Preview

Australian Society of Exploration Geophysicists

ABN 71 000 876 040 ISSN 1443-2471 June 2004 Issue No.110

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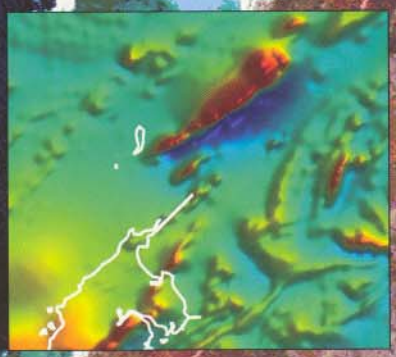

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Editor's Desk

David Denham

Sydney Conference August 2004

The ASEG-PESA Convention at Darling Harbour will soon be here, and it looks like being a terrific event. I have had a quick look at the abstracts and there will be some great presentations at a superb venue in Sydney. Make sure you have registered to be there.

In this issue of Preview, Philip Cooney from the organising Committee has written some words of encouragement and we have also included a short piece on our Platinum Sponsor, WesternGeco. Sponsors make all the difference the success of a Conference and we are delighted that WeternGeco has agreed to be associated with this meeting as the Platinum Sponsor.

Looking for Webwaver

Margarita Norvill, who has been writing the WebWaves articles since April 2003, will write her last WebWaves in the August Preview. I would like to take this opportunity to thank Margarita for the contributions over the past year and a half. They have shed interesting insights onto topics one would never normally have come across. I was particularly intrigued by the museum that display a series of inventions that monitored corpses in graves, just to make sure they had really finished breathing and had not buried alive. You don't usually read material on that subject!

Anyway we wish Margarita well in the completion of her PhD studies. She plans to be in Sydney and I am sure she would welcome talking about websites and geophysics.

Her departure will leave a vacancy on the Preview contributors list, so if anyone would like to have a go at surfing and writing please let me know.

Science meets Parliament 2004

Canberra is clearly in election mode, and, at the time of writing, there is the possibility of an August election. So FASTS has decided to postpone the Science meets Parliament days from August to 30 November and 1 December. You will need to change your diaries if you would like to attend.

Oil price rises

A lot has been made of the recent rise in the oil price as it hovers around US$40 a barrel. The Industry News section of this Preview contains further comments on this issue, and of course the government has provided encouragement in the 2004 Budget, to increase frontier petroleum exploration in Australia's offshore areas, in the form of a 150 % tax incentive.

The supply and demand balance sheet for oil has not looked good over the last few years, but with the inclusion of the Alberta's oil sands into the equation we suddenly have an increase in global reserves of another ~200 billion barrels equivalent. Very strange what the price if a barrel of oil can do to make marginal prospects real reserves.

In this issue

Once more we have a full and varied spread of feature articles in the Preview. They include Carbon Sequestration, which seems to be gaining more prominence by the month, Prominent Hill Geophysics, Tree Roots, Broken Hill-type deposits and Hymap techniques. So enjoy your reading and I look forward to the Sydney meeting and interacting with as many people as possible at the Convention.

David Denham

The Vision Thing

Mission Statements, Vision Statements, Strategy Statements, Statements of Goals and Aims – all the aphorisms spewing forth from corporations and organisations all sound unassailable. But often, alas, they are self-serving, and the levels of realisation of the ambitious goals are impossible to measure. I have been reading though ASEG's aims with the intention of comparing our current path with our stated goals. This can be a risky enterprise, and it is with some trepidation that I now take the risky step of going through the four aims of the ASEG to discover if the activities of the ASEG are in fact still furthering these aims.

1. To promote the science of geophysics, and specifically exploration geophysics, throughout Australia

How's this for a vague and unmeasurable aim? Nonetheless, ASEG's support for advocate organisations like ACG and FASTS certainly qualifies for promotion of our science. And the well-attended sesqui-annual ASEG international conferences, distinguished instructor short courses (DISC), and state branch technical speakers all contribute the Australian exploration geophysics. The Exploration Geophysics and Preview journals speak for themselves.

2. To foster fellowship and co-operation between geophysicists

I'm not sure how one measures how fully fellowship is fostered, but I can't think of a better way than the international cooperation the ASEG supports with organisations such as SEG, SEGJ, KSEG, EAGE, all of which were detailed previously in this column.

3. To encourage closer understanding and co-operation with other earth scientists

Closer understanding – I wasn't aware that understanding could be close or far. Pedantry aside, one way to foster relationships with a broad spectrum of geoscientists is to hold joint technical events. This is a general trend in the industry, and is exemplified by the joint ASEG/PESA Sydney conference scheduled for August this year and the upcoming ASEG/GSA international meeting in Melbourne in 2006.

And speaking of broader understanding, the new Affiliate Membership is designed to encourage understanding of geophysics by offering memberships to non-geophysical specialists such as earth science teachers. This membership status is one of the more innovative initiatives I have seen, and is gaining momentum.

Howard Golden

4. To assist in the design and teaching of courses in geophysics and to sponsor student sections where appropriate

This is one area where the ASEG excels. From DISC courses to state branch technical talks, from local Career Days to the scholarships awarded by the Research Foundation, from the recent environmental geophysics course to the ASEG Conference student day, the ASEG sponsors a wide range of educational and student based activities. This aim is so obvious it's almost not needed. And on reflection it's quite a measurable one as well.

There, that wasn't as bad as I thought it would be. While there is always room for improvement, it seems that the ASEG after 44 years is well on track to fulfil its mandate. As always, members are welcome to suggest other activities we can do to better serve the geophysical community, or to volunteer to assist with ongoing programs. Meanwhile, we continue to pursue ongoing and pending initiatives such as Exploration Geophysics on CD-ROM, a new relationship with South Africa's SAGA, new DISC programs, a program to encourage and facilitate the study of geophysics by Indigenous youth, and more.

Previous ASEG presidents, along with a legion of active ASEG members, have built the ASEG into an organisation that seems to honour its aims remarkably well. When it comes to the vision thing, I would say the ASEG is pretty close to 20-20.

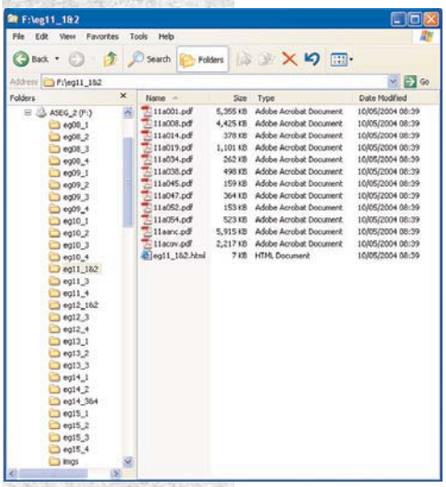
Howard Golden

Exploration Geophysics 1970 to 2003 Digital Volume Set now available on DVD

The ASEG is proud to announce that a complete collection of papers from Exploration Geophysics — from Volume 1 (1970) to Volume 34 (2003) — is now available in digital form as a two-DVD set.

Volumes 1 to 30 (Nos. 1 & 2) were produced by scanning hard copy originals to 300 dpi resolution tiff images and compressed as Adobe® PDF files (Adobe Acrobat™ version 6). Volumes 30 (3 & 4) to 34 were produced as Adobe® PDF files from original Quark Xpress™ digital print files.

In addition to the 1823 technical papers included in the collection, the cover pages and ancillary (advertising and editorial) pages have also been captured as two separate files for each issue. Individual papers are grouped on the DVDs in a directory structure that follows the volume and issue number (Figure 1).

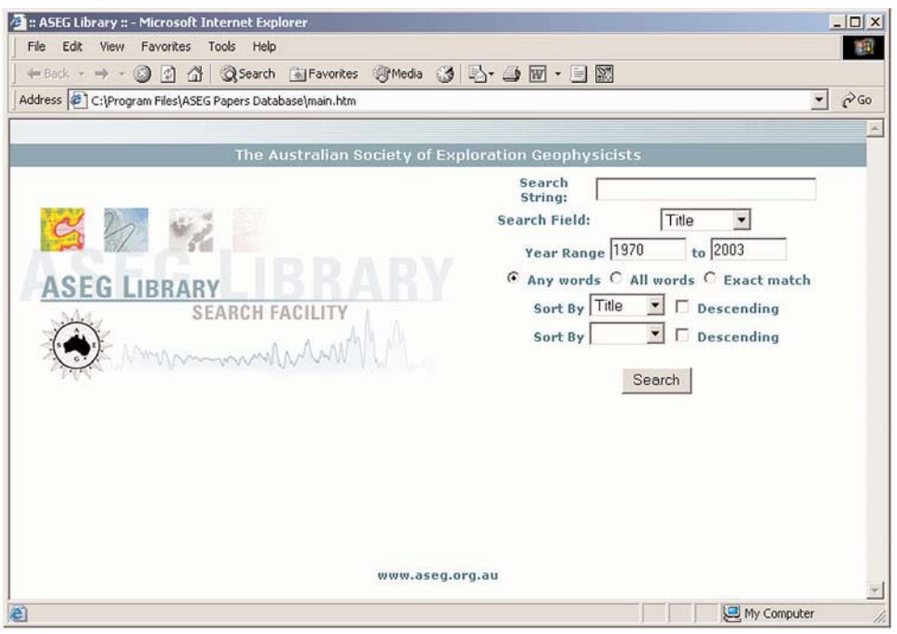


An accompanying database application (Microsoft® Windows® 98, 2000, XP only) enables full text searching for papers by title, author, keywords or abstract, providing a facility to find and sort papers of specific interest (Figure 2). An html contents page for each disk and volume is provided for non-Windows systems.

The scanning and com-pilation of back issues was undertaken following a decision of the Federal Executive in April 2003 as a pre-cursor to further consideration of electronic publication of EG and its distribution via the Internet. While the debate about full electronic publication and online distribution of EG — and whether or not hard copy publication should be maintained — is still continuing, the availability of the EG Digital Volume Set means that the electronic distribution of past papers is no longer a hypothetical consideration. It also means that digital versions of all papers from the current volume (No. 35, 2004) can be distributed to members in the same format in early 2005 as part of ASEG's standard membership services.

Fig. 1 (Above). Illustration of the directory folder and file structure by volume, issue and page number.

Fig. 2 (Right). Results page from a search on the database.



To place an order for the EG Digital Volume Set on DVD:

Download the information and order form from ***ASEG Online*** at:
www.aseg.org.au/forms/EGDigital-Order_form.pdf

Sample pages to illustrate scanning quality can be downloaded for viewing from ***ASEG Online***:

Monochrome page:
www.aseg.org.au/forms/EGsample_mono.pdf

Colour page:
www.aseg.org.au/forms/EGsample_colour.pdf

Price

Individual member — $165; Corporate member — $330; Library — $550 (all are GST inclusive). (*Postage and Packing extra: Australia $5.50; Overseas $10.00*)

New orders will be filled as they are received; note that numbers are limited. It is unlikely that a new print run will be made before March 2005 with the inclusion of Exploration Geophysics Volume 35 (2004).

2004

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

15-19 August
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

19-22 September
PESA Eastern Australasian Basins Symposium
Venue: Adelaide Convention Centre, Adelaide
Website: www.eabs.info
and
Pacrim 2004
Theme: Hi Tech and World Competitive - Mineral Success Stories Around the Pacific Rim
Venue: Adelaide Convention Centre, Adelaide
Website: www.ausimm.com/pacrim2004
Note, both the above events will take place at the same time at the same venue.

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

10-15 October
SEG International Exposition & 74th Annual Meeting
Venue: Denver, Colorado, USA
Website: www.seg.org

22-23 November
Theme: Orebody Modelling and Strategic Mine Planning Uncertainty and Risk Management
Sponsor: AusIMM
Venue: Hyatt Regency, Perth, Western Australia
Website: http://www.ausimm.com/ommp2004/home.html
Email: conference@ausimm.com.au

24-26 November
7th SEGJ International Symposium - Imaging Technology
Theme: Interdisciplinary integration of the geosciences for better understanding and Modelling
Venue: Sendai, Japan
Sponsors: SEG Japan, SEG, Australian SEG, EAGE, Korean SEG, EEGS
Website: http://www.segj.org/is7/

13-17 December
2004 AGU Fall Meeting
Venue: San Francisco, California, USA
Website: www.agu.org/meetings

2005

31 January - 4 February
The 16th Biennial Congress of the Australian Institute of Physics
Theme: Physics for the Nation
Venue: The Australian National University Canberra ACT, Australia
Website: http://aipcongress2005.anu.edu.au/

10-13 April
2005 APPEA Conference & Exhibition
Venue: Perth (at the new Convention Centre facility)
Contact: Julie Hood
Email: jhood@appea.com.au

23-27 May
2005 AGU Joint Assembly
Venue: New Orleans, Louisiana, USA
Website: www.agu.org

16-17 August
Central Australian Basins Symposium (CABS) 2005
Theme: Minerals and petroleum potential
Venue: Alice Springs (details TBA)
Contact: Greg Ambrose
Northern Territory Geological Survey
Email: greg.ambrose@nt.gov.au

19-23 September
22nd International Geochemical Exploration Symposium
Sponsors: The Association of Exploration Geochemists
Theme: From Tropics to Tundra
Venue: Sheraton Hotel, Perth, WA
Website: www.promaco.com.au/conference/2005/iges

6-11 November
SEG International Exposition & 75th Annual Meeting
Venue: Houston, Texas, USA
Website: www.seg.org

5-9 December
2005 AGU Fall Meeting
Venue: San Francisco, California, USA
Website: www.agu.org/meetings

2006

2-7 July
ASEG, in collaboration with GSA
ASEG's 18th International Conference and Exhibition, and GSA's 18th Australian Geological Convention
Venue: Melbourne, Victoria

ASEG-PESA 2004

We remind our members that the ASEG's 17th Geophysical Conference and Exhibition (in collaboration with the NSW Branch of the Petroleum Exploration Society of Australia) will be held at the Sydney Convention and Exhibition Centre at Darling Harbour, 15th – 19th August 2004

The theme of the conference – ***Integrated Exploration in a Changing World*** – focuses on the application of geophysics to petroleum and coal exploration, mineral exploration, geothermal, groundwater, and near-surface studies including forensics, archaeology, and ordinance.

Of particular interest is the number and quality of the **14 Keynote Speakers**. These range from academic to government to industry leaders. Among the better known are **Mike Bahorich**, Executive VP of Apache Corporation, the developer of the Coherency Cube used in 3D seismic interpretation and the rock physicist **Amos Nur**, Professor of Geophysics at Stanford University. Other industry leaders shaping the use of geophysical technologies who will be addressing the conference are; **Tom Whiting**, Vice-President Minerals Exploration BHP Billiton and **Keiran Wulff**, Chief Operations Officer Oil Search Ltd. The range of topics to be covered by other authoritative speakers extends from the regional such as **Phil Harman**'s talk on airborne gravity projects to the detailed as in **Heloise Lynn**'s presentation on the preferred direction of fluid flow in anisotropic rocks.

On the fourth and last day of the conference, registrants will have the choice, at no additional cost, of attending one of three symposia. Two of the symposia, "Inversion in mineral exploration" and "Salinity studies" will feature a number of prominent presenters and the world famous Professor Paul Weimer of the University of Colorado will be leading the workshop titled; "Petroleum systems in deepwater settings".

The Conference and Exhibition will be the geoscience technology event of the year and will attract up to 1000 delegates from throughout Australia and overseas. A large proportion of the delegates will be key decision makers, capable of influencing technology implementation and expenditure direction both within Australia and overseas. For more information regarding the event, visit our website at www.aseg-pesa2004.org.au

Introducing WesternGeco, Platinum Sponsor for the 2004 ASEG-PESA Conference and Exhibition

WesternGeco, the world's leading seismic services company, assists the E&P industry in exploration, and reservoir imaging, monitoring and development.

WesternGeco operates in every continent, with a distribution of resources to meet every geophysical challenge anywhere in the world. Seismic services available range from the planning, acquisition, and processing of conventional 2D and 3D surveys, to time-lapse (4D) and multicomponent surveys, and the provision of a very extensive multiclient seismic data library.

Q* is the WesternGeco proprietary suite of advanced seismic services and technologies for enhanced reservoir delineation, characterization, and monitoring. On land and offshore, Q-Technology* is playing a revolutionary role in helping asset teams locate, define, and monitor reservoirs, helping operators to manage risk and make reservoir management decisions with greater confidence and to extend the life of fields.

WesternGeco conventional marine seismic services cover 2D and 3D surveys over shelf and deepwater areas, seabed multicomponent surveys, and time-lapse 4D surveys. Additionally our proprietary Q-Marine* and Q-Seabed* services deliver the seismic technology breakthrough needed for new-generation reservoir management: exceptional data quality, unsurpassed repeatability, and the highest levels of operational safety.

WesternGeco offers comprehensive resources for high-quality conventional seismic data acquisition on land and across shallow-water transition zones. In each area, the survey design and choice of energy sources, recording equipment and field processing is customized to suit the specific environment, geological conditions, cultural setting, and survey objectives. Additionally, WesternGeco offer our proprietary Q-Land* services. Q-Land provides point-receiver recording - the dense digital data sampling means more effective noise attenuation and digital group forming can be performed. The result is an optimally sampled 3D wavefield ready for imaging, analysis, and interpretation.

WesternGeco seismic data processing technologies provide a full suite of tools for use in exploration, development, and production environments. In our worldwide processing centres, in client offices, and on our acquisition crews, WesternGeco processing specialists provide the industry's most advanced solutions.

The WesternGeco Reservoir Services group takes advanced seismic technologies into the reservoir. Reservoir Services provide life-of-field seismic services, assisting not only explorationists, but also reservoir and petroleum engineers, appraisal and production teams. Reservoir Services has the people, the tools and the technology to integrate all these disciplines and to help engineers and asset teams realize the full potential of their subsurface resources.

Multiclient surveys can significantly speed up the evaluation of frontier prospects and reduce finding costs.

The WesternGeco multiclient library is valued by clients for its high data quality, continuity across extensive areas, and geographical diversity. WesternGeco offers the largest breadth and scale of geographic coverage of seismic data throughout the world, including the Asia-Pacific region, Northern Europe, West Africa, the Gulf of Mexico and North America.

WesternGeco continues to invest in its global multiclient library in all regions of the world, while maintaining its industry-leading investment in seismic acquisition and processing R&D programs. These programs enable WesternGeco to continually introduce incremental improvements to current technology as well as many truly innovative breakthroughs.

WesternGeco recognizes that our long-term business success depends on our ability to continually improve the quality of our products and services while protecting people and the environment. Emphasis is placed on ensuring human health, operational safety, environmental protection, quality enhancement and community goodwill. This commitment is in the best interests of our customers, our employees, our stockholders and those in the communities in which we work and live.

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Conference Report – SAGEEP 2004

by Andy Green, OTBC Pty Ltd
Email: andy.green@ozemail.com.au

Andy Green

SAGEEP, the 17th Meeting of the Environmental and Engineering Geophysical Society was held at Colorado Springs from the 22nd to the 25th of February this year. Your correspondent, whose only experience with geophysics conferences is the warm and casual ambience of the ASEG, approached the cold of Colorado and the more serious world of North American geophysics with some trepidation. However, my fears proved unfounded. Not only was Colorado Springs snow-free and clear; most of the technical content was accessible and the hosts were pleased to see the small (but doughty) Australian contingent.

Over the three days some 160 papers were presented in 27 sessions. There were workshops, outdoor demonstrations (cold!), business lunches, technical lunches and social functions. The commercial exhibits were interesting, though rather serious and low-key by ASEG standards.

This meeting is an overwhelmingly practical affair. There are few discussions of theory, inversion, or data processing but lots and lots of case studies. Of these, while electrical and electromagnetic applications were the most common, a wide variety of seismic and potential field examples were also presented. There were also a few papers on the NMR and Seismoelectric methods. These weak "second order" geophysical responses would appear to hold considerable potential for near surface geophysics, because they provide information about new physical properties not detected by the traditional methods that have been around for the past 50 years.

However, if the techniques used were relatively standard, there is no lack of diversity with respect to the applications. In addition to the expected papers on salinity, voids, waste dumps, UXOs and the like, near surface geophysics is being applied to golf courses, dam spillways, Leonardo da Vinci's canals, landslides, CO_2 sequestration and a host of other fascinating problems. With three large sessions devoted to it, UXO detection is clearly a very active area of research.

In many of these applications multiple techniques are being used, creating stimulating data integration and joint inversion challenges. In contrast to mineral exploration, where large areas must be assessed cheaply, environmental and engineering geophysics is often focussed on small, high-value assets where there is commonly an abundance of ancillary information that can be use to constrain geophysical interpretations. I suspect it is from these problems that will, at last, emerge some real advances in genuinely integrated geophysical data analysis.

An interesting feature was that four papers, selected from the equivalent European near surface conference (formally EEGS and now NSGD/EAGE), were re-presented at this meeting. This exchange of "best papers" is now a regular feature of each conference and might provide an interesting model for interactions between the ASEG and other societies. The next SAGEEP meeting is scheduled for April 4-7 2005 in Atlanta and the next NSGD/EAGE meeting in Utrecht in September this year.

The proceedings of the conference are available on a well-produced CD from **http://www.eegs.org/pdf_files/publication_order_form.pdf** for US$100.

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Published for ASEG by:

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Kathy Hill new head of GeoScience Victoria

As we reported in the April Preview, Kathy Hill has been appointed Director of the new GeoScience Branch in the re-organised Minerals and Petroleum Division of the Victorian Government. Kathy has been a member of the ASEG for nearly 15 years and was Federal President in 1995-6.

For those who do not know Kathy, her career so far includes significant contributions to industry, academia and government. She is Canadian by birth, where she obtained a first degree in geology and experience in the oil and gas industry with Syncrude and Esso before graduate studies in the UK and employment with BP in the London.

She was transferred to Melbourne as a geophysicist with BP in 1985 and immediately fell in love with Melbourne. She decided not to return to the UK, taking a position lecturing at Monash University in petroleum geology and geophysics in 1989.

In 1994 she joined the public service as General Manager Petroleum Operations and is now Director of GeoScience Victoria, which was formed from the Geological Survey of Victoria and the Petroleum Basins and Information groups.

Kathy and her husband of 22 years Kevin Hill, who is also a geoscientist, have two children, Gareth and Naomi. We wish her well in her new appointment.

New Members

The ASEG welcomes the following new members to the Society. Their membership was approved at the Federal Executive meetings on 30 March and 28 April 2004.

Name	Organisation	State
Nicole Lisa Anderson	University Adelaide	SA
Mark Alexander Edmiston	James Cook University	Qld
Jane Margaret Larsen	CALM	WA
Amanda Malone	Shire of Mukinbudin	WA
Wesley John Manson	CALM	WA
Michael John Martin	Consultant	WA
Keith Neil Martins	Tap Oil Limited	WA
Ian Alexander Moffat	Ecophyte Technologies	Qld
James Colin Roberts	Monash University	VIC
Samuel Roberts	Encom Technology	NSW
Rowan John Spittle	Westclay	WA
Lydia Taylor	University of Sydney	NSW
Georgina Warren	Curtin University	WA
Ian Bruce Wheeler	CALM	WA
Helen Williams	School of Geosciences Monash University	Vic
John Michael Woodward	Origin Energy Resources	Qld

Happy 80th Birthday Harold Seigel

In April, our President, Howard Golden, sent a well deserved message of congratulation to Harold Seigel behalf of the ASEG, to celebrate Harold's 80th birthday.

For those not familiar with Harold's achievements, a short résumé is appropriate.

He has contributed greatly to Canada's reputation as a centre of excellence in mining geophysics, where he conceived and pioneered several new methods of mineral exploration. Today, he is best known for the broad and successful line of geophysical instruments marketed worldwide under the Scintrex label, a company he founded in 1967.

Harold has been called "a prospector at heart", and his efforts have contributed to the discovery of at least nine mines in Canada and abroad. As well, the vast proportion of the Scintrex equipment catalogue is still geared to mining exploration applications.

Seigel was born in Toronto, Ontario. He obtained his Ph.D. in geophysics from the University of Toronto in 1949, with his doctoral thesis encompassing the pioneering development of the Induced Polarization method.

He conceived and pioneered the development of two new methods of mineral exploration, Induced Polarization and Time-Resolved Photoluminescence, and was closely involved in the development of at least six other geophysical exploration methods.

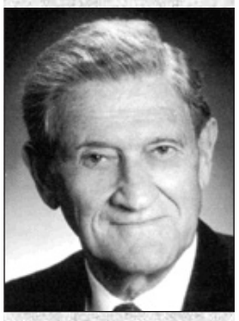
Those who know Seigel well, say that what distinguishes his work from that of other innovative scientists is his insistence on a mathematical-physical basis for his methods. He was able, with due regard to natural geological disorder, to develop simple and workable models that have been applied successfully to a wide variety of geological terranes.

Seigel's accomplishments led to industry acclaim. He has been awarded the J. Tuzo Wilson Medal of the Canadian Geophysical Union, the Distinguished Service Award of the Prospectors and Developers Association of Canada and the A.O. Dufresne Award of the Canadian Institute of Mining, Metallurgy and Petroleum, "in recognition of his distinguished scientific achievements and outstanding service to the geoscience community in the field of theoretical and applied geophysics".

During his career, Seigel maintained the profile of a man true to his profession; busy on the lecture circuit, active in industry affairs, and a willing and reliable participant on government and university committees.

He retired as president of Scintrex in 1993, but remains a full-time research director and Chairman of the Board.

Kathi Hill



Harold Seigel

NSW Branch office bearers for 2004 from left to right: Michael Moore (President), Carina Simmat (Student Liaison), Roger Henderson (Treasurer) and Naomi Osman (Secretary).

New South Wales – by Naomi Osman

The NSW Branch has continued to have interesting speakers at our monthly meetings. In March, Vladimir David from the Dept of Mineral Resources spoke on *Geophysical Interpretation of Potential Field Data: a Basis for Interpretation of Basin Architecture and Mineral Occurrence*. David focused on three-intracratonic, back-arc, Silurian/Devonian basins of NSW – the Hill End Trough, and the Cowra and Cobar Basins, using forward modelling of magnetic and gravity data combined with structural analysis to evaluate the relationship between the interpreted basement architecture and the pattern of mineral occurrences within the basins. In April, Art Raiche from CSIRO Exploration and Mining spoke on *Discovery and Delineation – EM Software Strategy for the Minerals Industry*. Art's research team is not only focused on developing more effective interpretation tools but also on making these tools more readily available by imbedding them within existing user's procedures. Art expanded on the five crucial strategies they apply to support these aims. The full abstract of all our recent talks are available on the NSW Branch website or they can be obtained by requesting them from me at nosman@awexp.com.au.

In other news, the ASEG-PESA Conference Committee has been hard at work and the conference is shaping up very well. The NSW Branch is developing ways to assist student members to attend beneficial conferences.

Finally a quick reminder, our branch meetings are usually held on the third Wednesday of the month 5:30 pm at the Rugby Club – Rugby Place, near Pitt and Alfred Streets, Sydney.

South Australia – by Dave Cockshell

The SA Branch AGM was held February 18th and attracted a good turnout to hear John Hughes from Santos talk on *Environmental Issues in Offshore Seismic Surveys*. The Committee were renominated, and office bearers remained as for 2003 (Graham Heinson: President, Dave Cockshell: Treasurer, and Tania Dhu: Secretary). Dave McInnes of Montana GIS Ltd. presented at our April meeting on *Mt Isa Downhole EM Exploration*, and by the time this edition of Preview is out our May meeting will have passed with Alan Mauger of PIRSA presenting on the *CSIRO Hylogger in South Australia*.

This year, the SA Branch Committee would like to thank our consortium of sponsors who make each meeting possible for our members. The sponsors are Australian School of Petroleum, Beach Petroleum, Cooper Energy, Minotaur Resources, Petrosys, PIRSA, Santos, Schlumberger, Stuart Petroleum and Zonge Engineering.

Victoria – by Ashley Grant

The Victorian Branch held its AGM on the 30th of March. The incoming committee consists of: Jim Cull as President, Suzanne Haydon as Vice President, Ashley Grant as Secretary, Ron Palmer as Treasurer, and the committee consists of Michael Asten, Matthew Purss, Paul St John, James Macnae and Ian Scott. Several topics were raised regarding the future of the Victorian Branch and the likely direction we should pursue. In the coming year we hope to host an informal seminar or workshop-style meeting, where we will invite members of other related societies i.e. IAH, GSA etc and highlight what geophysics can offer other societies. Target areas consist of geotechnical, groundwater, salinity, pipelines, NDT, remote sensing etc.

There has been significant progress with preparation for the 2006 ASEG National Conference. A final agreement has been signed off with GSA for a joint meeting to be identified as ***The Australian Earth Sciences Convention 2006***. The co-chairs of the COC for 2006 are Peter Pritchard (GSA) and Suzanne Haydon (ASEG). Work is proceeding on sub-committee structures and a general theme to ensure broad cross discipline participation. An overview will be presented in Sydney at ASEG-PESA 2004.

The world wide general geosciences job search

By Margarita Norvill

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A leading global independent energy company, engaged in the exploration and production of crude oil and natural gas seeks the employ of a processing geophysicist. The successful applicant must possess sound knowledge of interpretive processing and project management. The applicant must be able to working closely with clients and be prepared to travel. The applicant must be an effective as a team player, flexible and capable of taking responsibility for the quality and delivery of complex projects. The essential criteria are a relevant degree, 10-15 years experience working a similar role, experience with both land and marine surveys, very strong 2D and 3D interpretive processing skills, experience of time and depth imaging, AVO processing and inversion, demonstrated effectiveness as a team player, must have superior technical skills and be in the top percentile of your peer group……..sound familiar?

The livelihood of a geophysicist can be ever changing and their career path my not have a well defined course compared to other professions. As job availability is dependent on the ever changing barrel price and exploration rise and falls, a geophysicist can often find themselves looking for work. This issue of Web Waves highlights job sites on the World Wide Web.

Earthworks ★★★★½
www.earthworks-jobs.com

The Earthworks site comprises hotlinks directly to employment opportunities in the oil, mining, geodesy, environmental science, contaminated land, agriculture, forestry, oceanography, hydrology, soil science, remote sensing, GIS, geotechnical / civil engineering and related subjects. There is a large representation of many geographic locations. You can post your resume on the site for six months at the cost of $10 (US). Employer's job postings prices are determined via an individual quote basis.

Petroleum and Geoscience Jobs ★★★½
www.geosciencejobs.com

Owned and operated by the International Job listing Service (IJLS) and based in Houston Texas this site has been operating since 2001. The site is dedicated to finding and posting jobs for petroleum and gas industry professionals, jobs for geologists, geophysicists and environmental engineers. For the job seeker, membership to the site is $9 (US) a month, membership is required to view most of the employer contact information. There are two job posting options $15 or $45 (US) both offer a 45 day placement on the site, the extra $30 (US) is for greater exposure through an additional hotlink. The overwhelming majority of jobs are for North America featuring approximately 400 jobs posted for the United States and 30 for Canada in a one-month period. There are a small number of other jobs listed for other regions Europe, Middle East. All jobs viewed are by location, not qualification, this can make the job search time consuming.

Hunter Personnel ★★★½
http://www.hunterpersonnel.com

Established in 1976, Hunter Personnel provides human resources and services to two main industries: mining and civil engineering. The site advertises many mining jobs, mainly geological and engineering positions but some geotechnical, the main employment locations are Africa, Europe, Middle East, and the United Kingdom. Job titles are listed in a large non alphabetical list which you must sort through. Applications for all jobs are managed by Hunter Personnel. There are 20 000 personnel registered with Hunter, and registration is free.

Geopages ★★★½
www.geopages.co.uk

Geopages is an interactive web site devoted to geotechnical engineering. It has all the tools you need to explore the geotechnical world on the web. There are links to geotechnical software, on-line journals, book reviews, technical standards, patent search, scientific calculators, games, online discussion groups, as well as software to design your own web pages, which is free to download.

There is a comprehensive database of geotechnical companies and organisations on the web. The database has a search option or you can browse the database. It is free to submit your own company information.

As for jobs, head to the notice board for job postings, the site also features links to human resources companies.

Oil Careers ★★★★½
http://www.oilcareers.com/worldwide/

Oil careers is an independent company with the sole objective of facilitating recruitment and providing career related services to the Oil and Gas Industry. The site is not an employment agency and is not affiliated with any company. The job search is performed on a qualification

Star Rating

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

basis. Jobs are offered in Asia, Europe, the former Soviet Union, Africa, the Middle East, America and the United Kingdom. There is also a salary checker application, but to check you must be a registered member. Registration is free though you must provide a résumé.

NewScientist ★★★★★
http://www.newscientistjobs.com/search.action

This is a subset of the NewScientist magazine site. There is a comprehensive search engine for all scientific jobs and the job search includes discipline, sector, qualifications and location. There is an earth and environment discipline and with an explicit geophysics sector. Locations include Australasia, Europe and North America.

World Wide Worker ★★★★½
http://www.worldwideworker.com/

The World Wide Worker site boasts over 85 000 resumes and has clientele including CGG, ChevronTexaco, Halliburton, Landmark, Saudi Aramco, Schlumberger and Shell International. For job seekers they offer personalised communication, placement for the top jobs in the best companies worldwide. Job search is performed by category and company, registration is free, though you must provide your resume. Locations include Africa, Asia, Australia, Europe, including the former Soviet Union, the Middle East, North and South America.

Recruiters are able to advertise their vacancies or search for available, qualified employees on a global basis. Filtering matches the applicants to posting and allows direct contact between company and the selected individual.

Oil Survey ★★★★½
http://www.oilsurvey.com/php/jobs/index.php

The site hosts a collection of resources for the Oil and Gas Industry, it features over 15 000 links to other sites and an engineering library including free software and tutorials. Job search is by category and/or location. Locations are worldwide with explicit countries and states of the United States of America Listed.

Geologic Resources ★★★
http://www.geologicresources.com/jobs.html

Geologic resources is an environmental consulting company situated in Massachusetts, part of their website is dedicated to promoting networking to between geoscientist, engineers and other related professionals. They have a jobs page, which has links to other sites that are involved with human resources for geoscientists and engineers. Many of the geophysically relevant links are included in this issue, though others site may be worth a look. They also offer a free stuff page, with links to free software and other goodies.

Geoscience Gateways ★★★½
http://www.geogateways.com/default.asp

Geoscience Gateways is an informative site for petroleum geoscientists. There are links to news and business, universities, businesses and educational sights (for both the geoscientist and the interested browser). The employment section has links to 56 sites.

SEG Employment ★★★★★
http://seg.org/services/employment/job-list.shtml (side order)

This site is included in the SEG website, where businesses can place job advertisements. The great thing about it, is that it is straight and to the point. There is direct contact with the employer and no need to subscribe.

2004 Budget — a missed opportunity to invest for the future?

Mixed results for exploration industry

Good News – offshore petroleum incentive

The good news, in the 2004 Budget, is the 150% allowance on deductions for petroleum exploration in designated offshore frontier areas. The 150 per cent uplift applies to pre-appraisal exploration expenditure in the initial term of the exploration permit granted for a designated area.

Designated areas will have to be more than 100 km from an existing commercialised oil discovery and will not be adjacent to an area designated in the previous year's acreage release.

This decision was welcomed by APPEA and the Australian Geoscience Council. The AGC's media release stated:

"With petroleum being consumed faster than it was being discovered, it makes good sense to encourage the search for more oil in Australia.

Offshore petroleum royalties are estimated to be about $360 million in 2004/5, so the ~$6 million per year likely to be spent on this initiative is an excellent investment."

However, the $6m per year the government estimates it will spend on this initiative is still small in comparison with huge costs involved with offshore exploration. Last year, for example, Woodside Petroleum spent approximately $50m drilling one hole in the Great Australian Bight, and it did not find oil.

Bad News – nothing for onshore exploration

Unfortunately there are no new incentives to address the urgent need to encourage onshore minerals and energy exploration. The AGC argued that: "from the billions of dollars available from the budget surplus, a few million should and could have been invested to encourage exploration investment onshore and generate new wealth.

"For decades, the resource sector has contributed hugely to the prosperity of Australia and has made major contributions to the Government's budget surplus. Minerals and energy exports amount to about $50 billion each year and make up over one third of our total exports.

"Unfortunately, our share of the global exploration market is declining and we need to find new mineral and energy resources to ensure Australia's future wealth and sustainability. This is not an easy task.

"The government clearly recognised the problem and initiated two inquiries in 2003 to investigate this specific issue, but has yet to act on their reports.

"These inquiries (the Minerals Exploration Action Agenda (MEAA) and the Prosser Inquiry) produced 40 excellent recommendations on ways to encourage exploration and make resource exploration in Australia more innovative and effective. Unfortunately the May 11 Budget failed to commit any funds to capitalise on the outcomes of these inquiries."

The AGC identified two key areas, which should have been addressed in the Budget. These are:

1. The provision of financial incentives to ensure that Australia has a globally competitive environment to attract capital for exploration.
2. More money to increase our understanding of the geology of the Australian continent, so that we can identify new resource prospects and improve the management of our resources.

In fact the government has yet to respond to either the Prosser Report or the MEAA.

The Australian Gold Council was even more forthright in its assessment of the Budget:

Its CEO, Tamara Gorrie, said that "the Budget's neglect of mineral exploration was a significant blow to the gold industry, particularly given the industry's expectation that measures designed to reinvigorate exploration would be part of the 2004/05 Budget process.

"The Australian gold industry contributes over $5 billion dollars per annum in export income and is a major regional employer, however gold exploration has declined by 50% in recent years, jeopardising the industry's significant input to the national economy and regional Australia.

"It appeared the two years industry had spent working with the Federal Government on ways to stimulate mineral exploration via the Government's Parliamentary Inquiry into Mineral Exploration Impediments and the Mineral Exploration Action Agenda, had proved all but fruitless.

"The Budget has demonstrated a clear policy vacuum on mineral exploration in Australia and called on the Government to explain how and when it intends responding to the recommendations stemming from the Mineral Exploration Parliamentary Inquiry and Action Agenda."

There is clearly no doubt as to where the Gold Council stands.

Science and Innovation

The main plus for Science and Innovation was the government's ten year commitment to the second stage of the Backing Australia's Ability Program. However, in dollar terms there appears to be only a very small increase. According to the papers released with the 2004/05 Budget the government will provide $5.342 billion (an increase of $127.9 million on 2003-04) to invest in Australian science and innovation. This is an increase of only 2.5 percent, probably not even keeping pace with inflation, and in dollar terms, after 2005-6, the long term commitment declines.

The new funding for the Backing Australia's Ability II program is essentially a continuation of the original BAA initiated in 2001. The table below shows the BAA I & II funding from 2002-03 through 2008-09 and the total funding for the ARC and the CRC Program.

However, the total BAA funding is not quite as large as it might seem at first, because there are items in the new program that have been transferred from other parts of the previous budget. For example, the $30 million listed for the CSIRO Flagships listed in BAAII was previously not in BAA but was listed in CSIRO's allocation, where it is still included. So one has to be careful of any double counting. Another example is the $39 million allocation for the Science, Maths and Technology in government schools. This was announced in the original BAA pronouncement but not included in the BAA funding plan. It must have been elsewhere in the DEST budget. So one has to look at the numbers carefully to try and work out the full implications. In summary it appears that the BAA money has been made to look as large as possible, and in any case it flattens off by 2006/07. The CRC program flattens off even earlier with a decline in real terms from 2003/04 through 2008/09.

How the main science agencies faired

The main outcomes for the larger Commonwealth science and research agencies are given below and in Table 2.

CSIRO

In the 2004/05 Budget, CSIRO received a welcome $30m increase in its base funding to be allocated to its Flagship Programs. It also received a triennium funding commitment that will amount to $1.8 billion over the 2004-05 to 2006-07 triennium, a 15% increase compared with CSIRO's last triennium funding agreement for 2000-01 to 2002-03.

However, the net gain for 2004/05 will only be $10 m because it was allocated a one off $20 m for the Flagship Programs in 2003/04.

CSIRO will also have to achieve external earnings targets. In 2004/05 it has budgeted for $320 m or 35% of its total budget, rising to 40% in 2006/07. So the pressure for commercialization is bound to increase.

Australian Research Council

The ARC's Mission is to Advance Australia's research excellence to be globally competitive and deliver benefits to the community. The total appropriation for the ARC in the 2003-04 Budget is $481m. This is scheduled to rise to $616 m in 2010/11 (see Tables 1 & 2). So ARC effectively receives its full funding as originally outlined in BAAI.

The National Health and Medical Research Council

The NHMRC consolidates within a single organisation the functions of research funding and development of advice. One of its strengths is that it brings together and draws upon the resources of all components of the health system. Its budget for 2004/05 is $378m, which represents an increase of $66m over the previous year.

Defence Science and Technology Organisation

DSTO is one of Australia's largest research agencies; it has a budget of $287m in 2004/05, a decrease over the previous year's allocation, so it has not done well in the competition for operational funds within the Defence Department.

Table 1. Summary of Backing Australia's Ability funding and the ARC and CRC appropriations.

Year	2002/03	2003/04	2004/05	2006/07	2007/08	2008/09
	($m)	($m)	($m)	($m)	($m)	($m)
Total BAA funding	396	618	899	1077	1048	1028
ARC total	298	414	481	566	578	592
CRC Program	149	202	193	187	210	181

Bureau of Meteorology

The Bureau of Meteorology's allocation fell from $197m in 2003/04 to $190m in 2004/05; presumably because the additional money provided in last year's budget for equipment upgrades has been spent.

Australian Nuclear Science and Technology Organisation

ANSTO has a total appropriation budget of $153m. In summary, an increase over the $121m provided last year. Much of the increase will be allocated to the commissioning of the new reactor at Lucas Heights.

Geoscience Australia

The Budget outcome for Geoscience Australia was positive, but with the Government's response to the Mineral Exploration Action Agenda not included in the 2004/05 Budget, there is no additional money for onshore programs to encourage exploration.

GA will receive funding of $0.8m over 4 years from 2004-05 to contribute to the Government's Critical Infrastructure Protection (CIP) strategy.

This funding forms part of continuing efforts to ensure there are adequate levels of protective security in respect of critical infrastructure, minimal potential points of failure and rapid, tested recovery arrangements.

The Government announced funding of $61m over 4 years in the 2003-04 Budget for Seismic Data Acquisition and Preservation, and the Core Petroleum program. The Government is providing $5.0m and $8.9m for these measures respectively in 2004 05. This will enable GA to continue to provide vital geological and seismic data to companies considering oil exploration in Australian waters.

The Australian Greenhouse Office

The AGO is responsible for promoting a whole of government position on greenhouse issues to the broader domestic and international community. It aims to develop an integrated, balanced approach that will facilitate the realisation of both economic and environmental benefits for Australia from the opportunities arising from greenhouse response actions.

As a reward its budget was cut from $73m in 2003/04 Budget, to $$45m in this year's budget. It is not clear what this means in the context of outputs in its work program.

Antarctic Division

The Antarctic Division of the Department of the Environment and Heritage is responsible for Australia's commitment to the protection of the Antarctic as well as conducting world-class Antarctic scientific research. The 2004/05 Budget provides $87m which is similar to the appropriation provided in previous years.

Australian Institute of Marine Science

AIMS mission is to generate and transfer the knowledge to support the sustainable use and protection of the marine environment through innovative, world class scientific and technologies research. The basic operating budget has remained constant in dollar terms at $23m.

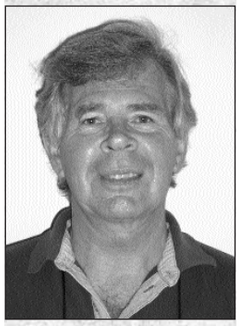
So there you have the numbers. It appears that ARC and NH&MRC are doing well, that CSIRO has improved its position, but that all the other agencies are either standing still or declining.

Eristicus

Agency	Government appropriation in $m				
Year	2002/03	2003/04	2004/05	2005/06	2006/07
CSIRO	532	569	576	590	603
ARC	363	414	482	556	566
NH&MRC*	273	360	426		
DSTO*	283	294	287		
CRC Program	149	202	193	206	187
BoM	162	197	190	200	204
ANSTO	182	121	153	168	167
Geoscience Australia	86	96	101	104	107
Australian Greenhouse Office	73	73	45	45	47
Antarctic* Division	84	85	87	88	
AIMS	24	22	22	23	23

*Table 2, Summary of appropriations for the main Commonwealth-funded science agencies. *Forward estimates not available.*

The Magnetic Shoal near Bezout Island



By Doug Morrison
sth.lands@optusnet.com.au

In the last decade of the 19th Century, the scientific discipline of exploration geophysics, as such, was still in its infancy and this story is an example of the scientific crossover typical of the era. It has relevance to navigation, hydrography, geophysics and geology.

In September 1885, HMS *Medea* whilst on an extensive hydrographic and magnetic (declination, inclination and intensity) survey west from Cape York and around the continent to Adelaide, discovered a remarkable compass disturbance when passing near Bezout Island (20.55° S, 117.180° E), off Cape Lambert (see Figure 1), Western Australia (Ellery, 1892). The magnetic observer onboard being Lt. Dockrell. This well-defined compass variation increased to over 30° from normal and being in only eight fathoms of water was immediately flagged as a hazard.

The discovery, when published, astounded maritime observers, navigators and scientists alike – nothing of such magnitude had previously been documented. Those producing global navigation charts generally considered local anomalies an annoyance and when they were recorded, new measurements were made away from the interference. This offshore anomaly was different and needed investigation.

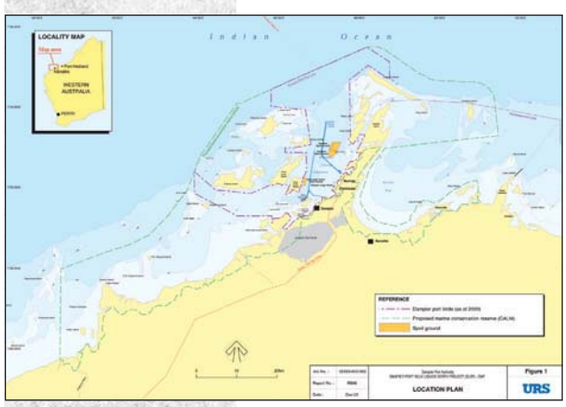


Fig. 1. Location diagram for Bezout Island and Cape Lambert.

The number of magnetic observations along the Australian coast were lacking to say the least, in fact in 1885 according to Creak (1896), there were "only some three or four stations at which either Dip or Force had been observed" from Adelaide west to Perth and the entire coast around to the tip of Cape York. This was a gaping hole in the accumulated global measurements of compass and intensity values and it needed correction.

By 1889 HMS *Penguin*, commanded by Captain W. U. Moore, was in service in Australia, and under instructions from the Royal Navy Hydrographer was continuing these Australian coastal magnetic observations (supervised by Lt. J. W. Combe RN). The "magnetic shoal", as it was described, at Cape Lambert was also to be investigated – and in late 1890 a small investigation by the *Penguin* defined the general limits of the anomaly.

Lt. Combe had at his disposal an "absolute" Elliot unifilar magnetometer (No.25), a Barrow Dip Circle, both for land observations, and a "relative" Fox Dip and Intensity Apparatus (No.C10), for onboard observations. The *Penguin* at 1130 tons was "composite built", i.e., wood and iron, but the iron content made the "absolute" instruments useless onboard ship. Magnetometer measurements taken on the vessel were made with the Fox instrument and calibrated (a procedure that included compass swings of the ship at various headings) against onshore observations made by the absolute instruments. All of this worked well.

Between the 22nd and 25th April 1891 a number of pre-planned survey traverses were sailed over the "magnetic shoal" anomaly, normal to the known strike, with the ship

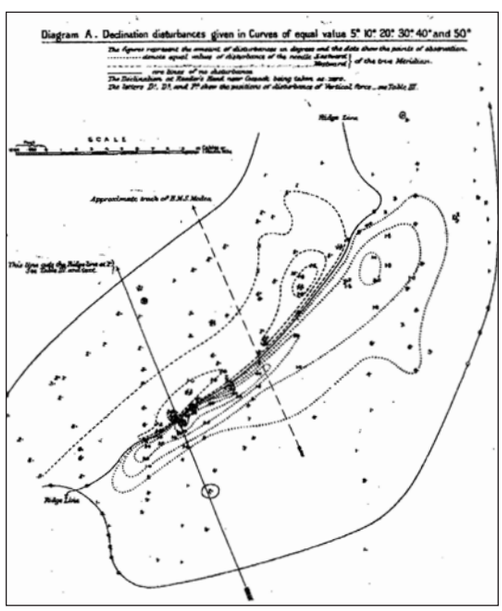


Fig. 2. Contours of magnetic declination over the "magnetic shoal" Western Australia, as mapped by HMS Penguin in 1891, courtesy of the Royal Society of London.

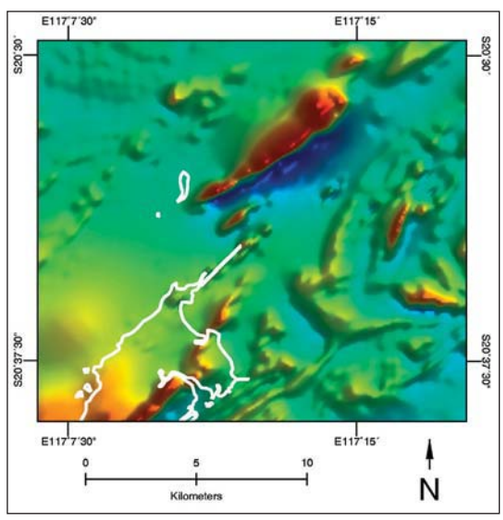


Fig. 3. Modern image of total magnetic intensity anomalies (pseudo-colour with NE sun angle) in the vicinity of Bezout Island, from the West Pilbara Survey; image provided courtesy of Geological Survey of WA.

being accurately positioned by theodolites stationed both onshore and onboard the *Penguin*.

Measurements of declination, inclination and intensity were made progressively and buoys were "placed at positions of greatest disturbance" (Creak, 1896). Water depth soundings were made and seafloor sand samples were also taken. The anomaly was well mapped, extending for over three miles with the declination, when measured across the most intense part of the source, deflecting the needle from 56° E to 26° W!!

Ellery has the following: -

"The focus is in latitude 20° 32' 35'' S., longitude 117° 13' 2'' E. from it Bezout Island summit bears S 78° 49' W., distance 2.17 miles. The greatest range in deflection was 82°, after applying the deviation for the apparent position of the ship's head; the actual traverse of the card 86°. The greatest inclination or dip of the needle was 81° 10'. The greatest intensity or total force found was 18.808 (British units), or nearly double the intensity, which, in this locality, is due to the earth considered as a magnet, i.e., the magnetic attraction is such as to draw a weight of 1 grain, 18.808 feet in 1 second, in opposition to the force of gravity."

The Chief Engineer of the HMS *Penguin*, J. J. Walker investigated the nearest coastline and produced a geological text and sketch of the coastal cliffs, including mapping of the ironstone and geologic strike, his short report was added as an appendix to Creak's paper without comment. The seafloor samples were taken to England where Professor A. W. Rücker later examined them for magnetic susceptibility (Creak, 1896). No conclusions were made regarding the cause of the anomaly until 1911 when, according to Day (1966), H. P. Woodward "established that the anomaly lay on strike with a magnetic-bearing jaspilite".

The operational description, documentation, tables and maps of this pioneering marine survey are significant records in the history of geophysics in Australia and comparison with current TMI imagery confirms the quality of the survey.

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140 Years ago – Neumayer and a meteorite

When the pioneer German geophysicist and hydrographer Georg Balthasar von Neumayer (1826-1909) left the Colony of Victoria for the last time in 1864 he took all of his scientific records with him for later publication. Luckily for us he published.

Neumayer holds a significant place in the history of science in Australia – he firstly established and maintained the Flagstaff Hill Observatory in Melbourne and over a number of years performed a regional magnetic survey of Victoria, part of which included two short inspections and surveys of the Cranbourne meteorites in 1861 and 1862.

Fig. 4. Richard Daintree's photograph of the meteorite. His caption reads: "Cranbourne meteorite in situ with screw-jack with which it was moved from its position fro the first time since its arrival on this planet, 21 February 1862". Note Neumeyer's chalk annotations S and E (N and W hidden) and the chalk line probably tracing the 'magnetic equator'. Photograph provided courtesy of the La Trobe Collection, State Library of Victoria.

His first visit to the largest of the meteorites was on 12th February 1861.

"...The earth around the meteorite had been removed to the depth of two feet; the lower part, however, was not visible, the hole being partly filled up with water. A magnetic needle suspended by a silk thread and approached towards it, showed at once that the upper accessible part was of northern magnetic polarity, the South end of the needle being attracted. Moving the needle about 1 foot 10 in. below the upper surface of the mass its magnetism changed from North to South, from which I concluded that its total height would be about 4 ft. But the distance from the top at which this change in polarity took place, was by no means constant for all parts of the sides of the mass varying from 2 ft. 4 in. to 1 ft. 4 in., from which I concluded that the shape of its lower part was that of a wedge; basing thereupon, I calculated the total weight of the mass to be 4.3 tons. ** I had four specimens taken off from the nucleus and one from the crust. Their specific gravities I found to be respectively 7.60, 7.51, 7.51, 7.12 and 3.66. Drawings were made and measurements taken..."

A year later, on the 20th and 21st February 1862, Neumayer joined R. L. J. Ellery, the government geologist of Victoria and his assistant Richard Daintree, following an invitation to witness the removal of this meteorite. Neumayer took more magnetic, orientation and physical measurements of the now exposed meteorite in situ and Daintree took photos (see Figure 2).

The above narrative is part of Neumayer's: *Results of the Magnetic Survey of the Colony of Victoria Executed during the Years 1858-1864* published in Mannheim, Germany 1869. Neumayer's description, tables, sketches and maps could very well be the earliest published interpretation in exploration geophysics.

The meteorite, by the way, went to the British Museum despite considerable pleading and protests from locals.

** *Subsequent actual weighing determined its weight to be 8200 lbs. (4.1 tons).*

Fig. 1. (Right) Sequesterable vs non-sequesterable sources of CO_2, and a further breakdown of the sequesterable sources by industry (Bradshaw et al., 2002a).

Fig. 2. (Below) Australia's point-source CO_2 emissions (20-year projected). Clusters of the top 50 sources are grouped into emission nodes. The percentage of national, stationary (sequesterable) emissions is calculated for each state, with the highest emitters being in the east.

Fig. 3. (Bottom) Location of the sedimentary basins assessed as part of the GEODISC project, the Environmentally Sustainable Sites for CO_2 Injection (ESSCIs), and the Implausible Sequestration Options (ISOs). ESSCI symbols are scaled according to risked storage capacities, the largest being located on the Northwest Shelf.

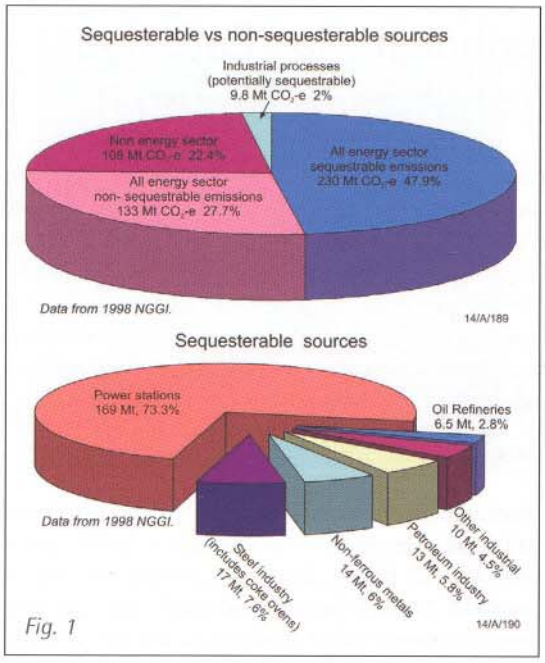

Fig. 1

employing sub-surface injection technology specifically for CO_2 emission reduction anywhere in the world (Kårstad, 2002).

The GEODISC Project 1999 – 2003

The GEODISC project, under the umbrella of the APCRC[4] program, included a revision of greenhouse gas emission estimates and sites for Australia and an assessment of regional storage potential of 300 sedimentary basins. This information was used to perform matching of CO_2 sources with sinks leading to economic modelling of the viability of the source-to-sink match. In addition to the basin overview research, four basins were the subject of detailed site-specific studies on geological modelling and storage potential. The methodology and risking was uniquely developed by the GEODISC researchers. During the analysis there was a progressive improvement in understanding of sequestration issues, improvement in technology and increased availability of data, meaning that the methodology underwent constant revision, a reflection of the rapidly evolving science of geological sequestration (Bradshaw and Rigg, 2001).

Emissions Mapping

The 1998 National Greenhouse Gas Inventory (NGGI) produced by the Australian Greenhouse Office estimated that Australia emitted 455.9 Mt or 8.5Tcf of CO_2 per annum (503.3 Mt CO_2-e in 1999, and 535.3 Mt CO_2-e in 2000). CO_2 Emissions that originate from point sources such as power stations are large, and this can be potentially sequestered. Emissions from random or non-point sources such as cars are considered non-sequesterable at this point in time. Currently in Australia, 50% of total CO_2 emissions come from large 'stationary' point-sources that have the potential of being sequestered. These point-sources can be further divided into various industry sectors, refineries, and power stations, with the latter proving to be the largest emitters of CO_2 (Figure 1).

Emissions mapping has shown that the top 50 point sources around Australia represent about 96% of the potential sequesterable emissions. Based on proximity to one another, these sources have been further grouped into major CO_2 emission nodes, allowing a possible reduction of infrastructure costs associated with sequestration (Figure 2).

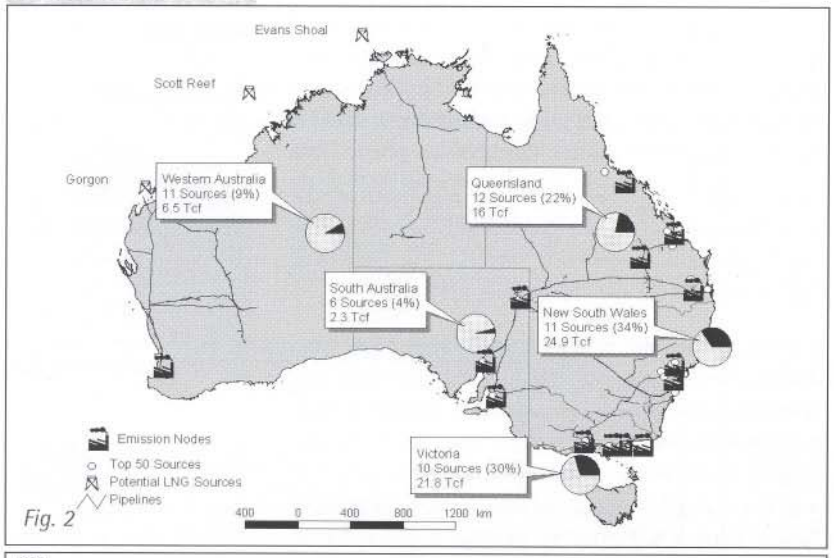

Fig. 2

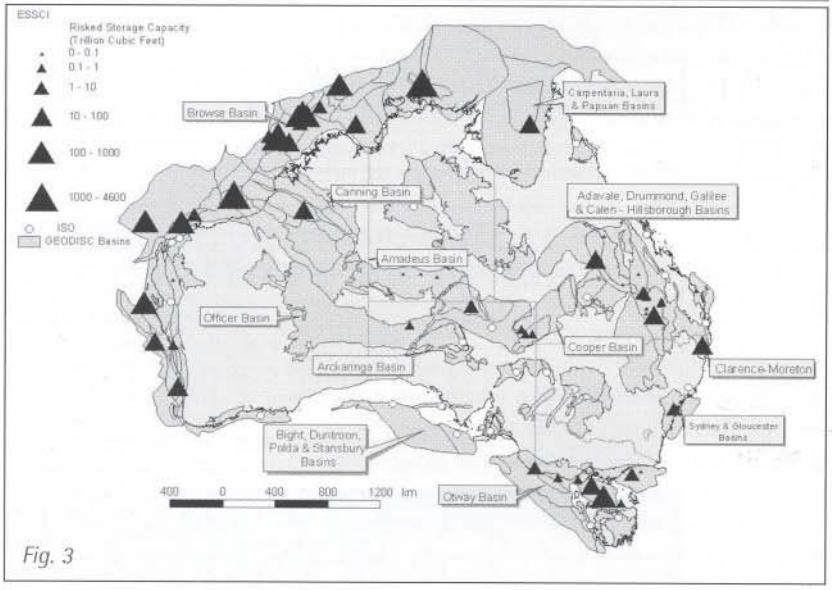

Fig. 3

Identification and Assessment of Storage Sites

Three hundred sedimentary basins in Australia were analysed by GEODISC researchers to determine their viability for CO_2 storage Bradshaw, 2003. In particular, basins near to known emission sites and possible future emission sites were included in the study.

Of the basins that were examined, 48 were then selected based on initially suitable geological characteristics (such as thickness, depth, stratigraphy, lithology and structural complexity) to assess the potential injection and storage of

CO_2. Within these 48 sites, 65 potential ESSCIs (Environmentally Sustainable Sites for CO_2 Injection) and 22 ISOs (Implausable Sequestration Options) were identified and ranked according to five ***risking factors***:

1. ***Storage capacity*** – the chance that the reservoir will meet the volume requirements of neighbouring, currently identified CO_2 sources.
2. ***Injectivity potential*** – the chance that the reservoir conditions will be viable for injection.
3. ***Site details*** – the chance that the site is economically and technically viable.
4. ***Containment*** – the chance that the seal and trap will be effective for storing CO_2.
5. ***Existing Natural Resources*** – the chance that there are no viable natural resources in the ESSCI that may be compromised.

Sites that had one or more of the risk factors fail, or had insufficient and poor quality data were deemed to be unsuitable for sequestration (*i.e.* ISO). Figure 3 shows the location of all the ESSCIs and ISOs examined by the study (Bradshaw *et al.*, 2002a, Bradshaw *et al.*, 2002b, Bradshaw, 2003).

Following the allocation of risking factors, an ESSCI *chance* was calculated by multiplying the five risk factors for each site. The resultant risk was rated between zero (fail) and one (complete success). The ESSCI chance allowed for comparisons between sites to be made and the most viable ones to be identified based on geotechnical, environmental and economic risk factors. Additional risk calculations were utilised to compare sites and to create an Australian wide seriatim. These were: *risked capacity* (i.e. ESSCI chance x total estimated storage capacity of CO_2), and *ESSCI rating* (i.e. ESSCI chance/radius of 1 Tcf CO_2 at the site), (Bradshaw *et al.*, 2002a).

Site-specific studies involved comprehensive modelling and geological interpretation of sites in the Petrel Sub-basin, northern Perth Basin, Barrow Sub-basin, and Gippsland Basin.

Modelling included geomechanical modelling and reservoir simulation modelling thus providing scientific understanding of how the CO_2 reacts when injected into various geological formations (Bradshaw *et al.*, 2002b, Streit., and Hillis, 2002). Each site study presented different challenges when modelling the response of CO_2 injection in the various trap types.

Each trap type had unique characteristics thereby influencing the risk assigned to the ESSCI. For example, ESSCIs associated with hydrodynamic traps were initially rated low, mostly due to the perceived higher risk for containment (*i.e.* CO_2 migrating to the edge of the basin has a higher chance of escaping). However, in the case of the Petrel Sub-basin, reservoir modelling results indicate that over a period of ten thousand years there would be complete dissolution of the CO_2 into the formation water. The CO_2 would move only tens of kilometres from the injection site and in that time not migrate anywhere near the edges of the basin located some 120 km away. In contrast, depleted fields have more certainty associated with them because they have stored hydrocarbons for thousands to millions of years. The ESSCI chance for dry structures (non-petroleum bearing) is wide-ranging, which reflects the variety of geological settings that were being examined.

Storage Capacity

The potential storage capacity of the different ESSCI trap types is highly variable. For example, about 43% of the sites studied were hydrodynamic traps, which actually represent about 94% of the risked storage capacity of all sites. Hydrodynamic traps have large storage potential relative to other ESSCI types. Figure 4 shows the distribution of ESSCIs plotted against risked capacity (Bradshaw, *et al.*, 2002b). On a national scale, the total risked capacity for the 65 ESSCIs studied is 740 000 Mt of CO_2. This amounts to a potential to store 1600 years of CO_2 emissions based on Australia's total net emissions for 1998 (Bradshaw, 2003).

Storage Costs

Following on from geological risk assessment and storage capacity, project costs for each source-to-sink match were also assessed so as to consider the relative costs for each ESSCI. Whether or not a site would be commercially viable would depend on project specific economics such as the cost associated with compression of CO_2, transport via pipelines and injection. Capital costs of the portfolio of 65 ESSCIs examined ranged from $US13M to $US1300M. Obviously sites examined with small CO2 sources adjacent to a depleted gas field with existing infrastructure facilities would be more cost effective than large sources more than 1000 km from an injection site (Bradshaw, 2003). However, significant benefits from having large flow rates in terms of a cost per tonne occur. Thus large separations between sources and sinks should not be immediately dismissed, until the project specific costs have been estimated.

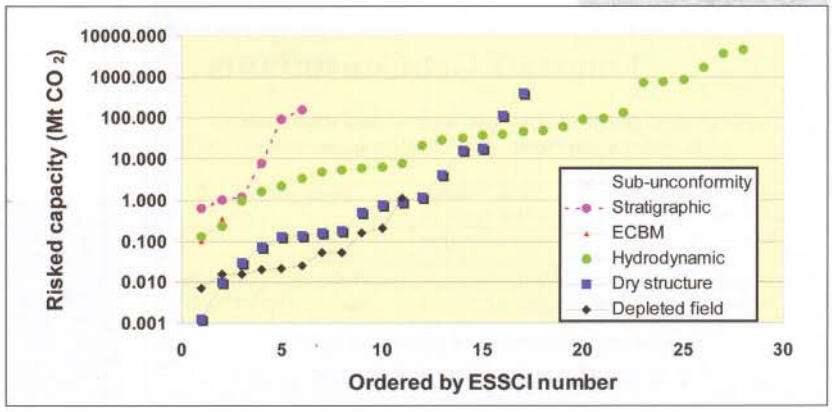

Fig. 4. ESSCI capacity (ESSCI chance x total pore volume) plotted against the number of ESSCIs for different ESSCI types (Bradshaw et al., 2002b).

Source to Sink

Source to sink matching is an estimation that any given ESSCI site will have the storage capacity to sequester the CO_2 from a nearby source over a 20 year period. This ratio is calculated by dividing the risked storage capacity with the 20 year emissions volume of a source. Results from this show that there is enormous potential for storage on the Northwest Shelf, whilst the potential in Eastern Australia is not as good due to poor reservoir characteristics and high source volumes of CO_2 (Bradshaw *et al.*, 2002a). A comparison of Figures 2 and 3 reveals the dichotomy observed between North Western Australia (i.e. low source volumes and high storage capacity) and Eastern Australia (i.e. high source volumes and low storage capacity), (Bradshaw *et al.*, 2002b).

From the preliminary work completed in the GEODISC project, a realistic estimate of the likely volumes of CO_2 that could be stored in Australia on a yearly basis was attempted. This estimate was based on matching sources with the best nearby sinks, and making some assumptions as to which might become commercially viable. Subsequent to this estimate, a more refined approach was adopted, whereby the storage potential was estimated based on an increasing credit for the storage of CO_2. This method suggested that 50 – 180 Mt of CO_2 could be potentially stored given a credit for CO_2 that ranged from $20 -$40 US/tonne (Bradshaw *et al.*, 2002a). Using this method, the storage potential of CO_2 for identified ESSCIs is estimated at 100 to 115 Mt/year, or up to 25% of the 1998 total net emissions.

The Cooperative Research Centre for Greenhouse Gas Technologies 2003-2010

Building on the success and partnerships established in the GEODISC project, the Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) is undertaking research into both carbon dioxide capture and storage technologies. Aside from a reduction of greenhouse gas emissions, there are other benefits to be gained through the successful injection and storage of CO_2. Commercial benefits can also be obtained, such as EOR (Enhanced Oil Recovery) or ECBM (Enhanced Coal Bed Methane). The CO2CRC will undertake research into all these options. Effectively using CO_2 as a commodity, and identifying a successful capture and storage process, may create new investment opportunities in Australia with the added benefit of decreasing CO_2 emissions (eg. the potential development of the high CO_2 gas fields on the Northwest Shelf).

Key research within the CO2CRC will encompass identifying sites for long-term geological storage, and developing a pilot/demonstration site where the migration and storage of CO_2 in the sub-surface will be tested and monitored. Future work by the CRC will involve refinement of the research thus far, by advancing the probabilistic analysis of potential ESSCIs. A comprehensive assessment of community risk will be carried out in order to provide the public with factual information and reassurance regarding the processes involved. An outcome of the work is to enhance public confidence in the contribution that development of capture and storage technologies will make to decreasing CO_2 emissions in Australia, and also globally.

One of the major challenges for the CO2CRC will be to assess sites more comprehensively and develop geological sequestration as a sustainable, cost effective and socially acceptable tool for lowering emission rates. The CO2CRC will address the mandate on carbon emission levels for Australia by providing a technical framework for geological sequestration. As a result of the major objectives, the knowledge generated by the CO2CRC on greenhouse gas technologies and their applications will advance Australia globally in sequestration research. The CRC will ultimately provide greenhouse gas mitigation options for industry and government that are cost-effective, thereby helping to provide a sustainable future for Australian fossil fuels and energy-intensive products, while producing real reductions in CO_2 emissions in Australia.

International Activity

Researchers within the CO2CRC are actively involved with the Intergovernmental Panel on Climate Change (IPCC), which is producing a Special Report on Carbon Capture and Storage (http://arch.rivm.nl/env/int/ipcc/pages_media/ccs-report.html). This report comprises advice from 100 international scientists and will be released publicly in late 2005.

Other international activity at the government level is occurring within the Carbon Sequestration Leadership Forum (http://www.cslforum.org) that comprises 14 nations that are focused on development of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage. One of the aims of the CSLF is to provide a mechanism by which international collaboration can be coordinated on major infrastructure projects for carbon capture and storage. The 2nd Ministerial Meeting of the CSLF, involving both the Policy and Technical Groups will occur in Melbourne in September 2004.

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Relationships of regolith and tree survival in a eucalyptus Blue Gum plantation[1]

The issue

Revegetation, using plantation crops, is a major initiative of the current state government, particularly in the study area of south west Western Australia, where pine and eucalyptus plantations are a growing element of the community. Revegetation is being used to tackle salinity and rising water-table problems, as carbon dioxide sinks and as a source of bioenergy. With an increasing need for revegetation of farmland to restore hydrological balances there is an increase in capital being invested into plantation trees and consequently there is a need for optimum plantings. Evaluations of sites for revegetation have thus become important to determine sustainability and profitability.

Factors involved in determining site suitability include climate, local hydrology, soil fertility and hazards such as salinity. Recently soil water storage has been shown by Conservation and Land Management (CALM) researchers to be important in sustaining plantation performance over drought periods. The variance of the weathering profile and the associated amount of root permeable soil plays a part in determining the soil-water storage capacity. In areas in which a deeper weathering profile occurs, there is a greater amount of soil and thus capacity to store water. The study site is thought to contain patches where the trees appear to have a shallow level of soil due to a soil change to more sandy soils. Gravel soils exist under well developed tree areas and are an indication of the deeper weathering profile. These surface correlations between regolith and tree survival have promoted the use of geophysics in this area to compare the subsurface regolith with the surface soil morphology.

Background

In the research area, and other areas in south west WA, CALM has observed a phenomenon of patches where the plantations have not survived drought periods (Figure 1). The plantation studied after plantings in 1997, has linearly delineated areas which were affected by the 2000-2001 summer drought in south western Australia (Figure 2).

Previous research conducted by CALM indicated links between the soil profile and thus soil water storage and its influence on vegetation. Studies completed by Richard Harper indicate soil depth as a major contributing factor to tree mortality, with >2m soil needed to sustain tree growth over drought periods. John McGrath defined the distribution of pine tree deaths as proportional to the capacity of soil-water storage over summer/drought periods. One of the conclusions of their study was that individual tree basal areas showed increasing "drought symptoms" with decreasing soil depth.

Results

Initially the main aim of the research was to identify areas, where shallow soils were contributing to the death of trees during a drought. The geophysical techniques were focused on determining the soil profile in the upper 5 to 10 m of the sub-surface. The regolith mapping would indicate areas unable to sustain tree growth due to limited soil depth. Techniques were also chosen to show any structural, as well as geological features, forming a conduit or barrier to ground water flow within the regolith.

[1] *This work, currently underway, is part of the honours thesis of Claire Robertson, under the supervision of Paul Wilkes (CRCLEME), Richard Harper (CALM) and Ravi Anand (CSIRO).*

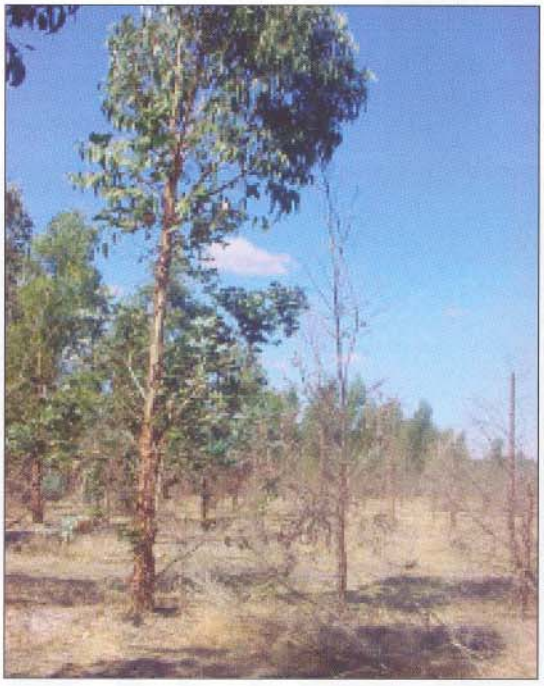

Fig. 1. (Right) The transition from dead to alive trees within a 4 m row.

Fig. 2. (For right) Aerial photograph showing outline of linear patches of yellowed trees.

Three sites, 18, 27 and 30, were chosen based on the presence of a distinct transition from dead to alive trees, which occurred in areas showing surficial soil changes indicative of a change from a shallow to deep weathering profile. Figure 3 shows the basic survey layout.

Geological Methods

Remote sensing data using aerial photography and Landsat TM images were able to highlight areas of the plantation where dead patches had occurred. These remote pictures alone could not be used for identifying dead areas on existing plantation. Differences in planting row direction and camera/sun angle illuminate tree canopy differences which aren't prominent in actuality.

Drill samples were taken at the junction of each Vertical Electrical Sounding (VES) transect and the main intersecting Ground Penetrating Radar (GPR) transect.

Geochemical analysis was compiled on selected drill holes. The drill samples were analysed for moisture content and particle size analysis, which enabled the basic textural differences to be deciphered and estimates of layer boundary depths to be picked. Two drill hole positions from each site were analysed for chemical and mineral composition using X-ray florescence and X-ray diffraction.

- ***X-ray Fluorescence*** indicated a dolerite dyke at the site 18 dead-tree sample, (high TiO_2 and Fe_2O_3) which is in agreement with the magnetic survey at this site. Slightly greater amounts of Na2O, along with K2O are present in soils below the dead trees than the alive ones. The consistently greater values of alkali and alkaline earth metals in the shallow regolith under the dead tree patches were taken as an indication of a slightly shallower depth of weathering profile than in the alive sections, because alkali and alkaline earths are soluble and mobile during weathering.

- ***X-ray Diffraction***: Most of the samples varied in the feldspar content and amplitude of the diffraction peaks indicating the amount of the mineral present. The feldspar content gives some indication of the maturity of the weathering profile. Samples showing higher contents of sodium, potassium and calcium feldspars, indicated immature granitic rock soils. More aluminous, Kaolinite (~40%Al_2O_3) indicates a deeper weathering profile as feldspar weathers to Kaolinite. Only slight changes in Kaolinite content were found, these changes in regolith products are thought not substantial enough to influence tree growth. The site 18 dead-tree sample showed Tremolite material.

- ***Particle analysis*** on the site 18 dead-tree sample revealed double (30%) the moisture content of other samples and a depleted soil water suction capacity compared with the average sample (1/50th). The sample is obviously saturated and may indicate the build-up of water at the dyke as it diverts flow into the adjacent ground.

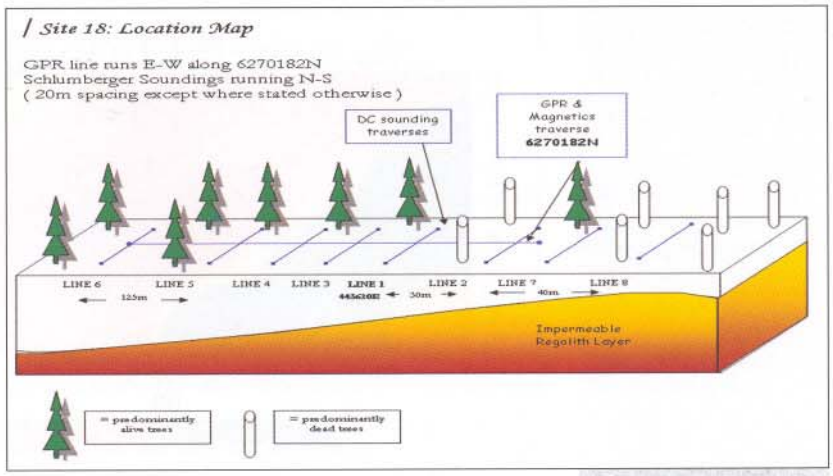

Fig. 3. The basic layout and model of basement topography for plantation surveys.

Overall the sites chosen had a shallow, saprolite based, weathering profile, in both dead and alive sections.

Geophysics Methods

Three sites were surveyed for changes in the regolith or structural features, which were affecting tree growth over the plantation.

GPR (Ground Penetrating Radar), was surveyed along one main E-W transect at each site, from dead to alive vegetation areas. It indicated general subsurface regolith layers, although no substantial differences were noticed. More noticeable were structural features, which coincided with the diffractions, indicating contrasting point source features. The features occurred within 10 m of the visual

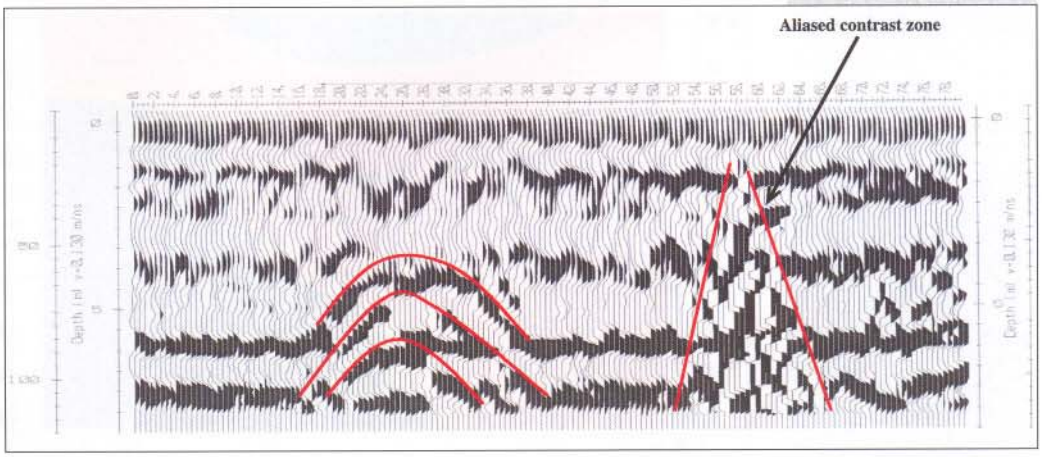

Fig. 4. A GPR profile taken from site 27, showing diffraction and aliased zone.

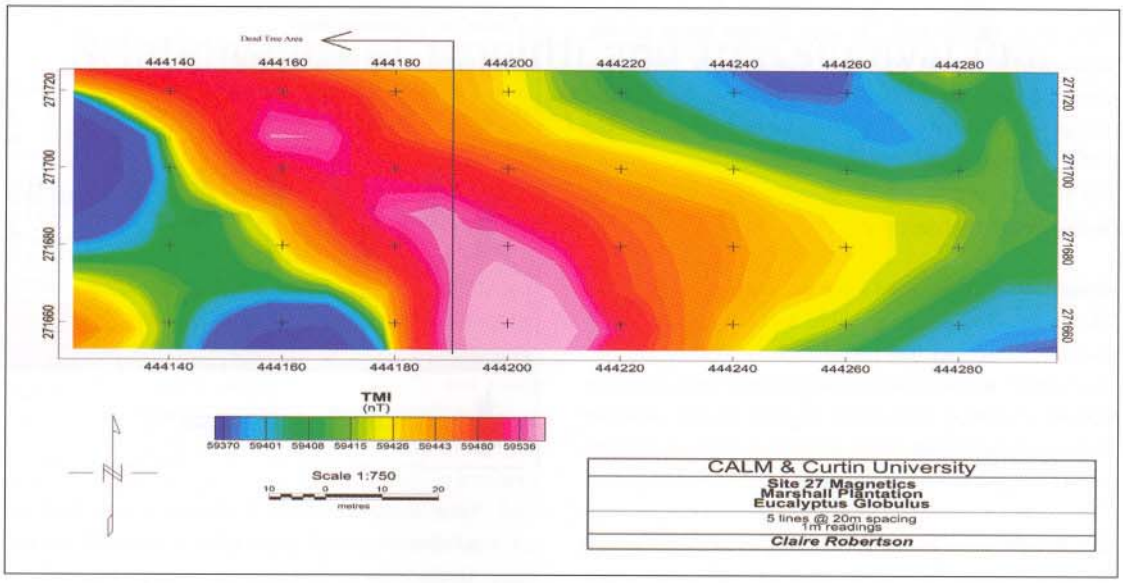

Fig. 5. Magnetic response from site 27.

tree change. A small rise in bedrock of approximately 1m was picked at the transition to alive trees at one of the sites (18). This change in the impenetrable boundary is thought not to be substantial enough to be the bedrock change expected across the dead to alive boundary. Aliased zones were noted at two sites (27 and 30, see Figure 4). The lower frequency bands occur where the visual surface change from dead to alive trees occur. Site 27 (Figure 4) shows a 10 m aliased zone which is where the visual surface change occurs and diffractions 30 m to the west, within the dead zone on the surface.

Four ***Magnetic*** E-W traverses were surveyed at each site. Anomalies occurred at two sites 18 and 27), the positions correlating to the dead/alive boundary. These were both N-E trending, linear anomalies, the contrast could indicate mafic dykes, as the soil sample from one site along this boundary confirmed the presence of mafic material or another impenetrable boundary restricting water flow over this transition. The third site showed no magnetic anomaly.

Five to eight ***VES*** (Vertical Electrical Soundings) transects were surveyed at each of the 3 sites. These were modelled and the results indicated the apparent resistivity property of the layers and the depths to these. The results suggest a consistent depth to basement of about 5-6 m across all sites, as confirmed in the GPR. Conductive sections underneath dead-tree areas could portray the water table rise where there are no roots to absorb the water. Figure 6 reveals a blue conductive zone and layered resistive section under the alive-tree area.

Using geophysics for plantation site analysis

Geophysics can be beneficial in site analysis prior to planting to optimize the tree survival of plantings. Further geophysical surveying should be undertaken to strengthen the comparison of the results between techniques. A survey over a known deep regolith profile on the plantation would be beneficial to gauge possible regolith profile changes.

20 m flying height magnetics over the plantation might also identify possible areas susceptible to restrictions to water flow. 50 m flying height magnetics over the area did not resolve the magnetic features at the scale required. Ground penetrating radar with smaller step sizes may also resolve the features indicated by the aliased zones.

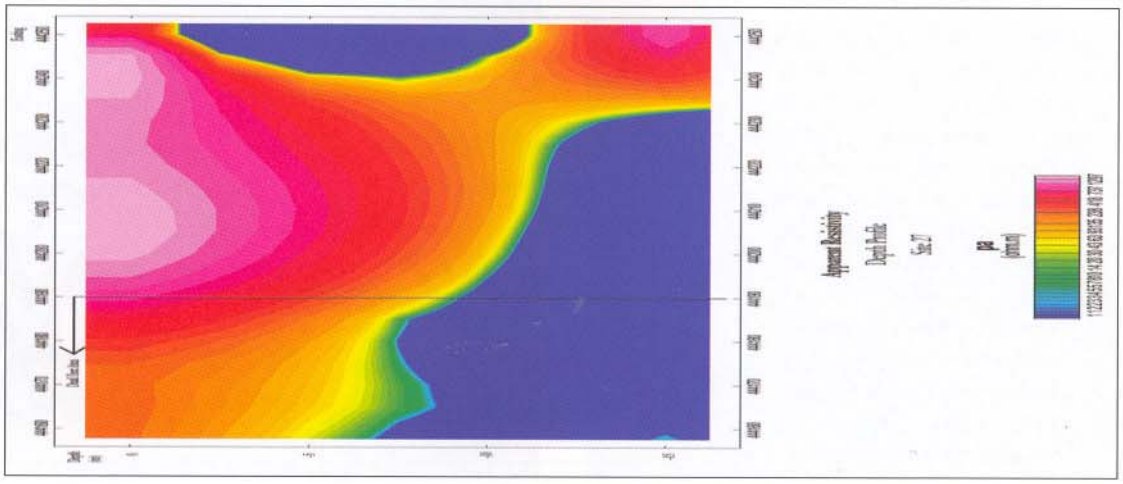

Fig. 6. VES section from site 27.

Geophysics of the Prominent Hill deposit, South Australia[1]

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[1] *This article is based on the paper appearing in the 'Geophysical Signatures of South Australian Mineral Deposits'.*

Introduction

The Prominent Hill copper-gold-(uranium-REE) deposit is located in the Mount Woods Inlier in north-central South Australia. The deposit is about 630 km northwest of Adelaide, and 100 km southwest of Coober Pedy. A location map is shown in figure 1.

Discovery hole URN001 was drilled in October 2001 on a discrete gravity anomaly. The vertical hole passed through 108 m of sediments before intersecting a massive haematite-supported breccia. The haematite breccia averaged 1.94% Cu and 0.66 g/t Au over 107 m from 200 m depth. Deepening of URN001 intersected a further 152 m averaging 1.20% Cu and 0.61 g/t Au from 429 m, also hosted in a haematite breccia. This same interval averaged 0.57% REE and 495 ppm U. A summary of the drill hole intersections is presented in Table 1.

Regional geology

The Mount Woods Inlier is a Palaeo- to Mesoproterozoic mobile belt located along the eastern margin of the Gawler Craton and bordering the eastern margin of the Christie Subdomain (Flint, 1993). Outcrop of Palaeoproterozoic rocks includes quartzofeldspathic and garnetiferous gneisses, migmatite, quartzite and quartz-feldspar-biotite schist (Daly *et al.*, 1998; Flint, 1993). Elsewhere, basement is obscured by up to 200 m of Palaeozoic to Mesozoic sediments. Exploration drilling has intersected probable Palaeoproterozoic lithologies that include banded iron formation, quartz-magnetite gneiss, calc-silicates and meta-igneous rocks. Interpreted equivalents to the Gawler Range Volcanics have been intersected in exploration drillholes in the south-western region of the Mt Woods Inlier.

Geology of the Prominent Hill Deposit

The Prominent Hill deposit is situated near the southern margin of the Mount Woods Inlier. Drilling has identified a terrane consisting largely of Gawler Range Volcanic-equivalent basalt and andesite, characterised by relatively low metamorphic grades and higher crustal levels of formation in comparison to the northern part of the inlier, which contains amphibolite to granulite facies metamorphic rocks.

The prospect is characterised by enormous fluid flux, iron-metasomatism and regional alteration systems associated with the Gawler Range Volcanic-Hiltaba volcano-plutonic event (~1590-1580 Ma). Mineralisation occurs within a sequence of haematitic breccias that intruded an east-west striking, >200 m thick package of low-grade metasediments and intercalated volcanics. Copper-gold mineralised haematite breccias have been intersected at a vertical depth of >600 m. The breccias exhibit widely varying characteristics, from clast-supported to matrix-supported varieties and polymict to monomict forms.

The main zone of mineralisation is contained within a sequence of intercalated unmetamorphosed sediments and volcanics. This sequence is considered to comprise equivalents of the Gawler Range Volcanics. Deeper-level magnetite-bearing skarns and breccias, associated with sub-volcanic intrusives, occur to the north, and are separated from the haematite breccia zone by an east-west trending fault.

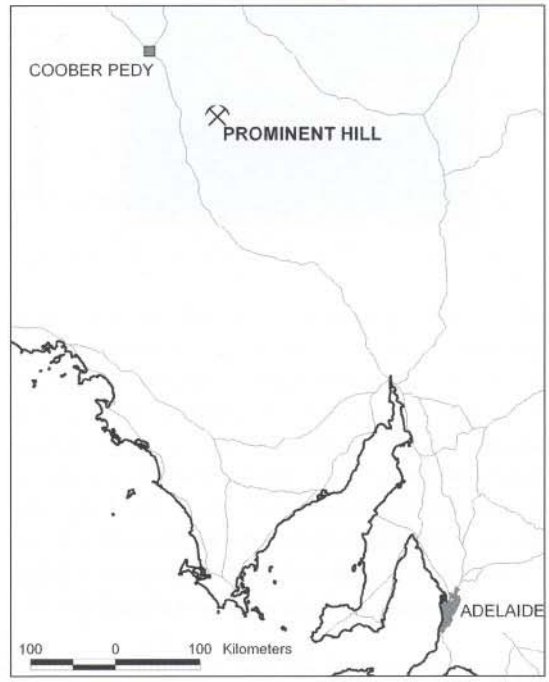


Fig. 1. Map showing location of Prominent Hill.

Table 1. Summary results for URN001.

From (m)	To (m)	Interval (m)	Copper (%)	Gold (g/t)	Silver (g/t)	RareEarth Elements (%)	Uranium (ppm)
107.8	128	20.2	--	3.03	--	0.24	--
200	307	107	1.94	0.65	1.6	0.22	--
Including 272	307	35	3.86	0.82	4.5	0.22	--
429	450	21	0.90	0.46	1.7	0.24	--
450	507	57	1.28	0.66	2.0	0.57	495
Including 450	467	17	2.35	1.07	3.3	0.66	1398

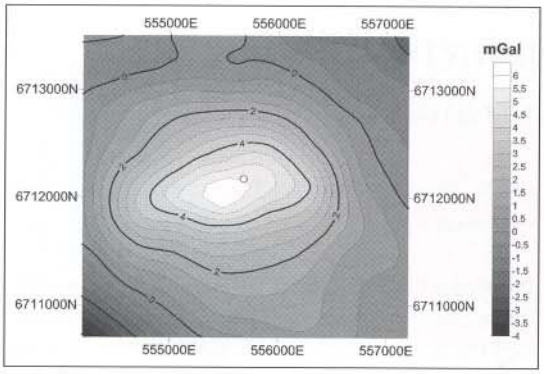


Fig. 2. Normandy residual Bouguer anomalies from Prominent Hill. Location of discovery drillhole URN001 shown by circle. Tick marks every 1km.

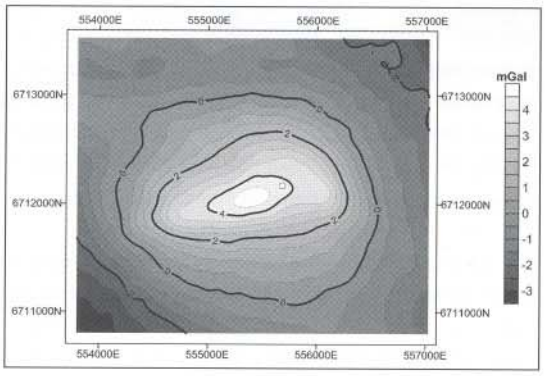


Fig. 3. Residual Bouguer gravity from Prominent Hill. Data collected on a 100m x 100m grid. Location of URN001 indicated by circle. Tick marks every 1km.

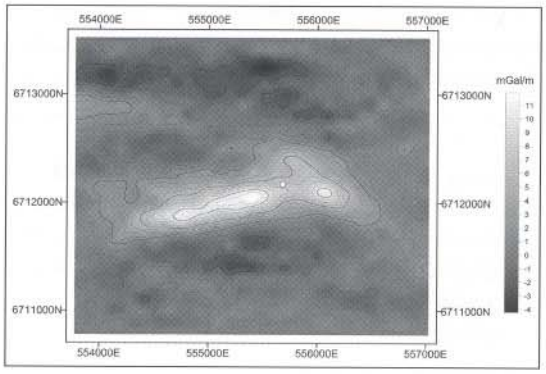


Fig. 4. First vertical derivative of Bouguer gravity data. Location of URN001 shown. Tick marks every 1km.

The shallow mineralisation in URN001 consists of predominantly chalcocite occurring as disseminations and thin veins within matrix-supported hematite-silica breccia. The breccia contained highly altered hematite-sericite-silica clasts of sandstones and volcanics. Copper mineralisation in the deeper breccia consists of predominantly bornite and chalcopyrite. The change from chalcocite in the upper part of the drill hole to bornite and chalcopyrite with depth is similar to the zonation of copper minerals seen at Olympic Dam (Reeve *et al.*, 1990).

Potential-field data

The initial drill hole (URN001) was sited using gravity data collected on a 400 m x 200 m grid by Normandy Exploration. A broad gravity high occurs to the south of a high intensity magnetic anomaly (see below). The drill hole siting was based on inversions of these data using the GRAV3D inversion routine developed at the University of British Columbia. A contour map of the residual Bouguer anomalies and the location of URN001 is shown in Figure 2. Shortly after the completion of URN001, more detailed gravity data were collected. These data, acquired by Fugro Ground Surveys, consisted of a 100 m x 100 m grid over the prospect area. A Scintrex CG-3 gravimeter was used in conjunction with an Ashtech OTF (on-the-fly) global positioning system. Accuracy of the gravimeter is +/- 0.01 mGal (0.1µm/s²) and the location errors are estimated at ±1 m in the horizontal plane and ±5 cm elevation.

A first order polynomial surface was removed from the Bouguer gravity data to produce a residual gravity map. The residual Bouguer gravity data show a broad, high-amplitude anomaly over the Prominent Hill Deposit area. The gravity anomaly covers an area of 3 km x 2.5 km (Fig.3). To aid in the interpretation of the gravity data, high-frequency filtering was carried out on the data. First vertical derivative and 2nd horizontal derivatives were calculated using the profile data, and the filtered data were then gridded. The derivative data highlight the presence of three main source bodies responsible for the overall gravity anomaly (Fig.4). One of these bodies corresponds with a magnetic source body (see below). The two other bodies have been demonstrated by subsequent drilling to be primarily composed of barren haematite.

In conjunction with the gravity survey ground magnetic data were collected by Fugro Ground Surveys using a Scintrex ENVIMAG proton procession magnetometer. This magnetometer has a claimed accuracy of +/-0 1nT. Data were collected on north-south lines 100 m apart, with readings taken every 2 m. An image of the ground magnetic data is shown in Figure 5. These data are dominated by the response from an eastnortheast-trending magnetic body. The associated magnetic anomaly has an amplitude of 3500 nT.

This magnetic anomaly had been drilled, prior to URN001, at two locations. Its source is a magnetite-phlogopite-tremolite altered andesite. No response attributable to the haematitic body is apparent in the data.

IP/Resistivity data

Published case studies, e.g. Webb and Rowston (1995) and Matthews and Jenkins (1997) have demonstrated the usefulness of IP/Resistivity surveys in mapping copper mineralisation in iron-oxide copper-gold deposits. Following the completion of URN001, a downhole resistivity and induced polarisation survey was performed to determine whether the mineralisation at Prominent Hill was conductive and/or chargeable. Data were collected using a Zonge GDP-32 receiver with measurements taken in the time domain. A dipole-dipole array was used with an a-spacing of 1 m. Readings were collected every 5 m. Resistivity lows coincided with the elevated copper assays and moderate chargeability values also occur in the

copper-enriched intervals. Both the chalcocite-mineralised breccia and the chalcopyrite-mineralised breccia give anomalous responses.

The downhole IP/resistivity data from URN001, gave enough encouragement to commence a program of IP/resistivity data collection. A frequency-domain dipole-dipole survey was carried out by Zonge Engineering and Research Organisation. A Zonge GGT-30 transmitter was used in conjunction with a GDP-32 receiver. Given the thickness of cover (100 m) and the depth to the top of mineralisation (200 m below surface), a dipole size of 200 m was used. Data were collected at 0.125Hz along six lines.

The IP/resistivity data were inverted using the Zonge 2D smooth-model inversion routine. The IP data on line 555,700E showed a phase anomaly to the south of URN001. The phase anomaly was essentially coincident with the dense body highlighted in the high-frequency filtering of the gravity data.

To complement the 2D inversion, a 3D inversion of the data was carried by GeoDiscovery, using the RES3DINV inversion routine. A depth slice through this data is presented in Figure 5. URN001 was located to the west of a large phase anomaly. The phase anomaly is virtually coincident with the dense body apparent in the high-frequency filtered gravity data (see Figure 4).

Summary of first phase of geophysical exploration

Surface surveys showed that a large, dense, conductive, chargeable and non-magnetic body, is situated adjacent to URN001. Downhole IP/resistivity logging showed that the copper mineralisation was chargeable with a low resistivity.

Two drillholes, DP001 and DP002, were planned to test the dense, chargeable body. Both drill holes intersected a sequence of pervasively haematite-quartz altered and brecciated volcanic rocks. The haematitic matrix was fine-grained and micaceous. This alteration was overprinted by steel-grey massive haematite veins. These rocks were essentially devoid of copper mineralisation. Petrophysical measurements and downhole IP/Resistivity logging confirmed that the haematite intersected in these drill holes was conductive and chargeable.

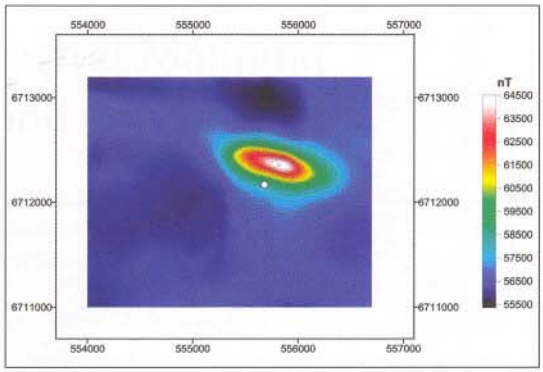


Fig.5. Reduced to pole aeromagnetic data from Prominent Hill. Location of URN001 shown. Tick marks shown every 1km.

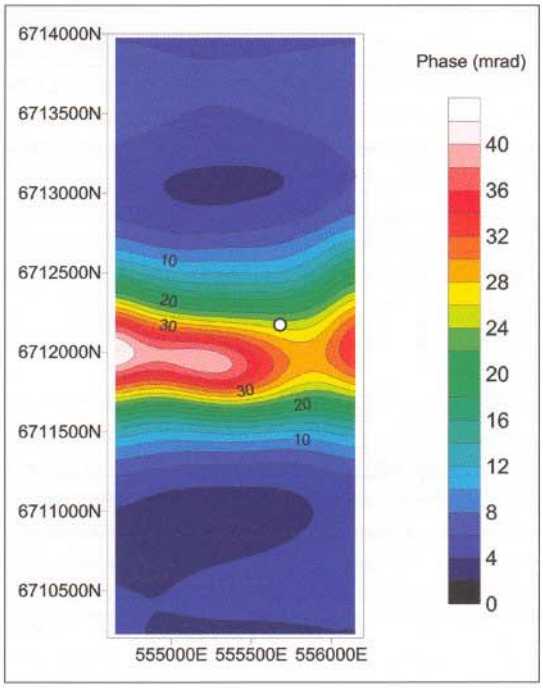


Fig. 6. Depth Slice (326 m) of IP Data from Prominent Hill. Location of URN001 shown by white circle. Tick marks every 500m.

Follow-up downhole IP/Resisitivity surveys

Downhole IP/resistivity logging was completed in thirteen holes. Specifications for these surveys were the same as for the initial URN001 survey. A summary of the data from the IP/resistivity logging is presented in Table 2. Both the chalcocite mineralised and chalcopyrite mineralised breccias have low resistivity and are chargeable. It is apparent from the downhole data that the high grade copper intersections correspond with resistivity and chargeability anomalies. However, it is also apparent that the barren hematite has similar properties to the mineralised breccia.

Rock Type	Den. g/cc	Mag Sus. (SI x10-5)	Res. ohm.m	Chg. Msec	Fe (%)	Cu ppm
Hematite Rock (79)	3.86	109.78	48.5	101	42.10	109
Chalcocite Breccia (38)	3.42	96	263	42.9	23.81	22915
Chalcopyrite Breccia (86)	3.74	167	185	57.3	33.25	14584
Massive Chalcocite (3)	4.92	3.21	20.5	66.5	29.85	100133
Magnetite Rock (61)	3.49	>100000	491	70.3	29.96	1170

Table 2. Summary of petrophysical data from Prominent Hill Deposit.

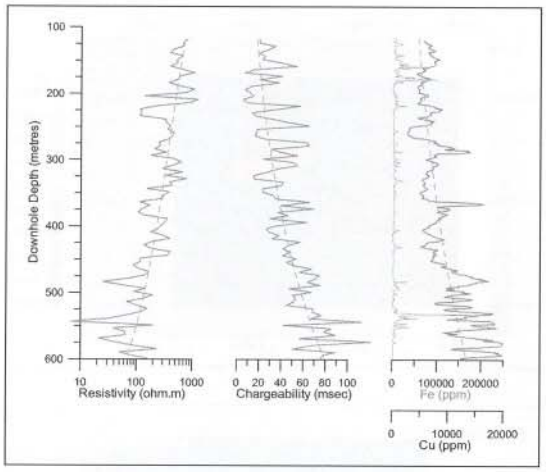
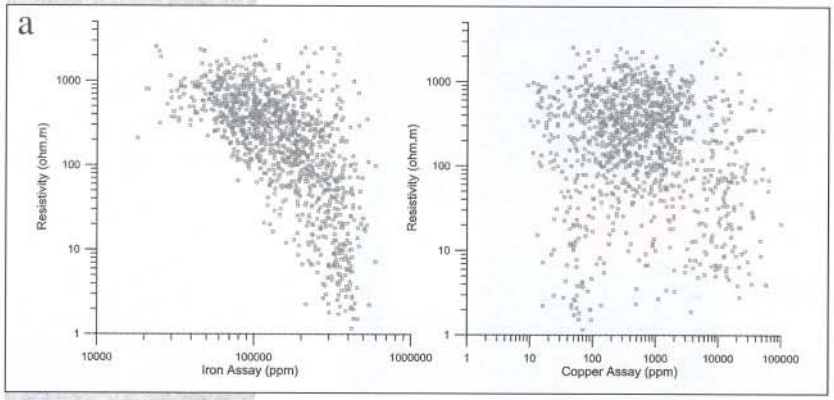


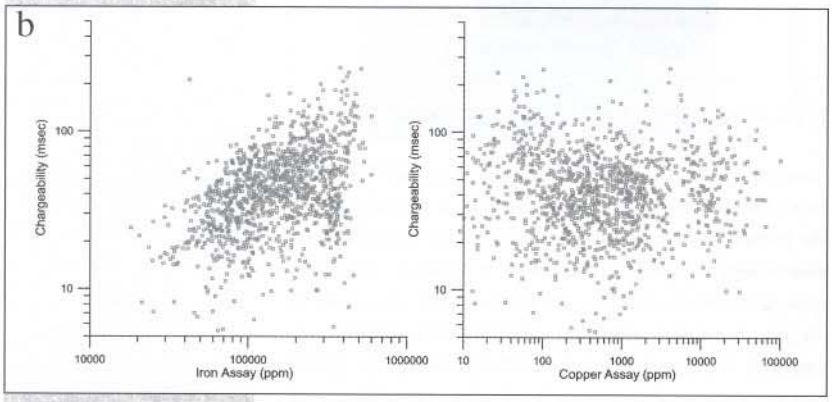
Fig.7. Downhole logging of drillhole DP004.

Fig. 8. Crossplots of petrophysical data from Prominent Hill.

a) (Below) Resistivity versus Iron and Copper.

b) (Bottom) Chargeability versus Iron and Copper





The effect of haematite content on chargeability and resistivity is apparent from the logging of drill hole DP004. This drill hole is located on the southern margin of the haematitic body intersected in DP001. DP004 intersected volcanic agglomerates, lapilli tuffs and andesitic lithologies with variable haematite alteration. An increase in haematite alteration of the volcanic host was noted from approximately 470 m depth, corresponding with gradually increasing density. A chalcocite-bearing haematite breccia was intersected at 530 m and this interval returned the highest copper assay in the drill hole. The IP/resistivity data from this drill hole are presented, along with copper and iron assays, in Figure 7. Both the increase in chargeability and decrease in resistivity appear strongly correlated with the increasing iron content of the intersected volcanics. The chalcocite-bearing breccia is visible as a resistivity low and chargeability high.

The assay data from the thirteen logged drill holes were re-sampled to the same intervals as the downhole logging. This enabled comparison of chargeability and resistivity with copper and iron assays. The relationship between iron and chargeability and resistivity is further emphasised by looking at crossplots of these datasets. A linear relationship between iron content and chargeability and log resistivity is apparent from these datasets (Fig.8a and b).

Project update

Since the publication of the original paper in March 2003, work has continued at the Prominent Hill Deposit. A change in ownership of the project occurred in August 2003. Minotaur Resources acquired BHP Billiton's 51% interest for $8 million in cash and the interests held by Newmont (23.94%), Sons of Gwalia (3.78%) and Sabatica (2.28%) for $4 million, the consideration being Minotaur shares. Oxiana Limited was introduced to the project through staged farm-in arrangements totalling up to A$34 million and earning it an interest of up to 65%.

A total of 17 diamond drillholes and 34 RC drillholes have now been completed. A plan of the completed drilling, along with copper intercepts greater than 1% is shown in figure 9.

Conclusions

The Prominent Hill prospect was discovered by drilling a high-amplitude gravity anomaly. The discovery hole, URN001, intersected a thick interval of high-grade copper mineralisation beneath 100 m of cover sediments.

Follow up geophysical surveys, in particular IP/Resistivity surveys, were designed to detect the high-grade copper mineralisation. These surveys have been unsuccessful, with barren haematite intersected in subsequent drilling.

Continued on page 36

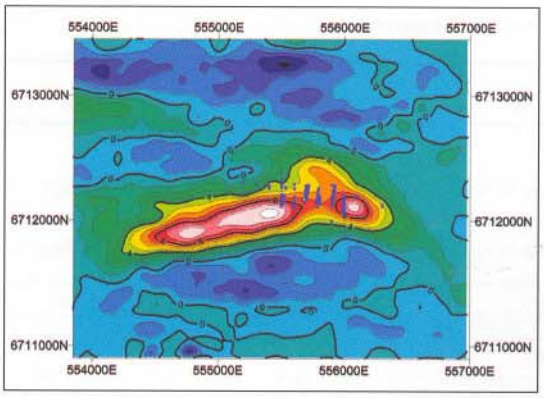


Fig. 9. RC and Diamond drillholes from Prominent Hill showing Copper Intersections > 1%. First Vertical Derivate of Bouguer gravity is also shown.

HyMap – Hyperspectral Mapping – GeoVision beyond the Visible

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Introduction

Most geoscientists are familiar with the colorful LandSat imagery we have been provided with for almost 30 years. These multispectral data sets have allowed us to see the earth in colors not accessible by the human eye and hence allowed discrimination of previous, not distinguishable geological features. Technology has progressed and it is now possible to view the earth not only in a few, but hundreds of different spectral channels over a wide wavelength range and to map the surface composition based on the spectral signatures observed. We call that 'hyperspectral sensing' and despite some attempts with satellite systems, airborne instruments are leading the way. An Australian designed and built sensor is one of the world's outstanding performers and has delivered high quality data sets worldwide in over 27 different countries. Applications range from mineral mapping to environmental monitoring, geothermal prospecting to oil seep identification. From small scale targeting to large area mapping, HyMap has demonstrated its usefulness equally to geological surveys, environmental agencies and exploration companies.

When trying to convince the classical exploration geophysicist of the usefulness of a detailed mineral map for his exploration lease, many seem skeptical and refer to hyperspectral as 'only' being a surface tool. However, quite often surface mapping can reveal astonishing details about the presence of alteration minerals, their mineral chemistry and spatial distribution. With a high spatial resolution of down to 3.5 m structures like quartz veins or gossans can easily be identified and can highlight new, previously inaccessible exploration targets. Even in the highly weathered, regolith dominated Australian environment, HyMap has discovered structures and residual anomalies previously unknown to geoscientists, many of which are not present in the standard geological maps of the area.

For many exploration managers remote sensing data is still synonymous with large-area overviews rather than detailed specific information related to an exploration issue. Often the data processing and interpretation skills are not advanced enough to extract the relevant information for the project. But demonstration projects by CSIRO and state mapping agencies lead the way and create insight into the potential uses of hyperspectral technology. If we can directly send the drill crew to a promising alteration/target/anomaly area and avoid 'blind' holes we may actually save money by investing in the right remote sensing technique. Having highly accurate mineral maps may actually allow us to correctly identify the exploration model to be used for a specific area. Hence acquiring HyMap data and getting the appropriate data processing done can prove to be quite a cost effective way to start an exploration project.

But hyperspectral data should also always be seen in conjunction with other geo-data sets, be it elevation models or magnetic data. The wise use of different information layers not seen in isolation, but as part of the whole, is an important element of the recent revolution seen within the geosciences. Today, whole-earth models that combine seismic-extracted fault structures, spatially located geochemical information, magnetics, gravity, age-dating and field mapping information are used to assess exploration prospects and leases. Continuous surface information from hyperspectral imaging is simply one more vital building block for our exploration models.

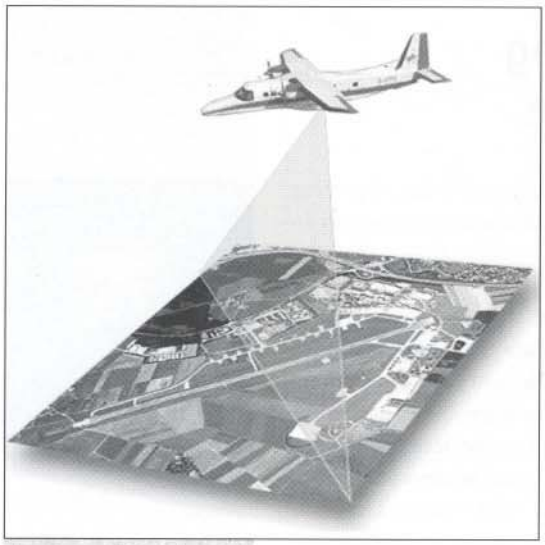
HyMap™ Airborne Imaging Sensor

The HyMap sensor (Cocks *et al.*, 1998) is an airborne imaging system that is used for earth resources remote sensing. It records a digital image of the earth's sunlit surface underneath the aircraft (Figure 1), but unlike standard aerial cameras, the HyMap records images in a large number of wavelengths. Spanning the wavelength range from the 0.4 to 2.5 μm (visible to shortwave infrared) spectral region (Figure 2), HyMap is an airborne spectrometer that detects and identifies materials by the spectral features contained in the recorded data.

The HyMap records an image by using a rotating scan mirror which allows the image to build line by line as the aircraft flies forward. The reflected sunlight collected by the scan mirror is then dispersed into different wavelengths by four spectrometers in the system. The spectral and image information from the spectrometers is digitised and recorded on tape.

To minimise distortion induced in the image by aircraft pitch, roll and yaw motions, the HyMap is mounted in a gyro-stabilised platform. While the platform minimises the effects of aircraft motion, small image distortions remain. These residual motions are monitored with a 3 axis gyro, 3 axis accelerometer system (IMU – inertial monitoring unit). Dedicated geo-correction processing restores the full geo-location information and allows the creation of GIS ready products.

The HyMap system has been designed to operate in aircraft that have standard aerial photo-ports. The angular width of the recorded image is 61.3 degrees or about 2.3 km when operating 2000 m above ground level. Typically, the spatial resolution achieved with the HyMap is in the range of 3 to 10 m.



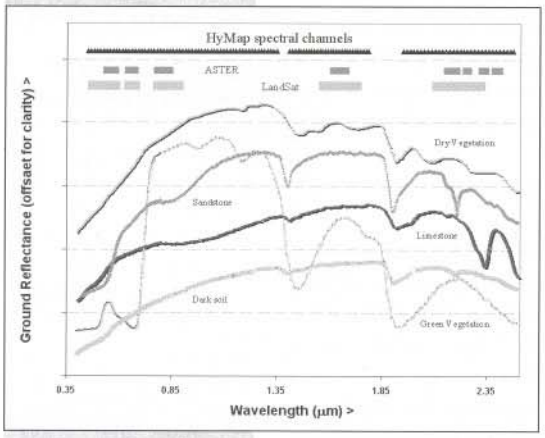


Fig. 1. (Top) HyMap data acquisition.

Fig. 2. (Above) Example for ground reflectances from a spectral library and HyMap spectral channel positions.

Hyperspectral Processing

The HyMap sensor acquires reflected surface radiation, which needs to be calibrated and corrected for atmospheric absorption to derive reflectance. Reflectance is then used for spectral signature analysis and comparison to spectral libraries of known materials (Figure 2). Using calibration parameters obtained in the laboratory, the initial digital numbers are converted to 'radiance at sensor' in 'μW/cm^2 sr nm' radiance units. Different atmospheric correction algorithm have been published such as AtCor (Richter, 2004) or FLAASH (Matthew *et al.*, 2000) and can convert the 'radiance at sensor' into reflectance using atmospheric model parameters and information such as sun angle, location and time of the survey.

Unlike other geophysical airborne sensors where the calibrated units can be used directly in the data interpretation stage, post-processed reflectance data from HyMap are only the first step in the information extraction process. Though colorcomposites of selected spectral channels do give a first indication about surface material properties (see Figure 3), the major power when using hyperspectral data comes when dedicated processing is applied. The data can be used to qualify the spectral properties of different surface materials and derive spectral indexes and spectral component maps. A spectral index utilizes the common spectral properties of a group of surface materials such as the dominant 2.2 μm spectral absorption of the clay group minerals. Based on surface-extracted spectral signatures, dedicated component maps can be derived, as shown in Figure 3 where 'mineral' maps are shown. Another commonly used methodology builds on initial principle component like MNF transformations which leads to semi-automated detection of spectrally different materials (Huntington and Boardman, 1995). Other ways of extracting the information in the data include monitoring an exact wavelength position of a spectral feature, such as that of the white mica minerals (e.g. muscovite), tracking its wavelength position and then deriving a so-called mineral chemistry map. In addition, various 'mineral' maps can be combined into alteration zone maps, such as advanced argyllic or epithermal. In a geological exploration model, these important pieces of information can lead directly to zones of higher exploration relevance and hence reduce exploration expenses.

In a similar way such processing techniques allow information extraction for other applications such as oil seep mapping (Figure 4) or environmental monitoring (Figure 5). Different water constituents or vegetation components can be separated, vegetation stress monitored or multitemporal comparisons obtained.

Hyperspectral application examples

The development of the HyMap sensor was inspired by the mapping needs of mineral explorers. Success in the mining industry with handheld spectrometers, such as the PIMA, complimented the successful development of the large-area airborne scanners that utilised similar technology. These first airborne scanners from Integrated Spectronics (www.intspec.com) eventually led to the HyMap series of sensors. They combine accurate, point-scale mineral identification from reflectance spectroscopy with the large-area mapping ability afforded by airborne scanning technology. The result is high fidelity, continuous surface information including mineral identification, lithology separation, vegetation classification, manmade material identification and a myriad of other material identifications and discriminations.

Significant contributions to Australian and international exploration programs have been made in the past ten years from airborne hyperspectral imaging and many prominent companies such as DeBeers, Falconbridge/Noranda and PlacerGold count on hyperspectral data for their exploration programs. The alteration systems around Panorama in Western Australia have been investigated by Cudahy *et al.*, 1999 and successful mica chemistry mapping was demonstrated, while Bierwierth *et al.*, 2002 demonstrated the distinct ability to identify and map gold indicator minerals such as pyrophyllite in the unforgiving regolith-dominated northern Pilbara region of WA. Other prospecting in remote regions of South America is benefiting from recent data fusion projects which involve large-area satellite reconnaissance followed by specific prospect-scale mapping with airborne hyperspectral (Kruse *et al.*, 2002).

In addition to mineral exploration, geothermal resource prospecting has also become a 'hot' topic for hyperspectral scientists in recent years. Hyperspectral surveys in the western US have served to define and refine geothermal exploration targets in several locales including expansion sites with previous production (Martini *et al.*, 2003; Kratt *et al.*, 2003) and green-field sites lacking current heat energy production (Martini *et al.*, 2004).

Oil and gas explorers have remained interested in the technology for many years and companies such as Shell

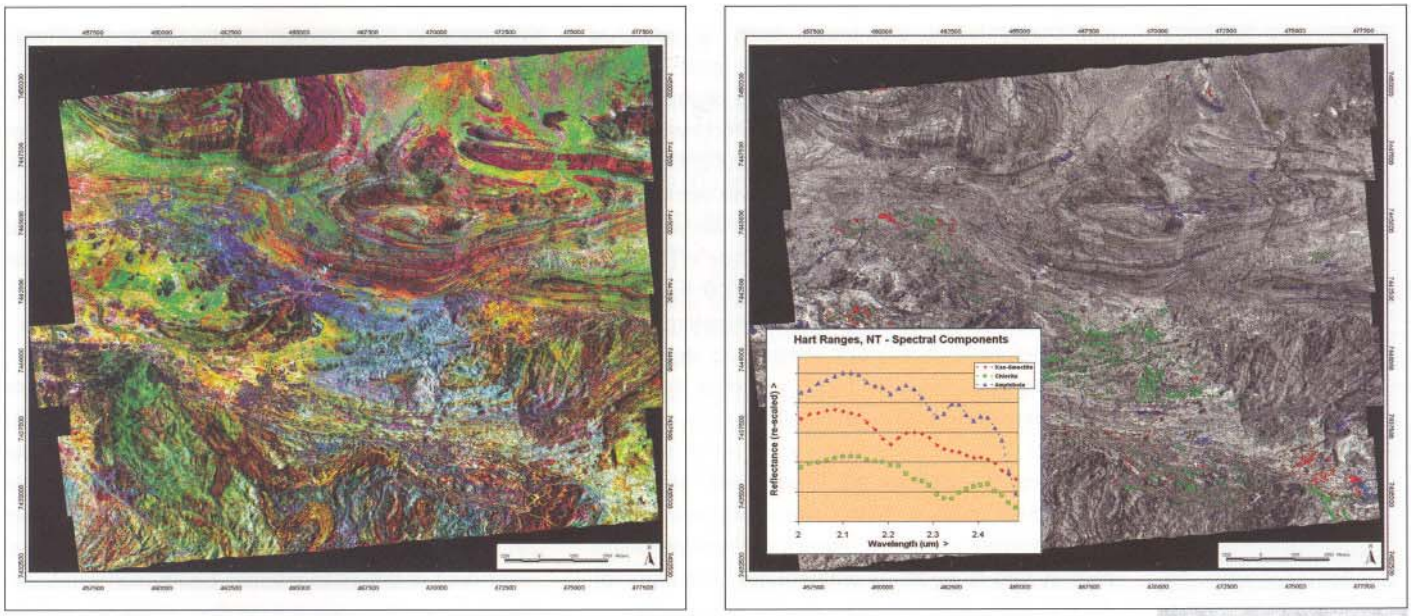


Fig. 3. HyMap derived imagery over the Harts Ranges, NT: Left: Narrow band color composite simulating LandSat 7/4/1 using the HyMap equivalent center channels. Right: Spectral component map superimposed on a single channel (0.65 µm). Insert: The SWIR spectral signatures of the displayed map components are displayed in matching colors and were identified by comparison to a spectral library.

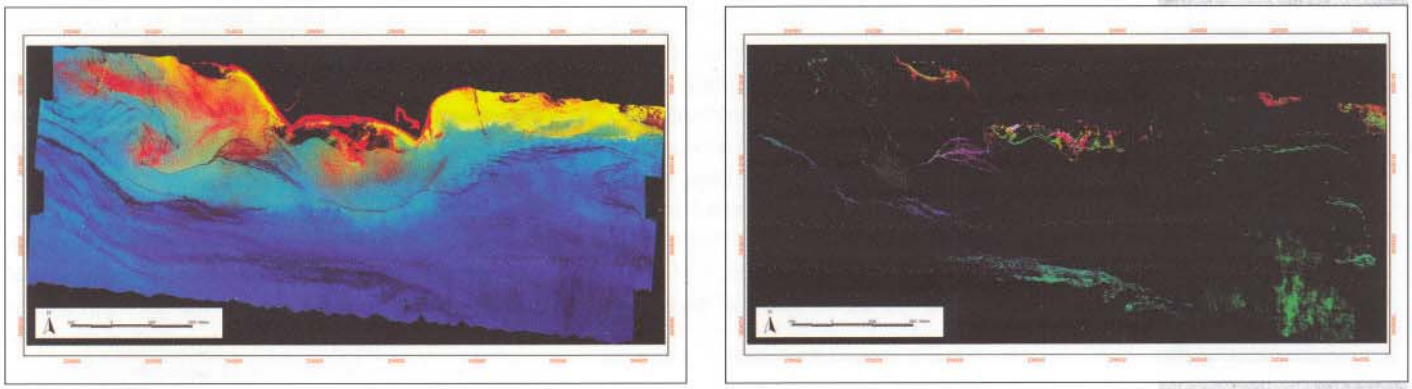


Fig. 4. HyMap imagery used for offshore seepage mapping near Santa Barbara California. Left: False color composite mosaic of the survey area highlighting different water constituents using spectral ratios in the visible and near infrared spectral region. Right: Spectral component map of slick areas. The land, open water and kelp beds have been masked out deliberately and the remaining data spectrally processed to highlight variations within these components.

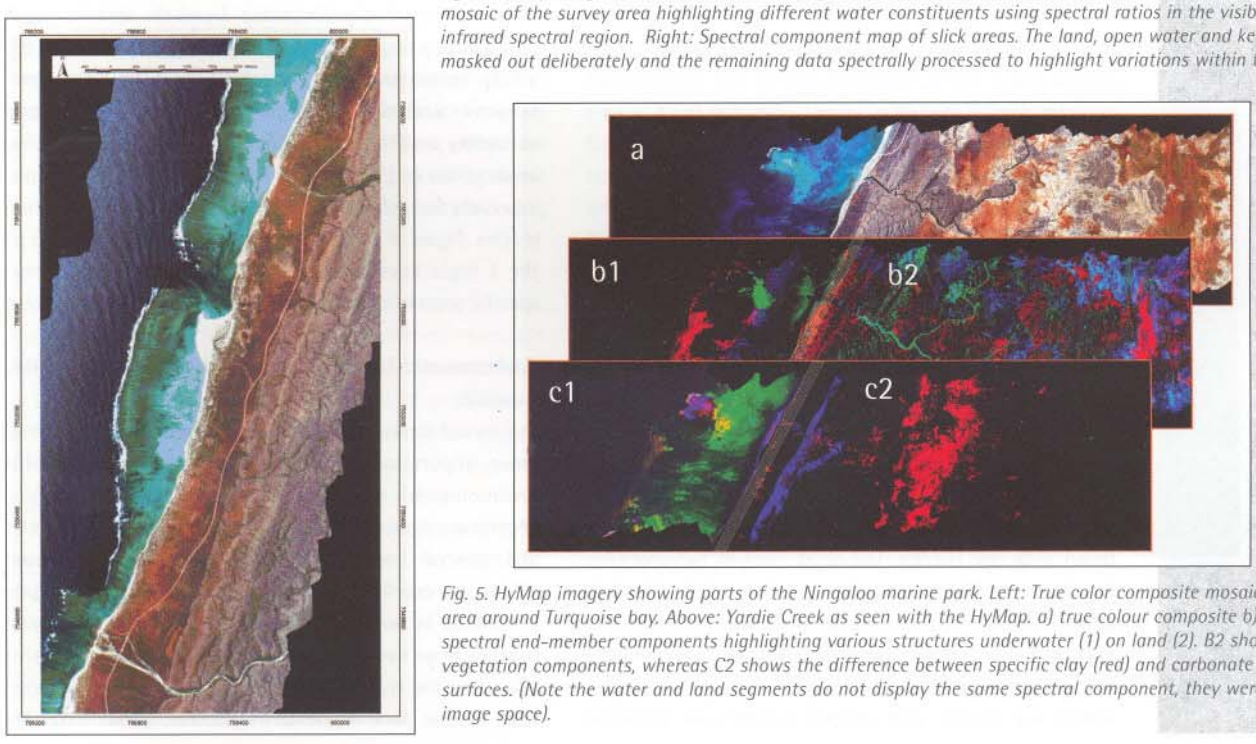


Fig. 5. HyMap imagery showing parts of the Ningaloo marine park. Left: True color composite mosaic showing the area around Turquoise bay. Above: Yardie Creek as seen with the HyMap. a) true colour composite b) & c) different spectral end-member components highlighting various structures underwater (1) on land (2). B2 shows different vegetation components, whereas C2 shows the difference between specific clay (red) and carbonate (blue) dominated surfaces. (Note the water and land segments do not display the same spectral component, they were merged to save image space).

and ChevronTexaco are known users. Detection of terrestrial hydrocarbon seepage is the most common application with practitioners measuring changes in soil composition, vegetation anomalies and direct hydrocarbon residue mapping (Van der Meer *et al.*, 2002; Ellis *et al.*, 2001). Recently, a concerted effort towards detection and mapping of offshore hydrocarbon seepage has been made, especially at well-known seeps such as those off of Santa Barbara, CA, (Richardson and Nusbaum, 2000; Hausknecht and Martini, 2004). Detecting and discriminating seepage from other materials may help explorers to identify new regions of interest and to target areas for other complementary geophysical data collects.

Hyperspectral imaging has also made significant contributions to environmental monitoring best-practices and has become a vital new research and application area. Work by Ong *et al.*, 2003a demonstrated quantitative pH measurements made in mine regions plagued by acid drainage including the gold, silver, lead, zinc mine of Leadville, CO, USA and the abandoned pyrite mine of Brukunga, SA, Australia. Quantification of dust loading on mangroves surrounding BHPBilliton's iron ore handling facility at Port Hedland, WA was also accomplished (Ong *et al.*, 2003b) and recent work by the USGS produced hyperspectrally derived asbestiform mineral maps relating to relative physical concentrations of such minerals around both the historic vermiculite deposits of Libby, Montana, USA and within the destruction of the World Trade Center (Clarke *et al.*, 2003).

In this article we would like to focus on three specific application examples.

Mineral Exploration: Harts Range , NT – Australia

The Northern Territory has been a region of increasing interest and prospectivity in Australia. Such areas as the Arunta Inlier in the southern 1/3 of the Territory has garnered special interest in recent years due to its proven mineral resources and has subsequently been examined with extensive suites of geophysical and geochemical surveys. Synthesis and analysis of these data is on-going by both state and national entities including the NTGS and GA and by individual and JV'ed mining companies working in the region. The broad goal has been to expand the understanding of the complex genesis and geology of this region including characterisation of fluid movement in the Tanami and linking the Tanami and the Arunta more convincingly. Constraining the formation and occurance of Cu-Zn-Pb deposits in the eastern Arunta has also been of primary interest. Several regions in the NT, including the rocks of the Harts Range in the eastern Arunta, have been flown with the HyMap. The eight lines of hyperspectral data, seen in Figure 3, capture portions of the Riddock Amphibolite within the Harts Range Group in the northern part of the dataset, various gneisses, schists, amphibolites and granulites of the Strangways Metamorphic Complex within the central part of the dataset and extensive Proterozoic to Paleozoic aged schists and amphibolites in the southern part of the dataset.

There are several exploration goals in this region of which determining possible Au and Cu prospectivity is paramount. Analysis of the hyperspectral data, such as that shown in Figure 3, highlights new geological information about the Harts Range and has provided new insight into Cu-mineralisation and host-rock character to local exploration companies.

Hydrocarbon seepage: Santa Barbara, California – USA

The hydrocarbon seepage off of Coal Oil Point, Santa Barbara, CA is one of the largest and most active seeps in the world. It continues to be of great interest both to government bodies as well as universities and private resource companies; including the primary research done by the UC Santa Barbara Hydrocarbon Seeps Group. Researchers in this group estimate that approximately 100 barrels a day of crude oil seeps from the Santa Barbara region in addition to 100,000 m^3 of gas per day. Tracking and quantifying this seepage has primarily been done with a combination of direct seep tent measurements and indirect sonar measurements. However, the overall spatial distribution of the seeps on the ocean surface is less well-known, especially temporally. Spatial extent and seep-slick movements are important pieces of information towards understanding the dynamics of slicks and the behavior of seeps and slicks over time.

Airborne hyperspectral seep mapping offers a new possibility of characterising seeps in an exploration area of interest. It offers the advantage of allowing spectral discrimination of seep components, which may not be separable with conventional techniques like radar. Initial analysis (Hausknecht and Martini, 2004) indicates that unlike the confusion imparted by such techniques as photography, multispectral and radar, hyperspectral has the ability to discriminate not only seep slicks from other biogenic materials, but may also track within-seep variability possibly due to chemistry, age, or thickness. The implications of this research may be far-reaching in time, especially for global seep detection and local seep variation studies. Figure 4 shows seamless data product mosaics of the 4 flight lines covering the area, with different seep-specific spectral components highlighted in the images.

Environmental baseline mapping: Ningaloo Reef – WA, Australia

In times of increased environmental awareness, it becomes more important to have tools available to monitor environmental parameters such as water pollution, vegetation health, habitat bio-diversity, invasive species and general human impact. Hyperspectral monitoring offers an excellent possibility to regularly investigate conditions in sensitive areas and create highly accurate baseline maps over areas of high importance. One such area visited by the HyMap sensor in late 2002 is the Ningaloo Reef marine park in Western Australia, about 1200 km

north of Perth. This area is not only one of Australia's most precious marine habitats and protected areas, but has also been suggested for inclusion as a 'World Heritage' site. HyMap not only allows for monitoring various land surfaces and native vegetation habitats in the coastal karst areas, but also penetrates the water and allows monitoring of the still pristine, but sensitive reef areas. Such a non-invasive remote sensing technique is the best way to keep an 'eye' on 100 % of the protected area at a high spatial resolution, without extensive ground work and disturbance of the already fragile habitats. Figure 5 on the left shows a HyMap line acquired parallel to the shore near Turquoise Pool with its colorful waters. The right hand images show an area near Yardie Creek flown perpendicular to the reef line showing both land and underwater features in the area. The clarity of these underwater features is remarkable and may allow spectral identification of the different reef components. Together with a spatial resolution of 3-5 m, HyMap offers the possibility for dedicated baseline mapping and regular monitoring of areas of such importance.

Conclusion

Hyperspectral mapping offers the geoscientist new possibilities for obtaining geo-information previously only available from extensive field work. The ability to spectrally map a variety of surface materials opens a range of applications. However, the acceptance of the technology appears somewhat lacking in the geoscience community. This may be due to its 'surface only tool' capabilities, but more likely to a lack of education about the individual possibilities, the perceived complexity of the software needed to do the data processing and/or the shear number of spectral channels and multitude of possibilities for combinations of data products. People seem to want to have only 3 or 4 choices of products they can work with – HyMap offers many more – Which do I take ? Hyperspectral experts will understand how to process the data correctly and deliver the products required in a limited amount of time. With current advances in computer processing power and data storage capacity – data volume and processing speed is not an issue anymore.

We also see a trend in the geoscience industry to move away from the 'We have to do it all ourselves' mentality towards asking service providers for specific products - like a target map for one particular mineral in an alteration zone or a vegetation stress map over a contaminated field. Once the geoscientist knows what hyperspectral mapping can do for them without actually having to do it themselves, then we will see acceptance multiply. Like the magnifying glass for the field geologist, hyperspectral mapping is an essential part of the GeoVision we have for the future in earth monitoring.

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Continued from page 30

Physical property measurements have demonstrated that the barren haematite rock and mineralised haematite breccia have similar density, magnetic susceptibility, resistivity and chargeability. Interpretation of electrical datasets is hampered by the presence of conductive overlying black shale. As a result of the lack of physical property contrast, it is difficult to distinguish between mineralised and unmineralised breccias by geophysical methods.

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Geophysical signatures of Broken Hill Type orebodies

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Broken Hill Type (BHT) orebodies may be broadly described as large bodies of sulphide hosted within Proterozoic sediments metamorphosed to amphibolite grade. The sulphides consist mostly of galena and sphalerite with silver making a significant, if not a major, economic contribution. Typically there are few other associated sulphides, but pyrrhotite may be sufficiently plentiful to enhance the conductivity and magnetics. Significant amounts of magnetite may also be present.

There are four main examples: Aggeneys-Gamsberg, South Africa; Cannington, Queensland; Zinkgruvan, Sweden and Broken Hill, NSW (see Table).

Geophysically, BHT orebodies are typically regarded as massive sulphides within highly resistive rocks and thus as potentially excellent geophysical targets. Often this is the case, but the type definition covers a range of deposits and there are some important provisos. This short paper summaries and speculates on the responses of the type orebodies to the usual geophysical techniques as well as to some of the less well known.

Magnetics

Some deposits contain magnetite within the ore (e.g. Aggeneys-Gamsberg and parts of Cannington) and pyrrhotite may also contribute. However, neither Broken Hill nor Zinkgruvan contain sufficient of either material to produce a recognisable magnetic response over the ore. Magnetic sequences occur in the vicinity of Broken Hill, but the ore itself is not magnetic. Thus, there are significant variations in the magnetic responses of BHT deposits. These are indicated in Figure 1 which also shows the very different magnetic settings of the four type deposits. Despite these differences, regional magnetics can be used to help look for the right setting and, it has been suggested, even for the right area within that setting (Walters, 1998). At the mine or deposit scale, magnetics can define structure and, for deposits with significant magnetite, map the extent of mineralisation. For example at Gamsberg, magnetics were "particularly important in determining the down-plunge continuation of the deposit" (Rozendaal, 1986). In summary, magnetics may be a direct targeting tool, but the absence of a response should certainly not lead to the conclusion that there is no potential orebody.

Gravity

Large tonnages of massive sulphides in pelitic and/or psammitic host rocks would be expected to give a significant gravitational response, however, amphibolites are ubiquitous in BHT environments and this dense rock type (>3 t/m^3) may totally mask any anomaly due to sulphides. Neither Broken Hill nor Zinkgruvan show a direct response and Cannington's apparent target-type response is actually due to a core of amphibolite at the centre of the deposit (notice the displacement between the magnetics and the gravity). The public domain gravity data for Aggeneys-Gamsberg is too sparse for meaningful imagery, but again gravity is probably not definitive for ore - although the deposits outcrop, the sulphide grades are low and amphibolites are (presumably) present. Figure 2 compares the gravitational fields for three of the four type deposits. Both Broken Hill and Zinkgruvan lie on the side of large gravity highs and one could argue that Cannington is similarly placed. Although the gravity anomalies are of quite different size, the positions of the deposits beside a large gravity high possibly provide the highest degree of geophysical commonality between the four deposits.

Electromagnetics

The high grade of metamorphism means that small tonnages of even relatively low-grade mineralisation are usually an effective EM target. For example the Flying Doctor deposit at Broken Hill (~0.5Mt at 10% Pb+Zn and less than ~2% total other sulphide), with a depth of weathering of about 30 m,

(1) Aggeneys - Gamsberg, RSA:	82Mt @	2.7% Pb,	0.6% Zn,		39 g/t Ag	Swartzberg
	85Mt @	3.6% Pb,	1.8% Zn,		48 g/t Ag	Broken Hill
	100Mt @	1.% Pb,	2.5% Zn,	0.8% Cu,	39 g/t Ag	Big Syncline
	150Mt @	0.6% Pb,	7.1% Zn			Gamsberg
(2) Cannington, Qld.	44Mt @	11.6% Pb,	4.4% Zn,		538 g/t Ag	
(Pegmont, Qld.	8.6Mt @	7.7% Pb,	3.4% Zn)			
(3) Zinkgruvan, Sweden	40Mt @	5.5% Pb,	6% Zn,		100 g/t Ag	Knalla mine
	including	1.5% Pb,	10% Zn,		45 g/t Ag	Nygruvan mine
(4) Broken Hill, NSW	280Mt @	10.% Pb,	15.% Zn,		160 g/t Ag	
(Potosi extended	~2Mt @	3.7% Pb,	13.7% Zn,		45 g/t Ag)	

Table. Broken Hill Type orebodies.

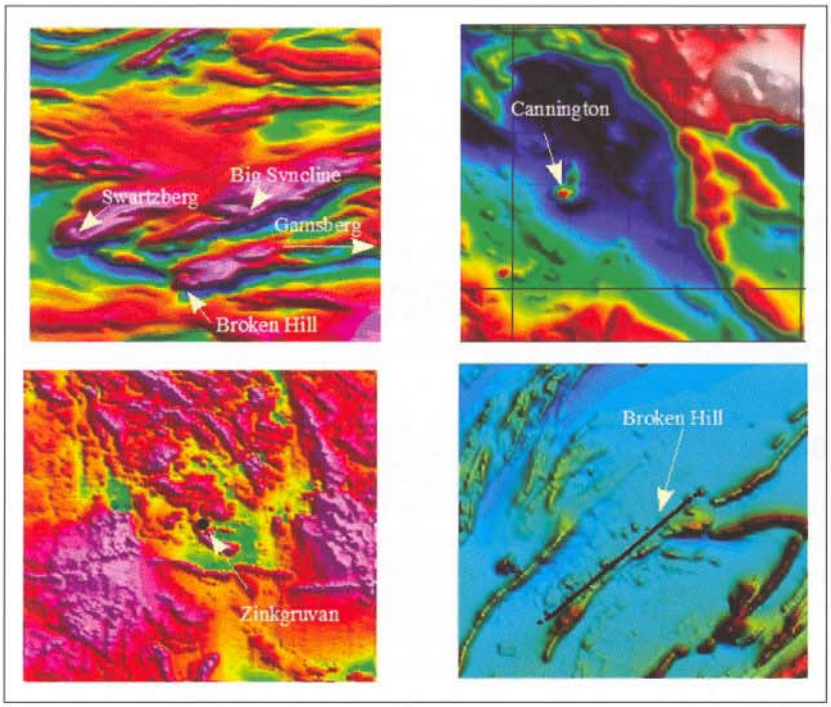

Fig. 1. (Top) Images of aeromagnetic data over BHT deposits. Image size is approximately 12 km x 12 km. Cannington was discovered by drilling the magnetic anomaly and the Aggeneys-Gamsberg deposits are also magnetic. However, neither Broken Hill nor Zinkgruven have (significant) magnetic ores.

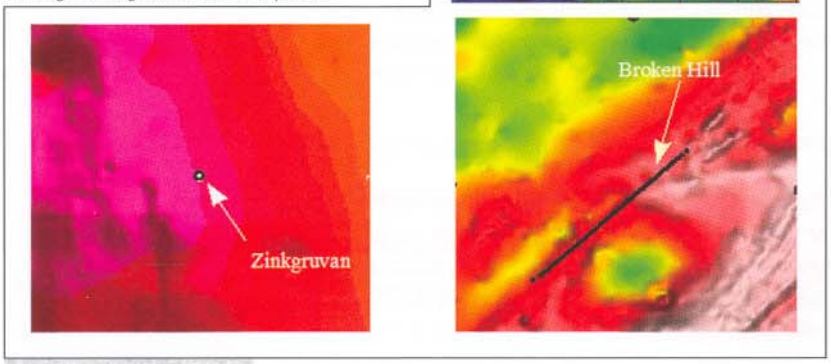

Fig. 2. (Right & Below) Images of gravity data over BHT type deposits. Image size is approximately 12 km x 12 km. The responses from all types (including the missing Aggeneys-Gamsberg data, which is too sparse for effective display) are dominated by amphibolites. There are no recognisable responses from the orebodies despite the large tonnages of massive sulphides.

gives a discernible airborne EM (AEM) response. Elsewhere in the region, the 'Lode Horizon' is recognisable as a less resistive feature within the highly resistive country rocks. Cannington is buried beneath several tens of metres of conductive Cretaceous sediments, but probably gives a recognisable AEM response over the northern lenses where the cover is thinnest (<30m). Thus, although graphite (e.g., at Aggeneys-Gamsberg) or barren sulphides (e.g., Zinkgruvan) may give rise to unwanted responses, AEM should be regarded as a useful technique to explore for relatively shallow BHT deposits. At the prospect scale, deeper penetration can be achieved with surface EM (to 200 m plus or with CSAMT (approaching ~1km) if the target is large enough. But as with magnetics, the lack of a response, whilst discouraging, should not be regarded as an absolute sterilisation: poorly conducting zinc-rich lenses do occur (e.g., Bishop *et al.*, 1997) and the ribbon-like shape of the lenses may also mitigate against a recognisable EM response.

Induced Polarisation

IP has been given credit for discovering at least one BHT deposit and even sphalerite-rich lenses should produce a significant response. Graphite will respond but sub-economic zones of sulphides are probably the main source of disappointment. IP is not a regional tool (though airborne IP might yet become a reality), but recent developments have resulted in much better penetration (perhaps to +500 m) and interpretation of the data (White *et al.*, 2003).

Other electrical methods, which have enjoyed success at the prospect scale, include applied potential and drillhole magnetometric resistivity. Both these methods are useful where the mineralisation is less resistive than the host rocks, but is not necessarily conductive enough for EM. More esoteric methods include piezoelectricity and other electro-mechanical methods can be tried (Bishop and Emerson, 1999).

Thus despite the relatively simple mix of mineralisation (sphalerite + galena +/- pyrrhotite) and uniform host lithologies (psammites, pelites), the geophysical responses are surprisingly diverse. Perhaps most surprising is the lack of a gravity response despite the large tonnages and, in some cases, quite high grades. Nevertheless geophysics plays an important part in exploration for BHT deposits and here, as elsewhere, a range of techniques is required to ascertain and properly use all of the significant physical property contrasts.

Acknowledgements

BHPBilliton, Anglo American and the Geological Surveys of Sweden and NSW are thanked for their data and permission to publish.

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Geoscience Australia

Airborne geophysical surveys in WA contracted by Geoscience Australia

Geoscience Australia (GA) is contracting out two airborne magnetic, gamma-ray and elevation surveys in Western Australia.

Information derived from these geophysical data and other complementary datasets will be used extensively to assist in the geological mapping of the Archaean rocks and is aimed at stimulating mineral exploration activity in this prospective region of Australia.

The **Cue** airborne geophysical survey (WA) was awarded to Fugro Airborne Surveys Pty Ltd. Data acquisition started on 14 April with flying to be completed by 7 June. The project comprises acquisition, processing and supply of approximately 55,437 line-km of airborne magnetic, gamma-ray and elevation data.

The **Kirkalocka** airborne geophysical survey (WA) was awarded to UTS Geophysics Pty Ltd. Data acquisition commenced on 20 May with flying to be completed by 8 July. The project comprises acquisition, processing and supply of approximately 52,287 line-km of airborne magnetic, gamma-ray and elevation data.

In both surveys flight lines will be flown 400 m apart at 60 m above ground level in an east-west direction.

The new datasets will be released in the second half of 2004.

Contact Murray Richardson or Mario Bacchin for more information.

New Magnetic Map of Australia

A totally new fourth edition of the Magnetic Anomaly Map of Australia is planned for release by Geoscience Australia in November 2004. Produced in collaboration with the State and Territory government geological surveys, this 1:5 000 000 scale map will be compiled from publicly available airborne and shipborne total magnetic intensity data.

Underpinning the new map is a database of the individual survey grids. These grids are stored separately, each at their best resolution, and are seamlessly matched using gridmerging software originally developed by Geoscience Australia, and now available commercially. Approximately 600 individual grids are being matched, with long-wavelength control provided by three special airborne survey lines flown in 1990 and 1994. Details of the database and map compilation will be presented at the forthcoming ASEG conference in Sydney during August. For further information Peter Milligan or Ross Franklin.

Absolute Gravity Measurements at Mt Stromlo

During March and April this year Geoscience Australia, with the Research School of Earth Sciences (RSES) at the Australian National University, assisted a party from the Kyoto University in Japan to make precise absolute gravity measurements at the Mt Stromlo Observatory near Canberra. The RSES operates a superconducting gravimeter, owned by the Kyoto University, which is capable of measuring changes in the Earth's gravity field of less than 1 microgal. This instrument is installed at Mt Stromlo and is used to measure long term variations in the gravity field. The absolute gravity measurements were made with Kyoto University's FG5 absolute gravimeter in order to calibrate the superconducting gravimeter (see Figure 1). This is done by making absolute gravity observations at hourly intervals over a number of days so that the tidal gravity variations can be accurately measured. These gravity variations are then compared with the corresponding variations obtained by the superconducting gravimeter and a calibration factor for the superconducting gravimeter is thus obtained. GA carried out vertical gradient measurements at the absolute site using a LaCoste & Romberg model D micro-gravimeter. These vertical gradient measurements are necessary to accurately transfer the absolute gravity measurement, calculated at about 1.3 m above the ground, to ground level.

For further information about these absolute gravity measurements, contact Ray Tracey: Ray.Tracey@ga.gov.au

Deep Seismic Surveys by ANSIR and Geoscience Australia

Over the last year, regional seismic refection surveys have been completed by GA in conjunction with other parties in the Gawler Craton and the Curnamona Province of S.A, mine scale seismic refection surveys in the Yilgarn Craton, WA and a high resolution shallow seismic refection survey in the Echuca region of NSW (see Figure 2). For this work, Geoscience Australia has used the facilities of ANSIR (Australian National Seismic Imaging Resource), a Major National Research Facility.

The Gawler Craton seismic survey was undertaken by Geoscience Australia, in collaboration with the Office of Minerals and Energy Resources, South Australia during August 2003 (see Figure 3). This survey was undertaken to provide a quantum jump in our understanding of the crustal setting of the Olympic Dam mineral system, to provide the foundation for new exploration models for Cu-Au deposits in the Gawler Craton and to stimulate the flagging Gawler Craton exploration strategies. The survey involved the collection of two seismic reflection traverses, a 200 km regional N-S seismic line and a 60 km E-W cross line. The regional N-S traverse was located just to the east of the world class Olympic Dam mine. Processing and interpretation of the data is progressing, with the interpretation of the seismic data to be presented at a Gawler Craton seismic workshop, currently scheduled to be

Fig. 1. Kyoto University's FG5 absolute gravimeter (vertical tower) operating in the seismic vault at Mount Stromlo to calibrate the superconducting gravimeter.

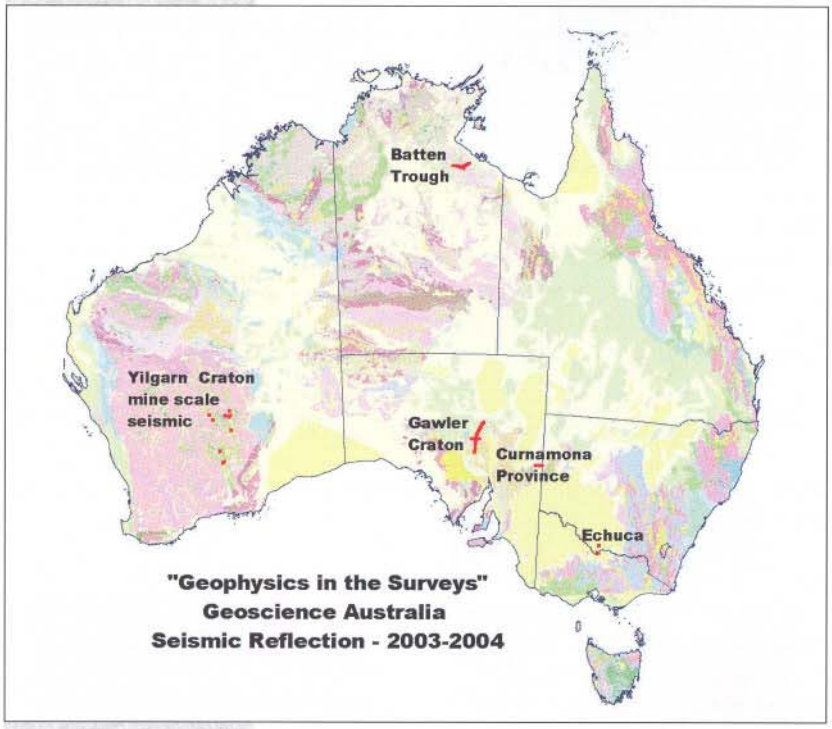

Fig. 2. Locations of seismic surveys 2003-04.

held in Adelaide on 6th August 2004. The results will also be published in a GA Record.

The Curnamona Province seismic survey was undertaken as a collaborative project involving the Office of Minerals and Energy Resources, South Australia, the Predictive Mineral Discovery Cooperative Research Centre and Geoscience Australia during late August and September 2003. The survey was undertaken to map the crustal structure of the province to identify the location of deep penetrating shear zones. Current mineral deposits in the Curnamona Province are believed to be controlled by such deep fracturing. The seismic results are contributing important information about basement architecture and will enhance exploration investment and targeting strategies. The survey involved the collection of a single E-W orientated seismic traverse that extends from a 1996 BMR Broken Hill seismic traverse westwards towards Hawker. Unfortunately only one third of the planned seismic was collected before heavy rains forced the postponement of the survey. The results from this survey will be presented once the entire survey has been collected and interpreted.

Four of the Yilgarn Craton's major gold explorers, in conjunction with Curtin University and MERIWA (the Minerals and Energy Research Institute of Western Australia) collaborated to gather mine-scale seismic reflection data around various operating mines to investigate the possibilities of the seismic technique as a useful tool for mine exploration (MERIWA project M363). The seismic results will provide a rapid image of the subsurface in these geological complex regions. 120 km of medium resolution seismic data from 26 traverses, ranging from 800 m in length to 14 km in length were collected at 8 mine locations. The data from these are being processed by Curtin University, with results confidential to the participants for the term of the MERIWA project.

Future work on the books includes some 120 km of seismic reflection acquisition to be undertaken in collaboration with NSWDMR in the Darling Basin, NSW. This will enable the continuation of the evaluation of the geology and sedimentary sequences of this basin to assess the ages, thickness and continuity of the formations, structural style and tectonic history. This information will be used to model the evolution of the basin and the maturity of the sediments within the various sub-basins.

Following this survey, the ANSIR crew will be going back to the Curnamona region to complete the rain affected Curnamona Seismic Survey.

Work is progressing on plans for a major deep seismic reflection survey in the Tanami project, involving Geoscience Australia, the Northern Territory Geological Survey and the Geological Survey of Western Australia as well as the local Tanami region exploration industry.

Contact Bruce Goleby for more information.

SA

SA Govt to spend $15m on Exploration

In April 2004 The Rann Government announced that it intended to spend $15 million over five years to help treble investment in mining exploration by 2007 and boost annual minerals production to $3 billion by 2020.

The comprehensive package of measures to stimulate greater mining exploration in SA provides the incentive to accelerate the rate of exploration. According to the Premier: "These measure are aimed at helping our State Strategic Plan's target of increasing investment and mining and exploration in SA, including a target to process a further $1 billion per year of minerals by 2020 above the current rate of $1.99 billion.

Mr Rann says that to increase the momentum of exploration and increase the level of interest in SA's potential, the Government's package includes:

Drilling Partnerships
$5 million over 3 years to fund drilling partnerships with private industry on a dollar for dollar basis. These partnerships are designed to increase geological knowledge of high-risk, frontier areas where little is known of the geological makeup especially at depth.

Mining Ambassador
$200 000 over two years to fund a mining ambassador who will visit senior mining executive interstate and overseas who are responsible for exploration decision making and outlining the case for exploring in South Australia.

Targeted Exploration Initiative SA (TEISA) acceleration
$2.75 m over 3 years to accelerate the rate of collection of pre-competitive data.

AP Lands Development Package

$900,000 over 5 years to provide a second tenement officer, provide legal assistance to the AP to reach agreements with companies, assist with the mapping of cultural and heritage areas within the lands, assist in developing a sustainable resource development policy as well as developing and running a cultural awareness training program for employees of mining and exploration companies.

Chair of Deep Cover Research

$300,000 per year for four years to establish a centre of excellence for deep cover research and to create a new professorial position to lead research in the centre.

Exploration geochemistry baseline for South Australia

$1.2m to conduct a baseline geo-chemical survey of the entire state in partnership with Geoscience Australia.

Next Generation Data Delivery

$1.2 m to develop and provide the next generation data products including a 3D geological map of South Australia.

Balancing Resource Development with Conservation

$900,000 over 4 years to develop and pilot an improved, scientifically based methodology that facilitates the economic and bio diversity values of the land within the state's parks and reserve system. It will also be used to foster research into the environmental impacts of exploration.

Fig. 3. ANSIR 27 tonne Vibratorsa working during the Gawler Craton deep seismic reflection survey.

NTGS

STRIKE to encourage exploration in the NT

STRIKE – Spatial Territory Resource Information Kit for Exploration – was launched by Kon Vatskalis the NT Minister for Mines and Energy on 13 May 2004.

STRIKE is a fully interactive web application, allowing minerals and petroleum exploration companies to add or remove layers of information, zoom in and out of the map display, and search for specific information, to determine the prospectivity of any area in the Northern Territory. STRIKE enables users to:

- query data such as the amount of gold found in geochemical samples,
- create customised maps,
- select a point on the map and show the associated data from all visible map layers,
- manipulate transparency of images,
- retrieve data for a specified layer within a selected area of the map,
- display all point data within a selected area, such as all geochemical samples within the boundary of an exploration licence,
- select historical exploration, licences and retrieve relevant records summarising previous exploration activity, and
- download data files.

In 2003/04, about $50 million was invested by the private sector in mineral exploration in the Territory, and it is hoped that this investment grow in the current commodity cycle upswing. "Exploration is crucial to new mining investment in the Northern Territory, and essential for sustained growth in the mining sector," said Mr Vatskalis.

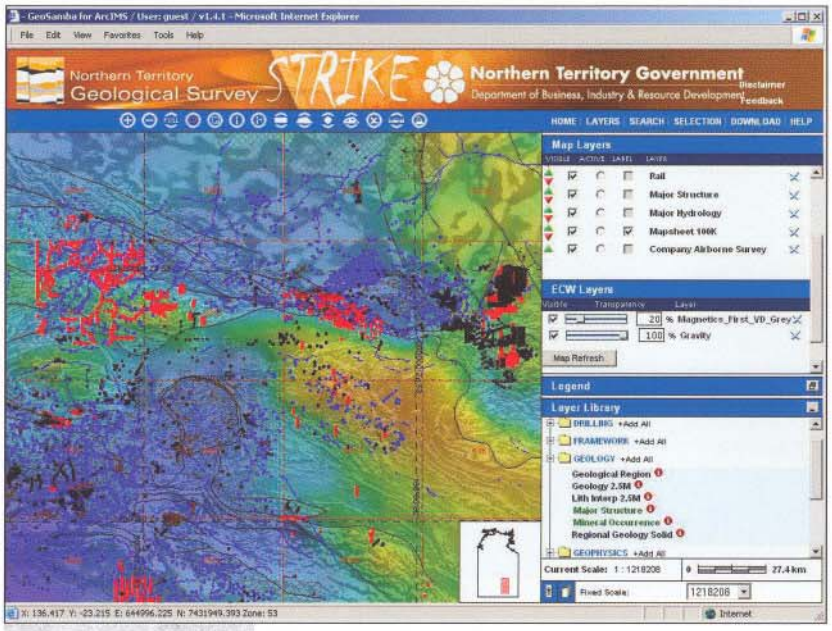

Fig. 1. STRIKE example.

"STRIKE has been funded under the Government's four-year exploration incentive program "Building the Territory's Resource Base", which aims to promote the prospectivity of the Northern Territory by delivering quality new generation geoscientific data to exploration companies."

It can be accessed at: www.minerals.nt.gov.au/strike.

Qld

Queensland to encourage geothermal exploration

Hot on the heels of South Australia, legislation paving the way for hot rock geothermal exploration has now been introduced into the Queensland Parliament by Mines Minister Stephen Robertson.

Robertson said the legislation would allow Queensland to begin developing an exciting source of renewable energy produced by hot dry rocks in the Earth's crust.

"We already have the country's only operational geothermal power plant, at Birdsville (where bore water is the heat source) and Queensland is believed to have more geothermal material than any other state or territory," Robertson said.

"These rocks, which are more than 200 degrees Centigrade and less than 5000 m deep in the Earth's crust, have staggering potential as a power source. If the technology stacks up, Queensland could produce enormous quantities of virtually emission-free energy from steam created when water passes through the hot rocks.

"One cubic kilometre of rock at a temperature of 250 degrees centigrade contains about as much energy as 40 million barrels of oil. By establishing a legal regime for geothermal exploration, we are putting the Smart State in the box seat for an exciting new industry."

Traditionally, geothermal power comes from volcanically active areas like geyser fields, but in the past 30 years more than $US500 million has been invested in research in artificial geothermal systems created by fracturing hot dry rocks and then pumping water into them. Promising trials of commercial generation from hot dry rocks are occurring in France, Germany and South Australia.

The geothermal exploration regime will be part of Queensland's Cleaner Energy Policy to reduce greenhouse gases by diversifying Queensland's energy mix towards the greater use of gas and renewable sources.

WA

2004-05 airborne survey program in WA

Western Australia's vast size presents a formidable challenge to providing detailed geophysical coverage over the large areas known to be highly prospective for a variety of minerals. To date, only about 25% of the State has been covered by aeromagnetic surveys of sufficient detail to be of real use to explorers.

The previously announced package (see April 2004 Preview, p 36) of additional funding for GSWA to provide much-needed regional aeromagnetic and radiometric coverage for some of the State's most prospective areas has been confirmed in the WA State Government budget for 2004-05.

The funding is in response to recommendations of the WA State Government's Bowler Inquiry into greenfields exploration, the Federal Government's Prosser Inquiry into impediments to increasing investment in mineral exploration, and the industry-led Mineral Exploration Action Agenda process. These reviews recommended greatly increased funding for pre-competitive geoscience data acquisition, in particular detailed aeromagnetic surveys, which are essential for mapping the rocks and structures hidden beneath the largely soil- and sand-covered prospective areas of Western Australia.

Unfortunately, the recent Federal Budget appears not to have made provision for matching funding in 2004/05 as had been recommended by the Strategic Leaders Group for the Commonwealth's Mineral Exploration Action Agenda. Nevertheless, the new State funding should enable coverage of an additional 25% of the Western Australia, concentrating on areas of highest potential for new greenfields discoveries.

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GFMS forecasts bright future for gold

In April, GFMS launched *Gold Survey 2004*. This is the 36th edition of their authoritative annual survey of the world gold market. GFMS is one of the world's foremost precious metals consultancies, specialising in research into the global gold, silver, platinum and palladium markets. It is based in London, and has representation in Australia, India and Russia. The following information has been obtained from their website: http://www.gfms.co.uk/.

At the launch of the 2004 survey, Philip Klapwijk, chairman of GFMS forecast that future gold prices have a strong bias to the upside, seeing US$450/oz as a good possibility should the conditions remain right for attracting further investor interest.

He commented "the US fiscal and current account deficits, on top of eye-watering levels of consumer debt, create huge risks of another hefty slide in the dollar, plus eventual recession and a slump in equity markets. Throw in instability in Iraq and you've got pretty good conditions for a further surge in investment. And don't forget that the financial inflows into gold last year – which we estimate at a little over $10 billion, on a net basis – were still tiny compared to the potential sums available."

The main highlights of the review are shown below.

Supply Highlights

International global gold mine production is holding steady as new mines partly offset ongoing declines in the mature mining districts of South Africa and North America. The table below summarises the results for 2003 compared to 2002, according to GFMS.

World Gold Production 2002 and 2003 in tonnes		
Year	*2002*	*2003*
Mine production	2590	2593
Official sector sales	545	606
Old gold scrap	837	943
Total supply	**3972**	**4142**

According to the report, mine closures, lower grades and operational difficulties adversely impacted production in North America and in South Africa, which reported a combined output decline of roughly 40 t from the previous year.

Offsetting the losses in these mature mining districts, a handful of new mines, coupled with a modest boost in production from the informal mining sector left global output a fraction higher at 2593 t.

Roughly two-thirds of the decline in North America was attributable to losses in the United States where output was cut back by nearly 14 t to reach 285 t, its lowest level since 1989.

According to GFMS, the considerable drop in South Africa was largely a result of operational difficulties, lower grades and the effects of a strengthening rand, which resulted in the suspension of mining activities at marginal production areas in the second half of the year.

In Australia, a handful of new mines that started operations in the final quarter of 2002, adding roughly 16 t of gold to the total of 290 t for 2003.

Elsewhere, start-ups in Saudi Arabia and Laos added a combined 10 t to the global total. Important growth was also measured in China (+6%), Peru (+9%) and Tanzania (+16%).

In Peru, higher grades at the country's giant Yanacocha mine largely explained the gains, whilst in Tanzania, a full years contribution from the new North Mara mine combined with higher grades at Geita partly accounted for the increase.

Higher cash costs were reported across all of the major producing regions in 2003, which left the global total up 23% year-on-year at $222/oz. The $42/oz rise in US dollar terms was primarily due to currency effects, although higher global energy charges and higher royalties and production taxes (which are linked to the price of gold) also contributed to last year's significant cost inflation.

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In 2004-05, new magnetic and radiometric survey contracts will be let in the southern Yilgarn and eastern wheat belt The resulting data products, covering six 1:250,000 sheet areas from Southern Cross to Ravensthorpe, will be released in late 2004 or early 2005. Before then, the Murchison Region Program, presently underway, will see the release of new data from GA-commissioned surveys from Ninghan to Cue complement the recently released GSWA-GA data over the Robinson Range - Belele area.

In addition to aeromagnetic data, the increased funding will allow some collection of other data of interest to mineral explorers, such as ortho-photography and hyperspectral sensing, geochemical and gravity surveys, and, in conjunction with Geoscience Australia and the Australian National Seismic Imaging Resource, some deep crustal seismic traverses in key areas of the State. Industry will have an input into how this new funding will be spent through the GSWA Liaison Committee, which meets in June and November each year.

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Demand Highlights:

The gold demand for 2003 is summaries below in the table.

World Gold Demand 2002 and 2003 in tonnes		
Year	*2002*	*2003*
Jewellery	2680	2533
Other fabrication	482	516
Bar hoarding	250	183
Net producer hedging	437	310
Implied investment	123	600
Total supply	**3972**	**4142**

The 6% drop in jewellery demand is of concern, with the bulk of this fall being in Europe, where demand was close to 110 t less than in 2002. In contrast, electronics demand was up 14%.

De-hedging fell 29% to 310 t though this was the second highest level ever. The decline was largely a result of a positive price outlook, shareholder pressure and buy backs of positions inherited through merger activity. Fresh project hedging, for example for Newcrest's Telfer, partly offset the drop.

Implied net investment rose by 478 t, chiefly through strong buying from hedge funds of over-the-counter paper products and on Comex. Purchasing by other institutions, high net worth individuals and retail investors was, in contrast, patchy.

Bar hoarding fell 27%, mainly due to a drop for East Asia. This left world investment (the sum of the implied, bar hoarding and coins) at 888 t, up sharply on 2002's 468 t.

Oil reserves plateau as price rises

Meanwhile the oil price has jumped to about US$40/barrel, well above the $20-30/bl (in 2002 dollars), which we have seen from 1986 through mid-2003.

This is due to three main factors. The first is the uncertainty of supply in the Middle East due to the unstable political situation, the second is due to the growth in the Chinese, Japanese and Indian economies, causing a major increase in demand, and the third is that the proven reserves are not increasing at the same rate as the global demand.

For example since 1990 the daily production of oil has risen by 21 percent from 65.4 million b/d to 79.2 mbl/d in 2003. However, the reserves from 1990 to 2002 only increased by only 4% to 1048 billion barrels.

In 2003 they suddenly increased to 1213 billion barrels by including Alberta's oil sands (an additional 175 billion bbl of bitumen is contained in the oil sands). So in reality this amount of new oil has not been suddenly discovered. By comparison Australia's reserves in 2003 were estimated at a meager 3.5 billion bl, unchanged from 2002.

This situation has placed pressures on some of the major producers, notably **Royal Dutch/Shell**, which earlier this year lowered its estimate of worldwide reserves, by 20 percent, or 3.9 billion barrels. A typical example is the Yibal Field in Oman, where Shell's production rates have been declining since 1997, despite the application of advanced production techniques.

It appears that the horizontal drilling methods used on the Yibal Field have not worked as hoped for. As a result additional water is mixed in with the oil (as much as 90 percent of the total volume), the production costs have increased significantly, and recovery has not been as good as expected.

Shell's experience may not bode well for other majors operating in the Middle East with similar mature reservoirs.

Meanwhile, in Australia, **Beach Petroleum Ltd** has reported its highest ever-quarterly production, revenue and profits. The results are underpinned by Beach's expanding exploration and production successes in both the South Australian and southwest Queensland provinces of the Cooper/Eromanga Basin.

Beach Petroleum managing director Reg Nelson said: "New discoveries in the past nine months or so have been important. During this period, Beach has discovered and started producing more than 1.5 million barrels of new oil from our fields in South Australia and Queensland."

In the three months to 31 March 2004, it produced a record for any quarter of 265,000 barrels of oil equivalent, a figure 4% higher than the previous December 2003 quarter and an increase of 12% over the previous corresponding period.

Maybe very small in the global context, but it shows that there is still significant oil to be found in Australia's poorly explored onshore basins.