Preview

Australian Society of Exploration Geophysicists

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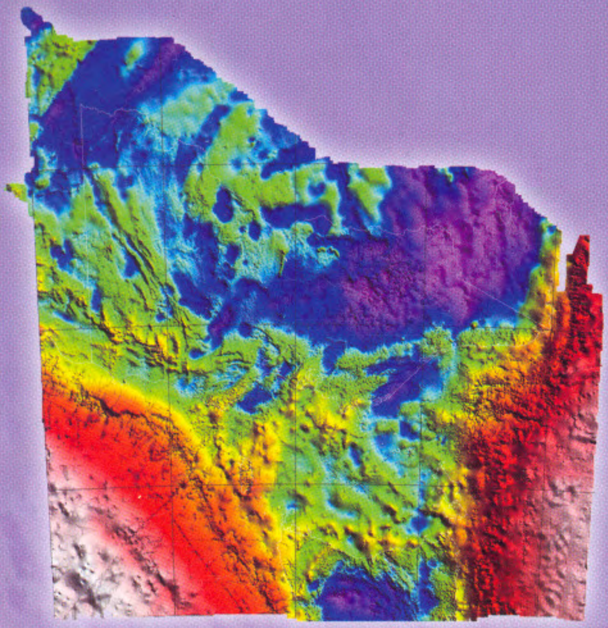

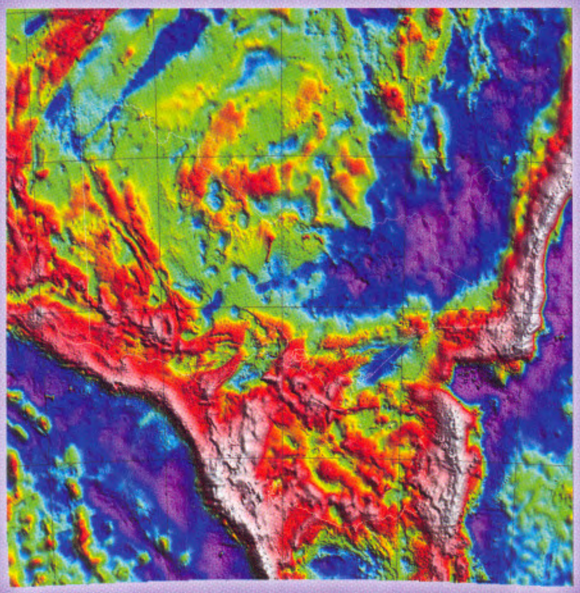

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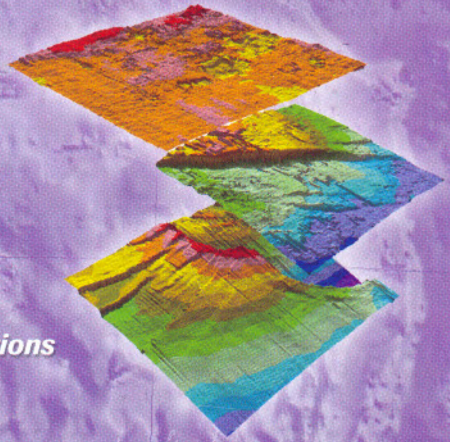

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Editor's Desk

In this Issue

This edition of Preview contains a mixed bag of articles. Dave Richards completes his contribution on the 'Calibration and use of portable gamma-ray spectrometers', Noll Moriarty provides an insight into the behaviour of 'Resource Stocks', Des FitzGerald shows some new images of offshore gravity, Alex Shepherd shows how to interpolate 2-D seismic sections and Agu Kanstler and Howard Golden summarize their excellent keynote talks at the Brisbane Convention.

Eristicus returns

With Eristicus back from holidays we have some comments on the 10 November Federal Election. For my part, I found the event very disappointing with both major parties intent on looking backwards: the ALP to the GST, and the Coalition to 'Sound Economic Management'. It was also disappointing to see how both parties strived to take the same approaches in response to refugees and the 'War against Terrorism' and how they both seemed to concentrate on the short-term advantages of living in a marginal electorate.

The emphasis on building wealth for the future, and on managing our resources in any time scale longer than about 2 years seems to have been relegated to the bottom of the heap.

If there is a lesson to be learnt, or a moral to the story, it is: 'Move to a marginal electorate to make your vote count and reap the benefits accordingly'.

Some good news

In all the doom and gloom in the exploration industry there are at least two good news stories. The first relates to the Minotaur discovery in South Australia. This is discussed in the Industry News section and indicates the power of geophysics in areas of extensive cover.

The second relates to the new Australian Resources Research Centre (ARRC), which was opened on 15 November by Geoff Gallup, the Premier of Western Australia. The ARRC is a $37 million facility located in Technology Park, Perth, and is an initiative of CSIRO, Curtin University of Technology and the WA Government. It has been developed in conjunction with the petroleum and mining industries and houses over 200 researchers from CSIRO and Curtin. The aim is to enhance collaboration with Cooperative Research Centres, universities, resource companies and suppliers, to deliver world-class research solutions, services, technologies and highly trained people to the resources industries in Australia and around the world.

Initially mineral and mining research at ARRC will concentrate on technologies that enable the discovery of new world-class, high quality mineral deposits and how to extract them at the lowest possible cost with emphasis on safety and the environment. Mining research at ARRC will focus around minescale geophysics, terrain imaging, modelling and visualisation, geo-sensors, risk assessment, rehabilitation and hydrology.

Research for the oil and gas industry will focus not only on improving oil exploration performance but also on preparing Australia and the region for the transition to new energy sources in the future. As production of liquid transport fuels steadily decline, ARRC researchers are developing technologies, which will enable us to utilise Australia's rich gas reserves and convert gas to liquid fuels. A longer-term objective is to develop the new technologies needed to allow Australia to enter the hydrogen age in around 20 years time.

ARRC was purpose built to house CSIRO's Petroleum and Exploration and Mining Divisions, along with Curtin's Departments of Exploration Geophysics and Petroleum Engineering and State Centres of Excellence in Petroleum Research, Petroleum Geology and Exploration and Production Geophysics.

The Centre was supported by both the previous Court Government and the present Gallop Administration. It is fitting that The Centre is housed in Perth, where more than half of the nation's petroleum and mineral exploration activity is based.

And with that good note to end 2001, I would like to thank our contributors, readers and publisher for their support throughout the year. I hope you all have a relaxing Christmas and that the New Year brings exciting and rewarding challenges for us all.

David Denham

David Denham

Contents

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

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

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

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 February 2001 edition is 15th January 2001.

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 February 2001 edition is the 22nd January 2001.

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New Members

We welcome the following new members to the ASEG. Membership was approved by the Federal Executive at its October 2001 meeting

Name	Affiliation	State
David Anderson	Quantec	
Michel Chouteau	Ecole Polytechnique	Canada
Adam Davey	Adelaide Uni	SA
Matthew Hutchens	Adelaide Uni	SA
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Bruce Mcmonnies	De Beers	Canada
Harry Mason	Orbital	WA
Wanida Rangubpit	Uni NSW	NSW
John Remfry	Essential	Vic
Kieran Ryan	Adelaide Uni	SA
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Email: guy@encom.com.au

2002

February 10 - 14
Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP 2002), Las Vegas, Nevada
Sponsor: Environmental and Engineering Geophysical Society
Theme: Geophysics: The Next Generation
Contact: Becky Roland, EEGS, 720 S. Colorado Blvd., 960-S, Denver, CO, 80246.
Email: eegs@neha.org
Website: www.eegs.org

April 14-16
Global Exploration 2002 - Integrated Methods for Discovery, Denver, Colorado, USA
Sponsor: The Society of Economic Geologists
Theme: The integration of geology, geochemistry, and geophysics, to discover new mineral deposits
Contact: The Society of Economic Geologists, Inc, 7811 Shaffer Parkway, Littleton CO 80127 USA
Tel: 720.981.7882
Email: SEG2002@segweb.org
Website: www.SEG2002.org

April 15-18
International Geophysical Conference and Exposition, Yogyakarta, Indonesia
Theme: Geophysics for Human Kind
Sponsors: The Indonesian Association of Geophysicists (HAGI), and the Society of Exploration Geophysicists (SEG)
Abstract Deadline: mid-August, 2001
Contact: Dr Wally Waluyo
Tel: 62 21 350 2150, ext.1434
Fax. 62 21 350 8032/351 0992
Email: wallywaluyo@pertamina.co.id

April 22-26
European Geophysical Society (EGS) XXVII General Assembly, Nice, France
Sponsors: EGS, American Geophysical Union (AGU)
Contact: EGS Office, Max-Planck-Str 13, 37191 Katlenburg-Lindau, Germany
Tel: +49 5556 1440
Fax: +49 5556 4709
Email: egs@copernicus.org
Website: www.copernicus.org/EGS/

May 12-17
International Association of Hydrogeologists, Australian National Chapter
International Groundwater Conference, Darwin, Northern Territory, Australia
Theme: Balancing the Groundwater Budget
Contact: Gary Humphreys
Email: Gary.Humphreys@nt.gov.au

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

May 28 - June 1
2002 AGU Spring Meeting, Washington, DC, USA
Sponsor: AGU
Contact: AGU Meetings Department, 2000 Florida Avenue, NW, Washington, DC 20009 USA
Tel: +1-202 462 6900
Fax: +1-202 328 0566
Email: meetinginfo@agu.org
Website: www.agu.org/meetings

June 30- 5 July
16th Australian Geological Convention
Theme: Geoscience 2002: Expanding Horizons
Adelaide Convention Centre, Adelaide SA
Contact: info@16thagc.gsa.org.au; Website: http://www.16agc.gsa.org.au

July 9-12
Western Pacific Geophysics Meeting, Wellington, New Zealand
Sponsor: American Geophysical Union (AGU)
Contact: AGU Meetings Department, 2000 Florida Avenue NW, Washington DC 20009 USA
Tel: +1-202 462 6900
Fax: +1-202 328 0566
Email: meetinginfo@agu.org; Web Site: www.agu.org/meetings

September 22-25
Applied Structural Geology for Mineral Exploration and Mining Symposium, Sponsor: Australian Institute of Geoscientists
Venue: WMC Conference Centre, WASM, Kalgoorlie, WA
Contacts: Julian Vearncombe at vearncom@iinet.net.au or Jocelyn Thomson at aigwa@iinet.net.au

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

October 6-11
SEG International Exposition and 72nd Annual Meeting, Salt Lake City, Utah, USA
Website: www.seg.org

October 20-23
West Australian Basins Symposium (WABSIII)
Burswood Convention Centre, Perth
Organised by PESA
Contact details: Peter Baillie
Tel: 0417 178764
Email: peterb@tgsnopec.com.au

2003

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

Northern Territory – by Gary Humphreys

Rio Tinto is shutting its Darwin office and staff working on NT/Queensland/Kimberley projects will be transferred to Perth. Angus McCoy, working in India, will remain in Darwin and work on a FIFO roster. Dave Johnson will be leaving the company and Darwin on 15th December.

Gary Humphreys visited Beijing (sponsored by the Ministry of Agriculture) to present at a workshop on Advanced Technologies in Agriculture. Gary was asked to present on the subject of remotely-sensed datasets and the use of GIS in development projects. The NTGS Exploration Initiative geophysical data featured prominently as an example of applying mineral-exploration technology to land and water investigations. Gary also gave short seminars at China Agriculture University and at Hebei Agriculture University in Baoding city.

Anthony Knapton and Gary Humphreys are both on the organising committee of the International Hydrogeology Conference to be held in Darwin in May 2002. The conference is developing well, with about 200 abstracts received from over 20 countries. The conference website will be loaded with the abstracts in early December, and registration is available online from late November. A number of papers reporting geophysical investigations have been accepted from several countries. Registration includes a full day field tour, and options include extended technical tours and groundwater workshops run by the Centre for Groundwater Studies. For further information, check the website www1.octa4.net.au/iahnt/conference.htm or email Gary. Sponsorship enquiries are also welcome from companies who wish to meet a good range of senior scientists/engineers from overseas and within Australia.

South Australia – by Michael Hatch and Andrew Shearer

Much to report from the SA Branch, especially as we missed the last issue of Preview.

Way back on the 11th July, Bruce Finlayson of Santos gave our technical session for that month. It was titled: *Integrated AVO Analysis in Offshore South Eastern Australia.* This talk was sponsored by Santos; many thanks to them for supplying the speaker and a great evening.

During August many of us headed over to Brisbane for the ASEG Conference. Many aspects of this successful conference will be definitely utilised when Adelaide hosts the next conference in 2003.

On the 3rd October we held our annual Industry Night. We always try to cover some of the old and some of the new innovations in our industry, as everyone is doing something new and we enjoy hearing about it. This year we had speakers from SANTOS, Origin Energy and Air Research Australia (ARA). Thanks to all of these companies for giving us insights into what makes them tick and what is new in the business. And thanks to these three for their sponsorship.

Then on the October 30th, Allan Trench from the WA School of Mines and Judicial Holdings Pty Ltd gave us insights into: *The Business of Mining - Avoiding the Commodity Trap.* Not our normal geophysical talk, but it proved an interesting insight into the performance of our industry. Many thanks to Judicial Holdings for sponsoring the fun on this evening.

Our annual Melbourne Cup Luncheon was, as always, a huge success. More than 70 of the local faithful attended. Thanks to event organisers Rod Lovibond, Suzanne Roberts, and Andrew Davids. Beach Petroleum was the sponsor for this event; thanks to them for helping out.

Things to look forward to include our annual Student's Night on the 28th November. Four recently finished honours students will present short talks on their projects. We look forward to seeing what the up-and-coming members of our society have been working on for the last few months.

And for the final event of the year, Andrew Shearer, local branch president, will host the Christmas party on the 18th of December. I am sure that he is looking forward to seeing many of you there.

A bit of bad news for the SA Branch may just turn out to be good news for the WA Branch. Andrew Davids, who has been on the committee since he arrived in Adelaide only a few years ago, and has been the Treasurer of the 2003 Adelaide Conference Organising Committee, has moved to Perth to take up a new position. We will miss him here both as a good friend but also for his organisational ability.

And no Branch News from SA would be complete without mentioning the wine tasting and sale. The tasting event was held in August at one of Adelaide's fine restaurants. We had the onerous duty of tasting 15 reds and 16 whites. And as usual we feel that we were able to supply our fellow members with an outstanding pair (actually trio) of wines at a very good price. All in a day's work for this hard working committee. Shipments should have already gone out so please let us know if you did not get your wines. And we all hope that you enjoy these for the next few months (and years?).

See you at the meetings.

Western Australia – by Mark Russell

Technical Meetings
Technical meetings are held on the third Wednesday of each month at the Celtic Club, 48 Ord Street, West Perth (5:30 pm drinks and food, 6:00 pm meeting starts). Admission is free for ASEG members and is $10 for non-members.

For information on upcoming meetings/events/agendas, please see our website at: http://www.aseg.org.au/wa

Technical meetings and happenings Sept-Nov 2001:
September Speakers comprised Bension Singer, CSIRO Petroleum (ARRC) who spoke on Fast Inversion of *Electromagnetic Array Data* and Chris Wijns, UWA who told us all about *Interactive Inversion in Geology*.

October had a number of events of public interest, from a *Strategy for Australia* by Bruce Hobbs, to an *Overview of 3D technology* from William French, held at the new

Australian Resources Research Centre.
Additionally there was a FESWA One-Day Seminar, a Minerals and Petroleum Resources Open day at the Novotel and a public lecture by Professor Hoffman at the Octagon Theatre in UWA.

What Kind of Australia Do You Want? A Strategy to get Australia to 2025 presented by Bruce Hobbs, Deputy Chief Executive CSIRO, was held on Thursday, 11 October 2001 at the Auditorium of the Australian Resources Research Centre (ARRC), in Perth. Bruce discussed this question in light of the fundamental issues of Australia's population including:

- Energy;
- Greenhouse and climate;
- Minerals and energy resources;
- Salinity and environment; and
- Land use and land rights.

The Department of Mineral and Petroleum Resources of Western Australia (MPR) held a Petroleum Open Day on 18 October 2001, in conjunction with the PESA WA October Luncheon and Technical Seminar. MPR is the abbreviation for the recently merged Departments of Minerals and Energy, and Resources Development.

Sponsorship
If your company would like to present a paper and/or sponsor at ASEGWA meetings please contact Kevin Dodds, CSIRO (08 9464 5005) or Guy Holmes, Encom (08 9321 1788) about speakers and sponsorship possibilities.

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ASEG 16th Geophysical Conference and Exhibition: Growth Through Innovation

16-19 February 2003
Adelaide Convention Centre

The ASEG Adelaide 2003 conference organising committee are now actively seeking platinum and gold sponsors for the meeting. The details of the platinum and gold packages are listed below. If you have any enquiries on conference sponsorship please contact the sponsorship sub-committee of John Hughes (john.hughes@santos.com.au) or Mike Sexton (mike.sexton@normandy.com.au).

The conference organising committee is also focusing attention on special sessions for the Adelaide meeting. One special session planned to be of particular interest to oil companies and contractors in the oil patch will cover 'challenges' the exploration geophysics industry must address in the next few years. What are the interpretive goals that are required and not yet being met? Key company personnel will be invited to present what they believe to be the critical 'challenges'. The aim of this session is to highlight (in oral only papers) the areas in which the geophysical industry can achieve 'Growth Through Innovation', and invite comment on how such issues might be addressed.

A number of other special sessions are being considered, including:

- Geophysical Signatures of SA Mineral Deposits
- Southern Margin - Otway & Bight Basins
- Cooper Basin
- Gawler Craton Exploration
- Curnamona Exploration
- Groundwater Salinity
- Archaeological & Forensic Geophysics
- Unconventional Geophysics
- AVO & Amplitude Analysis
- Geophysical Inversion

The conference organising committee welcomes additional suggestions of topical special sessions. Please contact the technical papers chair, Stewart Greenhalgh (stewart.greenhalgh@adelaide.edu.au). Ever on the lookout, we notice the recent exciting results from the Prominent Hill Prospect, approximately halfway between Coober Pedy and Olympic Dam. The intersection of apparent Olympic Dam-style copper-gold mineralisation in haematitic breccias in a hole drilled to test a gravity anomaly may spawn a session on Olympic Dam-style geophysics!

The full conference organising committee was listed in the previous issue of Preview. If you have any questions or suggestions regarding ASEG Adelaide 2003 'Growth Through Innovation', feel free to 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).

The Platinum and Gold Sponsorship Packages for ASEG Adelaide 2003, 'Growth Through Innovation' are as follows.

Platinum Sponsor - $33,000 (includes GST)

1. **Same rights as Gold Sponsors but only one platinum sponsorship** available meaning maximised exposure as the main sponsor.

Plus

2. **Naming rights to the Conference Nametags**
   The sponsor would be acknowledged on the conference nametags.

Gold Sponsors - $22,000 (includes GST)

1. Naming rights to the Conference Dinner
- The sponsor would have the opportunity of providing merchandising material and/or banners at the dinner.
- The sponsor's support would be formally acknowledged during the dinner and the sponsor's representative would have the opportunity to respond.
- The sponsor would be acknowledged on the dinner tickets and dinner menu and wherever the conference dinner is mentioned in all conference print material.
- The sponsor would be provided with 4 additional dinner tickets.

OR

Naming rights to a keynote speaker and technical program session
- Acknowledgment of keynote speaker sponsorship in the registration brochure and handbook.
- Verbal acknowledgment of your sponsorship by the session chairman prior to the keynote address.
- Slides of your corporate logo projected in the session room at the commencement of the keynote address and between each presentation.

OR

Naming rights to the welcome reception and farewell function
- The sponsor would have the opportunity of providing merchandising material and corporate signage at the welcome reception and farewell function.
- The sponsor's support would be formally acknowledged during the welcome reception and farewell function and the sponsor's representative would have the opportunity to respond.
- The sponsor would be acknowledged on the welcome reception and farewell function tickets and appropriately wherever the welcome reception and farewell function is mentioned in all conference print material.
- The sponsor would be provided with 2 additional welcome reception and farewell function tickets.

Upstream Oil and Gas in Australia: Where from here?

Agu Kantsler
Director
New Ventures,
Woodside Energy Ltd

The summary and slides printed here formed the basis of Agu Kantsler's keynote address at ASEG 2001

With contributions from
***Bruce Hobbs**, CSIRO;*
***Barry Jones**, APPEA;*
***David Maxwell**, WEL.*

Summary

The upstream Australian oil and gas industry has matured considerably since gas was first discovered at Roma in the early part of this century and oil was first discovered at Rough Range in 1956. Oilfield development began in the mid 60s and from fairly humble beginnings our industry in recent times has been averaging 750 000 bpd liquids and almost 3 bcf (480 000 boepd) per day of gas. This is quite substantial production on a global scale and, together with our coal and renewable energy resources, provides Australia with total energy self-sufficiency.

The issues, which will confront our industry in the next ten years, are:

1. Declining liquids sufficiency

In part we believe that this can be addressed through better fiscal terms for frontier (including deepwater) exploration and the streamlining of the various approvals processes surrounding the administration of Australia's Environmental and Native Title Legislation. In addition, areas offshore Queensland such as the Townsville Trough, remote from the Great Barrier Reef, must be released for exploration once an informed public enquiry has occurred.

2. Increased use of gas in our economy

This needs to be addressed by a sensible determination on the question of "effective life of assets" and a desire by government to facilitate, to the maximum extent possible, Australia's capture of new export markets for gas. Both are required to get our presently stranded gas ashore. Experience tells us that once the gas is available onshore it attracts significant new industry and the growth of new markets. Again however, better fiscal terms will be required to stimulate major new gas developments in Petroleum Resource Rent Tax (PRRT) paying acreage.

3. Technology and Greenhouse

Australia's obligations under the Kyoto protocol can largely be addressed by (2) above, but it is important to note that gas will also under-pin the development of many new "green" energy sources, including ceramic fuel cells, gas to liquids and gas to hydrogen.

4. Social Sustainability

Establishing our industry's social sustainability credentials in the minds of middle Australians will become increasingly important in future. Many of the issues related to environmental approvals under (1) and (2) above stem from the actions of highly motivated, media "savvy", single interest lobby groups. In general, our industry has an outstanding environmental track record and our footprint, particularly in the marine environment, is minimal by almost any standard. We will need to ensure that the population at large appreciates that our values and performance standards meet or exceed the expectations of most Australians.

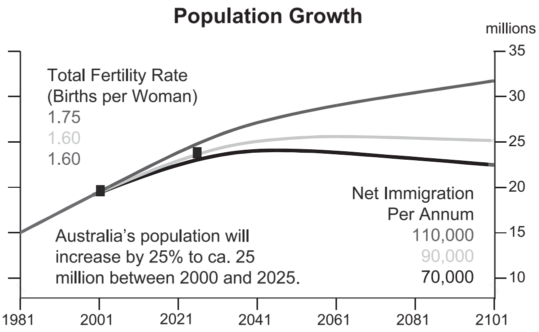
Finally, it must be stressed that our industry is of fundamental importance to the economic wellbeing of Australia, as we are proven, reliable suppliers of competitively priced energy. In fact, we are the primary suppliers of energy to our community. We will continue to grow and underpin the economic well being of Australian society provided that we can continue to make progress in the four key areas listed above. My belief is that we are well positioned to maintain our role well into the middle of the 21st century, but government must do its bit to create the appropriate strategic and regulatory framework that will allow us to succeed.

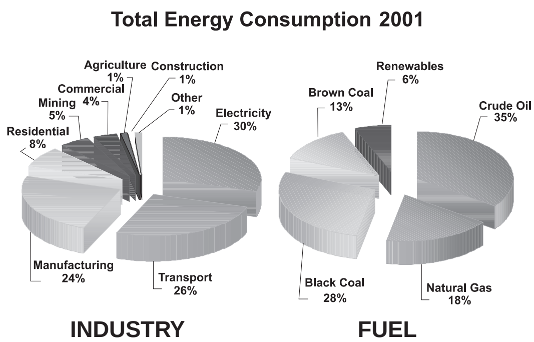
In addition to one of the above alternatives, sponsors would also be entitled to:

2. Two complimentary registrations
3. Two complimentary trade booths with first choice of location OR the opportunity to mount a features display up to 9 m x 3 m (i.e. 27sq m).
4. The sponsor's logo would be printed on the conference satchels
5. Acknowledgment (logo) on all pre-conference promotional material
6. Acknowledgment (logo and promotional paragraph) in registration brochure
7. Acknowledgment (logo, promotional paragraph and full page colour advertisement) in the conference handbook.
8. Acknowledgment (logo) on the conference's webpage and the opportunity to link pages back to sponsor's own home page.
9. Acknowledgment on the conference proceedings on CD-ROM (logo on CD-ROM cover)
10. Logo incorporated on conference slides
11. Complimentary satchel insert
12. Conference endorsement
13. Detailed delegate list

Energy

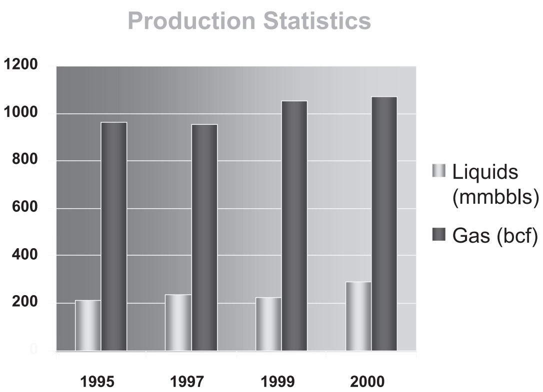
- Fundamental to our standard of living both economically and socially
- Demand growing both domestically and internationally
- Heavy reliance on fossil fuels for the foreseeable future
- 53% of Australia's primary energy sources from oil and gas





Society's Energy Demands

- Reliable supply
- Competitive pricing
- Environmental sustainability
- A fair share of the economic rent



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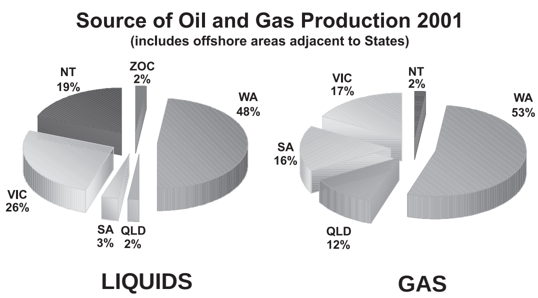
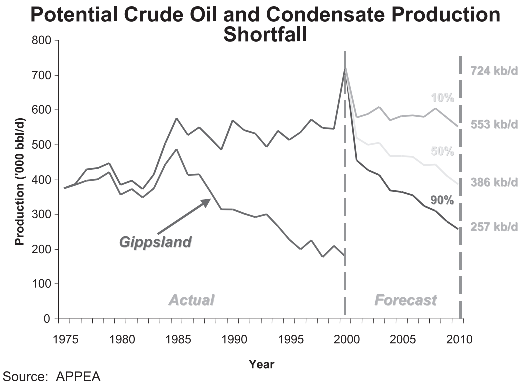


Australia's Oil and Gas Industry Challenges

- Declining self-sufficiency in oil and condensate production
- Unprofitable refining industry
- Ensuring greater penetration of gas in:
  - Transport/Manufacturing/Electricity
  - Reducing Greenhouse emissions



Source: APPEA

Implications of Liquid Hydrocarbons Shortfall

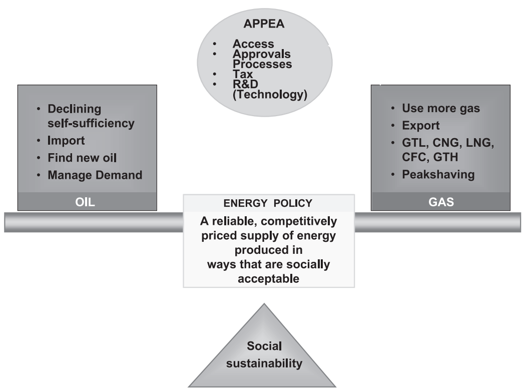
- 1% increase in imports=$100 million pa in BoP
- BoP problem $2 billion pa by 2010
- Rising prices as we pay to access more costly reserves
- Higher domestic raw material input costs
- Negative effect on international competitiveness
- Strategic impact

Options Resulting from Liquid Hydrocarbons Shortfall

- Import more
- Explore more (success rates, competition for capital)
- Recover more (infill drilling)
- Substitute more (gas, LPG, CNG, GTL, GTH, CFC)
- Manage (reduce) demand

Policy Issues Related to Liquids Supply Shortfall

- Competitive tax regime, frontier terms, effective life of assets
- More regional hydrocarbon habitat studies and research
- Streamline approvals processes
- Coherent R & D strategy or substitution



Environmental Issues

- Marine Mammals
- Reefs, areas with high conservation value
- Wetlands
- CBM - Waste water discharge
- Oil spills - loading operations
- Venting and flaring

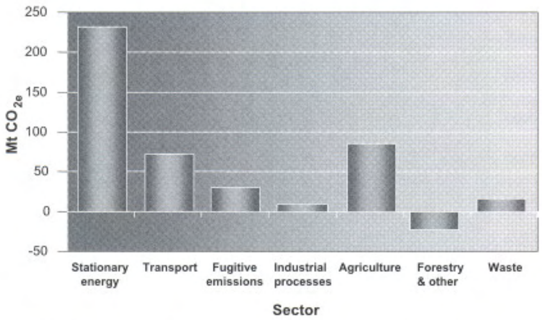
Social Issues: Vision

- Zero fatalities
- Zero serious injuries
- Zero high potential incidents
- Zero Emissions
- Zero Waste
- Minimum Environmental Footprint
- Native Title
- Nimby
- Community consultation

Technology Challenges

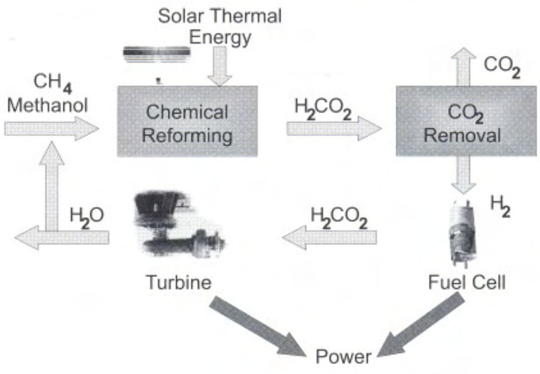
- Gas to diesel
- Leverage stranded / associated gas (floating LNG/GTL; Mini LNG/GTL)
- Hydrogen transport economy by 2020
- Distributed power systems based on gas
- Maximise renewable energies
- Greenhouse emissions (power generation, transport)
- Geothermal energy (HFR)
- Geo-sequestration of CO_2
- Efficiency

Greenhouse Emissions by Industry Sector



Planting three times more trees offsets Australia's transport problem.

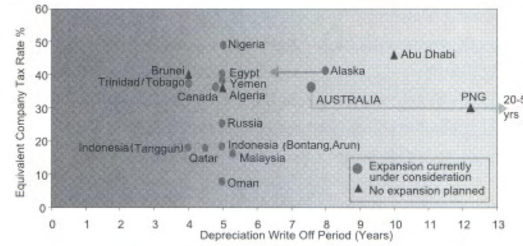
Towards Sustainable Energy



Profitability & International Gas Market Capture Issues

- **Expanded LNG production capacity is needed to delivery:**
  - Offsets for oil imports
  - Increased volumes of gas to domestic market
  - "Feedstock" gas for value adding projects such as GTL, petrochemicals
- **Fiscal System:**
  Projects are large scale, capital intensive, low ROR
  Need an internationally competitive depreciation regime
- **Labour Cost:**
  Technology
- **Leadership:**
  Commercial
  Political (competition: Qatar, Oman, Malaysia, Indonesia, Sakhalin all backed by government ownership)

International Company Tax Regimes for LNG Investment

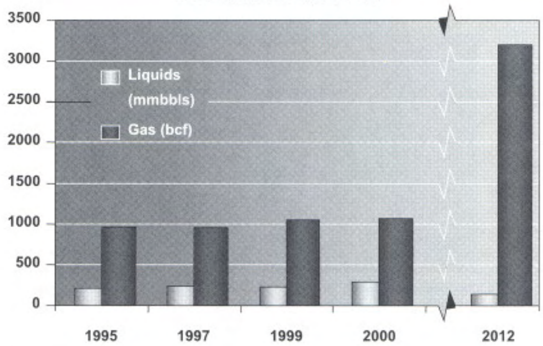


Sources: Review of Petroleum Fiscal Regimes, Petroconsultants (UK) Ltd., 1997
Suggestions for New Terms for the Alaskan North Slope LNG Project, Dr P H van Meurs
World LNG Trade, WA Department of Resources Development, April 1998,
Petroleum Economist, April 1998; Shell International Gas

What is Possible in The Year 2012

- **LNG sales to Japan, Korea, China, Taiwan and West Coast USA**
  - 9 LNG trains (28mtpa) in Western Australia and Northern Territory
- **Gas hub on the Burrup**
  - 2100 TJ/d (770 PJ/yr)
  - Feeding WA industry, petrochemical and chemical plants and gas to liquids plant(s)
- **Competing WA gas supply via Varanus Island**
  - Supplied from multiple projects and owners
- **Gas hub in Darwin**
  - 1300 TJ/d (470 PJ/yr)
  - Feeding NT industry, chemical plants and South Eastern Australia
- **Competing SE Australia gas supply via multiple offshore developments**
  - Additional 400 Tj/d (150 Pj/yr) available

Production 2012



What Will It Take?

Leadership, People, Innovation

a) Resource Companies
- Focus on size of pie not individual slice
- Co-operation not competition
- Effective utilisation of infrastructure
- Use of best available technologies

b) Government
- Work with industry to attract international business
- Government to government contact
- Stable labour market

c) People
- Attracting the best and brightest to our industry
- Training and competence development
- Focus on innovation and co-operation
- Develop leadership and passion

Australian Mineral Discoveries - A Question of Scale

Howard Golden
WMC Resources, Ltd.
Email:
howard.golden@wmc.com

After having been in Australia for only a few years, I can hardly consider myself an expert on Australian mineral discoveries. I came to the conclusion, therefore, that the only way I could properly address this session on Australian Mineral Discoveries was either to pour through historical records and learn all of the nuances of the long and rich history of mineral exploration in Australia, or simply tell a story. I have opted for the latter.

The story that I want to share with you involves a first aid training course that I completed a few years back with several colleagues, including a geologist named Sasha. Sasha was visiting the UK from Russia for the course. The tuition was given by an instructor named David, who was thorough, interesting, and patient. When David taught the all-important first aid kit module, he went through a comprehensive list of the contents of a properly stocked and maintained first aid kit. Inquiring of the students if there were any questions regarding first aid kits, David's composure was momentarily shaken when Sasha asked if it was appropriate to include vodka. David regained his cool, and patiently explained to Sasha that whilst victims can often be afforded a feeling of well being from drinking alcohol, in the end the effects are more likely to be deleterious. Without condescension he went on to gently suggest that, on balance, vodka is not an appropriate ingredient for a first aid kit. Sasha listened to David's discourse with interest, and immediately responded, " Thank you, but I believe you have misunderstood. You see, in Russia, if there is no bottle of vodka, the ambulance drivers won't respond to your call".

Now, on the surface this anecdote has little to do with mineral discoveries. I would put forward the proposition, however, that the vodka bottle in this story is the metaphorical equivalent of many geophysical techniques in use today - appropriate in the right context, but ineffective or even deleterious when used inappropriately.

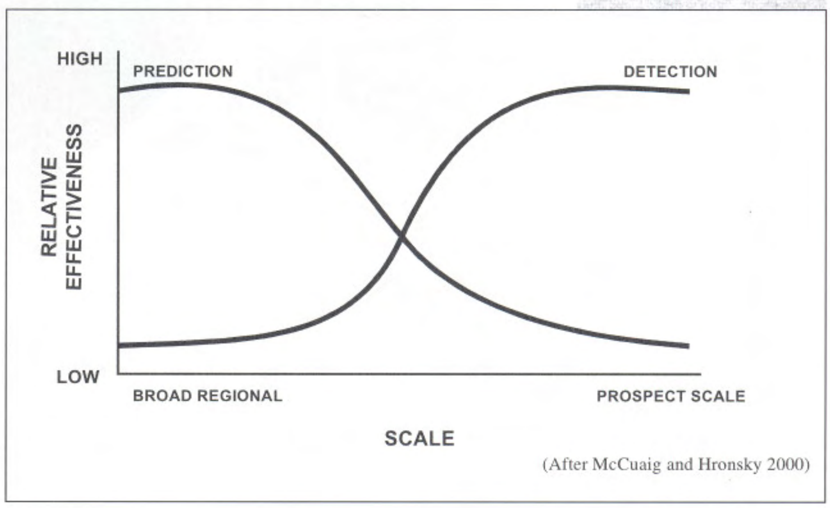
So, how do we determine which techniques are appropriate in what situations and at which scales, and how can we define scales of exploration work? I propose that the easiest way to discuss scales is by thinking of exploration as occurring on three levels: - prediction scale, detection scale, and ore body imaging scale. The prediction scale work we do as explorationists, manifests itself as broad regional studies, and adds value to the exploration process in that all subsequent work depends on the regional area selection process being accurate. At this scale, data such as seismic tomography, global magnetic data, global gravity data, and thematic mapper scenes can make a very significant contribution to the predictive exploration phase. Coupled with ever increasing understanding of lithospheric and mantle processes and ore deposit models, the geophysical contribution to the predictive scale of mineral exploration can be clear and measurable. In fact, no other data sets will give objective, continuous data coverage to which predictive concepts can be applied.

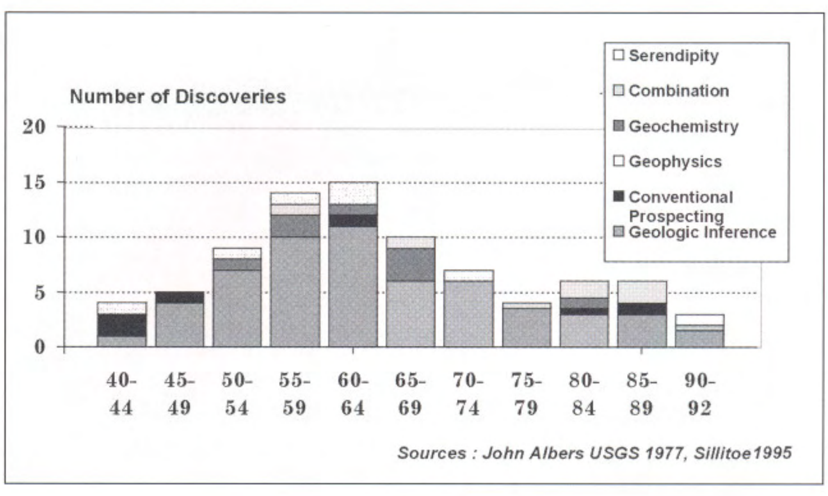
In the current environment, most of our emphasis is on the detection phase of exploration, particularly in the exploration geophysics discipline. Techniques, where much effort has been focused, are those such as EM and IP Inversion modelling, airborne EM systems, airborne gravity gradiometry, and distributed acquisition systems. These advances have been, in some cases, breathtaking, and add value to the exploration process. As shown diagrammatically in Figure 1, however, their value is only demonstrable after the predictive phase of exploration has directed us into a prospective region. That is to say, applying best detection techniques to the wrong area is destined to failure. My thesis, then, is that as exploration geophysicists, we must be certain to add value at all scales of exploration, as time and money invested in purely detection based endeavors can be value destroying. Ore body imaging is another interesting topic in its own right, but I will leave that discussion for another time.

It is significant to note that as more geophysical detection technology has been applied, discoveries of mineral deposits and the extent to which geophysics has contributed have declined. Figure 2 shows the extent to which not only is the total discovery rate decreasing, but the new discoveries attributable to geophysics are also tailing off. The factors behind these statistics are, of course, more complex than this. But the fact remains that as we push into more and more covered areas in new parts of the globe, the geophysical contribution to discoveries can only increase if close attention is paid to predictive techniques in the early phase of regional targeting.

Fig. 1. (Below) Diagrammatic graph illustrating the concept of relative effectiveness of exploration methodology with respect to project scale.

Fig. 2. (Bottom) Exploration discoveries from the 1940s to the 1990s, with information on the techniques utilised for discovery.





To illustrate the point, let's look at some of the more significant ore discoveries in Australia over the past decade. The Century (Zn), Cannington (Ag, Pb, Zn), and Ernest Henry (Cu, Au) discoveries were made as the direct result of innovative predictive scale exploration efforts. Some others, such as Cadia (Ridgeways) (Au, Cu), Bronzewing (Au), and Wallaby (Au) were discovered in areas already known to have significant endowment. In these cases one can assert that the predictive phase of exploration had been completed well in advance of the discoveries.

All of the aforementioned exploration philosophy is only truly applicable when put into the framework of an economic model. In most exploration groups today, the concept of the value chain is becoming the yardstick against which all activities are measured. This concept consists of the assertion that all tasks performed must add value somewhere along the chain of processes through which we do our business. The list below features some tasks that are performed daily in the exploration business, some more often than others, along with their effect on the exploration value chain.

- Effort and investment in the wrong area - *VALUE DESTROYING*
- Effort and investment in already mature areas where the best Detection scale technology has already been applied - *VALUE DESTROYING*
- Applying excellent Predictive techniques in immature areas - *VALUE ADDING*
- Following up good Prediction by good Detection techniques - *VALUE ADDING*
- Enhancing in-ground value to deposits by applying Ore Body Imaging - *VALUE ADDING*

In the end, exploration success, and our survival, depend on a positive investment/return ratio. This mantra will be repeated many times, and the successful explorationists will be the ones who have put their detection techniques to work in the best areas. Thus, the challenge for geophysical exploration will be to pursue a delicate balance, concentrating more effort on integrating predictive expertise into the exploration process while not allowing recent advances in detection and ore body imaging to suffer - a significant challenge indeed.

So, application of a bottle of vodka for the first response to a medical emergency isn't so crazy after all. Neither is the application of geophysics in the critical first phase of mineral exploration. Perhaps, by thinking at both large and small scales, we can avert the call for an ambulance to the scene of a geophysical industry crash.

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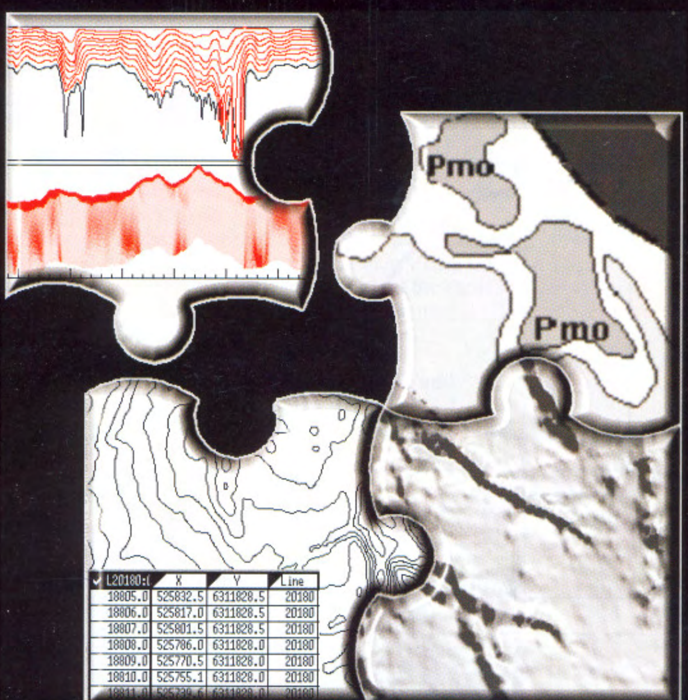
McCuaig, T. C. and Hronsky, J. M. A., 2000, The Current Status and Future of the Interface Between Exploration Research and Economic Geology Research: Society of Economic Geology Reviews, **13**, 553-559.

Sillitoe, R. H., 1995, Exploration and Discovery of Base- and Precious-metal Deposits in the Circum-pacific Region During the Last 25 Years: Metal Mining Agency of Japan.



Lindsay Thomas: New Managing Editor of Exploration Geophysics

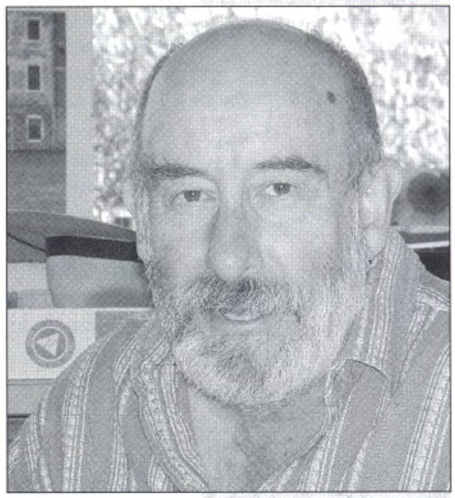
At the start of 2002, Lindsay Thomas will take up his appointment of Managing Editor, Exploration Geophysics. His career in Geophysics began with a PhD in global seismology at Adelaide University. During more than 33 years of teaching Geophysics and Geology at The University of Melbourne, he has been involved in some way with almost every aspect of exploration geophysics. He has been particularly interested, generically, in "using Geophysics to solve geological problems" although recently he has spent more time in technical aspects of electrical and EM problems.

Lindsay has been involved with the ASEG right from the original meeting at which the decision was taken to set up the Society, and has been a member of both State and Federal committees. He is serving or has served on various committees of the GSA, the AIG, and the AIP.

Outside Geophysics, to quote Lindsay "I have been interested in Orienteering, music, books, and bridge, and I hope that retirement will now allow me to keep my website up to date on those topics!

I see the opportunity to edit Exploration Geophysics as an opportunity to continue to indulge the curiosity about Earth Sciences that has underlain my career so far, and I hope to justify the choice of those who asked me to take this on."

We wish him well in his new role in the Society.



James Macnae moves to Melbourne

James Macnae has been appointed as Professor of Geophysics at RMIT University in Melbourne to set up a new geophysics research group the Environmental Geophysics Group within the Department of Applied Physics. Initial projects focus on the accurate electromagnetic imaging of subsurface conductivity, in particular applied to Dryland Salinity and contaminant mapping. As well, research into methodology for the detection of buried resistors (such as plastic landmines, tunnels, plastic piping) will be a second focus of the Group. This second application will ultimately be extended to medical imaging.

James will continue to have an interest in mineral exploration through AMIRA and other research projects, and is currently looking for a few good students with a geophysical, computational or instrumentational bent to pursue Masters or PhD degrees within the Group. His contact is james.macnae@rmit.edu.au or telephone (03) 9925 3401.

Obituaries

Adelmo Agostini 1941-2001

Well-respected Sydney geophysicist Adelmo Agostini passed away on the 8th September 2001. Adelmo had not long retired, after 40 years, from the Department of Mineral Resources and was enjoying a new life of travel and renewing family contacts.

Adelmo was born in Tientsin, China, on 3rd October 1941, to an Italian father and half Belgium - half Chinese mother (both deceased). The family moved to Mosman, Sydney, in 1960, from New Caledonia, and he attended Sydney University. In 1962, Adelmo obtained a cadetship from the (then) Department of Mines and graduated with Honours in Geophysics. His Honours' project involved torsion balance magnetometer investigations of basalt diatremes in the Sydney area.

After graduation he continued magnetic investigations with the Geological Survey and extended applications into general coalfield studies for dykes and sills. This work also provided the basis for an MSc. Adelmo was promoted to Senior Geophysicist in 1969 and during the 1970s conducted IP studies in the Central West of NSW.

In 1992 he transferred to the new Mineral Resources Audit Team and in this area his organisational skills were employed to plan major resource studies for land use planning and mineral exploration. During the 1990s his superior editorial and linguistic skills were utilised by the Department in proof reading of MINFO and other publications. Adelmo retired from the Department in February 2000 to travel and visit newly discovered family contacts in Europe, North America and South America.

Continued On Page 16

Howard Government Returned for Third Term

New Ministerial teams for Resources and Science

The new Howard Ministry was announced on 23 November, and there are major changes in areas of interest to ASEG members. The old Department of Industry, Science and Resources has been split up, with the Science arm moving to Education and Training, to form a new department of Education, Science and Training. Brendan Nelson will be Minister for these issues at Cabinet level and will be assisted by Peter McGauran as Minister for Science. In the Resources area we now have a new Department of Industry, Tourism and Resources. Ian Macfarlane is the responsible Minister in Cabinet for these issues, with assistance from Joe Hockey as Minister for Small Business and Tourism, and Warren Entsch who remains as Parliamentary Secretary for Resources.

One unexpected outcome from the reshuffle is the separation of science from industry. The Prime Minister stated that he wants to "increase opportunities for the commercialisation of new ideas" and we all know that industry's R & D efforts have been declining alarmingly, so what is the rationale for the separation?

Minimal policies for Resources and Energy

The 10 November Election, which returned the Howard Government for a third term, was dominated by the aftermaths of the Tampa affair and the 11 September terrorist attack in New York. These events relegated most policy debates to matters of secondary importance, but now that the dust has settled it is instructive to examine the policy statements of the Coalition and the ALP on Resources and Energy.

The Coalition at least had a policy statement on R & E but I couldn't find anything focussed on Resources or Energy on the ALP site. So what did the Coalition say? Because, if your pet project is not in the policy document, it is unlikely to be funded in the next budget.

In summary this is what was stated:

- **Delivering for Resources and Energy Sector**

1. The Coalition will continue to build on its strong support for the resources and energy sectors, including through the New Tax System and ongoing economic reform.

Continued From Page 15

He focused his non-work time towards Parish activities at the Sacred Heart Church in Mosman. He was devoted to several lay-ministry works and had a huge impact on the church members - most of who knew him from personal contact. Adelmo will be sorely missed in the life of the Parish.

Compiled by Steve Webster

John Edward Webb 1921-2001

John Webb's professional career spanned one of the most pioneering and interesting times in the history of exploration geophysics. Many pioneering workers were laying the groundwork for standard practices today. It was in this pioneering environment that John excelled. A keen sense of adventure and desire to achieve "best practice" methods lead to a very rewarding career.

John graduated from Adelaide University with a BSc in Electrical Engineering; from there he went to work for the PMG department in the radio branch during the Second World War. He then moved to the BMR, where for a while he was stationed north of Perth, in a geophysical monitoring post. Following this he moved back to Melbourne, the then location of the BMR, to establish a geophysics section.

In 1954 John commenced employment with the South Australian Department of Mines. In 1960 John was responsible for a reconnaissance survey from the Birdsville Track through to Oodnadatta, for the purpose of shooting a traverse from Boulia in Queensland to Marree in South Australia. The resulting survey enabled a successful water supply to be established for the township of Birdsville. The reconnaissance also resulted in John being one of the first people to cross the Simpson Desert and proved invaluable for a tour of the area by Sir Thomas Playford, the then premier of South Australia. In mid 1961 the geophysics section of the department was split into two, one section focussed on petroleum geophysics while the other on minerals, John was placed in charge of the minerals geophysics section.

In 1964 the challenge of running an IP survey in America beckoned. For the next eighteen months John coordinated a giant survey for the US navy and several power and phone utilities, running the length of the west coast of America. The size of the project necessitated that in some instances readings could only be made in conjunction with the local power authorities to insure that supplies to towns were not interrupted.

Following this John returned to Australia to establish Austral Exploration Services. Austral was not only a contract geophysical company, running three aircraft, but also acted as the Australian agent for an array of overseas equipment manufactures and also manufactured their own geophysical equipment. The company operated until 1983.

Throughout John's professional career he maintained strong links with the ASEG, SEG and EAEG, and was a member for over twenty-five years.

Compiled by Andrew Shearer with input from John's son Alan

2. The Strategic Investment Incentive and Major Project Facilitation processes will assist the development of major new projects and create new jobs.
3. Priority will be given to settling issues related to the effective life of assets for taxation purposes (*in other words look at depreciation issues*).
4. The Coalition recognises the importance of sensible Greenhouse policies, which will enable Australian industry to remain competitive and grow, and not cost Australian jobs particularly in regional Australia.
5. A Coalition Government will look at possible ways to amend the Native Title Act to provide all parties with certainty.

- Minerals

1. The Coalition reaffirms the importance of the minerals sector to Australia's economic well-being and its importance to our regional communities and economies.
2. The Regional Minerals Program will continue its studies to seek a more coordinated approach to mineral investment in regional areas.
3. The recommendations of the industry-led Light Metals Action Agenda will be implemented, to develop a vision for the aluminium, magnesium and titanium industries in Australia.

- Petroleum

1. The Coalition Government will remain committed to the work of the Downstream Petroleum Action Agenda and maintain support for the joint industry-government working group.
2. When the review of petroleum taxation reports in 2002, the Government will implement the recommendations that benefit our community.
3. The Government will initiate a review of the Gas Pipelines Third Party Access Code to ensure the maintenance of a light-handed approach to regulation that allows the further development of this important industry.

- National Energy Security

1. Reliable and competitive supplies of energy have been one of the foundations of Australia's economic growth. The Coalition recognises the critical importance of this to Australia's continued prosperity.
2. The Coalition will undertake further electricity and gas market reform through CoAG and other means.
3. The CoAG Review of Energy Market Directions will also provide an opportunity to continue the important work of economic reform and deliver benefits to all Australians. A Coalition Government will commit $1M to a study of the potential for a hydrogen industry based in Derby, WA.

Although these policies all appear to be sound and sensible there seems little to address the crisis in mineral exploration, or the contraction of Australian ownership in our resources caused by takeovers of Australian companies by multinationals.

Geoscience Australia gets a mention in the policy document with the Government reaffirming its strong support for the organisation. As stated "We will support the important strategic role Geoscience Australia plays in providing analytical services to the resource industry, particularly for exploration, mapping and geoscience information, which greatly assists industry and mining company operations." So GA clearly has strong support from the Coalition.

Mineral Resources NSW to move from Sydney

In a surprise announcement made in the New South Wales Parliament, the Premier of NSW, Bob Carr and Minister for Mineral Resources, Eddie Obeid announced on 23 October that 160 Department of Mineral Resources jobs will move from Sydney to Maitland in the Hunter.

Maitland is one of the NSW Government's most marginal seats and the decision is clearly aimed at that issue. To quote Mr Carr: "These are jobs going to where they are best suited and where they are needed most. The move will have a fantastic spin-off effect. These 160 families will spend their pay packets in local restaurants and shops. They will buy their lunches and clothing from Maitland businesses and employ local tradespeople for repairs around the home." The move by Department of Mineral Resources is the latest initiative in the State Government's comprehensive program to move government jobs and services to regional and rural NSW.

There was no mention of effect the move would have on the role and functions of the Department. Perhaps one should not be surprised.

Eristicus
26 November 2001

If you would like to share your favourite geophysical or geological websites with our readers, please email Natasha (natasha.hendrick@mim.com.au).

Where would our industry be without minerals? This edition of Preview I highlight just a few of the amazing web resources available on minerals and mining in Australia and around the world.

Web Mineralogy Database
webmineral.com

This mineralogy database contains more than 5000 pages of mineral data and 4205 individual mineral species descriptions. The huge quantity of information available on minerals at this site is categorised by crystallography, X-Ray powder diffraction, chemical composition, physical and optical properties, Dana's new classification, Strunz classification, and an alphabetical listing.

crocoite.com
www.crocoite.com

This site is designed to guide you to the minerals and mineral localities of Australia and New Zealand. There is an extensive listing of minerals. You'll also find links to some amusing earth science cartoons, geo-related artwork, contents and abstracts of articles from the "Australian Journal of Mineralogy", and links to many other mineral-related sites.

The Australian Mineral Collector
www.home.gil.com.au/~mineral

This website is financed by the Mineralogical Society of Queensland. It provides details on the all of the Australian Mineralogical Societies and provides links to interesting Australian mineral news items. There is also an extensive gallery of mineral images, and a guide describing where to see mineral specimens in Australia.

Virtual Atlas of Opaque and Ore Minerals in their Associations
www.smenet.org/opaque-ore

Sponsored by the Society for Mining, Metallurgy and Exploration, this site provides over 400 full colour photomicrographs of the major ore-forming associations and opaque minerals in non-mineralised rocks. The site describes typical examples of each material from many classical localities throughout the world. For each association there is a listing of major primary ore minerals, alteration products, typical textures, a brief discussion on geology and a list of references.

Athena Mineralogy
Un2sg4.unige.ch/athena/mineral/mineral.html

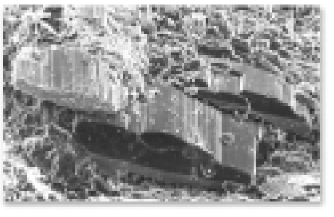
This site is another extensive mineral database, and includes an alphabetical listing of minerals and their formula, as well as a lists ordered by Strunz classification, mineral varieties, synonyms and foreign mineral names. The database is also fully searchable. In addition, you will find a gallery of pictures illustrating many uncommon minerals and numerous links to related shareware (including software for unit conversion, analysis of orientational data, calculation of molecular and crystallographic symmetry etc).

Australia Now - Mining
www.abs.gov.au
> Australia Now (a statistical profile of Australia) > Mining

Best accessed via the Australian Bureau of Statitistics web page, the 'Australian Now' profile on Mining tells you all you ever wanted to know about mining operations in Australia, including mining exports, imports, production and processing, exploration, resources and geology. There is also a series of interesting articles reviewing the Australian Mining Industry, including "The Australian Mining Industry: From Settlement to 2000", "A century of mining in Australia" and "The discovery of gold in Australia".

Miner Market
www.minermarket.com/news.asp

Check out this site for all the latest mining news, including current base metal prices and relevant corporate news releases from around the world. If you've got some time for trivia, browse through the Origin of Mineral Names in the Mining Glossary. Or if you're looking for a distraction from work, try the mining quiz and mining word search.



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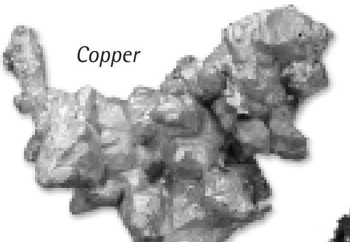

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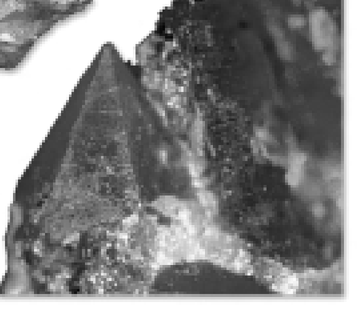

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Geoscience Australia

Merger and Name Change for National Spatial Information Agencies

As reported in the October Preview AUSLIG, Australia's national mapping agency was merged with AGSO-Geoscience Australia (formerly the Australian Geological Survey Organisation). Since then there have been two further name changes and the main structure of the new organisation has been firmed-up. The AGSO letters have been abandoned, the new institution is called Geoscience Australia and AUSLIG is now the National Mapping Division of Geoscience Australia.

As the media statement outlined: "Both agencies acquire, process, analyse and disseminate fundamental spatial information in one form or another. The merger has created a more robust *Geoscience Australia*, better equipped to carry out these responsibilities."

Geoscience Portal Launched

On 8 November the Australian Governments' Geoscience Portal was launched. This can be found at the website: http://www.geoscience.gov.au. It enables all people interested in Australian geoscience to gain access to the States, Northern Territory and Commonwealth geoscience information.

Investors, researchers and explorers should now be able to discover geoscience information at a national level and to further refine their searches down to regional and local scales via pathways to the relevant State and Territory datasets.

The geoscience portal is a result of collaboration between Geoscience Australia and its State and Territory counterparts. This initiative of the Chief Government Geologists is designed to improve general accessibility to fundamental data by integrating disparate agency systems into a single users interface via the web browser.

Prices Reduced for Geoscience Australia data

As indicated in the October Preview, the price of on-line government held spatial information will be provided free or at cost of transfer. This policy has already been implemented at Geoscience Australia and the cost cutting is significant. For example the Australian National Gravity Database which used to cost $5395.50 can now be acquired for $99 and the 400m airborne geophysics point located data for a 1:250 000 map sheet area has been reduced from $18 074.95 to $99. A challenge for post-Xmas sales reductions?

Regional seismic data from offshore northern and northwestern Australia now available

Geoscience Australia has released Record 2001/36 "Line Drawings of AGSO - Geoscience Australia's Regional Seismic Profiles, Offshore Northern and Northwestern Australia".

This Record provides in a graphical form, line-drawing interpretations of all 160 lines making up Geoscience Australia's regional seismic data set off northern and northwestern Australia. The data set extends from North West Cape in the south to the eastern Arafura Sea in the north. The Record complements the release earlier this year of the digital horizon and fault data of the interpretations.

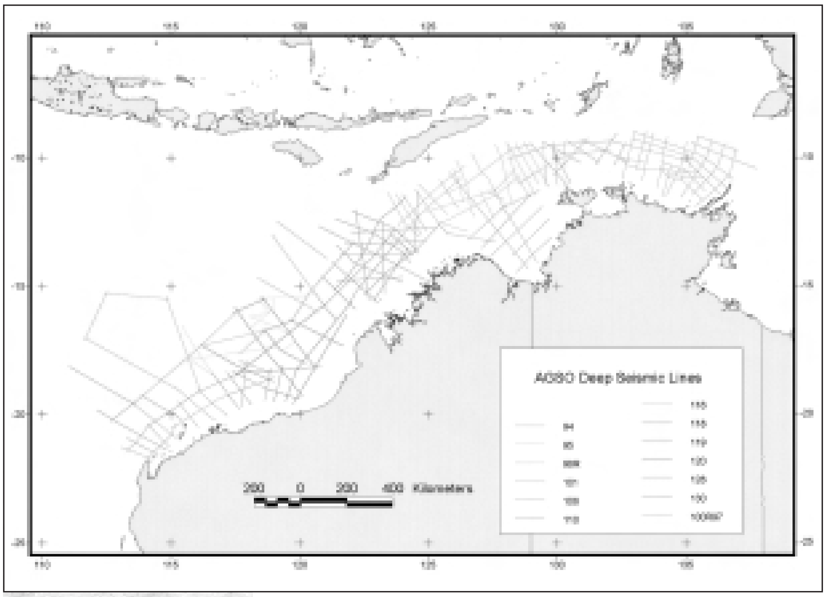


Fig. 1. Location of the interpreted seismic lines

The Record presents, as a 'pdf' document, line drawing interpretations of all 160 lines making up the approximately 35 000 km of regional seismic reflection data acquired by Geoscience Australia off northern and northwestern Australia between 1990 and 1994 (see Fig. 1).

Although these data have been widely used by industry, they had not been interpreted in a consistent fashion until a contract was let in 1999 by Geoscience Australia to a Perth-based company, IKODA Pty Ltd, to fully integrate the various interpretations. The Record provides a convenient overview of the interpretations through the entire data set. Sixteen horizons are routinely interpreted with the addition of extra horizons as determined by the local geology.

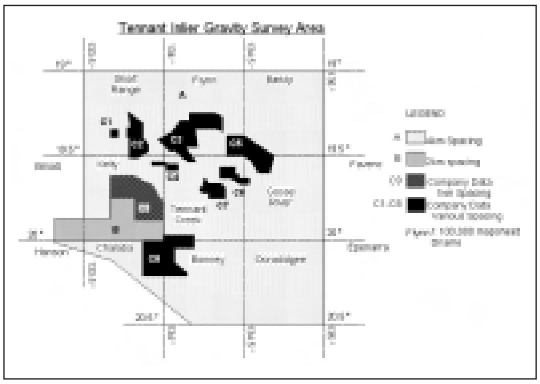
Geoscience Australia's regional deep-seismic data commonly image features and structures that are deeper than conventional industry seismic data and thus provide a valuable insight into the region's geological evolution. In many places, the deep structures have clearly had a major influence on the development of younger, shallower features that are prospective for hydrocarbons.

The Record is available from the Geoscience Australia Sales Centre for a cost of $250.

NTGS and Geoscience Australia

Tennant Inlier Gravity data now available

Geoscience Australia and the Northern Territory Geological Survey (NTGS) have released digital point-located gravity data collected over part of the Tennant Inlier area of the Northern Territory. This data release includes new data acquired on behalf of Geoscience Australia and NTGS as well as data previously collected on behalf of private companies and previously released data from the National Gravity Database. The gravity data set covers the entire Tennant Creek 1:250 000 Sheet area and parts of the Bonney Well, Green Swamp Well and Lander River 1:250 000 sheet areas.



The data set consists of 1605 new gravity stations collected on regular 4 x 4 and 2 x 2km grids together with 20 346 previously acquired company data and 2419 previously released stations. The new gravity data were acquired in July 2001. The company data were acquired in nine areas, labelled as C1 to C9 in the diagram below. No new data were collected for Geoscience Australia and NTGS in these nine areas. The company data were acquired at various station spacings between the years 1990 and 2001. Giants Reef Mining Ltd and Normandy Mining Ltd have provided the company data. The previously released data are from surveys conducted between 1960 and 1982 at various station spacings.

The complete data set of 24 370 stations, comprising newly acquired data, existing company data and previously released data will be made available to bona fide interested parties at no charge from Geoscience Australia on CD-ROM.

New Presentations of Gravity Anomalies in the Victoria/Bass Strait Region

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Intrepid Geophysics, working for the Victorian Department of Natural Resources & Environment (DNRE), has produced a new generation residual gravity anomaly grid for Victoria. This work follows the recent compilation of all sea-track bathymetry, gravity and magnetic data for the east coast of Australia. Over 400 separate offshore surveys, gathered over 40 years, have been compiled into coherent grids. Data have been supplied by local and overseas research vessels, geophysical contractors and recently acquired swath surveys from a Law of the Sea initiative, funded by the National Oceans Agency. This work was contracted and supervised by AGSO. At the same time, DNRE has continued to acquire many new onshore gravity surveys at high resolution. It also contributed open file offshore company data.

Tasmanian gravity data were also included. These were used to calibrate the computed terrain corrections with those done by hand and also to improve the model in the important land/sea transition zone in the south of Bass Strait and around Flinders and King Islands.

The high definition gravity map for Victoria was compiled using the following steps:

1. Level the offshore observations using GeoSat data as a broad reference. The ship-observed gravity has an IGSN71 datum. It is arguable that the gravity grid for GeoSat is close to a WGS84 datum (it is unstated). We have found the GeoSat data to be unreliable in shallow water so data processing was broken into shallow and deep regions. A level shift of up to 110 µ/m2 at the Bass Strait margin was required to compensate for differences between IGSN71 data and data leveled with reference to GeoSat.

2. Calculate a simple Bouguer anomaly for each original observation point:
   a. Onshore Victoria - 117 740 points using a density of 2.6 t/m^3.
   b. Offshore - 365 117 points using 2.2 t/m^3.

3. Calculate a terrain gravity correction using the Auslig 9 second DTM for on-shore and the new bathymetry models for offshore (250 m). (Desmond FitzGerald & Associates, 2001). The method used is based on calculating the gravity effect of variable terrain after the method of Hammer (1939) using prisms and radii of influence.

   There are concerns about using the current Auslig 9 second DTM for terrain corrections, as there are some inadmissible local gradients (too steep and too variable) in the Victorian Highlands. An alternative method, using the higher resolution contour strings for onshore is currently being explored. These contours were created using photogrammetric surveying methods.

4. Determine one coherent grid by using Intrepid's multi-data gridding routines to combine all the Bouguer anomalies (see Figure 1).

5. Individual ship tracks of observed gravity that did not "level" well were then given special attention. Various factors are at play here:

   a. In Bass Strait proper the water depths are generally less than 80 m and a 1 m error in the bathymetry creates noticeable and unacceptable lines in the gravity grid.
   b. Older ship track data have a greater positional uncertainty. Near-shore Gippsland Basin has several problem lines.
   c. Offshore in the Otway Basin a company survey was recovered from Bouguer contours and this required a shift adjustment to fit the general field.

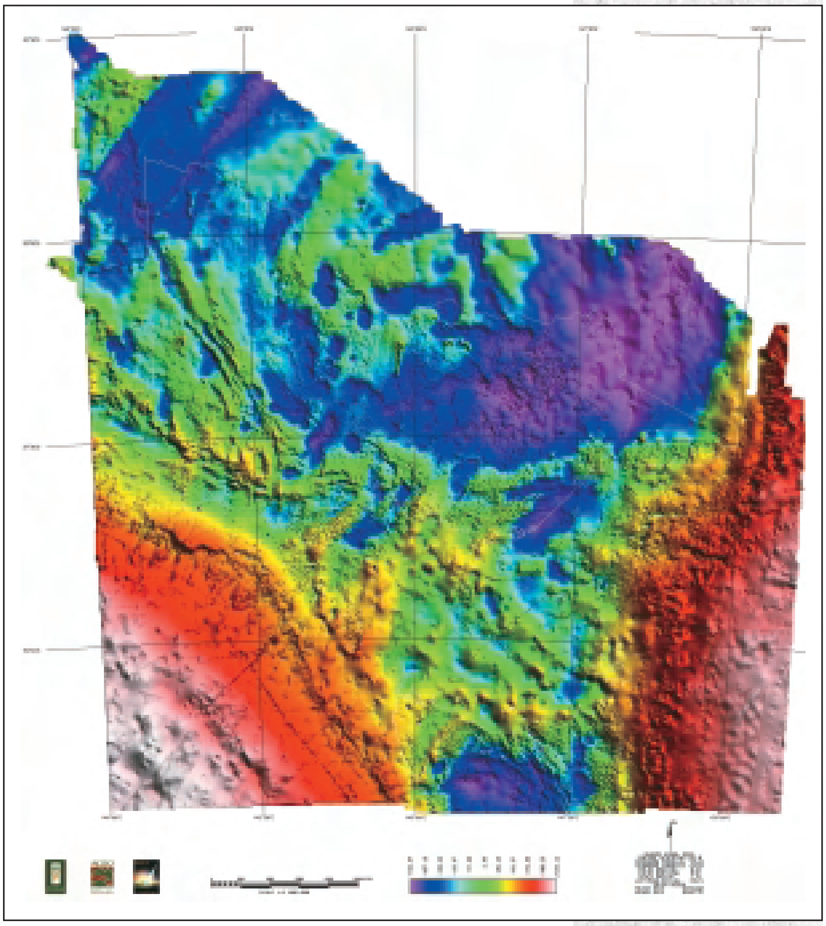

Fig. 1. Bouguer anomalies both on and off shore.

This approach is contrasted to the previous practice of using Bouguer anomalies on-shore and Free Air anomalies offshore (see Figure 2).

The new practice removes much of the continental ocean boundary (COB) high that is a characteristic of a Free Air anomaly over this boundary. The data can now be examined in much greater detail (e.g. to 1:50 000 scale), with the confidence that local distortions to the field due to sampling or leveling have been minimized. This is because there is a more complete aggregation of data, due

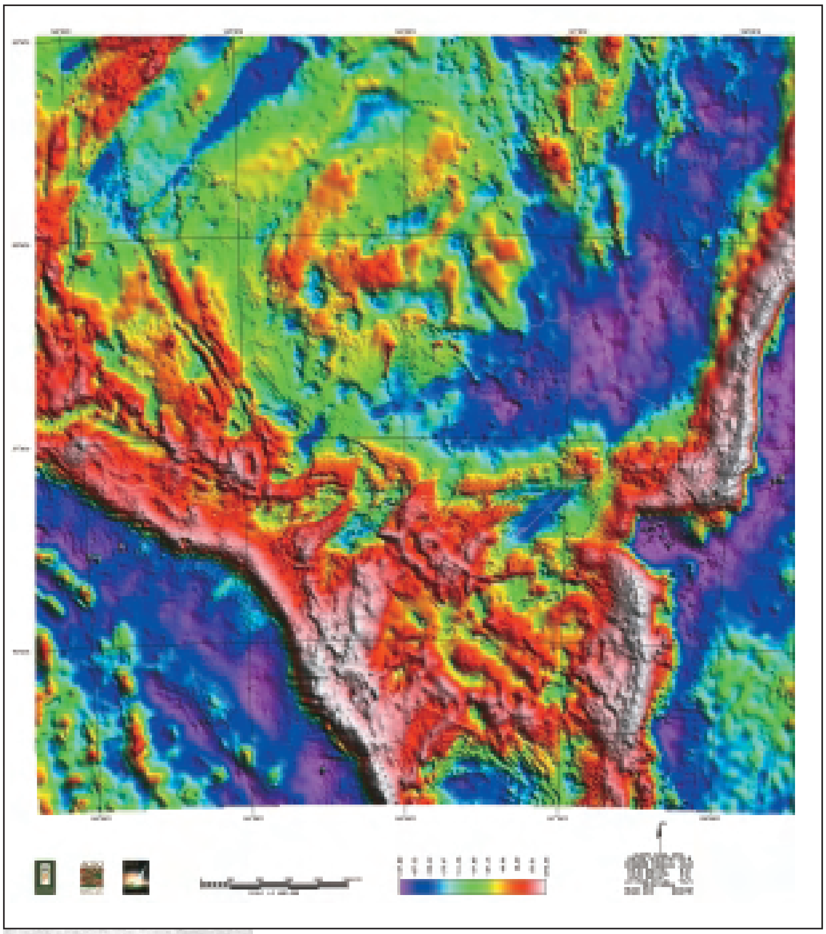

Fig. 2. Older Bouguer anomalies on-shore, Free Air anomalies off-shore.

to the considerable quantity of new data that have been acquired in the last 5 years, and the improved tools now available to deal with the compilations of gravity data. There was a belief that there was not enough ship track data to create a quality result offshore.

The rationale for using a Free Air anomaly offshore is that, except for the COB high, the dynamic range is comparable with onshore. However, as can be seen, the Free Air anomaly reflects a great deal of topographic information. For example, the Bass Canyon is very prominent (eastern side of Gippsland, off Sale). A Free-Air anomaly therefore contains signal from both topography and density. On the other hand, the offshore Bouguer nicely handles and removes topographic effects, leaving just density variations. The complete Bouguer both onshore and offshore is the best indicator of geology in that rocks of similar density report in the same range. The high density oceanic crust influences the dynamic range, as do the Alps (low in the Alps). For this reason, work on an isostatically compensated gravity model is proposed. This should compensate for the Victorian Alps and the oceanic crust and complete the picture.

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Calibration and Use of Portable Gamma-ray Spectrometers
Part 2 - Field Procedures and Calculation of Ground Concentrations

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Summary

In order to provide accurate and reliable information, portable spectrometers need to be calibrated adequately and used correctly. Part 1 of this article (see Preview 94, October 2001) outlined the theory and practice of calibrating portable gamma-ray spectrometers. This part develops guidelines for proper field practices based both on the physical principles of the method and on some important assumptions made during calibration.

Numerical examples show how to select an appropriate sampling time and how to calculate ground concentrations of potassium, uranium and thorium for a typical instrument. The effects of source geometry and uniformity, and of soil moisture are discussed and safety considerations and responsibilities are reviewed.

Applications

Historically, the main use of portable gamma-ray spectrometers and scintillometers has been as direct prospecting tools in the search for uranium (U) deposits. More recently they are increasingly being used to help calibrate airborne gamma-ray spectrometers, to support geological field mapping, for soil mapping, in environmental applications and in monitoring radioactive waste pollution.

In the search for U deposits, random or systematic traversing with a spectrometer or scintillometer (hand held or carborne) has now been largely supplanted by detailed, low level, inexpensive airborne spectrometer surveys. The main reason for this is that ground surveys are labour intensive and therefore costly. Also, ground surveys do not provide very good or efficient coverage compared with an airborne survey. In this context, portable instruments are now primarily used in following up radiometric anomalies recorded in airborne surveys.

Illustration: A ground survey of a 1 km² area on a 20 m grid would involve about 130 person hours (3 minutes per station, 2600 stations) or about three weeks work. If the spectrometer is placed on the ground at each station the survey is actually providing coverage of probably less than 1% of the surface area of the grid (each station monitors about 4 m² around the field point). A helicopter survey of the same area would be completed in under a day and could be designed to provide virtually 100% coverage.

Calculation of ground concentrations of K, U and Th

For a three-channel spectrometer having a sensitivity matrix **S**, the ground concentrations (**C**) of K, U and Th corresponding with a set of background-corrected field observations **N** is given by (see Part 1 of this article):

$$\mathbf{C} = \mathbf{S}^{-1}\,\mathbf{N} \qquad (1)$$

Numerical example: For background-corrected countrates of 7.90, 1.50 and 1.20 counts/s in the K, U and Th channels, respectively, recorded by the spectrometer whose calibration matrix is given in Table 1, the corresponding ground concentrations are given by:

$$\begin{pmatrix} C_K \\ C_U \\ C_T \end{pmatrix} = \begin{pmatrix} 3.36 & 0.250 & 0.062 \\ 0 & 0.325 & 0.075 \\ 0 & 0.011 & 0.128 \end{pmatrix}^{-1} * \begin{pmatrix} 7.90 \\ 1.50 \\ 1.20 \end{pmatrix}$$

and

$$\begin{pmatrix} C_K \\ C_U \\ C_T \end{pmatrix} = \begin{pmatrix} 0.298 & -0.229 & -0.010 \\ 0 & 3.139 & -1.839 \\ 0 & -0.270 & 7.971 \end{pmatrix} * \begin{pmatrix} 7.90 \\ 1.50 \\ 1.20 \end{pmatrix}$$

	counts/s per 1% Kper	counts/s 1 ppm Uper	counts/s 1 ppm Th
K window	3.36	0.250	0.062
U window	0	0.325	0.075
Th window	0	0.011	0.128

Table 1. Typical window sensitivities for a portable gamma-ray spectrometer with 76×76 mm sodium iodide detector (IAEA, 1989). Matrix S of Equation (1).

So that C_K =2.0% K, C_U=2.5ppm U and C_T= 9.2ppm Th. Note that the inverse of matrix **S** needs to be calculated only once after calibration, and can be used to convert all subsequent observations to ground concentrations.

Strictly speaking, we are calculating the concentrations of K, U and Th indirectly, using the assumptions of radioactive equilibrium and constant isotopic ratios for the radioelements in the ground. For this reason some authorities prefer to call the calculated concentrations *equivalent* potassium, uranium and thorium (eK, eU, eTh).

For field approximations, and if only U and Th concentrations are required, a graphical method can be used. The calibration nomogram of Figure 1 is constructed from elements S_{22}, S_{23}, S_{32} and S_{33} of matrix S, and could be taped to the spectrometer for quick field assays (Corner et al., 1979). The nomogram is scaleable for higher countrates, although dead time and extrapolation errors may be significant for very high radioelement concentrations.

Some modern instruments are able to store calibration constants and calculate radioelement concentrations directly in the field.

Selection of counting time

If N_K, N_U, N_T are the background-corrected observed countrates in the K, U and Th channels, and σ_{CK}, σ_{CU}, and σ_{CT} are the standard deviations of the calculated ground

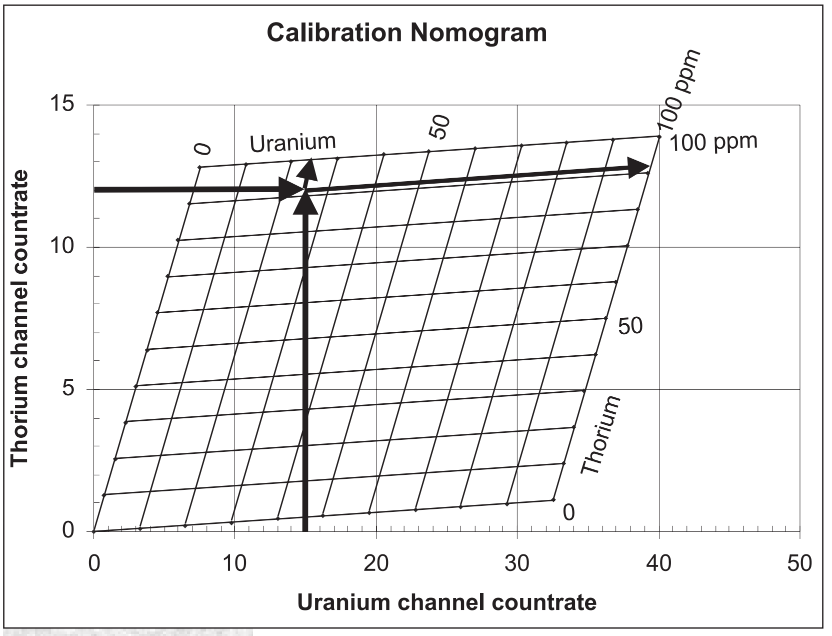

Fig. 1. Calibration nomogram for the spectrometer of Table 1. Use of the nomogram is shown for a background-corrected U channel countrate of 1.5 counts/s and a background-corrected Th channel countrate of 1.2 counts/s. The nomogram is scaleable, so the observed countrates can be multiplied by ten to bring them into a reasonable range on the nomogram, and the indicated U and Th concentrations are correspondingly divided by ten to give 2.5ppm U and 9.2 ppm Th as in the worked example above.

concentrations, then the counting time t_K to achieve a required σ_{CK} is given by:

$$t_K = \frac{1}{\sigma_{CK}^2}\left(S_{11}^2 N_K + S_{12}^2 N_U + S_{13}^2 N_T\right) \qquad (2)$$

Similarly the counting time t_U to achieve a required σ_{CU} is given by:

$$t_U = \frac{1}{\sigma_{CU}^2}\left(S_{22}^2 N_U + S_{23}^2 N_T\right) \qquad (3)$$

and the counting time t_T to achieve a required σ_{CT} is given by:

$$t_T = \frac{1}{\sigma_{CT}^2}\left(S_{32}^2 N_U + S_{33}^2 N_T\right) \qquad (4)$$

Note that the S_{ij} are the elements of the *inverse* of matrix **S** (equation 1 above) and these are here assumed to be accurately known.

In the case of the numerical example given earlier, to achieve a standard deviation of 1% in the calculated K concentration requires t_K = 0.8s. Similarly, a standard deviation of 1ppm in the calculated U concentration requires t_U = 19s, and a standard deviation of 1ppm in the calculated Th concentration requires t_K = 76s.

It will be apparent from 2, 3 and 4 that these times depend on both the instrument itself (matrix **S**) and also on the local conditions (the recorded countrates **N**), They may need to be reviewed if the recorded countrates change significantly.

In the situation where the countrates N_K, N_U, and N_T are unknown, but the expected concentrations of K, U and Th are known, the expected countrates can be calculated as decribed in Part 1 of this article. The required counting time t can then be estimated from Equations (2), (3) and (4) above.

The standard deviations σ_{CK}, σ_{CU} and σ_{CT} can also be made the subjects of Equations (2), (3) and (4) to estimate the K, U and Th errors for a particular counting time.

Field Practice

Some general guidelines for using calibrated portable spectrometers in the field follow directly from the assumptions made during calibration and are illustrated diagrammatically in Figure 2.

Uniformity: For quantitative measurements, the volume of rock being sampled by the spectrometer should have uniform radioelement composition. Before attempting any quantitative measurements, it is a good idea to survey a few metres around the proposed site to ensure that there are no local 'hot spots', which might violate this principle.

2π Geometry: The terrain around the field station should represent a flat infinite half-space at the detector. This means that there should not be any large boulders nearby, nor bluffs overlooking the detector, as these will contribute additional radiation to the detector. Ten metres of air will attenuate terrestrial radiation by only about 4-7%, so even bluffs several tens of metres from the detector may still have a significant effect at the detector.

For the same reason, the detector should not be placed in a hole or trench - the countrate will increase, and the unwary might conclude (falsely) that radiation increases with depth.

In general, deviations from a 2π geometry will tend to increase the recorded countrate and lead to an overestimate of radioelement concentrations. Where field situations dictate that 2π geometry cannot be achieved, a correction factor can be estimated. If the source completely surrounds the detector (4π geometry) the countrate would be doubled, so the correction factor will generally lie between 1.0 and 0.5.

Water is a strong absorber of gamma radiation, and since the human body has a high percentage of water, it is capable of shielding the detector. For quantitative measurements, therefore, the detector should not be carried in a backpack, nor be operated close to the body.

Following up airborne anomalies: Modern GPS equipment allows airborne anomalies to be recovered within a few tens of metres in the field. In some cases, however, the recorded position of an airborne anomaly can be significantly displaced from its true ground position. The wide field of view ("footprint") of the airborne detector means that it is sensitive to discrete sources, which may be several tens of metres to the side of the recorded flight track. At a flying height of 50 m, for example, the footprint of the airborne detector sweeps out a strip more than 100 m wide on each side of the flight path. If the anomaly is not found at its recorded location it may be necessary to search some distance to each side of the aircraft track from the recorded location.

The fields of view of portable and airborne detectors may be different by two or more orders of magnitude. At 50 m flying height, an airborne detector has a field of view of perhaps 50 000 m² whereas a portable detector held at a height of 0.5 m has a field of view of perhaps 10 m². A source that is small relative to the footprint for the airborne detector might be a broad source for the portable detector. It is important to appreciate this in follow-up, and when deciding whether or not the ground follow-up has adequately explained the airborne response.

Other considerations

Soil moisture can affect measured radiation in several ways. Increases in soil moisture, such as may occur after heavy rain, will tend to mask radiation, but may also interfere with diffusion processes and lead to a build up of ^{222}Rn (radon) in the soil (Grasty, 1997).

Rain tends to flush airborne dust particles and their adsorbed radon from the air and this can lead to a short term increase in the indicated levels of surface uranium as measured by portable spectrometers (Charbonneau and Darnley, 1970).

These effects are not easy to predict, and, in general, it is advisable to wait several hours after rain before undertaking portable spectrometer surveys.

Most of the radiation received by a portable detector originates within the top 35 cm or so of the earth's surface. The portable spectrometer does not provide any information about the earth materials below this depth. As a corollary, it requires only about 35 cm of barren overburden to completely mask the effect of a radioactive source below this depth. Dense vegetation, largely because of its water content, will also tend to mask radiation from earth materials.

The audible alarms on portable radiometric equipment can be helpful in identifying anomalous radioactivity and in locating geological boundaries that separate rock units with different radiometric characteristics. The alarm should be set in an area of low general radioactivity such that a few pulses per second can be heard. Any changes in radioactivity will be distinguished easily by audible changes in the pulse rate, and the operator is freed from the need to monitor the instrument display.

Normal precautions for sensitive geophysical equipment should be observed:

- Do not leave the spectrometer/scintillometer in direct sunlight.
- Do not leave batteries in the instrument for lengthy periods in case of cell leakage.
- Check the battery condition regularly and replace as required. Carry spares.
- Operate switches periodically to prevent build up of corrosion products.
- Have the instruments checked, cleaned and serviced regularly.
- Recalibrate after any major repairs or servicing.

Safety

In most situations, the radioactive sources used for calibration and gain adjustment will not constitute a significant health hazard, nor will the radiation associated with most rock types. Nevertheless, operators should be aware of the health effects of radiation and be trained to recognize and deal with potentially hazardous situations.

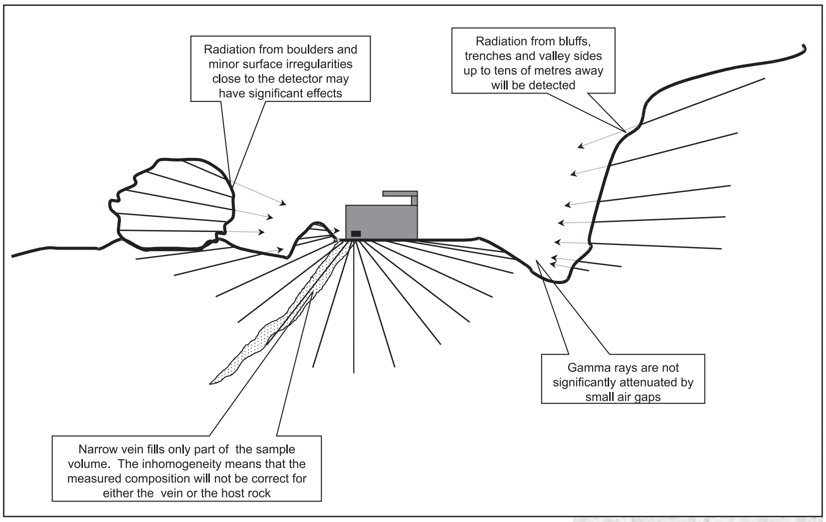

Fig. 2. The shaded portion represents the volume effectively sampled by the detector. Bluffs, boulders and surface irregularities close to the detector are likely to increase the radiation reaching the detector (2p geometry assumption is violated). Veins and hotspots within the rock volume sampled by the detector violate the assumption of source homogeneity. (Modified from Richards, 1982)

If high radiation levels are anticipated, such as in or near orebodies or in pollution monitoring, or if significant U mineralisation is encountered, appropriate dose measurement and hazard management steps must be taken.

Appropriate safety training of field staff who use radiation detection devices, such as spectrometers and scintillometers, is an intrinsic part of both the employer and employee's duty of care under Australian legislation.

Acknowledgements

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Interpolation of Horizon Contours from Sections Sampled from 3D Seismic Data and from Parallel 2D Seismic Sections

Abstract

This research examines the accuracy of contour maps subsampled from a 3D seismic survey. A 3D seismic data set was interpreted using LANDMARK's "Seisworks-3D" software to build three contour surfaces of stratigraphic horizons at various depths and structural complexities. These horizons were exported and imported to a Geographic Information System (GIS), resampled at various in-line and cross-line, and point spacings, and interpolated to create 3D surface grids from these subsamples of the horizons to simulate interpolation from 2D seismic lines.

In the first set of experiments, for both transect and point data structures, map error decreased as a power function of sample size. This systematic increase in error as sample size decreases allows prediction of the accuracy of interpolation according to sample size and distribution of the data. This relationship facilitates estimation of errors for seismic data interpreters picking a subsample of sections for a particular stratigraphic horizon, determination of receiver and line spacings for sufficient survey accuracy for least economic outlay. Another application of this relationship is to determine the accuracy of interpolative contour mapping on a series of parallel 2D seismic lines according to their spacing.

In a second set of experiments on the point data of a set sample size, map error increased with the local structural complexity of strata sampled. This relationship would allow prediction of the relative precision expected in areas of varying complexity. These findings corroborate earlier work on topographic maps and indicate that similar trade offs between map accuracy and both sample size and surface complexity apply to 3D geologicalal blocks.

Introduction

There has been a lot of cartographic research on the nature of errors associated with sampling strategies. Most studies of sampling errors have been performed on 2D or 2.5D topographic data sets as defined by Raper and Kelk (1991) where there can only be one z value for each x, y coordinate. It has been shown in these studies that higher sampling densities produce more accurate maps, however, the relationship between sampling interval and accuracy is not linear but exponential. For example, MacEachren and Davidson (1987) carried out research to evaluate the effect of sampling density on topographic contour interpolation error. They also examined the effect of the complexity of the interpolated surface on accuracy of the sample. Six topographical surfaces were chosen, each with an empirical value for complexity. Each surface was interpolated 8 times at varying sampling densities expressed in terms of the number of data points: 100, 225, 400, 625, 900, 1225, 1600, and 2025. They found that mean absolute error decreased at a decreasing rate with increasing sampling size. This relationship suggests that for a given purpose there may be an optimal sample interval at which sufficient relevant information is captured without an excessively large sample. In that experiment, contour maps were interpolated for the same area, from a 1:24 000 topographic sheet that features an eroded syncline dipping to the northeast, located in the Appalachian Mountains, USA. One map was derived using elevations sampled at 50 m intervals in a grid pattern, and the other map was derived using elevations sampled at 500 m intervals. Contour lines interpolated from the points at 50 m intervals clearly portrayed the geology of the area (Maltman, 1990), while on contour maps interpolated from the points at 500 m intervals the geologicalal structural pattern is completely lost.

This research evaluates the interpolation error as it is related to density of sampling of 2D and 3D seismic data sets.

Sampling Interval

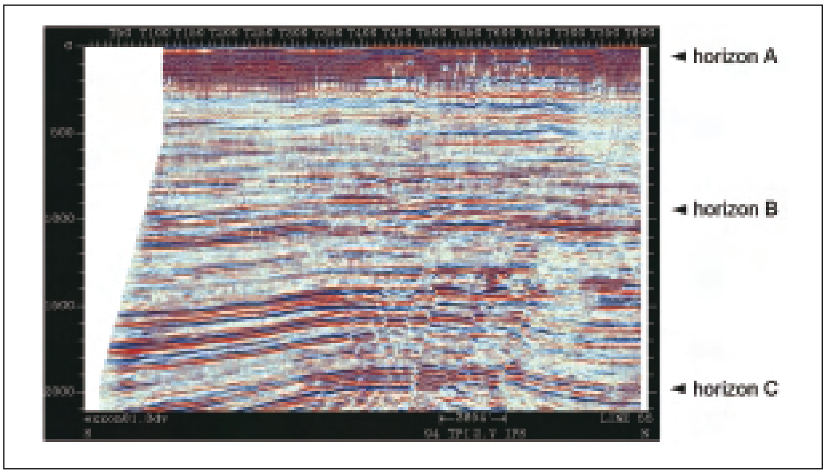
The relationship between interpolation accuracy and sampling density is complicated by the complexity of the contour surface. Thus, application of the sampling theorem which states that the sampling interval needs to be less than half the cycle of the highest frequency present in a distribution (Robinson et al., 1995; Brown, 1996; Sheriff, 1991) dictates that increased complexity will require increased sampling densities. In other words, the higher the frequency of change of the subject to be sampled, the closer the samples will need to be spaced to achieve a given accuracy. This is also known as the cardinal theorem or the Nyquist theorem (Sheriff, 1991).

Hypothesis

The hypothesis was tested that errors in interpolated sample grids would be strongly related to the sample size and spacing between picked lines. It was anticipated that there would be an increase in interpolation error as the distance between each of the sample lines was increased. As in the experiments of MacEachren & Davidson (1987), it was hypothesised that the relationship between error and distance between manually picked lines would increase slowly with distance at first but more rapidly with increasing distance; i.e., with decrease in sampling density. The hypothesis was also tested that errors in interpolated sample grids would be related to the structural complexity of the horizon. The three geological horizons that were mapped for this study were thought to require varying sampling densities to capture a given level of map accuracy. This was tested in the experiments.

Methods

Data processing involved the following steps, which are elaborated below. Three master stratigraphic horizons were picked from every in-line and cross-line section on parts of



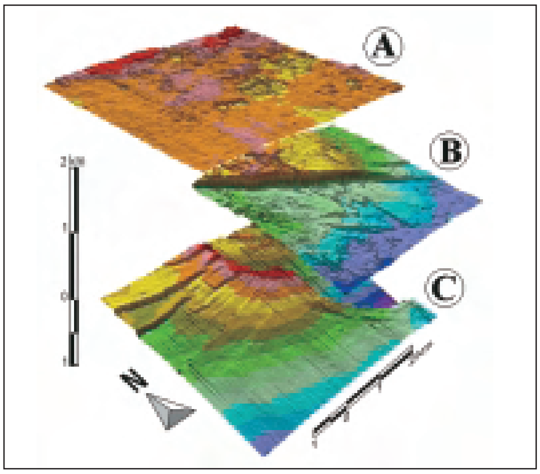


Fig. 1. A part of a north-south cross-section of the Exxon 2D survey in the Gulf of Mexico viewed from the east. Length of section shown is approximately 10 km.

Fig. 2. (Top Right) Perspective view from the south west of the three horizons (A, B, & C) within the 3D seismic block showing various geological complexities including the seismic "footprint" in the data.

the 3D seismic data set with different structural complexities (Figure 1) using LANDMARK's "Seisworks-3D" software (Landmark Graphics Corp., 1998). These master horizons were exported as database files with x, y, z coordinates to the ArcView geographic information system (GIS) (ESRI, 1995) where subsampling and further 2D spatial analysis was conducted including interpolation of contour surfaces and generation of error surfaces and statistics.

In ArcView GIS, the database files were converted into master grid surfaces for each horizon (Figures 2 and 3). Subsamples of x, y, z, data with varying sampling densities (e.g. Figure 4) were selected from the three master grids and were interpolated to create grids with the same area and number of grid cells as the original master grid surface.

The study area is located in South Timbalier in the Gulf of Mexico. The block is approximately 10 km east west by 14 km north south by 10 km deep and is in a thick sequence of sediments deformed by salt diapirs that have pushed up into the upper sediments since the Jurassic Period causing some folding and faulting in the overlying sediments (Rowan and Weimer, 1998; McBride et al., 1998). For this analysis, the master horizons were picked across faults without the introduction of fault surfaces. The horizons sampled were 6.4 km square and contained 65 536 data points arranged as 512 points north south (in-line) by 128 points east west (cross-line).

Anisotropy of Data

The ratio of hydrophone spacing (12.5 m) to streamer spacing (50 m) was of the order of 4:1, so the data array in the original post stack master data set was anisotropic in distribution. This irregular spacing called for special processing (Shepherd, 1999) and two samples were generated for each subsample spacing. These were defined as transect and point samples. Transect samples consisted of complete in-lines and cross-lines but point samples

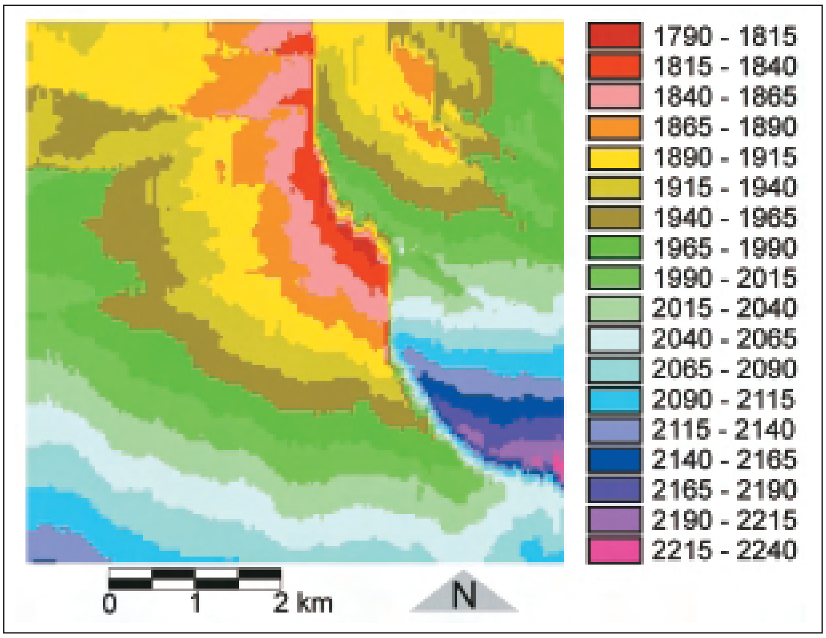


Fig. 3. Master 2.5-D surface for horizon C. Contours show two-way travel times in milliseconds. Number of data points, N, is 65 536

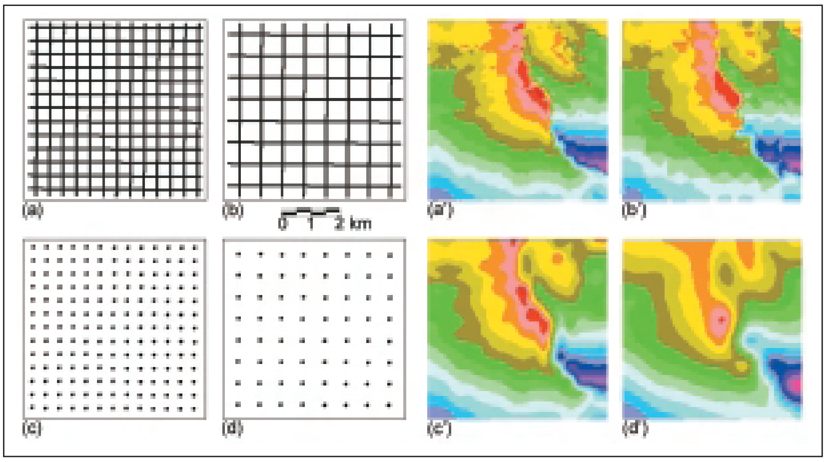
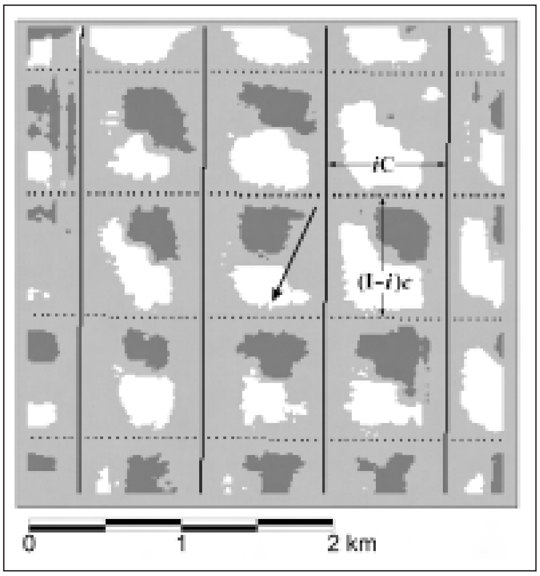


Fig. 4. (Above) Sample grids with corresponding interpolated surfaces for horizon C. For (a), sample size N = 9984, (b), N = 5056, (c), N = 169, and for (d), N = 64. Degree of generalisation increases with increasing line or point spacing. For sample sizes <= 169 (c & d) the structural interpretation would change. The discontinuity extending from the north-central edge to the southeast corner of the image is intercepted by an apparent feature trending northeast.



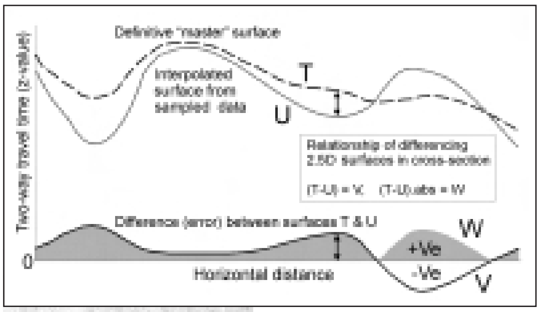


Fig. 5. (Top) Error distribution for transect sample (Fig. 4b) and map (Fig. 4b'). The dark areas are negative error and white areas are positive error. Arrow shows direction of downward slope of horizon C. The parameters for Equation 1 are shown.

Fig. 6. (Above) Cross-section of a difference surface (V) evaluated by subtracting the interpolated surface (U) from the "truth" surface (T). The shaded area (W) shows the absolute difference between the surfaces. The error surface (V) was used to calculate the standard deviation of error statistic and the absolute error surface (W) was used to calculate the mean error statistic.

retained only the intersections (single points in a regular pattern) between the in-lines and cross-lines. Due to anisotropy, sample spacings between in-lines and cross-lines were equal in distance in both orthogonal directions but not equal in number (4:1). It was decided to make the transect sample line numbers isotropic with ratio of 1 north south in-line for every 4th east-west cross-lines or multiples thereof. The transect sample size is arrived at by use of the formula:

$$N = iC + (I - i)\,c \qquad (1)$$

where **N** is the number of data points in the sample, ***i*** is the number of in-lines taken for the sample, ***c*** is the number of cross-lines taken for the sample, in these cases, equal to the number of in-lines, **I** is the number of in-lines in the master horizon data set, and **C** is the number of cross-lines in the master horizon data set. The component in the equation (**I - *i***) where ***i*** is subtracted from ***I*** is necessary to avoid counting the data points at the intersections twice (Figure 5). The values for ***i*** and ***c*** are obtained by:

$$i = I/n \qquad (2)$$

$$c = C/4n \qquad (3)$$

where ***n*** is the sample spacing for the in-lines. This takes account of the data points included in the cross-lines but not selected in the in-line spacings. 16 sample grids (8 transect and 8 point) were generated from each of the three master horizons. An interpolated grid surface was rendered from each of these 48 sample sets using a spline interpolation algorithm in the ArcView software (ESRI, 1991). The number of cells in each of the interpolated sample grids is on the order of 512^2 = 262,144 cells, being identical to the number of cells in the master grid surface (Figure 3). The grid cell size (12.5 m) was chosen to match the distance between each in-line hydrophone data point.

It was decided that the spline interpolation algorithm was the most appropriate interpolation method to be used in these experiments. Preliminary tests were carried out on a test point sample, N=64 (Figure 4d), to examine the two different algorithms. These were spline and kriging (Dubrule, 1983 and 1984). Results showed that the spline method was more suitable for this project. Hutchison and Gessler (1994) calculated interpolation error by running interpolations with some data points withheld. For each of these interpolations the root mean square error (RMSE) was less for the spline-interpolated surface than for the equivalent kriged surface. Regardless of which spline interpolation algorithm was used it was assumed that the outcome of this research would not be significantly influenced.

Evaluating Accuracy of Interpolated Horizons

Ehlschlaeger and Goodchild (1994) measured error distribution within a digital elevation model (DEM) by computing the difference between elevations of surveyed data points and elevation of the corresponding DEM pixel. Graphs of the distribution of error showed the effect of error sources. Fischer (1996) evaluated similar error maps. The root mean square error (RMSE) utilised for the tests has often been utilised in cartography to evaluate spatial error in interpolation of spatial data (Morad et al. 1994). Hunter and Goodchild (1995) discuss ongoing research into error modelling in spatial databases.

Each interpolated sample grid surface was subtracted from the corresponding master grid surface (differenced) to obtain an error-grid surface, which maps the magnitude and location of sampling error for each grid point. The statistics for the mean absolute error and the standard deviation of error were calculated, plotted, and analysed to evaluate interpolation accuracy with varying sample densities. Two error grids for each sample size were generated. In the first, the absolute value of error for each cell was mapped. In the second set of error maps, real error was mapped. For each error grid, an overall statistical value was calculated (Figure 6).

Regression of error on sample size and sample spacing was used to examine how errors were related to various sample intervals. Subsamples drawn from the error grids at areas of varying geologicalal complexity were also subjected to regression analysis to evaluate the hypothesis that errors would be related to structural complexity (Figures 7 and 8).

Results

The results of the data interpolation experiments for both transect and point samples clearly demonstrate a decrease in map accuracy as sample size decreases (Table 1). This decreasing accuracy shows up visually on the maps (Figure 4) for horizon C in the form of generalisation. For sample sizes smaller than 169 an apparent northeast-trending

	Horizon A		Horizon B		Horizon C	
Transect Samples						
sample size	mean error	standard deviation	mean error	standard deviation	mean error	standard deviation
36864	0.959	1.708	1.108	2.733	0.917	2.547
19456	1.916	3.22	2.429	5.33	1.981	5.146
12999	2.551	4.201	3.583	7.186	2.862	7.656
9982	3.152	5.185	4.598	9.379	3.962	10.611
8151	3.561	5.671	5.063	10.033	5.202	13.688
6919	3.998	6.31	6.162	12.464	5.591	11.502
5679	4.371	6.731	6.637	12.61	7.342	15.208
5056	4.537	6.837	7.235	13.974	8.07	17.298
Point Samples						
4096	2.408	3.73	2.921	5.896	2.508	6.222
1024	3.663	5.393	4.682	8.289	4.281	9.929
441	4.437	6.311	6.472	10.724	5.934	12.913
256	4.972	6.951	7.768	13.086	7.636	15.938
169	5.508	7.635	9.067	14.918	10.154	20.492
121	6.657	9.155	10.008	16.561	10.159	18.618
81	7.505	10.16	11.654	18.321	12.45	21.668
64	6.923	9.538	13.394	20.758	14.949	26.987

Table 1. Mean and standard deviation statistics for both transect and point samples for all 3 horizons (Shepherd, 1999).

feature is introduced dividing and obscuring the fault that extends across the north-eastern third of the image. The generalisation in these maps would likely lead to an entirely different structural interpretation than with use of maps derived from full resolution data.

When "standard deviations of error" are plotted against "sample size" for the transect samples (Figure 7) and the point samples (Figure 8), the systematic decrease in error with increase in sample size becomes clear. Trend lines were calculated by least squares computational methods for both the mean absolute error and the standard deviation of error in the three horizons. The best-fit trend lines were determined by maximum explained variance (R^2) values and graphical evaluation of regression residuals using various univariate models. Power functions fit best for Horizons B and C, but the best fits for Horizon A for both, the transect and point samples, for the standard deviation statistic, were logarithmic functions. Horizon A had less concavity (on linear scales) to the error versus sample size trend than the other two horizons, presumably reflecting the simple nature of the stratigraphic structure.

A comparison was made between the standard deviation of error for Horizons A, B, and C. There were substantial differences in the standard deviation statistics between the horizons, probably due to varying geological complexity between the horizons. Horizon A has no faults but may have a higher frequency of data while Horizons B and C each have faults of differing relief or throws. There was a greater decrease in accuracy with structural complexity for the point samples than for the transect samples (Figure 4a' and 4b'). If only power functions are considered then a possible trend between their constants and exponents can be analysed. This is justified because the regressions are all fairly strong with R2 > 0.97 for all values. The general form of the power function is:

$$E = a\,N^{-b} \qquad (4)$$

Where **E** is interpolation error, **N** is sample size, **a** is a constant representing the standard deviation of error at N=1, and **b** is an exponent expressing the rate of change in log E with log **N**.

The fact that the relationship between sample size and error, is inverse and alters exponentially is supported by the negative values (**b**<1) of the exponent **b** in the power functions. For the transect samples, the value of **b** ranges from -0.697 (horizon A) to -0.945 (horizons C) respectively, probably due to the much larger sample sizes whereas, for the point samples, the values are lower, being from -0.237 (horizon A) to -0.337 (horizon C), for the much smaller sample sizes. The distribution of the sampled data points could also be a factor and would require further investigation. The difference between the values of the constant **a** for the transect and the point samples is very great, likely due to sample data distribution as well as size (Table 2).

	Horizon A	Horizon B	Horizon C
Transect Samples			
constant a	2907.8	15156	56984
exponent b	-0.6965	-0.8114	-0.9448
Point Samples			
constant a	26.975	70.48	102.59
exponent b	-0.2371	-0.3033	-0.3368

*Table 2. Relationship between the constant **a** and the exponent **b** for all 3 horizons.*

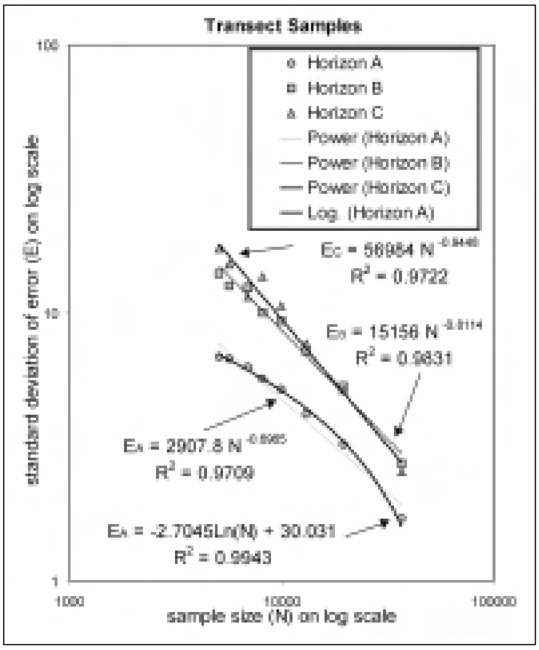


Fig. 7. Regression analysis for transect samples showing relationship between transect sample size and standard deviation of error plotted on logarithmic scales on both axes.

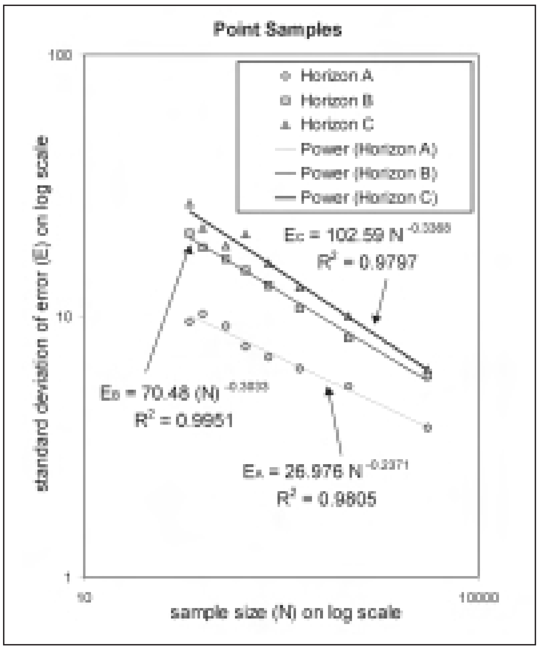


Fig. 8. Regression analysis for point samples showing relationship between transect sample size and standard deviation of error plotted on logarithmic scales on both axes.

For the standard deviation of error, values of the constant a and exponent b in Equation 4 show an apparent trend that supports the second hypothesis that error increases with structural complexity. Based on three sample-horizon experiments, values of a and b increase in value from horizons A to C. This empirical relationship appears to be linear for both the constant and the exponent in the point samples and for the exponent in the transect samples but is exponential for the constant in the transect samples (Shepherd, 1999). Although more experiments are needed to validate the relationship, this trend corresponds with increasing structural complexity.

One application for these results is to determine the interpolation accuracy of a series of parallel 2D seismic lines at equal intervals. For example parallel 2D lines were surveyed north of the Stag Oil Field in the Eastern Dampier Sub-Basin off the coast of Western Australia with a line

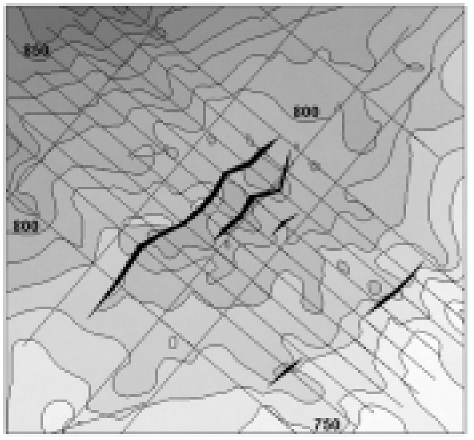


Fig. 9. Arrangement of parallel seismic sections from a 2D survey north of the Stag Oil Field in the Eastern Dampier Sub-basin off the coast of Western Australia. Closest line spacing is approximately 500 m.

spacing of approximately 500 metres (Figure 9); equivalent to the transect sample spacing shown by the grid (a) and the map (a') in Figure 4. Two-way travel time contours were interpolated using the LANDMARK Seisworks package. We can determine the accuracy of interpolation of this example from the regression analysis (Figure 7) and obtain an estimate of errors in the calculations of such things as volume of oil or gas in place and factor this into risk analysis assessments.

Conclusions

In two-dimensional analyses, it has previously been shown that map accuracy varies inversely with sample size on the one hand, and with the combination of sample size and feature complexity on the other. This study presents evidence that these relationships also apply to the accuracy of mapping three-dimensional features. Furthermore, this study provides a basis for quantifying this relationship. As hypothesised, the rate of decrease in interpolation error decreased with increase in sample size. This was found to be true for both types of sample sets: points and transects and corroborates the findings of MacEachren and Davidson (1987). However, there was a greater change in the rate of decrease in mean error and standard deviation of error for the point samples than for the transect samples. This is supported by the values of the exponent **b** in the power functions.

Sample size is not the only criterion that determines interpolation accuracy. The distribution of the data points also has to be taken into account. For example, the smallest transect sample size (N=5056) and the largest point sample size (N=4096) are similar in terms of sample size alone but radically different in terms of data point distribution.

The hypothesis that error increases with structural complexity is also supported by the analysis. The mean absolute error and the standard deviation are greater for horizons B and C than for horizon A. This is presumably because horizon A has no faults and a lower range of two-way travel times. All the graphs show a curvilinear trend (a nearly straight line on logarithmic scales) of summary errors (mean absolute or standard deviation) versus sample size (transect or point) where the slope is steepest at the smaller sample sizes. Power functions with a negative exponent fit most of these trends quite well.

Acknowledgments

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Volatility Matters: The Case for Investment in Resource Stocks

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Introduction

Investment by the public in resource stocks tends not to be fashionable, thereby impacting adversely on resources job security. Yet resources are one of the most significant contributors to Australia's GDP. In fact, the resource sector per employed person easily contributes the highest proportion of GDP of all industries in Australia.

Over the last 20 years, stock-market return from the investment in resource stocks has been about a third that of other heavyweight industries (eg banking and industrials). Therefore a *fait accompli* might be that public investors would ignore resource stocks.

This article shows that ignoring resources is shortsighted, because sophisticated investors look at more than the industry returns. They consider the efficiency of the investment, quantifying the returns and the variability in those returns.

The efficiency of an investment portfolio depends critically on how returns correlate between different stocks. Resources have the desired low correlation with other prominent industries, therefore adding resource stocks to a portfolio will increase its efficiency.

Mining contribution to GDP

Two measures of an industry's importance are its contributions to GDP at basic prices and to employment. A 1998-99 ABS survey[i] showed that manufacturing is the most significant industry (12.5% contribution to GDP) and is the second largest employing industry behind retail trade.

Where does Mining fit in? Mining contributed 3.9% to GDP and 0.9% to employment. Another way to look at these statistics is to compute the ratio of percent GDP to percent industry employment. Mining is by far the highest contributing industry. It has a ratio of 4.3, compared with 1.2 average of all industries.

Resources Industry - Stock-market returns

Resources, Banks and Industrials are three main industries for which stock-market data[ii] are available from the Reserve Bank. Figure 1 shows their cumulative stockmarket returns, assuming an index of 500 at December 1979. For reference, the ASX/S&P 200 is shown.

During the 1980s, we see that industrials were the best performer while resources had the lowest growth. During the 1990s, it was the turn of banks to shine. Resources growth was strong in the early part of the decade, but poorer in the later half.

Annual returns of these industries, on a financial year basis, are shown in Figure 2 and Tables 1 and 2. We see that over the last 20 years, banks were the standout performer (average return 14.2%), while resources had a 4% average return. Over the last 10 years banks still dominated, however resource performance was a little better, being closer to industrials.

Averages for 1980 - 2001	Banks	Indust.	Res.	ASX/200
Return	14.2%	11.5%	4.0%	8.2%
St. Dev.	17.0%	17.0%	25.5%	18.0%

Table 1.

Averages for 1990 - 2001	Banks	Indust.	Res.	ASX/200
Return	16.3%	9.7%	6.5%	8.8%
St. Dev.	15.2%	8.8%	13.8%	7.7%

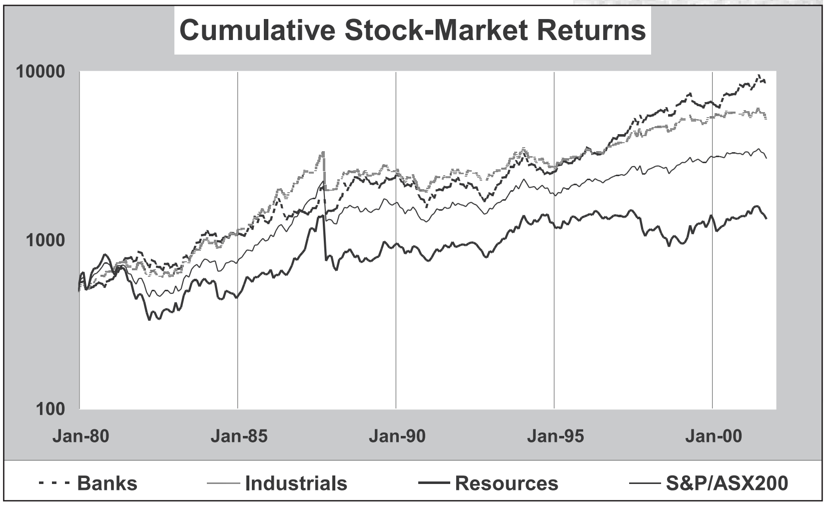
Table 2.

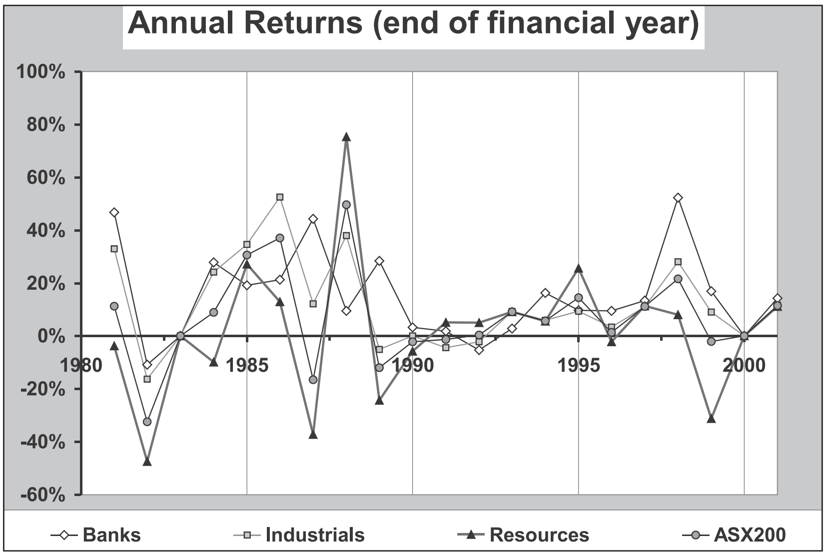
Given this information, where should investors put their money to maximise returns? All in banks, or diversify in some proportion among these sectors?

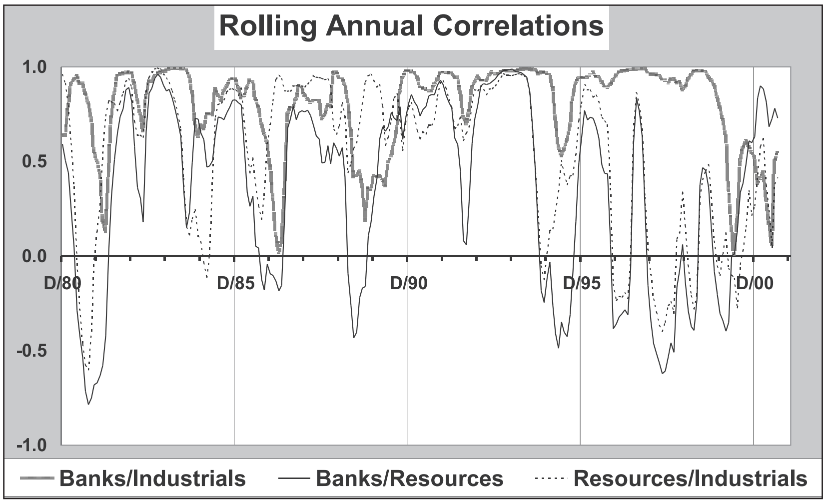
[i] "Industry Overview - Output and employment by industry" ABS, http://www.abs.gov.au/ausstats/abs@.nsf/0/B62C6D55E5E1C19ACA2569DE00263EE8?Open

[ii] Reserve Bank Statistical Table F6, accessed 2 Nov 2001 http://www.rba.gov.au/Statistics/Bulletin/index.html#table_f

Fig. 1. (Below) and Fig. 2. (Bottom)







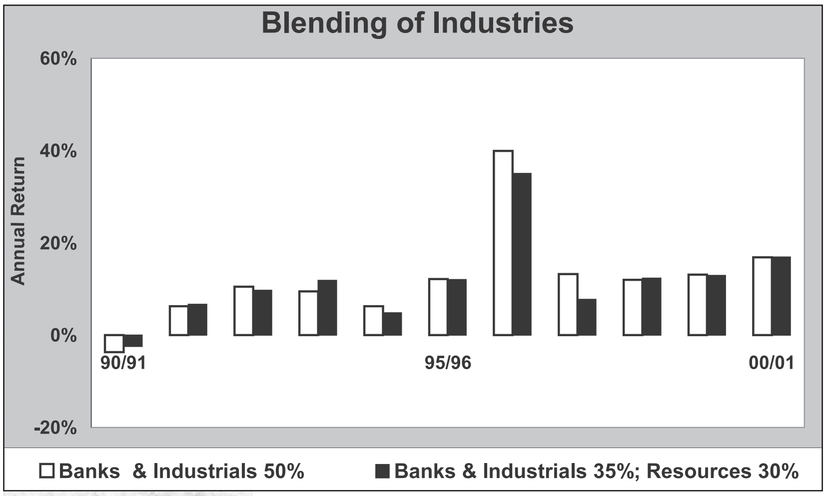


Fig. 3. (Top) and Fig. 4. (Above)

Before we answer this question, we need to introduce two concepts used by sophisticated investors - financial volatility and correlation.

Financial Volatility Concept

Financial analysts consider not only the expected return of an investment, but also quantify the volatility (uncertainty, or the range of possible returns). The standard deviation of the returns is taken as the measure of the volatility. Usually, investments with a higher return for a given volatility are favoured [Markowitz (1952, 1957) introduced this concept of "Efficiency" to the financial world, and was later awarded the Nobel Prize for Economics].

Tables 1 and 2 show the standard deviation (volatility) for each of the industries. We see that since 1980, resources have been the most volatile (25.5%), however in the last 10 years resources were less volatile than banks.

A portfolio of only resource stocks is clearly inefficient. To be efficient, highest volatility should provide highest returns.

Therefore, pundits might say that it is a waste of money to invest in resources... but they would be wrong. There is another factor to consider - *correlation.*

Correlation - Financial Concept

Financial analysts compute another measure of stock performance - the correlation of its returns with other stocks and industries. The correlation is required to calculate the volatility of a portfolio.

A portfolio's *expected return* is easily found from the weighted average of returns of the individual projects.

A portfolio's *volatility* is not the weighted average of volatilities, but is related to the covariance between stocks' return (see Moriarty (2001) for more discussion of this concept).

The outcome is that in a portfolio, individual stock volatilities cannot be added. As an example, it is possible to have two industries with high volatilities. Yet when combined, the portfolio volatility may be considerably lower than either of the individual volatilities. This happens if the correlation between these industries is low.

Financial diversification ("not putting all your eggs in one basket") is mathematically a consequence of selecting investments that have the lowest correlation. This reduces the volatility of a portfolio, thereby increasing its efficiency.

Rolling annual correlations for banks/industrials, resources/banks and resources/industrials are shown in Figure 3 and Table 3. Note that banks/industrials had the highest correlation (average 0.8), while resources/banks had the lowest (average 0.5).

Therefore a portfolio of only banks and industrials (which both have higher returns than resources) is less diversified than a portfolio of say only banks and resources. The case is proposed that diversification in a portfolio should include exposure to resources.

Average Correlation 1980 - 2001

	Banks	Indust.	Res.	ASX/200
Banks	1.0	0.8	0.5	0.7
Indust.	0.8	1.0	0.7	0.9
Res.	0.5	0.7	1.0	0.9
ASX/200	0.7	0.9	0.9	1.0

Table 3.

As an example, consider the performance of two portfolios over the last 10 years. One portfolio had 50% banks and 50% industrials, the other had 35% of both banks and industrials and 30% resources. The financial year average returns are shown in Figure 4. The average returns for the two portfolios were 12.4% and 11.6% respectively.

Many investors would prefer the non-resource portfolio, yet its volatility was 10.6%, higher than the resource portfolio 9.3%. To be relatively efficient, the non-resource portfolio having being exposed to higher volatility, is expected to achieve higher returns. (Note that higher volatility does not guarantee higher returns, just that it provides *potential* to achieve better returns).

Over the last financial year, these portfolios would have had the same 17% return (Figure 5). The volatilities,

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Minotaur Resources Announces Copper Find in South Australia

This month's good news story must surely go to Minotaur Resources Ltd, which is the operator of the Mt Woods Joint Venture. On 14 November it announced a significant copper discovery at the Prominent Hill Prospect (see Fig. right).

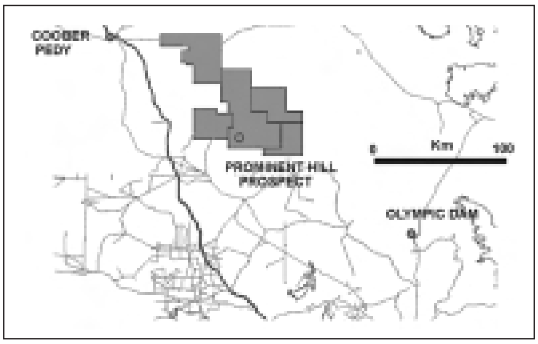

Fig. 1. Location of the Mt Woods Joint Venture Tenements and the Prominent Hill Prospect.

The results of the first hole drilled to test a discrete gravity anomaly measuring about 1500 x 500 m are shown in Table 1.

From (m)	To (m)	Interval (m)	Copper (%)	Gold (g/t)
107.8	128.0	20.2	0.03	2.3
200.0	307.0	107.0	1.94	0.66
including: 272.0	307.0	35.0	3.86	0.63
429.0	450.0	21.0	0.90	0.46

According to the announcement, "the vertical hole passed through 108 m of younger sediments before intersecting a massive haematite-supported breccia. Haematite dominates both the matrix and breccia clasts. The hole reached 450 m in mineralised haematite breccia at which point drilling was terminated pending mineralogical assessment and analytical data."

"Copper mineralisation (chalcocite) occurs as disseminations and thin veins within the haematite matrix. The chalcocite is concentrated at about the -300 m level,

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though, were different. The non-resource portfolio had 10.6% volatility, compared with 9.3% for the resource component portfolio. The latter portfolio is more efficient, because it achieved the same return with a lower volatility.

The case is made that efficient investment portfolios should contain some provision for resource stocks, despite their lower average return. Typically, resource stocks form about 5 to 20% of sophisticated investor's portfolios.

Determining the relative exposure of a stock in a portfolio is a factor of each its expected returns, the volatility and correlation of returns with other stocks. The optimal exposure of a stock depends on how much volatility an investor wishes to accept. Given this constraint of desired volatility, Monte-Carlo modelling is usually employed to determine the relative exposures that maximise the return.

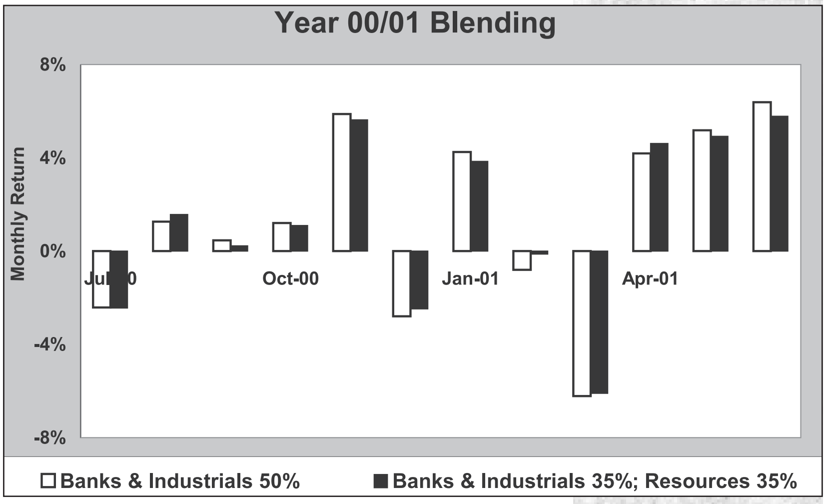

Fig. 5.

Summary

Resources are a significant and valuable contributor to Australia's GDP. Cursory inspection of past returns would suggest their performance is unattractive compared with glamour stocks such as banking.

During certain periods, resource stocks are good performers. However, the case is made that even during times when resource stocks are not the best performers, they should be included in a personal investment portfolio.

The returns from resource stocks have a lower correlation with other major industries. Including resources therefore decreases the volatility of a portfolio, thereby improving the efficiency (stability) of its returns.

Investment in resource stocks should be actively promoted. If the general public is made aware of concepts such as portfolio efficiency, it will be to the benefit of all those work in the resource industry.

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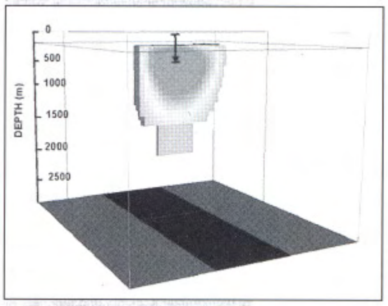
Fig. 2. Prominent Hill Prospect - Drillhole DDH URN1 on simplified 3D Gravity Inversion Model: view to Northeast



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although lesser amounts occur below this depth. Traces of bornite, chalcopyrite and some gold are visible in polished section. Gold is concentrated in the top section of the breccia with analytical results to be confirmed by fire assay."

The 3D model illustrated left shows the body extending to 1500 m depth.

"The gravity anomaly is partially coincident with a well-defined magnetic anomaly of approximately the same dimensions and lies on the southern margin of the Mt Woods Inlier. Two holes were drilled on the magnetic feature in the early 1990s and intersected altered ultramafic skarns. These holes did not intersect the haematite breccia.

The results support the concepts of the Minotaur generative team, which identified the southern margin of the Mt Woods Inlier as one of the most prospective areas in Australia to host Olympic Dam-style, copper-gold mineralisation.

The Mt Woods joint venture involves Minotaur (earning 19%), as operator, BHP Billiton (earning 51%) and Normandy Exploration Pty Ltd/Sons of Gwalia Ltd/Sabatica Pty Ltd. All the tenements have Native Title agreements while Heritage Site Clearances have been completed over the Prominent Hill Prospect."

The information above was obtained from the website; www.minotaurresources.com.au.

A challenge for the joint venture could be the marketing of the resource. Copper prices are not all that good at present, and with BHP Billiton and Phelps Dodge both recently announcing production cut backs totalling 390 000 t/yr, it would help to find some other goodies on the Prospect.

Morgan Proposes Splitting WMC

Changes in the Australian resource industry are continuing unabated. WMC, which had been identified as a take over target, is now looking to split the company into two listed companies (a demerger according to the current jargon). Apparently, the board of WMC was not prepared to recommend the $10.20-a-share or $11.2 billion offer by Alcoa of the US. Instead Hugh Morgan, its chief executive, is proposing to split WMC into two listed companies, with one (WMC Alumina) to hold its stake in the Alcoa-managed AWAC alumina business, and the other (WMC Minerals) to hold its copper, uranium, nickel and fertiliser businesses. As one might expect Alcoa is reportedly not happy with these plans and, as another signal that all is not well between the two companies, Hugh Morgan has quit the Alcoa board. This is where the matter stands at the time of writing and the final outcome is far from clear.

The WMC share price has been very volatile during the last few months with the value of the company surging to a high of $10.9 billion in mid-November from a low of $7.4 billion in mid-September. In this environment lots of money is changing hands.

One of the consequences of the happenings at WMC appears to be a major reduction in its exploration investment. Apparently, greenfields exploration will cease, and the annual exploration budget is reported as being reduced from $60 million to $25 million. This is a big turnaround for a company that has built its successes on the discoveries of new ore deposits, and very disappointing for mineral exploration in Australia.

Scintrex/Auslog Releases New 'Hand Meter'

Scintrex/Auslog has just announced a new, as yet unnamed, handheld meter, which is available in 3 sensor designs:

- Natural Gamma
- Magnetic Susceptibility
- Conductivity

The measurements can be taken in 3 modes:
1. Continuous logging measurement (effective for a quick measurement of the physical properties of an outcrop or drill hole core.)

2. Spot measurement (activated by trigger) for more detailed sampling of the material with a sample time set by the user between 0-250 seconds.

3. Combination continuous log and spot measurement to allow the user to continuously record, but also take a more detailed recording of a specific area of interest.

The sensors are used in conjunction with a Palm Pilot computer and more details can be obtained from the website: www.auslog.com.au.

Normandy's Future Unclear

In the October Preview, it was reported that AngloGold had launched a $3.2 billion bid for Normandy Mining Ltd. Well in mid-November, North American based Newmont Mining made a $3.8 billion counter-bid.

This comprises make a predominantly scrip-based takeover offer for all of Normandy Mining Limited issued shares in parallel with a merger with Franco-Nevada Mining Corporation Limited. If successful, the transaction will create one of the world's biggest and best international gold companies. Newmont would rank first in the world gold industry with respect to annual production and reserves, and would have one of the lowest cash cost profiles in the industry.

However, the AngloGold's bid of 2.15 of its shares for every 100 Normandy is still relevant because in the final analysis both bids have to be analysed in the context of the share prices of the interested parties and of course, and the price of gold. Depending on how and when the calculations are carried out there may not be much difference, in the context of Normandy's shareholders, between the two bids.

Whoever is successful, the outcome, as far as the Australian resource sector is concerned will be clear; another Australian company taken over by an Offshore multi-national.

It may be good for the Normandy shareholders, but the benefit to the Australian mineral industry is hard to see.

Sea Level Rise - History and Consequences

Editors:
Bruce C. Douglas, Michael S Kearney and Stephen P. Leatherman
International Geophysical Series, Volume 75, Academic Press, 232 pages
ISBN: 0-12-221345-9,
Price: $152.35

Reviewed by Tom Kerr

The subtitle of this book is rather a misnomer as the history and consequences of sea level rise comprise less than half the contents. The remainder is focussed on the instruments and methodology of measuring this phenomenon and, most importantly, the uncertainty of those measurements. This uncertainty has serious consequences in the ongoing debate over global climactic change also known as greenhouse warming.

The first chapter is an introduction; sea level and the geoid are explained and some of the many variables which affect them are introduced. Is sea level really rising? Apparently so, and though the exact amount is debatable, tide gauges suggest that a rate of just under 2 mm/yr is close to the mark. The most obvious cause is the thermal expansion of water as the planet warms up. Of course we cannot accurately know the true volume of the oceans but nearly all calculations indicate that this thermal expansion cannot account for the entire rise.

Chapter 2 does give us some history - specifically of the US Atlantic Coast in the late Holocene. It seems that sea level may have been several metres higher during a particularly warm spell 5-8000 years B.P. Obviously there were no tide gauges then but there are numerous raised scarps and very occasional basal peats well inland of the current shoreline. In fact the author spends considerable effort constructing a model for transgressive wetlands. I suspect this model would actually be very rare and that catastrophic processes are more common than he allows. The actual extent of the rise cannot be quantified: there is simply too much dubious data, isostatics, faulting, geoid variations etc.

The third chapter brings us into the era of the modern tide gauge. This is relatively brief. With a few exceptions, it effectively covers only the last century and most of the data comes from the coast of the North Atlantic. This is unfortunate as these coasts are still recovering from the weight of the last glaciation. The corrections needed to reduce this information to a common datum are so numerous that I was instantly reminded of a high precision gravity survey but with some very wooly assumptions made about the magnitude of the corrections. Besides, all of this information is purely coastal which makes it very sparse compared with the size of the open ocean.

In general, the most significant of the corrections for the North Atlantic is the Glacial Isostatic Adjustment (GIA) and, in Chapter 4, W.R. Peltier tackles this in a quantifiable manner. This is fairly complex as the glaciers had far-field as well as the more obvious effects and even affected the rotation of the planet. There is some serious mathematics here involving, among other esoterica, the viscosity of the mantle. Peltier admits that some fine-tuning remains to be done but this is a fairly heroic effort and, after all, somebody has to take the first step further than general arm-waving.

Chapter 5 concerns man's effect on the quantity of water reaching the oceans. Surprisingly, this is estimated to be negative, i.e. we are lowering sea level by 0.9+/-0.5 mm/yr. This seems astonishing to me when I see almost daily images of roaring floods caused by deforestation and contemplate the run off from urbanization. The author asserts that the culprits are reservoirs and irrigation with their attendant evaporation and infiltration. I think this theory could cause some contention.

Chapter 6 introduces us to the wave of the future - satellite altimetry. The author takes us through all of the hardware and software, and discusses the uncertainties of even this method. Among the corrections that have to be made is one for the humidity of the troposphere along the satellites flight path. The latest techniques reduce the net error of the measurement to about 2 cm. Of course the method is too recent to establish long term trends but a recent study of 5 years in the mid 90's suggests a rise rate of 2.5+/-0.7 mm/yr. The huge advantage of satellite altimetry is the overwhelming mass of data from the open ocean, which should be amenable to digital filtering (Besides, those pseudogravity maps look lovely on the office wall). Logically, this chapter should have followed Chapter 3, as they are both primarily about how we measure.

There follows a very brief chapter on some long-term sources of noise in the data. One, which was completely new to me, is called Rossby Waves, which take 5 years to cross the Atlantic! Now throughout the book, there are references to such phenomena as the Southern Ocean Index and this chapter could have been expanded to include the rest of the long-term sources of noise.

Chapter 8 relates some of the consequences of sea level rise. Here again, data are a problem as no coastlines are sufficiently mapped to predict how great a transgression would be caused by a rise of 1 m in sea level and traditional mapping methods are far too slow and labour intensive to make a meaningful impact. The solution would appear to be airborne laser altimetry with which we are familiar...airborne contractors, take note! The author briefly discusses:

1) Beaches are mostly eroded by storms which some predict will increase in intensity and frequency as global warming proceeds.
2) Coastal wetlands are probably in better shape because they are continually accreting biomass and sediments.
3) Deltas are a disaster. Add 1 m to the seas and roughly 16% of the land and 13 million people in Bangladesh are in grave trouble.
4) If you live in Kiribati or most of the Maldives, start packing.

This slender volume raises many more questions than it answers. There is general consent that sea level is rising and even a measure of agreement on the rate it is rising. However, nearly all calculations of thermal expansion, glacial melting, etc. cannot account for the magnitude of this rise. Where is all the water coming from? Moreover, a handful of old tide gauge recordings seem to indicate that sea level began its rapid rate of rising about the middle of the 19th Century before anthropogenic warming of the Earth's climate had any significant impact.

The book is well illustrated and contains numerous charts and graphs. The only serious mathematics are in chapter 4 though the interested non-specialist might balk at the $152 price tag. It includes a CD-ROM with tide gauge statistics and images of recent temperature fluctuation in the open ocean. There are exhaustive references appended to each chapter but the index is disappointingly brief.