Preview

Australian Society of Exploration Geophysicists

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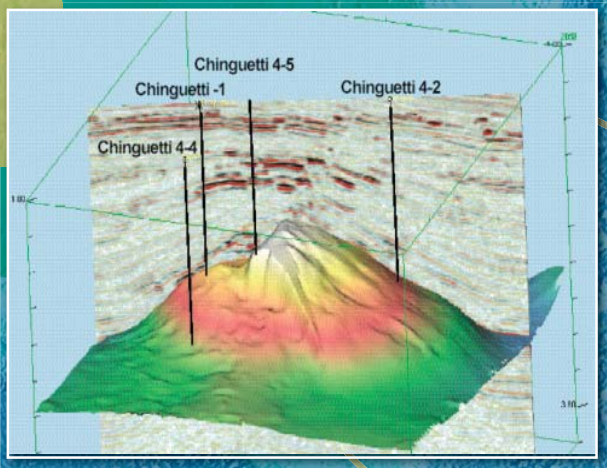
Risk Assessment in prospect evaluation from a geophysical perspective

Page 30

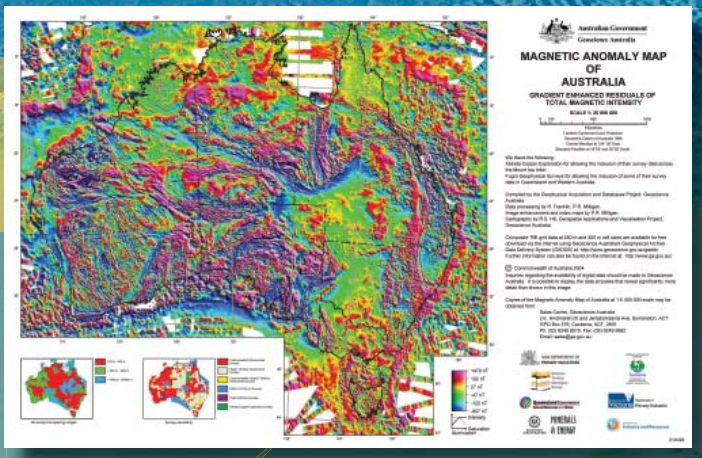


2003 Gawler Craton Deep-Seismic Survey Results

Page 35

A new generation Magnetic Anomaly Grid Database of Australia (MAGDA)

Page 25



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Background of front cover is an image from the global topography and bathymetry available via the Internet from the University of Alaska: http://www.gina.alaska.edu/page.xml?group=data&page=griddata. More details in the February 2005 *Preview*.

Howard Government returned to office

After an election campaign that seemed to have being going on for almost as long as one could remember, the result was somewhat of an anti-climax because nothing has really changed. We have the same minister for Industry, Tourism and Resources, Ian Macfarlane, and the government has made no new commitments to boost resource exploration in Australia.

One might have expected that, as the resource industries are a huge wealth generator, and Australia's place in the international exploration table is slipping (see Industry News in this issue), that maintaining a dynamic exploration environment would have been high on the political agenda; but this was not to be.

The whole campaign, from all the major parties, seemed to be focussed on spending money to get elected, rather than generating wealth to maintain a sustainable and prosperous Australia. Unfortunately this is now the way politics works these days.

Seismic Asia Pacific Pty Ltd new Corporate Member

Industry sponsorship is very important to the ASEG because of our links to many facets of the Resource and Exploration industries. It is therefore very pleasing to welcome a new Corporate Member of the ASEG: Seismic Asia Pacific Pty Ltd.

Seismic Asia Pacific Pty Ltd, supplies Geophysical and Hydrographic and Navigation data acquisition systems to the Australasian and Pacific Rim countries. Product fields include, acoustic positioning, geophones, hydrophones, GPS, DGPS, heave compensators, attitude sensors, hydrographic, oceanographic, magnetometers, tide and current meters, ROVs, side-scan sonar, sub bottom profilers, echo sounders and transducers.

The company is based in Salisbury, Qld., and the contact is Paul Duncan, who can be reached by phone on 07 3719 3400 or Email at: sales@seismic.com.au.

Tom Spurling now President-elect of FASTS

At the Federation of Australian Scientific and Technologically Societies' (FASTS) AGM, held in November, Professor Tom Spurling was elected President-elect of FASTS. Tom will serve as President-elect for one year and become President in 2006-7.

He is currently Dean of Engineering and Industrial Sciences Faculty, Swinburne University of Technology.

Previous positions include: Professor of Molecular Science and Director, Industrial Research Institute, Swinburne University of Technology, and Chief of the Molecular Science and Chemicals and Polymers Divisions at CSIRO.

Tom is an Elected Fellow - Royal Australian Chemical Institute, Elected Foundation Fellow - Federation of Asian Chemical Societies, Elected Fellow - Australian Academy of Technological Sciences and Engineering and Elected Fellow - Australian Institute of Management.

In addition to his strong academic and publications record, he has extensive experience with commercialisation and technology transfer issues including being a director of two technology-based firms.

The positions of Secretary and Treasurer were also voted on with John O'Connor and Mike Smith being returned unopposed.

FASTS is the Peak Body for Professional S & T societies in Australia and the ASEG is a member through the Australian Geoscience Council.

Reg Nelson elected Chairman of APPEA

Congratulations to Reg Nelson, who has been elected as Chairman of The Australian Petroleum Production and Exploration Association (APPEA) for 2004-2005. Reg is Managing Director of Australian oil and gas explorer Beach Petroleum Ltd. He has been associated with the ASEG for over 20 years and was President during 1984 and 1985.

CSIRO Division of Exploration and Mining re-organising

Neil Phillips stepped down as Chief of the CSIRO Division of Exploration and Mining on 31 October 2004 and Cliff Mallett was appointed Acting Chief from 1 November.

Broad-ranging discussions on the future direction and operations of the Division are underway and the Australian Geoscience Council has been asked for input into this process.

Season's Greetings

This is the last issue of *Preview* for 2004, and I would like to take this opportunity to thank our contributors, readers, advertisers, sponsors and publisher for their support during the year. I hope you all have a relaxing Christmas and that the New Year brings prosperity and exciting challenges for us all, and some good reading.

David Denham

The 'A' Stands for Australian

The 'A' in ASEG stands for Australian. While it is critical for us to understand the international nature of geophysics, it is also important to remember that the ASEG has a special connection to the unique issues facing the geophysics profession in Australia. As geophysical work by its very nature is associated with the land and its resources, any Australian geophysics organisation must certainly give some thought to the people who have traditionally been custodians of that land for thousands of years. To that end, ASEG is currently finalising plans to participate in a pioneering program to encourage indigenous Australians to pursue the study of geophysics and to assist them in that pursuit.

Each year since 1997 approximately 20 indigenous senior secondary students from across Australia have been selected to attend the Indigenous Australian Engineering Summer School (IAESS). The Summer School is the principal program of Engineering Aid on behalf of indigenous young Australians and is designed for young indigenous people who are entering Years 10 to 12. It is held in January each year in cooperation with various universities, principally the University of New South Wales, and aims to encourage them to consider tertiary studies in engineering.

The program was initiated by a remarkable man, Jeff Dobell, an engineer who noted that there were virtually no indigenous engineers to participate in engineering projects in local indigenous communities. That same realisation, with respect to the dearth of indigenous geoscientists to work on projects in Australia, inspired ASEG to contact Jeff to arrange for the IAESS to include a geophysics stream. At this writing, final discussions are being conducted with the NSW Branch of the ASEG and with Engineering Aid to make the first Engineering Aid Summer Program happen with a geophysical flavour.

It is worth a couple of words to explain how this worthy program works. Students selected for the IAESS program experience campus life, learn about various applications of engineering (and geophysics) through workshops and lectures and hear from mentors and role models about the way professional skills are applied in everyday settings that can benefit indigenous communities.

During the Summer School, students gain first hand experience of engineering, working in laboratories, using computers, visiting engineering projects and meeting role models. This year, geophysics will be included in the syllabus and project visits.

I am waiting with breathless anticipation to see the outcome of the program as these outstanding indigenous students, selected on merit from around Australia, come in contact with geophysics professionals to enrich the lives of the geophysicists involved, and to give the students a chance to see how developing geoscientific skills and obtaining professional qualifications may benefit their own communities in the future.

Students from throughout Australia attend at no cost to themselves. All expenses, including student travel and accommodation, are paid out of contributions made by sponsors and donors, including such notable contributors as The Rio Tinto Aboriginal Foundation, Coal and Allied Industries, Tenix Pty Limited, and ATSIC. The services of academic staff participating in the Engineering Aid Program are provided on a voluntary basis.

The IAESS has been noticed by many outside the worlds of academia and engineering. Former PM Bob Hawke and Senator Aden Ridgeway, to name a few, have lauded the work of Jeff Dobell and Engineering Aid. In a speech to the Australian Senate in 2002, Senator Ridgeway pointed out that only ten percent of indigenous Australians completed secondary school and the vast majority missed out on opportunities and choices in technical and professional fields. He said that in 1997 Australia's oldest Engineering Faculty at the University of Sydney acknowledged that, to the best of its knowledge, there had been only one indigenous engineer among the 11,700 people who had graduated in the Faculty's 85-year history.

These same issues apply to the intake of indigenous students into the geosciences. While all indigenous students are welcome in the program and benefit from it, it seems to me that there should in particular be a vast and untapped opportunity for geoscientists from rural communities to contribute to, and help to define and guide development in and around their communities.

I would like to think of this association with IAESS as only the first step toward engaging indigenous students in the study of geophysics. Perhaps ASEG can work with Jeff Dobell to begin a second dedicated Geophysics Summer School, or undertake other programs for indigenous students elsewhere in Australia. The first step is to ensure that this first IAESS with a geophysics component is a success. After that, the sky's the limit. I would encourage any ASEG member to volunteer to participate in the IAESS program, or to come forward with other ideas for expanding the effort to spread the geophysical work that we love into the indigenous community. The contact details are: Jeff Dobell; Tel: 02 9449-4353; Email: jdobell@bigpond.net.au.

Howard Golden

Preview is published by RESolutions Resource & Energy Services Pty Ltd (brian@resolutions-group.com.au) for the Australian Society of Exploration Geophysicists. It contains news of topical advances in geophysical techniques, news and comments on the exploration industry, easy-to-read reviews and case histories, opinions of members, book reviews, and matters of general interest. Potential contributions should be sent to the Editor: David Denham (denham@webone.com.au).

Deadlines

Preview is published bi-monthly, February, April, June, August, October and December. The deadline for submission of all material to the Editor is the 15th of the month prior to the issue date. Therefore the deadline for the **February 2005 issue is 15 January 2005**.

Advertisers

Please contact the publisher, RESolutions Resource and Energy Services, (see details elsewhere in this issue) for advertising rates and information. The ASEG reserves the right to reject advertising, which is not in keeping with its publication standards.
Advertising copy deadline is the 22nd of the month prior to issue date. Therefore the advertising copy deadline for the **February 2005 issue will be 22 January 2005.** A summary of the deadlines is shown below:

Preview Issue	Text & articles	Adverts Copy In
114 Feb 2005	***15 Jan 2005***	***22 Jan 2005***
115 Apr 2005	15 Mar 2005	22 Mar 2005
116 Jun 2005	15 May 2005	22 May 2005
117 Aug 2005	15 July 2005	22 July 2005

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

4-7 April
SAGEEP
Venue: Atlanta Airport Hilton Hotel, Atlanta, USA

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

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

6-7 June
11TH ANNUAL SOUTH EAST ASIA AUSTRALIAN OFFSHORE CONFERENCE
Venue: Darwin, NT
Email: rreilly@iir.com.au
Website: www.seaaoc.com

13-16 June
67TH EAGE CONFERENCE & EXHIBITION
Venue: Madrid, Spain
Website: http://www.eage.nl/conferences/

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, U.S
Website: www.seg.org

5-9 December
2005 AGU FALL MEETING
Venue: San Francisco, California, U.S.A.
Website: www.agu.org/meetings

2006

2-7 July
THE AUSTRALIAN EARTH SCIENCES CONVENTION 2006
ASEG, IN COLLABORATION WITH GSA; ASEG'S 18TH INTERNATIONAL CONFERENCE AND EXHIBITION, AND GSA'S 18TH AUSTRALIAN GEOLOGICAL CONVENTION
Venue: Melbourne, Vic.
Website: www.earth2006.org.au

2007

18-22 November
ASEG'S 19TH INTERNATIONAL CONFERENCE AND EXHIBITION
Venue: Perth, WA
Contact: Brian Evans
Email: Brian.Evans@geophy.curtin.edu.au

Melbourne 2006: the Australian Earth Sciences Convention

The Australian Earth Sciences Convention 2006 provides an opportunity for professional and academic geoscientists to promote and advance their science through interaction with their peers, learned members of their society, and scientists from other disciplines. The event is a merger of the Australian Society of Exploration Geophysicists' (ASEG) 18th International Conference and Exhibition and the Geological Society of Australia's (GSA) 18th Australian Geological Convention.

At the Australian Earth Sciences Convention 2006, industry, service providers, government and academia will have the chance to present their work, and market to a wide range of companies, organisations and individuals in the geosciences. A Speakers Program of at least six, and up to eight concurrent sessions is being developed. An exhibition of approximately 100 trade booths is planned, and more than 1000 delegates are expected. Delegates will also be encouraged to attend a variety of workshops and excursions.

In addition to the more serious side of the Convention, social events will provide occasions for catching up with old friends, making new friends and some informal networking.

The members of the Convention Organising Committee invite you to join us in Melbourne from 2nd to 7th July 2006 for the Australian Earth Sciences Convention 2006. If you would like to get in touch with us, please visit www.earth2006.org.au or contact the Conference Office, The Meeting Planners, 91-97 Islington St, Collingwood, Vic., 3066; Ph: +61 3 9417 0888; Fax: +61 3 9417 0899; Email: earth2006@meetingplanners.com.au

The 2006 Conference Organising Committee

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Conference Organiser	Colleen Wenn	cwenn@meetingplanners.com.au	03 9417 0888 / 0412 464 612

ASEG Awards at Sydney 2004

(Part Two)

Bill Peters (right) receives his ASEG Service Medal from President Howard Golden

Jim Dirstein (right) receives his ASEG Service Certificate from President Howard Golden

ASEG Service Medal for *extraordinary and outstanding service to the ASEG over many years*

Bill Peters

Bill completed a BSc (Hons) in Geology and Geophysics at UWA in 1972 and immediately gained field experience with McPhar Geophysics in Perth. Then from 1974-80, he worked for Anglo American Corporation based in South Africa, before returning to Perth to work as Senior Geophysicist for BHP in diamond exploration from 1980–82.

He subsequently moved to Sydney during the period 1982–83, as Consultant Geophysicist for Crosmin Pty. Ltd. consulting to Dighem Ltd. and Teck Explorations. In 1983, Bill once again returned to Perth to become a founding partner in Southern Geoscience Consultants, working as a consultant to companies and governments in Australia and overseas, a role that he has held to the present day.

Bill joined the ASEG in 1973, and has been heavily involved with the society at both State and Federal levels since 1985. During the 1980s and early 1990s Bill served on the WA State Branch Executive in a number of roles, including Treasurer. This led to Bill being installed as the Treasurer for the very successful 1987 ASEG Conference held in Perth.

When the Federal Executive moved to Perth in 1988, Bill was invited to serve as ASEG Federal Treasurer, no doubt following on from his success as Conference Treasurer. Much to the relief of three ASEG Presidents, Bill remained Federal Treasurer for three years. After a short break from these duties, Bill was lured back to again fill the role of Treasurer for the 1994 Perth ASEG conference.

In 1990, the then ASEG President, Greg Street recommended that an Honours and Award committee be set up to formally vet and recommend nominations for ASEG awards. Bill was invited to be on this committee, along with Lindsay Ingall as Chairman, and Barry Long. In 1998, Bill took over from Lindsay as Chairman, and remains in this role to the present day.

He is also actively involved with other industry professional societies and activities in WA. Bill is an active member of SEG and SAGA, and a fellow of the AusIMM. He is a member of the industry advisory board for CRC LEME, the Geoconferences committee, the SEG2004 Conference committee and has also been a committee member of AIG in Perth.

There is little doubt of Bill's consistent participation in the activities of the ASEG for over 20 years. The roles he has fulfilled on Conference Organising Committees and as State and Federal Treasurer are some of the more demanding roles within the Society. The ASEG Service Medal is a fitting award for Bill's many years of service to the ASEG.

ASEG Service Certificates for *outstanding service to the ASEG*

Jim Dirstein

Jim served on the Federal Executive in 2002-2003 and served as WA State President from 1998 to 2000.

The significance of Jim's contribution to the ASEG is that, while President, he completely re-invigorated the WA Branch activities, from technical evenings through to the finances. This leadership continued throughout his three year Presidency.

He was particularly active in getting the state's finances in order and instituted company sponsorship for technical meetings. He established a healthy technical program, which included the principle of double-billing talks, to include a minerals and petroleum presentation at each meeting. This and other initiatives drew much needed petroleum support into the society and encouraged interaction between minerals and petroleum members.

Jim also played a major role in convincing the SEG to bring the Distinguished Instructors Short Course (DISC) program to Australia. His role with DISC continued as his efforts in the planning and running of the very successful inaugural Short Course, which helped to ensure that the program would continue in Australia in future years.

For services to the ASEG from 1988 to the present Jim is a worthy recipient of the ASEG Service Certificate.

John McDonald

John is currently the Director of the Centre of Excellence for Exploration and Production Geophysics and also Director of the Curtin Reservoir Geophysics Consortium.

John took on the Presidency of the WA ASEG branch in 1997 soon after he arrived in Australia as a member of the Curtin Geophysics department. He remained Vice President of the WA Branch Committee until 2001 when he worked on the Federal Executive for the years 2001-2003.

He was a convenor of the Perth 2000 ASEG conference where he identified the key members of the 2000 conference committee and then acted as treasurer for that conference.

John has championed closer ties with the societies within our region. His main contribution has been in the area of developing inter-society relations, primarily with the SEG and he has been particularly influential in the

John McDonald (right) receives his ASEG Service Certificate from President Howard Golden

Rod Lovibond (right), receives his ASEG Service Certificate from President Howard Golden

Michael Asten (right), receives his Graham Sands Award from President Howard Golden

ASEG relationship with the SEGJ, acting as co-chairman of their international geophysics conferences.John has been very active in trying to link the students of Curtin University to the professional societies, through access to awards and the establishment of a WA Chapter for the students. From 1998 - 2000 he was Staff Advisor to the Curtin Student Chapter of the SEG.

For services to the ASEG from 1997 to the present John is a worthy recipient of the ASEG Service Certificate.

Simon Stewart, representing Fugro Instruments, receives the award for the best Exhibit at the Conference from Roger Henderson of the Organising Committee

Emma Nelson (left), receives her 'Best Overall Presentation Award' from Peter Gunn, Co-chair of the Technical Program Committee

Rod Lovibond

Rod Lovibond, originally from Origin Energy and now privately consulting, has been an enthusiastic and committed member of the South Australian ASEG branch for many years.

Rod was SA president from 1994-1995 and has been on the SA Committee continuously since at least 1993 and probably longer. He has organised and presented many technical meetings over the years and many popular social events. He has played a continuous mentoring role for students and junior geophysicists.

Rod's contribution has been essential to the year-by-year events that make up the bulk of ASEG's activities in South Australia. Mike Hatch, a former president notes that "During my time as President (and all of my time writing the SA notes for Preview) he has been the person that I could run anything past, and I could check on for historical precedent, etc."

The SA Committee feels that Rod's quiet but substantial contribution to the running of the SA ASEG warrants this well deserved award.

Petro du Pisani shows her award for the 'Best Environmental/Groundwater Paper' at the closing ceremony with Peter Gunn, Co-chairman of the Technical Committee

David Pratt (right) receives his award for the "Best Minerals Paper" from Peter Gunn, Co-chair of the technical Committee

Conference Awards

Laric Hawkins Award for the most innovative use of geophysical techniques from a paper presented at the ASEG 2004 Convention

Passive seismic methods using the microtremor wave field

by Michael Asten

Best booth in the ASEG 2004 Exhibition

Fugro Instruments

Best technical presentations:

Overall Presentation: The in-situ stress field of the West Tuna area, Gippsland Basin: implications for natural fracture-enhanced permeability and wellbore stability,

by Emma Nelson, Richard Hillis, Scott Mildren and Jeremy Meyer (presented by Emma Nelson).

Petroleum Geophysics: An efficient explicit 3D prestack depth migration, by Jiaxiang Ren, Clive Gerrard, James McClean, Mikhail Orlovitch and Andrew Long (presented by Andrew Long).

Environmental/Groundwater Research: The use of borehole radar for the delineation of thin tabular orebodies ahead of mining, by Petro du Pisani and Declan Vogt (presented by Petro du Pisani).

Minerals Geophysics: An improved pseudo-gravity magnetic transform technique for investigation of deep magnetic source rocks, by David Pratt and Zhiqun Shi (presented by David Pratt).

KSEG Toshiyuki Yokota (left) with his Award for the Best Poster and Peter Gunn, Co-chairman of the Technical Committee

Marion Walls displays her 'Best Student Poster' Award at the closing ceremony in the company of Peter Gunn Co-chairman of the Technical Committee

Poster: Basic experiments of seismic while drilling using a percussion drill as an energy source, by Toshiyuki Yokota, Kyosuke Onishi, Hirokazu Karasawa, Tetsuji Ohno, Akinori Ota, and Tsutomu Kaneko, Tokyo, Japan.

Student Poster: The geophysical exploration of the Ohura fault, North Wanganui Basin, NZ, by Marion Walls, University of Wellington, NZ.

Geophysics meets Engineering

Most exploration geophysicists assume that the Earth is heterogeneous creating "anomalies" that are the object of their search. Geotechnical engineers, however, assume the Earth is uniform or uniformly layered unless compelled to change. Therefore they see geophysics as a "test" of this model, one of many that they apply at a site, and as a potential provider of geophysical parameters related to engineering parameters, eg, S-wave velocity to dynamic soil modulus.

About 600 geotechnical engineers and geophysicists recently came together at ISC'2, the 2nd International Conference on Site Characterisation that was held at the University of Porto, Portugal from 19 to 22 September 2004. The proceedings are published in Geotechnical and Geophysical Site Characterization and available at www.millpress.com.

Porto is a world heritage city from which a favoured beverage of Australian geophysicists derives it name.

ISC'2 followed the highly successful ISC'1 held in Atlanta in 1998. Both conferences were sponsored by the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE) that is affiliated with the Australian Geomechanics Society of the Institution of Engineers and was organised by the Faculty of Engineering at Port University and the technical committees, TC 16 (In situ Testing) and TC10 (Geophysical Site Characterization).

The international core group members of TC10, Chaired by Professor Rainer Massarch is shown in the photo.

A total 219 technical papers were presented at ISC'2, many involving geophysical technologies, principally seismic (surface waves, downhole and refraction) but increasingly other methods such as resistivity and electromagnetics. A total of 27 specialist geophysical engineering and environmental papers, in two Sessions and two keynote addresses focussed on geophysics, were delivered. Much effort in the geotechnical community is being devoted to the development of geophysical tools e.g. the seismic cone penetrometer (SCPT) that enhance existing in-situ geotechnical tests and TC 10 is currently developing standard guidelines for the use of this tool and can be contacted at www.geoforum.com/TC10.

There is little doubt that geophysical methods are being increasing applied to geotechnical and environmental site characterisation. The proceedings of ISC'2 provide the opportunity for exploration geophysicists to evaluate the opportunities of this rapidly developing market.

TC 10 (Geophysical Site Characterisation) Core Group Members. Nils Ryden (Sweden), Tony Butcher (UK), Rainer Massarch (Chairman, Sweden), Amir Kaynia (Norway), Dick Campenella (Canada) and Bob Whiteley (Australia).

ASEG supports students to attend SEG's 74th Annual Meeting

From the 10th to the 15th of October, SEG 2004 was held in Denver, Colorado. For those of you who are interested, the State's name is derived from the Spanish for "color red" and refers to the colour of the mud found in the Colorado River by early explorers. The origin of "Denver" is much less interesting being named after James W. Denver, the then governor of Kansas Territory, of which eastern Colorado was a part.

Anyway back to the SEG. Thanks to support from their respective organisations and from ASEG, three PhD candidates from Australia attended and presented at the conference. These were Aaron Davis from RMIT, Yusen Ley-Cooper from Monash University and Don Hunter from Curtin University. The titles of the papers presented by Aaron, Yusen and Don were, respectively, *Surface loop monitoring of airborne electromagnetic systems; Amplitude corrections of HEM data using a theoretical approach and The effect of magnetic gradients on SNMR measurements.*

The conference was well attended with some 520 odd papers presented in 11 concurrent sessions and numerous workshops. The technical content of the conference was predominantly petroleum focussed and this was reflected in the somewhat sparse attendance at each of the three presentations. Nevertheless, the feedback received was very positive.

A very interesting and quite uncommon paper to this sort of conference was presented in the session named: **Recent advances and the road ahead.** The paper was titled *Emerging challenges for geophysical education* and was presented by Amos Nur from Stanford University. The paper sparked an interesting discussion on how and what sort of geophysics should be taught, generational gaps in the trade and the current boom in the petroleum industry in comparison to the other neglected, but no less important, areas such environmental studies.

Obviously conferences provide students with the opportunity to see technical advances and meet representatives from industry and academia. A much less documented aspect is the opportunity to procure lots of trade samples from exhibitor booths. In this respect the Australian students acquitted themselves well and were frequently seen sporting booty bags of Santa-Clausesque proportions about the exhibition hall.

Aaron, Yusen and Don would like to thank the ASEG for its support in our attending the SEG. We hope the ASEG will continue to give financial aid to students presenting at future conferences.

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New Members

The ASEG welcomes the following new members to the Society. Their membership was approved at the Federal Executive meetings on 29 September and 27 October 2004.

Name	Organisation	State	Name	Organisation	State
Theo Aravanis	Kennecott Exploration	Canada	Gregory Robert Leamon	The University of NSW	NSW
Karl Heinz Bauer	BHP Petroleum	WA	Ian Neil MacLeod	Geosoft	Canada
Emma Brand	The G-tek Group	Qld	Angus Donald McCoy	Geoimage Pty Ltd	NT
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Stephen James Fraser	CSIRO Exploration & Mining	Qld	Jill Slater	Curtin University	WA
Walter Garrido	Anglo American Chile	Chile	Mark Stanley	BHP Billiton	WA
Arnold Getz	City Acceptance Corp Pty Ltd	NSW	John Stanton	ECL Australia	WA
Peter John Goodwin	Sercel Australia Pty Ltd	NSW	Robert Weeden	Strike Oil Limited	WA
Sukhyoun Kim	Adelaide University	SA	Jeanne Ann Young	CSIRO Industrial Physics	NSW
Kenneth Campbell Lawrie	Geoscience Australia	ACT	Kenneth Campbell Lawrie	Geoscience Australia	ACT

Australian Capital Territory – by Jacques Sayers

The start of the year saw a new committee coming in to take the reins of the ACT Branch, comprising Ben Bell, Alice Murray, Eva Papp and yours truly. The club hit the ground running with an inspiring talk from Nick Rawlinson of the Research School of Earth Sciences – ANU entitled *Seismic Body Wave Tomography: Theory, Application and Recent Advances*. Other geophysical work goes on at the RSES: the Earth Physics Division investigates the structure and dynamics of the Earth, applying modern physical and mathematical techniques in the three related areas of Geodynamics, Seismology and Geophysical Fluid Dynamics. The Geodynamics Group focuses on modelling of tectonic processes, precise geodetic monitoring of crustal deformation (in Papua New Guinea and Antarctica), and the interaction between tectonics, ice sheets and sea level change during glacial cycles. The Geophysical Fluid Dynamics Group studies the dynamical processes governing ocean circulation, mantle convection and plate tectonics, magma transport in the crust and volcanic eruptions. The Seismology Group investigates the structure of the Earth at a variety of scales using seismic waves. Recent seismic experiments have been conducted in Tasmania, Antarctica and mainland Australia.

The start-up of the CO2CRC in August 2003 with Geoscience Australia playing a substantial role also attracted Kila Bale and Frank La Pedalina to join the organisation, both geophysicists from Western Australia. The growing business of capturing and storing greenhouse gases has become a world-wide 'in-vogue' trend requiring aspects of current geophysical monitoring technology to be enhanced and applied to subsurface migration of carbon dioxide. The Branch was lucky to host in October experts in the field Don Sherlock and Kevin Dodds from CSIRO Perth, and Milovan Urosevic and Brian Evans from Curtin University Perth. Don Sherlock gave a talk entitled *Time-lapse Analog Modelling of Turbidite Channel Sands*, a talk illustrating seismic responses to water flooding through a petroleum-bearing synthetic sandstone under controlled conditions in a measurable model situation! A rarity!

Other interstate visitors included Antonio Guillen and Patrick Ledru of the BRGM in France, both invites to the Intrepid Geophysics Group in Melbourne. These gentlemen gave an impassioned speech on their innovative 3D-WEG software, which uses a radical approach to invert gravity and magnetic data as well as being versatile in its input of structural and other data. Canberra wines were later tested on these gentlemens' palettes! Brian Minty of Geoscience Australia, well known for his many presentations on gamma-ray spectrometric surveys, was good enough to give a talk at the ANU. Ground radiometric surveying continues to be a substantial part of geophysical research at Geoscience Australia because of its application to minerals exploration. An increased area of interest is high resolution aeromagnetic surveys that are being used to help refine near surface salinity mapping and resolving the state of aquifers in the Murray-Darling Basin.

The ACT Branch was also happy to be able to sponsor Thomas Abraham Jones of the Geology Department of the ANU to attend the August ASEG Conference in Sydney. Thomas was inspired by attending the talks and will be doing his honours next year on a mineral's related subject. Unfortunately the ACT did loose one of its oldest and most distinguished members Jim Dooley who passed away earlier on this year. Jim was awarded Honorary Life Membership of the ASEG in 1983 for his many services to the Society and to the field of geophysics.

The ACT Branch of the ASEG continues to be active with a half dozen meetings a year usually built around the geophysical research being carried out at the ANU and at Geoscience Australia, where many working professionals undertake Doctorate studies as part of their work programs. Please feel free to contact us should you be in town by phoning Ben Bell on 02-6249 9828 or Jacques Sayers on 02-6249 9609.

New South Wales – Naomi Osman

In September Tara Deen from Macquarie University gave an interesting talk on *The shifting paleostress of the North West Shelf* incorporating the application of paleostress in estimating the likelihood of fault and trap reactivation. This research was part of Tara's PhD project, which she completed earlier this year. In October, NSW members braved the much needed rain to hear Chris Carty talk on the exploration experiences of Eastern Star Gas and the development of their own gas-fired power station near Narrabri.

Sydney University now has two Chairs of Geophysics. With the substantial support

of CRC Mining, a new Chair of Mining Geophysics has been created and Peter Hatherly has been appointed to this position. Several of our members have recently changed jobs. Simon Stewart, formerly Manager of FugroInstruments has moved to Coffey Geosciences and Mads Toft has joined Alpha Geoscience.

Finally, Geological Survey of NSW is moving to Maitland, the geophysicists in it, including the Director, Ted Tyne, and Dave Robson have pledged their determination to attend the branch meetings in Sydney when they can. NSW Branch wishes those leaving Sydney all the best in their new location.

Northern Territory – Roger Clifton

On 27 September, the NT Branch hosted a technical presentation from Wolf Marx, Chairman of Tawana Resources NL. Tawana is ASX-listed diamond explorer, with projects in Australia (including Timber Creek in NT) and South Africa. The South African project has been subjected to intense exploration activity after finding a diamondiferous paleochannel, which is fed from a currently-mined kimberlite pipe, using FALCON airborne gravity. The exploration history can be found in the announcements on the company's website.

The small group of ASEG members and GSA colleagues received a sound technical presentation on Falcon, paleochannels and diamond traps, in Wolf's friendly and inclusive style. One attendee commented afterward "they flew Falcon looking for a pipe and found a channel instead". Wolf showed us the Falcon data, the geological and geographical interpretations of the integrated geophysics/geology. Photos of sampling pits, plants and recovered diamonds told the whole story from cattle-fodder plains to pre-mining feasibility and resource estimation. Overall, the presentation was technically informative and also entertaining. The company's exploration success has been reflected in its share price.

All ASEG members are welcome to present to ASEG/GSA/IAH joint meetings if visiting Darwin (In this case Wolf was on his way to the Timber Creek tenements). Presentations can be as formal as a slideshow of profiles and cross-sections, or as informal as a chat over a beer, with geophysics as the topic. This Branch hosts a small group of geoscientists, and we feel the effects of isolation on the professional and educational fronts.

Attendees enjoying the SA Branches' Melbourne Cup lunch

South Australia – by Graham Heinson

ASEG and PESA SA student chapters were co-organisers of the inaugural Geoscience Student Information Night on Friday 8th October. Tania Dhu (ASEG) and Kaia Little (PESA) arranged a marquee on the Barr Smith Library lawns of the University of Adelaide, and invited 1st and 2nd year Geology/Physics/Maths/Engineering students from all three SA Universities and from TAFE to consider a career in the Geosciences. Lisa Nairn from URS Corporation and Richard Hillis from University of Adelaide gave entertaining accounts of their pathways in Geoscience, and various industry representatives talked to students during the evening. Attendance was over 100 people, mostly students; we are currently following up with career path information. We thank Santos for donation of the marquee for the evening, and the Adelaide University Geological Society for providing a BBQ and organising drinks.

One of our most popular technical meetings of the year is the Annual Industry Night, this year held on 20th October. A number of companies provide a perspective on their exploration direction. An audience of about 55 people heard Andrew Thompson from Zonge Engineering, Neil Gibbins from Beach Petroleum and Brendan Coleman from Geoscience Associates give an overview of their respective companies' activities. We thank all our speakers and, of course, our regular sponsors.

The ASEG Melbourne Cup Lunch has become one of the premier social events of the year amongst the Geoscience community in South Australia. Beach Petroleum Ltd. Was the exclusive sponsor of the event, which that attracted 93 people to the Duke of York Hotel on 2nd November. Past ASEG SA President Rod Lovibond and ASEG committee member Suzanne Roberts organised a marvellous event, with enthusiastic bidding in the Calcutta system of horse-trading. The race was shown on a big screen, and created a lot of excitement. Beach Petroleum provided prizes for Best Dressed and Best Hat for females and males, and their sponsorship kept people around for most of the rest of the afternoon (and evening!).

By the time you receive this, our wine offer will have closed: orders have been flooding in. Selina Donnelley, Dave Cockshell, Emma Nelson and Steven Tomlin from the ASEG Committee have worked very hard on this offer, and we hope that you all enjoy the wines selected, which should be delivered in time for Christmas.

Our final events of the year will be the Student Night on 1st December (usually a very popular event) and the Christmas Party. My tenure as ASEG SA Branch President will soon finish, and I would sincerely like to thank the SA Branch Committee for their enthusiasm, vitality and teamwork over the last two years. Our group of sponsors (Australian School of Petroleum, Beach Petroleum, Cooper Energy NL, Minotaur Resources, Petrosys, Primary Industries and Resources SA, Santos, Schlumberger, Stuart Petroleum Limited and Zonge Engineering) have been vital to the running of the society. Finally, our Christmas and New Year best wishes to all SA members for supporting the society so regularly; we look forward to another full year in 2005.

Microseismic Monitoring

Rockfalls remain the principal cause of serious injuries and fatalities in underground mines in Australia and around the world. As the mining industry seeks to obtain resources at deeper levels, the risk of rock burst increases. The hazard of rockfall can be managed by implementing mine design strategies that account for, and minimize the release of seismic energy. Microseismic monitoring has been used in underground mines for over 20 years. It is a well established and powerful technology that essentially captures the vibration signal (microseismic event) emitted by rock mass failure. High resolution seismic monitoring deploys a dense array of sensors, resulting in high monitoring sensitivity. It can identify the location of failure initiation with precision and has the potential to provide detailed information on the failure processes and mechanisms, and can potentially predict rockbursts. Microseismic monitoring can help provide a real-time long term solution to improving underground mine safety for personnel and facilities.

The 6th International Symposium on Rockburst and Seismicity (RaSiM6) will be held in March, 2005 in Perth. Details of the event are found below.

The use of microseismic monitoring is not limited to the mining industry. Some of its applications include reservoir monitoring, management of underground nuclear waste storage, civil engineering (tunnels, bridges, dams etc), earthquake prediction and volcanism. This issue of Web Waves highlights various research groups who study, and companies who offer microseismic monitoring services on the World Wide Web.

ESG Solutions ★★★★

http://www.esg.ca/

ESG Solutions is a leader in passive monitoring of induced microseismic events. Since its inception in 1993, ESG Solutions provide seismic hardware and software services that serves the industrial community worldwide. ESG offers a comprehensive range of seismic monitoring solutions, including software, instrumentation and monitoring systems for geotechnical, mining and petroleum applications.

iGeo ★★★

http://www.igeo.co.nz/Index.htm

iGeo is a New Zealand based company offering mining and civil engineering seismology services. Specializing in the integration of seismic and geotechnical monitoring systems, they provide a comprehensive seismological consultancy service including system design, data processing and analysis.

Advanced Geotechnology Inc ★★★

http://www.advgeotech.com/Consulting/microseismic.htm

Advanced Geotechnology Inc. (AGI) provides microseismic monitoring management services for a wide variety of geotechnical, mining and petroleum applications. AGI will design, organize and manage microseismic monitoring programs for: hydraulic fracturing, SAGD and CSS thermal recovery, casing deformation, natural gas storage, waterflood-induced fracturing, GHG sequestration, solution mining, subsurface waste disposal, rockslides, and earth structures.

Australian Centre for Geomechanics (ACG) ★★★★1/2

http://www.acg.uwa.edu.au/

The Australian Centre for Geomechanics (ACG) was established in 1992 to promote research and education in the field of geomechanics for Australia's extractive resource industries. Their aim is to ensure safer working environments for all resources (human and capital) and to add value to Australian resource industries. This up-to-date website broadcasts a comprehensive calendar of courses and conferences, and provides an ordering service for workshop and seminar notes. Detailed information on past, present and future mining geomechanics research projects is made available. A list of research reports, reference books and other relevant publications is also provided.

ISS International ★★★★

http://www.issi.co.za

ISS is one of the largest suppliers of seismic monitoring systems to mines in the world. ISS International offers products professional services on monitoring and modelling the seismic response of the rock mass and engineering structures to natural and/or induced forces, with mining, engineering, petroleum and environmental applications. This website is comprehensive and navigation friendly.

The Safety in Mines Research Advisory Committee (SIMRAC) ★★★★

www.simrac.co.za

The Safety in Mines Research Advisory Committee, known as SIMRAC, with the principal objective of advising the Mine Health and Safety Council on the determination of the safety risk on mines, and the need for research into safety on mines based on the safety risk. This website has links to a large number of reports on rockbursting, rock falls and seismicity. See also http://www.nyx.net/~dcypser/induceq/mis.html for a list of publications on mining & quarrying induced seismicity (last updated 1997).

6th International Symposium on Rockburst and Seismicity in Mines ★★★★

www.rasim6.org.au

In March 2005, the Australian Centre for Geomechanics will host the Sixth International Symposium on Rockburst and Seismicity in Mines (RaSiM6) in Perth. It will be the first time the event will be held in Australia since its inception in Johannesburg in 1982. The event will provide a forum for more than 200 mine personnel to explore rockburst and seismic technologies and case studies, as well as exchange views and disseminate the results of intensive global research. The theme for RaSiM6 is Seismic Risk: Understanding and Controlling Seismic Hazard.

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

Minerals Exploration Action Agenda Implementation Group — Progress

The Report of the Minerals Exploration Action Agenda (MEAA), *The Road to Discovery*, forms the core of the Resources Exploration Strategy (RES) announced by the Minister for Industry, Tourism and Resources, the Hon Ian Macfarlane, on 2 July 2004. The RES is the Government's response to the House of Representatives Inquiry into Resource Exploration impediments, 'the Prosser Inquiry' released in September 2003.

The Road to Discovery includes joint industry/government commitments to address access to finance, access to land, the quality and availability of onshore pre-competitive geoscience data, and the maintenance of a world-class pool of educated professionals for the industry.

Implementation of the Action Agenda is being driven by an industry-led group, which is chaired by John Dow, Managing Director, Newmont Australia.

The Group held its second meeting in Canberra on 5 November. The purpose of the meeting was to take stock of the Groups' progress since the launch of the MEAA on 2 July. The meeting included a discussion with Federal Resources Minister Ian Macfarlane, who reiterated his support for the exploration sector, and the implementation of the MEAA.

Progress on each of the four key strategies; Finance; Human & Intellectual Capital; Land Access; and Pre-competitive Geoscience Information is summarised below:

Finance Strategy
(Chair, Mitch Hooke CEO MCA)

Pursuing taxation options to encourage minerals exploration (including flow-through shares) is still the primary focus for this Group. Empirical data on capital raisings in the sector is necessary in developing arguments for the introduction of any such taxation options.

John Dow, Managing Director, Newmont Australia

As part of this, a Capital Raisings study will investigate capital raisings for resources exploration in Australia in the 2002-03 and 2003-04 financial years. The study will focus on the available means of raising capital, both private and public, including placements, rights issues, initial public offerings (IPOs), dividend re-investment and employee share plans. Specifically the study will investigate: the amount of capital raised, by means and by size of company the percentage of funds directed into exploration, including a distinction between exploration targets (greenfields (grassroots) and brownfields); recent developments in commodity markets and capital markets which have affected the means by which exploration companies raise capital, including the percentage of funds lost through costs associated with capital raising the performance of resources exploration IPOs relative to other comparable sectors, compared to other forms of capital raising for exploration and in terms of share price after listing.

The group is developing an options paper on reducing the regulatory burden on small companies listing on the Australian Stock Exchange (ASX), and working to develop a position paper on the need to restore key mining indices which have been dropped by the ASX, including the Gold Index, the Mining and Metals Index and the Resources Index. The lack of prominence of mining sectors on the ASX was identified in the MEAA as contributing to lower investment.

Human & Intellectual Capital (H&IC) Strategy
(Chair, Tim Shanahan, CEO Chamber of Minerals and Energy, WA)

The MEAA recognises the importance of maintaining access to high quality human and intellectual capital for the future success of the mineral exploration sector and the wider resources industry in Australia. This group is conscious that a great deal of work is already underway in this area, and as such, its initial work is focussed on a stock-take of existing initiatives to ensure synergies may be exploited and duplication avoided.

Linkages are being explored with the newly announced Mining Industry Skills Shortages Working Group which was provided with $500,000 in funding when it was announced on 10 June 2004 under the National Skills Shortages Strategy.

The group is also liaising with the Department of Education, Science and Training to gather information on processes for gaining access to funds through the Collaboration and Structural Reform (CASR) Fund. The CASR Fund will be an important initiative in progressing many of the issues associated with collaboration between universities and research institutions in delivering education in the exploration/geoscience area.

The group is also working on developing a document to fully argue the case for reclassification of earth science into cluster 10 of the Commonwealth Course Contribution Scheme. Information is being gathered from a range of industry bodies, with the view of developing arguments that focus on exploration but are consistent with the advocacy efforts of other sectors of the industry.

Land Access Strategy
(Chair not yet appointed)

In pursuing the Land Access Strategy the group recognises that much of the responsibility requires the involvement of State/Territory governments. As such, responsibility for implementing this strategy will be driven through the Ministerial Council on Mineral & Petroleum Resources (MCMPR) which regularly brings Ministers and officials from all jurisdictions together to work on issues associated with the future

sustainability of our minerals and petroleum industries. The Sustainable and Indigenous Issues Subcommittee will be directly tasked with driving progress under the Land Access Strategy.

The first action under the Land Access strategy seeks to identify and remove impediments to land access, and streamline processes between jurisdictions. It is to be implemented using Western Australia as a pilot jurisdiction.

The MEAA Implementation Group will maintain a watching brief on Land Access Issues as they are progressed through the MCMPR framework.

Pre-competitive Geoscience Information Strategy
(Chair not yet appointed)

While the bid for additional funding for a Commonwealth/State/Territory onshore pre-competitive geoscience program has not been successful there is still significant progress being made in addressing individual actions under the strategy.

In working toward the development of nation-wide protocols for internet-based access to and effective storage of geoscience datasets, and industry exploration data the following developments are underway:

- Geoscience Australia (GA) has implemented an online geophysical data delivery system (GADS) in Nov 2003. To the end of October GADS has delivered 92 gigabytes of compressed data (6-8 times compression) through over 6000 requests to over 1000 unique users.
- GADS has been migrated to the Geoscience Portal to enable States and NT to deliver their geophysical data (one source for clients).
- Also GA is working on an inter-operability project with the MCA and CSIRO for the delivery of geological point data.
- In addition GA and the States/NT have a pilot project on the delivery of polygonal data underway to deliver a continent wide tenements map. This work is coordinated through the Chief Government Geologists Sub Committee (CGGC) of the MCMPR.
- A consistent nation wide mineral occurrences data was also launched in July 2004.

The MEAA IG agreed that this initiative was progressing and would continue to monitor its progress.

For additional information contact Lisa Richards on 02 6213 7266 or lisa.richards@industry.gov.au.

But will any action be too late? We have now slipped to 5th in the world

Australia has slipped to fifth place in the global rankings for minerals exploration spending, highlighting the urgent need for industry and governments to reinvigorate the environment for exploration investment see (minebox-bounces@lists.highway1.biz, 12 November 2004).

Australia is now outpaced by Latin America, Canada, Africa, and countries classified in the 'Rest of the World' category.

The ranking is included in a new survey of 1,138 global mining companies' explorations budgets prepared by the Canada-based Metals Economic Group.

The report shows that global exploration spending on non ferrous metals exploration (including copper, zinc, lead, gold and silver) will surge by more than 58 per cent to $US 3.6 billion this year.

But Australia's share of that exploration is dwindling, falling to just 14.7 per cent this year (*see also Industry News page 39 of this issue*). The result continues a trend that has seen Australia slip dramatically from the world's 2nd largest explorer in the period 1994-2001, to fifth place today.

John Dow, chairman of the implementation group of the Australian Minerals Exploration Action Agenda (MEAA) said Australia's diminishing performance should raise alarm bells within the Australian Government.

Mr Dow, who is also Managing Director of Newmont Australia, said: "While the Government has adopted many of the Action Agenda's recommendations, it must move decisively on two outstanding issues – the introduction of a flow through shares scheme, and increased provision of geoscientific data. A flow through share scheme would enable the transfer of tax deductions of individual exploration companies to individual investors."

Minerals Council of Australia Chief Executive and Chair of the MEAA Finance sub group, Mitchell H. Hooke, said the imperative to revitalise exploration is critical.

"This is a practical and cost-effective way to boost investment in exploration, because many companies, especially start-ups, have no income against which to offset their deductions," Mr Hooke said.

Estimates prepared to date suggest such a scheme would cost $250 million over four years. Similar arrangements in Canada are credited with a substantial boost to minerals exploration in Canada.

In support of an expanded exploration effort, the MEAA is pursuing a number of initiatives including a study of capital raisings, an analysis of ways to reduce the regulatory burden on small companies listing on the Australian Stock Exchange, as well as an examination of options for the restoration of mining indices on the ASX.

The MEAA is also concerned about the ability of the leading government research body – Geoscience Australia – to expand its pre-competitive geoscientific data to better map Australia's prospective exploration capability.

Governments have made considerable progress on developing and implementing nation wide protocols, standards and systems for internet access to exploration data. "However, without funding for a new, national and innovative geoscience program, Australia is in danger of reducing its capacity to take advantage of the burgeoning market for mining technology services exports and growing global metal demand as new and emerging markets such as China and India industrialise," Mr Dow said.

An estimated $12.5 million per year, to be matched by the States, with a focus on the high risk frontier regions, would generate better geoscientific spatial data and assist exploration companies find the proverbial "needle in the hay stack.

Mr Dow warned that if real action, including a commitment on flow-through shares, is not forthcoming, there is a very real prospect that in 20 to 25 years, there will be only one remaining major base metal mine in Australia – Olympic Dam in South Australia.

"We will have lost the battle in this dynamic, globalised world economy and its increasing converging global supply, for Australia to be a strategic location for base metals production," Mr Dow said.

Mr Dow could also have listed the Land Access issue because now that the Coalition will have control of the Senate, it should have no problem in changing the Aboriginal Land Rights (Northern Territory) 1976 Land Act, as recommended by both the Prosser Inquiry and the Mineral Exploration Action Agenda. We will have to wait to see if the government will go down this path.

Research Infrastructure Advisory Committee announced

Brendan Nelson the Minister for Education, Science and Training has just announced (http://www.dest.gov.au/Ministers/Media/Nelson/2004/11/n10021104.asp) the membership of the Advisory Committee to develop the National Collaborative Research Infrastructure Strategy (NCRIS).

This was announced as part of *Backing Australia's Ability: Building Our Future through Science and Innovation* (BAA2) and bundles the existing infrastructure schemes into a $542M pool. One element of NCRIS is it locks in infrastructure at 20 cents in the competitive research grant dollar - well below the 40 - 50 cents in comparable UK and USA competitive grant schemes.

The Advisory Committee will be made up of highly experienced members, all leaders in their particular fields. The Chair will be Rory Hume, formerly Vice-Chancellor and President of the University of New South Wales.

Professor Hume will be supported by:

- Michael Barber, Executive Director, Science Planning, Commonwealth Scientific and Industrial Research Organisation, (CSIRO)
- Robin Batterham, The Chief Scientist
- Ian Chubb, Vice-Chancellor, Australian National University, (representing the Australian Vice-Chancellors' Committee)
- Phil McFadden, Chief Scientist, Geoscience Australia, (representing the National Academies Forum);
- Peter Nissen, National Broadband Advisor for Education;
- Alan Pettigrew, CEO, National Health and Medical Research Council;
- Ian Smith, Executive Director, Australian Nuclear Science and Technology Organisation, (ANSTO);
- Stephen Walker, Executive Director, Engineering and Environmental Sciences, Australian Research Council;
- Evan Arthur, Group Manager, Innovation and Research Systems Group, Department of Education, Science and Training, (DEST);

and

- Colin Walters, Group Manager, Science Group, (DEST)

I understand that the committee will be calling for proposals every soon and will also be travelling to capital cities to consult with university researchers.

Project Results

The ASEG Research Foundation has been supporting students in all facets of Applied Geophysics at the BSc (Honours), MSc, and PhD (or equivalent) levels for 14 years. In this issue of Preview we provide a summary of research outputs from Curtin and Queensland Universities.

ASEG Research Foundation Project RF00M07

Project and PhD title:
Time-lapse 3D Seismic Reservoir Modelling

Student: Jason McKenna
Host Institution: Curtin University
Supervisors: Brian Evans and Milovan Urosevic (Curtin University)
Funding: $8000 over three years

Project Summary

Geological sequestration is a new technology being developed to reduce CO2 emissions into the atmosphere. In 1996, a unique geo-sequestration project commenced in the Sleipner Field involving the injection of reservoir CO2 into a saline aquifer known as the Utsira Sand. This research thesis has investigated the effectiveness of 4D surface seismic data to monitor CO2 storage in a saline aquifer. Rock physics modelling has shown that free phase CO2 will significantly decrease the elastic moduli of an Utsira-like reservoir. By contrast, the very small change in elastic moduli caused by the dissolution of CO2 into brine is unlikely to be directly detected by seismic measurements. The eventual conversion of aqueous CO2 into carbonate minerals should cause an observable increase in the elastic moduli of an Utsira-like reservoir.

Interpretation of the 4D surface P-wave seismic data recorded over the Utsira Sand has shown that amplitude-based attributes can be used to validate structural trapping beneath an impermeable seal and infer the geological controls on CO2 flow. The calculation of in-situ volumes for verification purposes requires estimates of CO2 density and saturation. Deriving these estimates from amplitude-based seismic attributes will have high uncertainty due to tuning interference when CO2 accumulates in thin layers beneath impermeable shale barriers. The establishment of an alternating vertical sequence of shale and CO2-saturated sand was found to increase transverse isotropy in the Utsira Sand. Accounting for transverse isotropy during data processing was found to improve the quality of the seismic image. The assumption of transverse isotropy does not appear strictly valid in the Sleipner Field since some form of azimuthal anisotropy was observed in the 4D seismic data.

Changes in the rock frame associated with mineral trapping of CO2 will be difficult to interpret using amplitude-based seismic attributes in the presence of free CO2. This research has observed an apparent link between reduced attenuation of frequency-based attributes and potential locations for carbonate precipitation in the Utsira Sand predicted by geochemical modelling. Unfortunately, these inferences could not be validated by other independent measurements and no definitive conclusions can be made. Thus, other independent measurements may be required to constrain the conclusions that can be derived from 4D seismic data.

ASEG Research Foundation Project RF03P04

Project and Honours title:
Numerical modelling of pseudo-random land seismic sources

Student: Shaun Strong
Host Institution: University of Queensland
Supervisors: Steve Hearn, University of Queensland
Industry Monitor: Randall Taylor
Funding: $4900

Project Summary

Environmental, logistical and security considerations mean that non-explosive, surface seismic sources must assume increasing future importance. The challenge is to make such sources more competitive with dynamite in terms of resolving power and signal-to-noise ratio. I used numerical modelling to explore possible improvements in Vibroseis reference-signal design, and algorithmic approaches to Mini-SOSIE stacking.

I revisited an alternative Vibroseis sweep comprising a constant frequency carrier which suffers polarity reversals according to a pseudo-random coding sequence. Numerical models allow various comparisons with the conventional swept-frequency approach. Visually, the correlation wavelet from the pseudo-random reference appears less affected by side lobes than the conventional Klauder wavelet. On the other hand the correlated pseudo-random trace is noisier away from the wavelet itself. A pseudo-random sweep built from half-cycle components has interesting theoretical possibilities, but practical implementation may be difficult.

Pseudo-random design concepts extend naturally to the Mini-SOSIE source, which stacks, in real time, numerous low-amplitude impacts, occurring at approximately random time intervals. I demonstrated the undesirable effect of non-randomness, and examine the feasibility of using predictive deconvolution to improve the randomness of the impact sequence prior to stacking.

Sign-bit stacking provides better attenuation of noise bursts than standard Mini-SOSIE stacking, although it may be prone to some amplitude distortions. A stacking procedure which incorporates a median-filtering stage appears to provide good noise-burst attenuation whilst maintaining reflection amplitudes.

101 years ago on the island of Mauritius – a geophysical first

Not all pioneering exploration geophysics took place in Europe, the Americas or the Antipodes – the following is a prime example.

The name Thomas Folkes Claxton (1874-1952) would not be familiar to most earth scientists – and that is not surprising as he was a meteorologist and astronomer (see Dictionary of Mauritian Biography, 1968). For many years Claxton was the Director of the Hong Kong Observatory (1912-32) and previously had been the Director of the Royal Alfred Observatory at Pamplemousses, Mauritius (Figure 1). While there, in 1903, he had a problem.

A new observatory theodolite declinometer was to be installed at Pamplemousses and it was deemed necessary to mount it within the observatory grounds and as near as possible to the existing mounted declinometer, but far enough away to have no possible interference between the instrument magnets. It was also desirable to mount the new instrument, if possible, to be visible from a known astronomical mark some six miles away. Claxton had to decide where it was to go.

It should be mentioned that most meteorological and astronomical observatories in that era also observed geophysical phenomena (geomagnetism, gravimetry and seismology) in fact Claxton had given a lecture on Seismology in Mauritius to the British Association in 1899. Observatory geophysics was alive and well in those days.

Claxton built a new pillar for this declinometer some 90 feet away from the old one and even provided a protective pavilion over it (and its associated magnet some six feet away) but when the new instrument was activated to measure declination it was found the declination was 1° 20′ greater than at the old pillar. With the observatory being of some international importance, Claxton decided that this discrepancy was serious enough for some declination measurements to be made between the old pillar and the new one to confirm this difference.

He set up a straight line traverse between the two pillars and using the new declinometer took observations at 10 foot intervals and when plotted he found them to be so inconsistent that he really needed to make measurements at closer intervals. So he made a slide on a plank of wood for the declinometer and at six inch intervals set and read the declinometer, positioning each measurement by theodolite.

The declinometer, where possible, was kept at four feet off the ground but in one instance Claxton noticed the declination at four feet was 12° 40′ west and two feet lower at the same location it was 14° 00′ west.

Claxton was so concerned with these variations he decided to perform a detailed magnetic survey of the entire observatory grounds with observations at regular intervals, as close as three inches, using a rectangular ruled and grooved grid set out on a wooden table. He went on to make a total of 893 declination observations, all of which he positioned by theodolite. He also made selected magnetic dip and intensity measurements.

The survey results perplexed Claxton, for despite the nearly 900 observations he had made, he was not able to determine the true declination for the observatory – and this was not good (Claxton, 1905 and Figure 2).

Claxton did, however, calculate an average declination for the observatory as 9° 45′ west, which was more than 30 minutes different from the official and internationally recognized declination for the site. To compound Claxton's concern he found that the dip also differed significantly from 50° S to 58° S.

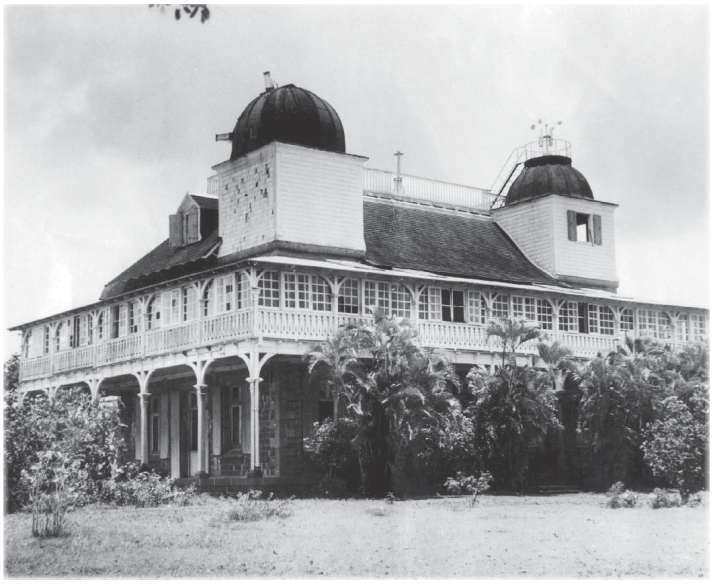

Fig. 1. The Royal Alfred Observatory at Pamplemousses, Mauritius, sometime in the early 20th century. The building was demolished in the 1960s (Author's collection).

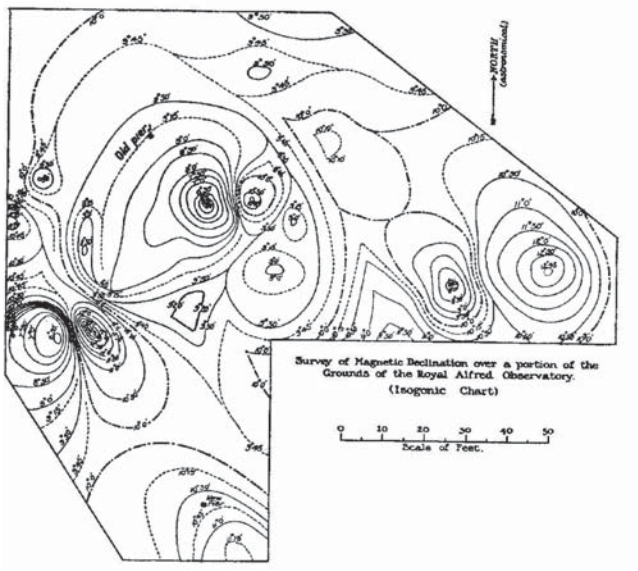

Fig. 2. Claxton's stylistic contours of declination of the observatory grounds made in 1903, from Claxton's 1905 paper. The contours are drawn at either 15 or 30 minute intervals.

Exploration NSW Seminar, 8th September

In conjunction with the Sydney Mineral Exploration Discussion Group (SMEDG), the Geological Survey of NSW recently held a seminar to present the outcomes and product releases from the fourth year of its mapping and research work carried out as part of the State Government's Exploration NSW initiative.

The seminar was well attended by more than 100 delegates from industry. The seminar was introduced by Ted Tyne, the Director of the Geological Survey, and contributions were made by six other eminent Geological Survey geoscientists.

Dr Tyne provided the audience with an update of the recent amalgamation of the Department of Mineral Resources into the Department of Primary Industries and its move to Maitland (see article in the October 2004 issue). Topics covered by the other presenters are described in sequence below.

New Exploration NSW products

Lindsay Gilligan detailed the latest Exploration NSW products. Five CD-ROM data packages and six new geological map sheets were described, as well as eight interpretative products. Figure 1 shows an example of one of the CD-ROMs now available. The new product list is as follows:

CD-ROM Data Packages

- Eastern Lachlan Orogen
- NSW diamond exploration opportunities
- NSW stream sediment geochemistry
- NSW digital geology 1:100 000 database
- Broken Hill whole-rock geochemistry database.

Geological Map Products

- Cargelligo 1:250 000 provisional geology
- Yass 1:100 000 provisional geology
- Manilla 1:100 000 provisional geology
- Cobham Lake 1:100 000 provisional geology
- Mt Arrowsmith 1:100 000 provisional geology
- Byrock, Sussex, Coolibah & Hermidale 1:100 000 regolith.

Interpretative Maps & Reports

- Byrock shallow reconnaissance aircore drilling (GS2003/048)
- Murray/Riverina survey interpretation map and report (GS2004/209)
- Braidwood geophysical survey interpretative report (GS2003/447)
- Nandewar mineral potential map & reports (GS2004/201, GS2004/221)
- Broken Hill Mt Gipps Hyperspectral maps & report (GS2004/167)
- Broken Hill audit & gaps analysis (GS2004/200)
- Koonenberry seismic line geological cross-sections (GS2004/185)
- Nuchea, Kayrunnera 1:100 000 notes.

One of the exciting new developments in NSW has come as a result of the new Murray/Riverina regional airborne geophysical studies. The Stawell and Bendigo geological zones, responsible for more than 2 tonnes of gold production since the mid-1800s, are interpreted to extend a considerable distance into western New South Wales (see Figures 2 and 3).

Following the success of recent mapping programs near Goulburn, Mr Gilligan informed the SMEDG attendees that in future both solid geology and outcrop geology maps will be produced as final products of all mapping projects. Figures 4 and 5 were presented and allow a comparison of the outcrop geology and the interpreted solid geology products. The solid geology map shows the benefit that can be gained by a geological mapping project in utilising high quality, closely spaced aeromagnetic data as an aid to geological understanding.

Mr Gilligan also referrred to the [1]FALCON® airborne gravity gradiometer survey, a joint project with the pmdCRC and Geoscience

Continued from page 18

Fig. 3. Heaped basalt boulders in a field of sugar cane - a typical Mauritian scene. No wonder Claxton had trouble with his magnetics (photo by author Jan 1976).

All of this variability was enough to have Claxton consider the observatory site completely unsuitable for magnetic measurements (see Figure 3) and from that time onwards the observatory, despite its prime use for astronomical and meteorological reasons, was progressively marginalised – other working sites were established. The building and its location was also not a popular site with Claxton and others - they had considered the climate there as "unhealthy". The observatory became unoccupied, except for visits to make observations, became progressively rundown, and eventually, after many years of neglect was demolished in the 1960s. Nothing remains. A geomagnetic observatory was established at that time near the international airport.

Despite some research by the author it appears as though Claxton's survey in 1903 is the first published magnetic survey of an engineering nature.

A significant but little known event in exploration or applied geophysics.

References:

Dictionary of Mauritian Biography, Published by Le Société de L'Histoire de L'Ile Maurice, Port Louise, Mauritius, 1968, 909 – 10.

Claxton, Thomas Folkes, 1905, Preliminary Report on a Survey of Magnetic Declination near the Royal Alfred Observatory, Mauritius, Phil. Trans. Roy. Soc. London, Series A, Vol LXXVI, 507 – 511.

Australia, and the HymapTM hyperspectral geophysical project, both of which were completed in the Broken Hill region. He also drew the delegates' attention to the newly released Braidwood geophysical survey interpretative report, utilising the government's 19 000 line-km Braidwood survey data set.

Exploration implications of a new Broken Hill ore fluid model and update on new science at Broken Hill

Barney Stevens, the Department's Principal Research Scientist at Broken Hill, presented two talks on the Broken Hill region. In his first presentation he described a new ore fluid model for the Broken Hill mineralisation. In his second he covered some of the key results of new scientific activities in the Broken Hill region which have implications for explorers. Geological mapping in Mutawintji National Park (completing the Nuchea 1:100 000 sheet mapping) has provided previously unavailable, valuable mapping data, which now better inform the interpretation of stratigraphy in the Bancannia Trough.

New geochronology from Pb-isotope and high resolution zircon analyses support a new proposal that the Broken Hill and adjacent Pb-Zn-Ag orebodies were formed at the sub-sea floor level. Associated BIFs may have formed on the sea floor from spent ore-forming exhalative fluids related to the mineralisation. Assuming this model, magnetic markers may indicate the possibility of Broken Hill style ore occurrences at stratigraphic depths up to 500 m below the markers. The new dating information suggests the oldest unit in the Broken Hill Block is the Redan Gneiss, now dated at approximately 1710 Ma.

Mr Stevens also demonstrated new cross sectional interpretations from Broken Hill and the value of regolith mapping by CRCLEME, from which a new basement subcrop has been interpreted in the Teilta area. Other data presented included groundwater geochemistry from CRCLEME

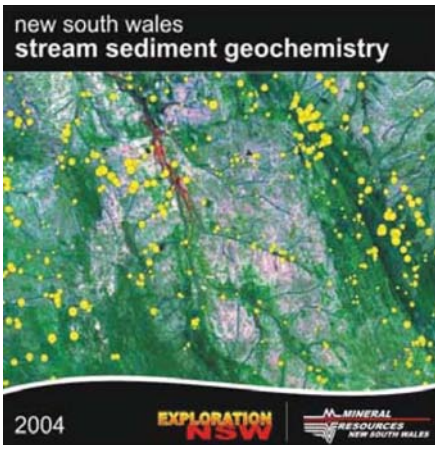

Fig. 1. NSW Stream Sediment Sampling CDROMs

Fig. 2. Interpretation of possible extent of Bendigo and Stawell Zones into New South Wales.

in the Southern Curnamona and whole rock geochemistry from the newly published Broken Hill Wholerock Geochemistry database, which contains data from more than 8000 rock samples.

Update on new technology applications at Broken Hill

Rounding off the first session of the seminar, Chief Geophysicist David Robson

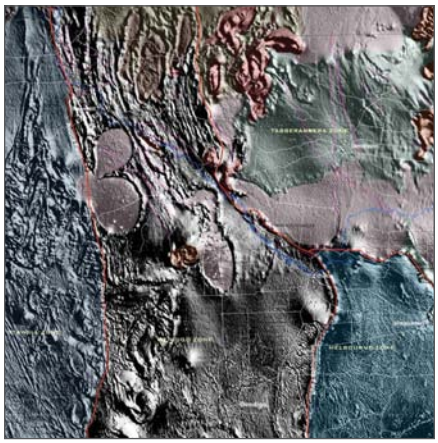

Fig. 3. Detail of part of the Murray/Riverina geophysical interpretation, including data provided courtesy of the Geological Survey of Victoria.

presented outcomes from several geophysics projects. Encouraging results were reported from follow-up company drilling of targets developed utilising data from the FALCON® AGG project.

A related project, to assess the BRGM's 3DWEG geological modelling software, carried out by Intrepid Geophysics and the pmdCRC, used the FALCON® data and regional gravity data in the Broken Hill area. The assessment included creation of 3D geological models from known Broken Hill stratigraphy and the application of these models in a gravity inversion process through the attribution of density data to the geological units in 3DWEG.

Mr Robson also presented a new interpretation by Geoff Taylor, from the University of NSW, of HyMap™ airborne hyperspectral imagery over the Mt Gipps 1:25000 sheet, previously acquired for the NSW Geological Survey by HyVista

[1] *FALCON® is a Trade Mark of BHP Billiton Innovation Pty Ltd*

Corporation. Dr. Taylor's interpretation has confirmed the minerals mapped by the Hymap™ survey include micas, clay minerals, amphiboles and garnets. He also confirms that all lithologies present in the region as well as Cainozoic surficial sediments were mapped. The hyperspectral imagery was also found to be able to map some of the lithologies critical to mineral exploration in the region such as gahnite-bearing quartz and manganese-bearing garnetiferous rocks.

The Lachlan Orogen Synthesis Project

The second session of the Seminar included a summary by Dr. Dick Glen of new strategic thinking about the tectonic and metallogenic interpretation of the Lachlan Orogen and the implications of this new orogen-wide tectonic framework in the exploration for new mineral deposits and mineral systems. Part of this focus is on the nature of the boundary between the Lachlan and Thomson Orogens and how they may relate to the continuity or termination of the Delamarian beneath the Darling Basin.

Fig. 6. David Robson speaking at the SMEDG-Geological Survey of NSW Seminar

Fig. 4. Goulburn 1:100 000 Outcrop Geology Map.

Fig. 5. Goulburn 1:100 000 Solid Geology Map.

The East Lachlan GIS – a demonstration of this new release

Mark Dawson demonstrated the operation and functionality of the new GIS database structures used by the Geological Survey in the Eastern Lachlan Orogen Project. These new mapping technologies have involved substantially increased automation of the cartographic processes, yielding higher productivity in the government's map production process.

Woodlawn Mine: implications of new mapping

Dr. Jeff Vassallo concluded the seminar on a challenging note with his paper, jointly prepared with Dick Glen, which places the iconic Woodlawn VHMS deposit into new structural context which could have regional implications for future mineral exploration in this area.

For any further information about these presentations, please contact:

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Email: graham.butt@minerals.nsw.gov.au

Geoscience Australia

State government geophysical data now available from GADDS (Geophysical Archive Data Delivery System)

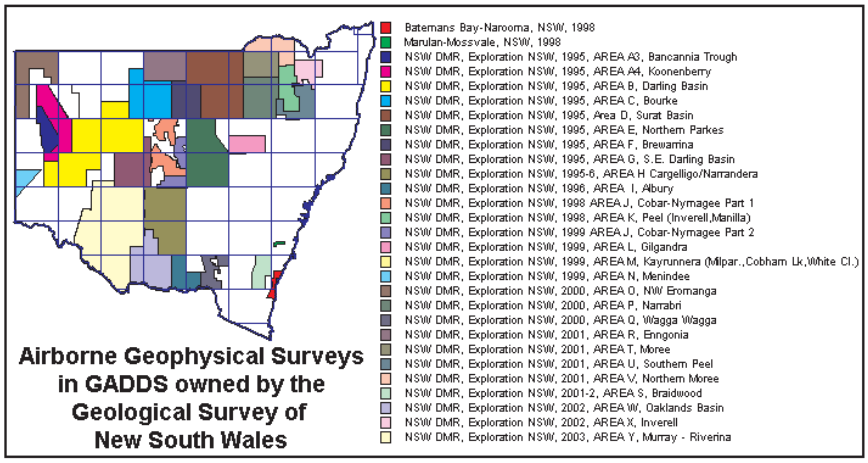
Airborne geophysical datasets acquired by the New South Wales, Queensland and Victorian State governments are now available for free download from GADDS (see the three figures to the right).

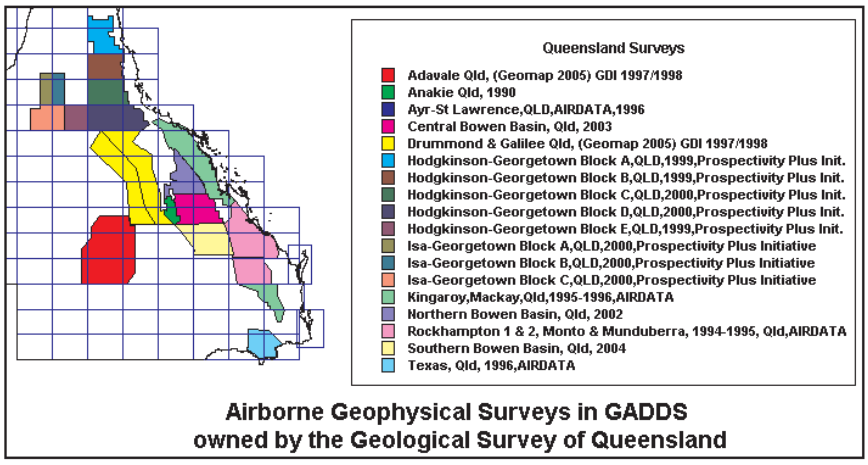
With the addition of airborne geophysical survey datasets from the States, GADDS is now delivering data through the geoscience portal (www.geoscience.gov.au/gadds).

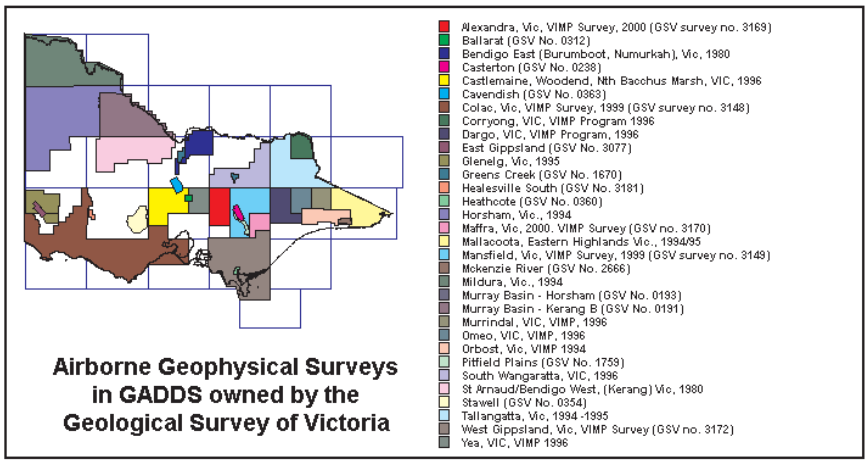
The main features of GADDS remain unchanged:

1. Data are requested using a standard web-browser.
2. Only the data required by the client are delivered to the client.
3. The format (ASCII columns or Intrepid Database) for data delivery, and the required datum and projection must be specified.

Both vector (line and point) and raster (grid) datasets are delivered to the user.







Geophysical Data Release – Murchison Region, WA

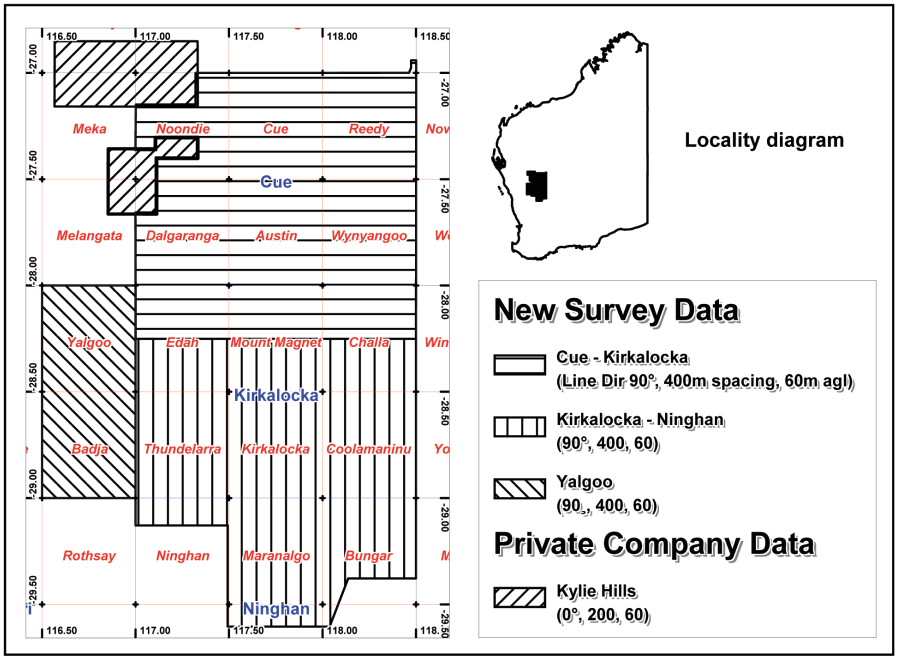
On 1 November 2004 Geoscience Australia (GA) released over 146 000 line-km of airborne geophysical data over the Murchison region of Western Australia covering the Cue, Kirkalocka, Ninghan and Yalgoo 1:250 000 Sheet areas.

In this area of high potential for gold mineralization, the absence of extensive geological outcrop has previously hindered exploration. These new geophysical data provide explorers with high quality pre-competitive information to significantly assist the mapping of the region's geology, and which, when used in conjunction with existing complementary data, may highlight exploration targets.

Data in the release comprised magnetic, gamma-ray and elevation located data and grids from surveys flown for GA between April and August 2004 and from one private company survey flown in November 1995. The company data have been levelled with the 2004 survey data to create a combined dataset giving a continuous coverage over the region.

The resulting magnetic, radiometric and elevation datasets have been gridded using an 80 m cell size. The survey areas are shown in the diagram on the next page.

The new data were acquired in three surveys collected at a flying height of 60 m along lines spaced 400 m apart. Magnetic data were sampled every 0.1 s (~ 7 m) whilst the sampling interval of the radiometric data was



1.0 s (~ 70 m). Navigation and flight path recovery information were provided by the satellite Global Positioning System (GPS), which was sampled every second (~70 m).

These digital data (point located and gridded) along with GA's entire geophysical database are available for free download using the Geophysical Archive Delivery System (GADDS) available at www.geoscience.gov.au/gadds. A CD-ROM of this newly released data is also available at a cost of A$99 (incl. GST; postage and packaging extra) from: The Sales Centre, Geoscience Australia, Tel.: (02) 6249 9519, E-mail: sales@ga.gov.au.

Calibration of Compasses and Magnetometers

The calibration of direction finding equipment and magnetometers is a little known service that is available through the Geomagnetism Program at Geoscience Australia. In the operation of a network of magnetic observatories in Australia and the Australian Antarctic Territory, the maintenance of precise and highly accurate magnetometers is a requirement. By comparing clients' direction finding equipment with observatory standards, corrections to the former can be determined.

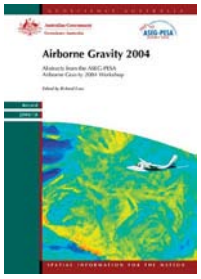
Diurnal variations of the background magnetic field are taken into account as these are monitored continuously at the observatories. Relative axis orientation and sensitivity of magnetometers can be determined by the use of the National Magnetic Calibration Facility at the Canberra Observatory, which houses a well calibrated 3-axis set of large coils (see the figure below).

Magnetometer in insulated compartment being tested within the large three-axis magnetic calibration coil system at the Canberra Magnetic Observatory

Charges for the calibration services are at standard cost recovery rates and inquiries may be directed to: geomag@ga.gov.au or contacting Peter Hopgood on 02 6249 9111.

Magnetic observatory data and near to real-time displays of magnetic variations are available on Geoscience Australia's Geomagnetism web pages at: http://www.ga.gov.au

State-of-the-art in airborne gravity



A comprehensive review of airborne gravimeter and airborne gravity gradiometer methods can be found in Geoscience Australia Record 2004/18. The Record contains 16 extended abstracts from the "Airborne Gravity 2004 Workshop", held in Sydney on 15 August 2004 in conjunction with the 17th Geophysical Conference and Exhibition of the Australian Society of Exploration Geophysicists (ASEG).

In addition to discussion of current systems, the Record also includes extended abstracts on airborne gravity systems under development, along with case histories on the use of these methods in minerals and petroleum applications. The Record is available for free download from:

http://www.ga.gov.au/rural/projects/index_2004_18.jsp

or a printed copy can be purchased from Geoscience Australia's Sales Centre at: http://www.ga.gov.au/sales.

British and Finnish Geological Surveys to operate joint airborne geoscience capability

The deHavilland Twin Otter aircraft being used by the British and Finnish Geological Surveys. The wheel-like devices are the transmitter and receiver coils for the EM system. The magnetic sensors are housed inside the wingtip mountings.

At a time when most geological surveys appear to be using contractors rather than developing their in-house capabilities, the British Geological Survey (BGS) and the Geological Survey of Finland (Geologian Tutkimuskeskus, GTK) have joined forces to operate their own geophysical survey aircraft and develop improved airborne survey techniques. According to a recent press release;

"The new **Joint Airborne-geoscience Capability (JAC)** will provide both partners with a cost effective, state-of-the-art capability for acquiring high resolution airborne geophysical data for their respective national strategic science programs and will also be available for a period of time each year for use by third parties.

GTK has a long-established track record in airborne geophysics and sees a continuing need to develop airborne geoscience to address a range of new applications. At the same time, BGS plans to acquire a new generation of high-resolution airborne data across the UK to define the properties of the shallow subsurface in relation to sustainable development and environmental protection. The rationale behind developing a joint capability is to share the cost of ownership, maximise the utilisation of the facility, share the cost of technical R&D and maximise collaborative scientific opportunities.

The joint facility will be based initially on GTK's existing 'Three-in-One' fixed wing technology comprising a dual frequency electromagnetic (EM) system designed and built by GTK, a multi-channel gamma spectrometer and a magnetic gradiometer. BGS has purchased the deHavilland Twin Otter aircraft, previously leased by GTK from Finnair Cargo Oy /Malmilento, and assigned it exclusively for use by the JAC (see the photo below). An early second phase of the co-operation will see the upgrade of the EM system to four frequencies, covering the range 900 to 25,000 Hz, together with the installation of enhanced GPS, laser altimetry and flight path video systems to be jointly funded by the partners.

In addition to the 'economies of scale', the need for the JAC is driven by the changing role of national Geological Survey organisations such as BGS and GTK. As well as their traditional roles of mapping geology and natural resources, the emphasis is increasingly on providing information to support protection of the environment and sustainable land-use management, driven by the need to meet national environmental regulations and EU environmental directives. This requires a much more detailed understanding of the structure of the near surface, contamination of the land from human activities and the movement of pollutants through the subsurface. Airborne electro-magnetic (EM) data provide information on the electrical conductivity of the sub-surface related to water quality, pollution and mineral content; magnetic data provide information on sub-surface structure and mineral resources; and radiometric data provide information on the natural and man-made radioactivity. Together, the three data sets acquired by the aircraft provide a cost-effective and non-invasive means of studying the near surface and providing essential new information to address both environmental and sustainable resource issues.

The JAC has the potential to expand to include additional partners and provide essential data sets to enable the nations of the European Community to address important environmental and land-use issues on a European scale."

Michael Lee (Director of Lands and Resources, BGS) at: mklee@bgs.ac.uk or

Harry Sandström (Director of Geoservice Centre, GTK) at: harry.sandstrom@gtk.fi

A new generation Magnetic Anomaly Grid Database of Australia (MAGDA)

– use of independent data increases the accuracy of long wavelength components of continental-scale merges

By:

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Abstract

A new Geoscience Australia Magnetic Anomaly Grid Database of Australia (MAGDA) has been developed. This database contains publicly available airborne magnetic grid data for on-shore and near-offshore Australia. Flight-line magnetic data for each survey have been optimally gridded and the grids matched in one inverse process. New composite grids at 250 m and 400 m grid spacing form the basis for the new fourth edition of the Magnetic Anomaly Map of Australia.

Aeromagnetic traverses flown around Australia during 1990 and 1994 are used in both quality control of the grids they intersect, and also to constrain grid merging by forcing grid data, where intersected, to the level of the traverse data.

Although matching and merging of many grids into a seamless compilation produces a pleasing result, without obvious short-wavelength artefacts, accurate long wavelength components of crustal origin are more difficult to obtain. Errors in the "tilt" of individual surveys, due either to older instrumentation, or errors in processing, or incomplete core-field removal, can lead to large long-wavelength errors when hundreds of surveys are combined across thousands of kilometres.

Quantification of the accuracy of long-wavelength components is only possible by comparison with independent datasets. A low-pass filtered composite grid of the Australian region has been compared with CHAMP satellite magnetic data, and it shows a considerable improvement in the correlation of long-wavelength components compared with the previous edition.

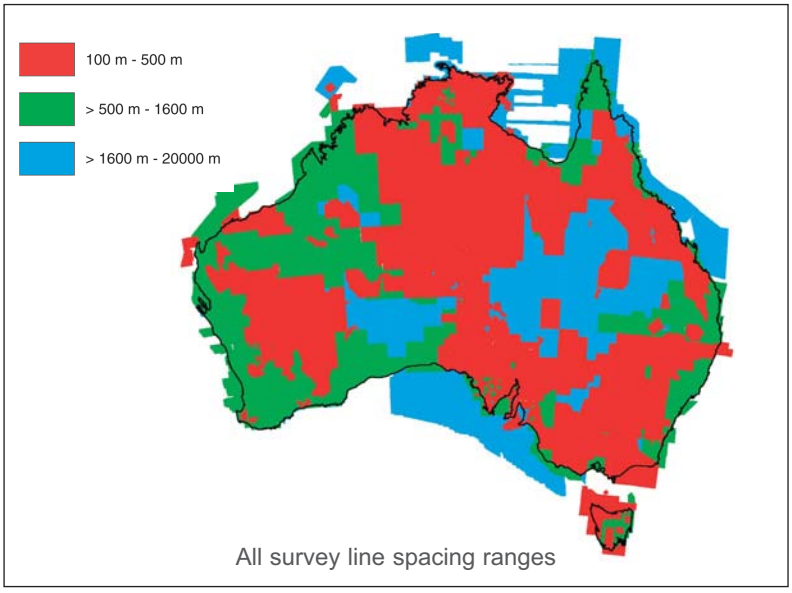

Fig. 1. The distribution of original survey line-spacings. Red represents line-spacings less than or equal to 500 m, green represents line-spacings greater than 500 m and less than or equal to 1600 m and blue represents line-spacings greater than 1600 m.

Introduction

Geoscience Australia has developed a new airborne Total Magnetic Intensity (TMI) crustal anomaly grid database of Australia (MAGDA). The original survey line data, from which the grids are derived, were acquired by Geoscience Australia, the state and territory government geological surveys and exploration companies. Most of the data are publicly available, although a few datasets provided by two companies have restrictions on their distribution.

It is estimated that 19 million line-km of survey flight-line data were acquired to provide the grids. Most of the more recent data (post-1995) have been acquired by the geological surveys, in many cases through their "Exploration Initiatives".

Most of the original survey line data were processed to "final form" by standard processing methods (Luyendyk, 1997). These methods include removal of time variations of the geomagnetic field (diurnal correction), removal of the Earth's core field (IGRF removal) and levelling (using line/tie cross-over intersections to minimise network differences). In most cases, "micro-levelling" has been performed to remove residual elongate along-line artefacts (Minty, 1991).

Each grid in the database has been optimally derived from the corresponding survey data using a minimum curvature algorithm (Briggs, 1974). In most cases the grid cell spacing is 1/5 of the survey line spacing. The grid data have a range of specifications and errors reflecting the variability of the original survey data. While most of the data were acquired post-1990, and are considered to be of high quality, there are still areas where only lower-quality older regional data are available (Figure 1).

The grids in the database have been "matched" together with a new process, using independent data as a constraint, and a new composite merged grid of the Australian region forms the basis for the fourth edition of the Magnetic Anomaly Map of Australia. The long-wavelength components of this composite have been compared with satellite magnetic data.

Processing procedures

(a) Constrained grid-matching using independent AWAGS data

Due to the nature of the processing, the grids have arbitrary base levels, and baseline offsets between grids need to be resolved if composite seamless products are to be generated. This involves calculating a shift for each grid based on the statistics of the data differences for the area of overlap with neighbouring grids. For earlier versions of the Magnetic Anomaly Map of Australia this was achieved by using a sequential process, in which pairs of grids were matched at a time using a one-pixel overlap of their common borders, and all grids had the same cell spacing (Tarlowski *et al*., 1996a). If this process was continued to match large areas of grids, long-wavelength warps would be introduced. For example, if the process was done in a circular fashion, the last grid would not match with the first grid.

To help overcome this problem, a new merging method was developed by Geoscience Australia. In this method, grid area overlap differences for all of the grids are minimised in one inverse operation (Minty *et al*., 2003; Milligan *et al.*, 2001). While this new method helps reduce long-wavelength errors, it does not eliminate them. To further reduce such errors, control must be provided by using other independent data. This is partly achieved by using the AWAGS (Australia-Wide Array of Geomagnetic Stations; Chamalaun and Barton, 1990) airborne traverse data (Tarlowski *et al*., 1996b). These data were acquired using two loops flown around mainland Australia in early 1990, and a further loop flown around southern Victoria and northern Tasmania in 1994 (Figure 2). The grids that are intersected by the traverse data are brought to the traverse data level and subsequently held there as "base grids" in the remainder of the processing.

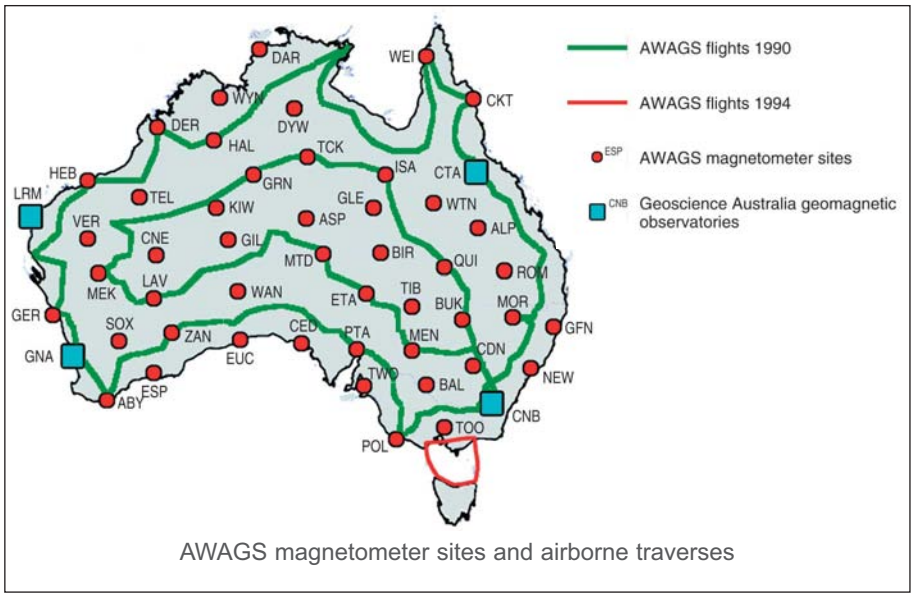

Fig. 2. The AWAGS magnetometer sites, Geoscience Australia magnetic observatory sites and the AWAGS airborne magnetic traverse locations.

A further option within the matching process is to calculate higher-order surfaces from the grid boundary differences and subtract them from the grid under consideration. Such "tilting" of grids needs to be used with caution, and is further discussed in the next section.

A significant improvement is expected in the accuracy of intermediate wavelength magnetic anomalies (about 100 to 500 km wavelengths) with the levelling of the survey grids to the AWAGS datum. There are significant advantages that could result from improving the intermediate wavelength anomalies for lithospheric magnetic investigations looking into the variations in temperature regime and the rheological nature of the Australian lithosphere. However, we are yet to rigorously test these improvements.

(b) Data quality control and indexing

The grid database currently contains over 680 separate grids, with a combined size of nearly 6 gigabytes (IEEE4ByteReal format data). With this number of grids, an automated indexing and quality control system is essential, and software has been developed for this purpose (Figure 3).

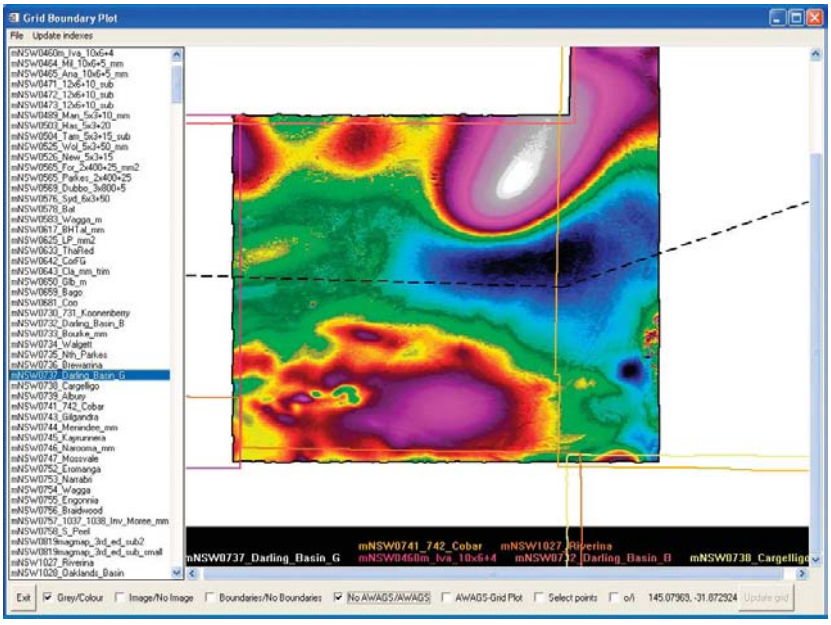

Fig. 3. The main interface into program Grid_boundary_view. The dashed black line represents the position of an AWAGS traverse.

At the heart of the system is a directory of exact grid boundary files and thumbnail tiff images. Any grid can be selected and displayed, together with its boundary and the overlapping boundaries of neighbouring grids. There is provision for interactive polygonal sectioning of the grid, as it is best to have "clean" boundaries without excessive overlap. The grid boundary plots are carefully examined to ensure that there are no redundant grid data. AWAGS traverse paths may be overlain on the image (Figure 3).

Comparison plots of AWAGS traverse data with grid data that they intersect are particularly important for quality control. Example plots are shown in Figure 4. Profile (a) is the AWAGS traverse data (diurnally corrected) and profile (b) the grid data interpolated at the positions of the AWAGS data. Profile (c) shows the diurnal data for the time of the AWAGS profile data acquisition. These have been calculated by interpolating the AWAGS profile data in a time–space volume of the AWAGS magnetometer data (Figure 2). The last profile, (d), shows the data in profile (b) subtracted from those in profile (a), and is diagnostic mainly of the quality of the grid data.

For example, if the difference in profile (d) shows a significant linear trend (e.g. Figure 4(b)), then the grid is "tilted" with respect to the AWAGS profile data. For modern data, this would most likely be due to an incorrect removal of the IGRF field. In old data, for example in surveys flown with fluxgate magnetometers, such tilts and higher-degree warps could easily have come from instrument drift and errors in levelling.

It is best to correct modern data for such errors, once diagnosed, and regrid the data. For older data, this may not be possible and, quite often, older survey grids do show significant tilts and warps. As previously mentioned, there is provision within the GRIDMERGE program to attempt a correction of such errors by calculating higher-order correction surfaces from the boundary overlap differences. This option is used with great caution; no higher than a degree 1 surface is removed, and modern surveys are not corrected in this way.

An automated index map generator has also been developed. This uses the Geoscience Australia four figure project codes, which are part of every grid filename, to relate to information in the master Oracle survey index. The index program has options for generating ASCII list files, with grid names ordered by such criteria as line spacing, date and ownership. These lists may then be used to control the ordering of grids when merging data into composite grids, or to produce colour images of the various criteria.

Further developments

(a) Magnetic Anomaly Map of Australia, 4th Edition

A major product being released by Geoscience Australia is a new fourth edition of the Magnetic Anomaly Map of Australia. Hardcopy products at 1:5 million and 1:25 million scales will be available, together with

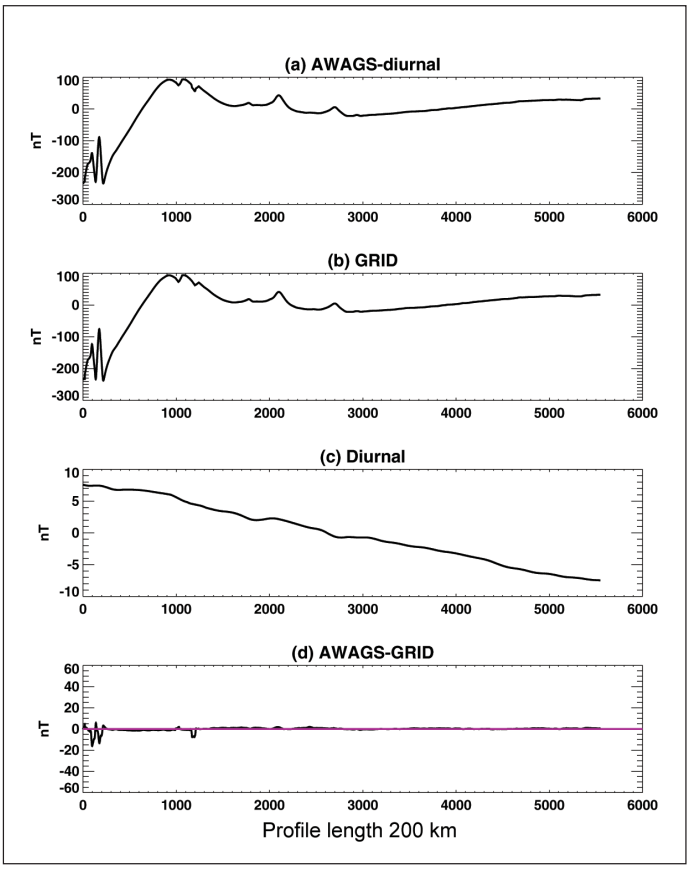

Fig. 4 (a). A good comparison of AWAGS traverse data with grid data. Profile (a) is diurnally corrected AWAGS traverse data, profile (b) is data interpolated off a grid at the AWAGS locations, profile (c) is the diurnal correction applied to the AWAGS data, and profile (d) is the difference between the data of (a) and (b).

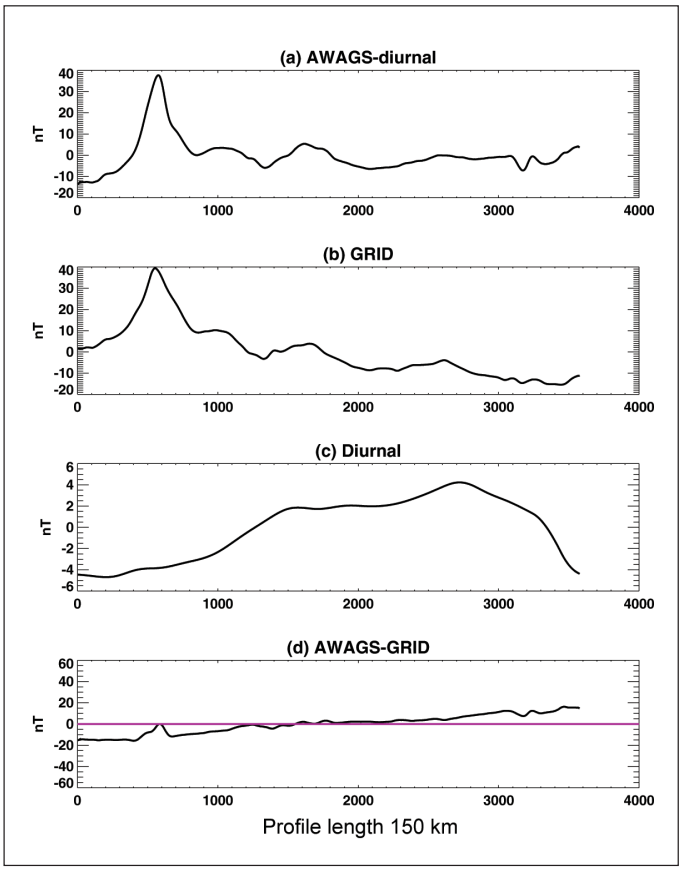

Fig. 4 (b). A poor comparison of AWAGS traverse data with grid data. Refer to Figure 4(a) for an explanation of profiles.

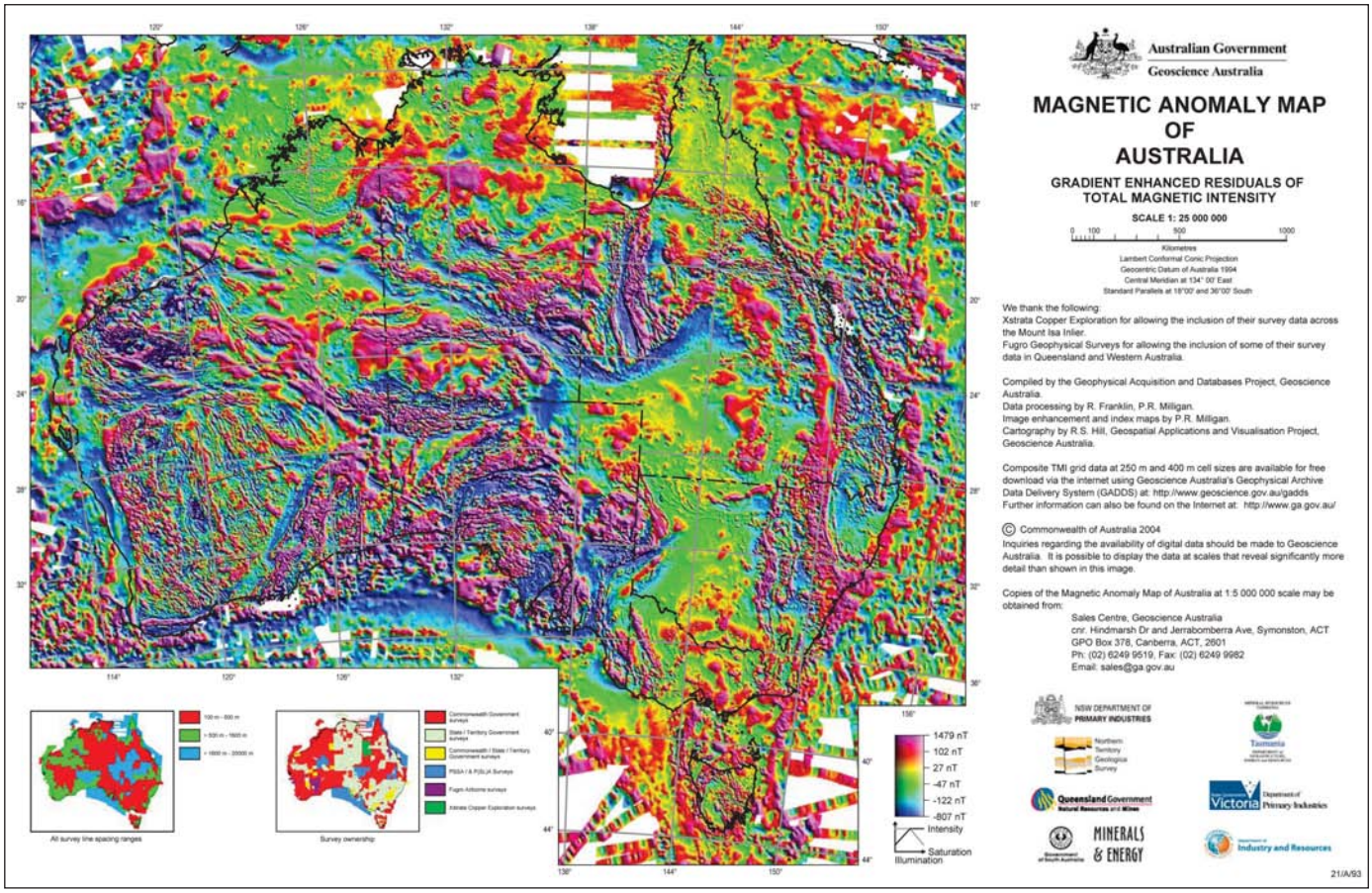

Fig. 5.The 1:25 million scale version of the fourth edition of the Magnetic Anomaly Map of Australia (A4 size handout).

composite grids of the Australian region at 250 m and 400 m grid cell spacings. With the addition of new data, and more accurate long-wavelength information, this map represents a significant advance in the representation of TMI data across the Australian region, compared with previous versions. Figure 5 shows the 1:25 million (A4 size handout) version of the map.

(b) Other derived products

Once a directory of matched grids has been produced, any number of further products can be automatically generated. For example, any region of interest may be chosen and the grids merged seamlessly to a user-specified cell spacing. Individual project grids of, for example, reduced-to-the-pole, vertical and horizontal gradients and the analytic signal can be calculated automatically. For continental-scale composite grid data at high resolution, preliminary reduced-to-the-pole and vertical derivative grids have been generated by using an overlapping tile system in a batch process.

(c) Comparison of Long Wavelengths with Satellite Magnetic Data

The "Decade of Geopotential Research" is now at the halfway stage, with perhaps the most impressive new worldwide magnetic data coming from the CHAMP satellite. This satellite was launched in 2000, at an initial altitude of 460 km. Although this is similar to the altitude of the older Magsat satellite, towards the end of CHAMP's life in 2007 it should collect data from considerably lower altitudes (to less than 300 km). This will enable resolution of shorter spatial wavelengths of the crustal magnetic field than has been possible previously.

Such satellite data provide an independent dataset for comparison with continental-scale compilations of airborne magnetic data, for the longest wavelengths of greater than 500 km.

The new Australian composite grid has been compared with the CHAMP MF3 crustal field model (Maus *et al*., 2004) using the method of Ravat *et al*., 2002. In this method, the satellite and aeromagnetic data are jointly inverted using an equivalent source layer. The jointly estimated anomaly fields at satellite and aeromagnetic altitudes are then compared with observed data to examine if they are compatible, or if there could be problems with one or both. If the same distribution of equivalent sources can reproduce (to a high level of correspondence) the potential fields over the same region at both aeromagnetic and satellite altitudes, then the data are compatible. If not, then one or both must have errors, at least in certain wavelength ranges, making them incompatible.

This comparison gives a correlation coefficient of 0.75 for the new Australian aeromagnetic data with the jointly estimated field (using wavelengths in a pass-band of 500 km to 3000 km) (Figure 6). But the amplitudes between the data sets do not match perfectly. However, this is much better than the correlation coefficient of 0.45 resulting from the comparison with the third edition grid of Australia. In computing the correlation, the aeromagnetic data is the independent variable and the satellite

data the dependent variable. Because we are using these correlation coefficients as a gross measure in a relative sense (i.e., in judging improvement with respect to another identical data set), rigorous consideration of errors in various data sets or data spacing is not critical.

For further insight into these numbers, some of the most compatible data sets in the world compared in this manner are the Canadian long profile data and the U.S. Project Magnet long profile data processed with the Comprehensive Model of Sabaka *et al*. (2002). Those comparisons yield correlation coefficients of >0.95 and the amplitudes among the data sets are also similar. It is very difficult to get the long wavelengths better in aeromagnetic data without making use of more long aeromagnetic profiles flown in a relatively short time.

Conclusions

A new database of matched grids for airborne TMI data has been developed by Geoscience Australia, using the independently-acquired AWAGS airborne traverse data as both a constraint in the merging process and as a test of grid quality. A variety of derivative products can easily be produced from this new dataset, and composite TMI grids at 250 m and 400 m grid spacing form the basis for the new fourth edition of the Magnetic Anomaly Map of Australia.

A low-pass filtered composite grid of the Australian region has been compared with CHAMP satellite magnetic data, and shows a considerable improvement in the correlation of long wavelength components compared with the previous edition.

A significant improvement is expected in the accuracy of intermediate wavelength magnetic anomalies (about 100 to 500 km wavelengths), but we are yet to rigorously test this improvement

Acknowledgements

We thank the Geophysical Acquisition and Databases Project of Geoscience Australia for collation, archiving and indexing of airborne geophysical surveys into the National Airborne Geophysical Database. In particular, we thank Murray Richardson and Peter Percival for valuable help and advice. We also owe much to the people of the old Airborne Geophysics group of Geoscience Australia, who were responsible for much data acquisition, processing and archiving over nearly 50 years of Commonwealth Government surveying.

We thank the following State / Territory government departments for their data:

- New South Wales Department of Primary Industries
- Department of Business, Industry and Resources Development Northern Territory
- Natural Resources and Mines Queensland
- Department of Primary Industries and Resources South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Primary Industries Victoria
- Department of Industry and Resources Western Australia

and also Xstrata Copper Exploration and Fugro Geophysical Surveys for permission to use their data.

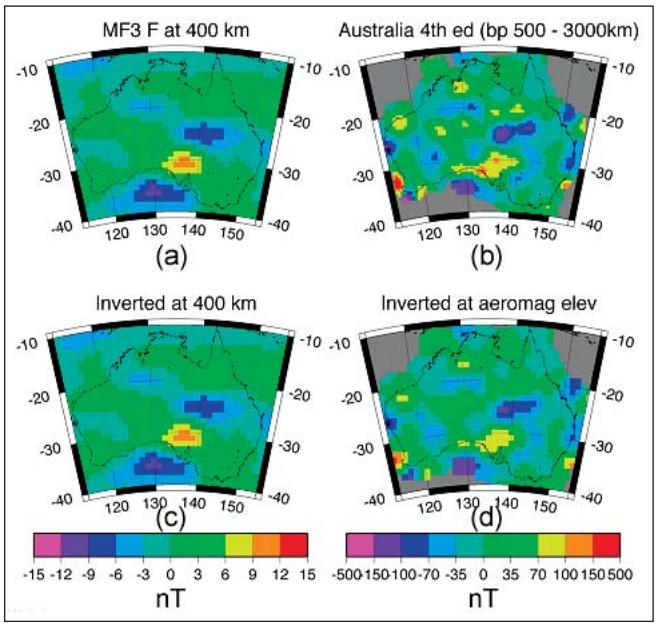

Fig. 6. Comparison of Australian composite magnetic grid with the MF3 CHAMP satellite data model for the total magnetic field. A correlation coefficient of 0.75 is obtained for the new composite TMI grid of Australia (b) with the jointly estimated field (d) (using wavelengths in a pass-band of 500 km to 3000 km).

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Risk Assessment in prospect evaluation from a geophysical perspective

Compiled, with the help of the authors
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Portfolio Managers and Geophysicists from a variety of disciplines attended an ASEG workshop on Risk Evaluation at the Australian Resources Research Centre in Perth on 22nd – 23rd July 2004. An insight was offered into risking techniques and the ways in which geophysical data can be used to enhance these techniques.

The workshop was opened by the SEG 2004 Spring Distinguished Lecturer, **Bill Abriel** with a talk entitled *Earth Model Complexity and Risk Description in Resource Exploration and Development*. He described accurate risk assessment of prospects as the "Holy Grail" of the petroleum industry and said that although Geophysics has had an important part in identifying prospects it tends to play a lesser role in quantifying the risk involved in drilling them. He stressed the need to understand the range of earth complexity of the overburden to determine the accuracy of the seismic imaging, and the complexity of reservoir rocks to correctly risk the quality and connectivity of flow compartments in oil and gas fields.

Seismic technology was considered to be a complex business. Historically, imaging and analysis tools have been adopted or required simplifying assumptions in order to complete projects in a timely manner or simplify the descriptive analysis. Many of these assumptions are in widespread use today. Examples of this can be seen in seismic data processing applications that rely on a "flat earth" simplification, or reservoir analysis based solely on "bright spot" amplitude anomalies.

The difficulty facing earth scientists today is to understand, use and describe the right level of earth complexity for reservoir discovery and analysis. Using more complicated tools than necessary destroys project value by spending too much money and/or extending project time lines unnecessarily. However, using a tool that is too simple for a complex earth leads to a false sense of certainty and a commonly incorrect prediction (often wrong but never in doubt!). He gave examples of decision analysis and ways of capturing uncertainty. His future prediction was that a deeper understanding of the complex earth, the use of even higher level geophysical tools and a combination of the two would be needed. Emphasis was placed on the communication of risking results and uncertainties.

Dennis Cooke of Santos spoke on *Quantifying Exploration Risk using Seismic Attributes*, and covered portfolio theory, empirical methods, Bayesian methods and stochastic inversion.

The Case Studies forum had a foreign flavour with **Troy Thompson** of Downunder Geosolutions speaking on *Application of integrated risking to a South African Prospect* followed by **Jan Rindschwentner** of Santos on *The importance of upscaling – in the context of Monte Carlo modelling*, a US example and **Greg Smith** of Woodside on *Uncertainty Management of the Chinguetti Field* in Mauritania.

The Chinguetti Field was discovered in 2001 offshore Mauritania in 800 m of water. Greg emphasised the need for careful risk management for the development of a moderate sized field in a deep-water environment. Chinguetti was described as being comprised of deep water, mid-slope turbidite reservoirs, trapped in a dome over a salt diapir. The hydrocarbons are compartmentalised by concentric radial faults, in a low net:gross sequence, with oil mainly in channel sands (see Figures 1 and 2).

According to Greg, the large number of uncertain variables required a structured approach and a rigorous assessment of the potential subsurface scenarios, using a synthesis of well and seismic datasets, to produce realistic 3D models. The main subsurface uncertainties were identified by uncertainty framing and included: structure; hydrocarbon contacts; fault seal; distribution of the channel systems; frequency and amalgamation of channel sands; shale drape; internal channel heterogeneity; effective pressure support; rock-fluid interaction; rock compaction; fluid composition/ properties; and rock properties.

A statistical experimental design determined 27 scenarios to accurately model the probability distribution of reserves. A 3D model was made for each and run through the dynamic simulator to estimate economic ultimate recovery (EUR). Multivariate statistical analysis produced a response equation for the reserves and the probability distribution. Greg described the range of scenarios and response equations as being extremely useful in testing development options that would otherwise not be apparent. The technique rapidly captures the range of likely outcomes and immediately focuses effort onto a flexible approach to the main uncertainties, thus saving considerable rework and development time.

Mark Beeson in his talk *Never Mind the Attributes where's the Geology* described the importance of the seismic image in extracting real information about geology. He advocated that the geological model based

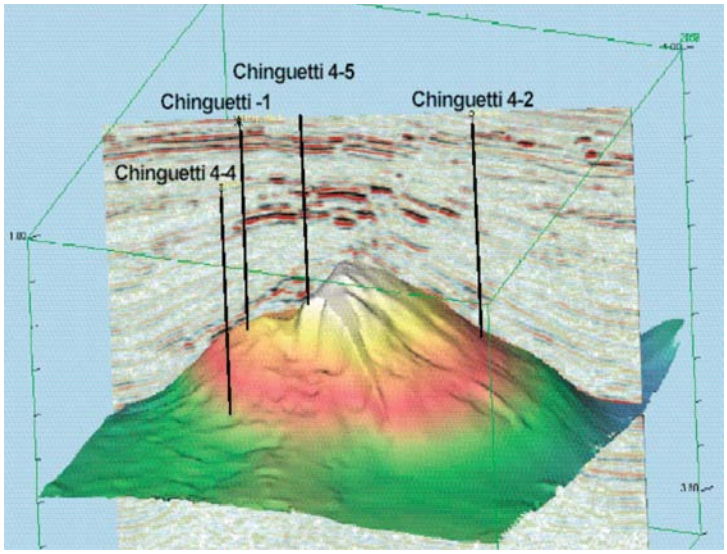

Fig. 1. 3D Schematic View at Base A Sand Reservoir Chinguetti field, Mauritania

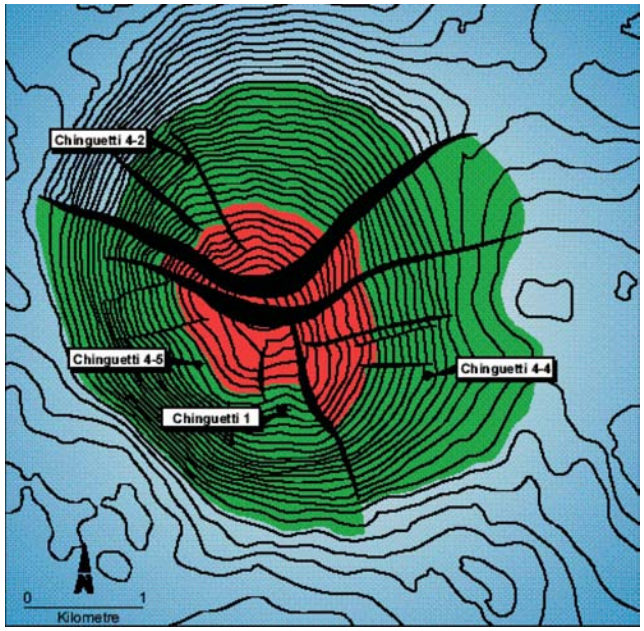

Fig. 2. Depth Structure Map Top A Sand Chinguetti Field, offshore Mauritania

upon the integration of well and seismic data should be kept accurate by minimising assumptions that link the data to the model.

The shortcomings of assuming attributes were considered to offer a short cut to making an accurate model when the seismic or well data are ambiguous were considered, and that the inappropriate use of attributes to reduce risk was more likely to increase it. An increasing number of attributes was recognised with the use of 3D/4D data allowing the generation of new ones all of the time e.g. 'sweetness' a combination of instantaneous amplitude and frequency. He referred to the basic suite of attributes in Taner's 1979 paper in which a major part was the use of colour to enhance the differentiation of events and attributes in the seismic data, which is routine using workstations in 2004, but was not so when using paper prints in 1979.

With the increasing amount of pre-stack data on our desktops, Mark saw attributes as an attractive way to reduce the volume of data to be considered. He warned of pitfalls applying the mathematical trick (Generalized) Principal Component Analysis, whereby a larger number of variables can be reduced into a few perpendicular elements. The task of analysing the volume of seismic attributes is thus reduced but their relationship to the geology is obscured. He stressed the need to directly link geology to any of the components to be confident of which attributes to use.

Acoustic impedance (AI) is an attribute that is often used to expand simple amplitude variations in the P-wave seismic field. The wavelet is extracted from the seismic leaving the layers whose boundaries generated the reflections. There are a variety of different ways to derive an answer and thereby a model but the answers are non-unique. The incorporation of a discontinuously sampled density field into the continuously sampled P-wave field imposes further assumptions. The addition of an inaccurate low frequency model from well data can corrupt an accurate model from seismic. If the original seismic image is poor, then its inversion for AI will also be so. AI is a post-stack process and with an increasing use of prestack data, which might carry more information about porosities and fluid content, AVO (Amplitude Variation with Offset) techniques for AI were developed.

Elastic impedance enhances the discrimination of fluids over acoustic impedance and is stabler than simple AVO measurements, but it too relies on some fundamental assumptions. One being that it fixes Poisson's ratio (Connolly, 1999). This may mask important changes in the fundamental physical properties of rock layers such as the bulk and shear moduli, which cause non-linear changes to P-wave and S-wave velocities. These can be described as changes in Poisson's ratio, in other words this assumption fixes the very thing that we know to be varying in the first place. Extended Elastic impedance improves upon Elastic impedance by some innovative mathematical manipulation in that it allows the development of a direct relation between porosity, fluids and the variation of extracted impedances with non-normally incident wavefields. These are indisputably useful attributes, which should be derived and applied with care. They are not to be trivialized by ignoring the impact of the assumptions that underpin them.

Which attributes are worth using and where or when is it a mistake to use even basic observations such as amplitudes? Kalkomey, (1997) set some excellent ground rules based upon observations of spurious attribute correlations with geology.

- "The probability of observing spurious sample correlations between a seismic attribute and well data can be quite large if the number of independent well measurements is small or the number of independent attributes considered is large."

- "When the probability of a spurious correlation is large, then selection of seismic attributes based solely on empirical evidence is risky – it can lead to highly confident, but highly inaccurate predictions and thus poor business decisions."

- "…only those seismic attributes that have a physically justifiable relationship with

the reservoir property be considered as candidates for predictors."

Fundamentally, use an attribute when you understand what geological changes are causing changes in the attribute. Do not use an attribute where you have low confidence or little understanding of the link between that attribute and the geology.

The Ceiba Field (Equatorial Guinea) was analysed by examining amplitude variations with offset and those amplitudes used to define the porosity and fluid distribution in a deepwater clastic geological model (Figure 3). The model was extended to attribute permeabilities and the amplitude derived porosities. Whilst core/log calibration of these is possible, uneven sampling of the geology in the well calibration points led to a systematic overestimation of permeability, which cannot be directly measured by conventional seismic-streamer acquired data. Ultimately this led to a gross overestimation of the field's reserves and a half billion dollar write down. Sad in any case, but when the field, indeed the entire company, had changed hands in the interim, a salutary example of the limitations of seismically derived attributes.

Bayes Theorem as used in risking, presented by **James Gunning** of CSIRO, introduced a new method for model-based Bayesian seismic inversion. It uses a layer-based prior model with rock physics information taken from log analysis as the basic structure to generate reflection seismic data. His model allowed for uncertainty in both the fluid type and saturation in reservoir layers: variation in seismic responses due to fluid effects are taken into account via Gassman's equation. The software supports multiple stacks and performs a full AVO inversion using approximate Zoeppritz equations. Uncertainties and irresolvabilities in the inverted models are captured by the generation of multiple stochastic models from the Bayesian posterior, all of which acceptably match the seismic data, log data, and rough initial picks of the horizons.

Post-inversion analysis of the inverted stochastic models then facilitates the answering of commercially useful questions, e.g. the probability of hydrocarbons, the expected reservoir volume and its uncertainty, and the distribution of net sand.

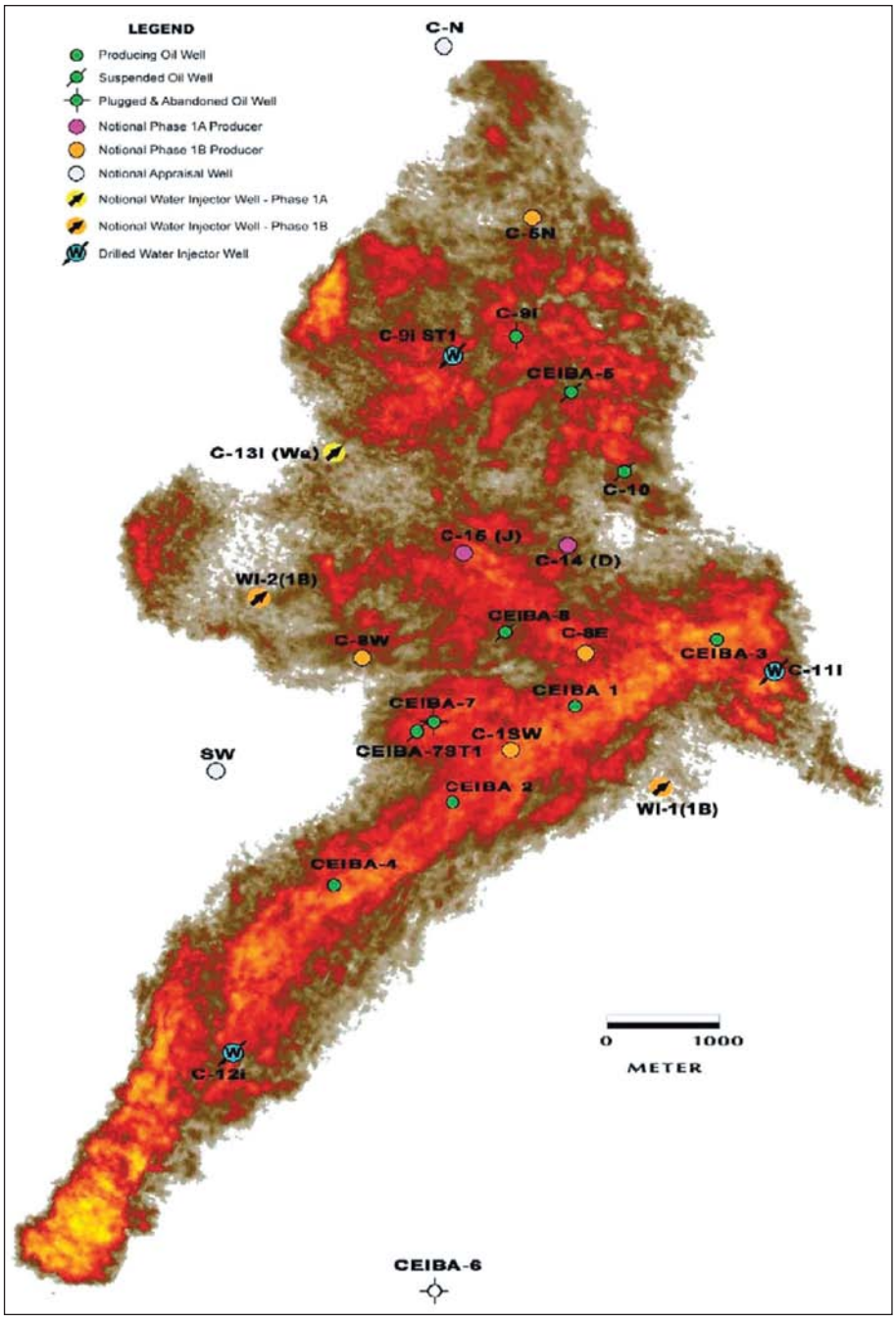

Fig. 3. Ceiba Field – RMS amplitude showing channelized nature of the field's geology and inferred (in conjunction with appraisal well control) to confirm the presence, connectivity and quality of reservoirs (Dailly et al., 2002)

- *2000 - >100,000 bopd 3 producers and three injectors. Facilities for 120,000bopd,*
- *2001 – Over 50,000 bopd. 41,000 bopd at Hess takeover August 2001,*
- *2003 – 22,000 -25,000 bopd. 12% reserves drop US$530M charge on Hess balance sheet.*

***Ceiba field** – permeability from AVO porosity & fluids (Dailly et al., 2002)*

- *2000 - >100,000 bopd 3 producers and three injectors. Facilities for 120,000bopd.*
- *2001 – Over 50,000 bopd. 41,000 bopd at Hess takeover August 2001.*
- *2003 – 22,000 -25,000 bopd. 12% reserves drop US$530M charge on Hess balance sheet.*

Matt Lamont of Downunder Geosolutions presented a quantitative way to assess structural uncertainty in the velocity field for pre-stack depth conversion. He recommended the use of tomography before high resolution velocity analysis.

Kevin Dodds of CSIRO gave his talk on Juniper entitled *Interval probability process as a tool for drilling decisions analysis - the R & D perspective: the uncertainty arising from the poor predictability of overpressure and its impact on drilling costs and prospect evaluation*. This paper illustrates such

a decision and risk analysis methodology through reference to the application of the process to a specific exploration prospect with a perceived high risk of overpressure. Although the case history was assessed prior to drilling, the process has the potential to be developed into a robust framework within which real-time decisions can be made. The risk analysis technique used is interval probability analysis and provides a framework for the incorporation of geological and geophysical studies along with the well construction, safety and planning decisions prior to selecting a well for drilling. This framework is also able to record the circumstances related to people, timing and resources, as well as absence of information which can be just as important within the risk assessment. The analysis used a rigorous process to elucidate and define the areas of uncertainty associated with each component of the process. The project was undertaken by a team comprising a number of disciplines and organisations from ChevronTexaco, Schlumberger, and CSIRO. This risk assessment was directed toward a decision point for well design, which had cost implications in anticipation of drilling.

The final talk was the SPE Distinguished Lecture given by **Steve Begg** from the University of Adelaide, entitled *I would rather be vaguely right than precisely wrong: a new approach to evaluating oil and gas investments*. He suggested that industry performance may be taking on a cult of mediocrity and quoted from Ed Merrow of Independent Project Analysis (IPA) that the last 10 years might be called 'a decade of unprofitable growth' for many upstream companies. Based on the analysis of more than 1000 E&P projects: two thirds of which were offshore $1million – $3billion projects, one in eight of all major offshore developments in the last decade falls into the 'disaster' category. This means that they failed on two out of three metrics: >40% cost growth, >40% time slippage, produced <50% than 1st year plan. The average CapEx for these is $670M. The record was even worse for mega-projects with a CapEx of $1 billion or more.

According to Steve, decision–makers need to make better, smarter decisions. But what is "better" and how is it defined in the context of uncertainty? His statement was based on two main observations;

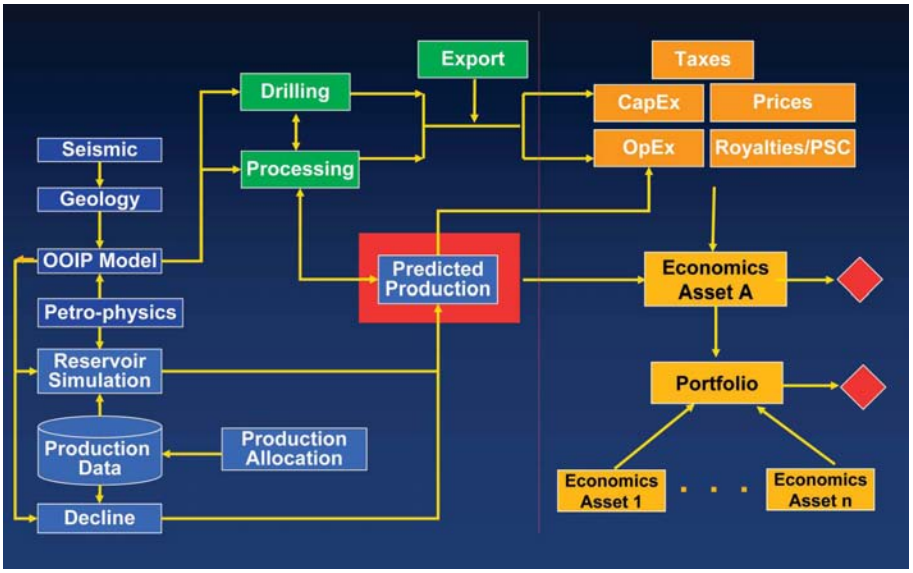

Fig. 4. Modelling the "system": uncertainties and dependencies are everywhere.

1. Over the past two decades, many oil companies have suffered disappointment from not returning forecasted technical and economic metrics that were the basis of their investment decisions. This implies a systematic over-estimation of returns and/or underestimation of the risk of loss, whose underlying cause is uncertainty around current and future "states of nature/ world". There is strong evidence that people in general, and experts in particular, grossly under-estimate uncertainties.

2. For improved margins, often by merger, down-sizing and reduced cycle times, is making it imperative for companies to do more with less. They need to make wiser, faster decisions that use an appropriate level of technical analysis with the acquisition of appropriate data (type, quantity and quality). But what is "appropriate" and how is it defined in the context of uncertainty?

Uncertainities and dependencies are frequently underestimated.

We spend a lot of money without always knowing which uncertainties really matter.

We were reminded of the reasons for most projects giving lower than expected returns. A look was taken at uncertainty at many levels and how it can affect decision-making.

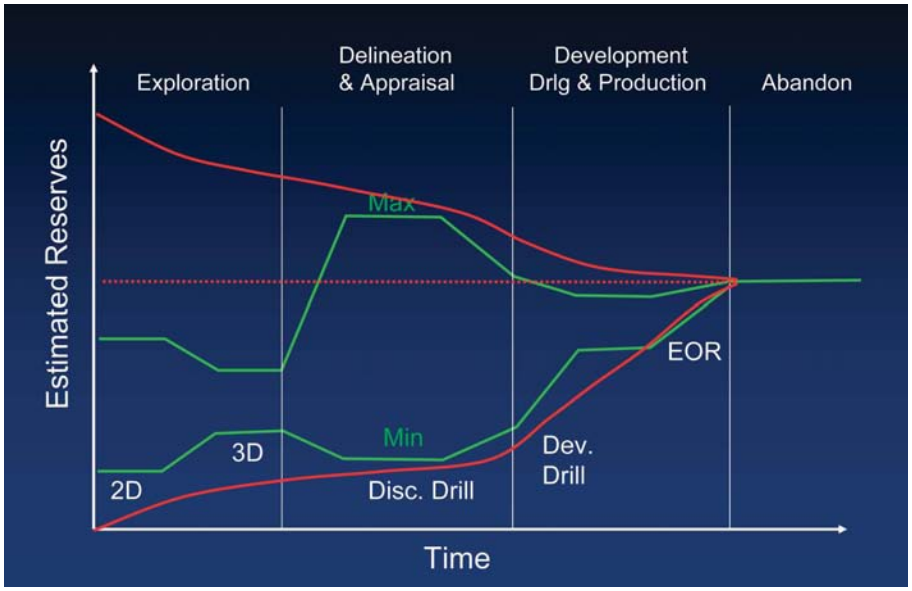

Fig. 5. Uncertainities and dependencies are frequently underestimated.

Four different options were presented for an uncertain world.

1. Ignore uncertainty - an historical E&P approach (at the decision stage)
2. Try to reduce uncertainty - value of information
3. Take measures to live with uncertainty - value of mitigation plans (passive flexibility)
4. Exploit the uncertainty - value of active flexibility

We spend a lot of money without always knowing which uncertainties really matter.

He suggested that uncertainty is not a bad thing whereas many managers believe that uncertainty is a problem and should be avoided. He suggested that you can take advantage of uncertainty. Strategic investments will be sheltered from its adverse effects while remaining exposed to its upside potential. Uncertainty will create opportunities and value. Once your way of thinking explicitly includes uncertainty, the whole decision-making framework changes (Amram and Kulatilaka, 1998).

Ample time was allowed between presentations for discussion or brainstorming sessions with experts in risk assessment. Panel discussions were steered by the Chair, John Hughes of Santos. During one discussion time Steve Begg gave the audience some light-hearted psychological tests that exposed their bias in decision making. I was one of the majority who made an ape of themselves by failing to spot a black gorilla amongst the basketball players.

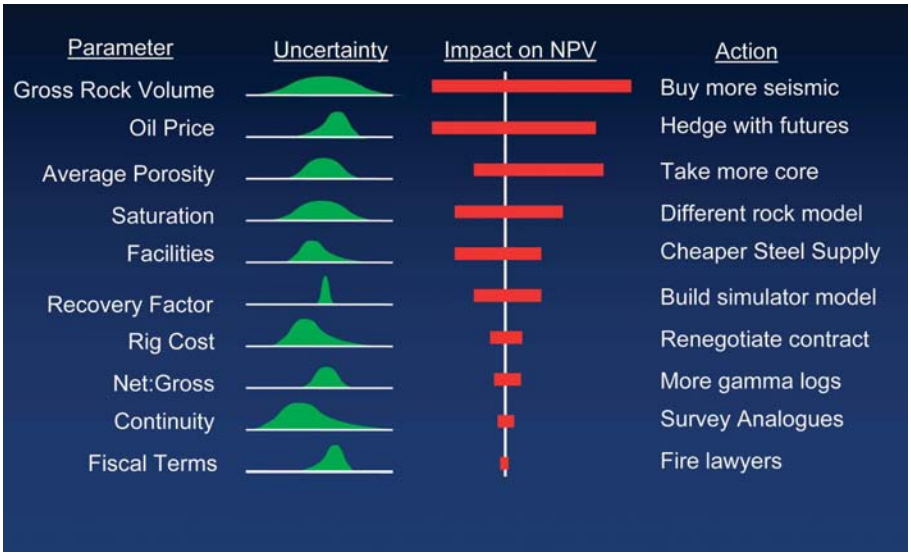

Fig. 6. We spend a lot of money without always knowing which uncertainties really matter.

In the evening, workshop delegates (see Figure 7) were treated to dinner and drinks at the Irish Club in Subiaco prior to day 2 of the workshop. A very successful workshop was due to the efforts of the organising committee of John Hughes, Matthew Lamont, Dennis Cooke, Andrew Long, John Cant and Don Sherlock.

Fig. 7. Delegates at the Risk Assessment in prospect evaluation workshop

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Rindschwentner, J. On the importance of upscaling – in the context of Monte Carlo modelling (US example). Presentation to workshop.

Smith, G. C., Rayfield, M.M., DePledge, D.D. & Gupta, R.The Chinguetti Deep Water Turbidite Field, Mauritania: Reserve Estimation and Field Development using 3D Models. Presentation to workshop.

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Thompson, T. Application of integrated risking to a South African Prospect. Presentation to workshop.

2003 Gawler Craton Deep-Seismic Survey Results

The eastern Gawler Craton is home to the gigantic Olympic Dam Cu-U-Au deposit, the type-example, and largest, of the Fe oxide Cu-Au class of deposit. The basement host rocks of the mineral system are completely concealed by hundreds to thousands of metres of sedimentary cover. The eastern Gawler Craton has been reluctant to reveal its secrets and mineral riches.

Because of the obscuring cover, what we know of the basement has come from geophysics and a scattering of drillholes from a region of tens of thousands of square kilometres. Although these potential-field geophysical data have given us many clues to the nature of the mineralised basement, more constraints are needed to build a 3D geological picture of the regions mineral systems. Geoscience Australia, in collaboration with the Primary Industries and Resources of South Australia, came to the fore when they shot 250 line-kilometres of deep seismic reflection data in August 2003 (Figure 1; see also Preview Issue 110, Deep Seismic Surveys by ANSIR and Geoscience Australia). The survey was done as two orthogonal lines, centred on the Olympic Dam minesite.

The data and results from the 2003 Gawler Craton seismic survey were released last August at the Gawler Craton: State of Play 2004 and Seismic Workshop, held in Adelaide (Figure 2). Presentations to over one hundred participants with exploration interests in the Gawler Craton, were well received and stimulated much discussion - even though they turned some people's cherished ideas upside-down.

The seismic survey has clearly imaged the crust to depths below the Moho (Figure 3). It shows the obscuring cover successions, the principal basement units, and the network of shears and faults that provided the plumbing system for fluids that formed the Fe oxide Cu-U-Au mineralisation.

The results confirmed some of the predictions from both forward and inverse potential-field modelling done at Geoscience Australia, notably, the lack of large mafic plutons implicated in many of the models of ore genesis.

The 2003 Gawler Seismic Survey is providing new insights for exploration strategies. Three-dimensional constraints on the geology and structure of the basement have been extracted from the two deep seismic lines and used as the framework for a new 3D model of the region. The seismic data are particularly valuable in that they provide depth constraints to 3D inversion of potential-field data, which has already gone a long way to showing the structural controls and regional distribution of the tell-tale magnetite and haematite alteration associated with the Cu-U-Au mineralisation. (see Preview Issue 109, Regional constrained 3D inversion of potential field data from the Olympic Cu-Au province, South Australia).

For further information please contact Patrick Lyons (Patrick.Lyons@ga.gov.au) or Bruce Goleby (Bruce.Goleby@ga.gov.au) or visit the Geoscience Australia website www.ga.gov.au.

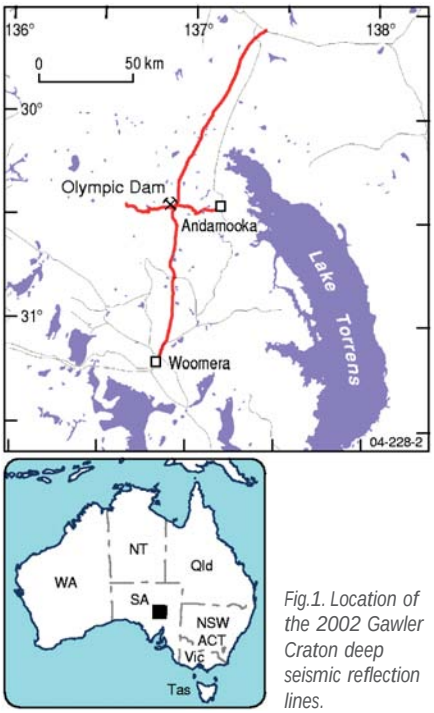

Fig.1. Location of the 2002 Gawler Craton deep seismic reflection lines.

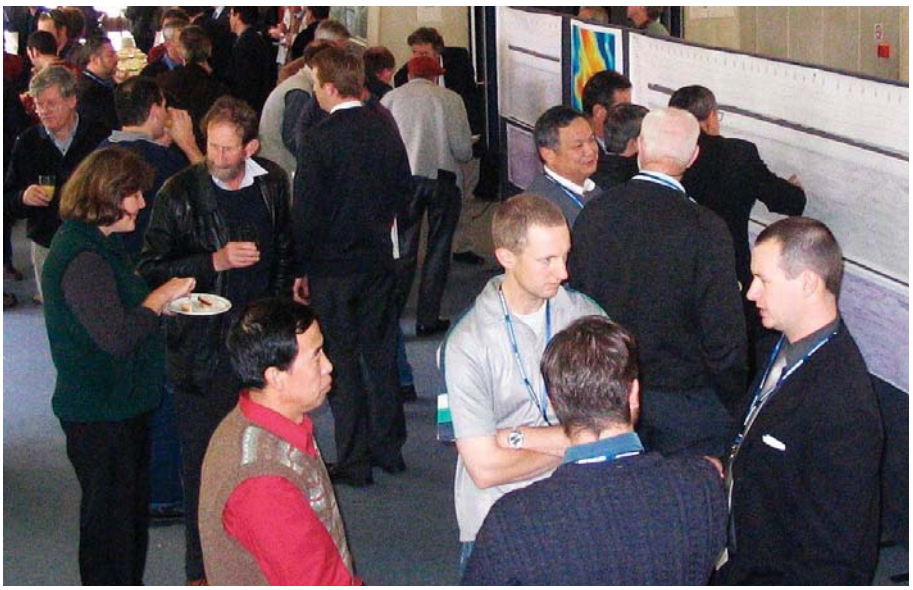

Fig. 2. Participants discussing implications of the recently released deep seismic reflection results from the Gawler seismic survey at the Gawler Craton: State of Play 2004 and Seismic Workshop, held in Adelaide last August.

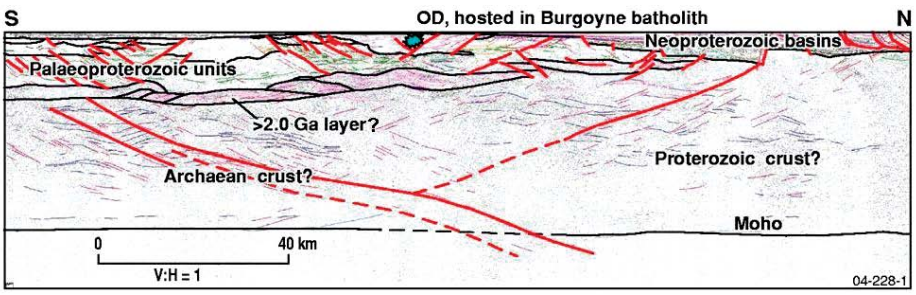

Fig. 3. Summary diagram showing key features of the 2002 Gawler Craton deep seismic reflection line 02GAOD1. OD is the site of the gigantic Olympic Dam Cu-U-Au deposit. Red lines are interpreted fault or shear zones. Black lines are boundaries to the main rock packages.

Doppler velocity – the next advance for airborne gravity?

If the velocity of an airborne gravity meter could be measured to an accuracy of an order of magnitude better than currently, the resolution of the gravity surveys would be improved by a similar factor.

Modern portable gravity meters measure the net acceleration vector with exquisite precision several times a second. Apart from measuring the gravity vector at each point in the travel, the gravity meter is simultaneously measuring the accelerations of the aircraft relative to the inertial or 'fixed' frame. That is different to the acceleration of the aircraft relative to the ground. Rotations make the difference.

'Acceleration' is a bit of a misnomer. It would be more correct to say that gravity is a 'specific force' because a gravity meter sitting on the ground seems not to be accelerating anywhere, but we still say that it measures 9.8 m/s^2 rather than 9.8 N/kg.

The aircraft does not jostle like a truck banging along a corrugated road. Its speed changes little. Rather, aircraft are designed for stability, so that a change in lift over this or that surface causes a passive response by the aircraft to swing into a corrective posture. That is, it rotates about one of its three axes. Similarly, the pilot's response to a deviation is to roll, pitch and yaw the aircraft – s/he does not stomp on the brake or accelerator. In both senses the acceleration of the aircraft is primarily a rotation of the velocity vector more than a change in its speed.

Perhaps you remember a diagram of a velocity vector rotating through angle delta theta in time delta tee, with the resulting delta vee being perpendicular to everything else? We end up with $\mathbf{V} \times \omega$, the vector acceleration for curved flight.

Angular velocity w is already measured with high precision by so-called 'optical gyroscopes', developed by navigation instrument makers like Rockwell. Passenger airliners commonly use them to navigate several radians around the earth with microradian accuracy. If the vector velocity can be measured to the same certainty, then the acceleration for curved flight is similarly known.

Currently airborne gravity surveys calculate the apparent acceleration from a double differentiation of the already noisy GPS positions, resulting in severe noise. Subsequent noise filtering obliterates the included signal out to a half-wavelength of 2.8 to 3.0 km. Instead, if we can account for most of the accelerations of the aircraft by calculating $\mathbf{V} \times \omega$ we are only introducing the noise due to at most a single differentiation. Further, we may be able to measure the velocity vector directly.

Apart from the acceleration relative to the ground, we have to correct for the fact that the aircraft is flying in a rotating frame. Any point we normally consider as fixed by having constant latitude, longitude and elevation is itself being accelerated as it is drawn around with the earth's rotation. And an apparently constant velocity vector is changing in direction for the same reason. We seek the resulting acceleration vector.

Why bother with the vector acceleration? Aren't we only interested in the vertical component? Two reasons say we should. Firstly, any real gravity meter is affected by transverse forces. If the correlation can be measured, a correction can be made. Secondly, the self-levelling table on which the gravity meter sits will not always be levelled exactly to the desired vertical, if only because there must be some lag between a detected pointing error and the response of the table. A larger lag due to a damped response may be intentional too. The gravity meter may perform better if deviations from vertical are corrected for rather than if it were subjected to excessive angular accelerations.

Apart from remaining linear accelerations, the value of $\mathbf{V} \times \omega$ is the total correction for the accelerations of flight and the earth's rotation. The logic of the correction reads more easily if we stick to the algebra of the velocity **V** and angular velocity w as measured in a geocentric fixed frame. However, we are more familiar with quantities measured relative to the surface of the rotating earth.

In the rotating frame, the algebra of accelerations quickly swamps one's page with puzzles and in my case at least, with errors. Linear accelerations must now be rotated algebraically, which I will not do here. However it is interesting to rotate the velocities.

Familiar factors such as the apparent velocity Va and the yaw, pitch and roll vector wa can be accounted for if we include the earth's rotation as Ve and we:

$$\mathbf{V} \times \omega = (\mathbf{V}_a + \mathbf{V}_e) \times (\omega_a + \omega_e)$$

Of the four terms arising from multiplying out the right hand side, only the first is intuitive.

$\mathbf{V}_a \times \omega_a$ describes the familiar flight of a bird through the air, swooping and swerving in response to changes of plan or bumps in the air. For a survey aircraft, mild turbulence can easily give rise to 1 m/s^2, and the gentlest of pilot's corrections can easily be 0.1 m/s^2 in any direction.

$\mathbf{V}_a \times \omega_e$ you may remember as the Coriolis force. Its direction is well defined, being perpendicular to the earth's axis and to the momentary flight path. Its vertical component is familiar to us as the Eötvös correction of marine surveys. Because $\mathbf{V}_a$ varies in direction and magnitude the correction needs to calculated for each point along the path. If $\mathbf{V}_a$ is 80 m/s then $\mathbf{V}_a \times \omega_e$ is 80*0.000073, ~ 6 mm/s^2.

$\mathbf{V}_e \times \omega_e$ is familiar to us as the centrifugal force. In ground surveys its vertical component is part of the latitude correction. It is remarkable only in that it causes the "vertical" of a plumb-bob to be different from the normal to the geoid and different again to the line of the geocentric vector. Up to 30 mm/s^2, it varies perhaps 1 mm/s^2 across a survey.

$\mathbf{V}_e \times \omega_a$ is the least intuitive of all the cross terms, seeming to be forced on us by the algebra. It would still be significant however, because $\mathbf{V}_e$ rises to a thousand knots, 500 m/s^1, at the equator. Further, ω_a expresses every wiggle of the flight path, typically on a radius of curvature of several kilometres, thus ~0.01 rads per second, pointing every which way. In isolation the $\mathbf{V}_e \times \omega_a$ term seems to contribute up to 5 m/s^2, so is presumably

offset somewhere else in the algebra. Perhaps I have made an error. Its wavelength is close to the wavelength of the signal, so would be important to the correction. The term has low noise, as it does not rely at all on GPS. But is it used in the corrections? It would be wise to check.

Regardless, my argument offers the combination of velocity **V** and angular velocity w as both being more important than the double differentiation of the GPS values and introducing less noise. Although the angular velocity w is already measured in the absolute sense by the optical gyroscopes, we still need a measure of the velocity **V** relative to the fixed frame.

There is a promising potential source of a very precise measurement of V in the fixed frame. The carrier-wave frequencies of the global positioning satellites are exquisitely pure, stable to an order of magnitude of 10^{-14}. The Doppler shifts of these signals as measured by a moving aircraft express the velocities of the aircraft relative to the satellites. When there are more than three satellites in the sky, the redundancy will allow an instrument to use the redundancy in carrier frequencies to provide an effective reference frequency. A set of Doppler shifts derived by this means would then be referenced to the known trajectories of the satellites to provide an absolute velocity vector **V**, that is, **V** in the geocentric fixed frame.

In 2004, hosted by the Australian Space Network, the European Space Agency toured Australia, inviting technology transfer ventures. At the Darwin meeting the possibility was raised of developing a portable Doppler instrument.

The timing is convenient. ESA is planning an independent global navigation satellite system called Galileo with the first launch in 2008. The know-how of Galileo's engineering team is already creating the spaceborne system of transmissions, the same know-how which would be needed for developing an airborne instrument to measure their Doppler shifts.

The first of the technical discussions is occurring as I write in November 2004, as the Australian Space Network co-ordinator, Philip Young, has his initial meeting with the Galileo engineering team in the Netherlands.

His authorisation is a letter signed by Howard Golden, President of the ASEG, asking if ESA knows how to build a system approaching an accuracy of 1 $\mu m/s^2$ over 15 s of flight, implying a half wavelength of 1200 m.

Once ESA establishes feasibility the question of development will arise.

Somewhere down the track we can hope to see an instrument that gravity contractors would hire to fly with their gravity meters. If our knowledge of the velocity vector is thereby improved to the level of the optical gyroscopes, so also will be our knowledge of the dynamic accelerations and the gravity signal they have been concealing.

Once built, the instrument would have a queue of customers. Between now and then there will certainly be room for partners to be involved in the project. Watch this space.

Feedback from the October Preview indicated that some of the charts showing the historical data on gold and oil prices could have been better displayed. We are therefore including in this issue, more detailed graphs on the price changes in these commodities since 1970, starting with gold.

Gold

The gold price has essentially been dominated by the huge 1979/80 peak (see Figure 1). Since then both the US$ and A$ prices have slowly declined in real terms, albeit with a few well defined excursions from the overall trends. Notice also that the price in US$ has declined more than the price in A$. However, in contemporary prices the price in Australian dollars has in general increased slowly but continuously since the early 1980s, whereas in US dollars the price has been slowly declining. It is clear that with the improvements in exploration and extraction techniques for gold in the last 30 years there is still money to be made by the efficient operator.

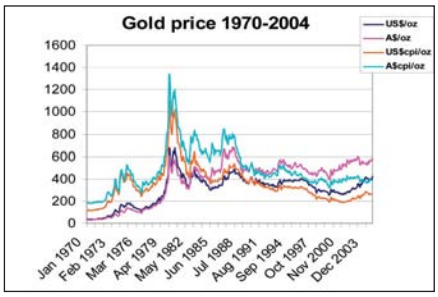

Fig. 1. Price of gold in $/oz from January 1970-2004. The US$/oz and A$/oz lines are in contemporary dollars. The US$cpi/oz and A$cpi/oz lines have been adjusted to a 1989/90 cpi index of 100 for both $A and $US.

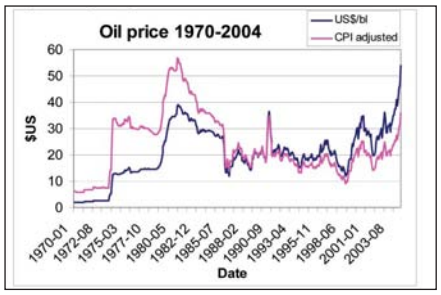

Fig. 2. The price of West Texas Intermediate crude oil, from 1970-2004. The cpi adjusted curve is normalized to a 1989/90 cpi index of 100. Notice the strong increase in price during the last five years. This contrasts strongly with the gold price and adds further support to King Hubbert's view that global oil production will peak in about 2010.

Oil

The oil price has varied much more erratically since 1970, particularly in the last five years. The price hikes in 1974 and 1980 dominate the graph. It is also evident that in the last five years the overall trend, whether in real or contemporary prices, has shown a clear increase in price. This is probably due to the increased cost of finding a barrel of oil, quite apart from the political aberrations that have also affected the price. It looks like King Hubbert got it right.

Australia's share of global mineral exploration declines

In a worrying trend in 2003, Australia's share of non-ferrous mineral exploration expenditure

fell to a record low of 15.5%. This was in spite of a slight increase in mineral exploration from $304M to $339M from 2002 to 2003. In fact since 1996 the Australian share has been either constant or has been in decline, as shown in Figure 3. The big mover has been Canada, which overtook Australia in 2002 and now attracts over 21% of the global exploration dollar.

The 2003 results are a real wake-up call for the Commonwealth Government to start being serious with the Resources Exploration Strategy and offer more attractive incentives to explorers.

Likely expansion at Olympic Dam

Encouraging drill results, expanding technical options and an improving long term uranium price mark the completion of WMC Resources Ltd's Olympic Dam Development Study.

A decision on the preferred mining option is expected early in 2005, with WMC due to deliver the Development Study findings in early 2006.

On 2003 numbers, Olympic Dam hosts the world's eighth largest copper and a third of the world's known uranium resources. The results of drilling to date suggest an expanded resource and more attractive mineralisation in the southern part of the orebody.

Speaking to investors and market analysts at Olympic Dam earlier this year, WMC Chief Executive Officer, Andrew Michelmore said, "The results to date of both our technical work and drilling program suggest that either massive underground mining techniques, or an internationally competitive cost base for open pit operations, are very viable options.

An "expanded Olympic Dam would become the world's largest uranium producer", Mr Michelmore said.

The first phase drill results suggest additional mineralisation at a shallower depth. The results indicate the potential for higher grade and higher copper-to-sulphur ratio mineralisation, possibly extending the utilisation of current surface plant operations and allowing an earlier commencement of mining in the southern ore body.

Building on the results so far, WMC is intensifying the drill program and technical work, while the study team has initiated detailed discussion with the South Australian Government on key infrastructure, environmental and logistics requirements.

Meanwhile Xstrata is on the prowl again

While Andrew Michelmore was extolling the virtues of WMC and Olympic Dam, Mick Davis the CEO of Xstrata is showing more than a passing interest in WMC. Less than two years after acquiring MIM for about $5 billion he allegedly bid $6.35 a share in a $7.4 billion bid for WMC. At the time of the bid (in October) the market capital of WMC was ~$5.8 billion. However, at the time of writing, this had risen to ~$8.2 billion. Not surprisingly the WMC board rejected the offer, but what an increase in value over such a short time! Presumable both Xtrata and WMC have benefited so far as a result of all the skirmishes, because all shareholders could sell and make a healthy profit.

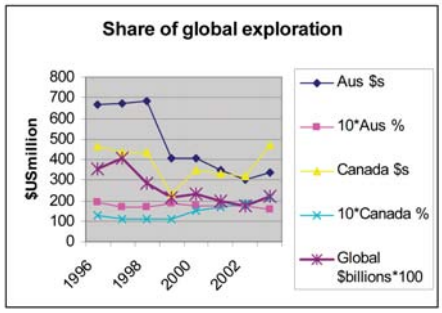

Fig. 3. Australian and Canadian share of the global non-ferrous mineral exploration from 1996-2003. Note that the Canada overtook Australia in 2002 and that the global expenditure rate rose in 2003 for the first time since 1997. The data were obtained from the Metals Economics Group website: http://www.metalseconomics.com/default.htm.

WMC is currently Australia's largest independent mineral resource company with good prospect, particularly at Olympic Dam, so the battle may not be over yet.

Santos drills in deep water Otway Basin

Meanwhile, Santos is about to start drilling in 1450 m of water in the offshore Otway Basin, 70 km south of Portland.

Amrit-1 will be the first ever deep water well to be drilled in the Otway Basin. It is a high-risk well but has high-impact exploration potential for both oil and gas. The well is situated in the VIC/P51 exploration permit area where the Callister-1 well, which is 23 km southwest of Portland, was plugged and abandoned in the same permit in mid-November.

The Amrit-1 has a target depth of 3179 m so it has a long way to go.

We will all watch with interest, but Armit-1 just shows how it is just getting harder and harder to find new deposits of oil and gas.

Geoscience Australia's Geohazards Web Site gets even better

A review (Norvill, 2003) of several natural hazards websites was published in the December 2003 Preview. Each site was rated according to content/information, friendliness of navigation, aesthetics, and currency of material. In this review, the Geoscience Australia Earthquake and Natural Hazards website was rated four and a half stars out of a possible five.

Geoscience Australia produces first-class geoscientific information and knowledge that enables governments and the community organisations to make informed decisions about the exploitation of resources, the management of the environment, the safety of communities and infrastructure, and the resultant wellbeing of all Australians. The Geohazards Division generates information and knowledge that underpin well-informed decisions on safety and the security of the community. Within the Division there are several projects covering geophysical hazard monitoring and alerts (earthquakes, nuclear explosions, tsunamis, geomagnetic storms), geodetic positioning, vulnerability of the built environment (including lifelines), collection and management of fundamental spatially referenced information on hazard, vulnerability and risk, assessment of risk from natural hazards, and economic loss assessment.

Since the WebWaves review, the hazard web site has expanded in size and improved its functionality. This letter informs readers about the additional factsheets, databases and GIS tools that are now available.

Efforts were concentrated on improving the content and currency of the web pages. These areas were identified by Norvell (2003), as being critical to an informative and innovative natural hazards website. The factsheets were updated to provide current natural hazard-related information including Australian examples and pictures of earthquakes, landslides, floods, tsunamis, volcanoes, geomagnetics, and karst systems. Each one of these factsheets provides comprehensive information and examples of local hazard events and the conditions required to ultimately cause them to become natural hazards to the Australian community.

Additional factsheet pages have been developed regarding the field work and risk modelling activities. The fieldwork pages describe how pre- and post-event spatial data are captured for use in risk modelling. A description of 'state of the art' data capture equipment and recent fieldwork sites are also featured. Linked to the data collected by field staff are the risk modelling pages. These factsheets provide a summary on the use of disparate spatial and aspatial data to model exposure, vulnerability and ultimately risk to urban environments in Australia.

Organisational web-use statistics indicate a significant increase in demand for online maps to serve wide and diverse purposes, particularly to improve the online mapping capabilities. These online GISs are developed using the open source software, Mapserver, and are built as Java and non-java applications.

New functionality has been added to the Recent Earthquake Online GIS. Users can now search for recent and historical earthquake events and can query the GIS by selecting an earthquake magnitude range to display on a map. The results can then be individually queried to obtain detailed information such as the date, time, depth, physical location and magnitude of the earthquake. Topographical and geological themes can also be overlaid within the GIS providing useful information such as the nearest town or crossroad to an earthquake's epicentre.

The Landslides GIS is the most recent edition to the online GIS tools. The application allows the user to browse or search for Australian landslides from 1842-2004. At present there are 759 entries in this database. Each entry outlines the landslide's physical location, date, class of slide, and a synopsis of the recorded event. Similar to the Online Earthquakes Search, the user can query the landslides database and access a variety of topographical and geological themes. The landslides database is available as a textual or GIS download, as is the case for other national GIS layers.

Future expansion of our online mapping databases will be available in late 2004-2005, including the Australian Tsunami and Flood databases. A regolith database will also be included as a layer in the Earthquakes Online Search page.

The results of earlier studies such as the 2003 Canberra Bushfires, the multi hazard risk assessments for Cairns, Mackay, Gladstone, Southeast Queensland, and Earthquake Risk in the Newcastle & Lake Macquarie region, can still be downloaded. These studies have proven to be high download pages, having been accessed and used by many educational institutions and all levels of government.

The Geohazards website has grown from a relatively small site containing just over 75 pages a year ago to a site that now contains well over 300 pages. Each month the Division's site receives an enormous number of hits from a variety of academic, government, and private users. The most popular page is currently the Recent Earthquakes page. We plan to update the Earth Monitoring Group's webpages and online mapping tools by the end of the year.

By the way the website address is: http://www.ga.gov.au/urban

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Mechanics of Fluid Saturated Rocks

Edited by Yves Guéguen and Maurice Boutéga
International Geophysics Series Volume 89
Elsevier Academic Press 450 pp
ISBN: 0123053552
Price: $AUD 150

This seven-chapter book is a collaborative effort by fourteen authors, including the two editors. It presents advances over the last few years in the understanding of mechanical and chemical compactive deformation, damage, and failure in porous rocks (Chapters 2, 3, 4 and 5), as well as a coherent treatment of the fundamentals of elastic, elastoplastic and creep deformation of fluid saturated rocks and fluid transport within them. The level of treatment, style and exposition are remarkably consistent for a multi-author work, although more uniform cross-referencing between chapters would have been beneficial.

Chapter 1 on poroelasticity, poroplasticity and rupture lays the theoretical foundations for development in subsequent chapters. Quasi-static microscopic continuum mechanics is employed along with a complementary microscopic approach which allows a better insight into rock behaviour.

The phenomenology of mechanical compaction in porous rocks and the micro mechanics of compaction are treated in Chapter 2. This chapter effectively combines a theoretical treatment with the results of numerous laboratory experiments on rocks, including graphs of mechanical behaviour, micrographs and 3-D reconstructions of microstructure.

Chapter 3 deals with sandstone compaction by intergranular pressure solution, beginning with the development of the theory for a grain scale model and a macroscopic continuum model. The theory is then applied to compaction creep of the simplest possible microstructure of cubic-packed spherical grains, and illustrated via numerical calculations.

Chapter 4 considers damage and rock physical properties, first examining microstructural and mechanical aspects of damage, before considering nucleation and propagation of fractures. Finally damage models are discussed, leading into a treatment of elasticity and permeability of cracked rocks.

Chapter 5 is a comprehensive treatment of localised deformation in shear and compaction bands, a process with implications for fault genesis and fluid flow in the earth. This chapter deals with theoretical considerations of localisation, bifurcation, constitutive models and pore fluid effects before turning to experimental and field observations.

The last two chapters concern the relationship between fluid flow and deformation. Chapter 6 considers fluid transport in deforming rocks, with applications from reservoir productivity, compaction and subsidence to seismically induced well level anomalies. Chapter 7 on hydromechanical behaviour of fractured rocks examines the effect of macroscopic fractures on the mechanical and fluid transport properties of rock masses.

Overall, this book is handsomely produced; with high quality black and white figures and grey-scale images (colour versions are available online). Mathematical equations are clearly set out and the inclusion of a notation index at the end of the book is particularly useful. Each chapter concludes with a comprehensive bibliography.

This book would be of interest to a broad spectrum of earth scientists and engineers, in areas such as fundamental geological and geophysical research, hydrogeology, and petroleum engineering, to name a few. It should be an essential reference for anyone involved in rock mechanics or rock physics research.

Copies can be purchased directly from Elsevier Australia Customer Service on Tel. 1800 263 951, fax (02) 9517 2249 or email service@elsevier.com.au