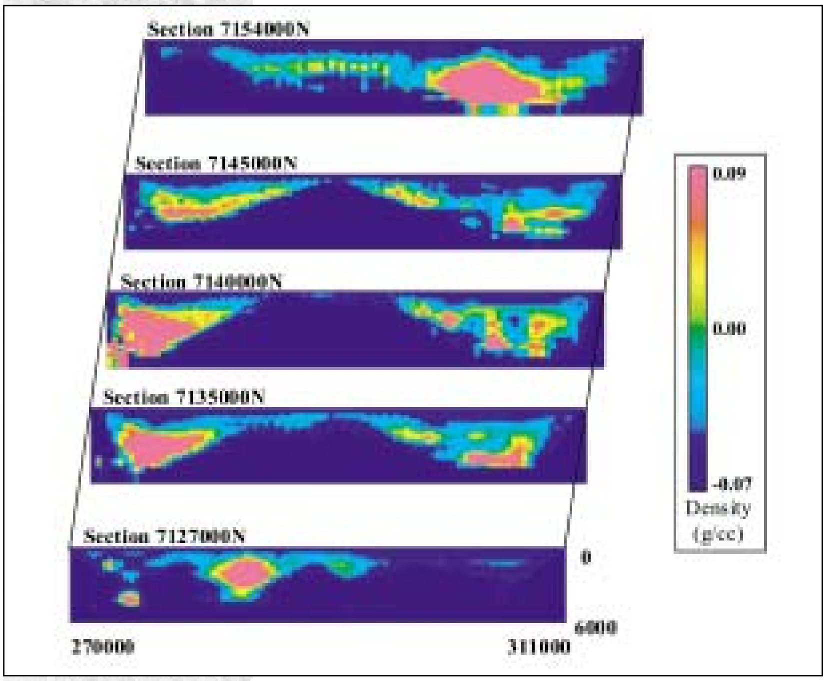


Fig. 1. RGB image of Landsat principal components 1,2,3 draped on topography (vertical exaggeration 1500). View is looking to the northeast.







Top right: Fig. 2. Total magnetic intensity image of Shoemaker structure from GA's Nabberu Survey flown in 1996.

Top left: Fig. 3. Bouguer Anomaly over the Shoemaker structure, dashed lines show the locations of inversion sections shown in Fig. 4.

Above: Fig. 4. Depth slices and sections through the inversion 3-D density model to describe the gravity field response over the Shoemaker impact structure.

target rock. Pilkington and Grieve (1992) show that in most crystalline targets the contrast between fractured and unfractured target rocks is between 0.13 and 0.17 t/m^3. For example, Iasky *et al.* (2000) calculated that for the Woodleigh impact structure, the density of the basement was reduced from 2.67 t/m^3 to 2.55 t/m^3.

A gravity survey was conducted by Plescia (1999), who defined a negative Bouguer Anomaly coincident with the core of the Shoemaker structure. This was based on 140 stations collected using a Lacoste and Romberg meter with readings spaced about 500 m apart along fencelines and station tracks. Forward modelling of these data suggested that the fractured crystalline core extends to a depth of 4-5 km. An additional 132 gravity stations were surveyed over a 35x35 km area centred on the Shoemaker structure during 2001 (Hawke, in press). An image of the Bouguer Anomaly over Shoemaker is shown in Figure 3.

High gravity anomalies near the edges of the survey area are interpreted to reflect concealed Archaean greenstone. A negative gravity anomaly is coincident with the crystalline core of the SIS. The absolute magnitude of this negative response is somewhat difficult to determine given the regional variations of the gravity field due to Archaean greenstone. However, assuming the gravity field to the east of Shoemaker as background, this negative anomaly has an amplitude of 100 µms^{-2}. The source of the negative anomaly is interpreted to be due to low-density granite in the crystalline core of the structure. A local gravity high, which appears to bisect the crystalline core in a northwest trend, is interpreted to reflect Archaean greenstone that was also caught in the central uplift of the structure. A small gravity shoulder on the outer margin of the gravity low is interpreted to reflect the dense ironstones of the Frere Formation.

A three-dimensional source model for the gravity field response over Shoemaker was created using the University of British Columbia (UBC) geophysical inversion utility ***"grav3d"*** (Li & Oldenburg, 1998). Gravity data were modelled over a 40 x 34 km area. The inversion was performed on the Bouguer Anomaly and no attempt was made to model the gravitational effects of the terrain. A model mesh of 500 x 500 x 200 m was used, requiring the resampling of gridded gravity data to a 500 m cell size prior to inversion. A uniform half-space with no density contrast was used as the starting model. The density model obtained from inversion is shown as a series of sections in Figure 4. Anomalous low densities modelled at the ends of each section show the limitation of the inversion process where little data is available.

Most of the variation in density model (Figure 4) can be related to geological units. A layered transition from low to high-density rock near the top of each section is interpreted as the contact between the siliclastic sediments of the Chiall Formations and denser ironstones of the Frere Formations. High-density bodies at depth are interpreted as a belt of Archaean greenstone, which has been deformed by the Shoemaker structure. These are concealed beneath

Cont'd on page 59

NTGS

Data from GA surveys now available from NTGS

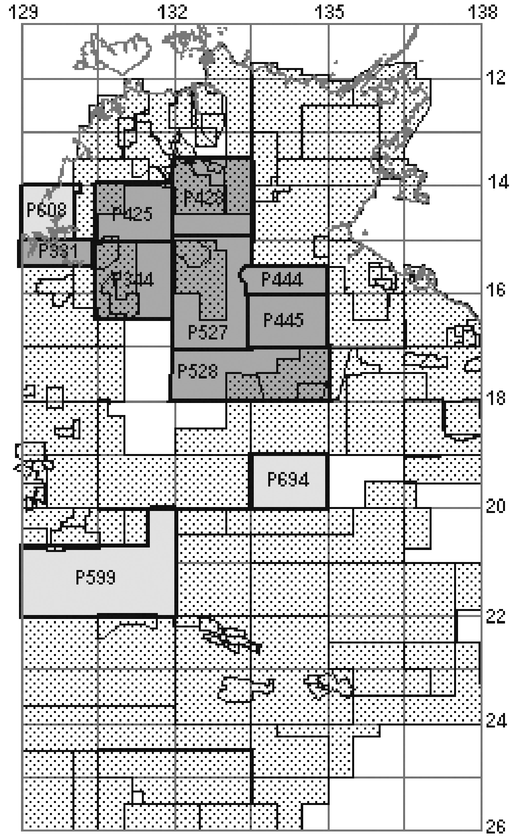
NTGS has made available the located and gridded data from 11 separate Geoscience Australia (GA) airborne magnetic/radiometric surveys flown in the Northern Territory during 1967-1998. Located data are available in ASEG-GDF2 format, and grids as ER Mapper ERS.

The surveys include 11 semi-regional and reconnaissance surveys as listed below:

Survey	Year flown	Line-spacing (m)
Mt Theo-Highland Rocks, P599	1993	500
Port Keats, P608	1994	500
Tennant Creek, P694	1998	200
Fergusson River, P425	1975	1500
Katherine-Mt Evelyn, P428	1976	1500
Larrimah-Daly Waters, P527	1987	1500
McArthur Basin, P444	1977	3000
McArthur Basin, P445	1977	3000
Newcastle Waters-Beetaloo, P528	1987	1500
Victoria River Basin East, P344	1967	1600
Victoria River Basin West, P331	1967	1600

The diagram (right) indicates the extents of the surveys, together with the more recent NTGS airborne coverage, which is shown as stippled.

These data are available through NTGS at no cost, from: geoscience.products@nt.gov.au



Information from 2002 surveys now available

NTGS has also released preliminary located magnetic, radiometric and elevation images from surveys either currently being flown or completed on behalf of NTGS earlier this year. They can be viewed on the NTGS Airborne Geophysical Image Web Server at: http://www.dme.nt.gov.au/ntgs/geophysics/air_map/2002Map/new_surv_map.html

This service has been introduced so that explorers have the opportunity to work with current airborne imagery during the field season, rather than typically having to wait until the end of the field season to receive data.

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1500 m of granite to the south of Shoemaker, and up to 2000 m of Earaheedy Group sediment to the north and west of the structure.

The geometry of the structural uplift of Shoemaker is well defined by the gravity inversion. Low-density granitic rocks forming the central core of structure and a surrounding collar of dense Frere Formation sediments can be interpreted from the sections. The inversion has insufficient resolution to determine whether the granite within the central uplift has a lower density than unmodified granite outside the structure. High-density material within the structural uplift is interpreted as a minor band of greenstone concealed beneath Quaternary sediment.

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Exploration investment may be ready to rise....

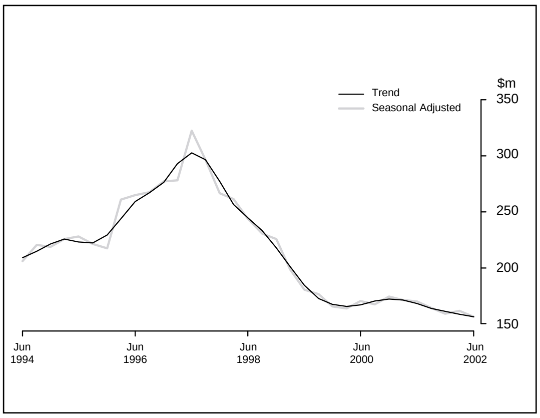
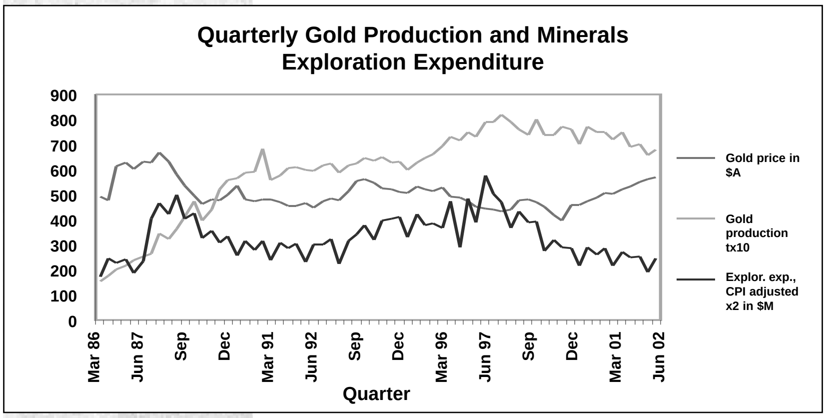


Fig. 1. Trend and seasonally adjusted quarterly mineral exploration expenditure from June-1994 to June 2002. (Provided by the Australian Bureau of Statistics).

Fig. 2. Quarterly figures for: gold production (in tonnes), the price of gold in $A/oz, and raw mineral exploration CPI adjusted to 1989/90 in $M.



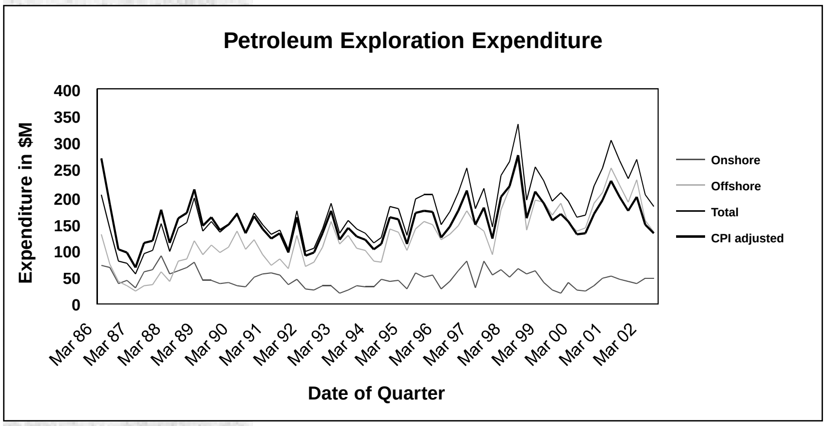


Fig. 3. Quarterly petroleum exploration expenditure from 1986-2002, from ABS statistics, corrected for inflation.

There are some good signs in the exploration scene. On the petroleum front, on top of the sale of LPG to China — Australia's largest single export deal, there are been some encouraging discoveries in the Cooper Basin as well as an increase in the oil price to make exploration more attractive.

For minerals, there was a record attendance at this year's annual Diggers and Dealers conference in Kalgoorlie, with about 1000 delegates attending. Apparently, for the first time in many years, a number of investment bankers and fund managers appeared as well, indicating a renewed interest in mining from the financial sector. Maybe they have been burnt by the dot coms, and the insurers, don't like the look of the banks and feel that the property market may be ready for a fall. Whatever the reason, it is good news.

Their interest possibly also resulted from some exciting greenfields discoveries such as Minotaur's Prominent Hill Prospect, which is looking very much like another Olympic Dam; Newcrest's new development plans at Telfer and Ridgeway near Parkes; Newmont's plans to spend $35M in 2003 and Gympie Gold, pleased with the success of previous exploration, will spend $25M over 3 years on one of the largest exploration programs by a mini-miner.

.... but both Mineral and Petroleum Exploration levels continue to fall in June 2002 quarter.

Minerals

Figures released in September 2002 by the Australian Bureau of Statistics showed a continuation of the steady downward trend evident over the last few years.

The trend estimate for total mineral exploration expenditure decreased in the March quarter of 2002 by 1% from the previous quarter to $156M. This is 7% lower than the trend estimate of $168M for the June quarter 2001.

The actual money spent amounted to only $168M, and you have to go back to June 1987 before encountering levels as low as this. Figure 1 shows the trend and seasonally adjusted numbers as reported by the ABS.

The largest decrease occurred in Western Australia ($4.4M or 5%). There was a slight decrease in NSW, the NT remained steady and there were slight increases in other states. However, at $92M, Western Australia still dominates the figures, as does gold at $87M.

It is interesting to look at some of the key statistics in the minerals' sector since the first issue of Preview in 1986. Figure 2 shows the quarterly gold production, the price of gold in $A, and the expenditure on mineral exploration (gold is usually 50-60% of the total expenditure).

The correlations between the curves are somewhat tenuous. There is clearly a significant correlation between the gold production chart and the mineral exploration expenditure over the last 12 years, but when the price of gold increased over the last two years the production levels and the exploration expenditure continued to decline. Very strange, perhaps it really is just getting harder to find, and the Hubbert peak for gold has already been reached.

Petroleum

Reported expenditure on petroleum exploration in the June quarter 2002 was $181M, 32% lower than the June quarter 2001.

The decrease occurred as a result of a 21% ($34M) drop in offshore exploration expenditure, partly offset by a $21M (33%) increase in on shore expenditure.

Figure 3 shows the Petroleum expenditure since Preview was first published in 1986. It is clear that the long-term trends indicate a slight increase in dollars invested, even when inflation is taken into account. However in the last few years the trend appears to have flattened out.

In the next Preview we will look at the relationships between reserves, crude oil prices and exploration expenditure in more detail.

Geodynamics Ltd to drill for Hot Dry Rocks in Cooper Basin... ..

"The Stone Age did not end because people ran out of stones. It ended because they found something better." Sheikh Yamani's famous quote is a good introduction to Geodynamics' Website

Geodynamics is a new company launched on the ASX in September 2002. It has raised $11.5 million to start a drilling program in the Cooper Basin to locate and develop a HDR resource. Clean sustainable energy is a Holy Grail in the 21st Century and an HDR source has enormous potential to contribute to this goal.

Over the past 30 years, oil and gas drilling in the Cooper Basin has discovered naturally occurring heat buried within massive granitic rocks. This geothermal energy is the resource for the Company's revolutionary energy project.

Gravity and seismic data analysis has located massive granite rocks at depths of approximately 3500 m, along with extremely high temperatures of 232 - 245^{o}C near the top of the granite. These temperatures are amongst the highest in the world at this depth outside tectonically active areas.

Drilling on Geodynamics #1 well, located approximately 8 km south of Innamincka, will start within 2 months.

The first stage of the plan is to prove the concept by developing an underground heat exchanger and to produce 20MW of thermal energy from a two well circulation test. Stages 2 and 3 involve drilling a third hole, installing a binary geothermal plant, producing power for the Moomba gas producing plant, and expanding the production to provide electricity to the national grid.

The Company has exploration licences over blocks GEL 98 and GEL 97, which cover 985km^2. It estimates that the stored thermal energy within an accessible 1000 m thick slab of granite within these leases is equivalent to 50 billion barrels of oil. By comparison, the proved oil reserves in the USA are estimated at approximately 30 billion barrels, and for Australia, 3 billion barrels. The challenge is to be able to extract the heat efficiently.

Metasource Pty Ltd, a wholly owned sustainable energy subsidiary of Woodside Petroleum, has the right to purchase certain environmental credits from Geodynamics once large-scale electricity production commences, so long as it continuously holds its initial shareholding.

The Federal Government, through AusIndustry, has also confirmed that all outstanding conditions for Geodynamics to access a $5 million Research and Development Start grant, have also been met.

Bertus de Graaf will be managing the company and Prame Chopra and Doone Wyborn will be directors and provide the technical expertise.

... .and clean energy is the flavour of the month.

Sustainable energy generation is certainly becoming more important. In Victoria, for example, wind generates about 40 MW at present, and there are plans for an additional 330 MW of wind-generated power on the drawing boards. Even the petroleum giant Shell is investing in wind power, and it seems that with Kyoto arrangements coming into line the trends away from burning fossil fuels will certainly continue.

Southern Pacific Petroleum (SPP) is also getting into the act with an announcement that it will build Australia's largest 'carbon sink' as part of its greenhouse gas strategy to address growing concerns over the emissions associated with oil from shale.

Under the plan, the company will plant 116 million trees to create permanent forests that would 'capture' or sequester 121 million tonnes of carbon.

They also plan to build an ethanol plant alongside the Stuart Oil Shale plant near Gladstone based on woody biomass sourced from local plantations and sugar wastes.

SPP has also undertaken scoping activity to develop a bio-ethanol plant that could be readily added to a fully developed plant to derive oil from shale. The Federal Government via its New Industries Development Program recently announced a grant to SPP for the continuing evaluation of a proposed ethanol from woody biomass plant.

We will watch progress with interest.

Data Metallogenica

With the demise of the Australian Mineral Foundation, there has been concern over the future of the Data Metallogenica collection.

AMIRA has initially taken it under its wing, and in July it launched a new web site for Data Metallogenica at: www.datametallogenica.com. Access for the first 12 months is limited to original 70-80 company sponsors through an annual subscription scheme, but when it becomes public in 2003 unlimited access will also be available to individual subscribers for an annual fee of $200.

The web site contains:

- High quality digital photographs of 3000 Lithotheque plates (each containing about 20 individual samples) as well as 1200 individual samples from important representative deposits,

- Over 5500 PIMA spectra and their interpreted alteration mineralogy from most epithermal and porphyry deposits, as well as some other deposit styles,
- Searchable deposit database (deposit name, country, region, commodity, deposit type) for over 4000 mineral deposits of all types from more than 100 countries (a total of over 65 000 samples of ores, host rocks and alteration),

- Progressive electronic access to deposit descriptions, typical cross-sections, geological maps, Macrotheque photographs, geological photo-libraries, technical bibliographies and other information for each deposit.

AMIRA International is currently circulating a new research proposal (P554A) seeking sponsorship for further funds to continue development of the project for the benefit of industry and educational institutions. The two year proposal will: enhance the capabilities of the operational web site; extend the range and content of deposit-related information, particularly information such as maps, cross-sections and geological field photo-library for key deposits; pilot-test new image and measurement programs, and; develop important alliances and linkages with researchers and content providers around the world. For more information contact Alan Goode at alan.goode@amira.com.au.

New School of Petroleum Engineering and Management opened at the University of Adelaide

The Prime Minister, John Howard, opened the new School in August this year. It will play a major role in easing a critical shortfall in petroleum engineering professionals needed for the growing energy industry in Australasia.

It has been established by the University with help of a 20-year commitment by South Australian-based Santos Ltd, one of Australia's leading energy companies.

The Federal Government also has contributed $1 million to the School for the establishment of the Reg Sprigg Chair, in honour of the late Reg Sprigg, an early pioneer of the nation's first oil and gas discoveries.

A new degree in Bachelor of Petroleum Engineering is to be offered by the School, as well as postgraduate courses in petroleum engineering.

According to Santos MD, John Ellice-Flint: "There are currently only 35 undergraduate students studying petroleum engineering in Australia — 25 of whom commenced first year studies in March this year at the University of Adelaide as a direct result of this new School of Petroleum. Overall, these numbers are insufficient for the industry's growing needs - but this School can now help redress that shortage."

Let us hope it all goes well.

Good gold values found at Mt Gibson WA

Oroya Mining Ltd, has received spectacular gold assay results, including 2 m at 23.7 g/t, from recently completed drilling at the Midway Resource Area at its Mt Gibson gold project, 280 km northeast of Perth. Other results include 2 m at 11.62 g/t of gold from 120 m, 2 m at 23.71 g/t from 49 m, and 3 m at 7.71 g/t of gold, from 83 m.

According to Steve Shedden, Oroya's MD: "Exploration is demonstrating that mineralisation within Midway is essentially a single contiguous zone which has the potential to be mined from one large amalgamated open pit. Resource studies and further drilling are to be undertaken as soon as possible. The extent of the Mt Gibson mineral field is now considered to be comparable to other major mineral fields in Western Australia. The full potential of Mt Gibson is yet to be realised, but wherever we test we regularly find high grade mineralisation," he said.

"The company aims to bring the operation back to production by mid-2003 with the Midway and Saratoga areas key targets for early production."

Mt Gibson was discovered in the mid-1980's and was a very successful mining operation from 1986 to 1999, producing over 868 000 ounces of gold. Oroya acquired Mt Gibson in April 2002 from PacMin and it is now estimated to contain 5 million tonnes at 3.22 g/t (518,000 ounces). Oroya started drilling in April 2002 and has now completed 242 drill holes totalling over 25 600 m, confirming the company's role as one of Australia's most active gold explorers.

Gympie Gold launches $25M exploration program

Meanwhile in Queensland, Gympie Gold Ltd has announced a three-year $25 million Gympie Goldfield Exploration Program. This is the largest exploration program in Queensland and one of the largest gold exploration programs in Australia.

The exploration budget for 2002-03 is $7 million for drilling-based activities of which $4 million is directed at grassroots targets in the Gympie Goldfield following recent successes with the:

- Discovery of gold mineralisation only 500 m laterally from the new Lewis Decline in the Southern Gympie Goldfield.
- Re-processing of geophysical data resulting in recognition of likely extensions of the major feeder system, the Inglewood Lode to the northwest and to the southeast of current mine areas over a strike length totalling more than 4 km.
- Identification of 14 additional prospects within the Gympie Goldfield, in which we include the Gympie Basin that surrounds the gazetted goldfield. Each of these prospects has the potential to host a major gold system.

A large proportion of the prospective areas is concealed by either thin alluvium or barren rock units and therefore represents unexplored, shallow extensions of the highly productive Gympie Goldfield. All areas are considered prospective but some of the 15 target areas have limited detailed information and will be high-risk during the first phase of exploration.

Most of the identified prospects are in the Southern Gympie Goldfield and all are potentially accessible via extensions to the newly developed Lewis Decline, which has been designed with haulage capacity exceeding one million tonnes. This compares with 2001-02 material mine haulage of 220 000 tonnes, principally via the pre-existing shafts.

Gympie Gold has launched the Gympie Goldfield Exploration Program in response to the substantial increase in geological knowledge achieved through exploration over the past 5 years.

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MIM Exploration Pty Ltd
www.mim.com.au

MIM Exploration Pty Ltd is part of MIM Holdings Ltd., an Australian-based international mining and mineral processing company whose major products are copper, coal, lead-zinc-silver and gold. It is one of the 60th largest companies registered on the ASX with a market capitalisation of approximately $2.3 billion.

The MIM Group has operations in Queensland and the Northern Territory in Australia, the United Kingdom, Argentina and Germany with around 8000 employees worldwide.

Assets

The main operational activities are:

- Mining and smelting of copper, zinc, lead and silver at Mount Isa, and refining at Townsville.
- Copper and gold mining at Ernest Henry (MIM 51%), for smelting and refining at Mount Isa and Townsville.
- Copper and gold mining at Alumbrera (MIM 50%) in Argentina.
- Gold mining at Ravenswood (MIM 50.1%) in north Queensland
- Refining of Mount Isa lead-silver at Northfleet in the UK, as part of the company's European Operations.
- Zinc, lead and silver mining at McArthur River (MIM 75%) in the Northern Territory.
- Zinc and lead smelting and zinc refining at Avonmouth in the UK and Duisburg in Germany, as part of the company's European Operations.
- Lead recycling at Wakefield in the UK, as part of the company's European Operations.
- Mining of coking coal at Oaky Creek, steaming coal at Newlands and steaming and coking coal at Collinsville (all MIM 75%), in central Queensland's Bowen Basin.
- Coal shipping from Abbot Point and Dalrymple Bay coal ports.
- Coke production at Bowen Coke.

Exploration

MIM Exploration (MIMEX) is actively involved in mineral exploration and project evaluation. Currently it is focussing on high priority terranes in Australia, Argentina and Mexico.

The commodity focus is on copper and gold, with major exploration projects in the Olary region of South Australia, the Lachlan Fold Belt of New South Wales; and close to existing mine infrastructure at the Mount Isa and Ernest Henry mines, and on the Jervois tenements in the Northern Territory.

Exploration in Argentina is concentrated in the district near the existing Alumbrera mine and the Andean Cordillera.

There is an emphasis on exploration near existing mines and infrastructure where operational and infrastructure synergies could benefit mine development, and on systematic regional evaluations in selected countries.

MIMEX is comprised of regional exploration teams supported by specialist technical groups in the fields of geophysics, geochemistry and project generation.

Geophysics

MIMEX has a strong commitment to use geophysics in its integrated approach to mineral exploration and in-mine and environmental operations.

It uses commercially available geophysical equipment and software and has also developed an acquisition system known as MIMDAS (MIM Distributed Acquisition System).

MIMDAS is a multi-channel distributed acquisition system capable of measuring a variety of physical parameters. The increased resolution and better depth penetration achieved by MIMDAS over conventional systems provides MIMEX with a superior mapping tool in geophysically challenging areas.

The geophysical team comprises three groups:

1. A project-based group whose role is to integrate geophysical techniques with exploration projects and to be part of the interpretation team. They are supported by two groups of specialists who assist with project work and who also undertake geophysical activities both within MIMEX and elsewhere within the MIM Group.

2. An "in-mine" group, which is responsible for undertaking geophysical work in and around the base-metal, gold, and coal operations. Its role is to maximise ore recovery, minimise waste, assist in mine planning, and participate in environmental studies. It is active in two and 3D seismics, and downhole geophysical work, as well as conventional geophysics underground.

3. The third group is charged with ensuring that field geophysicists are supplied with the correct tools to process and interpret data that have been collected. It tests and evaluates collaboratively-generated software, repackages it for ease of operation and distributes it. This group also produces software when it is not commercially available.

To strengthen the use of geophysics in the discovery process, MIMEX has placed a strong emphasis on cooperative research projects with universities and other organisations. Projects have included the development of specialised software for displaying and interpreting data from electrical surveys, both ground and airborne.

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Managing Director Harry Adams said "We have always seen the rebirth of the Gympie Goldfield as a carefully risk-managed, one-step-at-a-time process. The old-timers mined 4 million ounces at 24 grams per tonne grade. Over the past 6 years we have cut our teeth by mining 260,000 ounces at 8.2 grams per tonne grade in zones where the old-timers left off 100 years ago. The $25 million program will be the first time that substantial modern exploration is being undertaken away from the historical mine workings.

For the 100th issue of Preview we have selected our two Corporate Plus Members for Company Profiles.

Sponsorship is very important for the ASEG, and we are pleased to include these profiles in this issue. The MIM profile is based on information contained on its web site, and Velseis provided the Velseis contribution. Both companies have excellent web sites and are well worth visiting.

Geology

A small team of geological specialists provides project generation and field support services to regional teams. Much of this work involves the processing, integration and interpretation of remotely-sensed data such as airborne geophysics and satellite imagery. Custom designed computer software, including GIS (Geographic Information Systems) facilitates the exchange of data between project generation teams and district geologists.

Geochemistry

Exploration geochemistry involves the acquisition, processing and interpretation of chemical data in the search for economic mineral resources.

MIMEX undertakes the chemical analysis of both the materials recovered from drill holes (including groundwater), and the samples of rock, soil, and river sediment collected during each field campaign.

The steps taken to acquire such data conform to high standards of procedural practice. They include survey design, the choice of sampling method, the quality of each sample site, sample security and sample transport. The testing of data quality and analytical laboratory performance are also important geochemistry functions.

Today, explorers face the added challenge of locating new resources hidden by weathered or transported materials close to the surface. By supporting in-house and collaborative geochemistry research projects, MIMEX is exposed to the latest ideas of how metals and gases are transported from buried orebodies, through overburden, to the surface.

By actively testing these ideas and applying new sampling and analytical methods in a range of environments, MIMEX will further develop its capability to explore covered terrain cost-effectively.

MIMEX also contributes to mainstream industry-funded geochemistry research projects. This ensures exposure to the latest improvements in geological understanding and ore-forming processes.

Solid Foundations and Continuous Innovation -

The Evolution of an Australian Seismic Company

Velseis Pty Ltd
www.velseis.com.au
Velseis Processing
www.velpro.com.au

With over 25 years of experience, Velseis Pty Ltd has built a reputation as the leading Australian seismic contractor. From solid foundations in borehole and surface seismic acquisition, Velseis has evolved and expanded to offer fully integrated seismic exploration services to the petroleum, coal and mineral industries throughout the Asia-Pacific region.

The company's operations now encompass survey design, drilling, data acquisition (2D, 3D and multi-component), data processing and interpretation. At the time of writing, the company is engaged in petroleum exploration projects in the Surat, Cooper, Pedirka and Great South (NZ) Basins and Papua New Guinea, and coal projects in the Bowen Basin and Indonesia. Due to its relatively small size, Velseis has the ability to respond efficiently to specialised acquisition and processing requests. The extensive experience of Velseis' key personnel ensures reliable and technically-innovative solutions tailored to meet the needs of individual clients.

Seismic Acquisition

Velseis prides itself on providing comprehensive seismic acquisition services that not only satisfy the client's geophysical requirements, but also address logistical, climatic, environmental, and safety issues. Velseis' accumulated expertise in 3D seismic survey design is complimented by use of the industry-standard MESA package from Green Mountain Geophysics. Land seismic surveys are recorded using VELCOM hybrid telemetry systems, with total capability in excess of 1500 channels. Based on proven Sercel hardware, Velseis' recording systems are enhanced with a sophisticated software control system providing an efficient observer interface and a range of data QC options. A conventional Sercel 388 system is also available, providing additional capacity of over 1000 channels.

Velseis utilises a range of seismic sources for land and marine seismic surveys. Dynamite is often the preferred source for high-resolution 2D and 3D land imagery. In keeping with its full-service approach, in 2001 Velseis established Seisdrill to ensure efficient scheduling of shothole drilling. Seisdrill is an evolution of Geodrill Pty Ltd, a company with 20 years of shothole drilling experience, and currently operates a fleet of 6 Bourne 1000R/Ford Louisville rigs.

Velseis pioneered the use of Mini-SOSIE in the Asia-Pacific Region and has significantly enhanced the original concept via integrated computer control. Velseis uses SOSIE extensively as a cost-effective 2D reconnaissance tool and as a 3D alternative when logistics, environment or economics preclude the use of dynamite.

In 2001 Velseis added a small, shallow-marine seismic vessel to its equipment inventory. The 'Velseis Explorer' is purpose-built for multi-channel airgun recording, and utilises small-capacity airgun arrays. The 'Velseis Explorer' can operate down to very shallow water depths (1+ metres), and has proven to be extremely cost effective for 3D imaging of coal targets at depths of several hundred metres beneath lakes in the Hunter Valley.

Seismic Processing and Interpretation

Velseis implemented its original proprietary seismic processing system in 1985 to service the rapidly expanding high-resolution seismic market. In 1992 Velseis Processing, a subsidiary of Velseis, was incorporated, and has grown to be Australia's most experienced company in the processing of high-resolution seismic data. Velseis Processing provides a high-quality, interactive processing capability through use of ProMAX seismic processing software, and specialised interpretation services based on GeoGraphix Seisvision software. With experienced personnel and commitment to detail, Velseis Processing has established a highly respected coal-seismic division, and is at the forefront of 3D seismic mine-planning imagery.

Velseis Processing also has a growing oil and gas division, focusing on low- to medium-volume projects requiring specialised attention. To extend the company's production processing capability, Velseis Processing has recently installed a Linux cluster using ProMAX's SMP (Shared Memory Process) processing modules and, when it becomes available, will implement the SeisSpace package designed specifically for cluster processing. The cluster is scalable, allowing Velseis to quickly upgrade capacity to meet increasing activity in the oil and gas processing division.

Research and Development

Velseis has traditionally maintained its competitiveness with a proactive commitment to R&D. Currently the company employs five research geophysicists, with additional contract engineering staff in continuous employment. This R&D Division provides regular support to production acquisition, processing and interpretation projects. In addition, Velseis is currently engaged in a number of specialised research initiatives, including computer-controlled seismic acquisition, converted-wave acquisition and processing, optimum processing of high-resolution seismic reflection and high-volume finite-difference modeling simulations. The R&D Division utilises a range of proprietary software running on Linux workstations and a 16-node Beowulf cluster, and also has access to ProMAX and GeoGraphix software.

Corporate Philosophy

Velseis' continued stability and growth during a period of considerable industry consolidation is a testament to simple but effective corporate philosophies. The company has a flat management structure, with senior staff occupying key operational positions. This ensures flexible and rapid response to changing exploration trends and new technologies. The company's commitment to solution of client problems has resulted in a healthy portfolio of long-term client relationships. Possibly the key factor, however, behind the prosperity of this relatively small competitor in the seismic marketplace is technical strength and self-sufficiency arising from experienced, innovative and accessible personnel.

The ASEG Connection

Velseis' emphasis on technical strength is exemplified by its long term association with the ASEG. Velseis values ASEG's encouragement of geophysical research and innovation through information sharing. Company geophysicists have a history of strong involvement on federal and state ASEG committees, and the company has been heavily involved in three ASEG Conferences. Currently Velseis is one of two Corporate Plus members of ASEG.

The Future

Seismic imaging will be the core geophysical technology for many future resource developments. Unquestionably there will be many exciting challenges. Velseis looks forward to its next 25 years.

Ray Theory And Gaussian Beam Method For Geophysicists

By ***Mikhail Mikhailovich Popov***

Published by:
Editora da Universidade Federal da Bahia, Salvador-BA. Brazil,
172 pages
ISBN 85-232-0256-0
Price: not available

Reviewed by Brian Kennett

This short book, developed from lecture courses given in Salvador-Bahia with the support of Petrobras, provides an introduction to the mathematical development of ray theory, starting with the wave equation and culminating in a treatment of isotropic elastic media. The final chapters treat localised solutions around rays through Gaussian beams.

The treatment is thorough and in the early part of the book care is taken to provide all the critical steps in the development. The presentation, with mathematics produced with TeX, is very clear and the quality of the English is very high for a book produced in Brazil with a Russian author.

Popov is a well-regarded figure in the development of ray methods and Gaussian beams and his mastery of the material is clear. Unfortunately his treatment stops short of any actual examples of the use of ray theory and its extensions, which limits its usefulness for geophysical applications.

The book would provide a useful introduction for students interested in seismic modelling and provide a useful background for tackling the much larger (722 pages) volume "Seismic Wave Theory" by V. Cerveny published by Cambridge University Press in 2001.

The Insider's Guide To Investing In Australian Mining And Resource Stocks

By ***Allan Trench and Thomas Judge***

Wrightbooks (an imprint of John Wiley & Sons, Australia), Milton, Qld., 2002
214 pages, paperback
ISBN 0 7016 3691 2
Price $30

Reviewed by Ted Lilley

Described on the front cover as "50 ways to select the right shares (and avoid choosing the wrong ones!)" this book is written in a popular style, and is not a scholarly work. It gives 50 tips for buying Australian mining shares, rather as one might give 50 tips for betting on horse races (look at track record, study breeding, take handicap into account, etc.). The 50 tips are each discussed in a brief chapter, with the book divided into four parts: "An Introduction to Resource Sector Investments", "Investments in Mineral Exploration Companies", "Investments in Mining Companies" and "Valuation and Financial Risk Management in Mining". The first author has ten years experience in the Australian resources sector; the second author is Chicago-based.

For newcomers to the stock market, who want to have a flutter, the book should make rewarding reading. It makes clear that much of the funding of exploration geophysics depends on commerce and venture capital.

Amongst professional geophysicists, I expect that those on the financial side (exploration managers, etc.) will already largely know the commercial content in the book; just as those who practise field geophysics will know the technical content. For members of the ASEG it should thus be light and amusing reading, with the enjoyment that comes from a familiar topic.

In some respects the book is valuable for what it is not. The geophysical methods mentioned such as aeromagnetics have long-sustained development histories, and by no means have resulted from a somewhat glib approach to the funding of exploration which the book at times conveys. To help put in balance the long-term science upon which the Australian mining industry is based, and from which investors in mining shares can now profit, I would add four books to the bibliography:

"History and Role of Government Geological Surveys in Australia" by R.K. Johns (ed.), Government Printer, Adelaide 1976.

"Discovery: Stories of Modern Mineral Exploration" by Alan Trengove, Stockwell Press, Melbourne 1979.

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

"Geophysics in the Affairs of Mankind: A Personalized History of Exploration Geophysics" by L.C. Lawyer, C.C. Bates and R.B. Rice, SEG, Tulsa 2001.

I received the book to review shortly after a certain federal Labor politician advocated wider share ownership by Australians. The response in the Canberra Times was a marvellous cartoon by Pryor, showing the poker-machine room deserted at the Leagues Club, with all the players down at the stock market! It is a relevant point, that playing the stock market makes more sense than playing poker machines, which are designed to inexorably keep the money put into them; i.e. they are a classical sink of personal wealth. Mining, in contrast, is a classical source of wealth (but buy the right shares!).

An enquiry to a local bookstore produced a quote of $30 for the book. It is an unusual book, written with flair, and entertaining to dip into. Presumably quite a moderate successful flutter on the market would cover its cost comfortably.