Preview

Australian Society of Exploration Geophysicists

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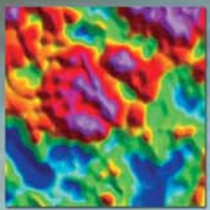
Air-FTG™: Bell Geospace's Airborne Gravity Gradiometer



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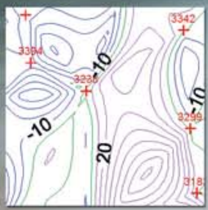
Seismic Imaging: Science and Art



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Geophysical Monitoring of Tree Root Zones

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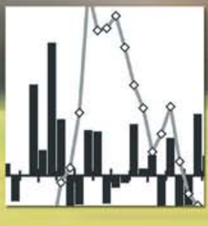
Performance of ASX Resource Stocks



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WMC Resources Limited
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David Denham

The Sydney Conference will be less that a year away when this Preview hits your desk, so take a look at the call for papers on the inside back cover and don't forget to mark the dates in your diaries for next year. It promises to be an exciting meeting which will be co-sponsored by the ASEG and PESA.

Take a note of the mineral exploration statistics on page 39. There is good news at last for the mineral exploration industry because exploration expenditure has increased for four consecutive quarters and appears to be coming out of the terrible trough we had during 2001 and 2002.

More good news comes from the membership levels in the Society. You can see on page 9 that 42 new members have joined since the last Preview was published. A great outcome, particularly for Western Australia, which recruited 26 new members.

The total membership of the ASEG at the end of June stood at 1382. This is much better than the 1312 number for 2002 and 1367 for 2001.

In an environment where professional societies appear to be ageing and declining, this is an excellent outcome for the ASEG.

We have four feature articles in this issue on widely different topics. Binzhong Zhou and Peter Hatherly contribute an article on 'Seismic Imaging: Science and art', Noll Moriarty tells us all about 'Investment in the Resource Industries', Anton Kepic analyses the geophysics of tree roots and Scott Hammond and Colm Murphy show us some airborne gravity results from Africa.

Something for everyone, enjoy the read.

Finally a reminder that the FASTS' Science meets Parliament event takes place in Canberra on 14th and 15th October 2003. This provides an excellent opportunity for members of professional societies to make an impact on federal politicians and present arguments on matters of concern in the Science Sector face to face with MPs. SmP days also provide a great insight into the happenings within the Commonwealth Government. I can recommend attendance and suggest that those interested inspect the FASTS website at: http://www.fasts.org/.

David Denham

David Denham

This month's article will focus on a very visible issue for all members: technical meetings in general and local access to world-class speakers in particular. In that regard, May was a very impressive month for many of us! Olivier Dubrule presented his one-day course on the use of geostatistics to incorporate information from seismic data in reservoir models. This course was made possible by the SEG through their Distinguished Instructor Short Course (DISC) program. The DISC was this year held in Perth, Canberra, and Brisbane. The DISC in Perth was very well attended with 60 participants, while the other two locations each had approximately half that number. Besides giving people access to a world-class speaker, the DISC also serves as a membership drive. Also in this aspect the DISC was very successful: 19 people signed-up for SEG membership and 22 for ASEG membership.

The other event of interest was the Multiple Elimination Workshop, which was held over two days in Perth at the end of May. Interest in this workshop was impressive with 60 participants flying into Perth from all over the world. The seismic processing contractors were especially well represented and, in many cases, they even went through considerable cost and effort by flying in their global experts. The ASEG had organised for Art Weglein to participate in this event and serve as discussion leader.

The workshop had unfortunately initially created an undercurrent of suspicion and antagonism. Fortunately, the mood improved greatly during the day and especially during the river-cruise dinner on the evening of the first day. Nothing breaks the ice like a good meal and a few glasses of wine! The ASEG managed to sign-up nine new members during this workshop. It is also good to note that all three DISCs and the workshop managed to break-even financially, not in the least due to generous sponsorship by participating companies.

Klaas Koster

Looking ahead at upcoming events, there are several opportunities to attend presentations. In August, Martin Landro will be giving a series of presentations on quantitative seismic methods throughout Australia. Also in August, there will be a one-day training course in Perth on interpretation of 3D seismic data by Tracy Stark, who used to work on visualisation at ARCO's research centre. In the not too distant future the ASEG will be organising a workshop in Perth on AVO with at least one (probably John Castagna) and possibly even two world-leaders in this field. Hopefully, you will have time to attend one or more of these events!

You may have noticed that WA and hydrocarbons feature rather prominently on our calendar. Other initiatives are certainly welcome! So, if you know of someone who could give an interesting and relevant presentation and want him/her to come down, get it organised. The first step is to contact your local state branch or someone on the Federal Executive and they will help you get started. You might be surprised to find out how many people share your interest in the subject and will make time and money available to participate.

Klaas Koster

Correction

In the June *Preview* on page 30 a symbol was omitted from the 2nd last line in the first column. It should read: "where ϕ is the geodetic latitude..."

Aims and Scope

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

Deadlines

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

Advertisers

Please contact the publisher, RESolutions Resource & Energy Services Pty Ltd, (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 **October 2003 issue will be 22 September 2003.** A summary of the deadlines is shown below:

Preview Issue	Text & articles	Advertisements
106 Oct 2003	15 Sep 2003	22 Sep 2003
107 Dec 2003	15 Nov 2003	22 Nov 2003
108 Feb 2004	15 Jan 2004	22 Jan 2004
109 Apr 2004	15 Mar 2004	22 Mar 2004

2003

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

October 26–31
SEG International Exposition & 73rd Annual Meeting
Venue: Dallas, Texas, U.S.
Website: www.seg.org

December 8–12
2003 AGU Fall Meeting
Venue: San Francisco, California, USA
Website: www.agu.org/meetings/fm03/

2004

February 8–13
Geological Society of Australia
17th Australian Geological Convention
Venue: Hobart, Tasmania
Theme: Dynamic Earth: Past, Present and Future
Website: www.17thagc.gsa.org.au

March 28–31
APPEA Conference & Exhibition
Venue: National Convention Centre, Canberra
Contact: jhood@appea.com.au
Website: www.appea.com.au/Events/AppeaEvents.asp

March 31–April 4
International Conference and Exposition (SEG Beijing/SPG/SEG) — postponed from 2003
Venue: Beijing, China
Website: www.spgol.org

May 17–21
Joint Meeting: AGU and the Canadian Geophysical Union (CGU)
Sponsors: AGU, CGU
Venue: Montreal, CANADA
Website: www.agu.org/meetings

June 7–11
66th EAGE Conference and Exhibition
Venue: Paris, France
Website: www.eage.nl

August 15–19
ASEG, in collaboration with PESA
17th International Conference and Exhibition,
Theme: Integrated Exploration in a Changing World
Venue: Sydney Convention Centre, Sydney NSW
Website: www.aseg-pesa2004.org.au

September 27–October 1
SEG 2004
Theme: Predictive Mineral Discovery Under Cover
Sponsors: Society of Economic Geologists, Society of Geology Applied to Mineral Deposits and Geoconferences (WA) Inc.
Venue: Perth, WA
Website: www.cgm.uwa.edu.au/geoconferences/seg2004/index.asp

CSIRO's Exploration and Mining activities at North Ryde to cease?

CSIRO's Division of Exploration and Mining is to be restructured and the Divisional Executive is considering substantial changes to realign its research activities to address priority issues for a sustainable Australian exploration industry. These changes follow considerable discussion with CSIRO's stakeholders, particularly industry and government, in an environment where the Division is receiving 9.6% fewer appropriation dollars.

The key outcomes are:

- Exploration research will be predominantly focused at the Australian Resources Research Centre (ARRC) in Perth.
- There will be a significantly reduced presence at North Ryde (Sydney) with the intention of closing CSIRO Exploration and Mining's activities there over time.
- Exploration research will be structured around four themes:
  - Where to explore;
  - Recognising ore systems;
  - Exploring under cover; and
  - Knowing what to mine.

There will also be consolidation of the exploration science areas including geophysics (ARRC), geochemistry (ARRC and Clayton) and geoinformatics (ARRC). Work on hyperspectral and EM Modelling will continue in Sydney for the present, but future expansion in these areas will occur at ARRC with the longer-term goal of basing these activities in Perth.

This year the focus of change will be on the Division's exploration component. Next year, the focus will shift to a critical analysis of the mining activities.[1]

It is sad to see the North Ryde facility scheduled for closure. It hosts one of Australia's main geoscience laboratories, which has been developed over many years, and will be a significant loss to the geosciences both nationally and particularly in the Sydney area.

The NSW Minister for Mineral Resources, Kerry Hickey, wasted no time in sheeting the blame at the Federal Government for not providing adequate funding.

In his media release on 7 July he "Condemned the Federal Government for axing 70 jobs at the CSIRO's mining and exploration lab in North Ryde and said the job losses could not have come at a worse time.

Australia desperately needs minerals and petroleum exploration and investment," Mr Hickey said.

"The Federal Government's refusal to properly fund the CSIRO is having a devastating impact across the scientific community. Nowhere is that more obvious than in mining and exploration."

It seems to me that the 10% cut applied by CSIRO's CEO Geoff Garrett to those Divisions not involved in the Flagship Programs, and the failure of CSIRO to meet its external earnings targets for 2002/03, have clearly triggered the re-organisation. The irony of the situation is that the Exploration and Mining Division was one of the better performers in attracting external earnings.

The key to the future will be the success of the programs to be developed under the four themes.

[1] The material in the section above was obtained from CSIRO.

More and more reviews

If you thought that there had been more than enough reviews and inquiries in the last twelve months, then you would be wrong because the evaluation and review process in government goes on forever.

We have just digested the National Research Priorities and the Higher Education Review and are in the process of analysing the 48 Recommendations in the House of Representatives Standing Committee on Science and Innovation's report on "Riding the Innovation Wave: The case for Increasing Business Investment in R&D". When along comes two new Reviews.

Review of closer collaboration between universities and major publicly funded research agencies

In May, Brendan Nelson the Minister for Education Science and Training announced that former farm industry leader and leading businessman Donald McGauchie has agreed to chair this Review.

According to Minister Nelson: "The Review will encompass all Australian public universities and four publicly funded research agencies — the CSIRO, the Australian Nuclear Science and Technology Organisation, the Defence Science and Technology Organisation and the Australian Institute of Marine Science.

The Review will also investigate alternative funding models to develop excellence across the national research effort, including the merits of broadening access by the publicly funded research agencies to the competitive grant schemes operated by the Australian Research Council and the National Health and Medical Research Council.

The review is not about the structural break-up of public sector research agencies such as CSIRO. The Government remains committed to the CSIRO Flagships initiative, which builds on the breadth of scientific expertise across the whole of CSIRO to address many of Australia's most pressing problems, and for which the Government provided an additional $20M in the 2003–04 budget.

Mr McGauchie has been asked to report to me by 30 November 2003 so that the review, along with the science and innovation mapping exercise, can serve as an input to the Government's post-Backing Australia's Ability science and innovation policy agenda."

In other words the review is about money, collaboration and funding models and is very important.

The website for the review is: www.dest.gov.au/ collaboration, and submissions can be sent to:

- Research Collaboration Review Secretariat, Department of Education, Science and Training at: collaboration_review@dest.gov.au

Committee appointed to assess research plans

Three weeks later the Federal Science Minister Peter McGauran appointed the Chief Scientist, Dr Robin Batterham, to chair a committee reviewing plans developed by Commonwealth Research Agencies and funding bodies to implement National Research Priorities.

The role of the seven-member Committee is to examine the extent to which the agencies plans support the National Research Priorities. They will assess plans from research funding bodies such as the Australian Research Council and the National Health and Medical Research Council and from research agencies ranging from the CSIRO to the Australian Nuclear Scientific and Technology Organisation. "The Government takes the research priorities and their implementation very seriously and these plans should reflect a strong commitment by each agency to deliver outcomes," Mr McGauran added.

The National Research Priorities are designed to focus research into key areas that can deliver significant economic, social and environmental benefits to Australia. The four priority areas for Commonwealth funded research are:

- An Environmentally Sustainable Australia;
- Promoting and Maintaining Good Health;
- Frontier Technologies for Building and Transforming Australian Industries; and
- Safeguarding Australia.

Further details are available on the National Research Priorities website: www.dest.gov.au/priorities.

Meanwhile.....

The following reports are being prepared:

The Cooperative Research Centres' Evaluation (see Preview June 2003),

- The National Science Stocktake (see Preview April 2003);
- The House of Representatives report on Impediments to Resource Exploration (due out in September 2003), and
- The report of the Mineral Exploration Action Agenda to Minister Macfarlane.

And I am sure I may have missed some!

Departmental and agency logos to go

In a surprise move announced on 23 July 2003. The Government has instructed all government departments and agencies to abandon their different logos, so that there is a single, recognizable Australian Government logo.

This decision runs counter to the "Yellow Pages" philosophy encouraged by the government for agencies and departments to become more business-like.

Agencies such as Environment Australia, Centrelink, Geoscience Australia, and the Australian Taxation Office, may have to abandon all the good work done at considerable expense designing and producing logos.

Even organisations such as CSIRO, ANSTO and the ABC will have to argue special cases to retain their distinctive signage, and the Prime Minister himself will evaluate each case on its merits!

So, there you have it, more changes in stationary, more u-turns in government policy and more control by the Prime Minister.

Eristicus

Koya Suto receives an Award for Merit from SEGJ

Congratulations to Koya Suto, Chairman of the ASEG Membership Committee. In May this year he received an Award of Merit from the SEGJ for his contribution to the society by acting as a bridge between SEGJ and ASEG. These awards are issued every five years and there were two recipients this time. The ceremony took place at the 108th Conference of the Society of Exploration Geophysicists of Japan, which was held in Tokyo from May 28 to 30th 2003. Incidentally, at the same meeting the SEGJ celebrated its 55th anniversary of the foundation.

Koya (on the left) receiving his award from the SEGJ President Yuzuru Ashida.

Ken McCracken to receive the 2003 Haddon King Medal

Congratulations also to Ken McCracken. At a ceremony to be held at the Shine Dome, Australian Academy of Science, Canberra on August 28th, Ken will be presented with the 2003 Haddon King medal for distinguished contributions to mineral exploration. This follows his award of the Ian Wark Medal in 2001 (see Preview of February 2002).

By some strange coincidence, both events have bushfire connections. When Ken was awarded the Wark medal in early 2002, he only just escaped from the 2002 bushfires that raged through his property, and of course the effects of the 2003 bushfires are still making a huge impact in Canberra.

New Office Bearers for the Australian Geoscience Council

For 2003/04, the following office bearers were elected to the Australian Geoscience Council:

President:	David Denham (ASEG, GSA, AusIMM) denham@webone.com.au
President -Elect:	Mike Smith (ASEG, AIG, GSA) mike_rpgeo@optusnet.com.au
Chairman:	Kevin Dodds (ASEG) kevin.dodds@csiro.au
Secretary:	Brigette Hall (AusIMM) bhall@ausimm.com.au
Treasurer:	Don Larkin (AusIMM) ceo@ausimm.com.au

The AGC comprises representatives of nine geoscientific societies and represents over 7000 members of the geoscientific profession. The societies represented are:

Association of Exploration Geochemists
Australasian Institute of Mining and Metallurgy
Australian Geoscience Information Association
Australian Institute of Geoscientists
Australian National Chapter, International Association of Hydrogeologists
Australian Quaternary Association
Australian Society of Exploration Geophysicists
Geological Society of Australia
Petroleum Exploration Society of Australia

Kabela Geophysics Pty. Ltd. closes

It is with regret that Kabela Geophysics Pty. Ltd. ceased business on June 30th 2003 owing to the illness of the Principal Geophysicist, Keith Lodwick. His current course of treatment for prostate cancer might allow him to return to geophysics in a private capacity later on. After working with BMR Australia and Union Oil Company of California (now Unocal), Keith established Kabela Geophysics as a consultancy in geophysics in 1979, catering mainly for clients in Australia and Indonesia.

We wish Keith well for a speedy recovery.

New Members

ASEG welcome the following new members to the society. Membership was approved by the Federal Executive at its meetings on May 28th and July 2nd 2003

Name	Organisation	State
Daniel Joseph Bishop	Woodside Energy Ltd	WA
Richard James Bisley	WesternGeco	WA
Peter Brazier	CSIRO Petroleum	WA
Lee Robert Bril	Veritas DGC	WA
Tristan William Campbell	Earth Connections	WA

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Christopher John Carty	Eastern Star Gas	ACT
Dmitri Chagalov	CGG	WA
Tessa Chamberlain	Qld Dept of Natural Resources & Mines	Qld
Radin Ciz	CSIRO Petroleum	WA
Dan Clark	Geoscience Australia	ACT
Ewen Jun Cowan	SRK Consulting	WA
Alain Delorme	CGG Australia Services	WA
Richard Evans	Curtin University	WA
Lincoln Fenner	BHP Billiton Petroleum	WA
Daniel Rene Guibal	SRK Consulting	WA
Bruce Maxwell Hartley	Curtin University	WA
John A. Hefti	ESSO Australia	Vic
Graham Hodgkiss	Veritas DGC	Singapore
Jessica Ann Horsley	MNA Global	Qld
Kevin Donald Jarvis	Jason Geosystems	WA
Andrew Trefor Jones	Geoscience Australia	ACT
Leano Kotlhao	GeoBot (Pty) Ltd	Botswana
Danielle Marie Kyan	SRK Consulting	ACT
Glen McFadzean	Woodside Energy Ltd	WA
Thabo James Metcalfe	Origin Energy Resources Ltd	Qld
Michael Bernard Mills	Velseis Processing Pty Ltd	Qld
Nigel David Mudge	CGG	WA
Bjorn Muller	WesternGeco	WA
Maighread Veronica NiDheasuna	Tap Oil Limited	WA
Ole Nielsen	Geoscience Australia	ACT
Timothy O'Hara	BHP Petroleum	WA
Damien Warwick O'Rourke	Woodside Energy Ltd	WA
Richard Patenall	WesternGeco	WA
Pierre Georges Arthur Plasterie	CGG	WA
Simon Matthew Polomka	Woodside Energy Ltd	WA
Kimberley Saflian	Coffey Geosciences	NSW
Sukumaralingam Suntharalingham	AL Technologies	WA
Bruno Thomas	Santos Limited	SA
John Hywel Thomas	Dept of Primary Industries	Vic
Maznix Vermaas	Jason Geosystems	WA
Felicity Jane Walker	Woodside	WA
Benjamin William Whitfield	Minerex Environmental Ltd	Ireland
Ian James Wilson	University of Tasmania	TAS

Applications called for Hohmann and Fulbright Scholarships

Hohmann Scholarships for Study in Electrical/Electromagnetic Geophysics

Following the successful *Third International Workshop in Three-Dimensional Electromagnetics* held in conjunction with the ASEG meeting in Adelaide in February, the G W Hohmann Memorial Trust is pleased to announce funding for several undergraduate and graduate scholarships for study in electrical or electromagnetic geophysics at an Australian university during the 2004 academic year.

Two $2,000 scholarships will be awarded to outstanding students starting an Honours or equivalent degree, and one $6,000 scholarship to an outstanding student in an MSc or PhD program.

Closing dates are October 31st 2003 for the Honours scholarship, and November 30th 2003 for the MSc/PhD scholarship. Applications forms are available from Doug Roberts, Secretary ASEG Research Foundation, at dcrgeo@tpg.com.au.

The Hohmann Trust is an active memorial to the work of Gerald W (Jerry) Hohmann as a scientist and educator. The Trust raises funds through personal donations and special events that are re-invested into education and training in electrical and electromagnetic geophysics. Special events have included an informal workshop at the University of Utah in 1993, a short course on electrical and electromagnetic methods at the 1994 Symposium for the Application of Geophysics for Environmental and Engineering Problems (SAGEEP), and two International Symposiums in Three-Dimensional Electromagnetics, the first in 1995 (Ridgefield, Connecticut) and the second in 1999 (Salt Lake City, Utah).

The Adelaide workshop, with the theme '3D EM at Work' focused on practical outcomes of EM methods in three dimensions, and was the first to be held outside North America. A CD with refereed proceedings will be published later this year and available through the ASEG.

Fulbright Scholarships for study, research and collaboration in the United States

The Fulbright Scholarship Program is the largest and most prestigious educational scholarship program in the world.

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New South Wales – by Roger Henderson

In an attempt to address the unbalanced age profile of the members of the NSW Branch — heavily skewed to the late stage — and its implications for the future, the Branch has formed a student liaison group to encourage young members to take a more active role in the Branch. The leader of the group is a member of the Branch Executive, taking part in all the agenda of committee meetings. In this way current experience will be transferred to the new generation.

The inaugural leader of the group is Carina Simmat, a PhD student at Sydney University. As part of her role, Carina will make sure that the geophysics students in the four universities are aware of each monthly meeting and urge them to attend. Her instant success has been illustrated by the leap in cost of the subsidised soft drinks provided by the Branch for students.

One outcome of this new youthful phase already is that it has encouraged Naomi Osman, a recent PhD graduate, to nominate for Branch Secretary next year. This is also pleasing in that the involvement of these two women attends to the gender imbalance at past meetings and it is hoped this will encourage more female members to take part in Branch functions.

Interstate visitors are always welcome to attend NSW meetings, which are usually held on the third Wednesday of the month at the Rugby Club near Circular Quay. The Branch can move this date if a visitor to Sydney, at some other time, is able to give a talk.

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The Australian-American Fulbright Commission annually provides 20–25 scholarships (valued up to$A20–40,000) for Australians to visit the US, and for Americans to visit Australia.

The criteria for Fulbright Awards are academic and / or professional excellence; a defined proposal justifying the value of such a program in the United States; and how this experience will be shared in Australia following the award. Applications for 2004 close on the August 31st 2003. See www.fulbright.com.au for information and applications.

There is also the US Fulbright Senior Specialist Program which supports Australian educational institutions in bringing US Senior Specialists to Australia for two to six week periods to collaborate on curriculum and faculty development, institutional planning and a variety of other activities. See http://fulserv1/nav/01frame.htm for information and application. Applications for 2004 close Friday October 24th , 2003.

Northern Territory – by Gary Humphreys

The last few months have been relatively busy for NT Branch members, with two multi-disciplinary technical meetings in the last week, and a number of changes for government staff.

The magnetic radiometric and elevation stitches from the NT Geological Survey received a first public release at the ASEG Conference in Adelaide in February, and were very well received by industry, other state surveys, research groups and processing companies. In a talk to the Australian Meteorological and Oceanographic Society (AMOS) in mid-July Roger Clifton demonstrated correlations between the dunes and the NTGS stitches of elevation, radiometric and magnetics. The correlation of the thorium, the flatness of the swales and the alignment of the dune pattern with the winter anticyclones suggests a model where mild willy-willys rather than the sandstorms of convention shape the dunes. Discussion on mechanisms of aeolian transport ensued among the gathered experts, which included members of AMOS, ASEG, GSA and IAH.

Several ASEG members attended a presentation by Geoscience Australia CEO, Neil Williams, to the NT Branch of the GSA. In a wide-ranging address, Neil's talk employed much of the material used to impress the national imperatives for resource replacement (especially oil) upon their political masters. This was a driving force behind the recent announcement by the Federal Government of an extra $61MM over four years for Geoscience Australia, primarily targeted at offshore oil exploration. Of particular interest to ASEG members was the statement by Dr Williams regarding GA's commitment to the encouraging and resourcing of advanced geophysical technology (such as airborne gravity gradiometry and EM) application to mineral exploration under cover and salinity issues.

Andrew Long, Head of Research at PGS, presented the advances in seismic surveying to the NT Branch. We applauded the spectacularly successful deconvolution of sea-surface multiples, which he attributed to the University of Delft.

Des Fitzgerald (DFA) presented the magnetic depth methods of Intrepid, in a quite lively discussion on estimation of structural geology, 28th May. This technical meeting was somewhat fortuitous, and only a few members could attend on short notice.

The Arid Zone Research Institute (AZRI) site south of The Gap on the road to the Airport site presently comprises the research and development farm of the Department of Business Industry and Resource Development and much of the former Conservation Commission of the Northern Territory (now part of the Department of Infrastructure Planning and Environment). The land will also incorporate most of the Alice-Springs-based facilities of the burgeoning Co-operative Research Centre for Desert Knowledge. Part of the AZRI farm area is presently being assessed for a soil aquifer storage project, where treated water from the Alice Springs sewerage facility will be stored in the soil, for use by horticultural cropping work. The water investigation is being managed by ASEG member Anthony Knapton, who will transfer from his present Darwin base for at least one year to work full-time on this project. Ground geophysics was used to plan the investigative soil drilling and determine the hydrogeological constraints on the water storage.

Websites for CRC: http://www.desertknowledge.com.au

Website for water re-use project: http://www.powerwater.com.au/powerwater/html/newsinfo/proj_water_reuse.htm

South Australia – by Graham Heinson

The SA Branch has hosted two meetings since the last edition of Preview. In May, Michael Whiting from Taylor Collison Ltd. gave an excellent and provocative talk on *Exploration Where Has The Money Gone? A Stockbroker's Perspective* to over 40 ASEG members. Thanks to Taylor Collison for their generous sponsorship. The June meeting, co-hosted with PESA, was given by Geoff O'Brien from the Australian Petroleum School, University of Adelaide. Geoff gave an excellent talk entitled *Margin to prospect scale foreland-related fluid flow processes within the offshore Bonaparte and Browse Basins*, north-western Australia to a good audience on a cold winter's night.

Victoria – by Ashley Grant

The Victorian Branch held its AGM in early May, with all the current committee re-instated (Jim Cull as President and Ashley Grant as Secretary). This was held as an interim AGM, as another AGM is planned for August to discuss the Branch's involvement in the approaching ASEG Conference in 2005.

Trevor Allen, a PhD student at Monash University also gave a presentation entitled: *New models for seismic attenuation in southeastern Australia: an analogue for crustal heat flow?*

Western Australia – Anita Heath

The WA Branch is looking for a new venue for technical meetings. The August meeting will be at the ARRC building in Bentley where presentation facilities are superior and without noise from squash courts. Refreshments are served at 5. 30 pm and technical talks begin at 6. 00 pm. Dates for meetings are:

September 3rd
Rejuvenation of old mine sites, how they are becoming financial again.

October 7th
Students Night

November 5th
Remote Sensing Techniques by Peter Hausknecht and Tom Cudahy

November 21st
ASEG/PESA Golf Day at the Vines (the Lakes course)
The organisers are seeking Gold and Silver sponsors for this event.

The SEG 2003 Spring Distinguished Lecturer, Arthur B. Weglein gave an ASEG - PESA Joint Industry Seminar at the Mercure Hotel in May. The subject was: *A Perspective on the Evolution of Processing Seismic Primaries and Multiples for a Complex Multidimensional Earth*. Art gave an amusing talk in which viewers were asked to ignore mathematical formulae and consider seismic events in communication or therapy with each other. His method of subsurface imaging did not rely on velocity fields to discriminate between multiples and primaries, instead he alluded to the use of complex algorithms and a higher computer capability.

Gravity was the theme of the June Technical meeting which was kindly sponsored by Barrick Australia. Guest speakers were Andy Gabell from Canadian Micro Gravity (CMG) and David Blair from the University of Western Australia, Australian International Gravity Research Centre.

The North West Shelf theme in July brought more interest from the petroleum industry. Bryant Korn of ChevronTexaco showed how knowledge of AVO signature contributed to drilling success rate in his APPEA presentation: *The Geryon, Orthrus, Maenad and Urania gas fields, Carnarvon Basin, Western Australia*. Chairman, Andrew Long, gave a Summary and Review of the 2003 ASEG Multiples Workshop. Emphasis was on practical demultiple considerations for a new 3D seismic survey on the North West Shelf.

ASEG Research Foundation: Project Results (part 3)

The ASEG Research Foundation has been supporting students in all facets of Applied Geophysics at the BSc (Honours), MSc, and PhD (or equivalent) levels for 13 years. In this issue of Preview, we complete (see April and June Previews for earlier parts) a summary of the research outputs from Honours students at Adelaide University during 2002.

ASEG Research Foundation Project RF02M02

Project Title:	*Algorithms for the 3D inversion of potential field tensor data*
Student:	Philip Heath
Honours title:	Algorithms for the 3D inversion of potential field tensor data
Host Institution:	Adelaide University
Supervisors:	Stewart Greenhalgh and Graham Heinson (University of Adelaide) and Paul Wilkes (Curtin University)
Funding:	$2200

Project Summary

Measurement of potential field tensor (vector gradient) data is rapidly becoming a new form of geophysical exploration. Data may provide significant improvements in resolution and discrimination of subtle geological basement and regolith features, particularly in areas of high remanence, low latitudes and in steep terrains. Algorithms have been constructed in MATLAB for the 3D inversion of potential field tensor data using Monte Carlo and Downhill Simplex approaches. Such algorithms have been used to invert simulated magnetic and gravity tensor data generated from simple geological structures, such as linear dykes and faults. The algorithms have been tested over a range of depths, from metres to kilometres. The project was sponsored by the ASEG Research Foundation and CRC for Landscape Environments and Mineral Exploration (LEME), and is currently in submission to Exploration Geophysics for publication during 2003.

Philip Heath at work, note the clean desk policy

Philip is currently working towards a LEME-funded PhD on *3D automated inversion and interactive modelling of gravity and magnetic data, including magnetic vector processing and gravity gradiometry*, with supervisors Stewart Greenhalgh and Nick Direen of the University of Adelaide.

By Margarita Norvill

Email: margarita@geophy.curtin.edu.au

International Geophysical Societies (Part 2)

Solid Earth Geophysics

AGU – American Geophysical Union (★★★★)
http://www.agu.org/

Established in 1919, membership to this Union now exceeds 38 000 scientists from over 117 countries. AGU consists of multiple sections, ranging from space physics to seismology to biogeosciences. It also contains focus groups, which are designed for scientists who overlap multiple AGU sections. Some focus groups include Atmospheric and Space Electricity, Mineral and Rock Geophysics and Study of the Earth's Deep Interior.

AGU publishes a plethora of journals, the most well known being the Journal of Geophysical Research, which is composed of the Divisions of: Atmospheres, Earth Surfaces, Oceans, Planets, Solid Earth and Space Physics. Other journals published by AGU include: Earth Interactions, International Journal of Geomagnetism and Aeronomy, Water Resources Research, Nonlinear Processes in Geophysics and many more.

The next major conference scheduled for the AGU is the 2003 Fall Meeting from December 8th –12th 2003, at San Francisco, CA.

CGU – Canadian Geophysical Union (★★)
http://www.cgu-ugc.ca
The CGU comprises a hydrology and a geodesy section. The next major conference to be held by the CGU will be in Montreal, May 17th –21st , 2004. This will be jointly hosted with the American Geophysical Union.

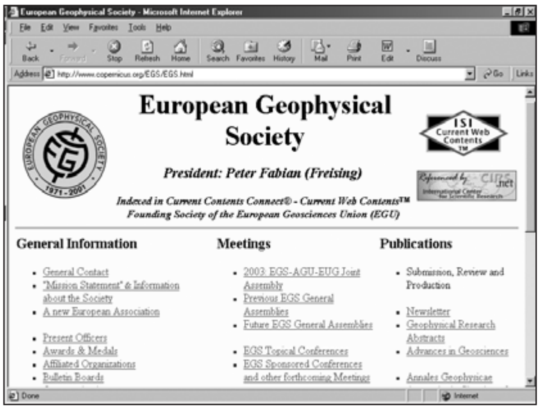
CNFGG – Comite National Francais de Geodesie et Geophysique (★★)
http://www.omp.obs-mip.fr/cnfgg/
For those who can speak French check out the CNFGG. The CNFGG consists of seven Sections; Geodesy, Seismology and Physical Interior of the Earth, Volcanology and Chemistry of the Interior of the Earth, Geomagnetism and Aeronomy, Meteorology and Physics of the Atmosphere, Hydrological Sciences and Physical Sciences of the Oceans. The CNFGG publishes 'Libellie Geophysicae'.

The next conference will be held in conjunction with the International Union of Geodesy and Geophysics (IUGG). The theme is 'State of the Planet: Frontiers and Challenge'; it will be conducted in Sapporo, Japan, from June 30th to July 11th 2003.

EGU – European Geosciences Union (★★★)
http://www.copernicus.org/EGU/EGU.html
EGU = EGS + EUG
The EGU was established by the Councils of the European Geophysical Society (EGS) and European Union of Geosciences (EUG) on September 7th 2002.

EGU produces the following Journals: Annales Geophysicae, Nonlinear Processes in Geophysics (this is a joint publication with AGU), Hydrology and Earth System Sciences, Natural Hazards and Earth System Sciences and, Atmospheric Chemistry and Physics.
The 1st General Assembly will be held at Nice, France, April 25th -30th 2004

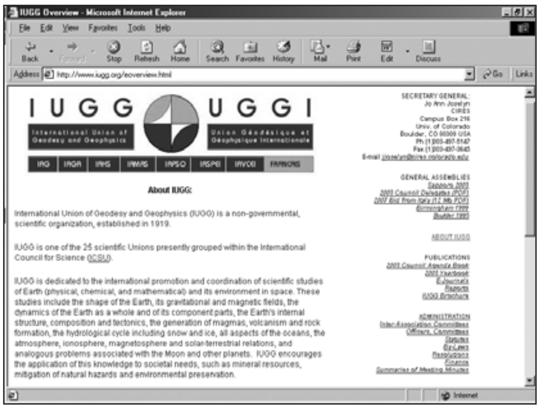
EGS – European Geophysical Society (★★★)
http://www.copernicus.org/EGS/EGS.html



Founded in 1971, the EGS is an interdisciplinary scholarly society devoted to the promotion of the Earth and its environment, to planetary and space sciences, and cooperation between scientists.

EUG – European Union of Geosciences (★★★)
http://eost.u-strasbg.fr/EUG/
Founded in 1981, EUG's aim is to promote cooperation between scientists in all fields of the Earth and Planetary Sciences (Geology, Geophysics, Geochemistry, Planetology, Oceanography, etc.) through general scientific meetings and specialised symposia, and the publication of journals.

IUGG – International Union of Geodesy and Geophysics (★★★)
http://www.iugg.org/



IUGG was established in 1919. It is concerned with the international promotion and coordination of scientific studies of the Earth (physical, chemical, and mathematical) and its environment in space. The IUGG is divided into seven associations: International Association of Geodesy (IAG), International Association of Geomagnetism and Aeronomy (IAGA), International Association of Hydrological Sciences (IAHS), International Association of Meteorology and Atmospheric Sciences (IAMAS), International Association for the Physical Sciences of the Oceans (IAPSO), International Association of Seismology and Physics of the Earth's Interior (IASPEI) and International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). Each Association has its own conference every four years and its own its own publications.

General Assemblies, where all the seven Associations participate, are also held every four years. The next General Assembly: 'State of the Planet: Frontiers and Challenges' will be conducted in Sapporo, Japan, from June 30th to July 11th 2003.

Miscellaneous Societies

AHG – The Association of Hungarian Geophysicists (★★)
http://www.ggki.hu/MGE/mge.html
Established in 1954, the Association of Hungarian Geophysicists represents experts of various fields of geophysics and related sciences. The association is composed of the following sections: Pure Geophysics, Surface Geophysics, Society of Professional Well-Log Analysts (SPWLA), and Hydrocarbons.

It is interesting to observe that the first isoseismal map in the world was constructed by the Hungarian polymath, P I Kitaibel, in 1814.

The AHG publishes the following journals: Magyar Geofizika - Hungarian Geophysics, Geophysical Transactions, and Acta Geodaetica et Geophysica – A Quarterly Journal of the Hungarian Academy of Sciences.

BGA – British Geophysical Association (★★)
http://www.geophysics.org.uk/
The BGA is an Association of the British Geological Society and the British Royal Astronomical Society. It aims to promote the subject of geophysics, and particularly to strengthen the relationship between geology and geophysics in the United Kingdom. The BGA consists of specialist groups in: education, environmental and industrial geophysics group (EIGG), geodesy, geomagnetism and palaeomagnetism, seismology and the physics of the Earth's interior

The BGA's journal, the Geophysics Journal international, is published on behalf of The Royal Astronomical Society in conjunction with the Deutsche Geophysikalische Gesellschaft and the European Geophysical Society (EGS).

A conference is planned for February 2004 on 'Advances in Geophysics' a topic is yet to be selected. Each year in September or October the BGA sponsors a one or two day meeting on Postgraduate Research, the meeting is held at a university with an active postgraduate geophysics program.

EIGG – and Industrial Geophysics Group (★★)
http://www.geolsoc.org.uk/template.cfm?name=geogroup12
The Environmental and Industrial Geophysics Group (EIGG) is a specialist group of the BGA focusing on shallow geophysics, with depths restricted to 500 m. It is concerned with applications of shallow geophysics in hydrogeology, engineering, archaeology, forensic science, environmental investigations and monitoring, mineral exploration, hazard assessment and geological mapping.

Star Rating
The star rating is calculated from estimates of the following parameters:

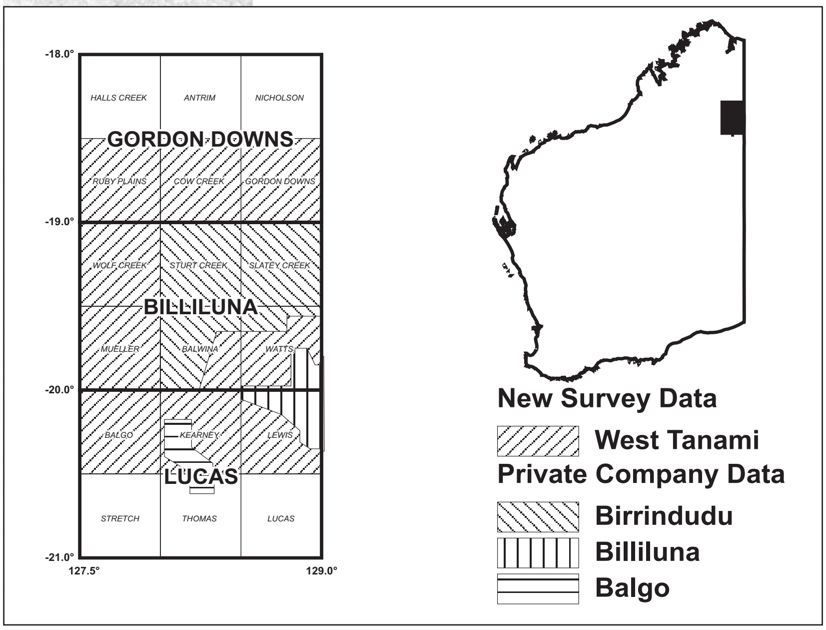
Content/information available on web pages	2
Navigation friendly	1
Aesthetically Pleasing	1
Currency	1
TOTAL	5

Fig. 1. Area covered by the West Tanami data release. The stippled parts of the Gordon Downs, Billiluna and Lucas Sheet areas represent the areas covered by the images in Figures 2 and 3.

Geoscience Australia

Geophysical Data Release West Tanami Region, WA Phase 2

The Geological Survey of Western Australia (GSWA) and Geoscience Australia (GA) have released Phase 2 of the airborne geophysical data over the west Tanami region of Western Australia covering the Billiluna 1:250 000 Sheet area and parts of the Gordon Downs and Lucas 1:250 000 Sheet areas (see Figure 1). This release includes point located data from private company surveys that were still confidential at the time of the Phase 1 release on 17 February 2003.



The Tanami region is one of the most exciting new gold provinces in Australia. Since the mid-1980s over 310 tonnes of gold have been produced in this poorly outcropping region of Paleoproterozoic sediments, volcanics and granitoids that straddles the border of Western Australia and the Northern Territory.

Data in this release comprise magnetic, gamma-ray and elevation located data and grids from a survey flown for GSWA and GA by UTS Geophysics in 2002, and from 3 private company surveys flown between 1989 and 1995. The older surveys have been appended and levelled with the new survey to create a combined dataset giving a continuous coverage.

The magnetic, radiometric and elevation data have been gridded using an 80 m cell-size.

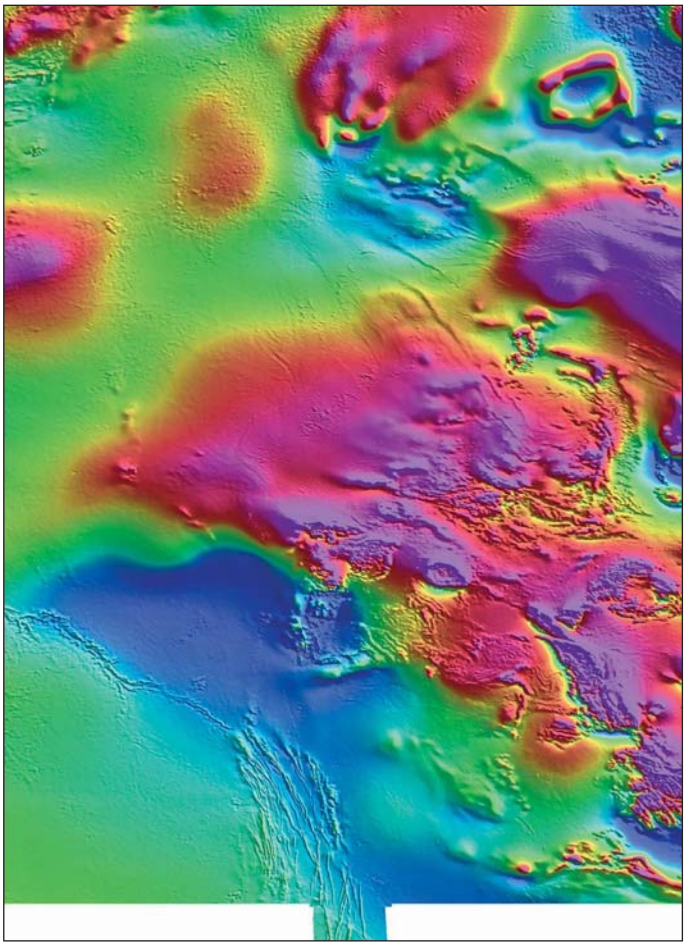


Fig. 2. Magnetic anomaly image of the West Tanami Survey region.

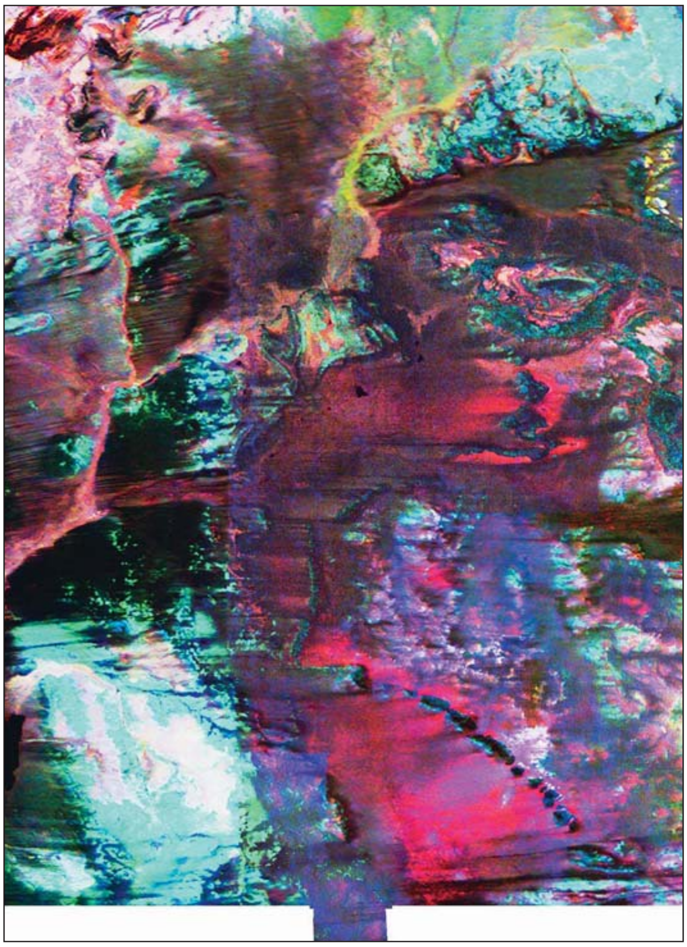


Fig. 3. Ternary γ-ray spectrometric image of the West Tanami region.

The new survey was flown between July and August 2002 and produced 68 000 line-km of geophysical data. Flight lines were flown north-south at 60 m above ground level and spaced 400 m apart. Magnetic data were sampled every 0.1 s (~ 7 m), and gamma-ray spectrometric data were sampled every 1 s (~ 70 m). Navigation and flight path recovery information were provided by the satellite Global Positioning System (GPS). These GPS data were sampled every second (~70 m).

The Birrindudu survey was flown in 1991 with north-south flight lines 300 m apart at a flying height of 70 m above ground level. The Billiluna survey was flown in 1989 with north-south flight lines 250 m apart at a flying height of 80 m above ground level. The Balgo survey was flown in 1995 with east-west flight lines 200 m apart at a flying height of 60 m above ground level.

The magnetic anomaly and radiometric images of the area are shown in Figures 2 and 3.

The digital data are available from GA. The contact is: sales@ga.gov.au

Hardcopy TMI, ternary radiometric images and pixel image colour plots at 1:250 000 can be obtained from the WA Dept of Industry and Resources on-line from: www.doir.wa.gov.au <http://www.doir.wa.gov.au>

Index of airborne geophysical surveys, index maps and digital files

Index Record   hardcopy and digital versions

The 7th Edition of the Index of Australian (Geoscience Australia/AGSO/BMR and State) government airborne geophysical surveys was released in May 2003 in both hardcopy and digital formats. This edition of the Index contains a more comprehensive coverage of surveys than the previous edition released in June 2002. Information on older surveys before 2002 has been updated and additional surveys have been included from various State and Federal exploration initiatives and the ongoing airborne survey work of Government bodies. Specifications of several open file surveys are also included in this release.

The hardcopy version of the index (GA Record No. 2003/10) contains a summary of the major specifications of over 900 airborne surveys. The digital version of the index is available in PDF format from the Geoscience Australia website.

Interactive survey coverage information and digital files

An updated interactive database of metadata for Australian airborne geophysical surveys has also been released. Digital data files of the Index of Airborne Geophysical Surveys are provided in AEROMAP, ESRI Shape and MapInfo formats showing the coverage over Australia of Geoscience Australia and State Government airborne magnetic and radiometric surveys. The metadata files have been updated to 30 April 2003 and are provided as three separate digital zip files for clients who require support for AEROMAP, ArcView and MapInfo applications.

The PC-based Windows software package AEROMAP is continuing to be supported with updated survey metadata

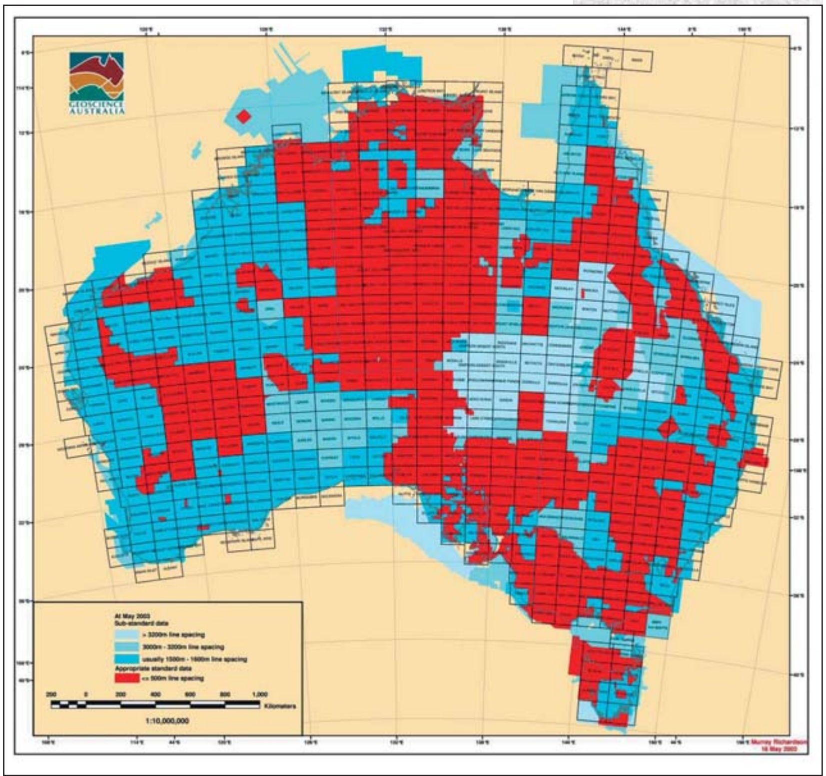


Fig. 4. Index map indicating airborne magnetic coverage of Australia.

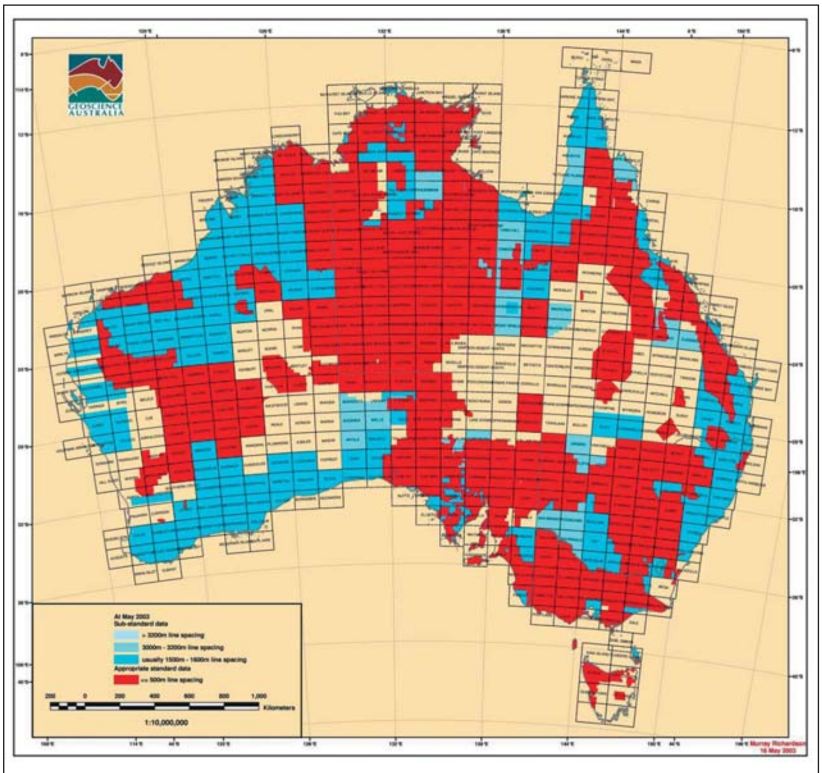


Fig 5. Index map indicating γ-ray spectrometric coverage of Australia.

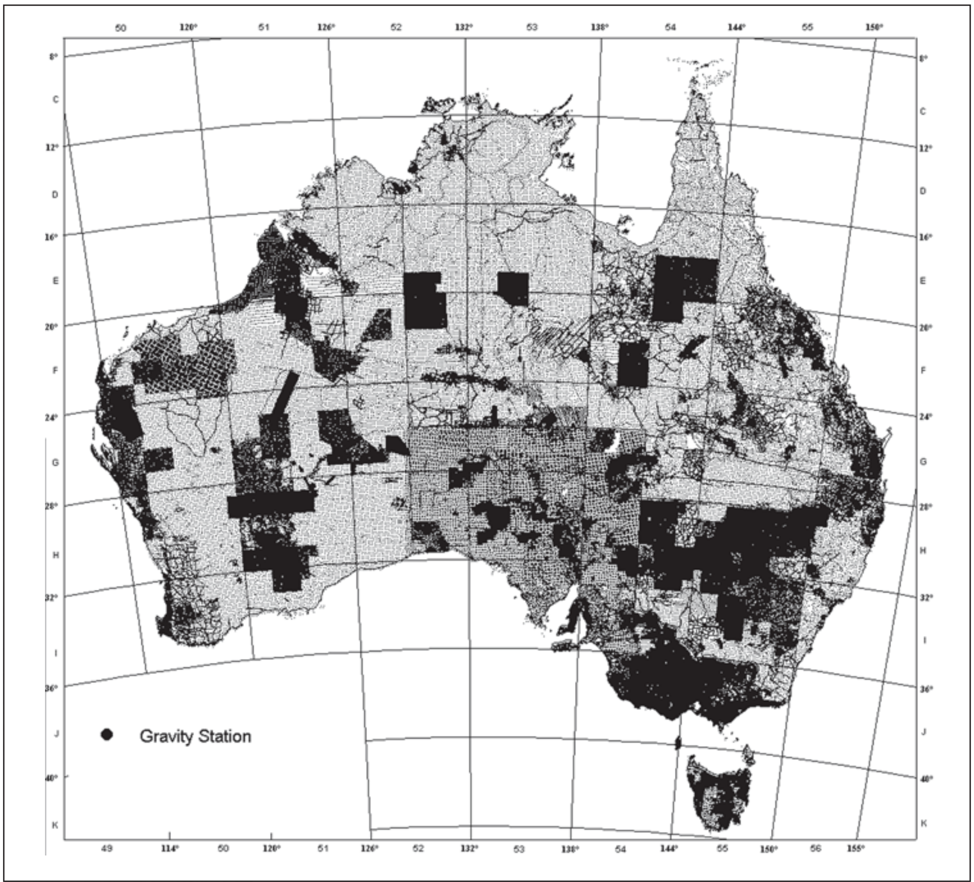


Fig. 6. Gravity station diagram.

files. The software is provided as a single digital zip file, which contains one copy of the program and associated digital information.

The latest Australian airborne survey coverage information is also available free via the online Airborne Surveys Index Database on the Geoscience Australia website at http://www.ga.gov.au/oracle/argus/.

Index Maps

Updated colour index maps showing the coverage over Australia of Geoscience Australia and State Government airborne magnetic, radiometric and gravity surveys are also included in this release. The airborne magnetic and radiometric survey coverage maps discriminate between surveys employing flight line spacings of 500 m and less, and wider line spacings. The maps (see Figures 4 and 5) also show State/Territory borders and the names of 1:250 000 Sheet areas.

For further information on the Index Record, Index Maps, AEROMAP or the digital data files contact: Murray Richardson, at GA, E-mail: murray.richardson@ga.gov.au

Release of Australian National Gravity Database (May 2003 Edition)

Geoscience Australia's National Gravity Database contains over 1 200 000 point gravity observations read over the Australian onshore and offshore regions. These data have been collected from gravity surveys dating back to 1937. This repository of gravity information is a valuable national asset with importance to the mineral and petroleum exploration industries, geodesy and the international scientific community. It is a cooperative effort among Geoscience Australia, state and territory Geological Surveys, private companies, universities and other organisations.

The May 2003 release contains point data values in the area extending from 8 S to 48 S and 108 E to 162 E. All data are provided in GDA94 coordinates. The 2003 release includes both onshore and offshore data and has approximately 390 000 gravity stations additional to the 2002 release. These additional data come from:

(a) Recent additions to the database;
(b) Data no longer embargoed; and
(c) Offshore data not included in the 2002 release.

The digital data will be supplied by Geoscience Australia on one CD-ROM. The CD-ROM will also include the ER Mapper gravity grid of Australia, produced at a cell size of 0.5 minutes of arc (equivalent approximately to 800 m), previously released in June 2001.

Both the database and grid may be downloaded for free from the Geoscience Australia website at:
http://www.ga.gov.au/rural/projects/20011023_32.jsp
For further information about the database contact: Phillip Wynne, E-mail: phill.wynne@ga.gov.au

Northern Territory

NT Government continues commitment to petroleum and mineral exploration

On 3 June 2003, the NT Business, Industry and Resource Development Minister, Paul Henderson, detailed a $15 million program to expand and promote the Territory's petroleum and mineral potential.

He announced a four-year, $15.2 M project, as one of the 2003-04 Budget initiatives.

"The Northern Territory is resource rich, and the mining and petroleum industries contributed more than $3.2 billion to the Territory economy in 2002-03," Henderson said.

"This new program will promote and develop our resources and position the Territory at the forefront of world-wide destinations for mineral and petroleum exploration."
"Building the Territory's Resource Base" will focus on:

- Providing the industry with high-quality, low-cost, new-generation geoscientific data, information and ideas for geological exploration;

- Promoting the Territory's exploration potential;
- Developing and maintaining good working relationships between Government, the mining industry and Indigenous groups; and
- Facilitating the granting of mining tenures in a timely and cost effective manner.

The new project will particularly focus on the sand-covered Arunta region which links the gold producing areas of Tennant Creek and the Tanami, which holds great potential but to date has been minimally explored.

"The Government is committed to opening up the Territory for exploration to drive our economy, and potential mineral explorers have access to extensive datasets and airborne maps of the Territory," said Henderson.

A very enthusiastic statement from the Minister.

More data released from the from Buchanan region

Earlier this year, NTGS released the Buchanan airborne survey, flown by Fugro Airborne Surveys during 2002.

The NTGS has now added approximately 25 100 line-km of data to this survey, as shown on Figure 7. The new data forms that part of the Birrimba B private sector survey located east of 132 deg, on the Daly Waters and Newcastle Waters 1:250 000 Sheet areas. Birrimba B was flown in 1997 along N-S flight lines spaced 250 m apart.

Survey location, specifications and located images for the Buchanan and all other NTGS surveys are available on the NTGS Image Web Server at: http://www.dme.nt.gov.au/ntgs/geophysics/air_map/air_geo_map.html

Order updated located and/or gridded data for the Buchanan survey from geoscience.info@nt.gov.au

Queensland

Queensland to invest $28 million to stimulate growth in the mining industries

Meanwhile in Queensland the Mines Minister, Stephen Robertson, announced on 4 June that the state government will invest $28 million in 2003-04 to further stimulate growth in Queensland's mining industries and improve health and safety procedures,

This investment will facilitate the growth of exploration and sustainable development of Queensland's mineral, petroleum and extractive resources while securing an appropriate economic return to the community.

"Mineral and petroleum exploration and development activities continue to contribute substantially to the Queensland economy and are worth $8.2 billion or 7.8% of Gross State Product each year.

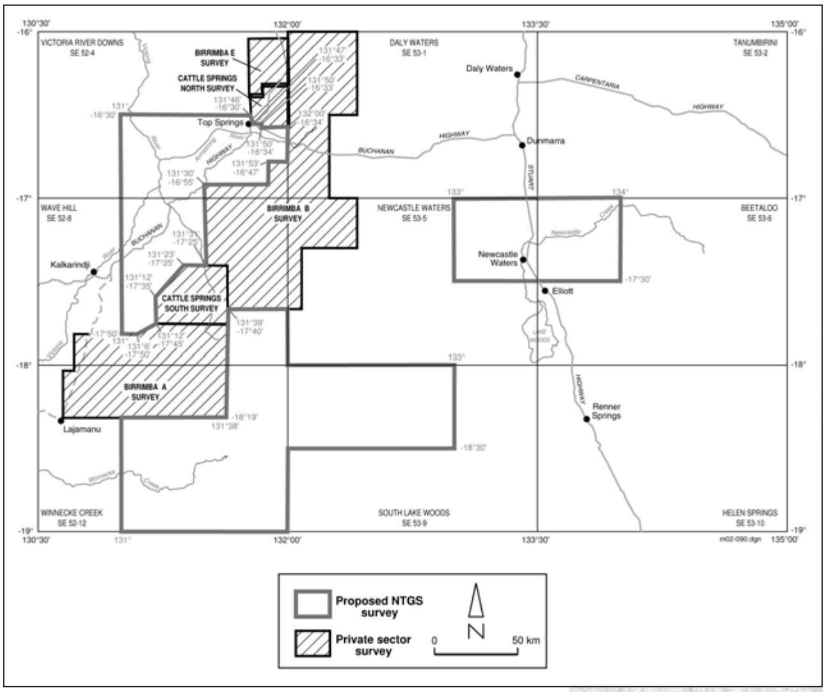


Fig. 7. Map showing the areas covered by the new data release and the areas planned for future surveys.

"During 2003-04 it is planned to further assess and promote the State's mineral and petroleum potential to attract more investment and industry development.

Key NRM mining programs during 2003-04 will:

- Progress the potential development of thermal coal deposits in the Surat-Dawson region.
- Expedite mining exploration and tenure through streamlined native title processes, which allow greater access to land while protecting indigenous rights and local cultural heritage.
- Facilitate development of the State's geothermal energy resources by continuing the development of a legislative regime that allows for the development of Queensland's "hot dry rock" resources.
- Complete the Petroleum and Gas (Production and Safety) Act 2003 which will allow for further development and safe extraction of coal seam methane.

UTS Geophysics to fly Central Bowen Basin Airborne Geophysical Survey

UTS Geophysics has been awarded the recently tendered Queensland government airborne geophysical survey, which will cover approximately 24,000 hectares (65,000 line-km) over the Central Bowen Basin. It is expected that data acquisition will start in early July 2003 with all final data and products to be provided before the end of October 2003 for release at the Mining 2003 conference to be held in Brisbane in October

South Australia

Minister outlines importance of the resource industries to South Australia

In launching the South Australian Resources and Energy Investment Conference in Adelaide in May this year the Minister for Mineral Resources Development, Paul

Holloway, emphasized the importance of the resource industries to SA. In his opening speech he said "The industry directly employs over 7000 people and produces annually a total of 1.7 billion dollars of minerals and petroleum products, currently 25% of the state's total primary production. Total export value for the industry is $1.36 billion (22% of the state's total) with related manufactured products a further $1.45 billion (16%). Clearly we have much to be proud of. Continued confidence throughout the industry will enable further discovery and development.

"This past year has been a very successful one for the industry with increased levels of exploration expenditure and development. I am delighted that further high-grade copper and gold intersections have been confirmed at Prominent Hill and high grade gold at the Barns Prospect in the Central Gawler Craton. The discovery of new oilfields in the Eromanga Basin and planned off shore exploration in the Bight Basin indicates continued commitment by explorers of significant exploration expenditure.

"The continued health of investment activity in South Australia is also reflected by the announcement this week of the joint venture by local mineral explorer Adelaide Resources and the world's biggest gold producer, Newmont to explore for gold on Eyre Peninsula. Newmont, Australia with the head office here in Adelaide reported yesterday that its group strategy was to support strong discovery potential early in their exploration life."

However, he seemed to be silent on his own Government's investment to encourage exploration.

Victorian Geological Survey

Radiometric map of Victoria

The Geological Survey of Victoria has merged all of the existing K, Th and U radiometric grids to produce a preliminary radiometric ternary image of Victoria (Figure 8). These grids have not been warped, decorrugated or filtered. The results of this exercise have shown that, although Victoria's radiometric data is already of a high quality, further reprocessing will improve the quality of the integrated grids. These new grids accompany the new Victorian TMI map of Victoria (April 2003 Preview #103) the Geological Survey of Victoria (GSV).

The GSV is about to start a new project, which will result in the reprocessing and re-gridding (to a 50 m mesh) for each channel (K, Th, U, TC) and all surveys. The resultant grids will then be merged with the aim of forming seamless coherent grids across the whole State. The project is expected to be completed in 2005.

Most of the calibrated surveys were collected under the Victorian Initiative for Minerals and Petroleum between 1994 and 2001. Where the emphasis was placed on acquiring high quality, calibrated, 256 channel radiometric data. The VIMP data together with some Geoscience Australia radiometric surveys means that Victoria has 25 calibrated radiometric surveys out of a total of 31.

15th VIMP launch

At the 15th VIMP launch held in Melbourne in May 2003, the Victorian Department of Primary Industry released the following products:

- The first ever digital model of the vast LaTrobe Valley coalfields,
- New geological mapping, regolith mapping and studies, and a detailed gravity survey in the rich central Victorian goldfields covering the Castlemaine, Bendigo and Ararat 1:100 000 Sheet areas,
- A seamless magnetic image of the State,
- Detailed gravity traverses over the Bendigo goldfields
- The results of an electromagnetic survey, which has greatly improved our understanding of salinity in the Benalla area,
- A new web mapping application: - ***Mapshare***
- Open file exploration licence reports available in CD format, and
- Upgraded GIS data packages covering the State and now incorporating historic mining lease records.

New web mapping application – ***Mapshare***

The Department's new web mapping application, ***MapShare*** is a GIS based application that allows users to search and interrogate various Victorian Minerals and Petroleum geospatial databases using standard web browser interfaces. The results are presented as maps or attribute tables, depending on the data type. Currently the maps are presented in Vicgrid projection based on the GDA94 datum. ***MapShare*** is built on the ESRI ArcIMS software.

Datasets that can be viewed and interrogated include the mineral, petroleum and extractive industries tenements, land-use and airborne geophysical survey boundaries, gravity, magnetic and radiometric images, borehole data, surface geochemistry results, mines and mineral occurrences, and geological maps and interpretations at various scales.

These layers can be made scale dependent, so that the data displayed is appropriate for that layer at that scale. For example, at whole of State views the 1:500 000 roads are displayed, but as the user zooms further in, these are changed to the 1:250 000 roads and finally the 1:25 000 roads database is displayed.

The polygons and images are semi-transparent, allowing multiple layers to be displayed, such as geological boundaries (or polygons) over magnetic intensity. MapShare also includes links to other databases. For example, selecting the attributes for an expired mineral exploration licence provides the opportunity to open a .pdf document that summarises the exploration history for that EL.

Cont'd on page 21

ASEG–PESA Sydney 2004

August 15th - 19th 2004

Integrated Exploration in a Changing World

Papers, Presentations & Posters

Abstracts due:	November 2003
Papers due:	March 2004
Contacts for papers, presentations s & poster:	John Mebberson mebberson@rocoil.com.au Peter Gunn gunngeo@AOL7.com.au

Other Contacts

Sponsorship:	Wes Jamieson jamieson@rocoil.com.au
	Mike Smith mike_rpgeo@optusnet.com.au
Exhibition:	Pat Hillsdon prh@ecsi.com.au Simon Stewart simon.stewart@fugro instruments.com
General Information	Barry Smith bsmith@mosaicoil.com Tim Pippett tpippett@alpha-geo.com
Conference Email:	aseg-pesa2004@ conferenceaction.com.au
Website:	www.aseg-pesa2004.org.au

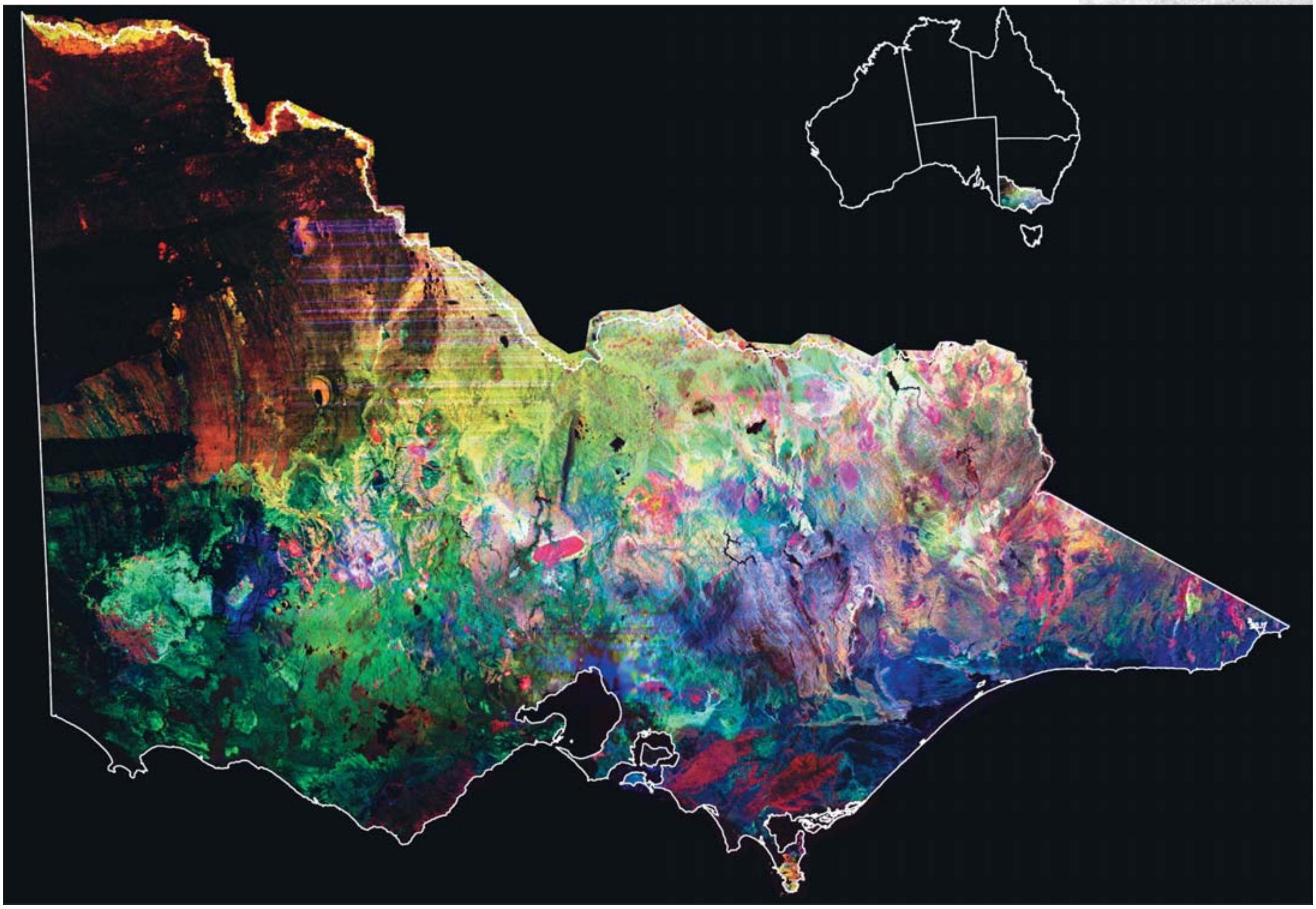
Cont'd from page 20

MapShare represents an initial step towards MPD's Deeply On-line Project. This project aims to have all appropriate databases searchable, and the results deliverable where bandwidths allow, on-line. The new MapShare application can be accessed at www.dpi.vic.gov.au/minpet.

Geological Survey of Victoria 150th exhibition on web

In 2002, the Geological Survey of Victoria celebrated its 150 years of scientific achievement with 4-month exhibition of maps, plans, photos and storyboards at the Melbourne Museum. The majority of the exhibits have been photographed and converted into a virtual exhibition now available on the Department's website: http://www.dpi.vic.gov.au/minpet

Fig. 8. Radiometric ternary (K, Th, U) Image of Victoria (Preliminary)



Air-FTG™: Bell Geospace's Airborne Gravity Gradiometer – A Descripton and Case Study

By Scott Hammond
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Houston, TX
Email:
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Colm Murphy
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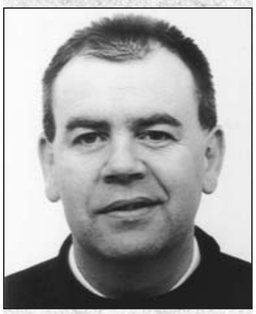
Aberdeen UK,
Email:
cmurphy@bellgeo.com



Introduction

In 1998, Bell Geospace took an underwater technology from the military and brought it to the surface for use in marine petroleum applications. Last year we took to the air! The technology we refer to is 3D-Full Tensor Gravity Gradiometry (3D-FTG) and although it has been measured for more than a century, it was only done from stationary measurements which meant slow surveys and limited coverage. As airborne methods have improved in the last 20 years, explorationists have looked for a density tool to complement airborne magnetics and EM. Recent attempts to fly gravimeters have met with limited success due to their high sensitivity to aircraft turbulence and their long spatial resolution.

The recent introduction by Bell Geospace of an airborne 3D-FTG ('Air-FTG ') has provided the technology to fill that gap and allow petroleum and mineral exploration companies to cover large areas with a true prospect level density sensing device in a short amount of time.

Method

The 3D-FTG uses a technology that was developed for the US Navy by Bell Aerospace (currently Lockheed Martin Corp.) for use aboard Trident Class nuclear submarines. Full Tensor Gradiometry utilises a set of three rotating disks (Gravity Gradient Instruments, GGIs), each containing two pairs of orthogonally mounted accelerometers (Figure 1). Each GGI is spun to a set frequency in order to avoid bias in measurement in the direction of the primary components. By taking the difference of the gravity field sensed by each pair of accelerometers, the Air-FTG is able to compensate for most of the turbulence experienced by the aircraft and retain the high frequency signal that is critical to prospect level geophysical surveying. The only other working airborne gravity gradiometer in the world is configured differently and as a result has to settle for a partial tensor measurement.

The gravity field is composed of three vectors, Gx, Gy and Gz. Each vector contains three gradients. A gradient describes the rate of change of that vector as you move in the three orthogonal directions. This means that Txy describes how the Gx vector changes as you move in the y direction. There are nine gradients that can be described in this manner but only five represent independent gradients (Figure 2), i.e. T_{xx}, T_{xy}, T_{xz}, T_{yy}, and T_{yz}. T_{zz} is the negative sum of T_{xx} and T_{yy}, satisfying LaPlace's equation.

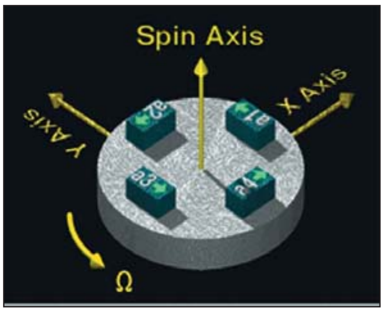
Air-FTG is currently acquired onboard a Cessna Grand Caravan 208B, which has been modified to house the instrument, all support electronics, differential global positioning systems, a magnetometer, and appropriate terrain measuring hardware. By positioning the FTG near to the centre of pitch, roll and yaw, rotational accelerations can be held to a minimum. Any accelerations that remain are measured by dedicated accelerometers and their effects are removed during post mission compensation. This design allows Air-FTG to fly in much rougher conditions and also eliminates the need for long lead-in or lead-out lines.

Air-FTG surveys can be flown at constant barometric elevation or in a gentle drape. As the Air-FTG is measuring the gradient field directly, and its signal strength falls off with the cube of the distance:

$$T_{i,j} \propto 1/R^3$$

it is usually desirable to survey as close to bodies as possible. Therefore, a gentle drape is normally used. Special software is used to factor in terrain, aircraft climb performance, and cross tie matching so that the survey crew can obtain the best possible survey results. Surveys can be flown as low as 80 m and line spacing is usually in the range of 50 to 2000 m depending on the target and scope of survey. Resolutions of less than 5 E tv s (0.5 mgals/km) over 400 m spatial wavelengths have been recorded on our recent African surveying program.

Data acquired is stored on disks during flight operations. Immediately following each flight, the data is downloaded to a processing computer where processing algorithms are applied to compensate for the aircraft turbulence, mass shifts, and the self gradient of the aircraft and instrument itself. At this stage a very strict quality control check is applied to the data which looks for excessive accelerations, calibration errors, repeat differences and a series of other predetermined benchmarks.



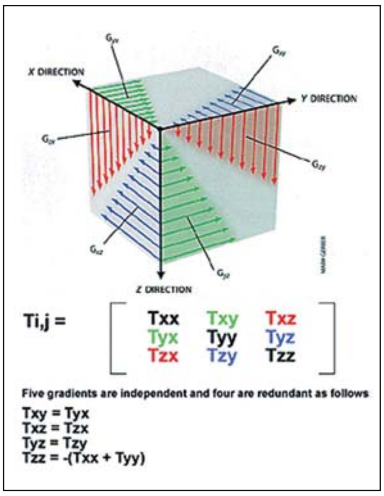


Fig. 1. (Above) Schematic of accelerometer arrangement on one of three Gravity Gradient Instruments (GGIs) in the Full Tensor Gravity Gradiometer.

Fig. 2. (Right) Description of the relationship between gravity vectors and their tensor components and the matrix description showing redundancies.

Once the field crew has determined that the survey data is of the highest quality, that data is sent electronically to the processing centre where another set of eyes performs even more rigorous QC checks on the data. If, at any stage, the data does not meet these strict quality standards, those lines are re-flown and merged into the survey.

When the entire survey is complete, overall analysis and processing of the survey can begin. The data from the spinning disks has to be deconvolved and slowly varying changes need to be compensated for. This is all done on the data as a network of lines rather than on individual lines. This is the stage where individual tensor components are calculated. The gradient value recorded in the field on each of the GGIs is dependent on the distance between the accelerometers, frequency of spin on each disc and spatial configuration of each GGI. It is only then that we are able to extract all independent components, i.e. T_{xx}, T_{xy}, T_{xz}, T_{yy}, and T_{yz}, from the recorded data.

The final step involves more typical potential field processing methods such as filtering and line levelling. One technique that is unique to FTG data is harmonic fit in which the Laplacian nature of the independent tensor components is used. Harmonic fit checks the signals to make sure that all of the components are solutions of Laplace's Equation. Any signal which does not meet this test can be considered noise and discarded.

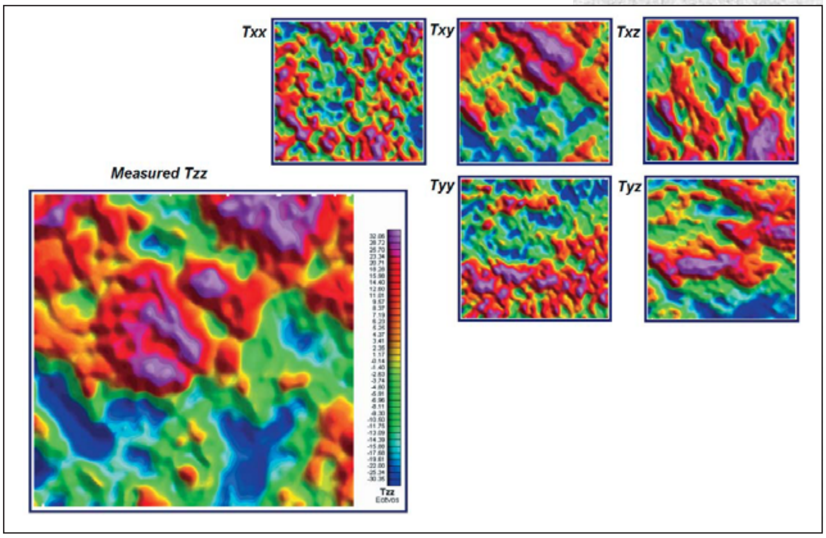
Final tensor maps are then created for the five independent tensor components T_{xx}, T_{xy}, T_{xz}, T_{yy}, and T_{yz} as well as the vertical component T_{zz}. T_{zz} is not independent because $T_{xx}+T_{yy}+T_{zz}=0$ (another Laplacian must) but it is presented because it puts the density anomalies in their appropriate spatial perspective, i.e. it is the one that is most easily related directly to subsurface geology.

Air-FTG™ case studies

To date, Bell Geospace has acquired 1,202 km of Air-FTG surveys in North America during initial testing and has acquired over 12,000 line km of commercial surveys in

Fig. 3. Geological map for the survey area (survey boundary shown in black is 6 x 6 km). The geology is dominated by the Malmani Dolomite (light blue colour) of the Transvaal Sequence and the local area exhibits a NE-SW regional trend that is faulted by a series of NW and ENE oriented transfer structures.

Fig. 4. (Below) The measured Air-FTG Tensor Component display. The five independent components, Txx, Tyy, Txy, Txz and Tyz resolve the dominant structural trends. Tzz identifies a series of low density anomalies (blue) attributed to subsurface cavities.



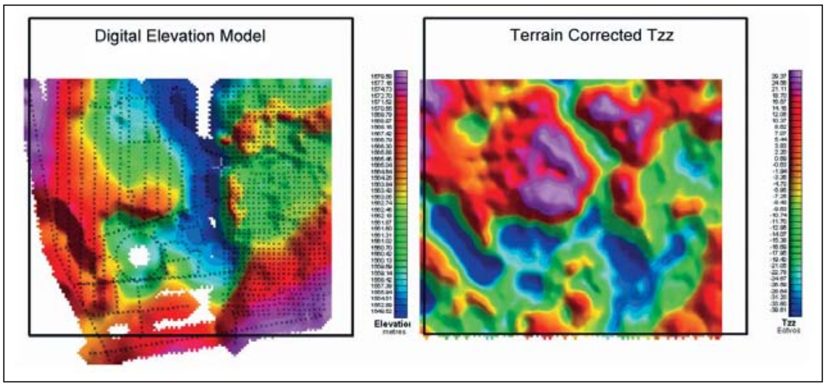


Fig. 5. Released elevation data (on left) and resultant Terrain Corrected Tzz for area of overlap between Air-FTG and elevation data. The Air-FTG survey boundary outlined in black, elevation measurement stations shown by black 'x's in elevation map.

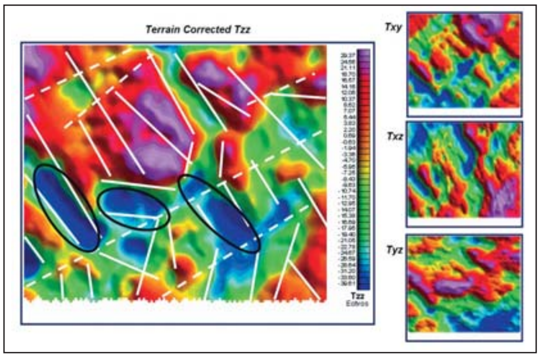


Fig. 6. Terrain corrected Air-FTG Tzz and horizontal component data, Txz, Tyz and Txy, for area of overlap with elevation data. Sub-surface solution cavities are identified in Tzz and appear offset via lineaments identified in the horizontal components. The cavities are outlined in black and interpreted lineaments in white.

Africa. Targets covered include a salt dome, base metals, precious metals, kimberlite and potential ground water storage. While results have been excellent, our clients have been using Air-FTG over active target areas and have not released many of these examples yet. One exception is a survey that was acquired for ground water storage identification.

Council for Geoscience, South Africa

The first Air-FTG survey outside the Americas was acquired for the South African Council for Geoscience in late 2002. The survey area is located west of Johannesburg over an area comprising Malmani Dolomite of the Chuniespoort Group, part of the Transvaal Sequence. Regional structure (Figure 3) shows a dominant NE-SW trend with NW and ENE oriented transfer faults. The dolomite sequences display a typical leached karstic environment with localised development of sinkholes and dolines. They are overlain by a manganese and iron rich soil that varies in thickness from a few centimetres to 30 m. The purpose of the survey was to determine the technology's suitability for locating and mapping sub-surface cavities for ground water storage, and the results indicate that it is indeed an excellent tool for this application.

550 line-km of data were acquired on a 6 x 6 km survey grid at a constant barometric height of 1745 m above mean sea level. In-lines are spaced 100 m with a N-S orientation; tie lines have 400 m line spacing and oriented E-W. The gradient data (Figure 4) exhibit a varying response from definitive density lows to more localised and trended highs. The horizontal components, T_{xz}, T_{yz}, and T_{xy}, identify a number of lineaments that follow the regional structure. They may also be indicative of fracture/joint development within the dolomitised limestone. Some of these lineaments partially display a positive response and are interpreted as a series of dykes.

Terrain Corrections confirm sub-surface cavity presence

Elevation data (Figure 5), partially overlapping the survey area, were released by the Council for Geoscience for our analysis of the data. Terrain corrections were therefore only applied to a subset of the data and a background density of 2.67 t/m^3 was assumed. However, the wide spacing between stations in the western half of the survey area prohibits analysis of the high frequency lineaments observed in the free air Air-FTG response. Nevertheless, these are interpreted as geological events as they are oriented obliquely to the flight path. Therefore, the terrain correction procedure is rather incomplete. On the other hand, the terrain corrections do confirm the longer wavelength low density anomalies observed in the free-air data. We interpret these as sub-surface cavities. Their wavelength indicates a maximum depth of 150 – 200 m below the surface for these caverns.

Horizontal Components reveal structural control on distribution of cavities

The horizontal components, T_{xz} and T_{yz}, typically map the central axes of mass bodies. However, their maxima and minima also allow mapping of structural or lithological contacts. In this survey (Figure 4 and 6), they identify the regional structural trends in the area. Additionally, T_{xy}, allows mapping of the NW oriented structures in this survey. T_{yz}, to a lesser extent, maps WNW trending structures. This suggests that the dominant structural trend affecting the area is NW oriented. However, subtle ENE oriented offsets are observed in T_{xz} and T_{xy}.

Figure 6 shows the terrain corrected T_{xz}, T_{yz}, and T_{xy}. The interpreted structures are summarised on the Tzz plot (also Figure 6). It is clear from the interpretation that the sub-surface cavities are not 'stand-alone' features, but show continuity. The impact of these for ground water storage is significant due to potential leakage from one cavity to the other.

Conclusions

Air-FTG offers an exciting opportunity to the exploration and surveying industries. The technology records all components of the gravity field allowing for a more precise determination of the gravity field. Important information relating to geological setting (structural and / or lithological) and target shape and size are readily determined.

The Air-FTG data acquired for the Council for Geoscience demonstrate the added value the technology brings to subsurface mapping of solution cavities within a karstic environment. Detailed information on the location and shape of the cavities is resolved. Furthermore, the identification and mapping of the geological structure from the horizontal components, T_{xz}, T_{yz}, and T_{xy}, helps to understand the potential subsurface continuity of these caverns and their significance in terms of leakage to each other for ground water storage issues.

Acknowledgements

The authors wish to thank Bell Geospace and the Council for Geoscience, South Africa, for their kind permission to publish the Air-FTG and elevation data. Edgar Stettler of the Council for Geoscience and Gary Mumaw and John Macfarlane from Bell Geospace Ltd in Aberdeen are thanked greatly for their contribution to this article.

Seismic Imaging: Science and Art

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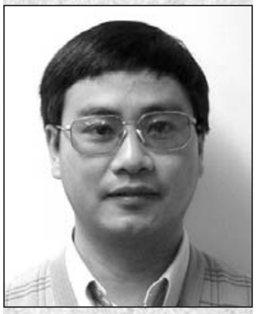

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Abstract

Seismic imaging is a process of geophysical inversion and consists of data acquisition, processing and interpretation. Errors introduced in any of these stages can have a serious impact on later stages and the final results. The processing stage probably has the greatest scope for error. Modern processing packages allow considerable freedom in the selection of processing algorithms and parameters. Even if essentially the same processing/work flow is followed, different results may be obtained from different data processors. End-users of the data can be unwittingly placed in a very difficult position.

The seismic method itself is firmly based on the theory of elastic wave propagation. However, the data processing and interpretation stages can be viewed as requiring the application of scientific art based on experience, a thorough understanding of the data in question, the field parameters, the options available for processing and the geological settings. This is not a new observation or theme, but in the light of recent experience in the application of seismic methods in mining, we revisit it in this paper. We use real data examples to illustrate the non-uniqueness of seismic data processing and the consequences of choosing different processing algorithms and parameters. The objective of this paper is to provide an awareness to some important issues in the contemporary use of seismic imaging in the hope that through this, better and more reliable results can be delivered and exploited by the end-users.

Introduction

Seismic imaging is one of the most effective geophysical methods for delineating geological structures and extracting lithological information. However, use of the seismic method requires the application of three complex and interrelated processes: data acquisition, processing and interpretation. Different groups of people tend to get involved in these various stages. Errors introduced in any of them can have a serious impact on later stages and the final results.

The process of seismic imaging has many attributes of an inversion. In general, inversions are intrinsically non-unique because we do not have enough information (measurements) to describe a usually complex problem - the geological targets (Parker, 1994). The processing stage probably has the greatest scope for error. Modern processing packages allow considerable freedom in the selection of processing procedures and corresponding parameters. Even if essentially the same processing/work flow is followed, different results may be obtained from different data processors. This, unwittingly, places the end-users of the data in a very difficult position.

The non-uniqueness of the inversion process requires selection of one solution from many, or even an infinite number of possible candidates (Parker, 1994). This leaves uncertainties in our results. The seismic method itself is firmly based on the theory of elastic wave propagation. However, the selection of the one most appropriate solution from many possible solutions involves the art of the processor and the interpreter. For processing, the geophysicist must select the appropriate algorithms and parameters on the basis of their experience and understanding of the data in question, the field parameters and conditions, the algorithms available for processing and the geological setting (Ulrych *et al.*, 1999). This is not a new observation or theme and examples can be found from Tucker and Yorston (1973) and Yilmaz (2001), but we revisit it in this paper in the light of recent experience in the application of seismic methods in mining. Our objective is to increase awareness of some important issues in the contemporary use of seismic surveying in the hope that better and more reliable results can be delivered to the end-users.

We use examples from recent work to illustrate the non-uniqueness of seismic data processing and the consequences of choosing different processing algorithms and parameters. We also discuss ways to reduce the risks of using inappropriate procedures and parameters.

Examples

Every data set is different and requires special attention to ensure a thorough understanding of it and the design of appropriate processing procedures. Otherwise, as Tucker and Yorston (1973) point out, the processing may unintentionally suppress the real structures or introduce false bedding, faults and other geological phenomena.

Velocity estimation

One of the issues in seismic data processing is the estimation of the velocities needed for static corrections, NMO corrections, migration and time-to-depth conversions. There are various ways to derive velocity information through refraction analysis, stacking velocity analysis, tomographic velocity inversion and sonic logging. Most of these only provide isolated velocities when compared to the density of seismic data and require some form of interpolation and extrapolation to match the density of the data. For example, when we want to transform a seismic time section into a depth section, we need the velocity information to be extrapolated from those known locations to all the trace locations. This is not as simple a procedure as it appears and can be the source of significant errors.

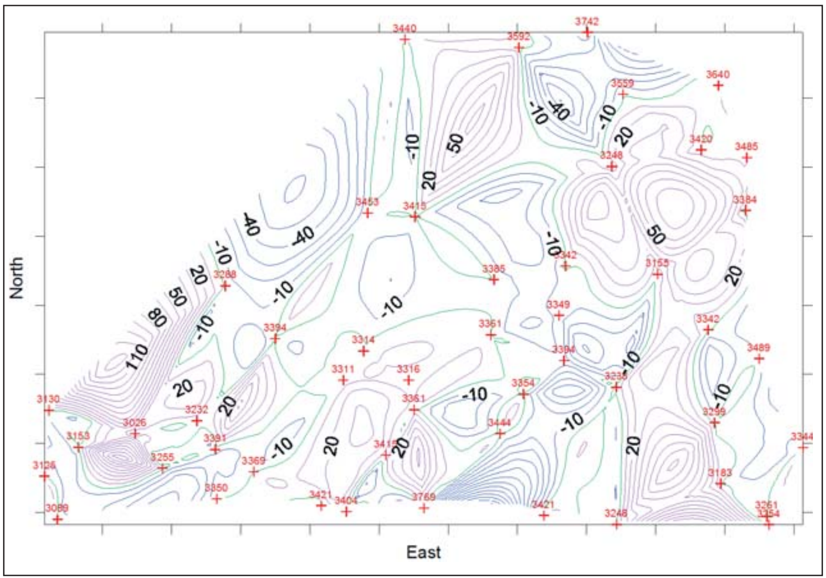

Fig. 1. The differences of the velocities derived using the triangular linear interpolation and the minimum curvature gridding algorithms from control boreholes shown by red crosses. The value above each borehole is the original velocity at this location. The purple contours indicate positive velocity differences while the blue contours are negative differences. The green contours indicate no velocity differences.

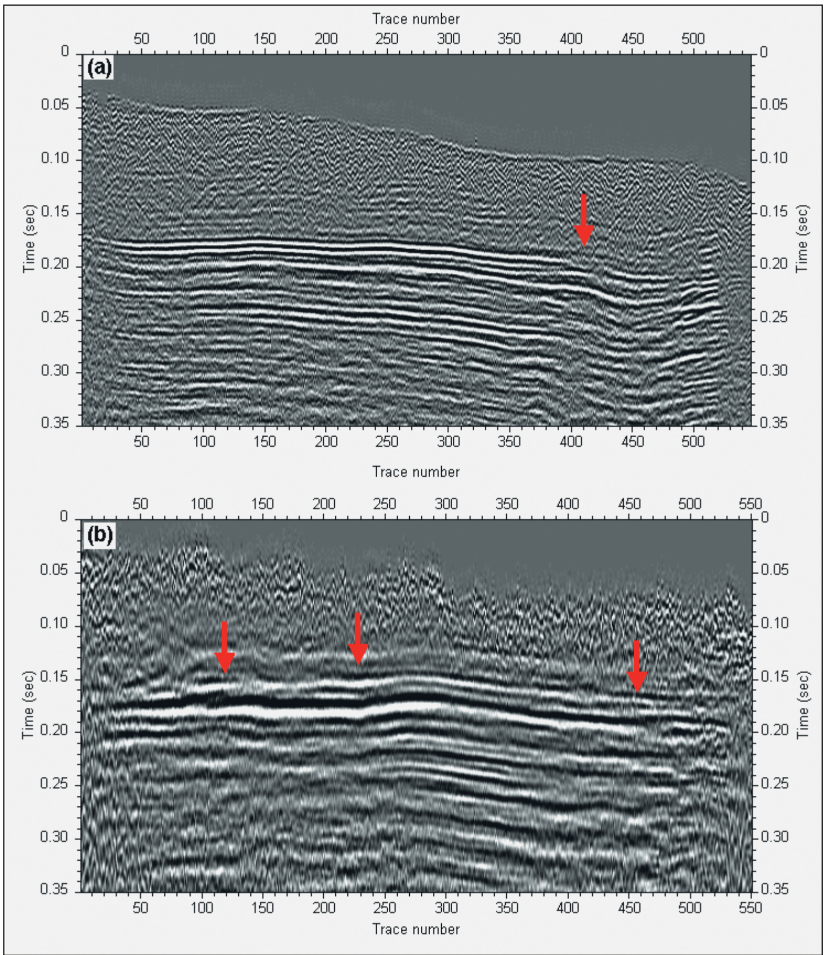

Fig. 2. The results of the same seismic line processed by two different seismic processing providers. The red arrows show the locations of possible faults. Different interpretations are clearly warranted.

To illustrate this, we use an example of 3D coal seismic horizon time-to-depth conversion. In coal mining situations, we usually have many boreholes in a relatively small area that can be used to control the coal seam depths. Once the target coal seam reflections have been picked, we can compute the velocities at the borehole locations based on the reflection times and the corresponding depth of the coal seams. These velocities should be very accurate around the borehole locations. The next step towards converting the tracked seam reflection times into depths, is to extrapolate the computed velocities at the control boreholes to all the trace locations. This can be done by 2D gridding algorithms.

There are many gridding algorithms available including polynomial regression, nearest neighbour, natural neighbour, Kriging, triangulation with linear interpolation and minimum curvature methods. Although they are all designed to honour the known data, each will give different results (Surfer 7 Manual, 1999). The selection of the griding algorithm is therefore, a challenging task. For example, Figure 1 shows the differences between the velocities obtained using the triangulation with linear interpolation method and the minimum curvature method. The differences can vary by up to 130 m/s and be translated into differences in depth of up to 20 m in this area where the average reflection times are about 0.3 s.

In this particular coal-mining example, the dip of the coal seam can be just as important as knowledge of the presence of geological structures. Care is clearly needed in the selection of gridding algorithm. The choice should include consideration of geological as well as any theoretical issues.

Choice of processing parameters

Just as there are many gridding algorithms available, there are numerous techniques in seismic data processing to enhance seismic data. New algorithms are constantly being developed and different combinations of algorithms and selection of input parameters can produce quite different final results even if essentially the same processing procedures are followed. Figure 2 shows such an example from coal seismic surveying. The two seismic sections in the plot are the results of the same seismic line processed in recent years by two different seismic processing companies. The processing flows were similar but from the appearance of these two sections, one would be hard pressed to say that they are the same line.

Firstly, the frequency contents are quite different: the top section has a higher frequency than the bottom one. Secondly, the the structural trend of the key reflection is different: in the top section, it dips from the left to the right while on the bottom one it shows an anticline in the middle. Thirdly, the top section appears to be affected by just the one fault to the right, while the bottom one has three. On the basis of these two sections, one would surely come up with different interpretations. Without any other information, this would put interpreters and other end-users of the data in a very difficult position in determining which section to use and its interpretation. Similar examples can be found from petroleum seismic in Yilmaz (2001).

While it is tempting for those involved in the seismic business to avoid such problems by presenting just the one final section, given the multitude of sections that could be produced, this is not the appropriate response to the situation. It is not a question of whether the section is correct or not, it is a question of whether it properly represents the true geological situation. This is not a trivial question. A proven response is to use acquisition, processing and interpretation teams who have a thorough understanding of the data (including the field acquisition parameters and conditions) in question, the algorithms to be applied, their assumptions and input parameters, and the geological constraints. Interaction between geophysicists, geologists, geo-engineers and interpreters is essential where all decisions need justification and understanding.

More quantitative means of evaluating uncertainties in the final results are also being developed. For example, in the case of time-to-depth conversion, we can estimate the velocity errors/uncertainties by using the cross-validation technique (Thore *et al.*, 2002). This involves taking out one of the known data points and measuring the difference between the interpolated value at this point and the true value (the one left out). This process is repeated for all the data points. It could help select the best gridding method suitable for the data based on the errors produced.

However, the quantification of uncertainties in seismic data is not an easy task and still needs development for most seismic processing procedures. The good news is that people are now more aware of the importance of this aspect and are working towards this goal. The work covers whole spectrum of seismic imaging including survey design, data processing and interpretation. For example, Thore et al. (2002) presented a general approach for determining and handling structural uncertainties from seismic data while Grubb and Tura (1996) and Houck (2002) have recently investigated the uncertainties in AVO analysis, and Kosloff and Sudman (2002) explored the interval velocity resolutions/uncertainties of typical seismic survey configurations by using a tomographic method. The uncertainties in quantitative time-lapse seismic data analysis are investigated by Yuh and Gibson Jr (2002) and Landr (2002). The importance of this topic is re-enforced by the papers presented at the 2003 ASEG meeting: Koster incorporated uncertainty in his quantitative interpretation workflow; Andersen et al. quantified fluid phase probability from seismic data using a Bayesian approach; Lamont et al. presented an integrated workflow for depth migration velocity model building with evaluation of structural uncertainties. It is clear that more and more work in this direction will come out in the coming years.

Discussions and Conclusions

Seismic imaging has a firm scientific basis: the theory of seismic wave propagation. However, it requires the application of scientific art to make it work. The results reflect our understanding/interpretation of the data, the available processing algorithms and corresponding parameters, which can be considered as a combination of science, technology, engineering and art (Herron, 1999). As an inversion process, seismic imaging is fundamentally non-unique and the variety of modern signal processing and enhancement techniques provides increased opportunities for producing different results and creating greater uncertainty. All these processing algorithms are scientifically sound and each has its merits, limitations and sensitivity to choice of input parameters. Different data sets also need their own choice of processing algorithm to maximise the amount of useful information that is obtained. This is where the experience of the processor, the understanding of the data in question and the available options in processing play a role. For now, this remains an art. In words of McQuillin *et al.* (1984): "Unlike an exact science, seismic prospecting for oil depends not only on high technology but also, and to very large extent, on the interpretive powers and experience of the practicing geophysicist. "

Uncertainty in seismic imaging is unavoidable. That is why we often get different answers from different data processors. This should not discourage people from using this most effective technology, but encourage them to use it intelligently. Methods of fully quantifying the uncertainty are not yet available but we can reduce it by:

1) Carefully examining the data so that we can choose appropriate processing options;
2) Monitoring the results of each stage to ensure that it has done its intended job (These intermediate results should be provided to the end-users where it is possible);
3) If possible, quantifying the uncertainty of each stage so that other users of the data can make their own judgements as to the uncertainty;
4) Collecting as much information as possible to guide the processing (including data acquisition parameters and field conditions, other people's understanding of the data, geological settings and other geological and geophysical data such as drill hole logs and geophysical logs); and
5) Encouraging interaction between data processing geophysicists, geologists, geo-engineers and interpreters so that all understand the merits of the data they are dealing with.

Acknowledgements

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(ACARP). The data were provided by Greg Poole of BHP-Billiton Illawarra Collieries. The need for this paper was prompted through the reprocessing and interpretation of seismic data from Wambo Coal Mine in a project lead by Dr Hua Guo (CSIRO EM). Special thanks go to Prof. Stewart Greenhalgh for his constructive comments.

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Courses

Seismic Petrophysics: A Multidisciplinary Course to Meet the Needs of a Multidisciplinary World

The Formation Evaluation Society of Queensland (FESQ), in conjunction with ASEG, is planning a "ground-breaking" course in late September/early October 2003 to combine petrophysics, rock physics and seismic attributes into the one course that will be attractive to petrophysicists and geophysicists alike.

Following an extensive worldwide search, FESQ are in the final stages of confirming arrangements with Professor Wayne D. Pennington of Michigan Technological University, USA, to provide this course to the industry for the first time ever. We are pleased to announce that this first course will be held in Australia. Wayne Pennington is SEG First Vice President and was an editorial board member for *The Leading Edge* during 1997–2001.

The concept that drove the development of this innovative concept was that a course in Seismic Petrophysics must include:

i) material for the log analyst or petrophysicist;
ii) material for the seismic processor or interpreter and;
iii a clear linkage between the two disciplines.

Participants in such a course will then be able to appreciate not only their specialised subject material but that of other disciplines and will be better able to communicate with practitioners in those fields toward their common goals.

The course will be split into a two-day introductory and theory module, followed by a two-day advanced and computer-assisted practical module. Attendees will have the option to attend either one or both modules.

Details of this course, to be held in Brisbane, Perth and, potentially Adelaide, will be available in the coming weeks. In the meantime, if any member is interested in more details they can contact Chris Shield at chris.shield@upsteam.originenergy.com.au
or John Hughes at john.hughes@santos.com

Geophysical Monitoring of Tree Root Zones

By A. Kepic and T. Campbell

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Introduction

Several years ago one of us, Anton Kepic, met a soil scientist (at a children's birthday party) and discussed how geophysical methods might be used to monitor the behaviour of trees. One point that arose in the discussion was that our understanding of how trees influence their soil environment is remarkably limited given their importance in forestry, agriculture and in solutions to the salinity problems in Australia. In addition, the methods used by botanists and soil scientists to study the rizosphere (root-zone) appear somewhat crude by the standards of physical scientists. The most popular method of study is to instrument the tree and its environment with some basic non-invasive sensors (if at all), let it grow to some size, and then dig it up to begin the research. The principal instrument used in these studies is a large backhoe. Clearly, this approach makes time-lapse studies difficult as the subject of the study is killed and the earth surrounding the tree is disturbed in the process. So the possibility of non-invasive monitoring the rizosphere via geophysical techniques is appealing to those who study trees.

It is important at this point to note that reliably imaging the roots themselves is well nigh impossible with present geophysical technology, although there are scientists who appeared to have tried. Generally, ground penetrating radar (GPR) of fairly high frequency, 400 MHz or higher, is used. At such high frequencies the presence of even a small amount of clay in the soil will attenuate the electromagnetic energy sufficiently to stop any useful imaging more than 50 cm deep. There also appears to be little point in mapping the major roots as these are merely conduits for sap to the fibrous parts of the root system that actually do the work of extracting water and nutrients. A three dimensional map of the active root zone appears to be one wish we can't grant for the foreseeable future.

The role of geophysics

What can geophysics do to help the study of trees root zones? Well, it would be nice to monitor the soil moisture content over time, measure salinity levels in the soil locally, determine which part of the root system is active (tap root verses upper branches), map the extent of the roots, and investigate how trees compete for resources. However, mapping the distribution of water and ion content over the rizosphere does appear to be an achievable goal. Geophysical techniques such as GPR and electrical resistivity methods would appear to be useful tools for this type of study as the dielectric constant and electrical resistance provide some means to study changes in these quantities. Accurate estimates of water saturation and ionic concentration are likely to prove elusive without calibration from samples near the area of interest. These samples can be gathered from augers or shallow boreholes and piezometer measurements can complement the surface measurement.

Determining which part of the root system is actually active is tricky, as there isn't much in physical contrasts for a geophysicist to work with. However, the movement of water and ions through membranes of the roots appears to either generate or be facilitated by small electrical currents and associated self-potentials. Many geophysicists have noticed that vegetation tends to generate significant self-potentials, which are generated by the root system. This provides a possible means to study the chemical activity of the root system. Unfortunately, the self-potential method is also one of our less reliable geophysical methods, and is not noted for its ability to image or discriminate sources.

Another significant problem for plant scientists is the issue of how plants compete for resources. For example, current forestry practice is to plant many seedlings and let competition determine the optimum number of trees that can occupy an area. This would appear to mimic the natural process; however, nature normally has a distribution of ages and plantations generally don't. A not uncommon consequence is that the trees grow to a certain size and then all die together at a relatively young age. The question is why doesn't the normal Darwinian process of the weak dying first open up resources for the stronger specimens? This leads to further questions such as: do the root systems of trees intermingle or do they tend to avoid direct competition? We don't really know as current methods of measuring root density rely on manually counting the number of fibrous roots per unit area in a trench. How do you tell the roots from one tree from another? You can't do it visually if the trees are the same species, and so plant scientists have few options available to them to accurately map the extent of a tree's root system in the presence of competition. A novel approach is required for this problem and we believe that we have a useful approach to help the soil scientist or agricultural scientist. The method is applied potential, or mise- -la-masse, and it works by placing a current electrode into the tree trunk and measuring the distribution of potentials around the tree with a small dipole. A variation of this method is to compare the potentials generated against those generated with the current electrode placed into the ground near the tree trunk. The rationale for the method is simple: the electric current follows the fluid in the tree (the sap) and exits the tree system where the roots exchange water and ions with the earth. In theory, the potentials will start to decrease rapidly once the current exits the roots if the sap is more conductive than the earth.

These ideas of using geophysical methods of investigation were tested at a few areas of interest to agricultural/soil

Fig. 1. A Blue gum plantation in the West Swan area north of Perth. This small plantation was established about seven years before the geophysical surveys were conducted. The survey area is roughly in the area where people can be seen standing, and the view is towards the south.

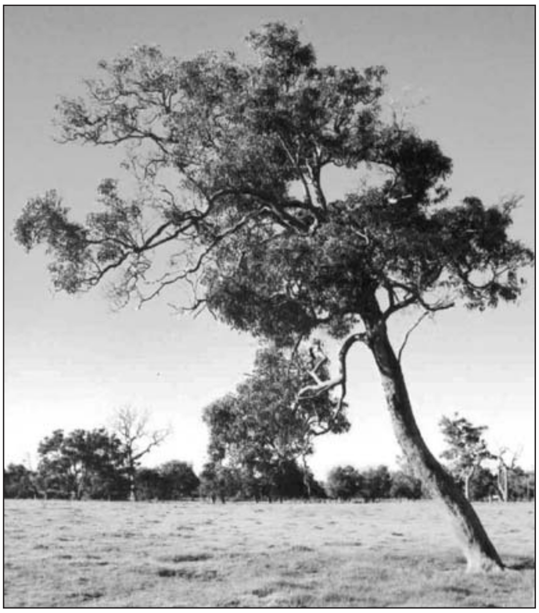

Fig. 2. A lone red gum near Pinjarra. This was the test subject of many of the methods. The view is towards the east and it can be seen that the tree is leaning considerably to the north. Rising salinity has caused the taproot to die and the tree has insufficient support to withstand prevailing winds.

scientists. At this stage the research is still in the preliminary phase and there is much more work needed to understand how to gather useful information in a non-invasive manner. The results presented here are to illustrate some of the work we have done, and show some interesting approaches to the abovementioned problems.

Sites Investigated

West Swan

The West Swan site is a small Blue Gum plantation located in the West Swan area, 40 minutes drive north of Perth (Figure 1). It consists of a narrow strip of land, 40 m wide and roughly 500 m long running approximately east-west. The Swan River is a few hundred metres to the east and there are a series of terraces stepping down from the road entrance on West Swan Road to the riverbank. The western-most area of the site is a hydroponic lettuce farm, operated by the Faculty of Agriculture at the University of Western Australia. The main line was located in a clearing in the blue gums on a bearing of 337 and was 25 m long, roughly perpendicular to the lines of trees.

This site has a large aquifer underneath and the first 6 years saw very fast growth of the trees. However, the recharge of the aquifer was less than the uptake of the trees and the phreatic surface has since dropped considerably. As a result of this reduction in the water available in the near surface in the past few years, many of the trees are showing signs of stress. This is indicated by re-growth near the base of these trees and quite a few trees have died. Only the largest trees are still healthy as their roots can reach deeper to the current water table.

The initial surveys were conducted at the end of summer. A combination of no rainfall for several months with the gradual depletion of near surface water by the trees since the beginning of the plantation meant that the first 6 to 8 m of the soil profile were extremely dry. This interfered with the initial SP and resistivity surveys, as the ground was too resistive to ensure sufficient electrical contact between the electrodes and the soil. Later surveys were conducted after significant rainfall. This produced zones of high moisture content on top of the clay layers in the subsurface. The different sets of data were compared with the intent of mapping the change in distribution of water after rainfall in the soil profile.

Pinjarra

The second principal site of investigation is a pastoral property near the town of Pinjarra about 70 km south of Perth, WA, and is typical of much of the pastoral land between Mandurah and Bunbury. Prior to clearing and farming, much of the land was classified as wetlands. Red gums were the main tree present and many still stand in pockets through the area. Unfortunately, the clearing of the land has caused the water table to rise. This has brought with it very high concentrations of salt in most areas. Thus, many of the original red gums die when their tap-roots meet this salty water: the roots are shut off from the tree, die and rot, and the tree topples over. The paddock in which the surveys were conducted has lost most of its trees in the past 10 years through this process.

A single tree was surveyed, a large red-gum, leaning at a significant angle towards the north-east, as the image in Figure 2 shows. This indicates that the tree's tap-root has already been shut off from the tree. From this lack of stability, the tree is slowly falling over. A borehole drilled during the project showed that the water table was very shallow at depth of only 1.1 m and very saline; the salt was sufficiently concentrated to be easily detected by taste. The soil profile consists of fairly homogenous beach-style sands with a high organic content. These sands originated from coastal sands deposited during times of higher sea level.

Boddington

The data from the last example comes from an area near the Boddington Gold mine in the south-west of WA, about 200 km south of Perth. In this case the test subject was a single tree located near the edge of an unused tailings dam now undergoing rehabilitation. The tree was a small gum sapling, less than two metres tall with foliage extending out to approximately a metre radius. The gum tree was isolated from other trees by at least 30 m. This gave us an opportunity to study a single isolated tree in a fairly uniform medium, as the depth of tailings is about 4 to 5 m in the area before bedrock. After the geophysical survey a trench was dug beside the tree, and the root system was mapped by traditional means (eye inspection and manual counting of root fibre density).

Self-Potential Method

The first self-potential (SP) survey at West Swan did not yield any useful results due to the poor electrical contact between the ground and the potential electrodes. Near surface resistivity was of the order of 5000–20,000 Ωm due to a long period without rain in the Perth area. A plot of the results from the first and second SP surveys is displayed in Figure 3, superimposed on a plan view of the site showing the locations of the major trees. The second SP survey performed at West Swan produced the highest anomalies, voltages of up to 70 mV where the trees were closest to the survey line. From Figure 3, it can be seen that small negative anomalies were also seen from trees up to 5 m away from the survey line. This initial survey indicated that we can indeed obtain an indication of lateral changes in electric potentials created by the uptake difference in ionic concentration between the tree roots and the soil profile.

A third (2D) survey at the West Swan area was conducted and meant to follow up on the encouraging results of the second survey. However, it did not yield much useful information regarding tree root extent or activity. This survey and other follow-up surveys conducted in the area soon after were discouraging. Basically, most of our negative anomalies disappeared and the range of SP voltages were nearly an order of magnitude smaller. These surveys were conducted within a week after significant rainfall and it appears that the rainfall produced at least one other source of SP signals, and the source produces predominately positive SP anomalies. We suspect that the additional source of self-potentials is from decaying organic matter. Throughout the West Swan site there are many fallen and decomposing logs from trees that have died. Decaying organic matter releases organic acids into the surrounding environment, thus, changing the near surface ph and ionic balance. The position of some of these zones of decaying vegetation were noted and do correspond to some of the major changes seen since the second survey.

The other major test of the SP method was at the lone tree at Pinjarra. This was thought to be an ideal target because of the relative isolation of the tree and a fairly uncomplicated geology in the local area. The grid size for the self-potential survey was 30 m by 30 m, with line and station spacing set to 3 m intervals. The tree was positioned in the centre of the grid.

Figure 4 shows the SP results around the tree, and there are some radial features from the centre, which could be activity from major root systems. Data from our ground penetrating radar (GPR) cannot totally support this data as the GPR found major near surface diffractors in many locations, indicating roots. Unfortunately, some of these anomalies are coincident with roots and some are not. As discussed previously, any lack of evidence of a major root does not rule out the root system from being the cause of the SP pattern, as the roots most likely to be responsible for exchange of ions and water cannot be imaged directly. In addition, the tree is clearly dying and not all of its root systems will be functioning normally.

Surveys over a larger grid area may have provided further information on the zone of influence of the tree, as there appears to be a gradient across the grid, with a general trend of the electrical potentials decreasing to the north. The source of this gradient is unknown as the topography of the site is very flat and there are no surface features for some distance from the survey grid. However, it should be noted that the general negative trend to the potentials lies roughly in the direction that the tree is leaning (towards

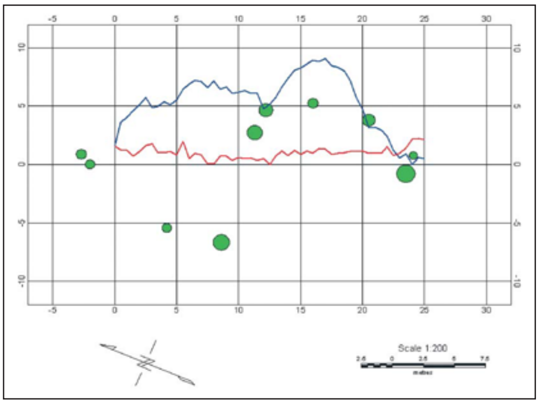

Fig. 3. A plot of self-potential measurements at the West Swan area superimposed upon a plan view of the area showing the relative location and size of the trees. Note that the survey line is along the horizontal 0 m axis. The red line is from summer measurements, and the blue line if from early winter measurements. The peak-to-peak amplitude of the SP signal is 80 mV. Negative anomalies from the early winter data correspond well with proximity to trees.

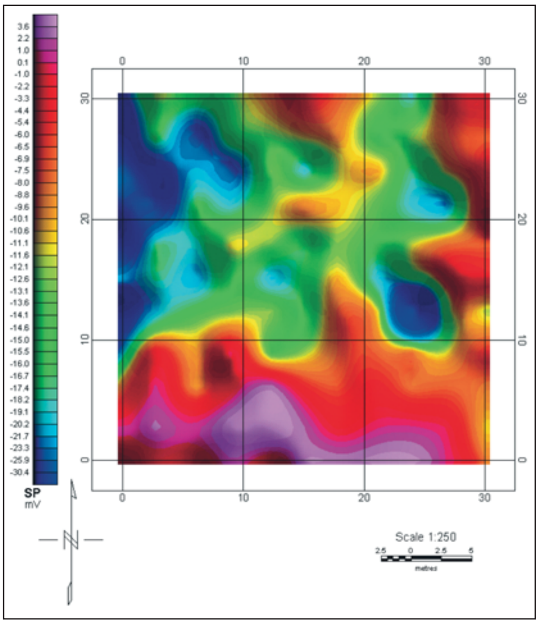

Fig. 4. The results of a self-potential survey at the Pinjarra site. The tree is positioned in the centre of the survey. SP anomalies can be seen radiating outward from the centre, indicating the possible location of active root systems. The gradient seen in the SP data may be due to the better health of the roots in the northern area of the tree.

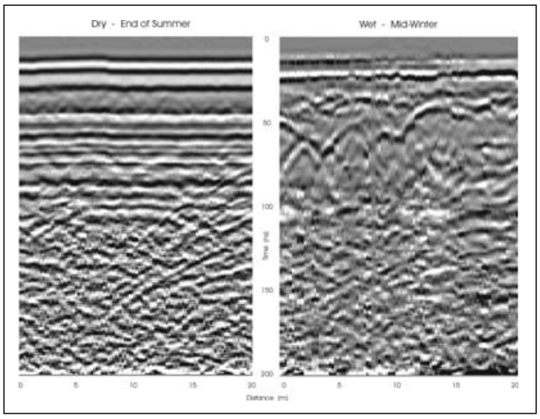

Fig. 5. (Above) Time-lapse GPR data from the West Swan area. The left panel is from data collected during the end of a long and dry summer, whilst the panel on the right was collected with an identical configuration in mid-winter. Both panels have been processed and plotted the same way, but the difference is striking. The weak diffractions at about 30 ns in the left panel have become stronger and arrive later in time over 0 to 10 m along the survey line. This effect is due to the increase moisture from recent rains in the area. However, the diffractions appearing in the first 50 ns in both panels 12 to 20 m along line have not changed in arrival time appreciably because the roots from nearby trees are extracting the water from the soil.

the north to north-east). This could indicate that the roots are more active in this direction and this hypothesis is supported by the prevailing weather conditions of the site; the prevailing wind direction is south-west and hence the tree's lean is to the north-east. As the tree's lean becomes more and more pronounced, the roots to the south-west become stretched and damaged by the movement of the tree. This was seen at the surface immediately to the SW of the tree's trunk, where several large lateral roots have become exposed at the surface. The disturbance of these roots means that they are unlikely to be as active as the roots to the north-east, and hence the increased negative potential to the north-east of the tree.

Ground Penetrating Radar

We used a Pulse Ekko IV equipped with 200 MHz antenna to conduct GPR surveys. Several different survey parameters were tested at West Swan and at Pinjarra to determine the most suitable settings for the subsequent surveys. It was found that an antenna separation of 40 cm produced the least interference between the transmitter and receiver. Data were collected in step mode (rather than continuously sampling whilst moving) with 256 stacks to produce reasonable signal-to-noise, and stations were spaced 20 cm apart. Common mid-point surveys were also conducted to collect EM velocity information at Pinjarra

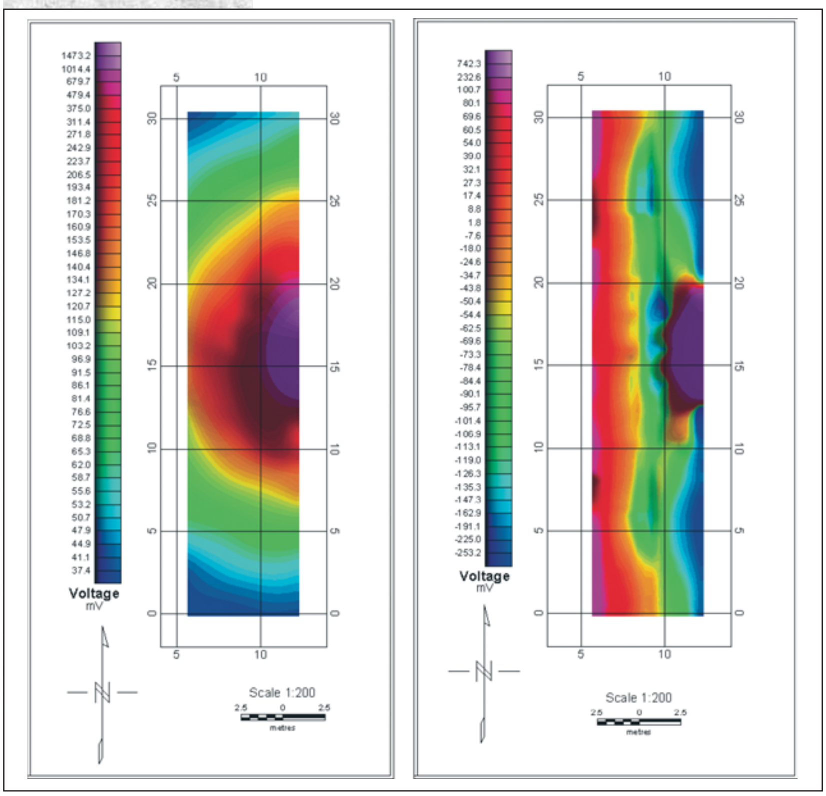

Fig. 6. (Left) Mise- -la-masse survey results from Pinjara, and a first vertical derivative of this data in the right panel. The current is exiting the root system via the lateral root system producing an overall potential pattern similar to that from a current dipole in a layered earth. Some structure can be seen (which is accentuated in the right panel) and shows that the root system is asymmetric. Three ridges running from centre to the east appear to be from large roots that were imaged by GPR.

and West Swan areas. The GPR data from the West Swan area is the most interesting, as we were able to do some time-lapse comparisons. We will only discuss GPR data from this area, as the GPR data from the Pinjarra site did not produce any definitive data by itself.

The first full set of transect data collected at the West Swan site is shown in the left panel in Figure 5. The data appears to be interpretable for the first 100 ns and then the noise generally dominates. However, there are some dipping interfaces than can be traced almost down to the bottom of the section at 200 ns. Many of the layers present in the upper half of the section appear to be multiples or a product of antenna coupling (often seen as "ringing"), appearing at regular time intervals and of a regular, similar lateral variation. Several features in the data appear to be definite geological boundaries as the arrival time of the features alters between stations. Artifacts from antennae interference tend to be constant in their time of occurrence. The lowest of the sub-horizontal geological features, appearing at roughly 90 ns, is most likely a clay layer. The dramatic drop in the signal-to-noise ratio below this feature indicates that it is an area with a significantly higher dielectric constant that the ground above it as the lower velocity causes a decrease in the signal energy reflected back from the interface. This interface does not appear to be the water table, as nearby boreholes show the water table to be deeper. It also occurs at roughly the same depth as a more conductive layer found by a Schlumberger sounding performed on the same date. Below this interface there are some faint interfaces that dip towards the north. None of these features can be traced through the interface discussed above, indicating it is an unconformity of some form. This confirms the interpretation of the above interface being a clay layer, as these dipping layers beneath it are very likely sedimentary features from when the nearby Swan River was at a higher level. The clay layer was most likely formed when the river dropped and the dipping beds were exposed for weathering.

A common mid-point survey that was calibrated with the borehole soils samples confirmed that many of the bands seen in the raw data were in fact due to interference effects, such as multiples, rather than from primary reflectors. Comparing the depth at which the primary reflectors occurred to the depth at which there were changes in the soil properties from the textural analysis yielded a good positive correlation between results. Soil analysis from a shallow auger hole in the area reveals that the water content of the soil is fairly constant at 10% by weight until a depth of 1.0 m when the water content drops to about 5%. The textural analysis of the soil samples also showed an increase in the clay content at this point as well. Hence, this clay layer has formed a semi-impermeable layer to the water through which the water can only seep through slowly. As a result, the soil moisture above the layer is greater than that beneath the layer.

While there are densely planted trees at the site, there is little obvious evidence of tree roots in the left panel in Figure 5. Some small disturbances (diffractors) can be seen along the interface at approximately 30 ns. These appear to be from tree roots. The second panel in Figure 5 was surveyed after significant rainfall. The presence of water in the soil profile for this survey has significantly altered much of the section; as opposed to the multiples and clay layer in the first 80-100 ns, a series of diffractions are clearly seen in this portion of the section. Below this, the signal-to-noise ratio is lower than that in the left panel. The upper surface reflector (approximately 20 ns) arrives at a later time. This is consistent with a higher amount of water in the near surface. The most significant temporal changes are in the first 60 ns of data where the weak diffractions occurring along 0 to 12 m along the line in the left panel arrive later in the right panel of Figure 5, and have greater amplitude. Diffractions seen (in the first 50 ns) 12 to 20 m along the line are largely unchanged in position in the section. Note that in the plan view in Figure 3 there are a number of large trees close to the line from 10 to 20 m along the survey line. It appears that the velocity changes can be attributed to changes in water moisture from recent rains, and that the root systems are depleting the soil of moisture with reasonable efficiency. In addition, stronger amplitudes from diffractions seen in the right panel of Figure 5 may indicate that the source of the diffractions, the roots, has changed too. Presumably, the roots are rich in sap after the rainfall and provide greater contrast.

Mise- -la-Masse

A portable electric drill was used to put a 10 mm diameter hole into the tree trunk and a steel stake then was embedded into the tree with a hammer to serve as a current electrode (and later pulled out). A Resistivity/IP transmitter was used to inject a current between 80–90 mA for all measurements, and the surface potential measurements made with a high quality voltmeter. Grids were set with line and station spaced 2 m apart, and the far current electrode was located several hundred meters from the survey grid.

The mise- -la-masse survey conducted at the West Swan site did not yield much signal or structure. Despite potentials of the order of 100 V placed into the tree, the total surface potential variation recorded was only of the order of 1 V. This indicates that the current going into the tree was not exiting the tree through any near surface root system; it was almost certainly exiting via the taproot directly into the water table. While this means that we were unable to examine the lateral extent of the active roots, as there were none, this result agrees well with the Schlumberger sounding performed earlier. The lack of water in the soil near the surface means that there would be little to no moisture content in the lateral roots. As a result of this, the rhizosphere around these lateral roots

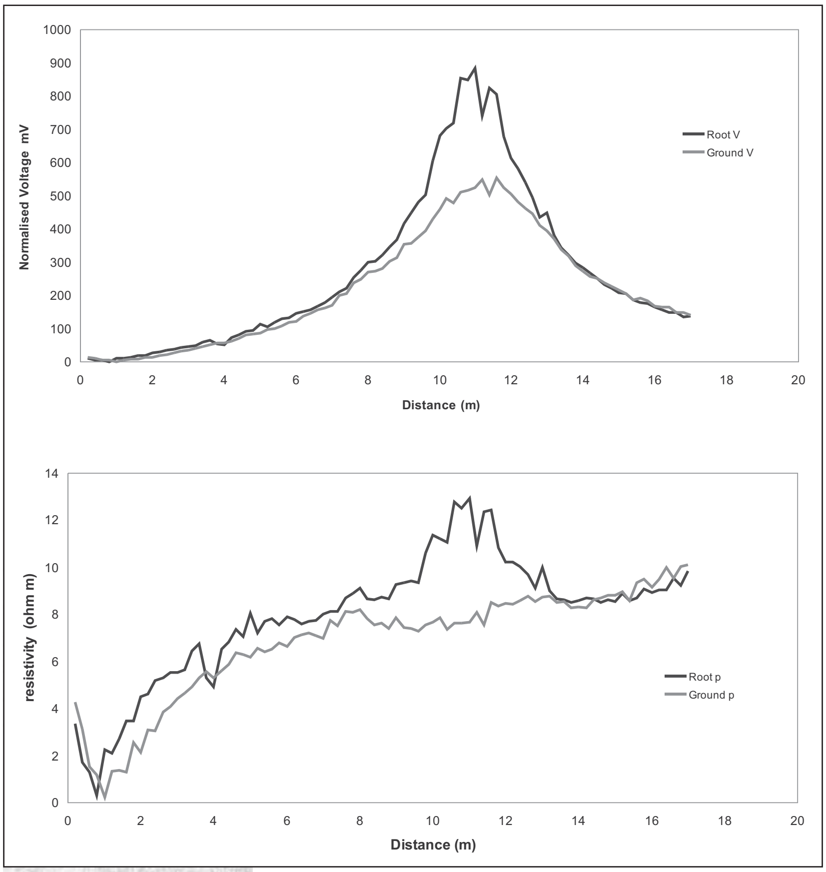

Fig. 7. A comparison was made between planting the mise- -la-masse current stake into the tree versus into the ground near the tree's base. The data was collected from a lone sapling in a rehabilitation area near the Boddington Gold mine, 200 km south of Perth, WA. The tree is located close (1.5 m away) to the survey line at the 11 m mark. The responses will differ when the current exits the tree root system via sap conduits. The data indicates that the root system extends 3 to 3.5 m laterally from the tree trunk and was confirmed by later excavation and visual analysis.

would be inactive and there would be little current exiting out of these roots. The only roots that would contain significant moisture would be the taproot system. This means that the current would be transmitted directly into the water table, and the high resistivity of the near surface would not reveal any lateral variation in the voltages on the surface as the current would be flowing underneath. So, while this method did not allow us to actually map the root system in this case, it still yielded useful information as to which roots were active in the soil profile.

The results from the mise- -la-masse surveys at the Pinjarra site produced a more exciting dataset (Figure 6). The raw potential data shown in the left panel of Figure 6 appears similar to the expected response from a single electrode in a homogenous half-space (or layered earth). This indicates that the tree is transmitting the current from its trunk into the surrounding earth through its lateral root system. There is clearly some polar asymmetry in the response that should represent the extent of the root system. Several methods of highlighting these asymmetrical anomalies in the response were tried by fitting a distance-related potential decay, but these were all hampered by the oblate nature of the decay of the current as the electrodes were stepped away from the tree.

Despite the failure to find a decent algorithm to remove the decay of the signal with distance from the tree, some small amplitude ridges can be seen radiating out from the central tree in northerly and southerly directions, indicating possible root systems in these areas, but the ridges are very indistinct. In an effort to enhance the lateral variations in the potentials measures, a vertical derivative of the grid was calculated (right panel of Figure 6). The presence of currents exiting the tree via the lateral roots would produce a ridge leading out from the tree. By applying the vertical derivative data, these ridges would show up as lows, because there is a slower change in amplitude across them, with the boundaries of the roots becoming highs, as there is rapid change in the voltage over the boundary. The use of this filter, as shown in the right panel of Figure 6, displays the presence of several roots in the area. The most noticeable of these is the group of three immediately to the east of the tree. These roots were confirmed in the images provided by a GPR transect of the area.

The last mise- -la-masse experiment was at the Boddington site after our experiences with the method at West Swan and Pinjarra. One of the shortcomings of the previous experiments was that an anomaly map is produced, but what can it be compared to? So another approach was trialled: two surveys are done with one placing the current electrode into the tree trunk and the other survey performed with the current electrode placed into the ground near the base of the tree. In theory, if the same current is used then the two datasets will have the same response if the current is in the earth, but be different when the current is still in the root sap. This would allow us to remove some the effects on non-homogeneous ground by subtracting the responses from the two data sets. An example of the success of this approach can be seen in Figure 7. The tree is closest to the survey line (1.5 m away) at 11 m. Apparent resistivity for a pole-dipole system were calculated to normalize the data A low bias due to low signal strength provides artificially low resistivities at the northern end of the survey line (0 to 5 m). From this data we would infer that the current exits the root system at approximately 9 and 13 m along the survey line. This corresponds to the root system radiating out to 3 to 3.5 m. This was confirmed by later trenching and manual counting of root fibre density by soil scientists.

Conclusions

All of the geophysical methods trialled can provide useful information, but all have their shortcomings and quirks. The self-potential method is clearly difficult to use in a quantitative manner, and in the case of the West Swan area was not even able to provide repeatable measurements. If suitable soil interfaces are available then ground penetrating radar would appears to be a good method for estimating soil moisture content once calibrated. Time-lapse studies would benefit greatly from GPR surveys, as the method is fairly quick and clearly very

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Performance of ASX Resource Stocks

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Executive Summary

Investment in resources is often seen as a poor cousin to the more highly promoted industrial companies of the Australian stock market. This paper analyses the performance of resources as an ASX Sector, finding there is good investment potential if you know where to look.

The crux of the comparison is that averages can be misleading as an indicator of sector performance. In addition, resource investors exhibit a rare quality — being able to correctly anticipate commodity prices of the next 1–2 years.

ASX Investment Sectors

The global perception of the Australian market is that it is a resource-based economy. This is not true, as demonstrated from a breakdown using the 10 sectors of Global Industry Classification Standard (GICS). The Financials Sector in particular dominates the Australian market, while sectors such as Energy, Healthcare and IT are poorly represented (Figure 1).
The Resources Sector comprises the Energy Sector plus part of the Materials Sector (S&P, 2003). The Materials sector aggregates many sectors from the old ASX system, including Gold, Other Metals, Diversified Resources, Building Materials, Chemicals and Paper.

As a percentage of the ASX All Ords, Resources have declined from over 60% during the 1980s to about 14% today (S & P, 2003). Resources have largely been displaced by growth of the Financials Sector, many from the rush of privatisations during the 1990s.

Resources vs ASX All Ords and Industrials

The cumulative price performance over the last 13 and 20 years of resource stocks, compared with the ASX All Ords and Industrials, is presented in Figures 2 & 3. (Monthly price data is sourced from ASSIRT Library, April 2003 version).

For the first half of the 1990s, performance of Resources was similar, or better than, Industrials and the All Ords. During the late 1990s, Resources performance fell away during the Asian financial crisis, but has since regained some ground. During the mid-1980s, there was another period of significant under-performance.

Since 1983, Industrial stocks have returned compound 10.5% pa compared with Resources 6.4% pa. Note this price performance does not include re-investment of dividends.

On the face of it, the significant out-performance of Industrials makes one wonder: If you want to make money,

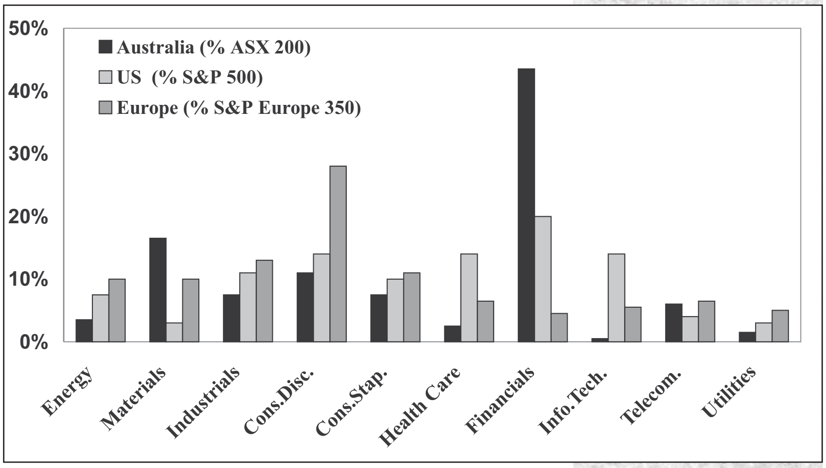

Fig. 1. World stock market proportions in the major sectors; Australia is over-exposed by financials and under-exposed to IT, Healthcare, Utilities.

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sensitive to changes in water content. GPR could also be used to map major root systems if ground conditions permit, but the usefulness of this data is questionable if parts of the root system are inactive. Mise- -la-masse shows much promise in doing the well nigh impossible: mapping the active root boundaries. However, interpretation of the results and technique refinement requires more investigation.

Our research is a first pass at many issues and we can't expect to get it right the first time. The fact that so many positives have come from such exploratory work indicates clearly that there is a role for geophysical methods in the scientific studies of trees and their root systems. In addition, following success in scientific studies there is a likely a role for geophysical methods in forestry management and rehabilitation via tree planting.

Acknowledgments

We would like to thank Chris Hinz of the Department of Soil Science in the University of Western Australia for his help in getting this work underway, support, and in advising on the issues in this area of science. Additional thanks to our casual field hands, especially to Matt Noteboom, and our trusty technician Dominic Howman.

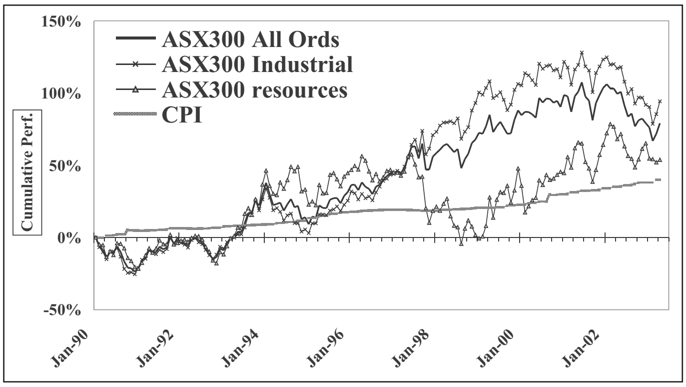


Fig. 2. Performance for resources, industrials, ASX during 1990 2003;resources were competitive for first part decade, then lagged after the Asian financial crisis.

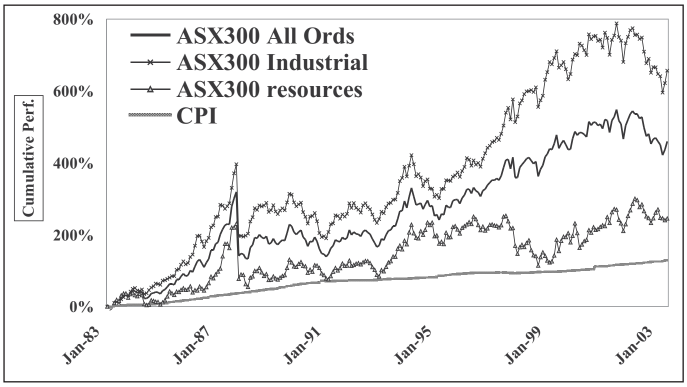


Fig. 3. Performance for resources, industrials, ASX during 1983 2003; two periods of resources significantly under-performing occurred in mid 1980s, late 1990s.

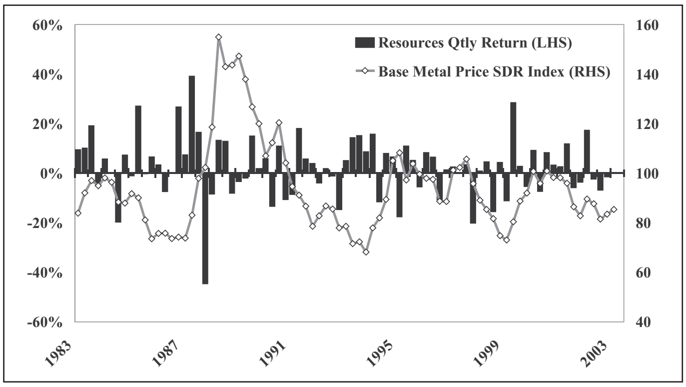


Fig. 4. Quarterly performance for resources and base metal price index; no direct correlation is apparent.

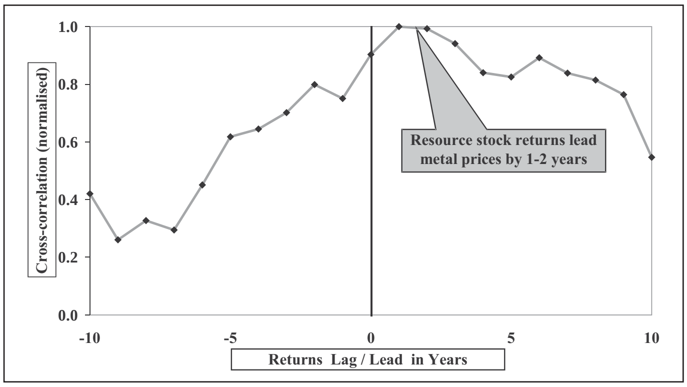


Fig. 5. Cross correlation of resources and base metal price index; a strong correlation is apparent, with returns leading commodity price index by 1 2 years.

is Resources the place to invest? An answer will be suggested later in this review.

Drivers for resources returns

The main driver for resources is health of the world economy. When economies are performing strongly, there is demand for resources, and vice versa. This controls commodity prices, in a demand and supply fashion.

Figure 4 shows the correspondence between commodity prices and resource returns. The Reserve Bank website publishes an index of commodity prices, one of which is an average of base metal prices in foreign currency terms (defined in terms of special drawing rights, the SDR index). This commodity price index is plotted against Resource returns (from Assirt Library), determined at quarterly intervals since 1983.

No correlation between the two series is apparent (in fact, the correlation is -0.1). This lack of correlation may be misinterpreted to mean the two series are not related.

Figure 5 shows a more appropriate measure of cross-correlation between the two series, which determines if there is any lead/lag time between them. (The two series are smoothed with a rolling annual filter, with the stock returns run past the commodity prices).

The cross-correlation shows the series are related, with stock returns anticipating *correctly* commodity prices by 1–2 years.

I find such a strong relation a little surprising. The general investing public is more noted for reactionary and herding tendencies, instead of being anticipatory, let alone correct. Typically, I would have thought resource returns would lag, or be in phase with, the commodity prices. Not so!

Therefore, may we conclude resource investors are more sophisticated than the general public?

Analysing performance beware of averages

When comparing performances among sectors, a common pitfall is to assume average performance is representative of the sector. (Such an assumption may be applicable when returns of individual companies within each sector have a symmetrical distribution, with the same standard deviation).

Figure 6 shows the cumulative percentage for the top 5 companies by capitalisation in the major Australian GICS sectors (S&P, 2003).

It is apparent only a few companies dominate that Resources Sector (Energy & Materials). In the Energy Group, the top 3 companies by capitalisation (Woodside, Santos,

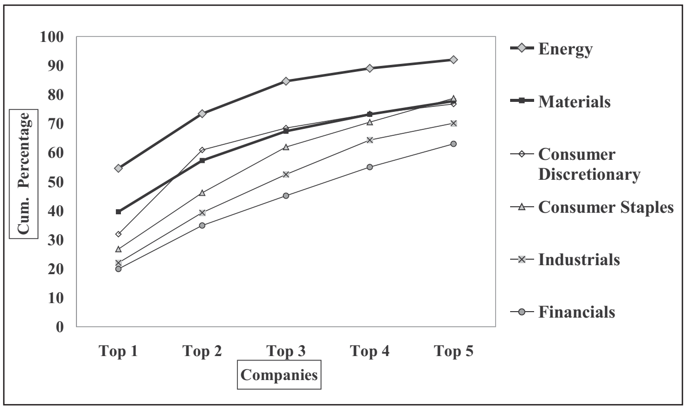


Fig. 6. Capitalisation weight of top 5 companies in major Australian sectors; note that Resources (Energy & Materials) are dominated by a few companies.

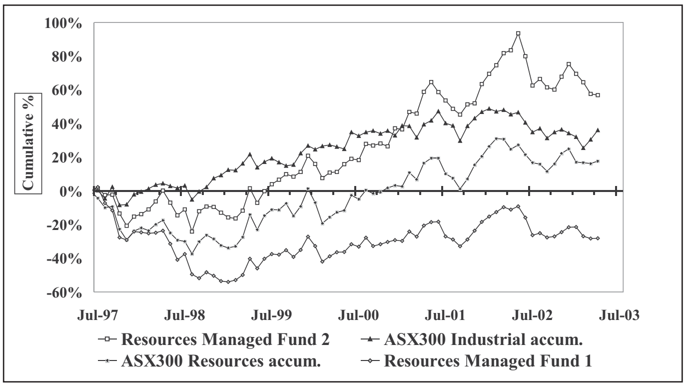


Fig. 7. During the last 5 years, resources and industrials had similar performance; subsets of resources stocks, using managed funds, significantly out-performed or under-performed industrials.

Origin) comprise 85%; in Materials, the top 3 companies (BHP Billiton, Rio Tinto, WMC) comprise 67%.

The weighted average return for the Resources Sector would be diluted by the returns of many small companies. Consequently, an average return may not be indicative of the best performers in that sector.

This concentration of production in only a few resource companies is a worldwide phenomenon, with the number of mergers increasing significantly since the early 1990s. The implications of mergers on the rate of exploration should be a topic for active discussion in the industry.

Quoting an average return for a sector can be misleading, as illustrated in Figure 7. Over the last 5 years, Industrials and Resources finished with similar compound performances (around 5% pa).

However, a subset of resource stocks, using managed funds specialising in resources, can have quite a different return. Managed Fund 1 has under performed the Resources index. On the other hand, Managed Fund 2 has returned 10% pa, significantly outperforming the Industrial index. (It should be noted this managed fund also includes international resources companies).

Figure 8 shows the annualised 3-year performance of the top 3 companies by capitalisation, where available, in each GICS sector, together with ASX500 accumulation index. We see that Resources companies, highlighted in black, were well placed, compared with the ASX index.

Ranking sectors by average returns may miss good investment opportunities. While it is acknowledged that most resources companies have not provided a return commensurate with the ASX, some resource companies have outperformed the ASX. As we shall see, these out performers are often not the larger companies. Finding the good future performers is a challenge for astute investors.

Where's the Next Resources Generation?

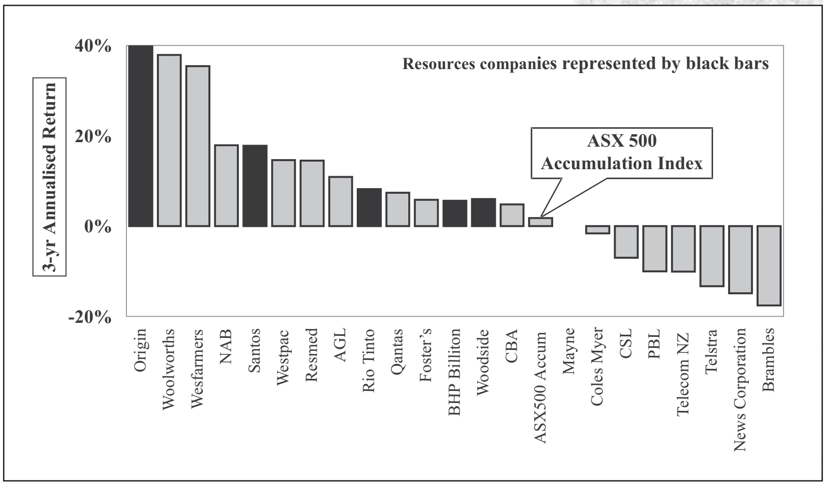
Resource investment is controlled by capital flows that "are determining the future of companies and countries. The world's major investors are focussing their investment on fewer and fewer companies in any industry. They are choosing to invest in those companies with sustainable and relatively stable earnings, and with the potential for significant growth" (WMC, 2001).

This focus on sustainable earnings reduces opportunities for smaller explorers, with adverse flow on effects on the rate of green-field exploration. Raising necessary capital will always be a challenge for small companies.

Given the decreasing number of resource companies after takeovers and mergers, the question arises: *Where will the next generation come from?*

The good news is that the next resources generation resource has been born, but is yet to be noticed by the general public. While the proportion of resources companies in ASX100 is about 14%, the remaining 1,200+ companies in the ASX comprise about 27% resources (Acorn, 2002). This suggests large potential for resource exploration.

Fig. 8. Ranking of top3 companies in each GICS market sector. Resources companies were well placed compared with ASX accumulation index.



Why haven't we heard about this multitude of companies? Stockbroker and institutional research usually covers only the top 200–300 companies in the ASX. The remaining 1,000+ "microcap" companies are mostly left to their own devices. The total contribution of Microcap companies is not small: an estimated 350,000 employees, generating $40b in goods and services (Acorn, 2002).

Potential investor rewards from the microcaps are large. If 10 years ago a prescient investor chose 50 ASX stocks that were to be the best performers for the next decade, 46 would have been microcaps (Officer, 2003). Of these, 10 were resources (all metals).

All is not doom and gloom. Investors and employees of larger resources companies can take hope!

Future for resources stocks?

We now look into our crystal ball for future performance of resources stock. There are two trends to disentangle — commodity prices in the medium and long term. (Only people who don't mind seeing predictions regularly proved wrong should try forecasting short-term prices).

Firstly, the very long-term trend for commodity prices is not encouraging. "Over the past 140 years real world commodity prices have declined by about 1% each year on average As incomes rise, it is likely that a smaller percentage of income will be spent on commodities. Technological advances have increased the supply of commodities, while demand has been tempered through the replacement of products by newer and more effective alternatives. With strong productivity gains and changing demand, it is not surprising to find commodity prices trending downwards" (Government Budget, 2002/03).

This is not of concern if all industries become more efficient. Profit margins are not necessarily threatened since resources companies also have lower operating costs.

The trend in the medium term for commodity prices is not clear. Given there is greater economic uncertainty now than at most times, the risks of a more prolonged economic downturn are increasing. Apart from the unquantifiable influences of the Iraq war and SARS, traditional barometers of economic activity are slowing in the USA, Europe and Asia ex-China.

The biggest X-factor in commodity prices is China's import demand for its massively developing economy. Booming Chinese demand rescued commodity markets from the worst effects of economic downturn in 2001 and 2002. While contributing 5% to the world's GDP and 6% of the world's trade in 2002, China consumed close to 20% of the world's basic materials and so contributed to over 50% of the materials growth in 2002 (Whitten, *pers. com.*).

In 2003, Chinese demand growth may be more subdued as the pace of economic activity abates and surplus inventories are absorbed. There are also questions about the sustainability of growth.

However, on the positive side, should world economic growth recover more strongly than expected and China keeps growing, this should drive global consumption to peak cycle levels and correspondingly higher prices.

In summary, the medium term outlook for resources is unclear. Resources returns 1-2 years ago were moderately positive only time will tell if the resource investors continue to correctly call the trend for commodity prices.

Conclusions

This paper contends it may be misleading to compare the average returns of the resources industry with industrial companies. There are some periods when high commodity prices allow investors to gain good returns from many resource companies. However, over the longer term only a limited number of resource companies are likely to post returns comparable with industrial companies.

Resource investors can pat themselves on the back, as they exhibit an unusual ability to correctly anticipate movement of commodity prices. This skill provides hope to employees of the resources industry - their employment is a vital part of the process of delivering results when market conditions are favourable.

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Mineral exploration increases in March quarter and petroleum exploration stays steady

Minerals

Figures released in June by the Australian Bureau of Statistics showed that investment in mineral exploration is continuing to climb from the low point of $158.3M experienced in March 2002.

In the March quarter 2003 the trend estimate for total mineral exploration expenditure increased by 3.8% to $188.7M following similar increases in the previous four quarters. The trend estimate is now 19.2% higher than in March quarter 2002 (see Figure 1), but still a long way down from the dizzy heights of 1997.

The other good news from the March quarter is that the ratio of expenditure on production leases over that on non-production leases has decreased by more than 5%. In other words, there has been a significant increase in proportion of expenditure on green field areas.

Petroleum

Meanwhile, in the March quarter 2003, expenditure on petroleum exploration fell slightly (by $3.9M or 1.4%) to $266.5M, which is 31.3% higher than the March quarter in the previous year.

There was a significant decrease in exploration on production leases (down $25.5M or 71.6%), which was offset by an increase in exploration on 'all other areas' (up $21.7M or 9.2%).

While onshore exploration expenditure decreased significantly by $40.4M (57.5%), offshore exploration increased by $36.5M (18.2%), with drilling activity being the driver in each case. Figure 2 gives an indication of the trends over the last 15 years.

Expenditure on land access for mineral exploration 2001-02

In several of the government inquiries into impediments to mineral exploration, the land access issue has also rated as an important factor. The ABS has completed a timely analysis into the costs of land access in the context of the mineral exploration budgets and its report is contained in the June 2003 release.

Land access expenditure included all 2001-02 financial year expenses incurred in obtaining (or attempting to obtain) access to land for mineral exploration purposes. Expenses included payments made at the start of the exploration cycle (such as exploration licence application fees) through to notification, negotiation, and other processes up to the point where access to land was obtained to physically start mineral exploration or attempts to access land had been abandoned. Land access expenditure also included any on-going payments made in 2001-02 for land access (for mineral exploration purposes) for which an agreement had been made before 1 July 2001.

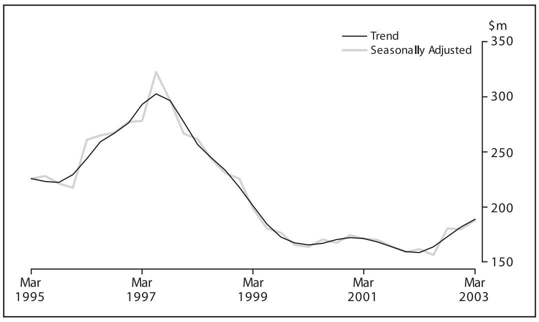

Fig. 1. Trend and seasonally adjusted quarterly exploration expenditure from March 1995 to March 2003 (provided by the Australian Bureau of Statistics).

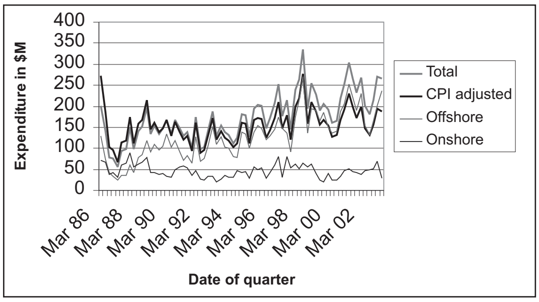

Fig. 2. Quarterly petroleum exploration since March 1986 for onshore and offshore areas.

It turned out that during 2001-02 land access expenditure amounted to $38.1M. This represented 7.5% of the total mineral exploration expenditure on Australia's non-production leases in 2001-02. On a regional basis, land access expenditure as a proportion of mineral exploration expenditure was highest in Queensland at 9.9%, followed by Northern Territory (8.2%), Western Australia (7.8%), South Australia (7.2%), New South Wales and Tasmania (both with 4.3%) and Victoria (2.3%).

ABARE forecasts decline in exports from the resource industries

According to the June issue of Australian Commodities, released by the Australian Bureau of Agricultural and Resource Economics (ABARE), the value of Australia's minerals and energy exports in 2003-04, is expected to decline by about 5%.

The report said that the value of Australia's minerals and energy exports is forecast to be $52.6 billion in 2003-04, down 5% from an estimated $55.5 billion in 2002-03.
However, export earnings are forecast to increase in 2003-04 for such mineral resources as gold, iron ore, iron and steel, titanium and nickel.

ABARE's Executive Director, Brian Fisher, said that: "this forecast decline in 2003-04 reflects the carryover effect of drought on rural exports, a modest outlook for growth in commodity demand and an assumed higher average value of the Australian exchange rate, especially against the US dollar."

In the 2003 March quarter around 60 per cent of the minerals and energy commodities surveyed recorded falls in production, compared to the December 2002 quarter. This translated into a

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Geophysical Signatures of South Australian Mineral Deposits

It has been some 8 years since I reviewed the sister publication to this volume "*Geophysical Signatures of Western Australian Mineral Deposits*", published in 1994. I commented at the time of publication that comprehensive compilations of this sort would make invaluable future references to explorers. Like its predecessor, this volume is no exception, bringing together a wealth of material on all major deposits and significant occurrences of mineralisation in the state of South Australia. This ranges from the truly world class Olympic Dam deposit, historical producers such as the Iron Ore deposits of the Middleback Ranges, relatively new discoveries such as the Challenger Gold and Prominent Hill Iron Oxide Copper Gold deposits and potentially interesting mineral occurrences.

As outlined in the Preface, this volume has taken some years to compile and required considerable collaboration and effort by a number of organisations and individuals to complete. It is a comprehensive compilation of 20 papers, four of which are based solely on reviews of public-domain material. The volume's purpose is to provide reference for use by geoscientists involved in mineral exploration in South Australia, but it has relevance to other similar terranes and deposit styles worldwide. Included are papers on all the important commodities and styles of mineralization known in the state, including base metals, gold, iron ore, uranium and industrial minerals. However the most extensive coverage is for the Iron Oxide hosted Cu/Au deposits for which the state is renowned, largely because of the range and scope of this type of mineralization and the presence of the world class Olympic Dam deposit. The content covers regional through to prospect-scale geophysical surveys and thus deals with everything from geological setting as well as methods applicable to the direct detection of mineralisation.

The first paper is an overview of the geology and mineral deposits in South Australia. The following case histories are roughly organised according to the age of the host rocks containing mineralisation. Some 71 deposits and mineralised occurrences are covered within the 20 papers.

Many of the papers have excellent coverage of the facts needed to explore for the deposit style covered. This includes regional and deposit scale geological setting and airborne, ground and borehole geophysical data and signatures. Physical rock property data are also included for many of the deposits. To the reviewer's knowledge much of the Olympic Dam ground geophysical data has never been published before. Of special mention are the excellent images published in most of the papers. These really exhibit how far this science has come since the publication of the first volume.

Although this volume does not have the scope of the first due to the more limited variety of deposits (particularly World Class deposits) present in South Australia as compared to Western Australia, I thoroughly recommend it for the reasons outlined above. The volume again is a credit to the Editor given it was compiled by his own admission during a very different time in the minerals exploration cycle as compared to the first. Let's hope that the next volume covering another state is compiled during a more positive exploration era than that of the past 5 years, and that it won't take another 9 year hiatus to achieve this.

Cont'd from page 39

fall in export earnings from mineral resources of 1.9 per cent in the March quarter 2003. In dollar values this amounted to a decrease of $260 million to $13.6 billion.

The main falls were in: crude oil, down $152 million to $1504 million; and iron ore, down $146 million to $1236 million. However, gold bucked the trend and posted a $278 million increase to $1441 million.

New world-class institute for petroleum at The University of Adelaide

The Australian School of Petroleum was formed in June this year by the merger of the university's School of Petroleum Engineering & Management and the National Centre for Petroleum Geology & Geophysics.

According to the University's Vice-Chancellor, Professor James McWha:

"It is one of the very few schools of its kind in the world - and the first of its kind in the southern hemisphere - to combine the engineering and geoscience disciplines into the one school."

This will produce a world-class educational environment for students that is supported by cutting-edge research across the two key petroleum-related fields, and it will firmly stamp Adelaide as a centre for petroleum research and consultancy."

More than 70 full-time undergraduate and postgraduate students are now enrolled, including 24 from overseas.

John Kaldi, formerly the Director of the NCPGG will head-up the new School. Other key staff are: Peter Behrenbruch, who holds the Santos Chair in Petroleum Engineering, Richard Hillis, the South Australian State Chair in Petrophysics and Reservoir Properties and Hemanta Sarma, holder of the Regg Sprigg Chair in Petroleum Engineering.