Preview

Australian Society of Exploration Geophysicists

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CONFERENCE HANDBOOK

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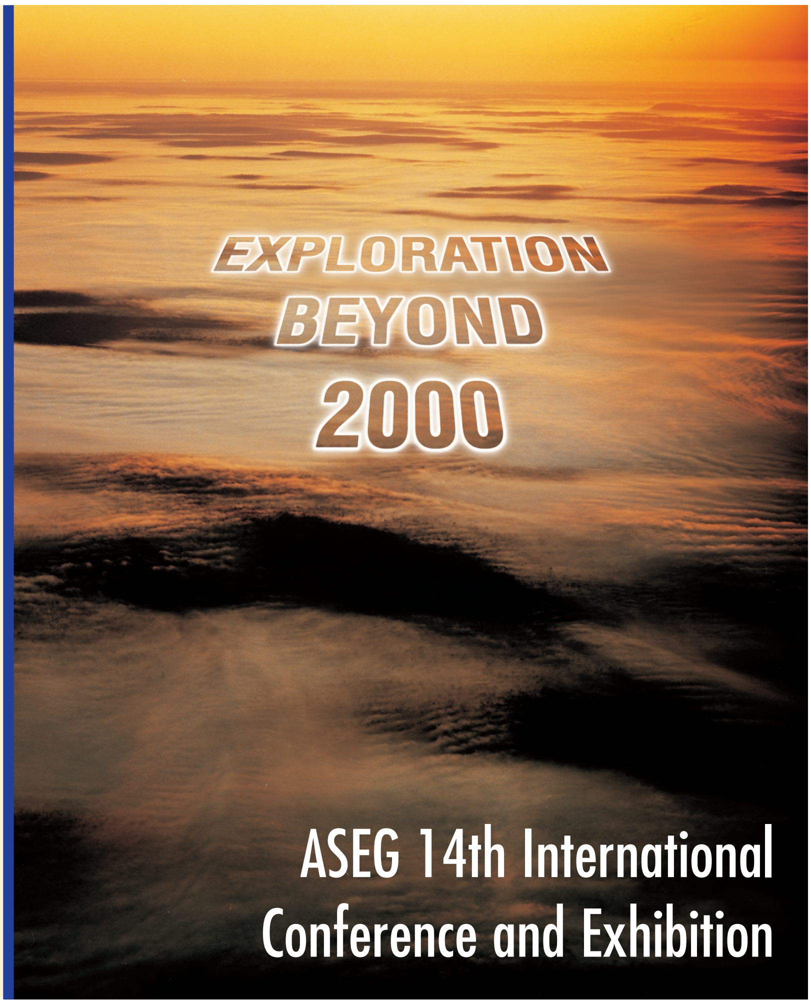

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Exploration Beyond 2000 · ASEG 2000 · Perth, Western Australia

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Preview

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

All contributions should be submitted to the Editor via email at pdenham@atrax.net.au. We reserve the right to edit all submissions; letters must contain your name and a contact address. Editorial style for technical articles should follow the guidelines outlined in Exploration Geophysics and on ASEG's website www.aseg.org.au. We encourage the use of colour in Preview but authors will be asked in most cases to pay a page charge of $400 per page for the printing of colour figures. Reprints will not be provided but authors can obtain, on request, a digital file of their article, and are invited to discuss with the publisher, RESolutions Resource and Energy Services, purchase of multiple hard-copy reprints if required.

Deadlines

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

Therefore, editorial copy deadline for the April 2000 edition is **15th March 2000.**

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 first week of the month of issue. Therefore, the advertising copy deadline for the April 2000 edition is the first week of April.

Instructions for New Membership Applications

Determine the grade of membership for which you wish to apply according to the following descriptions.

Complete the application form and mail to the ASEG at the address on the form with payment for a one-year membership fee. If you are paying by a credit card, you can apply by fax.

Membership Eligibility

Abridged - exact wording of eligibility is in the Article of Association found on the ASEG website: <http://www.aseg.org.au>

Active Membership

A person actively engaged in practising or teaching geophysics or a related scientific field. The applicant must have at least eight years professional experience of which at least three years must be of a responsible nature calling for exercise of independent judgement and the application of geophysical or geological principles.

An applicant having worked toward a degree in a scientific field from a recognised college or university may count time as a student toward a portion of the required eight years' professional experience, not to exceed the following: Bachelor's degree, four years; Master's degree, five years; Doctor's degree, seven years. Time spent solely as a full-time student, even in pursuit of a doctorate, cannot be counted toward the requirement of at least three years' professional experience of a responsible nature.

Associate Membership

A person actively interested in geophysics.

Student Membership

A graduate or undergraduate student at a recognised university or college.

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS
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Tel: +61 7 3257 2725 Fax: +61 7 3252 5783 Email: secretary@aseg.org.au

2000 MEMBERSHIP APPLICATION

Refer to 'Instruction to new membership applications' on page 2

Surname: ________________________ Given Names: ________________ Date of Birth :________

Affiliation: __________________________________

Address: __________________________________

____

____

Tel: __________________________________

Fax: __________________________________

Email: __________________________________

Membership Grades and Rates GST+

☐	Active	A$70.00	+ A$3.50
☐	Associate	A$70.00	+ A$3.50
☐	Student*	A$20.00	+ A$0.60

** Student applicant must fill the box at the bottom*
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Mailing Surcharge

☐	Australia, NZ	no surcharge
☐	Rest of the World	A$50.00

Donation to ASEG Research Foundation

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Amount Payable **A$**__________________

☐ Cheque No.__________________

☐ MasterCard ☐ Visa ☐ Bankcard

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Expiry Date: ___ / ___ Signature: ______________________________

MEMBERSHIP RECORD

PROFESSIONAL RECORD (most recent first)

Dates From	To	Employer	Address	Position Held

TERTIARY QUALIFICATIONS (with institution, dates and major area of study)

____

PROFESSIONAL SOCIETIES

____

REFEREES (SEG members do not need referee)

Name Address

(1) __________________________________

(2) __________________________________

ALL STUDENT MEMBERS (Please provide information below)

Institution: ____________________ Course: ____________________

Lecturer/Supervisor/Head: ______________________________

Conference Handbook

Section 1

Welcome from the Organising Committee

Welcome to the 14th International ASEG Conference and Exhibition, Australia's premier geophysical conference.

As we move into the 21st Century with commodity prices reversing their most recent downward cycle, we look forward to a more positive future. Although you may see many new technologies and ideas over the next five days, this conference brings with it the traditions and achievements spanning the Society's 30 years of history.

We particularly welcome all delegates from overseas, especially those from our sister societies the SEG and EAGE who are co-supporters of this conference.

We extend thanks to our principle sponsor, Baker Hughes-Western Geophysical, whom along with the major sponsors, Veritas, Geosoft, Kevron and Sun Microsystems has provided the much-needed support to make this conference a success. We also gratefully acknowledge the numerous other companies and organisations who have added their support for the Conference.

This conference offers a unique opportunity for the local and international geophysical community to catch up with friends new and old, and to review the latest trends and technologies in the geophysical world.

The Theme - 'Exploration Beyond 2000'

The conference this year looks to the future with the theme "Exploration Beyond 2000". No doubt it will pose many questions;

- How to adapt to the challenges of searching for resources for our developing planet?
- How to locate the more difficult to find resources at lower costs?
- What will our industry look like in 10 or 100 years from now?

The answers to some of these questions lie in the minds of today's geophysicists and through conferences such as this these answers may begin to be found.

Technical Sessions

A highlight of 'Exploration Beyond 2000' will be the technical sessions, with more than 200 papers and four concurrent sessions over the four days of the Conference.

The technical program carries a number of themes pertinent to our industry;

- Groundwater and environmental applications
- Wavelett transforms and Inversion
- Potential Methods
- Electromagnetic methods and Interpretation
- Reservoir Geophysics
- Case Histories

A comprehensive list of pre-conference workshops has been planned to complement the conference. All disciplines are covered with sessions on electromagnetics, seismic attributes, aeromagnetics, groundwater, overpressure, fractures and risk analysis.

Student Day

A traditional part of any ASEG conference is the students' day, which will be held on Tuesday 14th March. This year it will provide a bonus for students with an excellent response to our call for support from sponsors and organisations eager to encourage budding geophysicists. A range of geoscientists will address students and teachers to convey their experiences in the fields of mining, petroleum and the environment.

Trade Exhibition

The Trade Exhibition has surpassed all expectations, and extra floor space has been allocated to accommodate additional exhibitors from around the world. This exhibition is one of the biggest and best to be hosted by the ASEG, with a large floor plan adjacent to the technical sessions and a cafeteria, allowing excellent exposure for all exhibitors under the huge Burswood Superdome

Conference Dinner

A special highlight this year will be the Conference Dinner, set at night in the unusual and exotic surrounds of the internationally acclaimed Perth Zoo - an event not to be missed!

To you all, a rewarding, stimulating and enjoyable conference.

Kim Frankcombe and Mike Sayers
Conference Co-chairmen
ASEG Conference 2000,
Perth, Western Australia

Conference Organising Committee

CO-CHAIRMEN
Kim Frankcombe
Southern Geoscience Consultants
Mike Sayers
Chevron Australia

TECHNICAL PAPERS
Kevin Dodds
CSIRO Petroleum
Special thanks also to **Tony Endres, Mike Dentith, Mike Middleton, Marcus Flis, Duncan Cowan, John McDonald, Anton Kepic**

SPECIAL CONFERENCE CO-EDITORS
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University of WA
Mike Middleton
Dept of Applied Geology
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Don Howman
Dept of Exploration Geophysics
Curtin University of Technology

SEG/EAGE LINK
Bill Abriel
WAPET

PUBLICITY
Larry Tilbury
Woodside Energy

ASEG President

Welcome to all delegates, speakers, sponsors and exhibitors to the 14th International Conference and Exhibition of the Australian Society of Exploration Geophysicists.

You are the visible, vibrant heart of our Society. Our regular national gatherings in a major city of this vast country display our technical innovations, our commercial ingenuity, and especially our tenacity in hard times. These events demonstrate a very healthy spirit of competitiveness, both internally within our specialist areas and across the broad spectrum of applications of geophysical technology. New instruments, new processes, new strategies and new applications create wider market opportunities for our skills. The ASEG Conference and Exhibition showcases the evolving and maturing capacity of the geophysical community to influence and lead this nation's resource, engineering and educational industries. We anticipate exciting times during March in Perth. ASEG extends a special welcome to all our international visitors to Australia on this occasion.

Pictured from left to right: Mike Smith (ASEG President), Prof. Toshifumi Matsuoka (SEG Japan), William Barkhouse (SEG President) and Etienne Robien (EAGE President-Elect).

Thank You To So Many

The major sponsors and supporting sponsors of this conference are thanked for their critical financial leadership, which enables these events to generate momentum; these organisations are listed prominently on the cover and inside pages (check locations of these acknowledgements - thanks) of this volume and also throughout the conference venue. The co-chairmen (Kim Franckcombe and Mike Sayers) and members of the Conference Organising Committee contribute vast personal energy and sacrifice huge amounts of private time to achieve the detailed operations of this event. The speakers and workshop organisers take risks in standing forward and deserve our appreciation and accolades. The trade exhibitors provide much of the fun and finesse of the conference, and the exhibition hall is a constant source of education and entertainment for ASEG delegates. We thank you all for your participation in Perth 2000.

SEG and EAGE

The Society of Exploration Geophysicists provides great promotion of our gatherings and it is a pleasure to welcome President William Barkhouse and Business Executive John Van Gundy to Perth. It is great to have Past President Brian Russell attending as an exhibitor. The SEG shows sustained commitment to assisting its international members of whom over 40% reside outside the USA. The International Affairs Committee of the SEG provides a broad forum for our involvement in SEG affairs, while the SEG Student Section contributes educational resources for secondary and tertiary students. Similar bonds are evolving with the European Association of Geoscientists and Engineers and the ASEG Executive welcomes EAGE Secretary-Treasurer Jean-Claude Grosset to our Perth Conference.

Federal Executive

Deliberations of the Federal Executive have focussed during 1999 on the financial capacity of the ASEG to continue delivering its high standard publications and educational assistance. The funds available to the FEDEX (excluding those of the states and trust accounts) have consistently declined over recent years. The matter was highlighted by Past President Noll Moriarty (Preview 77). Subsequent ASEG actions have included a change in the ASEG publisher and the appointment of a Revenue Committee to look at opportunities to generate ASEG income, complementing the other committees which deliver services to our members and which therefore tend to spend the Society's funds. While attending the 1999 SEG Council Meeting in Houston, I was struck with the same issues of financial management demanding the attention of the SEG Executive. In part, reduced ASEG income reflects the current and extended recession of the resource sector. Steps to contain expenditure tend to focus on the greatest cost centre of the Society, namely our publications, and the size and colour content of successive issues; and alternative or complementary publishing methods need to be considered. Increased Society revenue is achievable through greater advertising revenue. However the greatest revenue centre of the ASEG is our major conference and exhibition, which suggests that a conference held every 12 months rather than every 18 months may be the best mechanism to achieve a more consistently balanced annual ASEG budget. The conferences also provide a substantial financial boost to the host State Branch.

The financial management of the Society, including demanding obligations of the new GST legislation, and various other issues will be raised at the ASEG Council Meeting in Perth. This meeting provides the only substantial forum for exchange of ideas with State Branch representatives. A goal of past ASEG executives has been to increase input from the states so that decisions reflect the opinions of a wider range of members. For practical reasons the executive has historically been centred on one or other of the capital cities. With modern teleconferencing facilities, it is quite simple to establish a national executive, with elected representatives from several or many cities participating directly in all meetings. This option for the evolution of our Society will be canvassed at the Council meeting.

Final Remarks

This will be my last President's Piece, so I take the opportunity to write some thoughts beyond the immediate issues of the Society.

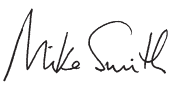
The field of geophysics in Australia encompasses the educators and the innovative researchers who stimulate development of new technologies. It includes the government teams who strive to stimulate investment by providing informative syntheses of geoscientific data, the contracting companies who consistently improve their service capability despite a highly competitive environment and the company staff who fund many of the operations and who face the risk of failure as each expensive drillhole tests new concepts based on positive thinking and creative interpretation.

The Australian Society of Exploration Geophysicists contributes to sustaining this national scientific effort by publishing the results of geophysical research and case histories of practical applications. The Society holds conferences and exhibitions to bring practitioners into close contact and to facilitate the dissemination of knowledge. The Society also provides recognition of excellence in geophysical achievement and encourages the highest professional standards. Above all, the Society aims to promote and enhance the science of geophysics, primarily within Australia, but also in our neighbouring countries of the southwest Pacific region. Indeed the ASEG's influence extends throughout the world by collaboration with sister international societies and by the strong demand for employment of our talented Australian geophysicists overseas.

ASEG members have experienced considerable difficulties in recent times resulting in substantial retrenchments among our colleagues. These problems are due largely to historically low commodity prices, partly to problems in gaining access to land for field studies and exploration, and also due to management weakness within our own industry, where short term performance (demanded by the unduly influential fund managers) is ranked higher than intellectual capacity. The repeated peaks and troughs of the resource sector demand a long term perspective, naturally with restrained spending in lean times, but with a policy of nurturing a core of skilled, motivated geoscientists who are committed to their employer's objectives.

These are economic factors beyond the control of a learned society such as the ASEG. We continue to support our members through communication, education, social contact and networking opportunities, convinced of the value of our contributions to Australian society, and delighting in the love of a field of scientific endeavour, which provides access to the most sophisticated technology, and the pleasure of undertaking the majority of our work in the wide landscapes of our country.

An important function of the resources sector is the generation of new wealth and the creation of new employment in the country areas of Australia, thus contributing to an essential national goal of reversing the drain of citizens from the bush to the city. The steady drift to coastal cities leads to overcrowding, reduced employment and increased urban crime, directly as a consequence of the decline of a traditional and historically highly valued Australian lifestyle. At Canberra's 'Science Meets Parliament' I conveyed to my political counterparts a wish for state and national politicians to design fiscal and social policies, which lead to the repopulation of country Australia. Our Society's practitioners can contribute to resource delineation (minerals, hydrocarbons, water and others) providing an important short-term basis for local revivals. While these contributions are very helpful, the issue is much broader than our industry. Australia needs incentives for regional growth, solutions to high operating costs in remote areas, new industries such as outback research centres, and a genuine commitment to reversing a sad and dangerous trend in this land. In the future, we may look back and say, "we should have done something!" - Now is the time when our leaders could take action.



Mike Smith, President of the Australian Society of Exploration Geophysicists

SEG President

William ('Bill') Barkhouse, President of the Society of Exploration Geophysicists

It is with deep personal pleasure that I say 'Thank You' to the Australian Society of Exploration Geophysicists for leading our members and sister professional societies into the new millennium with the 14th ASEG Conference and Exhibition, ASEG 2000. 'Exploration Beyond 2000' captures the spirit and challenges of a rapidly changing world that is seeing increasing globalisation and internationalism connected with new and innovative technology. Your conference leaders are providing a unique occasion for global 'people-to-people' networking and interaction where new ideas may be generated, which in turn, encourages new technology and innovation.

Bringing together a 'combination' and 'mixture' of various technical disciplinesoffers our technical community a rich 'brew' for new technical 'break-throughs'. ASEG sets a new standard for fostering global intersociety cooperation and collaboration that benefits our members by enhancing professional learning opportunities that may lead to 'lifelong employability', new 'brews' and new standards.

Thank you ASEG.

EAGE President

Markku Peltoniemi, President of the European Association of Geoscientists & Engineers

Knowledge - another commodity?

The new Millennium makes a bold start for the resources exploration industry with the ASEG Perth Conference, for which I want to wish all success on behalf of the EAGE. Much hype and noisy communication was provided at the change of century, but I am pleased to acknowledge the most interesting and thought-provoking signals that many of the key persons in our profession sent out by expressing their views and expectations for the future in the January 2000 issue of the First Break. Although relative weights given for various topics differ from one expert to another, several common themes are clearly recognisable in these interviews.

The dilemma between the costs of long-term investment in creating the expertise and knowledge within a research or service group and the short-term requirements for shareholder value was addressed by many of the experts interviewed. Increase in computer hardware performance can be taken for granted for many years to come. This will create better opportunities to improve the methods and tools used in acquisition, processing and interpretation / imaging of geophysical datasets. The big question is: who is going to invent, design and implement all these new marvellous tools? The trilateral relation between the oil and mining companies, the service companies and the universities has suffered blows to the extent that the third domain, the universities, may not be able to fulfil their essential role in this challenge. "The majors now claim that they don't need to do research since any needed technology can be bought off the shelf on a 'just in time' basis", was Sven Treitel's formulation of the problem. Knowledge acquired in long-term education and research is equated to short-term commodity products.

At the end of the last millennium, the concept of 'Lifelong learning' was widely publicised and celebrated, especially in Europe, as a new concept, which will contribute to a major change in future business and individual levels of knowledge. The concept has not met much enthusiasm so far in our profession, for obvious reasons. As support for lifelong learning is very hard to achieve in the current industry and business environment, I would optimistically want to believe that professional societies will be capable of taking more and more responsibilities in this field. No society alone is capable of providing the whole spectrum of continuing education necessary for all the multidisciplinary skills of the future, so maybe we will see much more of the co-operation between universities and professional societies so that the gaps created by vanishing in-house 'Continuing Education' services and research funding can be filled. Someone must fill the needs for providing access to the knowledge behind and ahead of all this new technology, otherwise we end up with the infamous black box situation.

Principal Sponsor

BAKER HUGHES

Western Geophysical

Western Geophysical, the world's leading seismic company, provides comprehensive seismic services for oil and gas exploration, field development, and reservoir monitoring. Headquartered in Houston, USA, Western's 5,000 employees around the globe conduct seismic surveys on land, in deep waters, and across shallow-water transition zones. The seismic surveys encompass high-resolution 2-D, 3-D, and multi-component surveys for delineating exploration targets and extend to the integration of seismic data with borehole-derived information to describe petrophysical properties throughout a reservoir. Western has also conducted some of the industry's earliest time-lapse 4-D seismic surveys for monitoring reservoir fluid movement.

Over the years, Western's R&D and Applied Technology groups have contributed to the development of many of the sophisticated techniques that have become industry standards - air guns, vibrators, GPS positioning, 3-D surveys, 24-bit digital recording, radio telemetry & bottom cable surveys, on-site quality control, 3-D visualization, complex imaging, stratigraphic analysis, and fracture detection. In addition to contributing to the state-of-the-art in each of these areas, Western's geoscientists and engineers are also helping to advance seismic technology to the next frontier — 4-D surveys for time-lapse reservoir monitoring.

In late 1993, Western Geophysical acquired the assets of Halliburton Geophysical Services (HGS). Western integrated HGS services and experienced personnel. In 1998, Western Atlas and Baker Hughes merged, combining premier information technology with leading execution capability to deliver a full range of first-in-class services worldwide. Western Geophysical is the largest division in the Baker Hughes family, with revenues of over US$1 billion.

Today, Western Geophysical is advancing the state-of-the-art in all phases of seismic services through an aggressive combination of geoscientific research, field engineering, and software development. In each global sector, Western is expanding service capabilities and investing in new equipment to deliver the highest value possible in seismic services. Western's emphasis on technology and service is matched by a commitment to safety and concern for the environment.

Major Sponsors

Geosoft Australia is very proud to once again be a Major Sponsor of the ASEG Conference. We feel that it is very important to support the Society in every way we can, which supports Exploration Geophysicists in general. Geosoft Australia is very active in the society, with staff freely giving time to serve on the Western Australia Branch committee. We are also heavily involved in the running of this conference, in particular with Mark Russell as Exhibition Coordinator and Nick Valleau is giving a poster presentation.

GEOSOFT

This 14th ASEG Conference is especially important to us, being held in our home town of Perth and we would like to send out a warm welcome to our interstate and overseas visitors to this great city. Please come by our exhibition stand (41 & 48) and meet with the Geosoft crew - Nick Valleau, Mark Russell, Levin Lee, Chris Bishop, & Vanessa Maugey. We are also pleased to have Greg Hollyer from our Toronto office as well as Gerry Connard of NGA Assoc. from the United States.

Please refer to our exhibitor listing for details on our company and most of all, enjoy your time at the conference.

Kevron Geophysics Pty. Ltd.

Kevron Geophysics was established in 1986, although the Kevron Group has been flying aeromagnetic and radiometric surveys since 1968. The company, based at Jandakot Airport in Perth, operates four Aerocommander Shrike aircraft, all equipped for recording horizontal magnetic gradient, multichannel radiometrics and DTM.

Kevron Geophysics has developed the enviable reputation for producing high quality data at economic rates.

Sun Microsystem

Sun microsystems

Since its inception in 1982, a singular vision - The Network is The Computer[tm] - has propelled Sun Microsystems to its position as a leading provider of industrial-strength hardware, software and services that power the Internet and allow companies worldwide to ".com" their businesses.

At **Veritas**, our mission is to acquire, process and sell seismic data to the oil and gas industry.

VERITAS Geophysical Integrity

Veritas offers a complete portfolio of services, including land, transition zone and marine seismic data acquisition; seismic data processing, attribute analysis, interpretation, and visualization; multi-client land and marine data sales.

With more than 30 years of experience in acquiring and processing seismic data, we've achieved a reputation for responsiveness, quality and performance.

Flagstaff GeoConsultants

Sponsors of the Students' Day

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General Conference Information

Internet CAFÉ

Sun Microsystems' Internet Cafe

Delegates will be able to use Sun's latest offering in thin client computing - the SunRay - to access the web, trial Star Office (office productivity tool) and check email. During the course of the conference, Sun Microsystems, in conjunction with software partners, will demonstrate ASP applications relevent to the oil and gas industry. ASPs host and manage business applications on behalf of a client. These applications can range from Enterprise Resource Planning (ERP) through to upstream engineering applications.

Session Location

All sessions of the conference and the exhibition will be held within the Dome structure.

Conference marquee 1 and 2 are located on the main floor immediately behind the restaurant area. Conference venues 3, 4 and 5 are located in Suites 32-35 on Level 3 and can be accessed via the stairs or lift. See the enclosed map for room location.

Morning and afternoon teas and lunches will all be served in the exhibition area and adjacent restaurant.

Name Badges

Each attendee of the conference will be issued a name badge at registration. The badge is the official pass to sessions and must be worn at all times.

Delegates not wearing badges may not be admitted to social functions, lunches or conference sessions.

Please note: Replacement of lost badges will be charged at $4.00 per badge.

Registration Desk

The registration desk will be serviced from 0745 - 1800 Monday to Wednesday and 0745 - 1500 on Thursday.

Mastercard, Bankcard and Visacard will be accepted at the desk for payment of registration, tours and social functions.

Social Functions

Entry to the conference dinner and conference farewell is strictly by ticket only.

Pre-booked tickets have been included in the delegate envelope collected from the registration desk.

Additional tickets may be purchased from the cashier.

No refunds will be given for social functions cancelled or missed.

Lunch

Delegate lunches will be served from the restaurant area. Lunch tickets must be presented to serving staff each day. Additional lunch tickets may be purchased from the registration desk for $22 per lunch.

Separate arrangements have been made for exhibition staff. Details are included with the exhibitor kit.

Speaker Preparation

The speaker preparation room is located in Suite 23 on Level 2. Speakers are asked to reconfirm their audiovisual requirements at the registration desk prior to their session.

Facilities will be available for speakers to check their slides, audiovisual and video presentations in advance. Technicians will be on hand for audio assistance.

The room will be operational on Sunday 12 March between 1400 - 1800 and also daily throughout the conference from 0730 - 1800, Monday - Wednesday and from 0730 as required on Thursday.

Messages

A notice board will be in the registration area for messages to delegates. Please check this daily. No guarantee will be given to deliver messages personally.

Urgent messages may be telephoned through to the registration desk by calling the Burswood Resort on 9362 7777 and asking for the ASEG registration desk.

Smoking Policy

Burswood Dome is a no-smoking venue. A strict no smoking policy will be observed within the Dome Complex during the sessions and throughout the exhibition.

Day Tours

Perth has many and varied things to see and do.

General tour enquiries and bookings can be made at the registration desk.

Most of the day tours will collect participants from their hotels.

Partners and delegates who have pre-booked tours must check their tickets for the correct pick-up times and points of departure.

Taxis

Taxis are available from the front of the Resort or can be prebooked by telephone:

- Black & White taxis **9333 3333**
- Swan taxis **13 1388**

Parking

Car parking facilities are available outside the Dome free of charge to all delegates and visitors and underneath the Burswood Resort at a cost of $5 per day.

A separate parking area has been set aside for exhibitor staff requirements.

Mobile Telephones

As a courtesy to speakers, mobile telephones and pagers are to be turned off within the lecture rooms during all sessions.

Credit Cards

Bankcard, Mastercard and Visa will be accepted at the registration desk. Most hotels, larger restaurants and specialty shops will accept these and other credit cards.

Personal Insurance

Participants shall be regarded in every respect as carrying their own risk for loss or injury to property, including baggage during the conference and exhibition

The policy taken should include loss of deposit through cancellation, medical insurance, loss or damage to personal property, financial loss incurred through disruption to accommodation or travel arrangements due to strikes or other industrial action.

The organisers are in no way responsible for any claims concerning insurance.

Car Rental

Arrangements may be made for delegates who require a hire car. Please advise requirements to the registration desk. All budgets will be catered for.

Shopping

Shops are open from 0900 to 1730 hrs during the week, with late night shopping in the city on Fridays to 2100 hrs and in the suburbs on Thursdays to 2100 hrs. On Saturdays, most shops are open from 0900 to 1700 hrs and on Sunday, shops in the city are open from 1100 to 1700 hrs.

Banking

Banks are open from 0930 - 1600 hours from Monday to Friday and from 0930 to 1700 hours on Fridays. Banks are closed on Saturday and Sundays. Automatic Teller Machines are available at the Burswood Resort. Facilities for exchange of currency are also available at the larger hotels.

Eating Out and Nightlife

The area of Northbridge houses a magnificent delight of culinary feasts, from cafes and restaurants of all nationalities, to gourmet shops and patisseries as well as most of Perth's nightclubs. Taxi fare from the city is approximately A$10.

Fremantle too boasts a number of delightful eateries and attractions. Taxi fare from the city is approximately A$23.

More information about eating out can be found in the magazine 'All About Town' included in the delegate satchel.

Disclaimer

Promaco Conventions Pty Ltd, ASEG and the conference organising committee shall not be liable for damages or loss of any nature sustained by participants or their accompanying persons as a result of attending the ASEG 14th International Conference and Exhibition and related events.

Conference Secretariat

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Sunday 12 March 2000

1730 – 1930
Official Opening Ceremony and Icebreaker Welcome Reception
Burswood Dome

The official opening of the conference will begin at 1730 in the Marquee 1 inside the Burswood Dome.

The opening will be followed by an 'Icebreaker" welcome reception to be held in the exhibition hall.

Included for fulltime delegates and exhibitors.

Guest tickets: A$30.

Monday 13 March 2000

1730 – 1830
Exhibition Happy Hour

A Happy Hour will be held throughout the exhibition area at the close of sessions.

All delegates and exhibitors are invited to attend.

The Happy Hour on Monday 13 March is proudly sponsored by Geo Instruments.

1830 – 2330
Perth By Night Evening Tour

While in Perth enjoy all that the 'City of Lights' has to offer while enjoying a progressive dinner. Start the evening with pre-dinner drinks and appetizers. Then take in the magnificent city skyline across the river from South Perth. Your coach captain and dinner host will point out the top nightclubs, cafes, and restaurants of Perth's nightlife area - Northbridge - before you enjoy your mediterranean meal, including drinks. After dinner visit the Burswood Casino for a short time to explore the gaming floor. (Burswood casino requires smart dress. Jeans, sports and all denim clothing not permitted in the Casino).

Cost: A$89 per person (Minimum number required).

Tuesday 14 March 2000

1900 – late
Conference Dinner at Perth Zoo

Imagine exotic bird greetings and a lion's deep roar as delegates mingle. The lush setting of the Perth Zoo makes the perfect venue for the Conference Dinner and guarantees a unique and memorable evening. Pre-dinner drinks and canapes will be enjoyed on a guided walk through the African Savannah where native and exotic creatures can be viewed in enclosures that closely replicate their natural habitats.

Guests will move to a magnificent marquee on the main lawn to enjoy an evening of fine wine and food, Western Australian style. Music and entertainment will accompany a delicious meal. Bookings are essential.

Dinner tickets A$105 per person.

The conference dinner is proudly sponsored by Veritas DGC Australia.

Wednesday 15 March 2000

1730 – 1830
Exhibition Happy Hour

A Happy Hour will be held throughout the exhibition area at the close of sessions.

All delegates and exhibitors are invited to attend.

The Happy Hour on Wednesday 15 March is proudly sponsored by Fugro Airborne Surveys.

Evening free for networking

Thursday 16 March 2000

1500 – 1700
Conference Farewell

At the conclusion of sessions, delegates, partners and exhibitors are invited to a farewell function to mark the close of the conference.

Included for fulltime delegates and exhibitors.

Guest tickets: A$35.

Friday 17 March 2000

0800 – 1500
Golf at Burswood Resort

The traditional 'Golf Challenge' is on again. Delegates will tee-off from 0900 and enjoy 18 holes on a world class course. Play will be followed by lunch and presentations.

Cost: A$55 per player inclusive of lunch and refreshments. Hire of equipment extra.

Subject to sponsor response.

Students' Day

A students' day will be held on Tuesday 14th March to promote geophysics as a career option to upper school students.

Sponsorship funds have been willingly donated by Anglo American • Apache Energy • Ashton Mining • BHP Petroleum • Chevron Australia Pty Ltd • ExxonMobil • Faculty of Science - University of Western Australia • Fugro Airborne Surveys • Homestake Gold of Australia • Normandy Exploration • Woodside Petroleum • Curtin University - Department of Exploration Geophysics is also providing technical assistance.

Prominent geophysicists from all aspects of industry will address the students in the morning on their experiences and interests. The accompanying teachers will also attend a miniworkshop, where they will be provided with a range of resource material and get a chance to preview the latest geophysical and geological educational CD-ROM's. This will enable the teachers to keep spreading the word of geophysics to their students.

After lunch, teachers and students will have a tour through the ASEG trade exhibition so they can see state-of-the-art technology and products associated with the geophysical industry.

Opening & Closing Ceremonies

Sunday 12 March 2000
Official Opening

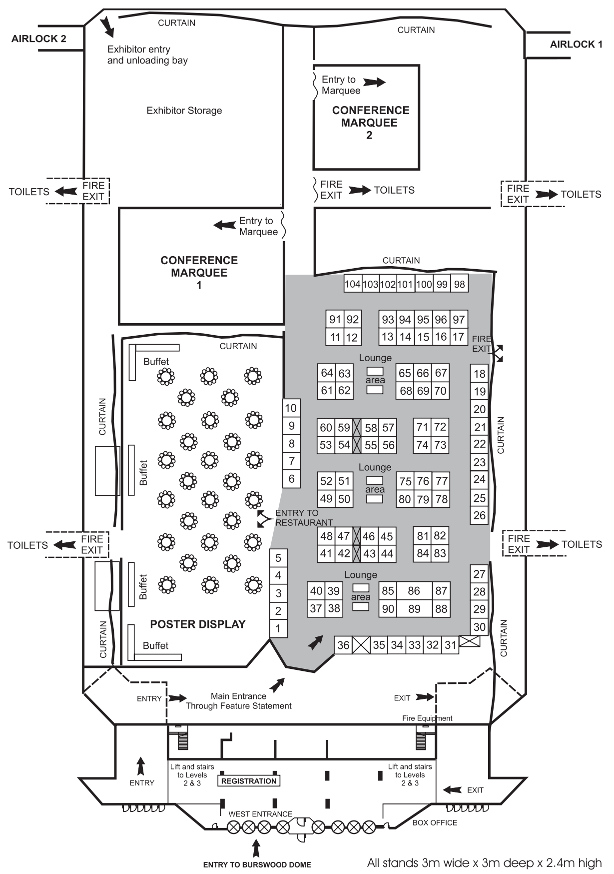
1700	Welcome and introduction Mike Sayers, Conference Co-Chairman
1705	Mike Smith, ASEG President
1715	Jean-Claude Grossett, EAGE Past President
1725	Bill Barkhouse, SEG President
1735	Address from the Principal Sponsor Western Geophysical - Baker Hughes
1740	Awards Presentations Mike Smith, ASEG President Graeme Sands Award ASEG Gold Medal Honorary Membership
1750	Opening Address The Hon Hendy Cowan, Deputy Premier and Minister for Commerce & Trade
1805	Invitation to the Icebreaker Reception Mike Sayers, Conference Co-Chairman

Monday 13 March 2000
Opening Program

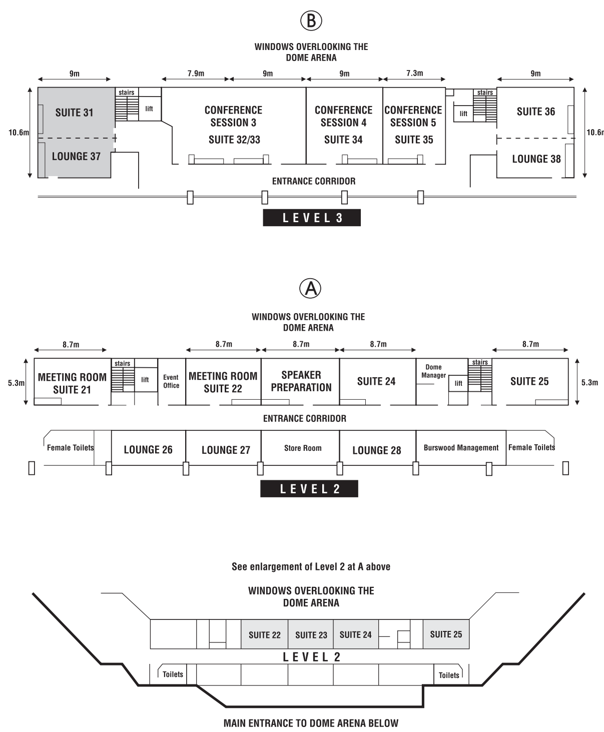
0830	Welcome and introduction Kim Frankcombe, Conference Co-Chairman
0835	Keynote Address Time Reversed Acoustics Professor Mathias Fink, Professor of Physics, ESPCI and Denis Diderot University, France Questions
0930	An industry perspective Pat Cuneen (Minerals) John Gibson(Petroleum)
1000	Invitation to morning tea in the Exhibition Kim Frankcombe, Conference Co-Chairman

Thursday 16 March 200
Closing Ceremony

1500	Thankyou to delegates, exhibitors and sponsors Kim Frankcombe and Mike Sayers, Conference Co-Chairmen
1505	Awards Presentations Kim Frankcombe and Mike Sayers, Conference Co-Chairmen • Laric Hawkins Award • Best Published Paper • Best Petroleum Geophysics Paper • Best Mining and Engineering Geophysics Paper • Best Poster • Best Exhibition
1515	Introduction to 15th ASEG Conference 2002
1525	Invitation to the Conference Farewell Conference Farewell



Main Arena



Levels 2 and 3

Venue Floor Plan

Conference Program

SUNDAY 12 MARCH 2000

1400	Conference Registration
1700	OPENING CEREMONY AND ICEBREAKER WELCOME RECEPTION

MONDAY 13 MARCH 2000

0700	SPEAKERS BREAKFAST IN THE RESTAURANT AREA				
0830	INTRODUCTION AND WELCOME				
1000	MORNING TEA IN THE EXHIBITION HALL				
Theme	PORE PRESSURE AND INVERSION	SEISMIC VELOCITY	GROUNDWATER	ADVANCES IN EM EQUIPMENT (1)	POTENTIAL METHODS (1)
VENUE	CONFERENCE 5 / LEVEL 3	CONFERENCE 3 / LEVEL 3	CONFERENCE 4 / LEVEL 3	MARQUEE 2	MARQUEE 1
1030	**(58)** *Effects of porosity and clay content on P- and S-wave velocities in Cooper Basin sandstones* **A Khaksar (University of Adelaide, SA)** C Griffiths	**(221)** *Velocity as an attribute: continuous velocity estimation from 3D preSDM CRP gathers* **B Virlouvet (CGG Perth, WA)** S Zimine, I Jones, M Taylor	**(183)** *Airborne and ground geophysical surveys for groundwater targeting in hard rock terrains Orissa, India* **G J Street & P N Chakravartula (World Geoscience, WA)** , W Crowe, K C Mohapatra, K C Salu, S Baron Hay	**(137)** *The development of a large fixed loop airborne TEM system* **P Elliott (Elliott Geophysics International, Indonesia)**	**(16)** *Screening kimberlite magnetic anomalies in magnetically active areas* **D Cowan (Cowan Geodata Services, WA)** L Tompkins, S Cowan
1100	**(52)** *Pore pressure-stress coupling and its implications for seismicity* **R Hillis (University of Adelaide, SA)**	**(164)** *Rapid travel time calculations for simple earth models using computer algebra* **B Hartley (Curtin University, WA)**	**(1)** *The use of transverse resistance in the determination of aquifer quality from electromagnetic soundings in the Gascoyne flood plain deposits, WA* **N Al-andoonisi (Curtin University, WA)** N F Uren	**(60)** *The TEMPEST airborne electromagnetic system* **R Lane (World Geoscience Corporation, WA)** A Green, C Golding, M Owers, C Plunkett, P Pik, D Sattel, B Thorn	**(21)** *Enhancement of subtle features in aeromagnetic data* **M Dentith (University of WA)** D Cowan, L Tompkins, S Cowan
1130	**(28)** *Describing pore shape and volume changes: a key element in modelling pressure effects on the physical properties of porous rocks* **A Endres (University of Waterloo, Canada)**	**(42)** *Seismic velocities in the North West Shelf Region, Australia, from near-vertical and wide-angle reflection and refraction studies* **A Goncharov (AGSO, ACT)** G O'Brien, B Drummond	**(230)** *Crosshole resistivity imaging of aquifer properties* **S Greenhalgh (University of Adelaide, SA)** B Zhou, J Zhe	**(197)** *The development of the 25 Hertz GEOTEM: an example of a successful collaborative R & D model* **K Witherly (Condor Consulting Inc, USA)** S Thomson, J Silic	**(22)** *Enhancement of airborne magnetic data using the variation method* **T Dhu (University of Adelaide, SA)** M Dentith, R Hillis
1200	**(37)** *Joint porosity inversion* **L Fu (CSIRO Petroleum, WA)** **K Dodds**	**(108)** *Calibrated wide angle 3D AVO processing for improved lithology classification* **A Strudley (Schlumberger Geco-Prakla, WA)** T Brice, S B Reymond	**(241)** *Hydrogeological applications of airborne geophysical data in Australia* **G J Street (Consulting Geologist, WA)** P N Chakravartula, R J George, D Heisler, J de Silva, I Gordon, G Pracilio	**(40)** *Broadband (ULF-VLF) surface impedance measurements using MIMDAS* **S J Garner (MIM Exploration, QLD)** D V Thiel	**(175)** *Palaeo-channel modelling from airborne magnetic data* **T Mackey (AGSO, ACT)** K Lawrie, P Wilkes, T Munday, R Chan, D Gibson,

Day 1 - Monday 13 March 2000

1230	LUNCH IN THE EXHIBITION HALL AND RESTAURANT AREA *Sponsored by Velseis*			
Theme	OVERPRESSURE AND RESERVOIR PROPERTIES	GROUNDWATER ENVIRONMENTAL /GEOTECHNICAL APPLICATIONS (1)	ADVANCES IN EM EQUIPMENT (2)	POTENTIAL METHODS (2)
VENUE	CONFERENCE 3 / LEVEL 3	CONFERENCE 4 / LEVEL 3	MARQUEE 1	MARQUEE 2
1330	(14) *Overpressure prediction using surface seismic, VSP and LWD* **H Cao (Schlumberger Australia, VIC)**	(209) *Groundwater contamination monitoring with multichannel electrical and electromagnetic methods* **G Buselli (CRCAMET, NSW)** K Lu	(61) *Experience with SQUID magnetometers in airborne TEM Surveying* **J Lee (BHP Minerals, NSW)** R J Turner, M A Downey, A Maddever, G Panjkovic, C Foley, R Binks, C Lewis, W Murray, M Asten, D L Dart	(8) *Quality control of gridded aeromagnetic data* **S Billings (Geophysical Technology Ltd, NSW)** D Richards
1400	(53) *Estimating pore pressure in the Cooper Basin, South Australia*: **R Hillis (University of Adelaide, SA)** P J van Ruth	(129) *Geophysical quantification of a moisture content profile in the near surface* **P Hahesy (Flinders University, SA)** G Heinson, A Endres	(170) *Avoid pink, go for blue: noise power spectrum preferences in TEM* **A Kepic (WA)**	(35) *Aeromagnetic drape corrections applied to the Turner Syncline, Hamersley Basin* **M Flis (Hamersley Iron Pty Limited, WA)** D R Cowan
1430	(77) *Constrained modelling of a hydrodynamic environment beneath a regional pressure seal, Northwest Taranaki Basin, New Zealand* **A McAlpine (Spectrum Exploration Limited, New Zealand)**	(92) *Pitfalls in environmental geophysics* **T Pippett (Alpha Geoscience Pty Limited, NSW)**	(126) *Applications of computer data acquisition systems in electric and electromagnetic methods* **J Macnae (CRCAMET, NSW)** Y P Yang	(54) *The total-field geomagnetic coast effect: the CICADA97 line from deep Tasman Sea to inland NSW* **A Hitchman (Australian National University, ACT)** P Milligan, F E M Lilley, A White, G S Heinson
1500	(27) *Size scale considerations in modelling the electrical conductivity of porous rocks and soils* **A Endres (University of Waterloo, Canada)**	(248) *Geophysical studies for groundwater assessment in the Sturt Plateau* **A Knapton (DLPE NT)** G Humphreys, D Y Foo, D Chin, R Sinordin		(95) *The magnetic vector and gradient tensor in mineral & oil exploration* S Rajagopalan **A Christensen (BHP Minerals, VIC)**
1530	AFTERNOON TEA IN THE EXHIBITION HALL			
Theme	WAVELET TRANSFORMS AND ANALYSIS	GROUNDWATER ENVIRONMENTAL/ GEOTECHNICAL APPLICATIONS (2)	IN MINE/MINESITE GEOPHYSICS	POTENTIAL METHODS (3)
VENUE	MARQUEE 2	CONFERENCE 4 / LEVEL 3	CONFERENCE 3 / LEVEL 3	MARQUEE 1
1600	(25) *Attenuating coherent noise by wavelet transform* **B Du (PGS Australia Pty Ltd, WA)** L Lines	(189) *Subsurface vegetation mapping and soil classification by ground penetrating radar for Kyoto ARD activities* **S Urata (University of Tokyo, Japan)** S Rokugawa, Y Katoh	(135) *Detailed orebody mapping using borehole radar* **G Turner (SenseOre Services Pty Ltd, WA)** I Mason, J Hargreaves, A Wellington	(31) *The determination and application of vector gravity anomalies* **W Featherstone (Curtin University, WA)** M C Dentith, J F Kirby
1630	(11) *Wavelet based inversion of gravity data* **F Horowitz (CSIRO Exploration and Mining, WA)** P Hornby, F Boschetti	(122) *The application of mise-a-la-masse and electrical imaging to the detection of pipe source pollution* **W Wood (Geo-Eng Aust. Pty Ltd, QLD)** D Palmer	(81) *Downhole magnetometric resistivity surveying for refractory gold ore at Wiluna Gold Mine, Western Australia* **J Meyers (Astro Mining NL, VIC)** M Cooper, J Bishop, M Hatch	(39) *Drilling-constrained 3D gravity interpretation* **P Fullagar (Fullagar Geophysics Pty Ltd, QLD)** J Paine, N A Hughes
1700	(65) *Interactive seismic event recognition and its applications* **M Li (University of Sydney, NSW)** I Mason	(148) *Fractured rock hydrogeophysics at Clare Valley, South Australia* **T Wilson (Flinders University, SA)** G Heinson, A Endres, T Halihan	(229) *Underground seismic reflection experiment in a gold mine* **S Greenhalgh (University of Adelaide, SA)** S Bierbaum	(75) *Regional structure and distribution of magnetite: implications for the interpretation of aeromagnetic data in the Broken Hill region,NSW* **D Maidment (AGSO, ACT)** G M Gibson, J W Giddings
1730	CLOSE OF SESSIONS			
1730	HAPPY HOUR IN THE EXHIBITION HALL *Sponsored by Geo Instruments*			
1830	PERTH BY NIGHT TOUR (Optional Tour)			

TUESDAY 14 MARCH 2000

0700	SPEAKERS BREAKFAST IN THE RESTAURANT AREA			
Theme	RESERVOIR GEOPHYSICS (1)	DRYLAND SALINITY AND FARM PLANNING (1)	REGIONAL STUDIES (1)	ELECTRICAL / EM CASE STUDIES
VENUE	MARQUEE 2	CONFERENCE 3 / LEVEL 3	CONFERENCE 4 / LEVEL 3	MARQUEE 1
0830	(224) *Reducing resource uncertainty using seismic amplitude analysis in the Southern Rankin Trend, North-West Australia* **D Sibley (West Australian Petroleum Pty Limited, WA)** F Herkenhoff, D Criddle, J Schrull, L Clegg, M McLerie	(161) *KEYNOTE PAPER - Airborne geophysics improves the diagnosis, prognosis and treatment of dryland salinity in Australian landscapes* **R J George (Agriculture WA)**	(127) *An interpreted ~1240 km-diameter multi-ring structure, of possible impact origin, centred beneath the Deniliquin region, southeastern Australia* **A N Yeates (AGSO, ACT)** A J Meixner, P J Gunn	(140) *High resolution gravity and EM grid surveys for mapping of firehole overburden hazards in open-cut brown coal deposits* **G Pettifer (Geo-Eng Aust. Pty Ltd, VIC)** P McDonald
0900		(171) *A farmers perspective on geophysics in agriculture* **M Ladyman (Agraria Ltd, WA)** K Tedesco	(123) *Bathymetry, sediment thickness and crustal structure from satellite derived gravity* **D Woodward (Institute of Geological and Nuclear Sciences, New Zealand)** R Wood	(136) *Large fixed loop airborne EM surveys in the equatorial, arid, and polar regions of the earth - case studies* **P Elliott (Elliott Geophysics International, Indonesia)**
0930	(157) *Rock property estimates from walkaway VSP surveys* **R P Clough (CGG Borehole Services Division)** S Rodriguez, V Dirks	(185) *Airborne geophysical surveys to assist planning for salinity control National Airborne Geophysics Project case studies* **G J Street (World Geoscience, WA)** G Pracilio, R J George, D Heislers, I Gordon	(144) *Interpretation of the crustal structure between the Ashburton Trough and the Hamersley Basin from gravity and magnetic data in the Wyloo region, Western Australia* **D Howard (Geological Survey of WA)** W Guo, M Dentith	(120) *Geophysical responses over the Mount Ararat Prospect* **A Willocks (Geological Survey of Victoria)**
1000	MORNING TEA IN THE EXHIBITION HALL			

Theme	MIGRATION (1)	DRYLAND SALINITY AND FARM PLANNING (2)	EM INTERPRETATION (1)
VENUE	MARQUEE 2	CONFERENCE 3 / LEVEL 3	MARQUEE 1
1030	(33) *The use of horizon velocity analysis in optimising static control and the resulting implications for depth migration* **N Fisher (Kenmore Geophysical, QLD)** R Taylor	(176) *The application of the TEMPEST broad-band AEM system for land management in landscapes characterised by a thick, very conductive regolith* **T Munday (CRCAMET, WA)** R George, R Lane, G Street, G Pracilio, J de Silva	(4) *Imaging and identification of thick electrical conductors using conductance and differential conductivity parasections of TEM data* **M Asten (Flagstaff Geo Consultants, VIC)**
1100	(160) *Travel-time computations for true-amplitude migration of constant-offset seismic data* **J Gazdag (OGS Borgo Grotta Gigante, Italy)**	(212) *Utilising the DIGHEM helicopter-borne EM/magnetic/radiometric system for salinity and water resource mapping in the Chapman Valley, Western Australia* **M Hallett (Geoterrex-Dighem Pty Limited, NSW)** R Speed	(231) *Analytical computation of EM field components in a uniform half-space* **M Sykes (Curtin University, WA)**
1130	(43) *Seismic migration in near-vertical and wide angle reflection and refraction studies: towards a unified approach* **A Goncharov (AGSO, ACT)** V Pylypenko	(203) *Airborne radiometric and magnetic data contributes to the mapping and understanding of soil: Lake Toolibin and Chapman Valley case studies* **B Verboom (Agriculture WA)** T Griffin, N Schoknecht	(236) *Airborne bathymetry via inversion of electromagnetic frequency soundings and conductivity depth imaging using "EM Flow"* **J Vrbancich (DSTO, NSW)** P Fullagar, J Macnae
1200	(76) *Pre-stack depth migration of seismic multiples* **C D Manuel (Curtin University, WA)** N F Uren		

Day 2 - Tuesday 14 March 2000

1230	LUNCH IN THE EXHIBITION HALL AND RESTAURANT AREA			
Theme	RESERVOIR GEOPHYSICS (2)	DRYLAND SALINITY AND FARM PLANNING (3)	NEW METHODS	EM INTERPRETATION (2)
VENUE	CONFERENCE 3 / LEVEL 3	CONFERENCE 4 / LEVEL 3	MARQUEE 2	MARQUEE 1
1330	(181) *Delineation of reservoir boundary using AVO analysis* **D Santoso (Institute of Technology Bandung, Indonesia)** W G A Kadir, S Alawiyah	(177) *Parna petrophysics - implications for its detection using airborne geophysics and their potential application for land management in western NSW* **T Munday (CRCAMET, WA)** K Lawrie, T Scott, C Chartres, J Wilford, P Wilkes	(169) *Underground tests of thehigh frequency seismoelectric method at the Lynx Mine, Canada* **A Kepic (WA)** R D Russell, M Maxwell, K E Butler	(105) *The effect of magnetic anomalies on transient electromagnetic data* **D Sattel (World Geoscience Corporation, WA)**
1400	(163) *Using multi-attribute transforms to predict log properties from seismic data* **D Hampson (Hampson-Russell Software Services Ltd, Canada)** T Todarov, B Russell	(180) *Interpretation of geophysics for salt hazard identification and watershed management Western Australian Case Studies* **G Pracilio (World Geoscience Corporation, WA)** G J Street, A Anderson-Mayes	(18) *A new Australian airborne gravity system* **T Crabb (Airborne Gravity Australian Geophysical Surveys, WA)**	(182) *IDM solver for 3-D modelling of electromagnetic field* **B Singer (Macquarie University, NSW)** A Mezzatesta, T Wang
1430	(15) *The effect of low velocity channels system on amplitudes, imaging and depth conversion* **J D Cocker (WAPET, WA)** E F Herkenhoff, B E Lockhart, WL Abriel	(162) *The National Airborne Geophysics Project (1997-1999)* **R J George (Agriculture WA)** R Speed, D Heislers, I Gordon, R Beasley, R Brodie, P Woodgate	(210) *Maximum noise fraction (MNF) method reveals detail in aerial gamma-ray surveys* **B Dickson (CSIRO Exploration and Mining, NSW)** G Taylor	(125) *Efficient solutions of full domain 3D electromagnetic modelling problems* **Z Xiong (CRCAMET, NSW)** A Raiche, F Sugeng
1500	(249) *New plays in the Browse Basin - NW Australia* **D Peace (Veritas Exploration Services, UK)**		(74) *The development of non-contacting electric field sensors for IP measurements* **J Macnae (CRCAMET, NSW)** Y P Yang	
1530	AFTERNOON TEA IN THE EXHIBITION HALL			
Theme	SEISMIC SURVEY DESIGN	DRYLAND SALINITY AND FARM PLANNING (4)	IP/DC RESISTIVITY	PETROPHYSICS
VENUE	MARQUEE 2	CONFERENCE 3 / LEVEL 3	MARQUEE 1	CONFERENCE 4 / LEVEL 3
1600	(220) *Implications of marine survey design on aquisition efficiency* **E F Herkenhoff (WAPET, WA)** C Singer	(154) The use of *ground EM systems to accurately assess salt store and help define land management options for salinity management* **D L Bennett (Agriculture WA)** R George, B Whitfield	(103) *The 2D smooth model inversion applied to dipole-dipole IP/resistivity data* **H Rutter (Flagstaff Geoconsultants Pty Ltd, VIC)**	(17) *Opaque mineralogy and rock magnetism - the missing link* **D Cowan (Cowan Geodata Services, WA)** L Tompkins
1630	(13) *3D VSP survey design, data processing and interpretation* **H Cao (Schlumberger Australia, VIC)**	(187) *Mineralogical and petrophysical properties of the regolith at Broomehill, WA-implications for mapping salinity using AEM data* **J Rutherford (Water and Rivers Commission, WA)** T Munday, L Mathews, L Leonhard	(38) *EM coupling removal from time-domain IP data* **P K Fullagar (Fullagar Geophysics Pty Ltd, QLD)** B Zhou, B Bourne	(30) *Towards geophysical grade estimation via automated interpretation of borehole logs* **G N Fallon (MIM Exploration, QLD)** P K Fullagar, B Zhou
1700	(110) *Environmentally sensitive 3D land geophysical survey design - a case study* **P van Baaren (Schlumberger, WA)** T Brice		(150) *Depth of investigation for Schlumberger, Wenner and dipole-dipole arrays over homogeneous, anisotropic and inclined half-space in DC resistivity methods* **F Abdolahi (Ministry of Energy, Iran)**	
1730	CLOSE OF SESSIONS			
1730	MEETING OF CURTIN RESERVOIR GEOPHYSICS CONSORTIUM			
1845	CONFERENCE DINNER AT PERTH ZOO *Sponsored by Veritas DGC Australia Pty Ltd*			

WEDNESDAY 15 MARCH 2000

0700	SPEAKERS BREAKFAST IN THE RESTAURANT AREA			
Theme	MIGRATION (2)	MULTI-COMPONENT AND 4D	INVERSION	CASE HISTORIES (NICKEL) (1)
VENUE	CONFERENCE 4 / LEVEL 3	CONFERENCE 3 / LEVEL 3	MARQUEE 2	MARQUEE 1
0830	(200) *Tomographic velocity model updating methods for prestack depth migration in practice* **J Zhou (Western Geophysical, WA)** R Bloor, M Brewer	(130) *Diffraction stacking with stacking velocity analysis - its application to a surface seismic survey in an active fault area* **J Matsushima (Geological Survey of Japan)** S Rokugawa, T Yokota, Y Kato	(67) *Bayesian inference applies to joint inversion of contemporaneous data* **A Lockwood (University of WA)** A Endres	(245) *Comparison of frequency-domain and time-domain surface-to-borehole EM data on a nickel prospect* **R Pietila,** B Bourgeois, C Alayrac
0900	(153) *Geophysical applications of equivalent offset migration (EOM)* **J Bancroft (University of Calgary, Canada)**	(106) *Time-lapse 3-D seismic physical modelling* **D H Sherlock (Curtin University, WA)** B J Evans, J McKenna	(26) *Crosswell seismic tomography without ray tracing* **B Du (PGS Australia Pty Ltd, WA)** L Lines	(143) *The role of geophysics in the discovery and delineation of the cosmos nickel sulphide deposit, Leinster area, WA* **B Craven (Southern Geoscience Consultants Pty Ltd, WA)** T Rovira, T Grammer, M Styles
0930	(207) *Geohazard information from conventional seismic data in deep water areas* **N S Smith (West Australian Petroleum, Pty Limited, WA)** E Herkenhoff	(51) *A comparison of multi-component wavefield separation techniques* **N Hendrick (University of QLD)** S Hearn	(118) *A D I plus interpolation - accurate finite-difference solution of 3-D wave-equation migration* **Y Wang (Robertson Research Australia Pty Ltd, WA)**	(145) *The Maggie Hays and Emily Ann Nickel deposits - a geophysical case history* **B Peters (Southern Geoscience Consultants Pty Ltd, WA)** P S Buck
1000	MORNING TEA IN THE EXHIBITION HALL			
Theme	RESERVOIR GEOPHYSICS (3)	SEISMIC ANISOTROPY (1)	WAVELET TRANSFORMS	CASE HISTORIES (NICKEL) (2)
VENUE	CONFERENCE 3 / LEVEL 3	CONFERENCE 4 / LEVEL 3	MARQUEE 2	MARQUEE 1
1030	(215) *Geometry of the oil pool in the Rough Range trend, Western Australia* **J A McDonald (Curtin University, WA)** S A Kawagle, M Hagan	(29) *Stress induced anisotropy: the effects of stress on seismic wave propagation* **T Thompson (Curtin University, WA)** B Evans	(119) *Wavelet estimation of a local long memory parameter* **B Whitcher (EURANDOM, The Netherlands)** M J Jensen	(107) *Electromagnetic methods applied to exploration for deep nickel sulphides in the Leinster Area, Western Australia* **E Stolz (WMC Resources Limited, WA)**
1100	(228) *Moving to a layered impedance cube, advantages of 3D stratigraphic inversion* **Y Lafet (CGG, France)** F Bertin, P Duboz	(195) *Analysis of higher order moveout in terms of vertical velocity variation and VTI anisotropy* **R G Williams (Veritas DGC Ltd, UK)** R Leggott, S Cheadle, P Whiting	(3) *Inferring geological structures using wavelet-based multiscale edge analysis and forward models* **D J Holden (Fractal Graphics, WA)** F Boschetti, W Jessell, N J Archibald	(10) *Horses for (conductive) courses: DHEM and DHMMR* **J Bishop (Applied Geophysics Pty Ltd, TAS)** R Lewis, E Stolz
1130	(101) *Optimised reservoir characterisation workflow using multi-attributes classification - a case study on the Wandoo field, NW Shelf, Australia* **S B Reymond (Schlumberger Geco-Prakla, WA)** C Steiner, A Duckett, A Strudley	(66) *Inversion technique for transverse isotropy with a tilted symmetry axis* **R Li (Curtin University, WA)** P Okoye, N Uren		(167) *Mineral potential evaluation based on airborne geophysical data* **P Keating (Geological Survey of Canada)** C J Chung
1200	(251) *Better, faster decisions through collaborative volume interpretation* **M Roth (Landmark Graphics, USA)** H Chambers, N Purday, B Keach	(242) *Experimental observation of wave propogation along interfaces in anistrophic media* **B Hartley (Curtin University, WA)** K Trigg, E Person		
1230	LUNCH IN THE EXHIBITION HALL AND RESTAURANT AREA			

Day 3 - Wednesday 15 March 2000

Theme	MIGRATION (3)	SEISMIC MULTIPLES	REGOLITH (1)	CASE HISTORIES (GENERAL) (1)
VENUE	CONFERENCE 3 / LEVEL 3	CONFERENCE 4 / LEVEL 3	MARQUEE 2	MARQUEE 1
1330	(24) *Comparison of diffraction tomography to Kirchhoff Migration* **B Du (PGS Australia Pty Ltd, WA)** L Lines	(246) *Practical implementation of interbed multiple attenuation* **I Moore (Western Geophysical, UK)**	(138) *Using AEM data to map Palaeo to Mesoproterozoic lithology and structure in areas of complex regolith and topography* **T Munday (CRCAMET, WA)** A Green, D Hunter	(47) *Recent base metal discovery at the Hill 800 Prospect, Victoria* **S Haydon (Geological Survey of Victoria)**
1400	(149) *Pre-stack imaging - time or depth?* **C Notfors (Veritas DGC Asia Pacific Ltd, Singapore)** P Whiting	(48) *Predictive deconvolution for non-random reflectivity sequences* **S Hearn (Veritas DGC Australia Pty Ltd, QLD)** S Coombs	(9) *Lawlers 1: electrical structure of the regolith in the Lawlers District, WA* **J Bishop (Mitre Geophysics Pty Ltd, TAS)** D Sattel, J Macnae, T Munday	(82) *Aeromagnetic imaging of gold mineralised structures in Archaean greenstone and granite terranes northwest of Kalgoorlie, Western Australia* **J Meyers (Centaur Mining and Exploration Limited, VIC)** G Tripp
1430	(247) *Fast kirchhoff migration in the wavelet domain* **D Kosloff (Tel Aviv University, Israel)**	(104) *Seismic preconditioning before autoconvolution based multiple attenuation* **B Sanderson (Curtin University, WA)** B M Hartley	(73) *Lawlers 2: simplified electrical structure models at AEM scales* **J Macnae (CRCAMET, NSW)** J Bishop, T Munday	(132) *Geophysical surveys at the Nkomati Mine, Mpumalanga, South Africa* **M Nyoni (Anglovaal Mining Ltd, South Africa)** J Bishop
1500	(232) *A comparison of indirect and direct near surface velocity measurement for velocity model building and pre-stack depth migration in an area of shallow carbonate overburden* **L Hansen (Apache Energy, WA)** A Lau, T Allen, S Grant		(86) *Geological constraints on regolith electrical structures: Lawlers, Western Australia* **T Munday (CRCAMET, WA)** J Macnae, J Bishop	
1530	AFTERNOON TEA IN THE EXHIBITION HALL			
Theme	SEISMIC METHODS	SEISMIC ANISOTROPY (2)	REGOLITH (2)	CASE HISTORIES (GENERAL) (2)
VENUE	CONFERENCE 3 / LEVEL 3	CONFERENCE 4 / LEVEL 3	MARQUEE 2	MARQUEE 1
1600	(155) *Direct hydrocarbon indicators in the Macedon-Pyrenees Field* **J A McDonald (Curtin University, WA)** A Brockmann	(46) *Determination of the average and interval elastic parameters in multi-layered transversely isotropic media: physical modelling approach* **N Gyngell (Curtin University, WA)** P Okoye	(178) *Geological constraints on electrical structures identified in Gilmore Fault Zone TEMPEST AEM data - implications for exploration in an area of complex regolith cover* **T Munday (CRCAMET, WA)** K Lawrie, R Chan, D Gibson, P Wilkes	(36) *Geophysical signatures associated with the Gossan Hill Deposit* **A Foley (Normandy Mining Ltd, WA)** M Dunkin
1630	(213) *Wide angle reflectivity - another amplitude dimension* **F Herkenhoff (West Australian Petroleum, Pty Limited, WA)** J Cocker, P Criddle, N Smith	(190) *Attenuation measurements in the South Sydney Basin* **M Urosevic (Curtin University, WA)** M Brajanovski, B J Evans	(84) *Automatic merging of gridded airborne gamma-ray spectrometric surveys* **B Minty (AGSO, ACT)**	(71) *Physical properties of the Lawlers Regolith WA* **J Macnae (CRCAMET, NSW)** D Emerson, D Sattel
1700	(250) *Depthfold illumination - shedding new light in difficult data areas* **G Hofland (Landmark Graphics Corp, USA)**		(165) *OARS - A new system for mapping surface mineralogy simultaneously with airborne geophysics* **P Hausknecht (World Geoscience, Corporation, WA)** L B Whitbourn, P Connor, G Wells, J Flack, P Mason, J F Huntington, R Hewson, S Batty, J Boardman	(7) *Geophysical response of the Hercules Base Metals Deposit: a case study from Western Tasmania* **P Basford (Pasminco Exploration, VIC)** N A Hughes, C Dauth
1730	CLOSE OF SESSIONS			
1730	HAPPY HOUR IN THE EXHIBITION HALL *Sponsored by Fugro Airborne Surveys*			

THURSDAY 16 MARCH 2000

0700	SPEAKER BREAKFAST IN THE RESTAURANT AREA			
Theme	BOREHOLE MODELLING	EXPLORATION PHILOSOPHY (1)	POTENTIAL METHODS (4)	ELECTRICAL METHODS
VENUE	CONFERENCE 4 / LEVEL 3	MARQUEE 2	MARQUEE 1	CONFERENCE 3 / LEVEL 3
0830	(121) *Acoustic compression wave performance modelling in sedimentary sequences* **M Wiltshire (Wiltshire Geological Services, SA)** L Huggard	(219) *GIS mapping of the Cobar Region* **D Robson (NSW Department of Mineral Resources)** P Ruszkowski	(156) *A low cost ATV towed array magnetometer survey for mapping intrusions in coal fields-Kayuga, Hunter Valley* **P J Clark (Geophysical Technology Limited, NSW)** M Donaldson, T Schwartz	(113) *Airborne electromagnetic bathymetry of Sydney Harbour* **J Vrbancich (DSTO, NSW)** M Hallett
0900	(199) *Well-site quasi-2D inversion of array resistivity logging data using neural networks and dimensional reduction* **Z Zhang (Baker Atlas, USA)** A Mezzatesta, S Painchaud	(151) *Systematic spatial analysis as an approach to interpretation of Airborne geophysical data* **K Beckett (University of QLD)** A Anderson-Mayes, G J Street	(55) *Interpreting crustal scale features using wavelet-based multi-scale edge analysis of regional gravity datasets* **N J Archibald (Fractal Graphics, WA)** D Holden, F Boschetti, F Horowitz, P Hornby	(93) *Electromagnetic investigation of the Eyre Peninsula conductivity anomaly* **I Popkov (Flinders University, SA)** A White, G Heinson, P Milligan, S Constable, F E M Lilley
0930	(193) *Effects of the outermost boundary on acoustic waves in an artificial cased borehole* **X Wang (CSIRO Petroleum, WA)** K Dodds			(235) *Airborne electromagnetic bathymetry: an overview of several Australian surveys with implications for Maritime Defence in Littoral Waters* **J Vrbancich (DSTO, NSW)**
1000	MORNING TEA IN THE EXHIBITION HALL			
Theme	RESERVOIR DYNAMICS	EXPLORATION PHILOSOPHY (2)	SEISMIC \METHODS IN MINERALS (1)	REGIONAL STUDIES (2)
VENUE	CONFERENCE 4 / LEVEL 3	MARQUEE 2	MARQUEE 1	CONFERENCE 3 / LEVEL 3
1030	(166) *S-wave observation by down-hole hydrophone array* **N Kano (Geophysical Survey of Japan)** T Inazaki, M Takahashi	(41) *Regional aeromagnetic interpretation of Australia and Southern Africa - the identification of several proterozoic rift related dyke swarms* **A S Goldberg (Monash University, VIC)**	(20) *Seismic refraction inversion of a palaeochannel system in the Lachlan Fold Belt, Central NSW* **T Deen (Macquarie University, NSW)** K Gohl, C Leslie, E Papp, K Wake-Dyster	(168) *Basement reactivation and control of neogene structures in the Outer Browse Basin, North West Shelf* **M Keep (Tectonics Special Research Centre, WA)** S Moss
1100	(83) *Magnetic signatures produced by fluid flow in porous sediments* **M F Middleton (Curtin University, WA)** D Winkler, M Bick, T Sahlin	(222) *Advances in geophysical/geological mapping in the Lachlan Fold Belt, NSW* **A Willmore (NSW Department of Mineral Resources)**	(88) *Can amplitudes resolve ambiguities in refraction inversion?* **D Palmer (University of NSW)**	(234) *Re-activation of the pre-Permian Najd Fault System and its importance in the oil province of Saudi Arabia* **D Perincek (D Perincek and Associates, WA)** S Saner, K G Al-Hinai
1130	(62) *The cause and effects of multilayer-generated guided-waves* **D M Leslie (Curtin University and Australian Petroleum CRC, WA)** B J Evans	(80) *Potential field evidence for the existence of an Archaean Suture Zone in the Western Yilgarn Craton, Western Australia* **J Meyers (Astro Mining NL, VIC)**	(117) *Imaging coal seam structure using 3-D seismic methods* **C Walton (Curtin University, WA)** B J Evans, M Urosevic	(90) *Crustal structure across the Vulcan Sub-basin from seismic refraction and gravity data* **P Petkovic (AGSO, ACT)** C D Collins,

Day 4 - Thursday 16 March 2000

1200	LUNCH IN THE EXHIBITION HALL AND RESTAURANT AREA			
Theme	AEM	SEISMIC VELOCITIES	SEISMIC METHODS IN MINERALS (2)	REGIONAL STUDIES (3)
VENUE	MARQUEE 1	MARQUEE 2	CONFERENCE 4 / LEVEL 3	CONFERENCE 3 / LEVEL 3
1300	**(196)** *The application of airborne EM to minerals discovery: the Canadian camp experience* **K E Witherly (Condor Consulting, USA)**	**(56)** *A braver approach to seismic velocity in the Taranaki Basin, New Zealand* **D Woodward (Institute of Geological and Nuclear Sciences, New Zealand)** D Humphris, J Ravens	**(87)** *The effects of spatial sampling on refraction statics* **D Palmer (University of NSW)** B Goleby, B Drummond	**(70)** *Structural framework of the McArthur Basin, Northern Australia interpreted from aeromagnetic data* **T Mackey (AGSO, ACT)** P J Gunn
1330	**(94)** *Choosing the best AEM system for the target* **A Raiche (CRCMET, NSW)** D Richards	**(59)** *Velocity structure of the Argo and Roebuck Basins, North West Shelf of Australia* **A Kritski (University of Sydney, NSW)** R D Muller, C D Collins, G I Christeson	**(128)** *Pushing coal seismic to its limits: through computer aided interpretation and 3D seismics* **B Zhou (CSIRO Exploration and Mining, QLD)** P Hatherley	**(78)** *The nature of the basement to the Cooper Basin Region, South Australia* **A J Meixner (AGSO, ACT)** P J Gunn, R K Boucher, A N Yeates, L M Richardson, R A Frears
1400	**(100)** *Current channelling in time-domain airborne electromagnetic data* **J Reid (CRCMET, NSW)** J Macnae	**(159)** *Acoustic structure and seismic velocities in the Carnarvon Basin, Australian North West Shelf: towards an integrated study* **T Fomin (AGSO, ACT)** A Goncharov, C D Collins,B Drummond	**(89)** *Can new acquisition methods improve signal-to-noise ratios with seismic refraction techniques?* **D Palmer (University of NSW)**	**(64)** *A deep-crustal seismic image through the Bancannia Trough and Koonenberry Zone, NSW* **B Willcox (AGSO, ACT)** J Leven, A Yeates, D Johnstone, K Wake-Dyster, K Mills, R Shaw
1430	CLOSING CEREMONY AND AWARDS			
1500	CONFERENCE FAREWELL			

Posters

Modelling the airborne electromagnetic response of a vertical contact
D. Annetts, F. Sugeng, J. Macnae and A. Raiche

Geophysical Exploration in the Xi-Cheng Lead-Zinc Orefield, Gansu Province China
W. Guo, M. Dentith and Y. Zhao

A new multi-frequency AEM System
R.J. Henderson and Z. Beldi

A new distributed acquisition system for ground TEM
R.J. Henderson and B. O'Neill

Passive seismic profiling of the Moon
A.S. Long and J. Rickett

Victoria revealed: stripping off the cover to show the basement features
B.A. Simons

Geophysical signatures of porphyry copper mineralisation in Victoria
S. Rajagopalan and S. Haydon

Drape corrections of aeromagnetic data using wavelets
T. Ridsdill-Smith and M. Dentith

Reduction-to-the-pole of regional magnetic data with variable field direction, and its stabilisation at low inclinations
C.J. Swain

Wavelet transform-based derivative calculation for use in the interpretation of magnetic data via euler deconvolution
F. Walker

Geophysical evidence for crustal fluids in a region of active continental convergence - the South Island of New Zealand
S. Kleffmann

Influence of anisotropic elastic parameters on seismic imaging : Numerical and Physical modelling studies
P.N. Okoye and N. Uren

Precise GPS Measurements for Regional Gravity Surveys - the AGSO Experience
R.M. Tracey

Practical overview of HEM data processing
N. Valleau

Detailed ground magnetics as an exploration tool in Central Victoria
P. McDonald

Targeted exploration initiative South Australia (TEISA); unlocking the secrets
D. Calandro

High-resolution seismic imagery of palaeochannels near West Wyalong, NSW.
Christopher Leslie, Leonie Jones, Éva Papp, Kevin Wake-Dyster, T.J. Deen and K. Gohl

Exploring the Kanmantoo Trough using detailed targeted exploration initiative South Australia aeromagnetic and radiometric data
A.C Burtt., J.C. Gum and P.J. Abbot

Imaging spectrometry: more than the theory offers
V. Stamoulis

3-D fluid flow tomography
J. McKenna, D. Sherlock, and B. Evans

Daily variation of geomagnetic H-field at equatorial and low latitudes
F.N. Okeke and Y. Hamano

Keynote Speaker

Professor Matthias Fink will open the program on Monday 13 March at 0900. Professor Fink is a Professor of Physics at the École Normale Supérieure de Physique et de Chimie Industrielles de la Ville de Paris (ESPCI) and at Paris 7 University (Denis Diderot), France. In 1990 he founded the Laboratory Ondes et Acoustique at ESPCI. In 1994, he was elected at the Institut Universitaire de France. His current research interests include medical ultrasonic imaging, ultrasonic therapy, nondestructive testing, underwater acoustics, active control of sound and vibration, analogies between Optics and Acoustics, wave coherence in multiple scattering media and time reversal in geophysics. He has developed different techniques in wave focusing in inhomogeneous media, speckle reduction and in ultrasonic laser generation. He holds twenty patents and he has published more than 180 articles. He received the Silver medal of CNRS in 1995, the Prix FOUCAULT of the French Society of Physics in 1995, The Grand prix de la creativity SNECMA in 1994, the Outstanding Paper Award of IEEE Transactions in Ultrasonics in 1992 and his laboratory received the Prize from the magazine : Le Nouvel ECONOMISTE and from the CNRS in 1996. He was the Distinguished Lecturer at the American Acoustical Society meeting in June 1997 (Penn State University) USA.

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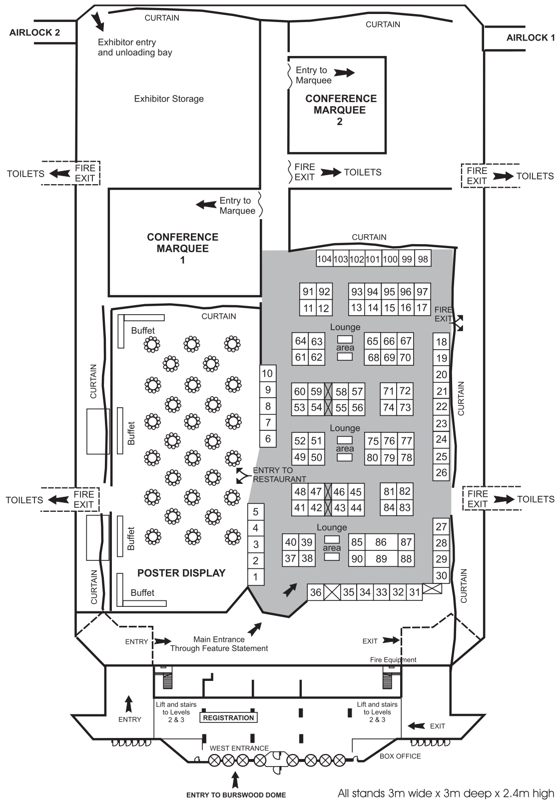
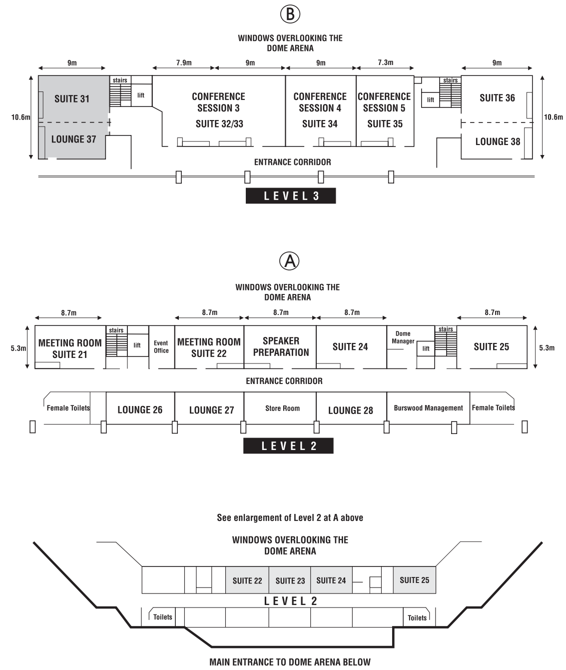


Main Arena



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The Australian Geological Survey Organisation (AGSO) is Australia's national geological survey and the largest geoscience organisation in Australia. It is a research agency within the Commonwealth Department of Industry, Science and Resources.

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The Australian Society of Exploration Geophysicists (ASEG) is a learned society of approximately 1100 members, embracing professional earth scientists specialising in the practical application of the principles of physics and mathematics to solve problems in a broad range of geological situations.

The ASEG is a non-profit organisation which provides members a forum for fellowship, communication and enhancement of the science and education of exploration geophysics by providing regular publications, high quality conferences, regular technical meetings and social functions; offers subsidised continuing education courses and promotes interest in the profession at secondary and tertiary school levels; fosters postgraduate research projects and is promoting interaction with other earth scientists.

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Email: j.thomson@dem.csiro.au
Website: www.dem.csiro.au
Contact person: Judy Thomson

CSIRO is working with the mining industry to develop new geophysical techniques and interpretation methods designed to increase exploration success rates and the efficiency and safety of mining operations, while lowering their environmental impact.

Since 1992, CSIRO has been a major participant in the CRC for Australian Mineral Exploration Technologies, which has developed new, cost-effective airborne electromagnetic systems for detection of deeply-buried orebodies.

CURTIN GEOPHYSICS **STAND 14**

Curtin University of Technology
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or enq@geophy.curtin.edu.au
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Contact Person: Deirdre Hollingsworth

The Department of Exloration Geophysics specialises in education and research in Minerals, Groundwater and Petroleum Geophysics. In 2000 the Department has 14 Staff and 130 Students. Since the inception of a geophysics program at Curtin, over 400 persons have been awarded degrees at all levels. The Department is a member of three CRCs; APCRC, CRCAMET, CMTE and has recently been chosen as a Centre of Excellence for Exploration and Production Geophysics. The annual operating budget of the Department is $2.5 million.

DAISHSAT Pty. Ltd. **STAND 33**

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AUSTRALIA
Tel: +61 8 85310349
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Mob: 0418 800122
Website: www.daishsat.com
Contact person: David Daish, Geodetic Surveyor

Daishsat is the leading provider of GPS positioned gravity surveys in Australia having surveyed in excess of 170 000 gravity stations over the last 8 years since the introduction of precision GPS techniques to the exploration industry in Australia. We also offer precision GPS surveys, magnetics surveys, image processing and modelling.

DEPARTMENT OF MINES AND ENERGY QUEENSLAND — STAND 23

Queensland Minerals and Energy Centre
61 Mary Street
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Fax: +61 7 3235 4074
Email: geological_info@dme.qld.gov.au
Website: www.dme.qld.gov.au

The Geological Survey of Queensland enhances the State's minerals and energy prospectivity by providing quality updated geological data from Departmental mapping and airborne geophysical data acquisition. Information is continually being upgraded, and enhanced through project mapping procedures. Direct access to timely preliminary and manipulated data is encouraged through 'client-focussed' promotion.

DESMOND FITZGERALD & ASSOCIATES P/L — STAND 13

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Email: info@dfa.com.au
Website: www.dfa.com.au
Contact person: James Heywood, General Manager/Director

Desmond FitzGerald and Associates (DFA) has 20 years experience in providing specialist services to the mining and exploration industry, including consulting and computer software, hardware integration and support services.

DFA's main product, Intrepid, is a geophysical processing, interpretation and archiving system. Magnetics, Gravity, Radiometrics and Bathymetry data are processed in an integrated environment supporting a wide range of quality control, processing, interpretation, visualisation and hardcopy tools.

EARTH RESOURCE MAPPING — STAND 81-84

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Contact person: Clive Poole

ER Mapper is an industry standard image visualisation tool for the exploration community.

The recently released Image Web Server can serve images of any size over the web. Using the revolutionary open standard ECW wavelet compression, the images are created in ER Mapper, then served to many simultaneous users for viewing in their choice of application.

ELECTROMAGNETIC IMAGING TECHNOLOGY PTY LTD — STAND 29

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EMIT develops and sells instrumentation and software for electromagnetic geophysics.

The SMARTem V Geophysical Receiver System is a rugged Windows PC-based 8 channel receiver with the capability to interface to most transmitters and sensors. It has powerful signal processing to function well in noisy environments, a large hard disk to record raw time series, full PC functionality, crystal sync and software to carry out any type of electrical geophysics.

Maxwell is powerful Windows software for displaying, processing and modelling any type of EM geophysical data. It is user-friendly, has a range of powerful modelling and processing utilities, great graphics, superior quality hardcopy and a generic interface to external modelling routines.

ENCOM TECHNOLOGY PTY LTD — STAND 24-25

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Fax: +61 2 9922 6141

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Contact person: Graham Butt

Melbourne Office:
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Fax: +61 3 9428 0470

Encom Technology Pty Ltd provides innovative geophysical software solutions, geoscience consulting, information services and training.

At ASEG 2000, Encom is announcing the launch of GEMeX, an exciting new geophysical software product for airborne EM data management.

For petroleum explorers, Encom's GPINFO permits information service and its Encom Data digital transcription and archiving service are currently the subject of significant development investment, the results of which will flow through in the 2nd quarter of 2000."

EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS (EAGE) — STAND 19

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With more than 5300 members worldwide, EAGE is the leading European based international organisation of geoscientists and engineers. Members receive the EAGE journals, and enjoy other benefits such as reduced registration fees for the Annual Conference. For more information please visit stand number 19 or contact the EAGE Business Office.

EXPLORATION CONSULTANTS AUSTRALIA Pty Ltd (ECL) — STAND 93

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Contact persons: Paul Miller and John Stanton

A member of the ECL group of companies providing a complete range of exploration consultancy and project management services to the hydrocarbon and minerals industries worldwide. ECL has also developed a suite of specialised software products to support seismic and navigation data acquisition and processing QA & QC. ECL also provides hydrographic, engineering and construction survey supervisor consultants to the offshore industry.

FUGRO AIRBORNE SURVEYS PTY LTD — STANDS 53-54, 74

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Contact persons: Nick Daws / Sandy Sanders

Fugro Airborne Surveys Ltd (FAS) is a world leader in airborne geophysical survey contracting, specialising in low level remote sensing technologies for mineral, petroleum and groundwater resource exploration, geological mapping and environmental monitoring.

FAS is a subsidiary of Fugro NV of Holland, a multinational organisation offering geotechnical consulting, surveying and positioning services to the petroleum E&P, engineering, construction, communication, utilities and transportation sectors.

The company was formed in January 2000, following Fugro NV's acquisition and merger of three of the largest and most well established companies in the airborne geophysical survey industry, Geoterrex/Dighem and High Sense of Canada and World Geoscience Corporation of Australia. The combined experience, resources, technical expertise, R&D, geographic spread and operational capability of these three companies is now offered to clients through Fugro Airborne Surveys, along with an uncompromising commitment to the highest standards in quality, safety and service.

The company offers the most comprehensive range of airborne geophysical survey technologies available, including:

- Fixed wing time domain and helicopter frequency domain electromagnetic (EM)surveys;
- Fixed wing and helicopter high resolution magnetometer and gamma spectrometer surveys;
- Fixed wing gradient magnetometer surveys;
- Airborne laser fluorosensor (ALF) surveys.

The extensive aircraft fleet operated by FAS enables airborne surveys to be undertaken safely and cost effectively in a wide variety of terrains and almost any location.

In addition to airborne surveys, FAS can also offer products and services in:

- Geophysical data processing;
- Geophysical data interpretation and consulting;
- Geological mapping;
- Ground geophysics.

The company has a long- term commitment to R&D in order to deliver innovative, cost effective solutions for the natural resource exploration and environmental management sectors. Current projects under development include an airborne gravity system, a mineral mapping system and a multiple survey system, which will combine electromagnetic, magnetic, radiometric and mineral mapping systems onto a single aircraft platform.

Fugro Airborne Surveys Ltd is headquartered in Ottowa, Canada. Subsidiary offices are currently located in:

- Canada - Toronto, Calgary
- USA - Houston
- Brazil - Rio de Janeiro
- Chile - Santiago
- UK - Guildford
- Botswana - Gabarone
- Zimbabwe - Harare
- UAE - Dubai
- Indonesia - Jakarta
- Australia - Sydney, Perth

The company employs approximately 350 people worldwide, many of whom are highly experienced geophysicists, geologists, remote sensing specialists and field survey operators.

GEO INSTRUMENTS PTY LTD — STAND 4-5

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Contact person: Roger Henderson

Geo Instruments is a leading supplier of high-quality earth science products and services to the geophysical, geotechnical, engineering, & environmental sectors.

We promote Australian-made instruments and services internationally, and also represent major North American & European suppliers in the Australasia-Pacific regions. Geo Instruments offers sales, rental & servicing of ground systems & software, as well as high-resolution helicopter & fixed-wing surveys.

Recent innovations include our revolutionary ARTEMIS TEM System and the MIDAS-750 fixed-wing FEM System.

GEOLOGICAL SURVEY OF NAMIBIA — STAND 73

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The Geological Survey of Namibia is the national institution responsible for Earth Sciences and Geological Research. In 1994, the Geological Survey embarked on a programme of high resolution airborne geophysical surveys designed primarily to assist and promote mineral exploration.

To date over 1 million line-km of data are available to the exploration industry and a contract for a further 750 000 line-km is currently in progress. Further surveys are planned for this year and in following years so as to achieve complete national coverage by 2008.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA — STAND 35

(Division of the Department of Minerals and Energy)
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Fax: +61 8 9222 3633
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Website: http://www.dme.wa.gov.au/geology
Contact person: Dr D F Blight

The Geological Survey's role in promoting and enhancing the prospectivity of Western Australia is of crucial importance to the State's economy. The maps, publications and datasets produced by the Survey provide explorers with the basic tools for the design of successful exploration programs. These lead to mineral and petroleum discoveries, which in turn generate royalties, create jobs, and make other important contributions to the economy of the State.

GEOPHYSICAL TECHNOLOGY LIMITED — STAND 94

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Website: geotec.com.au
Contact person: Andrew Davis

GTL is a technologically advanced supplier of geophysical exploration and sub-surface mapping services with Australian offices in Brisbane and

Armidale. It is a respected global operation with a long record of delivering airborne (helicopter and fixed-wing), vehicle-towed and hand-held services world-wide. Services available include specialities such as Sub-Audio Magnetics (SAM), multi-sensor airborne and towed-array magnetometer systems, GPR and high-definition multi-period TEM plus most of the industry standard techniques such as magnetics, gravity, IP, EM, radiometrics and seismic refraction. GTL's markets include mineral exploration, engineering and archaeological site investigation and environmental decontamination (chemical, industrial and UXO). Established clients include most of the world's major mineral explorers, its leading environmental engineering firms and several national Departments of Defence.

GREEN MOUNTAIN GEOPHYSICS — STAND 28

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Fax: +(303) 444-8632
Email: marketing@gmg.com
Website: www.gmg.com
Contact person: Schelly Olson

Green Mountain Geophysics has been developing geophysical software for use in exploration for over 20 years. GMG specializes in the following areas:

- 3D Seismic Survey Planning
- Model-based Survey Design
- Acquisition Project Management
- Field QC and Refraction Statics Solutions
- 3D Survey Design Consulting/Training

GUARDIAN DATA SEISMIC — STAND 47

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Established in 1984, Guardian Data Seismic a wholly owned subsidiary of Veritas DGC is a major international provider of data transcription and archiving services with strategically located centres throughout the world. Over a decade of proven experience and service to oil companies, government departments and processing centres makes Guardian Data Seismic an ideal choice when considering data management, data transfer and archiving projects which impact a company's asset of irreplaceable data.

HAINES SURVEYS — STAND 36

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Contact person: Graeme Haines

Haines Surveys are specialists in the acquisition of high quality gravity data using the latest GPS technology. The Company has been operating since 1991 and was one of the first to introduce GPS Surveying to the industry. Haines Surveys have completed gravity projects in all parts of Australia and several regions overseas including North America, Europe, West Africa and South East Asia. Their clients are provided with a highly automated, reliable and economical gravity service through the use of experienced staff, in house developed processing software, the latest state-of-the-art Trimble GPS Receivers and Scintrex CG-3 Gravity Meters.

HAMPSON-RUSSELL SOFTWARE SERVICES LTD — STAND 67

Agent in Australia and New Zealand
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Contact person: Jim Dirstein

Hampson-Russell is a seismic software company based in CALGARY, Canada , with technical support offices in HOUSTON, U.S.A and LONDON, UK. We develop seismic modelling and processing programs for geophysical interpreters and processors. Our programs packages enable: AVO analysis, post stack seismic inversion, geostatistical analysis and mapping, 3D refraction statics analysis and multi-attribute analysis and reservoir parameter prediction.

INTEGRATED SOLUTIONS AUSTRALASIA — STAND 12

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Contact person: Karen O'Donahoo, Country Manager

"ISA - Providing high value services and solutions based on innovative technology and applications"

With offices in Perth, Jakarta and Aberdeen, ISA provide data management and integration solutions to E&P companies throughout Australia, Asia, United Kingdom and the United States. ISA can be found on the web at http://www.isa-web.com

JASON GEOSYSTEMS AUSTRALIA — STAND 59-60

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Contact person: Gary Klomfass, Business Manager

Jason Geosystems is a fast growing, high-tech company that offers innovative solutions for reservoir modeling and characterization. Using our core product, the "Jason Geoscience Workbench", we provide tailored solutions based on an integrated approach. Quantitative analysis techniques employed include seismic inversion, elastic inversion, geological modeling, velocity modeling, stochastic modeling and combined stochastic modeling with inversion.

JONMICH BIODIAGNOSTICS LTD — STAND 100

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LANDMARK GRAPHICS CORPORATION — SUITE 31/37

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Landmark is the leading supplier of integrated E&P technical and economic software and services to support decision making about finding, drilling and producing oil and gas. Knowledge-based E&P companies now are turning to Landmark for technical-to-business (T2B) process integration for improving returns on their investments. Visit the Landmark Web site at http://www.lgc.com

GEOGRAPHIX

(Division of Landmark Graphics Company)
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Web: www.geographix.com
Contact person: Peter Brazier or Rodziah Daud

Geographix offers the petroleum industry's most comprehensive suite of pc-based applications for the upstream e&p industry. Our integrated system addresses the fundamental and practical requirements of geoscientists, land professionals, engineers, and petrophysicists. Geographix's products provide clients with a comprehensive suite of easy-to-use, intuitive, powerful, and cost effective applications that increase productivity and enable clients to achieve a competitive edge within the marketplace.

MAGNet DATABASE SERVICES PTY LTD — STAND 103

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Tel: +61 8 9367 6700
Fax: +61 8 9367 6745
Email: max@geoimage.com.au
Contact person: Max Bye

Pitt Research
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Thebarton, SA 5031
Tel: +61 8 8152 0422
Fax: +61 8 8152 0433
Email: mjd@pitt.com.au
Contact person: Mark Deuter

MAGNet, the Multiclient Airborne Geophysics Network, is a database of company-funded airborne geophysical surveys. It has been jointly established by Pitt Research Pty Ltd. and Geoimage Pty Ltd.

MAGNet provides:

- A centralised, current and consistent database of airborne geophysical surveys available for re-sale (and where appropriate open-file) to the exploration community.
- A mechanism which will relieve contributor companies of much of the day-to-day distractions of managing, negotiating, and effecting geophysical data swaps and sales.
- A repository that meets the requirements of the current guidelines for WA Dept of Minerals and Energy for the lodgment of "multi-client" surveys

MICROMINE PTY LTD — STAND 98

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Mobile: 0411 588 331
Email: dbowie@micromine.com.au
Website: http://www.micromine.com.au
Contact person: Doug Bowie, Sales Manager

Move into Mine Control Systems with PitRAM by Micromine Pty Ltd.

Micromine is recognised as the leading provider of software where excellence in data acquisition, data management, reporting, and visualisation of all geological, geophysical, and mining data is required.

These products, combined with bureau, consulting and data management services, position Micromine as the total software and services solution for the exploration and mining industries.

MINERALS AND PETROLEUM VICTORIA — STAND 71-72

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Website: www.nre.vic.gov.au
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Minerals & Petroleum Victoria is a division of the Department of Natural Resources & Environment. The Department promotes exploration and generates high quality data through its program of geological mapping and geophysical surveys. Digital data from airborne surveys, gravity, GIS sets, and geology is FREE and available on CD.

NEW SOUTH WALES DEPARTMENT OF MINERAL RESOURCES — STAND 75

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Tel: +61 2 9901 8342
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Website: minerals.nsw.gov.au
Contact person: David Robson

Geophysicists within the NSW Department of Mineral Resources are responsible for all geophysical data and interpretations that cover Regional Geology, Coal and Petroleum Resources, Minerals Assessment and the Discovery 2000 Exploration Initiative. During the 1990's, just over 40% of the State were covered with high resolution airborne geophysical data.

NEW WAVE GEOPHYSICAL PTY LTD — STAND 97

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New Wave Geophysical was formed in 1998, with the main focus of business being the conversion of hard copy seismic sections to digital SEGY format by scanning and trace reconstruction. A wide range of post-stack processing, including migration, may also be applied.

New Wave maintains an extensive database related to Australian exploration, including seismic navigation, and incorporates line locations together with wells and permit boundaries in a user-friendly GIS product.

NORTHERN TERRITORY GEOLOGICAL SURVEY STAND 45-46

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Website: www.dme.nt.gov.au/ntgs <http://www.dme.nt.gov.au/ntgs>
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The role of the NTGS is to collect, interpret, synthesise and disseminate geoscientific data to attract and render more effective mineral and on-shore petroleum exploration, and also to provide geoscientific advice in the formulation of resource policies. It proactively undertakes regional geoscience programs, mineral resource assessments, metalliferous deposit studies, petroleum system studies, exploration reviews and airborne geophysical surveys.

OMNI STAR PTY LTD STAND 21

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OmniSTAR is the world market leader in the provision of satellite delivered Differential GPS corrections. OmniSTAR provide users with a dependable source of quality controlled DGPS corrections, offering sub-metre accuracy for any application.

OmniSTAR offers worldwide coverage, unsurpassed reliability and unrivalled customer service and support.

PARADIGM GEOPHYSICAL PTY LTD STAND 55-58

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website: www.ParadigmGeo.com
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Paradigm Geophysical is the largest independent developer of Geoscience software and service solutions to companies engaged in oil and natural gas exploration and production. Paradigm's comprehensive range of software offers cutting edge solutions for seismic data analysis, 3D earth modelling, interpretation, visualisation, well data processing and reservoir characterisation, through the integrated product suites ECHOS , ERGOS and POROS. The use of a shared earth model within and across these product suites provides oil and gas exploration and production asset teams with the opportunity to build, work with, and visualise a common knowledge base for the reservoir being investigated, so optimising efficiency and accuracy of results.

With today's ever-increasing workload and lack of personnel resources, interpreters are often left with little time for detailed seismic investigation. Paradigm offers our own geophysical and geological specialists and computer resources to assist clients with skilled data processing, velocity model building, depth imaging, seismic inversion and petrophysical services.

PETROLEUM GEO-SERVICES STAND 61-64

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Petroleum Geo-Services is a technologically focused oilfield service company principally involved in two businesses - geophysical services and production services. PGS acquires, processes, manages and markets 3D, 4D and 4C marine seismic data. Such data is used by oil and gas companies in the exploration for new reserves, the development of existing reservoirs, and the management of producing oil and gas fields. In its production services business, PGS owns four floating production, storage and offloading systems and operates numerous offshore production facilities for oil and gas companies. FPSO's permit oil and gas companies to produce oil and gas from offshore oil and gas fields more cost effectively. The Company also provides data management solutions, 4D reservoir monitoring, interpretation and characterization studies and other specialized geophysical services. PGS operates on a worldwide basis with headquarters in Oslo, Norway, and Houston, Texas.

PETROSYS PTY LTD STAND 49-50

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Petrosys provides software for the analysis, management, and presentation of petroleum exploration and production data using a cartographic framework. Petrosys mapping, data management, and velocity analysis systems are a mission critical component of the E&P toolkit, integrating information from seismic, well, surface and other sources in presentation quality maps.

PRIMARY INDUSTRIES AND RESOURCES SOUTH AUSTRALIA STAND 34

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Website: www.minerals.pir.sa.gov.au
Contact person: Domenic Calandro

Primary Industries and Resources South Australia (PIRSA) encompasses: Office of Minerals and Energy, Agricultural Industries, Fisheries, Aquiculture, Office of Energy Policy, Rural Communities Office and the South Australian Research and Development Institute (SARDI). PIRSA is a key partner in maximising the sustainable economic contribution of primary industries and resources which are self reliant, market driven, internationally competitive, environmentally and socially responsible. As a key economic development agency of the SA Government, PIRSA works with people and organisations helping to make the right development decisions.

RESOLUTIONS STAND 42

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RESolutions Resource and Energy Services provides specialist publishing and marketing services to the Australasian/South East Asian resource industry. Publishers of Preview and Exploration Geophysics on behalf of the Australian Society of Exploration Geophysicists and publishers of PESA News and PESA Journal on behalf of the Petroleum Exploration Society of Australia.

Representatives in Australasia for: AMEEF's publication, Groundwork PetroMin, Hydrocarbon and OPL, offering the world's largest selection of oil and gas concession maps, geological maps, technical books and databases.

ROBERTSON GEOLOGGING LIMITED STAND 101

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Robertson Geologging Ltd. is a leading manufacturer and contract operator of slimhole digital logging systems for mining, water and geotechnical investigations. Based in the UK, the company is represented worldwide. RG will be displaying surface systems, a portable winch and Optical Televiewersonde.

A selection of OYO equipment will also be on display.

ROBERTSON RESEARCH AUSTRALIA PTY LTD STAND 65-66

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Robertson Australia has been in Perth since 1980 and specialises in land, marine 2D and 3D data processing services on either an exclusive or non-exclusive basis. Interpretive processing services (AVO, inversion, PSDM and petrophysical log analysis) are also provided at our office. Robertson Australia is part of the Robertson Research International group, the headquarters of which are at Llandudno in North Wales.

SCHLUMBERGER OILFIELD AUSTRALIA PTY LTD STAND 7-10

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Schlumberger Oilfield Services provides virtually every type of service to the upstream exploration and production industry. Schlumberger is particularly well positioned to respond to the oil companies' need for maximizing asset value because it offers a spectrum of exploration and production services ranging from seismic data acquisition to drilling and completion, evaluation, reservoir monitoring and control, and data services and software.

SCINTREX / AUSLOG STAND 78-79

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Fax: +61 7 3376 6626
Email: auslog@auslog.com.au
Website: www.idsdetection.com.
Contact person: Bill Smith, Marketing Manager

Scintrex Earth Science Instrumentation enjoys a worldwide reputation as the leading designer and manufacturer of geophysical technology. For more than 31 years, they have been providing geophysical instrumentation worldwide for a wide variety of applications including mineral exploration, oil & gas exploration, groundwater studies, archaeology and environmental site characterization.

Products such as the CG-3 Gravimeter, the ENVI Magnetometer, the SMARTMAG High Resolution Magnetometer and the IPR-12 Induced Polarization Receiver, are industry standards in their fields.

From there Brisbane facilities, Scintrex/Auslog manufacture a wide range of Geophysical Borehole Logging Systems, supporting the full Scintrex Earth Science range of Instrumentation at this office.

SCINTREX PTY LTD STAND 76, 77

20 Century Road, Malaga, WA 6090
Tel: +61 8 9248 3511
Fax: +61 8 9248 4599
Email: glinford@scintrex.aust.com
Website: www.idsdetection.com
Contact person: Dr. Graham Linford

Scintrex Pty Ltd, is wholly owned by IDS Intelligent Detection Systems, and is part of its Survey & Exploration Technology Division. Scintrex is a geophysical contracting company and its survey methods include induced polarization, MIP, MMR, SIROTEM, HEM, magnetics, radiometrics and borehole logging DGPS and gravity including Heligrav, Seagrav, Boatgrav.

SOCIETY OF EXPLORATION GEOPHYSICISTS STAND 20

8801 S. Yale
Tulsa, OK 74137 USA
Tel: +918-497-5500
Fax: +918-497-5557
Email: jvangundy@seg.org
Website: www.seg.org
Contact person: John Van Gundy

The Society of Exploration Geophysicists (SEG) (founded 1930) has 17 000 members in 100 countries. SEG publishes two journals, Geophysics and The Leading Edge, seven technical books per year, and has over 10 000 pages of geophysical material on its Web site: www.seg.org. SEG has hosted international meetings and expositions for explorationists for more than 40 years. Major conferences/expositions in 2000 will be held in New Delhi, Caracas, Bucharest, Bahrain, Bali, and Villa Hermosa, Mexico. For details about SEG's products or services, contact the SEG Business Office, 8801 S. Yale, Tulsa, OK 74137, or phone 918-497-5500, or facsimile 918-497-5557.

SURTRON TECHNOLOGIES PTY LTD STAND 31

15 Catalano Road
Canning Vale, Perth, WA 6155
Tel: +61 8 9455 8000
Fax: +61 8 9455 8080
Email: surtron@ozemail.com.au
Contact person: Martin Mulliner

Surtron Technologies was established in Australia in 1987 as a Borehole Surveying, Directional Drilling and Geophysical Logging services company. Surtron is a leading supplier of: Density, Natural & Spectral Gamma, Resistivity, Porosity, Inductive Conductivity, Full-Wave Sonic, Borehole Televiewer, Magnetic Susceptibility, 3-Component Magnetics, Gyroscopic & Magnetic Deviation as well as Steering Tool services.

SYSTEM DEVELOPMENT, INC. STAND 6

10500 Westoffice Drive # 100
Houston, TX 77042 USA
Tel: +1-713-266-5667
Fax: +1-713-974-4911
Email: ndaly@sysdev.com
Website: www.sysdev.com
Contact person: Noel Daly

Based In Houston, Texas with regional offices in London & Beijing, System Development, Inc. (SDI) have been supplying supplying Graphics Software Solutions since 1988.

Unix & Windows 95/98/NT based Graphics Software Tools; Including CGM/CGM+.

Application Development Libraries; Presentation Graphics Montaging; Graphics Metafile conversion to/from CGM/CGM+; MicroStation Import/Export drivers for CGM/CGM+; Tri-level Plotting Solution - Single user (Workstation) - Client/Server (Network) or LPD based print filter.

TESLA GEOPHYSICS STAND 43-44

Head Office
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Applecross, WA 6153
Tel: +61 8 9364 8444
Fax: +61 8 9364 6575
Email: Tesla10@tesla10.com.au
Website: www.tesla10.com.au
Contact person: David Abbott

Tesla Geophysics is a dynamic group of companies supplying geophysical services to the exploration and environmental markets worldwide.

Formed in 1983, Tesla10 offers data processing expertise as well as ground geophysical surveys and instrument rentals. Salinity surveys are offered through the Geoliner - a vehicular towed system providing valuable information for landcare groups and farm planners as well as explorers.

Tesla Airborne Geoscience, a quality assured company, was launched in 1993, and has successfully collected millions of line kilometres of data for government bodies, exploration companies and consultants both locally and internationally.

TGS-NOPEC GEOPHYSICAL COMPANY PTY LTD STAND 32

Level 5, MLC Building
1100 Hay St, West Perth, WA 6005
Tel: +61 8 9480 0000
Fax: +61 8 9321 5312
Email: contact@tgsnopec.com.au
Website: www.tgsnopec.no
Contact person: Rachel Loomes, Marketing Geophysicist

TGS-Nopec is a leading global provider of non-exclusive seismic data and associated products to the oil and gas industry. The Perth office is responsible for the Asia/Pacific operations of the group and markets the Australian Geological Society Organisation's (AGSO) library of regional 2D seismic data.

TOTAL DEPTH PTY LTD (EXPLORATION SERVICES) STAND 27

21 Churchill Avenue Subiaco 6008 Western Australia
Tel: +61 8 9382 4307
Fax: +61 8 9382 4308
Email: dirstein@iinet.net.au
Contact person: Jim Dirstein

Established in Australia in 1993, Total Depth's clients include companies involved with Oil and Gas Exploration/Production, Research and Software Development. Our objective is to help our clients develop and facilitate innovative workflows to address their exploration and exploitation challenges.

Our services include interpretative studies, attribute analysis and training/sales/support for a growing number of geophysical software applications.

UTS GEOPHYSICS STAND 17

PO Box 126
Belmont WA 6104
Tel: +61 8 9479 4232
Fax: +61 8 9479 7361
Email: Neil_goodey@uts.com.au
Contact person: Neil Goodey

UTS offer specialised airborne and ground based geophysical surveys with particular expertise in the acquisition of low level, ultra-high resolution data.

Our services include low level fixed wing magnetics and radiometrics, helicopter electromagnetics, magnetics and radiometrics.

UTS conduct surveys internationally through their head office in Perth and regional office in North America.

VELSEIS PTY LTD STAND 80

83 Jijaws Street (PO Box 118)
Sumner Park, QLD 4074 AUSTRALIA
Tel: +61 73376 5544
Fax: +61 73376 6939
Email: enquires@velseis.com.au
Website: www.velseis.com.au
Contact person: Mike Reveleigh

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Tel: +61 7 3279 0400
Fax: +61 7 3279 0743
Email: info@velpro.com.au
Website: www.velseis.com.au
Contact person: Karel Driml

VELSEIS (through Velseis Pty Ltd & Velseis Processing Pty Ltd) acquires and processes 2D and 3D seismic data using Dynamite, Mini-SOSIE and Vibrator acquisition techniques, and ProMAX data processing software. VELSEIS offers a complete service to the exploration industry, including seismic survey planning and design, acquisition, processing and final interpretation.

ZONGE ENGINEERING & RESEARCH ORGANIZATION (AUST) PTY LTD STAND 1-2

98 Frederick Street
Welland, SA 5007
Tel: +61 8 8340 4308
Fax: +61 8 8340 4309
Email: zonge@ozemail.com.au
Website: www.zonge.com
Contact person: Michael Hatch

Zonge Engineering and Research Organization is a recognised leader and innovator in the development of electromagnetic and induced polarization survey technology. We specialise in providing field services and equipment for all aspects of electrical geophysics. We have new capabilities in engineering geophysics, downhole EM and DHMMR. Come and see the new GDP-32 II multifunction receiver at our booth! It is the latest upgrade in the GDP series, incorporating hardware as well as software improvements.

Preview

Section 3

Editor's Desk

Welcome to ASEG's 14th International Conference and Exhibition, and particularly to our visitors from overseas.

These meetings just seem to get better and better and how fitting it is that the '*Exploration Beyond 2000*' Conference is being held in Perth. After all, Perth is the exploration capital of Australia, with more than 50% of both the mineral and petroleum exploration activity being carried out in Western Australia.

During the 1998/99 financial year this amounted to over \$520M for mineral exploration and \$530M for petroleum search. Although the mineral exploration activity has declined significantly from the peak year of 1996/97 when \$706M were invested in WA, the current level is still very large and there are signs that the bottom of the cycle has been reached.

Although we live in difficult times when the health of our resource industries may seem somewhat precarious, there can be no denying the enormous contributions made by this sector to our economy. This Conference exemplifies these contributions, and the depth of the technical capabilities on show here is most impressive. We must continue to try and increase the awareness of the general public of the importance of geophysics and also continue to make our presence felt at all levels. Our President's letter to Minister Obeid, which is printed in this issue of Preview, is a good example of our input to government policy. Through FASTS we have an avenue for representation at the Prime Minister's Science, Engineering and Innovation Council, and the opportunity for lobbying at high levels in government. We should all be on the lookout for every opportunity we have to enhance the cause of geophysics and the geosciences - if we don't, nobody else will.

Delegates should take full advantage of the offerings available in Perth during the Conference, both in the city and at Burswood. For example, those who visit the GSWA booth can obtain both the new Magnetic Anomaly Map of Western Australia and the Geological Map of Western Australia for a special price of \$15. The 1:2.5M scale Magnetic Anomaly Map has been specially produced by AGSO and the GSWA to celebrate the filling of the last significant gap in the magnetic coverage of the State. It should be an excellent memento, and am sure that attendees will find other goodies if they hunt hard enough. Delegates at the Conference will be able to sample over 240 presentations in either oral or poster mode and this edition of Preview contains all paper and poster abstracts, author biographies, exhibitor profiles, lists of our sponsors, and much more.

During the Conference I will be scouring the corridors for future contributors to maintain the quality of Preview that has been set in recent years. We still need an *Internet Editor* to surf the web and review key geophysical websites on a regular basis, and are always on the lookout for interesting reviews and case histories of a general interest.

Enjoy Perth, and have a rewarding Conference.

David Denham

David Denham, Editor

On behalf of the Federal Committee I wish to thank all the Perth Conference Committee for ensuring the conference and exhibition is a success.

I recommend that members attend the ASEG General Meeting to be held during the conference on Wednesday 15th March at 5:30pm in the Burswood Superdome. Some of the items to be discussed will include the Society's financial affairs, business plan, proposals and initiatives for the constitution of the Federal Executive, conference frequency, sustaining membership levels, publications, education and registration of geoscientists.

To assist current and future Federal Committee members, the Executive is preparing an ASEG Procedures Manual. This manual will detail the functions and responsibilities of the ASEG committees of the Executive Committee. It will also include standard letters for needs such as membership renewals/reminders for both individual and corporate members. It is partly modeled on the SEG Procedures Manual and will be an active document that will change with the needs of the Society. A draft copy of this manual will be available for comment at the ASEG booth at the Perth Conference.

With the need to keep a balance between revenue and costs, the Federal Committee encourages all members to consider advertising in either Exploration Geophysics or Preview. This could either be as a one page corporate advertisement or just simply as a business card. 1600 copies of each publication are printed and nearly 200 copies are circulated to libraries throughout the world. Please contact Brian Wickins of RESolutions whose address is on page 4 if you would like to place an advertisement.

During 1999, the Executive, Membership Committee and State Branches have endeavoured to follow-up over 600 non-financial members. A few of these members are again financial but due to the high costs of publications, non-financial members cannot be subsidised by the Society. Would all members who have not yet paid their membership for 2000, please pay promptly. Follow-up of late payment by the Society is at a cost in time (often voluntary) and money. Depending on the circumstance, it may be a fairly easy process for non-financial members to rejoin our society. Unemployed members may also be able to postpone payment for up to 12 months. All inquiries should be directed to the Secretariat in Brisbane.

Starting in July 2000, the Society will be required to pay GST every three months. To streamline our payments, the Federal Treasurer and Secretariat will need to be kept fully informed on all financial transactions across our society. Thus State Branch Treasurers will need to complete regular and timely reports to the Federal Treasurer.

The results of a recent SEG survey on Exploring Communication Preferences showed an even preference for either hardcopy or electronic publications but few members were prepared to pay extra. One of the possible concerns with the electronic transfer of publications is how it can be attractive to our advertisers. The current plan is for Preview to be revenue neutral within 12 months and follow with a positive cash flow.

Over the past year there has been a steady increase in the receipt of papers for Exploration Geophysics (EG) and the Publications Committee is considering an extra publication during 2000. This is very encouraging and illustrates the high regard members have for EG.

With the large number of presentations at the Perth Conference the Executive has asked the Conference Advisory Committee to consider the possibility of an Annual Conference. This will be discussed with State representatives at the ASEG Council Meeting and at the ASEG General Meeting to be held during the Perth Conference.

On behalf of all members I give a special thank-you to Voya Kissitch for his efforts in developing the ASEG web site. It is now accessed on an average of 2,500 visits per month with approximately 25% of these visits coming from outside Australia. Voya is currently developing a 3-year business strategy for our site that will include more links to other sites.

Late last year our President and Ray Shaw attended and gave submissions to 'Science Meets Parliament' in Canberra. This was organised through FASTS (Federation of Australian Science and Technology Societies), which has prepared a strong policy document: 'Australian Science: An Investment for the 21st Century.' To add to our SEG liaison, Past President Noll Moriarty has been appointed co-chairman of the Far East Region (Australia, New Zealand and Asia Region) on the SEG International Affairs Committee. In this role, Noll will promote SEG publicity, membership and coordinate SEG activities such as their education courses. Congratulations Noll.

David Robson
Honorary Federal Secretary
robsond@minerals.nsw.gov.au

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ASEG Officers

Events for 2000/2001

2000

March 15-17
GeoQuest Asia Forum 2000 - "Unlocking Asset Value"
Fremantle, Australia

Forum 2000 is a three-day program for decision-makers and asset-team members of the exploration and production industry. The Forum will provide a unique opportunity for E&P managers and professionals to share the experience of innovative techniques, interpretation methodologies and processes, thus leveraging technologies and services, to readily evaluate and monitor asset performance and value.

Being spread over three days, the Forum program is structured to provide a platform for the exchange of ideas, to learn new techniques and provide feedback for future software development. Topics range from global electronic data delivery through geo-science, and petroleum economics. The Forum will contain a mix of activities including papers, panel sessions, technology demonstrations and tutorials. There will be in excess of 60 presentations and a keynote address by Agu Kantsler and Keith Spence , Managers of Woodside Energy, titled "Volume to Value". The President of Schlumberger Reservoir Management (located in Houston, USA), Mr. Peter Goode, will deliver the opening address entitled, "Unlocking Asset Value - a service perspective". Other featured speakers include the President of Oyo Corp., Japan; a presentation entitled, "Open Systems Strategies", by Adam Lomas from Shell Netherlands; and a talk entitled, "Integrated Earth Science & Engineering Data Management Strategies", by Gerald Edwards of Caltex.

Additional information, and registration, can be found on-line at http://www.ing-slb.com/forum2000

March 16
Southern Africa-Australia Mineral Sector Synergies Symposium. AusIMM 5th annual Australia-foreign mineral country collaborative symposium
Information: hancock@geology.anu.edu.au

April 26-27
4th Australian Geomagnetism Workshop, Canberra ACT
Organised jointly by the AGSO and the ANU
Tel: +61 2 6249 9111 Fax: +61 2 6249 9913
Email: Heather.McCreadie@agso.gov.au
Website: http://www.agso.gov.au/geophysics/geomag/

May 3-4
Australian Palaeomagnetism, Rock Magnetism, and Environmental Magnetism Meeting, Canberra ACT
Organised by AGSO, CSIRO and ANU
Tel: +61 2 6249 9611 Fax: +61 2 6249 9913
Email: Charles.Barton@agso.gov.au

May 25-26
Asia Pacific Technology Forum - Landmark Graphics Corporation. 'Touchstones for the future: Managing Uncertainty and Risk' - Ho Chi Minh City, Vietnam
For further details on 'Call for Papers' and 'Registration information: www.lgc.com

May 7-10
APPEA 2000, Brisbane, Queensland
'Innovation for the Third Millenium'
Call for papers to Steve Taylor, APPEA Technical Papers Committee Secretary,
Santos Ltd., GPO Box 1010, Brisbane Qld 4001
Email: steve.taylor@santos.com.au
Other enquiries: http://www.appea.com.au

May 23-26
The 8th International Conference on Ground Penetrating Radar, (GPR 2000) Gold Coast, Queensland, Australia
Call for Papers and information to:
Email: grp2000@csee.uq.edu.au
Website: http://www.cssip.uq.edu.au/gpr2000

May 29-June 2
European Association of Geoscientists & Engineers, 62nd EAGE Conference and Technical Exhibition, Glasgow, UK
Website: http://www.eage.nl

May 30-June 3
American Geophysical Union, 2000 Spring Meeting
Washington DC, US
Website: http://www.agu.org

July 3-7
Geological Society of Australia, 15th Australian Geological Convention, Sydney, NSW - "Understanding Planet Earth - searching for a sustainable future"
Call for papers and information to:
GSA, Suite 706, 301 George Street, Sydney 2000
Tel: +61 2 9290 2194 Email: 15thagc@gsa.org.au
Website: http://www.science.uts.eedu.au/agc/agchome.html

August 6-11
Society of Exploration Geophysicists, International Exposition and 70th Annual Meeting, Calgary, Canada
Website: http://www.seg.org

September 19-22
Indonesian International Oil, Gas & Energy Conference And Exhibition 2000 - (IIOGE 2000)
Jakarta Convention Centre, Jakarta, Indonesia
Contact: Ramson Piter
Email: rpiter@ptrei.com
Web: http://www.ptrei.co.id

October 15-18
2000 AAPG International Conference & Exhibition
(AAPG in partnership with Indonesian Petroleum Assoc.)
Contact: AAPG Convention Department
Tel: +918 560 2679
Fax: 918 560 2684
Email: convene@aapg.org
or
Indonesia Petroleum Association
IPA Secretariat, Plaza Kuningan Menara Selatan
Tel: +62 21 527 3663
Fax: +62 21 520 7672
Email: ipa@cbn.net.id
Website: www.ipa.or.id

October 22-24
Bowen Basin Geologist Group
Symposium 2000 - The New Millennium
Leichhardt Hotel Rockhampton
Contact: Troy Peters
Email: tpeters@velpro.com.au

December 15-19
American Geophysical Union, 2000 Fall Meeting, San Francisco, California, US
Website: http://www.agu.org

2001

May 29-June 3
American Geophysical Union, 2001 Spring Meeting, Boston, Mass., US
Website: http://www.agu.org

August 5-8
Australian Society of Exploration Geophysicists, 15th International Conference and Exhibition, Brisbane, Qld
Theme: '2001: A Geophysical Odyssey'
Website: http://www.aseg.org.au
Event Manager: Jacki Mole
Tel: +61 7 3858 5410
Email: aseg2001@im.com.au

IIOGE 2000

Indonesian International Oil, Gas & Energy Conference and Exhibition 2000 (IIOGE 2000)

The IIOGE '99 held last year in Bali was successful with a total attendance of 1008 participants from 28 countries and more than 500 conference delegates and 58 companies in the exhibition space. This year the conference is to be held on 19-22 September 2000 at the Jakarta Convention Centre, Jakarta Indonesia.

Key Topics

While the development of the national energy agenda remains the central topic of the IIOGE 2000 Conference, a complementary examination and presentation of Indonesia's relationships with international buyers and sellers of oil and gas products will be provided, giving a critical global perspective on domestic strategies.

Specific areas to be addressed include:

- Developing international gas markets
- Maintaining stable crude oil prices
- Meeting domestic energy demand
- The new Oil & Gas Bill
- Challenges & opportunities for Pertamina
- Developing Indonesia's downstream sector
- Maximising exploration & production revenues
- Evaluating the structure of fuel subsidies
- Challenges & opportunities in the power generation sector and
- Decentralisation and the Oil & Gas Industry.

For further information visit the website: www.ptrei.co.id

ASEG Support for Regional Geophysical Programs

The ASEG was invited to make a submission in support of the continuation of the New South Wales Government's Discovery 2000 Program of regional geophysical surveying which is currently scheduled to conclude in June 2000. While the following letter to NSW Minister Obeid addresses the value of such programs to that particular state, the ASEG would present similar views in support of maintaining regional geophysical programs in other Australian States.

12 November 1999

The Hon. Eddie Obeid, OAM, MLC
Minister for Mineral Resources
Room 808, Parliament House
Macquarie Street
Sydney NSW 2000

Dear Minister

Continuation of the Discovery 2000 Exploration Initiative

The Australian Society of Exploration Geophysicists (ASEG) urges the Government of New South Wales to sustain the Discovery 2000 Exploration Initiative. The ASEG is a professional body of over 1200 geophysicists with most members having direct involvement into all exploration programs for minerals and petroleum.

The Discovery 2000 Exploration Initiative has included airborne geophysical mapping, interpretation and information release to the industry and the general community. The program is very beneficial because it is contributing to a recognition of NSW as a preferred place for investment in natural resource development, particularly in forestry, mining and agriculture.

The application of state-of-the-art technologies by Discovery 2000 has its greatest reward in the less populated areas of the State, giving rise to opportunities for new industries to evolve in parts of the State where traditional sources of employment are in serious decline. The continuing movement of our young people from the country to the city is a major concern for the health of the community. This is measured by increased stress due to competition for jobs, increased crime due to the lack of useful occupation of young people's time and the further social upheaval of family break-up. Any effort by Government which assists in reversing the migration to the cities is of great importance.

The Discovery 2000 program provides a consistent, broad coverage of accurate scientific data which may be used by various industry groups to make decisions and increase the efficiency of their activities. The effect of the new data is to focus and bring forward the achievement of success. Examples of this kind of acceleration of positive goals are given below.

- The radiometric results allow the characterisation and classification of soil types for agriculture and forestry planning.
- The magnetic data assist the calculation of the thickness of sedimentary sequences to guide petroleum exploration.
- The assessment of sedimentary sequences also helps in the quantification of the ground water resources of the State.
- The geophysical data facilitate the interpretation of the geology of the extensive covered areas of NSW. Without such data, it is not possible to assess the resource potential without relying on speculative and expensive drilling.
- The identification of intrusive bodies is important in the assessment of potential for various types of base metal mineralisation.
- Identification of volcanic intrusive rocks which may transect or penetrate coal seams is critical to the planning of longwall mining operations, and to safe mining operations.
- The new geophysical data present a stimulus to re-thinking old concepts. While many areas of lengthy historic mining have been considered to have been fully evaluated (eg the Broken Hill district), the new information from regional geophysics encourages the development of new ideas about the distribution of favourably mineralised horizons. The Discovery 2000 data provide the basis for revisiting old mineral fields with fresh ideas. The existence of "favourable horizons" is an important factor in successful mineral exploration - these are time events in the Earth's evolution when economic minerals were preferentially laid down. However, tracing such layers in the complexly contorted

rocks of NSW is a great challenge, one which is facilitated by the Discovery 2000 datasets. An example of successful use of regional magnetics is the discovery of the Tritton copper deposit at Girilambone near Nyngan. The regional data provided evidence for the planning of ground electromagnetic surveying, using new perceptions of the location of the favourable mineralised trends. Drilling of responses from the follow-up electromagnetic studies led to the intersection of high grade copper mineralisation.

- Mineral discovery strategies are revised, tuned and perfected using concepts of structural control of ore bodies. While the Discovery 2000 program is not designed to detect orebodies directly, a correct understanding of the structural setting of prospective terrains is a great aid to the design of exploration programs. Such understanding is a major consequence of this program.

- Hydrothermal alteration is another guide to ore discovery. In some settings the alteration contains minerals which are measurable by airborne geophysics. An example is the magnetic alteration assemblage associated with the Cadia Ridgeway mineralisation near Orange. Such alteration does not always define economic minerals but is an encouraging indication. The effect of the availability of data like that provided by Discovery 2000 is to bring forward success. When explorers must carefully assess the duration of exploration efforts before moving on to new areas, possibly in other States or other countries, it is very valuable to have access to data which accelerate exploration success.

We therefore submit that the Discovery 2000 Exploration Initiative is of great benefit to the people of NSW. The task of comprehensive coverage of the State requires

continuation of this effort. We urge the Government of NSW to continue this valuable program.

Thank you for your support for Discovery 2000 and for your efforts in ensuring its continuation. Our members were very pleased with the support by the Premier and yourself at the Department's Exploration and Investment Conference last May.

We would be pleased to meet personally with you to discuss the views summarised above in greater detail.

Yours sincerely,

Mike Smith

Mike Smith
President
Australian Society of Exploration Geophysicists

New Members

(approved by Federal Executive in December 1999)

NAME	COMPANY	STATE
Mattew Lawrence	World Geoscience	WA Associate
Paul Tradgett	Baker Hughes /Western	SA Active
Michael Purucker	Raytheon	MD, USA Active
Allan (Yinxia) Li	NWEDC	QLD Active

Missing Members

State of the last known address shown in bracket

Justin Anning	(WA)
Duncan Cogswell	(UK)
Harry Cornelius	(Aust)
Robert Elliott-Lockhart	(VIC)
Cliff Allen	(WA)
Ken Horsgall	(ACT)
William McLellan	(Botswana)
Allister Wood	(UK)
Stefano Zannoni	(WA)

ASEG Silver Certificates

ASEG Silver Certificates for 25 years of membership are awarded to following 39 members this year:

Andrew	Nelson	Chatswood West	NSW
Andrew	Svalbe	City Beach	WA
Brian	Rau	Ridleyton	SA
Chris	Anderson	Kent Town	SA
Chris	Porter	Adelaide	SA
Daryl	Eyles	West Pennant Hill	NSW
Dave	Isles	West Perth	WA
Derecke	Palmer	Sydney	NSW
Doug	Price	Everton Park	QLD
Eugene	Urschel	Adelaide	SA
Fred	Bruvel	Brisbane	QLD
Graham	Butt	Milsons Point	NSW
Graham	Rau	Ridleyton	SA
Greg	Blackburn	Melbourne	VIC
Hugh	Rutter	Richmond	VIC
Ian	Edwards	Adelaide	SA
Ian	Hone	Canberra	ACT
Ian	McMahon	Jakarta	Indonesia
John	Hart	Milton	QLD
John	Moore	Southbank	VIC
Jorg	Bein	South Yarra	VIC
Kevin	Wake-Dyster	Macgregor	ACT
Koya	Suto	Brisbane	QLD
Marion	Rose	Glen Iris	VIC
Michael	Covil	Kent	UK
Michael	Leys	Blayney	NSW
Mick	Micenko	Mosman Park	WA
Norm	Uren	Perth	WA
Paul	Harrison	Liverpool	NSW
Peter	Gunn	Canberra	ACT
Phil	McInerney	Melbourne	VIC
Phillip	Schmidt	North Ryde	NSW
Pop	Zarzavatjian	Forestville	NSW
R.D.	Ogilvy	Nottingham	UK
Robert	Kirk	London	UK
Robert	Nunn	Perth	WA
Robert	Whiteley	Turramurra	NSW
Stephen	Mudge	Nedlands	WA
Terry	Ritchie	Indooroopilly	QLD

With addition of the above members, one hundred and ninety-one members have been awarded with the Silver Certificates to date.

Will members who believe that they are eligible for the Silver Certificate please contact the secretariat. It is possible to miss some eligible members, as our old membership records started pre-computer database age and have been through several crises. If your name has changed by marriage or other reasons, it is likely to be missed in the search for silver members.

Western Australia Branch – by Mark Russell

1999 ASEG/PESA Golf Tournament

The 12th Annual Western Australian PESA/ASEG Golf Classic was held at the Meadow Springs Country Club near Mandurah on 3th December 1999. Thanks to the support of our generous sponsors, this year's event shaped up to be another popular and successful day, with the enthusiastic participation of over 140 PESA and ASEG members and their friends playing in the traditional Ambrose 4's format and, for the first time, including seven corporate teams competing for a separate prize pool.

Here is how the event unfolded:

Players, wearing the distinctive shirts once again provided by our principal sponsor, SGI, unerringly hit the complimentary golf balls from Veritas DGC off tees from Exploration Consultants Australia into holes marked by flags from PGS, whose sponsorship, together with the contribution from Robertson Research, provided the liquid nourishment required to keep up the pace.

The teams taking the general winners' prize from Schlumberger, the Corporate Challenge prize from IHS Energy Group and the general runners-up prize from SGI, together with those individuals fortunate enough to have won one of the novelty prizes put up by Tesla Geophysics, Mobil and Paradigm Geophysical, threw their CGG Borehole Services caps into the air for joy.

Those not winners found consolation in a chance to win spot draw prizes from Ansett Australia, Hotel Grand Chancellor, The Atrium Hotel Mandurah and Ellis Drafting & Graphics. And everybody who stayed on enjoyed a drink or three during the BBQ by courtesy of Western Geophysical, after which those that did not drive down were chauffeured back to Perth by the TGS-Nopec bus service. Final results are posted on the website at www.aseg.org.au/wa/golf

And incidentally, the WA Branch AGM was held on Dec 8th, 1999. Pretty much the same office bearers as throughout 1999 for the coming year. The President's Report is available on the website at www.aseg.org.au/wa

Queensland Branch – by Natasha Hendrick

The Queensland Branch hosted its Annual Student Presentation Night at the University of Queensland in November. This final technical meeting for 1999 was well attended both by industry representatives and university students. Daryn Voss gave a presentation on 'The Application of Generalised Linear Inversion to Prestack Multiple Attenuation', and Ruth Kettle discussed 'Resolution Analysis of Seismic Tomography for Mineral Exploration'. Well done to both students for very professional presentations. Daryn and Ruth will be presenting papers on these topics at the Perth 2000 Conference.

Many of our members joined together to celebrate the Festive Season at 'About Face' in Brisbane during December. A big thank-you must go to our sponsors for the night:

- ASEG: Queensland Branch;
- Geco-Prakla;
- Geoquest;
- MIM;
- Oil Company of Australia;
- Veritas DGC;
- Velseis; and
- Velseis Processing.

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Entertainment for the night was provided by Nick Sheard and his audio-visual performance 'Why Do We Do It?' We hope everyone had a great time!

The Brisbane-based 2001 Conference Organising Committee, under the leadership of Noll Moriarty and Wayne Stasinowsky, has met a number of times recently to start work on the details of the 2001 conference. Intermedia has been appointed as the PCO and the conference will be held in August 2001 at the Brisbane Convention and Exhibition Centre. Any members who have not yet had the chance to volunteer their services to help with the Brisbane 2001 Conference can contact Wayne (staz@mining-geophysics.com.au) or Noll (n.moriarty@uq.net.au) for more details.

The Queensland Branch AGM will be held during March 2000. Nominations for Branch Chair, Secretary, Treasurer and committee members are being called for. No prior experience necessary! If you are interested in helping out please contact Troy Peters (tpeters@velpro.com.au). A big thankyou to the outgoing committee - Troy Peters, Kathlene Oliver, Grant Asser, Natasha Hendrick, Gary Fallon, Fiona Duncan, Wendy Watkins and Wayne Stasinowsky - for the time they have put into organising technical and social gatherings for ASEG members in Queensland over the past year.

Plans are under way for another busy year in 2000. Highlights for the first half of the year include the Branch AGM, a Beer Tasting Night, and the popular ASEG Geophysics Student BBQ. Keep an eye out for more details on our webpage (www.aseg.org.au/qld/).

May 2000 prove a successful year for all and never mind … the sooner you fall behind the more time you'll have to catch up!

Victoria Branch – by Trudi Hoogenboom

Monthly meetings held at the Kelvin Club, Melbourne included the following:

Due to the two meetings our Branch supported during October (Honours Thesis Presentation Night, & The Selwyn Symposium), we took a holiday in November to concentrate our efforts on our Xmas party.

December 7th marked the date of the Victorian Branch Christmas meeting. For something different we invited a speaker with a difference in the form of Kevin Masman. Originally coming from a geo-science background, Kevin now makes his living as a Feng Shui consultant. He provided an interesting presentation on 'The interaction of People with Geomagnetism'. Much fun was had by all, despite the controversial nature of the talk.

New South Wales Branch - by Richard Facer

The New South Wales Branch started its 2000 meetings program with a presentation by Derecke Palmer - on 16th February 2000 at our regular meeting place, The Rugby Club (in Rugby Place in Sydney). As usual we met at about 5.30 pm (or even 1730) for a social interchange before the technical address.

There will be no March meeting because our normal third Wednesday time will be during the Conference in Perth. Hence our AGM (and ordinary monthly meeting) will be on 19th April.

There is widespread concern in New South Wales about the relatively low number of students studying Geology and Geophysics at University. They are our next generation of professionals! There is a new syllabus in High Schools from 2000 on *Earth and Environmental Science* - new topics, new sequence, and new treatments. The ASEG has been involved with other like societies, the Board of Studies, the Department of Mineral Resources, universities and others in addressing concerns. Of particular importance is the need to assist teachers, many of whom have no formal Geology or Geophysics training. To that end, the New South Wales Branch is happy to support a co-ordinated effort between the Geological Society of Australia and the Department of Mineral Resources in preparing a teachers' resource kit. Other professional groups have also assisted and, like the ASEG, will receive acknowledgement in the kit, along with additional publicity/information. The kit has now been prepared and was available for circulation in the first week of February. There is a need for continued involvement of professional groups and individuals in maintaining an up-to-date information base for educators.

Mineral Exploration Expenditure Still Declines

Mineral exploration expenditure has declined for the ninth consecutive quarter, and is at its lowest level in six years in seasonally adjusted terms, according to the latest data released by the Australian Bureau of Statistics.

During the September quarter of 1999 only $177M was spent on mineral exploration, of which Western Australia accounted for $105M. This compares with $324M in the record 2nd quarter of 1997. However, the drop between the 2nd and 3rd quarters of 1999 was only 0.2%, indicating that the bottom of the cycle has hopefully been reached.

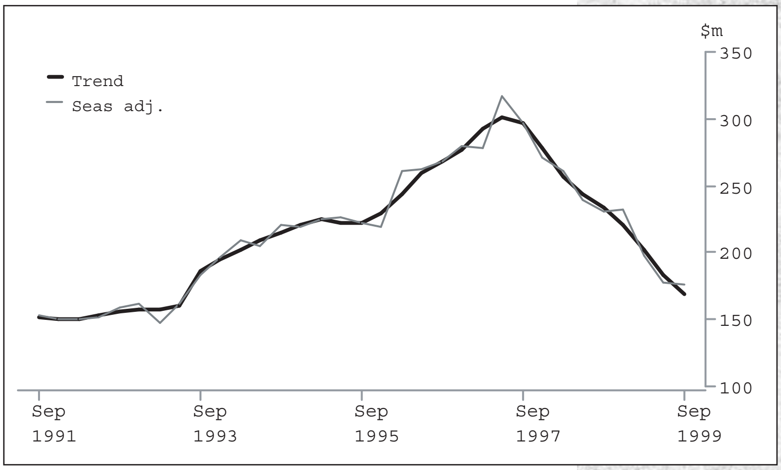

Fig. 1. Mineral Exploration Expenditure (other than for petroleum).

Petroleum Exploration Levels Hold

The Petroleum sector presents a very different picture. During the 3rd quarter of 1999 the total expenditure was reported as being $206M, which is very close to the average of $202M over the last five years. As with the mineral exploration statistics, Western Australia captures more than 50% of the total exploration investment.

The biggest change is the slump in onshore activity. In the September quarter only $20M was spent throughout the whole country. This is only about 33% of the average expenditure onshore during 1998.

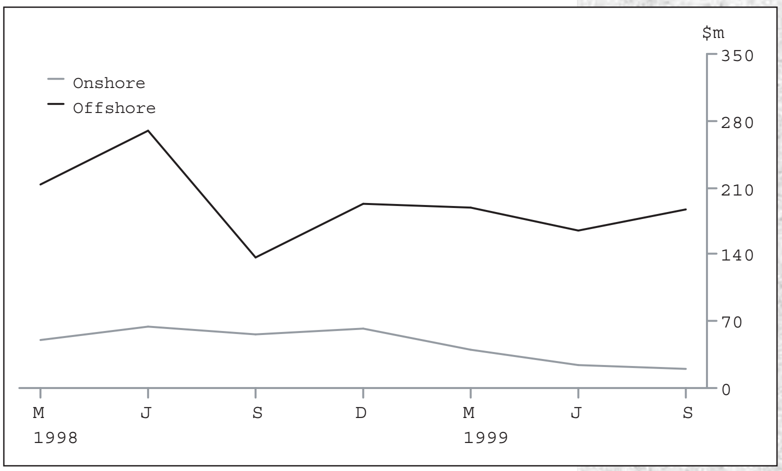

Fig. 2. Petroleum Exploration Expenditure.

Fugro Continues to Grow

In Preview 83 we reported on Fugro's acquisition of World Geoscience Corporation and Geoterrex-Dighem. It has now made an offer to acquire Geodass through a Letter of Intent at the end of January 2000. Geodass was established in 1979 as an airborne geophysical company and operates across the whole of the African continent. Its headquarters are in Johannesburg (South Africa) and it has subsidiaries in Botswana and Namibia. Geodass is the premier airborne geophysical survey company in Africa and will strengthen and complement Fugro Airborne Survey's activities on the continent. The group's annual turnover is currently US$ 6M and it employs 40 staff.

Fugro currently operates globally from some 200 offices, employs about 5000 staff and has an annual turnover of ~A$1B.

The competition in Australia for the provision of airborne geophysical services was further reduced earlier this year when Australian Geophysical Surveys closed its offices.

Many see it as very sad that our capacities in airborne geophysical techniques have contracted so rapidly of late.

BOP & RMP for Electrical Geophysics

The availability of high powered IP/EM systems coupled with modern inversion software has the potential to produce reliable pseudo-sections that may be accepted almost as readily as seismic sections. This approach will become a vital means of discovering deeply buried deposits and its usage should become more widespread.

However, the use of high powered IP/EM transmitters can be potentially lethal unless experienced crews are using best operating practices and risk management procedures (BOP & RMP).

Unless the geophysical operators/contractors can convince mineral exploration companies that there is an appropriate and uniformly adopted BOP & RMP, then the possibility exists that the use of these techniques will no longer be allowed.

There have already been concerns by some clients in signing contracts where flying heights are less than 70 m. These have been aleviated for the moment, by the contractors presenting a united front, through the formation of the International Airborne Geophysics Safety Association, and convincing clients that BOP & RMP have been adopted.

It is strongly recommended that electrical geophysical operators/contractors present a united front on this critical safety issue.

The geophysical contractor GPX Services Pty. Ltd. has produced an impressive web page containing

- Section 1: Occupational Safety and Health Policy.
- Section 2: Environmental Policy.
- Section 3: Company Best Operating Practices & Risk Management Policy.
- Section 4: Company Safe Operating for GGT Transmitters.

This can be accessed at www.gpx.com.au/

I would urge all interested parties to read this document and take the opportunity to produce a BOP & RMP that is effective and universally accepted. The March ASEG Conference in Perth may be a suitable venue to address this issue.

Graham Elliott
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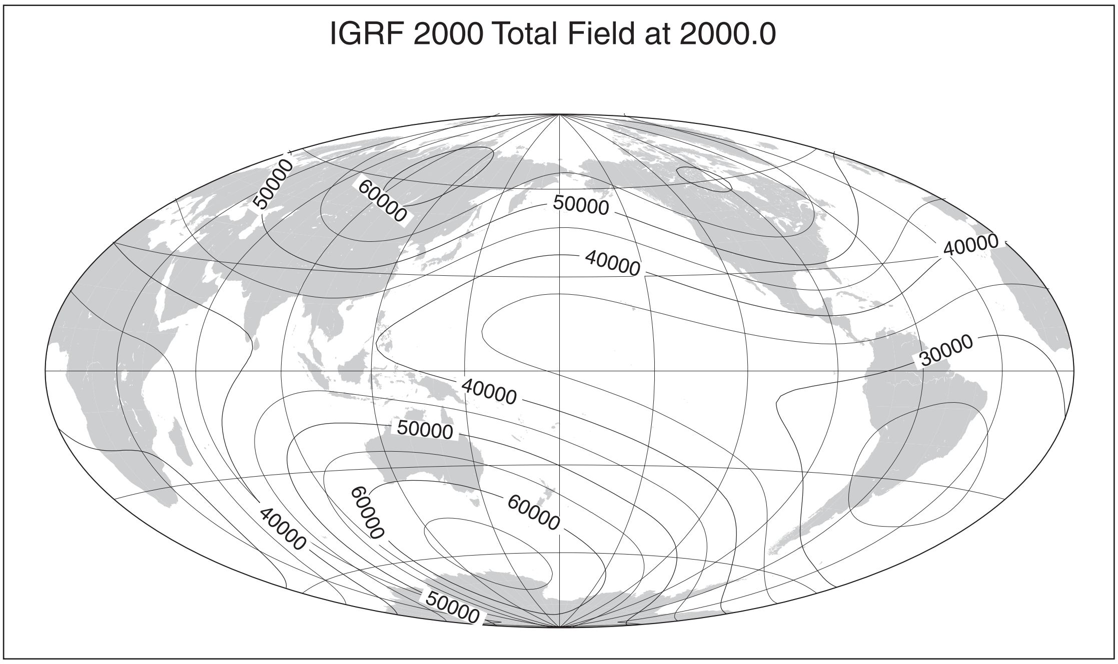
International Geomagnetic Reference Field for 2000

In Preview 83 the figure below from Andrew Lewis and Charles Bartons' article 'Revision of the International Geomagnetic Reference Field for 2000' (page 25), was not included due to space constraints.



Total Intensity of the Earth's Magnetic Field, as given by IGRF 2000 at epoch 2000.0.

Fugro Airborne Surveys Lifts Off

On January 1st 2000, Fugro NV acquired the business and assets of three leading airborne geophysical survey companies, Geoterrex - Dighem and High Sense Ltd of Canada, and World Geoscience Corp. Ltd of Australia. In addition, Fugro has signed a letter of intent to acquire Geodass, a South African based airborne geophysical survey company.

The new company has been named Fugro Airborne Surveys. Fugro NV is treating the company as a new business stream, which will operate independently of Fugro's other business streams.

The structure of the new company consists of five regions around the world, with the Australia/Asia Pacific region headed by Stephen Thomson, who previously headed up Geoterrex-Dighem out of Sydney.

The acquisition and merger of these companies by Fugro signals a transformation of the airborne geophysics industry, which has suffered from a severe contraction in exploration activity over the last three years. The new company will employ over 300 staff worldwide, many of whom are highly experienced geophysicists, geologists, remote sensing specialists and field survey operators.

"Each of the former individual companies tried to operate on a global basis, whether it be in a mineral or petroleum field activity, and were spread so thinly so that in no one area did they have enough critical mass to operate commercially", said Fugro Survey director, Grey Roughan.

According to Thomson the combination of the companies will form sufficient critical mass to make the worldwide group viable. "One of the obvious areas that will benefit from having critical mass and the resources available is R&D", he said. It is intended that the various R&D groups will be brought together and combine efforts to bring out the very best of the various technologies.

Fugro Airborne Surveys has five operational aircraft in the Australia/Asia Pacific region and it is intended that flight operations for electromagnetics, magnetics, ALF and airborne gravity work for Australia will be consolidated out of Perth's Jandakot airport.

As the company presently stands, Thomson said they wanted to minimize having to cut into the operational side of the business. "While there will be some attrition of administration staff", added Roughan, "with half an ounce of luck, if the resource sector picks up, we could have a few vacancies on the technical side."

Stephen Thomson, Managing Director Fugro Airborne Surveys, Australia/Asia Pacific region.

The company will maintain a strong presence in the Asia-Pacific region, with the former World Geoscience Corp and Geoterrex-Dighem offices being maintained in Sydney, Perth and Jakarta. Australia is recognised as a regional development centre of airborne geophysical technologies and, through the Perth office, Fugro Airborne Surveys is committed to the continuation of a number of R&D projects.

One of the key core competencies of the new company in the minerals sector is in airborne electromagnetics (AEM). Fugro Airborne Surveys intends to continue development of TEMPEST, the broadband AEM system developed by CRC-AMET, for which the former World Geoscience Corp. developed visualisation techniques, in addition to the GEOTEM style of technology, which they hope will complement each other.

On the petroleum side, Fugro Airborne Surveys intends to continue development of the ALF system for exploration and where feasible, for environmental work.

The combined group has available the industry's best expertise, technologies, R&D and geographic infrastucture, supported by an uncompromising commitment to the highest standards in safety, quality and client service.

Heard in Canberra...

Applications called for new CRCs

On 19th January Senator Nick Minchin formally invited applications for the seventh selection round of the Federal Government's Cooperative Research Centres (CRC) Program. The closing date for applications is 5th July 2000. New and emerging industries are being encouraged to participate and the industry commitment is expected to grow.

Lack of industry commitment was probably the main factor for the failure of the two Earthscience CRCs (Geophysical Exploration Technologies and Geodynamics) in the last round of applications. It is now time for the major resource exploration companies operating in Australia to rectify this situation for this year's applications and make substantial commitments to long-term strategic research in exploration techniques.

There are currently 65 CRCs with annual funding of $140M from the Federal Government and another $320M from other participants including industry, universities, the CSIRO and State Government bodies. Funding provided to the ten CRCs in the Mining and Energy sector amounts to $22M in 1999/2000. However, unless new CRCs are successful in the 2000 round this level of funding will drop to well below $20M.

There is a very good website on the CRCs at www.isr.gov.au/crc. This contains the new guidelines, application forms and all the current funding provided to the present set of CRCs.

AGSO's building for sale

By the time this edition of Preview is printed, tenders will have closed for the sale of AGSO's special purpose building in Canberra (29th February 2000). It was opened in January 1998 by the then Minister for Resources, Senator Warwick Parer, and cost approximately $105M to build.

The successful purchaser is guaranteed an income of at least $13M per year for 20 years. This should ensure that an AGSO or its equivalent will be maintained for the next 20 years and is therefore good for Australian geoscience.

What is not so good is the amount of money the taxpayer will have to invest to pay the rent. $13M/year is non trivial and the economic arguments to justify the decision to sell the building do not appear to have been made. At present staffing levels, the rent amounts to about $30,000 per year for each occupant. Is this value for money?

I also notice that the Government plans to do the same with CSIRO's buildings.

National Innovation Summit

The National Innovation Summit was held in Melbourne, from 9th -11th February. The Summit was a major attempt to bring together leaders in business, government, academia and the research community to encourage innovation in Australia to the benefit of the nation.

Delegates were tasked with helping to identify what needs to be done to accelerate the rate at which new ideas are translated into commercially successful products and services in Australia. The meeting had strong support from the Prime Minister, who addressed the summit, and who has recognised the need to build on our intellectual resources to our 'long-term national advantage'.

The core themes were: *Creating a competitive environment, Investing in new ideas, and Building industry and research linkages.*

Working groups examined national innovation performance and Australia's strengths, opportunities and impediments in the following areas: *Industrial Innovation, Institutional structures and Interfaces, Innovation and Incentives, the Resource and Infrastructure base, the Human Dimension of innovation, and the Intellectual Property framework.*

Roger Batterham, the Chief Government Scientist, also gave a preliminary report at the summit on his review of Australian Science (see Canberra Observed in Preview 82). Let's hope the many words he delivered can be translated into worthwhile action.

For those who want more details please access the excellent **ISR** website for the summit at http://www.isr.gov.au/industry/summit

Knowledge and Innovation a Fizzer

The embattled Federal Minister for Education Dr David Kemp released his vision for the future of university research funding three days before Christmas, when most universities had effectively shut down. Strange timing for a document that purports to shape the new framework for higher education research funding for the next five years.

The white paper, '*Knowledge and Innovation*: a policy statement on research and research training', is a big disappointment. It starts off with all the right words:

> 'The government appreciates that the return on investment from research is long-term. The social and technological progress of humanity is underpinned by the discovery and dissemination of knowledge, critical scrutiny of argument and evidence, creative design, clever application and an entrepreneurial culture. A vigorous research base makes an essential contribution to a democratic, learning society. The same research base is vitally important to the economic development of the country. The producers of knowledge are critical players in our national innovation system, providing the ideas and techniques that can be transformed into economic development.'

Then it proposes miniscule changes and does not tackle the resource problems affecting the universities. The key changes are as follows:

- '*New legislation to establish the Australian Research Council as an independent body, with broader membership, and a more strategic role.*' However, there will be no extra money and the changes proposed will cost more to administer than the present arrangements.

- '*Transfer of the management of current targeted research grants to the ARC, whilst retaining the balance between basic and applied research.*' Useful consolidation but again no more money and no arguments to support the appropriateness of the current balance between applied and basic research.

- '*A component of competitive funding to specifically focus on research to meet the needs of regional and rural communities, and opportunities for regional universities underpinned by funding guarantees.*' Clearly an attempt to tackle the political problems being faced in regional Australia. However, the funds set aside come from the current budget allocations, are specifically allocated to 13 'regional' universities (more Canberra bashing here because the University of Canberra cannot apply for these funds but Newcastle and Wollongong can), and only amount to $12M per year - less than the annual AGSO building rental!

- '*HECS exempt scholarships for up to 25,000 research students.*' One of the more positive steps to encourage more students to undertake research.

- '*Allocations of resources to institutions to support quality research and research training on a performance basis; institutions to develop their own priorities and develop plans for their research and research training activities focus.*' This is an extension of the present arrangements whereby each institution tends to compete for everything. I would have thought that with resources for research limited, it would have been better to encourage active cooperation in priority areas.

- '*A quality assurance process to verify the claims made by institutions on their research performance as part of the recently announced quality verification process.*' There is probably a need to have a performance assessment process, but the criteria used will inhibit quality, innovation and basic research because the weights for each element are 50% for completions, 40% for research income and 10% for publications. There is no mark for excellence or impact. All measures will be the average of each institutions performance for the preceding two years and the formula will be applied twice a year to adjust funding levels in response to student numbers. You can see the bean counters at work maximising the numbers to get a share of the action.

Anyway the bottom line is: no more money; more accountability; and apparently little or no consideration of the links between the universities, PMSEIC, CSIRO, industry and the other non-academic research centres in the country.

Needless to say the national press had a field day. *The Australian* editorial of 22nd December said, "Achieving real and substantial breakthroughs in research across the board requires continuing financial investment. It would be disappointing if the only real outcome of the white paper was to save Dr Kemp's political skin." However, *The Sydney Morning Herald's* editorial of the 27th December hit the nail on the head when it concluded that: "His white paper needs to go back to the drawingboard".

Eristicus, Canberra, February 2000

NTGS Releases More Airborne Geophysical Data

Richard Brescianini, Chief Geophysicist, Northern Territory Department of Mines & Energy has advised that the NTGS released the magnetic, and 256-channel radiometric data on 28th January 2000 from the remaining three of the five airborne surveys flown on behalf of NTGS during 1999. These are for the Amadeus West, Bonney Well and Elkedra areas.

You can place an order via e-mail to the NTGS Reference Geologist at: reference.geologist@dme.nt.gov.au clearly stating the type of data (located, gridded, 256-channel) you require, along with your contact name and address. All data will be supplied '*free-of-charge*' on CD-ROM.

The images of magnetic and radiometric data from all five of the 1999 surveys can be viewed on the NTGS website: http://www.dme.nt.gov.au/ntgs/ntgs/geophysics/new_survey.html

Brescianini says that requests for these data have been overwhelming, and he has received very positive feed back from clients. Australian Geophysical Surveys and Tesla Airborne Geoscience flew these surveys, which complement the results from the Rum Jungle and South Lake Woods surveys acquired earlier by WGC and Kevron, and released in December 1999.

The sheer volume of data being released necessitates the NTGS to 'stage' the release so that all clients who have asked for both gridded and located data (or gridded data alone) will receive the gridded data first. Over 600 CD's are being burnt to fill current orders for these new data.

For further information call **Richard Brescianini**
Tel: +61 8 8999 5389
Email: richard.brescianini
@dme.nt.gov.au

Palaeoweathering, Palaeosurfaces and Related Continental Deposits

Edited by Médard Thiry and Régine Simon-Coinçon
Special Publication Number 27 of the International Association of Sedimentologists, Blackwell Science
A$198, ISBN 0-632-05311-9

This volume of 16 papers is a contribution from the International Geological Correlation Program IGCP 317 *Palaeoweathering Records and Palaeosurfaces*. It is mainly about problems relating to the reconstruction of ancient continental surfaces and their environments. The volume is one of a number on the topic that has appeared in the last 10 years or so. The importance of weathering in the evolution of modern landscapes has been recognised for a long time. The papers in this volume look at palaeoweathering as a means of understanding palaeolandscapes. Differences between modern and palaeoweathering profiles demonstrate that there are differences between modern and palaeoenvironments. As Ollier has pointed out, the timescales in geomorphology and weathering are the same as plate tectonics and biological evolution, and palaeoweathering profiles therefore most likely developed under different conditions from those present today.

In their *Introduction*, Thiry et al. point out that preservation of weathering profiles on old landscapes is important - we cannot study things that have been removed. They note that preservation is most likely along the passive margins of basins. Dating of weathering is a problem. K/Ar, Ar/Ar and isotopes can be used, as can palaeomagnetism, although they do not mention the latter. They also discuss induration of weathered materials, and note that some surfaces and profiles are exhumed from beneath sedimentary covers.

In the first of three papers in a section on *Geochemistry and isotopes*, Schmitt notes that palaeoweathering profiles reflect the climate and atmospheric composition under which they formed, and therefore are a good indicator of past environments. Unfortunately, pedological terms are mixed with regolith terms and, especially in Figure 2, they are incorrectly used. The correlation of profile zones with various water table positions is also suspect. The other two papers in this section, by Cerling, and Mora and Driese, are concerned with the use of stable carbon isotopes in soils as evidence for environmental conditions.

The second section of the book, *Peculiar palaeoweathering types*, has five papers. Thiry reports on silicification in the Paris Basin. He notes that pedogenic silcretes are related to surface conditions, while groundwater silcretes are related to groundwater and water table positions. The importance of landscape position in silcrete formation is stressed. Calvo et al. present results of research into clay minerals in arid environments, both modern and ancient. Valeton, and Bardossy and Combes, discuss bauxites, which are common palaeoweathering profiles in many continental areas. Valeton discusses lateral variations in bauxite profiles, and explains them in terms of changes in vertical processes. The final paper in this section, by Gall, looks at Precambrian palaeosols and notes that they are very different from modern soils. He attributes this to their development in an anoxic atmosphere.

Seven papers make up the final section on *Regional palaeosurfaces and palaeoweathering reconstructions.* Simon-Coinçon notes that the sedimentary record in basins reflects the surrounding source areas, and that upland areas contain only rare clues to the events that are recorded in the basins. He also notes that most palaeosurfaces are polygenetic, and have survived a variety of environments without major changes. Widdowson and Gunnell write about laterites, and the evolution of the great escarpment and coastal lowland of western India. This is an area that has much in common with other passive continental margins. Lidmar-Bergstöm et al. point to the importance of weathering, and the presence of weathering profiles, even in formally glaciated areas in Scandinavia. Krause and Aslan, and Cojan, show that ancient floodplains, and lake sequences, contain palaeosols that reflect the evolution of these environments, as we know them from modern examples. Alley et al. study the Tertiary palaeodrainage channels of south-central Australia, reporting on processes of sedimentation and weathering, and their inferred environments. Finally, Schwarz and Germann report on ancient surfaces, sediments and mineral deposits in northeastern Africa.

This is a very well produced, if expensive, book. Each paper has a comprehensive and very useful reference list that allows readers to follow up relevant work. There is also a 16-page index, unusual in collections of papers, and very useful for those who wish to follow up on specific topics.
The general feeling one gets from this volume is that more detailed geochemistry combined with modelling of various environmental factors is the way of the future. However, there is also a place for more rigorous regional studies of regolith and geomorphology, using geophysical methods as well as those that look at the chemical and mineralogical details. Without these details, no amount of modelling will solve any of the problems associated with palaeoweathering and palaeosurfaces.

Finally, although this book is not about mineral exploration, it is worth pointing out that an understanding of palaeoweathering and palaeosurfaces is essential for efficient exploration. In particular, deep-weathering profiles must be taken into account when various geophysical data are interpreted. After all, they cover a fair proportion of most continents, yet their geophysical response is very different from that of most bedrock materials.

Reviewer: Colin Pain
CRC LEME, Australian Geological Survey Organisation

Geophysical Signatures of Base Metal Deposits in Victoria

Edited by A.J. Willocks, S.J. Haydon, M.W. Asten and D.H. Moore
Geological Survey of Victoria Report 119
Australian Society of Exploration Geophysicists Special Publication No 11

This volume, published jointly by the Victorian Department of Natural Resources and Environment and the Australian Society of Exploration Geophysicists (ASEG), follows an ASEG publication on the Geophysical Signatures of WA Mineral Deposits (ASEG Special Publication No 7, 1994) and is contemporaneous with an ASEG volume on the geophysical responses of South Australian mineral deposits. What strikes the reviewer is that the Victorian volume is not so much a series of case histories demonstrating how different geophysical techniques have successfully been applied to discover and delineate various mineral deposits, but is instead a volume that appears to be aimed at promoting the mineral prospectivity of Victoria. This emphasis probably relates to the activities of the Geological Survey of Victoria through the Victorian Initiative for Minerals and Petroleum (VIMP), which is aimed at attracting exploration to Victoria. Only one of the deposits described in the volume has been mined. Virtually all the papers describe investigations of sub-economic deposits or mineral occurrences that are best described as prospects. The object of the volume appears to be convincing the reader that Victoria is prospective for a range of different types of base metal deposits. The foregoing comments are not meant to detract from the quality of the volume nor the usefulness of its information content but to point out that it probably should be viewed primarily as providing information for individuals and organisations intending to explore in Victoria rather than a basic reference for geophysical responses of base metal deposits.

The volume is of high quality, and appears to have been carefully edited. The figures have been carefully drawn to a uniform standard and a liberal use has been made of colour, which is now virtually indispensable for the display of geophysical images. The volume follows a logical format. An excellent chapter giving an overview of current ideas on Victorian geology together with an outline of the types of base metal mineral deposits likely to occur in Victoria provides the introduction. This chapter gives a valuable update on recent advances in the ideas of Victorian geology, many of which have been based on studies of regional geophysical datasets. The remainder of the volume is subdivided into descriptions of deposits assigned to the following the following deposit types:

Volcanic Hosted Massive Sulphides

The Benambra deposits (Wilga and Currawong) hosted by a Silurian sedimentary/volcanic sequence:
This paper provides the only really classical description of exploration and delineation of base metal deposits in the volume. Wilga has been mined. Detailed geological descriptions of the deposits are provided with TEM surveys being the definitive delineation method. The results of various other geophysical tools that were tested are described. IP appears to be mapping adjacent disseminated mineralisation and frequency domain EM methods appear to have failed.

The Hill 800 Prospect in the Eastern Highlands:
This 'deposit', as acknowledged by the authors, is really a prospect that has not fully been investigated. IP appears to be mapping pyrite associated with copper-gold mineralisation. The mineralisation does not appear to have distinct geophysical responses.

The Wickcliffe Prospect in the Cambrian Mount Stavely Complex of Western Victoria:
The copper - gold mineralisation in this area has been interpreted as occurring in the feeder zone to a massive sulphide deposit from which the massive sulphide portion is missing. The disseminated mineralisation and associated pyrite appears to give an IP response but other geophysical methods are limited to mapping geology in the area.

Greenstone hosted copper-gold

(note: the Victorian definition of greenstone means assemblages of predominantly mafic units plus sediments and is not the same as Archean greenstone belts):

Mount Ararat:
a 1 Mt massive sulphide copper gold deposit giving electrical and EM responses.

Heathcote:
Exploration in this area, primarily based on geochemistry, has delineated disseminated sulphides and aggregates of massive sulphides containing minor chalcopyrite. Geophysical surveys do not appear to have detected any mineralisation.

Porphyry Mineralisation

Porphyry -type copper deposits in eastern Victoria (notably Dogwood and Sunday Creek):
This paper demonstrates how intrusive bodies associated with porphyry-type copper mineralisation give magnetic responses. IP maps associated disseminated pyrite but does not appear to be able to distinguish responses from copper mineralisation. Potassium responses over the mineralisation are low. This may reflect the low grades of the prospects.

Thursdays Gossan:
This prospect occurs in the Mount Stavely Complex of western Victoria. While IP appears to map pyrite mineralisation genetically associated with copper mineralisation a high conductivity zone over the prospect associated with a gravity low appears to be the response of a localised area of deep weathering.

Base metals in limestones of the Buchans Rift

Minor lead deposits in this area are inferred to have similarities to Irish deposits. IP appears to detect a response correlating to the mineralisation.

Copper associated with iron deposits at Nowa Nowa

These magnetite masses, which contain pyrite and minor amounts of chalcopyrite magnetite, are proposed as being possible analogues of the Tennant Creek copper-magnetite ore bodies. The magnetite gives a clear magnetic response. The reviewer considers that coincident IP responses arise from magnetite as well as the pyrite or chalcopyrite as proposed by the author of the paper.

The above summary is intended to give an appreciation of the scarcity of significant mineralised masses in Victoria, which show clear geophysical responses. Much of the exploration success to date appears to have resulted from geochemical surveys. Detailed drilled sections are lacking for some of the studies so that the exact spatial distributions of any mineralisation present are not always clear. Notwithstanding these comments, the individual authors have done a fine job of describing the chosen deposits and in assembling the available data to present and explain how geophysics has worked in Victoria to date. The volume shows that Victoria is prospective for various deposit types and should help in encouraging exploration in that state

Reviewer: Peter Gunn

Log Analysis for Mining Applications

By David Firth
Published by Reeves Wireline 1999, 156pp, RRP $65.

This publication can be regarded as the long awaited revision of the 1981 'Coal interpretation manual', as the generic title hides the strong content bias towards coal applications.

The formal, but easy reading style, directs the reader through the process of designing, acquiring and interpreting geophysical logs, mainly for coal applications. A brief history of slimline logging precedes a description of the current tools available, an introduction to the physics behind the measurements they make and how these measurements are displayed. A handy inclusion in these sections is a detailed description of tool calibration and borehole environment considerations.

The interpretation of slimline geophysical logs is not a unique science, however a well illustrated series of chapters, occupying two thirds of the publication provides the reader with some guidelines and helpful hints on how to undertake such a task. These chapters start by introducing the concepts of lithological identification, boundary thickness and inter-borehole correlation using full colour illustrations of different lithologies and their physical property attributes. For the structural enthusiast, the chapters on the processing and interpretation of dipmeter and acoustic scanner data will help unlock the many insights hidden in the vast amount of data these tools collect. Progressing from exploration and feasibility to mining considerations, David Firth outlines the generation of rock strength and coal quality estimates from geophysical log data. The book concludes with a series of sections designed to illustrate how slimline logs can be used to support the design and interpretation of seismic refraction, reflection and in seam surveys.

The publication lacks a reference or bibliography, metalliferous mining applications and a discussion on a broader range of tools e.g. full waveform sonic and spectral gamma-gamma. However, if I may finish, by recommending that a bias publication, with a very generic title is a valuable asset to professionals in the coal industry (geologists, mining engineers), novice log analysists and students. Indeed, if Reeves Wireline were able to condense the publication to fit into the back pocket, the book would get the desired use.

Reviewer: Gary Fallon
MIM Exploration

Abstracts

Section 4

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Thursday 16th March

Alphabetical Index of Speakers

Alphabetical Index of Speakers

KEY SPEAKER

TIME-REVERSED ACOUSTICS

Mathias Fink
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Time-reversal invariance is a very powerful concept in classical and quantum mechanics. However, simple experimental evidence of this concept is difficult to obtain. In the field of acoustic waves, where time reversal invariance also occurs, time-reversal experiments may be achieved simply with large arrays of reversible transducers (both receiver and transmitter). Time-reversal mirrors are made of such reversible acoustic retina, allowing an incident acoustic field to be sampled, recorded, time-reversed and re-emitted. Such a device can re-create a sound or an ultrasound and send it back to its source as if time had been reversed.

Theses mirrors have a range of applications including medical imaging and therapy (destruction of kidney stones and tumor hyperthermia) as well as non-destructive testing (detection of flaws) and underwater acoustics (long-distance communication and mine detection). Experimental results illustrating these applications will be presented and potential applications of TRM in geophysics will be discussed.
Time reversal mirrors can also be used for elegant experiments in pure physics and several surprising experiments will be presented.

PORE PRESSURE AND INVERSION

Effects of porosity and clay content on compressional and shear wave velocities in sandstones

Abbas Khaksar and Cedric Griffiths*
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Laboratory velocity measurements on cores along with petrographic and core porosity data have been used to investigate the effect of porosity and clay content on acoustic wave velocities in 22 core samples from the Cooper Basin, South Australia. Empirical equations are determined for Vp and Vs as a function of porosity and clay content for air- and water-saturated samples under elevated effective stress. Results are compared with other studies. At elevated effective stress, porosity is the rock property best correlated with velocity. Statistical analysis of experimental data shows that considering a clay content term improve the velocity-porosity transform for the studied samples. This observation is consistent with previous works. However the influence of clay content on velocities in Cooper Basin samples appears to be weaker than has been reported in the literature for other sandstones. The lack of correlation between clay content and velocity in those Cooper Basin sandstones studied is initially attributed to the textural characteristics and the type of clay distribution within the studied samples. Considering the effect of clay and fines on velocities and velocity-porosity transforms in shaly sandstones is necessary, but this effect may not adequately be explained if only the volume fraction of clay is taken into account. Other factors including pore geometry, textural pattern and microstructure of the rock such as grain or matrix supported, type and the position of clay particles within the rock skeleton should also be considered. The clay models of Minear (1982) and the velocity-porosity model of Vernik (1994) for "wackes" provide an analog for the observed velocity-porosity-clay content relationship in the Cooper Basin samples. The existence of non-potassic clay minerals such as kaolinite complicate the interpretation of shaly sandstone formations and the application of 'standard' velocity-porosity-clay content equations to well logs.

Pore pressure/stress coupling and its implications for seismicity

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Periodic pressure measurements made during the depletion of oil fields and virgin pressure measurements through normally- and over-pressured sequences in sedimentary basins both demonstrate that changes in pore pressure and minimum horizontal stress (sh) are coupled to one another. Pore pressure/stress coupling is predicted by poroelastic theory. Data from the North Sea (Ekofisk Field) and Texas (Travis Peak Formation of east Texas and Vicksburg Formation of south Texas) suggest that sh decreases at approximately 80% and 50% of the rate of depletion of reservoir pore pressure respectively. Virgin pressures in overpressured sedimentary basins suggest that sh increases at approximately 70-80% of the rate of increase in pore pressure in the Canadian Scotian Shelf, the Australian North West Shelf and the Gannet/Guillemot Fields area of the North Sea. The total vertical stress (sv) is given by the weight of the overburden and is unaffected by changes in pore pressure. Hence, contra to simple, uncoupled models of the effect of pore pressure on rock failure, differential stress in normal fault regime basins (sv -sh) increases as pore pressure decreases, and decreases as pore pressure increases. Increased differential stress with decreased pore pressure can account for depletion-induced seismicity, despite effective stresses increasing. Decreased differential stress with increased pore pressure implies that a greater increase in pore pressure can be withstood prior to failure than would otherwise be predicted, and increases the propensity of tensile, rather than shear failure, occurring with overpressure development.

Describing pore shape and volume changes: a key element in modelling pressure effects on the physical properties of porous rocks

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The physical properties that govern the geophysical response of a porous rock are dependent on the confining pressure and pore fluid pressure conditions prevailing in the rock. The pressure effects are primarily due to the connection between these physical properties and pore structure of the rock. Variations in the pressure conditions cause alterations in pore shape and volume, leading to changes in the physical properties.

Inclusion-based formulations are commonly used to predict and analyse quantitatively the dependence of physical properties on pore structure. These formulations view the porous rock as a solid matrix with embedded inclusions representing the individual pores. Pore geometry information is expressed in terms of the inclusion shapes and concentrations. To simulate the effects of varying pressure, it is necessary to have a mathematical description for the resulting changes in pore shape and volume. Previous attempts to describe pore changes related to pressure conditions in inclusion-based formulations have used simplifying assumptions and a limited range of pressure conditions.

This paper presents a mathematical framework for pore shape and volume variations that overcomes these limitations. This framework uses an oblate spheroidal inclusion, which permits a range of realistic pore shapes while reducing computational complexity. The inclusion major and minor axis lengths are varied independently to avoid assumptions about inclusion evolution. Confining pressure and pore fluid pressure are treated as independent variables, allowing the consideration of general pressure conditions. The result is a system of first-order differential equations that can be solved numerically with ease.

Joint Porosity Inversion

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The ambiguous dependence of observed geophysical data in relation to subsurface reservoir properties suggests that practical reservoir characterization problems can be characterized by both physical mechanism and its statistical behavior. A new neural network for space- and time-varying signal processing, including neural wavelet estimation, input signal reconstruction, and nonlinear factor optimization, has been developed in this paper as an information integrated approach. Some deterministic petrophysical models are incorporated with the neural network via nonlinear activation functions of neurons. This results in a joint lithologic inversion scheme to integrate broadband seismic impedance data, well data, and geological knowledge for porosity estimation. First some appropriate deterministic petrophysical models can define optimal overall trends to fit a cloud of data points for different rocks and lithology types in their impedance-porosity response. Next the neural wavelets are used as scanning operators to determine the scatter distributions of data points that deviate from the trends so that these different rocks and lithologies can be separated in the impedance-porosity space. The joint porosity inversion scheme consists of two subprocesses. First, inverse neural wavelets are extracted at the wells, and then the inverse-operator-based inversion is used to estimate the initial porosity model. Secondly, forward neural wavelets are estimated at the wells, and then the forward-operator-based reconstruction can improve the initial porosity model. Finally, the scheme is applied in a complex continental deposit with strong heterogeneities in western China to estimate porosity.

SEISMIC VELOCITY

Velocity as an attribute: continuous velocity estimation from preSDM CRP gathers

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Here we present a technique for fine tuning the velocity associated with a final preSDM image.

Essentially we employ techniques of continuous velocity estimation used for iterative model update, but apply them in a different context.

Rather than using the velocity estimation on a set of sparse lines, we apply the estimation techniques to the all CRP gathers resulting from the final 3D migration.

This achieves two things: firstly it estimates a residual velocity correction for stacking the final CRP gathers to obtain an enhanced depth image, and secondly, it delivers a dense estimate of velocity for the entire 3D volume in a geologically coherent manner.

It is this second feature which is developed in this paper. The resolution obtained in the velocity cube is observed to be the same as the expected theoretical post-migration Fresnel zone resolution: velocity regions with significant velocity differences appear to be bounded by faults seen in the seismic images. This could be of use in pressure prediction.

Rapid travel time calculations for simple earth models using computer algebra

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This paper describes the use of computer algebra in the derivation of analytical expressions for travel times of rays at finite offsets for a 3D earth model comprising a few layers where layer thickness, velocity and dip angles are represented symbolically. Expressions for offset and travel times are derived symbolically in terms of the initial ray directions and parameters of the earth model. These expressions and the derivatives of the offsets with respect to ray direction are converted to C program subroutines. Numerical techniques are then used to find travel times for given values of offset, limited only by computer precision. Since derivatives of offsets with respect to initial ray directions can also be calculated directly, a modified Newton's method was used to give rapid convergence to initial ray directions required for a given value of offset. The travel time is then calculated from the ray directions so derived. This is an alternative to previously used techniques based either on approximations or on purely numerical calculations. Numerical values of model parameters may be readily changed and the calculations repeated for the changed model. Analytical solutions have been derived for a number of multiple and inter-bed ray paths as well as for primary events. Travel time calculations are fast and accurate since they are based on analytical expressions. Shot records, CMP gathers or other geometry can be readily defined. This paper discusses the potential use of these travel time calculations for improving numerical modelling, identifying multiple reflection events, identifying anisotropic effects and determining the variation of reflection point locations in CMP gathers. The potential for, and possible limitation of, extensions to include multi-layer earth models, converted waves and calculation of amplitudes is also discussed.

Seismic velocities in the North West Shelf Region, Australia from near-vertical and wide-angle reflection and refraction studies

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A significant limitation of the conventional reflection technology is that it poorly constrains seismic velocities in the deep part of the crust. These velocities are needed to enable seismic migration, to convert seismic results from time to depth scale, and to determine the likely rock composition at depth. Seismic observations at large offsets can compensate for this limitation.

To address this issue, the Australian Geological Survey Organisation (AGSO) has recorded high quality refraction and wide-angle reflection seismic data on Australia's North West Shelf using ocean-bottom seismographs (OBSs) along 5 profiles, to maximum offsets of 300 km . All of these OBS transects coincided with previously acquired deep crustal seismic reflection profiles. Consequently, velocity information can now be derived from two independent data sets: CDP (near-vertical reflection) data and refraction/wide-angle reflection data. As a result, residual (between these two velocity data sets) velocity images can be produced and analysed.

Even within the top 5 km of the crust, residuals between the OBS- and CDP-derived interval velocities vary from -1000 to +3000 m/s and they further increase with depth. Depending on what velocity is preferred for depth conversion of near-vertical reflection data, the depth equivalent of 5 s two-way time will vary by 1.5 km or 10%. Practical implications of co-processing of seismic velocity information are: improved seismic velocity estimation in the crust; more accurate depth migration of seismic data; conversion of near-vertical reflection seismic data from time to depth scale for the whole crust; estimation of distortion of amplitudes of geological structures after depth conversion.

Calibrated wide angle 3D AVO processing for improved lithology classification

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Whilst AVO analysis for reservoir identification is a well established tool in many basins there are some lithologic sequences for which the technique has not been uniformly successful. In this paper we review one such problem case where conventional AVO analysis has been' proven unable to discriminate between reservoir gas sand, water wet sand and organic shale despite evidence from well measurements of differing elastic modulii.

As a first step in the study a multi-well AVO synthetic modeling exercise was undertaken, using both ray theoretical and elastic wave equation approaches. Due to a significant impact from local mode conversion, thin bed effects and multiples the wave equation synthetics were seen to match much more closely the observed AVO responses. Additionally reservoir discrimination was seen to require angles of incidence of greater than 50 degrees; much greater than could be adequately handled by conventional (sub 30 degree) AVO techniques.

Preservation of wide angle reflection amplitudes requires adaptions to more standard processing approaches. In particular angle dependent geometrical spreading and anelastic attenuation losses become important as does higher order normal moveout correction. Further, as angle of incidence increases the importance of anisotropic propagation effects, both kinematic and dynamic, cannot be ignored. Accomodation of these factors during pre-processing was seen to greatly improve the match between AVO synthetics and measured data. For wide angle AVO analysis a quadratic expression for amplitude vs $\sin^2\theta$ is required with the added benefit over linear expressions of enabling compressional, shear and density reflectivities to be derived.

Combining the above processing procedures resulted in 3D AVO class maps which offered clearly improved reservoir discrimintation.

GROUNDWATER

Airborne and ground geophysical surveys for groundwater targeting in hard rock terrains, Orissa, India

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A major problem in hardrock terrains is to locating sustainable groundwater sources. The Orissa groundwater project has shown identification of brittle fractures is essential for sustainable groundwater yields. High resolution airborne geophysical survey carried out in Orissa, India covering 75 000 sq. km. area to improve the groundwater exploration in drought stricken regions of northern and western Orissa. Airborne magnetic, radiometric and digital topography data were collected at a nominal altitude of 80 m with line spacing of 250 m. Orissa groundwater project carried out from 1993 to 1998 provided an opportunity to evaluate brittle and ductile faults interpreted from the airborne geophysical data by different ground geophysical methods. Phulbani district in, Orissa, India was chosen as the test area for groundwater exploration. The groundwater exploitation in Phulbani is either by shallow tubewells or dugwells targeting the weathered zone aquifers. Geology of Phulbani comprises of high-grade metamorphic rocks. Groundwater occurs in weathered zones as well as in fractures of the basement. Brittle faults were delineated and fault zones with suitable hydrogeological conditions were chosen as drill targets and were tested by different ground geophysical methods. Results and correlation of the ground and airborne geophysical data were presented in this paper. Highest yields were recorded from the brittle fracture zones and low to nil from the ductile fault zones interpreted from the airborne geophysical data.

The use of transverse resistance in the determination of aquifer quality from electromagnetic soundings in the Gascoyne flood plain deposits, Western Australia

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In the Carnarvon area, water is drawn from the Gascoyne riverbed for town and agricultural use. Mapping of aquifers within the clay alluvium is very difficult. Electrical and electromagnetic (EM) surveys, which are best suited for this task, suffer from severe ambiguities known technically as equivalence and suppression problems. EM surveys are easier and faster to use but are less sensitive to nonconductive layers than are DC resistivity surveys. A method has been devised to reduce the uncertainty caused by the above two problems.

Resistivity and the thickness of conductive clay layers can be detected with a fair degree of accuracy. Resistivity and thickness of the relatively poorly conductive aquifers are difficult to determine directly from inversion of electrical and electromagnetic surveys. It is found that while inversion results for the depths and resistivity of the aquifer are widely varying, they do yield a good estimate of transverse resistance in the Gascoyne River flood plain. The depth to basement is fairly uniform in the area, and this value subtracted from the depth to the top of the aquifer (giving the thickness of the aquifer), is used to obtain an estimate of aquifer resistivity from the transverse resistance. A second inversion of the field data holding this constrained estimate of aquifer resistivity fixed yields revised estimates of depths to the top and bottom of the aquifer. It is found that by using repeated inversions together with constrained resistivities based on an estimate of the transverse resistance of the aquifer, that the values of aquifer thickness and resistivity may be obtained within a narrow range of equivalence. Where comparisons have been made with the ground truth from boreholes, the estimates of thickness of the aquifer are in close agreement with those measured. The resulting accuracy of aquifer resistivity is then an acceptable basis for an assessment of aquifer quality.

Crosshole resistivity imaging of aquifer properties

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Crosshole resistivity tomography has been trialled at the Bolivar site north of Adelaide to delineate aquifer properties and preferential flow paths associated with artificial recharge and recovery operations. To date only the pre-storage electrical measurements have been carried out, but follow-up monitoring and background subtraction will be conducted at various stages of pumping to delineate storm-water injection and harvesting from the aquifer. This paper presents the results of the resistivity imaging experiments before water injection at the Bolivar site. The resistivity imaging experiment has entailed crosshole profiling and scanning with a specified bipole-bipole electrode array between four pairs of boreholes located on a circle of a radius of 75 m from the water injection well, and the data were inverted for the resistivity structure of the aquifer using a new imaging scheme. The four resistivity images obtained between each pair of boreholes show a somewhat similar pattern, with alternative zones of high and low resistivity within the aquifer. There are at least five zones which can be recognised. They correlate with the major subdivisions found from geophysical logging of the boreholes and correspond with the stratigraphy of the T2-aquifer, which consists of variably cemented fine carbonate and sandstone layers.

Hydrogeological applications of airborne geophysical data in Australia

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Traditionally hydrogeological investigations relied on geological interpretation from aerial photographs and groundwater data obtained from drilling. Advent of airborne geophysical data has given more indepth geological and hydrogeological information thus largely contributing to the understanding of the hydrogeological processes. Airborne geophysical techniques comprising of magnetic, radiometric and electromagnetic data allow to cover large areas in less time. Aeromagnetic data identifies the subsurface geological and structural features which influence the groundwater movement in the catchment where as interpretation of radiometric data provide a better understanding of the nature of soils and weathering history. The electromagnetic data provide information on regolith and distribution of salts for salinity studies and to locate favourable hydrogeological target zones for groundwater investigations. Airborne geophysical surveys were carried out at Balfes Creek in (Queensland), Willaura (Victoria), and Toolibin Lake (Western Australia) under 'The National Airborne Geophysics Project' in Australia.

The hydrogeological interpretation and the water resource target maps from airborne geophysical data problems and advantages are discussed in the present paper.

ADVANCES IN EM EQUIPMENT (1)

The development of a large fixed loop airborne TEM system

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A new fixed loop AEM (airborne EM system) was conceived in 1991, and developed with the assistance of AMIRA between 1991 and 1993. The AEM system has been used in a number of experimental and commercial surveys since 1993, with some encouraging results. The main difference between the new fixed loop AEM system and previous systems is the utilisation of recent technology to achieve a Time Domain fixed transmitter loop configuration in airborne mode. The new system incorporates:

- crystal synchronisation between transmitter and receiver
- large effective area ferrite core sensor coils
- accurate RTGPS positioning
- stable low noise bird design
- vibration mounting for sensor coils
- large mass storage facility for up to 31 time windows
- automatic winders for cable laying and retrieval
- interfacing with aircraft instruments such as radar

The purpose of this paper is to show how the various technologies incorporated in the new AEM system were selected and adapted to achieve an integrated system. Some exposure will be given to the experimental development of the system.

An example of 3D conductivity mapping using the TEMPEST Airborne Electromagnetic System

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The TEMPEST airborne electromagnetic system is designed to measure the information that is required to derive accurate, high-resolution three-dimensional conductivity estimates of the subsurface.

TEMPEST is configured with a transmitter loop located on a fixed-wing aircraft and receiver coils located in a towed bird. The system measures the EM response of the ground over a wide-bandwidth (25 Hz - 37.5 kHz). The transmitter waveform is a square wave with 50% duty cycle, i.e. equal on and off times, and variable switching ramp. Very low noise levels are achieved by recording the received signal at a high sampling rate, 75 kHz, then applying sophisticated signal processing techniques. The signal processing operates in the frequency domain to perform a full deconvolution of the measured response, removing the system transfer function characteristics and dynamically compensating for variations in the transmitted waveform. The broad bandwidth allows the variable primary field effects that result from changes in coupling between the receiver coils in the towed bird and the transmitter loop to be more accurately removed by reducing the uncertainty in the ground response. To assist interpretation, the deconvolved ground response signal is converted to a 100 % duty cycle square-wave B-field response, allowing a single transient decay to be presented for the full 20 ms half cycle length available for a base frequency of 25 Hz. The system geometry is accurately monitored at all times. This involves measuring the orientation of both the transmitter loop located on the aircraft and the receiver coils located inside the towed bird. These orientation measurements are used to compensate the ground response data for the effects that result from variations in the system geometry as the aircraft flies along the survey line.

The development of 25 Hertz GEOTEM an example of a successful collaborative R&D Model

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Airborne electromagnetics (AEM) technology is one of the main tools used by geophysicists world-wide to explore for mineral deposits. Since the first application of AEM in the early 1950s in Canada and Scandinavia, AEM has resulted in more discoveries than any other method. However, while AEM has been used in Australia since the mid-1950s, the follow-on discoveries attributed to AEM are far less than almost any other major exploration setting.

A major reason for this lack of discovery performance in Australia has to do with the fact that until the early 1990s, basically all AEM system development was dominated by a mind-set that saw the major role for AEM was in geological conditions typical of eastern Canada. This being a terrain that is low and flat (like Australia) but as well a bedrock which is covered by a thin veneer of moderately conductive glacial soil, arguably the antithesis of conditions found in Australia and many other semi-arid settings in the world.

In the early 1990s the AEM problem was addressed. At almost at the same time, two programs were undertaken, the Australian Mineral Exploration Technology (AMET) CRC-World Geoscience Corporation program and the Geoterrex-Aberfoyle-BHP collaboration. While the AMETCRC-WGC effort is well documented in the annual reports of the two participants, the later program, termed the 25 Hertz Project, was commercially confidential and hence little known outside the sponsoring organizations.

An examination of the 25 Hertz Project will show that it was basically a simple undertaking technically and commercially, modestly funded but also one which the sponsors felt was enormously successful. At a time when needed R&D support for the exploration industry is seemingly becoming a scarce commodity, the lessons from the 25 Hertz Program should be given a close examination.

Broadband (ULF-VLF) surface impedance measurements using MIMDAS

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Radiation from distant, discrete, ground-to-cloud lightning return-strokes can be recorded as atmospherics (spherics), using both electric and magnetic field antennas. The Earth-Ionosphere waveguide filters this radiation into the ULF-VLF radio bands from 3 Hz to 30 kHz with a notch at approximately 2 kHz. The relationship between the horizontal electric field and the horizontal magnetic field time domain signatures at the receiver is directly related to the surface impedance of the earth at that point. Transforming the transient fields to the frequency domain allows the calculation of the surface impedance over the frequency range determined by the sample rate and record length. From this, the apparent resistivity-depth profile of the earth can be determined. This paper demonstrates that a discrete spheric can be considered as a broadband vertically polarised dipole source suitable for AMT/MT style geophysical surveying and that the data collected could be used to deduce upper layer resistivity. The results from measurements made with MIM Exploration's proprietary distributed acquisition system (MIMDAS) are presented. Multi-station data were acquired in a telluric profiling mode (without a magnetic field reference) to demonstrate spatial coherence and correlation with conventional MIMDAS MT pseudosections and IP inversion models. The advantages of the technique include the broad band of measurement and rapid data-acquisition time for reliable statistics. Valid data were collected between 24 kHz and less than 100 Hz and while stacking improves data integrity, useful information may be extracted from less than 5ms of a 6s record, corresponding to a single strong spheric. This technique has potential value in near surface geotechnical applications and as an aid in removing statics from conventional continuous-MT survey data.

POTENTIAL METHODS (1)

Screening Kimberlite Magnetic Anomalies in Magnetically Active Areas

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Airborne and ground magnetic surveys are a primary exploration tool in the search for kimberlites. Interpretation of magnetic data provides direct information on possible pipe magnetic signatures and indirect information of the structural setting of the area.

Magnetic anomaly screening in an area of highly active magnetic relief and magnetic texture such as an Archean shield area or volcanic terrain is very difficult. Conventional techniques such as stacked profile interpretation and modelling/inversion are almost impossible, as there is so much interference and overlap between adjacent anomalies. There is also the additional problem of distinguishing possible kimberlite sources from other sources with very similar magnetic signatures. However, the magnetic signature of kimberlite pipes is band limited so enhancing wavelengths of interest plays an important part in interpretation.

Semi-automatic interpretation, using a combination of specialised filters and analytical techniques can provide objective information on anomaly attributes. These can be used in conjunction with the geological setting of the area to prioritise anomalies for follow-up. The application of separation or layer filters allows deconvolution of the causative sources around a particular mean depth. Plotting of gradient maxima/strike symbols maps circular or elliptical anomalies as closed clusters. 3D Euler deconvolution provides first-pass depth estimates and an indication of the nature of the source. Finally, matched filtering using a cylinder model can identify roughly circular anomalies over a broad range of amplitudes and wavelengths.

Anomalies selected in the first phase are refined by automatic profile analysis and the total anomaly attributes compiled into a database. Finally targets are assessed in their geological context, using available geology and the magneto-tectonic interpretation of the area.

Enhancement of subtle features in aeromagnetic data

Mike Dentith, Duncan R. Cowan, Linda A. Tompkins and Sheila Cowan*
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Qualitative magnetic interpretation involves manipulating magnetic relief and magnetic texture. Magnetic relief consists of anomaly amplitude and shape and is relatively objective. Magnetic texture consists of shape, size and continuity of adjacent anomalies and is more subjective.

Conventional filtering responds primarily to amplitude variations within the data and high amplitude anomalies often mask more subtle anomalies of interest. Reducing amplitude dependence using an AGC filter may amplify any defects in the data and the filtered output is band limited.

Three fundamentally different approaches to enhancing subtle anomalies have been implemented and tested on a wide range of sedimentary basin and low gradient basement areas. The first approach uses separation or layer filtering to deconvolve the effects of magnetic sources around a mean depth. The second uses texture filtering mainly using GLCM filters and the third uses the gradient tilt angle.

Results show that each method has its advantages and limitations. Each method shows different amplitude and wavelength response for a given dataset but all three are relatively broad band compared to a conventional filter such as an AGC filter. No single method performed well on all datasets. Combining filters with different bandwidth such as the separation filter and tilt angle can be very effective.

Enhancement of Airborne Magnetic Data using the Variation Method of Fractal Dimension Estimation

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Textural-based processing of airborne magnetic data is becoming a recognised tool of image enhancement. The variation method of fractal dimension (FD) estimation is a measure of texture that can resolve subtle textural contrasts as well as edge features that are otherwise difficult to discern.

Application of the variation method to synthetic fractal datasets highlighted its ability to distinguish textural contrasts when using local estimates of FD. The variation method was also able to enhance thin linear anomalies, linear ramp anomalies and sinusoidal ramp anomalies contained in synthetic datasets. The variation method clearly resolved these features even in the presence of Gaussian noise. The results demonstrated that smaller window sizes will more effectively discriminate and enhance edges.

Application of the variation method on the Ghanzi Chobe aeromagnetic dataset highlighted structural features that were not resolved in the greyscale total magnetic intensity image. Comparison of the variation method with standard derivative-based enhancements showed that the variation method enhanced similar structural trends but with greater clarity. It also enhanced structural features that were not revealed by horizontal and vertical derivative images. Whilst the variation method needs to be applied to data from a wider variety of magnetic regimes, the results suggest that the technique can provide useful information not available from conventional enhancement processes.

Palaeochannels Near West Wyalong, New South Wales: A Case Study in Delineation and Modelling Using Aeromagnetics

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In November 1998, the Australian Geological Survey Organisation (AGSO) and the New South Wales Department of Mineral Resources acquired high-resolution airborne magnetic and gamma-ray spectrometric data along lines spaced 50 m apart and 60 m above ground level north of West Wyalong, New South Wales. In addition, AGSO post-processed a proprietary dataset of similarly high-resolution from an area immediately to the south, between West Wyalong and Temora, along the Gilmore Fault Zone. Anomalies interpreted to be caused by palaeochannel deposits have been identified in these datasets. Modelling of the airborne magnetic data was used to define the geometry of the palaeochannel deposits. These models were constrained using data from drill holes and downhole magnetic susceptibility measurements.

Mapping palaeochannel deposits is of potential significance for mineral exploration and land and water research. Historically, alluvial gold, often palaeochannel-hosted, has accounted for a large proportion of Australia's gold production. The study area is part of the historic Wyalong goldfield and is part of the Bland Creek palaeovalley. Palaeochannel deposits may also be reservoirs of saline groundwater, and therefore are important in developing hydrogeological models for dryland salinity hazard assessment.

Due to their depth of burial (often concealed beneath surficial sediments, to depths of 150 m), the palaeochannel deposits in the study area are mappable using either airborne magnetic or electromagnetic data, but not using gamma-ray spectrometry. The palaeochannel deposits contain detrital ferruginous maghemitic pisoliths (which have extremely high magnetic susceptibility) concentrated in lenses in sand and clay.

The resolution of the aeromagnetic datasets is compared with results obtained from surveys with different acquisition parameters. These tests suggest that an airborne geophysical survey flown with line spacing of less than 100 m can reveal important information about regolith materials, including channel-fill deposits such as in the sedimentary fill of the Bland Creek palaeovalley.

OVERPRESSURE AND RESERVOIR PROPERTIES

Overpressure prediction using surface seismic, VSP and LWD

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VSP data were combined with surface seismic data to give a very good prediction of the overpressure zone. This prediction was continuously updated using ISONIC real time velocity information as the drill-bit was approaching the predicted overpressure zone. At the same time, the pore pressure was constantly monitored by an independent prediction method PERT using all the logging-while-drilling (LWD) data. Casing was successfully set immediately above the overpressure zone, which was subsequently confirmed by the open hole logs.

Before spudding, the analysis of surface seismic stacking velocities showed that the interval velocity dropped off in an expected depth interval in which nearby wells experienced varying degrees of overpressuring. Thus, the drilling program was designed to allow for the acquisition of two intermediate VSP datasets above the expected overpressure zone. Between the first and second VSP, RAB, CDR and ISONIC LWD tools were also deployed to measure the resistivity, natural radioactivity and velocity in real time. The VSP data were inverted for the impedance profile with the constraint of ISONIC velocity data. The VSP impedance profile provided a much improved definition of the overpressure zone seen from the stacking interval velocity profile. The PERT calculated pore pressure was correlated with the impedance profile in the well section drilled between the two VSPs. This correlation provided a calibration to convert the VSP impedance profile into a predicted pore pressure profile.

In the third stage of drilling, both CDR and ISONIC tools were deployed. The real-time velocity information from the ISONIC tool was used to accurately convert the depth of the drilled trajectory into a time-based index. This conversion offered a way of tying the bit position to the predicted pore pressure profile. As the drill-bit was approaching the predicted overpressure zone, both the VSP impedance profile and the predicted pore pressure profile were updated periodically with newly acquired ISONIC velocity data. Casing was set when the depth-to-time converted position of the drill-bit reached the top of the predicted overpressure zone.

After setting the casing, the RAB tool was deployed. The pore pressure was continuously monitored with the real-time resistivity data from the RAB tool. The predicted overpressure zone was confirmed by the real time PERT pressure, the open hole logs and full VSP after TD.

Estimating pore pressure in the Cooper Basin, South Australia: sonic log method in an uplifted basin

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The use of sonic log data to analyse overpressure in the Cooper Basin, South Australia is complicated by the occurrence of Tertiary uplift in the basin. Uplift and overpressure are both associated with anomalous porosity/depth relationships: the former being witnessed by overcompaction and the later by undercompaction. Hence uplift may mask overpressure effects on log data. A normal compaction trend was determined for the Cooper Basin by averaging sonic log data from 29 wells. The Maree Subgroup was omitted from the normal compaction trend because it has a markedly different sonic log signature. Shale sequences were isolated for study by applying a gamma ray filter (API > 100). In order to remove the effects of uplift, the normal compaction trend was adjusted to fit the trend of the upper, normally pressured part of the sequence in each well. Quantitative pore pressure analysis was undertaken on shale sequences from 8 wells using the Eaton (1972) method once the effect of uplift had been removed. The predictions of the Eaton (1972) method are consistent with pressure measurements (DSTs and mud weights) in sandstones in 7 of the 8 wells, suggesting that both uplift and overpressure have been successfully determined. Assuming that the shales at Moomba 55 are overpressured, as suggested by the Eaton (1972) method, these shales must be isolated from adjacent near normally pressured sandstones. Furthermore mud weights, which are only at best an approximation of formation pressure, are especially unreliable in overpressure shales adjacent to near-normally pressured sandstones.

Constrained modelling of a hydrodynamic environment beneath a regional pressure seal: an example from the Northwest Taranaki Basin, New Zealand

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The northwest offshore Taranaki Basin contains near-normally pressured Cretaceous and Palaeocene reservoirs beneath overpressured Eocene shales. In order to better understand maturation and migration in the area, Spectrum Exploration Ltd., in a joint venture with Fletcher Challenge Energy Taranaki Ltd., have undertaken a PetroMod™ 2D thermal and fluid-flow modelling study of the region and constrained the results to match various geophysical, petrophysical and thermo-chemical parameters. The overpressures in the Eocene shales occur immediately beneath Oligocene marls, which have low permeability and act as a regional pressure seal. The amount and distribution of this compaction-disequilibrium overpressure has changed during time and corresponds with the rate of sediment loading beneath a thick Mio-Pliocene overburden. Lack of significant overpressures in the underlying reservoir section is attributed to these having acted as carrier beds for hydrodynamic groundwater flow and pressure escape. The 2D modelling results have been constrained to match available well and seismic data. These include: oil-geochemistry; petrophysical and geophysical estimates of overpressures; maturity indicators; and fluid-inclusion data. The calibration of the modelled present-day overpressures to seismically derived overpressures is considered to be a particularly novel aspect of this study. Localised high-velocity zones close to some of the major faults correspond with areas where modelling suggests the Eocene shales have de-watered into the faults. Thermal modelling results show the overpressured Eocene shales have acted as a thermal blanket and increased the maturity of the source-rocks above the levels previously assumed. Whilst the overpressures appear to hinder vertical escape of hydrocarbons, they also set up hydrodynamic effects which create a more complex migration history than might otherwise be thought in this relatively benign part of the Taranaki basin.

Size scale considerations In modelling the electrical conductivity of porous rock and soils

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Various types of inclusion-based approximations have been used to investigate the relationship between the microstructural configuration of components in porous rocks and its electrical conductivity. The microstructure corresponding to a given model is determined by the composition of the background and inclusions, the inclusion shape spectrum and the nature of the inclusion interactions. A frequently used inclusion-based approximation for modeling electrical conductivity of porous rocks and soils is the differential effective medium approximation (DEMA). However, DEMA possesses significant microstructural properties that are not often considered when it is applied to the analysis of geophysical measurements. While neglecting these properties can lead to errors, they also present an opportunity for incorporating important microstructural features and relationships. In particular, the conductivity estimates obtained from DEMA strongly depends on the inclusion embedding sequence. An increasing inclusion size scale is implied in the embedding process (e.g., from intergranular cracks to vugs). In addition, structural features of the initial background matrix are smaller than any inclusion size scale. This paper presents a framework for DEMA estimates of electrical conductivity that explicitly incorporate size scale relationships that occur in porous rocks and soils. This approach is illustrated using an example where the porosity is divided into smaller intergranular pores and larger main pore spaces having a size scale similar to that of the solid grains. The resulting DEMA estimates show that the relationship between electrical conductivity and porosity, as well as the apparent cementation exponent of Archie's Law, are very sensitive to the types of pores involved in the porosity changes.

GROUNDWATER ENVIRONMENTAL/GEOTECHNICAL APPLICATIONS (1)

Groundwater contamination monitoring with multichannel electrical and with electromagnetic methods

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Electrical and ground-based electromagnetic surveys have been carried out at the Ranger minesite to investigate their use in detecting any seepage from structures used to store ore processing tailings. The main aim of this work have been to develop a clearer understanding of any seepage problems at this minesite using a combination of self-potential (SP), direct current (DC) resistivity, induced polarisation (IP), and transient electromagnetic (TEM) methods, with the results being interpreted in conjunction with hydrogeological data. Ultimately, it is aimed to apply an optimal combination of the methods to long-term monitoring of potential seepage.

A multichannel system developed at CRC AMET has been used to measure simultaneously record the response at a number of electrodes with the SP, DC resistivity and IP methods. The simultaneous measurements enable telluric noise associated with SP responses to be minimised and permit efficient measurements to be made with electrode spacings as small as 10 m required for high resolution sounding with the DC resistivity and IP methods. Measurements with such small spacings can be made in reasonable time at a number of stations only with multichannel systems.

Data collected north of the Ranger tailings dam in October and December, 1998 have been processed and plotted. These results show that the initial surveys have proved to be very successful. Qualitative interpretation of the plotted data indicates that possible seepage has been detected by the SP and IP methods, while the resistivity and TEM methods help to resolve the geological structure of the area.

Geophysical quantification of a moisture content profile in the near surface

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Geophysicists commonly have a simplistic view of the watertable as a sharp interface between the vadose zone (i.e., unsaturated region) and the phreatic zone (i.e., saturated region). In reality, this boundary is a transition zone where moisture content continuously varies with depth. Since geophysical methods respond to the depth variation in water content, the use of this simplistic model could lead to significant errors in the interpretation of geophysical data. An improved model for the moisture content profile that incorporates different soil structures, soil type and water qualities would allow better interpretation of near-surface geophysical surveys. In addition, this model would permit the extraction of important near surface hydrological information from geophysical data. In this study, a systematic analysis of the relationship between moisture content profile and the response of commonly used near surface geophysical methods (i.e., resistivity sounding, ground penetrating radar, and electromagnetic induction) have been performed. Using a computational model that considers the water and chemical regime in the vadose zone, the water content profiles for various soil types were generated. The corresponding geoelectrical profiles were constructed using petrophysical relationships for dielectric permittivity and electrical conductivity. The resulting geophysical responses were computed for these geoelectrical profiles.

The results of the theoretical work are being compared with geophysical data from the North Adelaide Plains. The geophysical surveys were conducted close to test borings from which information about soil type, soil structures, water quality and water content profile were obtained. The analysis of field data is currently in progress.

Pitfalls in environmental geophysics

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Environmental Geophysics, like other forms of geophysics, is used as a cheap alternative to intrusive investigations. Unlike the exploration arena, the environmental field can undertake intrinsic investigations at a relatively low cost and therefore geophysics needs to be able to show not only cost savings but also aerial coverage. The other major difference between exploration and environmental geophysics is the size of the surveys. With the fine balance of costing and small survey sizes, environmental geophysics has substantial opportunity to have pitfalls. These pitfalls can vary from the ability to acquire good clean data due to the site, and surrounding influences, to having to undertake the processing and interpretation in a very short period of time during and at the end of the survey. As most clients supervising these surveys have no geophysical background, there is need to also be an educator, to inform the client of the benefits and limitations of geophysics. A number of examples will be presented of the pitfalls that both the geophysicist and the client can fall into when planning and undertaking an environmental geophysics survey. These examples will include the selection of the most suitable tool for the target being investigated and an example of difficulties encountered when a suitable tool is selected but the site is not as appeared.

Geophysical studies for groundwater assessment in the Sturt Plateau

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The Sturt Plateau is located to the south of Katherine and covers much of the Larrimah and Daly Waters 1:250,000 map sheets. Land is primarily used for pastoral fodder production for beef cattle. However, due to the monsoonal climate of the region, with an extended dry season occurring from May to October, poor runoff potential and high evaporation rates, surface water options for stock watering are generally not proposed. Groundwater is considered to be the most reliable source and is being utilized in the vast majority of cases.

A three year project jointly funded by the Northern Territory Government and Natural Heritage Trust, studied the water resources on the Sturt Plateau. Data obtained from this project has enabled property scale mapping of water resources for development planning as well as regional scale information for evaluation studies

Test drilling has indicated that the most suitable resource for groundwater development is in a limestone aquifer overlying an undulating basalt basement. In some areas of the Sturt Plateau the success of individual bores has been dependent on the level of the basement in relation to the regional groundwater level. Localised variations in basement structure, evident in drilling results, are not reflected as surface depressions, therefore indirect methods for determining the basement topography were required.

Geophysical methods were employed to map local variations in the depth to the top of the basalt. The region has been studied in considerable detail using airborne geophysics, ground geophysics and bore-hole methods.

Bore-hole geophysics has provided stratigraphic correlation between bores. In cases where drilling circulation, due to cavities or fracturing in the limestone, had been lost and sample return was poor or nil, bore-hole logging was the only way of determining lithological variations, primarily the occurrence of limestone and the limestone/basalt contact.

Vertical electrical soundings and TEM soundings were conducted over much of the study region. The electrical contrast between the limestone and basalt has since been determined (from modelling and induction conductivity bore-hole logs) to be insufficient to provide any diagnostic information. Originally it was thought that the model results from joint soundings were producing estimates of the depth to the base of the basalt layer. (which if considered to be of constant thickness across the study area could define the elevation of the top of the basalt). However, estimates of basalt thickness were constrained by TEM results which it is suggested have been affected by SPM.

Airborne magnetics has provided the most useful information concerning features in the basalt and indirectly information about the occurrence of limestone. Regional structures have been shown to control basement highs and delineation of such features has been possible. Joint swarms in the basalt evident from the magnetics have been shown to correlate with confined regions of increased depth to basement. The increased depth is thought to be associated with preferential weathering of the basalt along the joints prior to limestone deposition

ADVANCES IN EM EQUIPMENT (2)

Experience with SQUID magnetometers in Airborne TEM Surveying

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High temperature superconducting quantum interference device (SQUID) magnetometers have been developed in a collaborative project between BHP and CSIRO specifically for application in airborne time domain electromagnetic (ATEM) surveying. The objective of this development was to improve the performance of the system in detection of conductors with longer decay time constants, particularly in the presence of a conductive overburden. The sensors were incorporated into a specially designed receiver system and successfully trialed as receivers for the GEOTEM system with the assistance of Geoterrex-Dighem. Their performance was shown to be comparable with, but not superior to current induction coil TEM systems. The development of the receiver system required solutions to a range of problems for the sensor devices and for the receiver system . For the receiver the principal obstacle was in overcoming the high dynamic environment of the towed receiver bird and the consequent high level of noise associated with motion of the sensor in the Earth's magnetic field. The high dynamic range of the of the magnetometer response which arises from this motion was addressed by a combination of modification of the sensor flux locked loop and periodic resetting of the sensor offset. A digital stacking filter was used to eliminate low frequency noise associated with motion and a specially designed suspension system was developed to isolate the sensor from higher frequency motions of the towed bird.

Avoid pink, go for Blue: Noise power spectrum preferences in TEM Acquisition

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Significant improvements in TEM data quality can be made if we are able to choose or alter the noise power spectrum in TEM acquisition. The standard processes of windowing the acquired time-series to produce time channels, and stacking to average the results attenuates higher frequencies more strongly than low frequencies. Thus, these processes work more effectively for a noise power spectrum that is rich in high frequencies, a white-blue spectrum, than one that is rich in lower frequencies, a pink-white spectrum. At the same total RMS noise level a blue noise power spectrum will deliver much better estimates of the amplitudes of late channels than a pink power spectrum, but at the expense of worse estimates at early times. For most applications in TEM there is an abundance of signal at early times and it is the late time channels that need a boost in signal-to-noise ratio; therefore, a bluer spectrum is to be preferred.

In many cases we can choose our noise spectrum as it is often our equipment, rather than other EM signals, that dominates the accuracy of the measurement. Compact sensors such as small induction coils and magnetometers provide the best opportunities to use a coloured noise spectrum because their intrinsic noise is usually greater than other natural sources. By choosing or designing a sensor to have a blue-white noise spectrum the limits of sensitivity can be improved significantly.

Applications of computer data acquisition systems in electric and electromagnetic methods

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A computer based data acquisition system was designed at CSIRO in 1992 containing two 486 computers, each with a 4 channel, 12 bit ADC card , 2GB data storage, receiver coils and electrodes, amplifiers with optional filters and gain controllers, and a field power supply. While the system was originally designed for a noise rejection study, it has been successfully applied in experiments on MT, CSAMT, ISTF, TEM, SP and IP as well as EM noise background monitoring. The system was used to continuously acquire data from natural sources as well as with Zonge, Scintrex, and Geotronics grounded dipole transmitters and Sirotem, UTEM and Protem ungrounded loop transmitters.

The relatively limited 12 bit digitisation was dictated by a requirement for high bandwidth, and was a compromise determined by factors such as cost, maximum addressable computer RAM (since data could not be written to storage as fast as it could be acquired), available storage media. Present computer, storage and A/D technology has advanced to the point that a much higher number of bits can and should be digitised. With a limited number of bits comes the need for adjustable gain in the system and other issues.

The advantages and disadvantages of a computer based system have been well illustrated in the experience to date. . The prime advantages of continuously sampled data is an ability to apply post-survey processing to the noise reduction problem. Disadvantages of computer bases systems include fragility of the system and the clutter of application specific peripheral devices compared to dedicated systems. A second disadvantage is that at the time of acquisition, it is difficult to predict what the final processed S/N ratio might be; at least in conventional instrumentation, S/N rations are usually easy to determine and stacking times easy to optimise to achieve required levels. Conventional instruments may also achieve advantages through synchronisation, particularly if they stack data or if logarithmic sampling is required (as is the optimum for EM). Continuously sampling instruments without synchronisation must 'oversample', or sample at a faster rate than the shortest required 'delay times' to achieve the same benefit. This increases the data storage requirements in a general purpose system. However, the versatility of a general purpose system far outweighs these disadvantages in any cases where 'problem noise' is encountered, and in out experience is a very cost-effective means to achieving versatility on a single instrument for electrical and EM data acquisition.

POTENTIAL METHODS (2)

Quality control of gridded aeromagnetic data

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Many gridded images of aeromagnetic data include artifacts and 'unlikely' correlations of anomalies across flight lines. This distorts the anomaly shapes and patterns used to interpret the data, as well as introducing (or removing) power at frequencies which may be important for further processing. Some of the features may be due to poor data quality, inappropriate choice of survey parameters, poor gridding algorithms or inappropriate choice of the parameters used by the gridding algorithm. We present a method for quality control of aeromagnetic images that utilises the Fast Fourier Transform algorithm in the calculation of the image's power spectrum. Visual inspection of the power spectrum allows many image and data problems to be diagnosed including over-smoothing, notch filtering, ineffective leveling and directional bias caused by the sampling pattern and/or gridding algorithm. Using the FFT to calculate the power spectrum requires careful consideration of the techniques used for edge mismatch and the filling of survey gaps. Otherwise, these methods make quality control difficult by distorting the power spectrum. Existing gap filling methods were found to be inadequate and an alternative based on the thin-plate spline was developed and used successfully. The most effective method for edge mismatch was to multiply the image by a window function that tapered to zero at the image edges. The method was used to determine sensible input parameters for the two main gridding methods in Geosoft, and to suggest the best method for a given situation. We found that Geosoft's bi-directional splines can exploit the fast sampling along-lines but distort anomaly shapes when the line spacing is too wide. Geosoft's minimum curvature is unable to exploit the fast sampling along-lines but suffers less distortion of anomalies at wide line spacing. Additional examples are presented of the application of the method to images created using other algorithms.

Aeromagnetic drape corrections applied to the Turner Syncline, Hamersley Basin

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Aeromagnetic surveys in rugged terrain, such as the Turner Syncline in the Hamersley Basin are often flown as loosely draped surveys within operational safety limits. Loose draped surveys are a compromise between retaining good spatial resolution of small magnetic sources and maintaining fairly constant terrain clearance. The main problems in these surveys relate to lines flown in opposite directions. Over deep, narrow valleys, the magnetic source depth increases, anomaly amplitudes are reduced and spatial resolution of small sources lost. Over narrow ridges, the magnetic source depth decreases, anomaly amplitudes are increased and resolution of small sources much improved. The high wavenumber content of lines flown in opposite directions may be very different, resulting in zones of marked texture differences, especially for race track flight paths.

The ideal drape correction involves projection of the field onto a surface with constant terrain clearance, preserving the full bandwidth of the data. Several grid and profile based drape correction algorithms have been tested on the Turner Syncline with varying degrees of success. The best results were obtained with a two pass correction approach. A first order drape correction was applied to the located data prior to tie-line and microlevelling. The gridded data were then further refined using a grid based drape correction. The results show that the drape corrections have been effective in reconstructing anomaly amplitudes but less effective in preserving the texture of the data. Conventional approaches to drape correction appear unable to restore the missing high wavenumber information content, caused by extreme height variation. A fractal stochastic deconvolution method offers a way of reconstructing the texture of the data.

The total-field geomagnetic coast effect: the CICADA97 line from deep Tasman Sea to inland NSW

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In the CICADA97 experiment a line of simultaneously-recording stationary vector magnetometers was deployed from inland NSW, across the east Australian coast, and into the Tasman Sea. The purpose of the experiment was to investigate the effect of electrical conductivity structure near a coastline on natural time-variations in Earth's magnetic field. Aeromagnetic surveys regularly take place in such coastal areas, and removal of time-variations of the magnetic field is a prime task of data reduction. CICADA97 data show that long-period variations of the total field are systematically enhanced near the NSWi coast, while spatial patterns of short-period variations (such as pulsations) may be strongly influenced by electrical conductivity structures on a smaller scale, such as bays and inlets.

The magnetic vector and gradient tensor in mineral & oil exploration

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Though early surveys measured the separate components of the earth's magnetic field, current practice is restricted to the measurement of the intensity of the total magnetic field. But this emphasis on the measurement of intensity without direction is currently being questioned. In this paper, the applications of the magnetic vector are shown for two cases critical to mineral exploration. Firstly, in the case of intensely magnetic sources, e.g. banded iron formations, the resultant field direction is significantly non-parallel to the present field direction, and the current method of calculating the anomalous field is grossly incorrect. The resulting anomaly map is therefore difficult to interpret in terms of detecting targets. Secondly, at low magnetic latitudes, the horizontal nature of the field results in a total field map from which it may be impossible to identify the location and geometry of the magnetic sources. Knowledge of the magnetic vector can easily be used to overcome these problems.

However, there are major logistical errors associated with the measurement of components during an airborne survey. Because of the movement of the aircraft, the orientation of the component magnetometers will not always be parallel to the intended measurement detraction. A one-degree shift in the vertical will lead to a 100 nT error measurement in the vertical component. To measure down to 0.1 nT accuracy, the orientation needs to be known correct to 10 seconds of arc.

The solution may lie in measuring the gradient tensor rather than the vector components. Apart from the cases discussed previously, the gradient tensor has additional applications, for example, in diamond and oil exploration, where typical anomaly amplitudes can be quite small and knowledge of the across-line horizontal gradient critical. Also, at high magnetic latitudes, the tensor is only marginally affected by the normally high diurnal variations, unlike the total field intensity. Just as with airborne gravity surveys, the measurement of the gradient tensor of the magnetic field is likely to prove the next major breakthrough in magnetic surveys.

WAVELET TRANSFORMS AND ANALYSIS

Attenuating coherent noise by wavelet transform

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For a crosswell synthetic data set, three filtering approaches were used to attenuate the strong and aliased tube waves: median filtering, F-K filtering and wavelet filtering. It was found that the wavelet filtering method was superior to the other two methods. Application of wavelet filtering to the Glenn Pool crosswell data sets successfully attenuated the up-going and down-going tube waves and therefore recovered the weak later arrivals.

Developments in the analysis of potential field data via multiscale edge representation

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Traditionally, potential field data are represented and analysed as 2D images. In previous works, we have proposed an alternate 3D representation in terms of multiscale edges. In image processing, the main features in an image may be skeletonized by finding their edges. In potential field data, these skeletal edges correspond to the boundaries of major anomalies, geological contacts, faults, etc. The set of edges found at multiple upward continuation levels are termed multiscale edges, and can be seen as a transform of the image (i.e., they contain the same information as the original data, and the image itself can be reconstructed from them through an inverse transform). This representation can be advantageous for a number of potential field applications. First, by automating the extraction of the main features in the image, it objectively facilitates the visual interpretation of the image. Second, by manipulating the multiscale edges before image reconstruction, a set of 'feature-based' image processing operations are available (de-noising; feature removal, isolation, or enhancement, etc). Because both the edges and the wavelet have localisation properties, such operations can be applied to specific anomalies with limited perturbation of adjacent areas. Third, the multiscale edges contain information about the geometry of discontinuities in sources, which can be exploited for inversion. Several paths are evident towards stable downward continuation using wavelet operations, and our first experiments in this direction look promising. In the paper, we will describe the theory of this suite of operations. We will also give 2D and 3D examples of these operations, applied to both synthetic and real data.

Interactive seismic event recognition and its applications

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A number of automatic event picking methods have been proposed by seismologists over years. All fully automatic methods lack robustness. Given that present-day machines can at best mimic human picking procedures, it is hardly surprising that they will fail when thing gets tough - for example when attenuation degrades signal to noise ratios. In common with all phase-sensitive detection systems, seismic time picking procedures do not fall over gracefully when signal-to-noise ratios fall. Attenuation, sensor coupling variations, the competition of multiple arrivals for a given time slot all complicate the task of designing a robust picking machine.

In this paper we set out the architecture of a semi-automatic seismic event recognition system in which robustness is achieved by allowing a user to train the machine interactively both to accomplish a given pattern recognition task and to cope with variations in the nature of that task - such as waveform changes caused by selective attenuation of say high frequencies. The pattern-recognition task itself is accomplished using conventional windowed cross-correlation using models in a user guided range. The art of enhancing the precision of time picking robustly lies in supervising the change between envelope/amplitude threshold gating and phase sensitive detection.

The scheme has been used to extract arrival times from full waveform sonic logs, reflection and tomographic in-mine borehole radar surveys, and 3D land seismic reflection surveys conducted over faulted coal measures. The last-named in particular yields massive data volumes. The picking scheme has proved flexible enough to enable observers to cope well with arrival identification and imaging tasks on a standard PC. Picking procedures will be reviewed and examples presented.

GROUNDWATER ENVIRONMENTAL/GEOTECHNICAL APPLICATIONS (2)

Subsurface vegetation mapping and soil classification by ground penetrating radar for Kyoto ARD activities

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Estimation of carbon sinks in forest vegetation and soils is an important problem as recognized as the results of Kyoto Conference(COP3,1997) for the reduction of green house gas emission. The "Kyoto Forest" referring Afforestation, Reforestation and Deforestation(ARD) in Article 3.3 of Kyoto Protocol should be considered as the definition of carbon sinks in this stage. The amount of vegetation on the ground can be easily measured by the remote sensing or be simply calculated by the inventory data base, however the effect of soil and vegetation under the ground can hardly be identified. To solve this problem, we proposed the ground penetrating radar (GPR) for visualizing the subsurface vegetation and soils as a non-destructive method. The subsurface data by GPR were acquired through the 200MHz and 400MHz antennas. The effectiveness of GPR exploration has been demonstrated for profiling the shallow subsurface structure and characteristics.

The application of the Mise-á-la-masse and electrical imaging geophysical methods in the detection of pipe source pollution

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Recent developments in Electrical Resistivity data acquisition and inversion routines have expanded the capability and the potential application of resistivity methods. Equally important is an ability to recognise situations where improved capabilities may provide a superior/cheaper methodology. The detection of leakage of pollutants from underground pipes is one such application. Leakage from sewage pipes in the Sydney area results in year round pollution of waterways, which is of environmental and political concern. Traditional methods provide inaccurate and qualitative interpretations.

This study trialed two geophysical electrical techniques for locating the source of pipe leaks within sandy and clay soils. The Mise-á-la-masse method detects electrical continuity between the sewage and the surrounding soil. A decrease in resistance, or an increase in electrical continuity, is caused by leaks in the resistive sewerage pipes. Electrical imaging, using the Wenner array, measures the electrical resistivity in the subsurface as a function of depth below, and distance along the traverse. A decrease in resistivity, particularly at the depth of the sewerage pipe may be caused by the leakage of pollution.

The results demonstrate that electrical geophysical methods are able to detect situations of electrical continuity and low electrical resistivity at the depth of the pipe. The Mise-a-la-masse method is able to detect the leakage of pollution given a sufficient anomaly compared to variations in subsurface inhomogeneity, which depend on the geology/subsurface conditions. The resistivity pseudosection provides a firmer confirmation of the existence of a leak as it indicates the resistivity, and resistivity contrasts above, below and along the pipe. Correlation of anomalies, gives a high degree of confidence that subsurface conditions are commensurate with the leakage of pollution. The limited use of 3d measurements provide a significant contribution to the interpretation. These anomalies also correlate with within-pipe closed circuit television, and observed surface features. Confluence of this evidence strongly indicates leakage along the pipe, and indicates that surface geophysical methods are capable of detecting it.

Fractured rock hydrogeophysics at Clare Valley, South Australia

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Within Clare Valley, groundwater occurs in fractured rock aquifers. As such aquifers underlie approximately 40% of Australia, an understanding of sustainability and distribution of groundwater resources is important for agricultural and domestic purposes. The long-term sustainability of groundwater resources in this and other fractured aquifers depends on the ability to characterise the local and regional hydraulic properties of the aquifer. The combination of geophysical measurements with data from other hydrological and geological techniques offers an efficient and accurate method for evaluating groundwater resources in fractured aquifers.

The primary goal of this project is to assess the value of geophysical methods in determining the capture zones of irrigation bores in the Clare Valley. This work is being done in conjunction with the Clare Valley Fractured Rock Aquifer Project that involves hydrological and geochemical monitoring at over 100 observation wells, as well as pump tests at selected bores. Azimuthal resistivity surveys utilising both DC resistivity and EM induction were performed to evaluate the ability of these methods to predict fracture orientation. Initial results have found that the DC resistivity ellipses for Wenner array electrode spacings greater than 40 m align with the known bedding plane orientation at our test location. Asymmetric EM-34 azimuthal surveys indicate presence of significant heterogenities that affect the results. Analysis of these azimuthal surveys is ongoing, and additional azimuthal field experiments are planned. Mise-á-la-masse surveys, a direct method for mapping individual fracture systems, have also been performed; the analysis of results is continuing. The use of self potential methods for mapping groundwater flow patterns are scheduled for a pumping test in the near future.

IN MINE/MINESITE GEOPHYSICS

Detailed orebody mapping using borehole radar

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Detailed orebody delineation on a mine scale is usually carried out predominantly by the interpretation of information from drillhole core and cuttings. Inaccurate interpolations between drillholes can result in dilution and ore loss. This paper presents examples of the use of borehole radar to provide more continuous maps of orebody outlines. These examples show that these maps can substantially reduce the uncertainty of orebody models resulting in improved mine plans, reduced dilution and improved ore recovery.

The data presented were collected with the GeoSonde borehole radar system. This system is not directional. However, by combining information from other sources, the 3D locations of the reflectors that are imaged can often be accurately estimated and the potential errors quantified. Difficulties have been encountered when the system has been operated in salt water filled holes but good results have been obtained in these holes after they have been flushed with fresh water. The system has also been used in up-dipping holes up to 120 m long.

The results obtained to date indicate that substantial cost benefits can be obtained at some mine sites by incorporating borehole radar surveys into the ore delineation process.

Downhole magnetometric resistivity surveying for refractory gold ore at Wiluna Gold Mine, Western Australia

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The downhole magnetometric resistivity (DHMMR) technique is shown for the first time to be capable of locating off-hole refractory gold mineralisation. DHMMR surveying at Great Central Mines Limited's Wiluna Gold Mine was used to explore for deep extensions of weakly conductive gold bearing sulphides along the Bulletin Shear Zone. Over 80% of the gold at Wiluna is contained within sulphide minerals (3 to 7% pyrite, less than 3% arsenopyrite and trace chalcopyrite). It has an average run of mine grade of 8 g/t and average sulphur content of 2%. Ore conductivity is very low, averaging 8x10-4 S/m, but this is at least 10 times greater than background. One target area sits within the shear zone at a downhole depth of 1,400 m. The DHMMR technique was chosen as the only method likely to be able to find weakly conductive ore at depths of 1 km or more, below a conductive overburden, and at significant distances from the drillholes.

Combinations of downhole-surface and downhole-downhole electrode configurations were used to channel current through the shear zone. The source was a 1Hz 100% duty cycle square wave at 500 V, that produced a current of 0.65 A over an electrode interval of 1 km. The survey hole was located in between the electrodes, and the MMR response was measured with a three component EM probe connected to a GDP16 receiver. The data were corrected for the contributions from dipole wire and earth return fields.

All 4 holes surveyed had MMR responses in the shear zone, and these were strongest in the vicinity of in-hole mineralisation. Noise levels were high and some data points were not repeatable where the holes came close to underground mining operations. This pattern was also evident in the phase. Data spikes were recorded in all three components within the shear zone. These spikes are interpreted to be caused by in-hole sulphide stringers and current gathering along fluid-filled cracks. Coherent, longer wavelength MMR responses were observed in every hole and are indicative of conductive bodies sitting off-hole and within the shear zone. Qualitative interpretations indicate that the conductive bodies have sub-vertical aspects, consistent with the known geometry of ore shoots at shallower levels. Modelling software that handles three component DHMMR data is currently being refined to confirm the qualitative interpretations and to provide more precise target locations for drilling.

Underground seismic reflection experiment in a gold mine

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An underground seismic reflection survey was carried out at the Revenge Gold Mine in the Kambalda area of Western Australia, in an attempt to map the shear-hosted ore lode. The experiment entailed 140 small explosions fired into a 47-element geophone array laid out along the floor of a section of tunnel. The target mineralisation was located approximately 100 m below the tunnel floor. This was the first such experiment ever attempted in an Australian gold mine. The data quality was generally good, with 1-2 kHz signals propagating over distances of greater than 100 m. Strong P and S direct arrivals were observed, but reflections from the shear zone were not found, even after CDP processing. One problem was sensor mount resonance.

Another was the lack of target contrast and the rough/diffuse nature of the interfaces being mapped. The experiment demonstrated capability to retrieve high frequency seismic data under difficult circumstances. The experience should be beneficial to future reflection surveys in metalliferous mines.

POTENTIAL METHODS (3)

The determination and application of vector gravity anomalies

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Conventional gravity measurements are only of the maximum magnitude of the gravity acceleration vector. This is because the gravimeter is aligned with the gravity vector and not in a self-consistent reference frame. However, when a high-resolution geoid model is available, vector gravity data can be computed. The geoid model is used to compute the deflections of the gravity vector from the ellipsoidal normal, thus providing direction to the measured magnitude of gravity acceleration. This allows the components of the gravity vector to be computed from the gravity measurements. Since the geoid is mostly generated by deeper earth structure, the components of the vector gravity anomaly enhance the information on deeper mass variations above that contained in the conventional gravity anomaly. This approach has been applied to the Australian gravity data and shows a number of linear features not clearly evident in conventional Bouguer gravity anomaly maps.

Drilling-constrained 3D gravity interpretation

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In interpretation of gravity surveys, it is essential to exploit all the information available from drill holes in order to reduce the ambiguity. Accordingly, a new modelling and inversion methodology has been developed to expedite joint geological/geophysical interpretation of gravity data. The key features of the approach are the enforcement of drill constraints (pierce points) and the imposition of density bounds on geological formations and basement. 3D density models are constructed from close-packed vertical rectangular prisms with internal contacts. Prism tops honour topography, so that terrain effects are modelled, not 'corrected'. Detailed local models can be embedded in regional models to permit fitting of full free-air data, not residual gravity. The geological sense of models is preserved during inversion: the shape and density of homogeneous geological units are adjusted iteratively, subject to the drilling and density constraints.

The methodology has been illustrated using data from an advanced exploration project in South Australia. Integrated interpretation of a drilled area has been undertaken in four stages. The first stage entailed construction of a 'regional' density model, satisfying gridded gravity data on a coarse mesh over a large area centred on the drill grid. Next, a local density model was created on a fine mesh for the drill grid area, based on drill intercepts and density logs. Thirdly, the detailed density model was inserted into the regional model. Finally, constrained inversion was performed, to adjust the local starting model until a fit to the free-air gravity data was achieved.

Regional structure and distribution of magnetite: implications for the interpretation of aeromagnetic data in the Broken Hill region, New South Wales

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Magnetic anomalies in the Palaeoproterozoic Willyama Supergroup in the Broken Hill region have a number of different sources, including stratiform magnetite, structurally controlled magnetite and magnetite in igneous rocks. Magnetic sedimentary units are relatively uncommon; most metasedimentary rocks are chemically reduced and host few stratiform anomalies. Exceptions include units within the Paragon Group and volumetrically minor banded iron formation. Structurally controlled anomalies are common across the region and are caused by magnetite in high-temperature shear zones, tectonic fabrics, or in high-strain zones developed along the contact between rocks of contrasting competency. Magnetite formation occurred more than once during the deformational history, during both high-grade and lower-grade metamorphism. Many of the observed linear anomalies coincide with the regional S3 fabric, which formed during upper greenschist to amphibolite-facies metamorphism. Retrograde shear zones are generally magnetite-destructive and form linear zones of low magnetic intensity. Amphibolite has a generally low magnetic susceptibility, although certain units have a high susceptibility, possibly due to alteration as a result of fluid flow. The abundance of structurally controlled anomalies and the relative paucity of stratigraphic anomalies hamper the detailed extrapolation of lithological units beneath cover and means that a 'magnetic stratigraphy' is difficult to construct for the Willyama Supergroup. Rather, aeromagnetic data are more useful in the delineation of high-strain zones that have acted as channels for fluid flow, resulting in the formation or destruction of magnetite. Tracing these zones of fluid flow has potential benefits for the reconstruction of mineralising systems and magnetite formed in these zones may have acted as a chemical trap for metals such as gold.

Rock property estimates from walkaway VSP surveys

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Very few wells have given the opportunity to check upscaling of rock parameters like AVO and anisotropy from core sample measurements through full waveform sonic, VSP and surface seismic measurements. In 1997 the possibility arose for a well in the North Sea Ekofisk field where a set of 2D walkaway lines were recorded, sonic logs run and core samples taken. This paper describes the VSP results. To measure azimuthal AVO for the top and the base of the Ekofisk reservoir formation, six walkaway lines were recorded, using 3 azimuths at each of the two array depths. Since the tool was positioned above as well as inside the reservoir, the local anisotropy could be measured, and a joint inversion of the AVO and anisotropy compared. The basic idea behind estimating AVO with VSP measurements is to position a multi-level array close to the reflector of interest.

It is then possible to use the downgoing wavefield for deterministic (shaping) deconvolution of the reflected wavefield and to correct for all propagation effects, i.e. geometrical spreading, attenuation and the effects of local inhomogeneities in the overburden. To interpret the measured AVO curves synthetic P-wave reflection coefficient curves were calculated for different, isotropic and anisotropic (TIV) models. Modelling was restricted to elliptical anisotropy with the values for e and d being the same. Densities and Vp/Vs ratios were derived from calibrated log data. The reflection coefficient curve for the isotropic/isotropic models was the exact Zoeppritz solution, whereas the curve for the anisotropic/isotropic models was an approximate solution for TIV media. For the same formation strong azimuthal variation of the AVO estimates were detected showing less anisotropy in one direction compared to strong anisotropy in another direction. This interpretation result was confirmed by independent local anisotropy measurements.

RESERVOIR GEOPHYSICS (1)

Reducing resource uncertainty using seismic amplitude analysis in the Southern Rankin Trend, North-West Australia

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Between 1973 and 1996 West Australian Petroleum Pty. Limited (WAPET) discovered five major gas fields on the Southern Rankin Trend including Spar, West Tryal Rocks, Gorgon, Chrysaor, and Dionysus (Greater Gorgon Resource). Recent discoveries at Chrysaor and Dionysus emphasise the role of subtle 3D seismic attributes in finding hydrocarbons and defining reserves with a minimum number of wells. The Gorgon, Chrysaor, and Dionysus fields were covered by 3D seismic data shot in 1991 and 1995, which led WAPET to recognise first Chrysaor and later Dionysus. Subsequent to the 3D acquisition, field reservoirs have been correlated with anomalous seismic events (in both stack amplitude and amplitude versus offset) that conform to depth structure. This new observation led to the Dionysus discovery where combining these 3D seismic attributes has improved our ability to predict wet sands, gas sands, and other lithologies. Extrapolation to nearby exploration prospects and some Gorgon Field reservoirs was similarly successful. The resulting understanding and confidence that was provided by 3D seismic has driven an aggressive exploration program and defined field reserves at a high confidence level. Results include the recent award of permit area WA-267-P to WAPET and the ongoing studies to begin development of the Greater Gorgon Resource.

DRYLAND SALINITY AND FARM PLANNING (1)

Keynote Paper

Airborne geophysics improves the diagnosis, prognosis and treatment of dryland salinity

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Biophysical information provides the technical basis for sound catchment and farm planning and is essential for management of dryland salinity. However, the information available is often scant (for example, only aerial photography, topography and geology) or at an inadequate (for example, 20 m elevation contours, regional scale (1:250 000) geology mapping) scale for its intended purpose. Current catchment and farm plans aimed at salinity management are generally based on insufficient and inadequate information which is poorly interpreted, leading to misplacement of treatments and engendering little confidence that implementation will achieve the desired outcomes.

Achievement of the required level of landscape evaluation is hampered by Australia's size and subsurface (hydrological and geological) complexity. New systems of airborne and ground data collection and interpretation for environmental management provide an affordable bridge across much of the biophysical gap. Between 1980 and 1990 developments in ground and airborne systems were taking place, however they were limited in application and scale. However in the past decade the systems have become more robust and applied. New dGPS systems now make the acquisition of ground based measurements practical while studies linking crop and tree responses measurements have created a market fro the services. Similarly at a catchment scale, airborne systems are now delivering spatially accurate and complex pictures to environmental managers.

In Australia today geophysical data have the ability to:

- map paddock scaled changes in EC and yield (ground based only)
- map geologic structures critical for the management of land and water salinity,
- adequately map farm-scale changes in regolith salt-store and groundwater salinity,
- map local and regional patterns of soils,
- add information for better salinity hazard assessment and land management not previously available from other data sources,
- compile geophysical and other GIS data in a simple to use format which brings a significant amounts of 'hard to access' biophysical information together for the catchment community.

AEM still requires improvements to allow the user to accurately distinguish paddock scale changes in regolith thickness. It also requires that the contractors and geoscientists work together to achieve better interpretation products. The ability to profitably use AEM and other geophysical data in all landscapes and at both a paddock and catchment scale is currently being discussed.

A farmers perspective on geophysics in agriculture

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In modern agricultural management, planning systems and methods for adressing environmental degradation has been neglected.

The 1980/90's method of farm planning was based upon the use of a minimal number of spatial data sets to develop 'best bet' plans to adress salinity.

The latest farm planning methodology as developed from R&D utilising airborne and ground geophysics as a base for farm planning has been applied in Broomehill and subsequent projects at Trayning, Wyalkatchem and Moora.

The major objective has been to gain an understanding of the regolith, and the influences of ground water movement upon the expression of salinity and waterlogging. Interpretation of how degradation will appear in the landscape and its affect upon sustainable agriculture.

Where does geophysics fit into environmental management?

What are the costs and benefits from accessing this level of detail of the regolith?

These questions and many others were investigated in the Broomehill project where 28 farmers in the Wadjekanup/Byenup Hill Landcare Group have been involved in applying this methodology on their respective properties. This paper will highlight the difficulties encountered by the farmers in understanding the technology and how this technology can be applied to the farm business.

Examples will be provided to illustrate the productivity gains possible in implementing farm plans utilising geophysics, and how these farmers have moved on to develop new and exciting enterprises and farm practices using geophysics as a planning tool.

The increasing call by the Government and community for the agricultural industry to improve its environmental record is influencing the environmental implementation practices of farmers across the wheatbelt.

Practical examples of the application of geophysics for selecting new enterprises and the location of these enterprises will be shown. How are farmers selecting areas for intensive agriculture? What are farmers' requirements from geophysics as an information source? How can geophysics add to spatial data and farmer experience?

Airborne geophysical surveys to assist planning for salinity control, National Airborne Geophysics Project case studies

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Airborne geophysical data, specifically electromagnetic (SALTMAP), magnetic and radiometric, in conjunction with existing data, was assessed for the contribution that these tools can make in the understanding and management of dryland salinity through trial evaluation at Lake Toolibin, Western Australia, Willaura, Victoria and Balfe Creek Queensland. In all survey areas the data sets acquired added value to the existing data base and knowledge. Traditional reconnaissance mapping has relied on airphoto interpretation which is limited to mapping surface features. Geophysics maps the sub surface so that hydrogeological models of catchments can also be developed. In all the case study areas magnetics accurately mapped geological structures important for the movement of groundwater flow. These included dolerite dykes, basalt flows and sedimentary basins. Radiometrics mapped surface features of soils and outcropping geology that were related to geomorphological development. Electromagnetic data mapped regolith properties that were primarily related to salt storage. This enabled discrimination of important structures for groundwater movement/impedance such as bedrock highs, dolerite dykes, reactivated faults, palaeochannels and weathered surfaces beneath basalt flows. The following interpretative products were then produced as part of the project: Geology, Soils/Regolith, Water Resource Target maps and Salt Hazards maps. In conjunction with other data sets such as Digital Terrain Model and bore information, geophysical derived information assisted towards the understanding of hydrogeological processes and salinity development.

REGIONAL STUDIES (1)

An interpreted ~1240 km-diameter multi-ring structure, of possible impact origin, centred beneath the Deniliquin region, southeastern Australia

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Aeromagnetic and gravity signatures, and circumstantial geological evidence, are interpreted in terms of a late Lower Cambrian ~1240 km-diameter multi-ring structure centred 50 km northwest of Deniliquin, southeastern Australia, within pre-Lachlan Fold Belt basement.

Magnetic basement 2-4 km deep and bodies 11-12 km-deep define the 220 km-diameter "Deniliquin structure" which includes a central 17 km-deep high-density magnetic body. A circular de-magnetised zone and relicts of a gravity low surround this centre. Low seismic velocities and gravity modelling suggest basement fracturing.

Gravity lows due to troughs of later sediments, and overlapping magnetic anomalies, as well as arcuate features beneath the Adelaide Fold Belt suggest a multi-ring structure. Ring locations have ~Ö2 spacings. Younger rocks obscure the eastern multi-ring but basement ring patterns are inherited into their trends. Some later faults are tangential.

Narrow de-magnetised zones, narrow zones of later turbidite-hosted vein quartz-Au deposits, locations of depocentres, magnetic bodies and rare alkaline igneous rocks all suggest the existence of related radial fault zones ("master faults") which extend to distances of 950 km within the basement. Deep reflection seismic profiling can locate them.

It is suggested that the Deniliquin structure originated beneath sea, causing the main event in the Delamerian Orogeny at ~514 Ma but prior to emplacement of allochthonous mafic-ultramafic masses older than 513 Ma. At this time, there is no known faunal passage from confirmed Early into Middle Cambrian strata. It is suggested the event also triggered ~30 Ma of igneous activity and tectonism in southeast Gondwanaland and possibly at its antipode.

Though unproven, a large meteorite impact is the most likely origin for the Deniliquin structure. Entry of seawater into the hot central cavity may have caused rapid expulsion of mantle-derived mafic-ultramafic "allochthons" over Victoria, Tasmania and other places, the first event in the Lachlan Fold Belt and comparable elements in Tasmania.

Bathymetry, sediment thickness and crustal structure from satellite derived gravity

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Analysis of satellite gravity data offers an opportunity to rapidly evaluate the sedimentary structure of frontier basins. The accurate and evenly distributed gravity determined from satellite orbits contains information about the bathymetry, sediment thickness and crustal structure of the world's oceans. It has been used by various authors to extrapolate bathymetry from depths measured along ships tracks to areas with no bathymetric readings. This work was pioneered by Sandwell and Smith (1994) who inverted the satellite-derived gravity to obtain pseudo-bathymetry. This predicted bathymetry was then compared with the measured bathymetry and the results modified to allow for variations in the sedimentary and crustal thicknesses.

The method presented here varies from the previous techniques. Water, sediment and crustal thicknesses determined from marine surveys are extended throughout the study area by solving equations to invert the gravity data. The seabed, basement and crust/mantle boundary are defined by a series of triangular facets. The sizes of the facets vary as the amount of available information changes. Hence, in areas with detailed bathymetric profiling the facets of the water bottom layer are smaller than those in areas where there is little or no previous bathymetric data. The facets defining the sediment/basement boundary and the base of the crust are defined by larger facets than those defining the bathymetry.

On its own the gravity information is insufficient to define the interfaces. Additional equations are formed from the depths determined from seismic and other data. The interfaces are also constrained by conditioning equations that smooth the interfaces and make the depths tend towards the input values. Other constraints ensure that the interfaces don't intersect each other. The degree of influence of these various constraints are set by a priori weighting factors. A degree of ambiguity between long wavelength shallow structures and short wavelength deeper features inevitably remains in unconstrained areas.

Interpretation of the crustal structure between the Ashburton Trough and the Hamersley Basin from gravity and magnetic data in the Wyloo region, Western Australia

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The crustal structure of the WNW-trending, central part of the margin between the Hamersley Basin and the Ashburton Trough near Paraburdoo in the northwest of Western Australia has been investigated previously using seismic refraction and gravity data obtained in the late 1970s and early 1980s. However, little work has been done on the NNW-trending western margin north of the Wyloo Dome. This area is the focus of a study using recently acquired gravity data over the Wyloo 1:250 000 map sheet area, incorporated with the regional aeromagnetic data and a newly established density database of the Hamersley Basin. Both the Hamersley Basin and the Ashburton Trough are clearly distinguished by their gravity and magnetic responses. Long wavelength magnetic anomalies over the Ashburton Trough indicate not only the presence of weak magnetic sequences but also, in some areas, possible mafic and ultramafic intrusions into the middle-lower crust. In contrast, the Hamersley Basin is characterized by short wavelength magnetic anomalies, from the banded iron formations, and associated local gravity anomalies. The regional decrease in the Bouguer gravity values, from +100 mm/s^2 in the south to about -500 mm/s^2 in the north, implies an increase in crustal thickness from the Ashburton Trough to the Hamersley Basin. Based on a statistical relationship between known Moho depths and the gravity field in the central and eastern parts of the margin, it is inferred that the crustal thickness may be 28-30 km under the Ashburton Trough and 30-35 km under the Hamersley Basin. This interpretation is supported by a model of the crustal structure in the Wyloo region derived from forward modelling of the gravity and magnetic data.

ELECTRICAL/EM CASE STUDIES

High resolution gravity and EM grid surveys for mapping of firehole overburden hazards in open-cut brown coal deposits

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Fireholes in brown coal overburden are major excavation hazards and exist as irregular shaped depressions of clays up to 50 m deep within overburden averaging less than 20 m in thickness. Drilling alone has not proven satisfactory in delineating the fireholes, therefore since 1986, a series of geophysical surveys have been progressively carried out at Hazelwood Mine, Victoria for firehole mapping. The survey techniques used have been gravity and electromagnetic conductivity (EM 34) methods on high spatial resolution (20 m x 20 m) grids. Gravity and EM methods have proved most effective in delineating fireholes. Initially mathematically derived residual gravity qualitatively outlined the shape and approximate depth of fireholes and EM conductivity has indicated fireholes which are wholly or partially filled with geotechnically unstable soft lacustrine clays. High resolution magnetic and seismic reflection methods have also been trialed with limited success.

The combined Hazelwood Mine gravity and EM surveys now cover 5 km2 and comprise 12 305 gravity stations, 6551 EM stations and 508 bores to base of overburden. This dataset forms one of the largest high resolution gravity datasets available and illustrates the detail that can be extracted from such a survey. Residual gravity modelling (anomalies < 6 mm/s2), using all borehole control has improved the residual gravity anomaly integrity, over previous mathematical residual extraction approaches. It has also enabled derivation of a new overburden thickness model, for input into mine planning. Gravity modelling using all borehole data for control of the residual has also shown variations in overburden density related to the nature of the firehole infill material, complementing the EM information. Ground subsidence and overburden dumping effects were issues that were addressed in the modelling and interpretation.

Large fixed loop airborne EM surveys in the equatorial, arid, and polar regions of the earth-case studies.

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Between 1993 and 1997, a number of airborne fixed transmitter loop EM surveys have been carried out in Australia, Papua New Guinea, Indonesia, and Alaska. Some of these have been experimental and others have been of a commercial nature. This paper describes the development of the airborne EM system and experimental surveys completed in 1993. The paper continues on to the describe the results of later surveys completed in 1994 through to 1997. Results are presented from surveys over Woodchester, and Maronan, in Australia, Frieda River in PNG, Wetar Island in Indonesia, and Delta Junction in Alaska. It is the objective of this paper to highlight the results obtained from the various surveys, and not the commercial aspects of the system used.

Geophysical responses over the Mount Ararat Prospect

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The Mount Ararat Prospect is hosted in Cambrian greenstones in western Victoria. Early exploration showed excellent correlation between the soil geochemical copper peaks with electromagnetic anomalies (EM) over a gossan. Follow-up drilling resulted in discovery of the Mount Ararat Prospect by Pennzoil in 1975. Massive banded and disseminated chalcopyrite-pyrrhotite-sphalerite mineralisation occurs in mafic and pelitic schists. The deposit is uneconomic, with an inferred resource of approximately 1 Mt with grades of 2.7% copper, 10 g/t silver and 0.6 g/t gold. Chalcocite is common in a zone of supergene enrichment.

Geophysical surveys, including airborne EM (INPUT) survey, vertical-loop EM, ground magnetic surveys, magnetic induced polarisation, induced polarisation and rapid magnetic induced polarisation RRMIP, were used to delineate the extent of mineralisation. The INPUT survey and gradient-array induced polarisation results were disappointing due to a very conductive surface layer. Magnetic induced polarisation surveys were effective in delineating an anomalous conductive zone corresponding to the mineralisation. Negative transient voltages in a SIROTEM survey were recorded over the mineralised zone in the later channels. The early time EM data is affected by a highly conductive near surface layer.

Downhole resistivity and IP logs show the mineralised zone has coincident chargeability and resisitivity responses but the chargeability response is broader and more extensive indicating a possible disseminated pyrite halo in a broader zone around the massive sulphides.

The magnetic responses associated with the deposit are caused by the host rocks, and are not a direct response from the mineralisation. These units remain prospective along strike for base metals and gold.

MIGRATION (1)

The use of Horizon Velocity Analysis in optimising static control and the resulting implications for Depth Migration

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Contemporary land seismic data is generally recorded with a number of deep upholes which are used to provide initial static control. Very often this control is taken as absolute with ensuing residual static profiles being tied back to zero at the uphole locations. Field experiments with upholes have suggested errors of the order of at least 3 ms. While residual static errors of this magnitude generally have minimal effect on the quality of stacked time sections, they can have profound effects on the accuracy of depth migration. Trials using synthetic data indicate the importance of commencing depth migration with accurate near-surface static corrections. Recent depth migration work suggests that Horizon Velocity Analysis (HVA) is a valuable tool in identifying and assessing uphole static errors. The method proposed is to run HVAs along a number of interpreted horizons as part of the processing sequence and to smooth the results prior to running surface-consistent residual statics. The results include uphole error estimates and these are left untied. In a real data example, depth processing was performed over a grid of lines both with this method and with the more conventional approach. The results show better agreement in the derived depth models with the HVA method. Not all land data has accompanying deep uphole information. Additional ideas are presented as to how static computation may be optimised in this situation so that later depth imaging may be more accurate.

Travel-time computations for true amplitude migration of constant-offset seismic data

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Accurate travel times are essential for three-dimensional imaging. This is particularly true when the obliquity factor in the Kirchhoff integral is designed to preserve the amplitude of the wavelet. The required attributes involve partial derivatives of the travel-time function, and thus are extremely sensitive to travel-time errors. This paper describes an approach to computing travel times and their derivatives with high accuracy. It is based on a ray tracing method in which ray paths and travel times are computed using exact analytical formulas. The velocity function is defined on a 3-D Cartesian grid and treated as a system of discrete cubic cells, each with a constant velocity gradient. Rays enter and exit at cell boundaries. Within such a cell the ray path is a circular segment. Rays are traced through a sequence of cells and, consequently, the entire ray path becomes a contiguous set of circular segments or straight lines. It is demonstrated that travel times along a circular segment can be computed from an exact analytical formula. As a result, travel time errors are limited to a fraction of a millisecond. This order of precision facilitates the estimation of geometrical spreading by monitoring the behaviour of a beam composed of three rays with take off at angles differing by only a fraction of a degree. The effectiveness of this approach to computing travel times, ray paths and geometrical spreading is demonstrated on velocity models in which these attributes can also be computed analytically, and thus be used to estimate the accuracy of the proposed method.

Seismic migration in near-vertical and wide-angle reflection and refraction studies: Towards a unified approach

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Conventional deep reflection profiles usually image upper to middle crustal levels quite well. The ability of this methodology to image the lower crust and transition to the mantle is often limited. We have made a step forward in developing a methodology for processing, interpreting and presenting near-vertical reflection, wide-angle reflection and refraction seismic data and velocity information derived from the three data sets within a unified approach. The key elements of this approach are: pre-stack depth migration of wide-angle reflection and refraction data; wave field analysis of the refraction and wide-angle reflection data prior to and after depth migration; unified analysis and presentation of seismic velocity information. For the finite-difference continuation of the wave field we use a special oblique time-spatial grid. The time field calculation is based upon a finite-difference approximation of the eikonal equation and the grid used in this task is curvilinear. The coordinate lines are based on ray paths and wavefronts in the medium. Such a grid is particularly effective at large offsets. The overall configuration of the oblique grid used for the downward continuation of the time field is determined for the domain where the solution of the eikonal equation exists. The initial conditions are defined by the recorded travel times. We demonstrate how this approach works on an example from the Petrel sub-basin where conventional CDP (near-vertical reflection) data were supplemented by the wide-angle reflection and refraction data recorded by ocean-bottom seismographs. Depth migration of refraction/wide-angle seismic data presents them in the same style as the conventional reflection data thus radically enhancing the seismic image of the lower crust where the CDP data lacks detail.

Pre-stack depth migration of seismic multiples

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Seismic multiples still present a major impediment to exploration on the North West Shelf of Western Australia. Considerable effort is being expended on the removal of multiple events from the seismic record to improve the quality of the image of the subsurface, hence reducing the risk of drilling dry holes. Most of the published multiple attenuation techniques to date are based on the premise that multiples are noise and hence need to be removed. The technique presented in this paper is based on the assumption that multiples are signal, and that image quality will be enhanced by assigning their energies to the appropriate place in the final migrated section. A new procedure has been developed for the pre-stack depth migration (PSDM) of seismic multiples which correctly images both primary and multiple energy to give a depth section without visible multiples. The three key processes in the PSDM process are the determination of a suitable velocity model, a method for the computation of travel-times, and a method of mapping seismic shot record data to the final output depth section. The velocity model in the new procedure can include horizontal, dipping planar, and irregular boundaries. Travel-time mapping is achieved by implementing Huygen's principle (Podvin and Lecomte, 1991) while also incorporating the curved wavefront approach of Schneider et al. (1992). By extending the work of Zhao (1996), reflections are modelled using the generalised exploding reflector model (Lambert, 1996) which was used by Manuel (1998) for modelling multiple reflections. This technique is capable of handling large velocity contrasts in structures with irregular boundaries. Zhao et al. (1998) showed how to map first and later arrivals arising from different travel paths in the subsurface. This new procedure treats primary and multiple events as first and later arrivals respectively, and maps them to the final depth section. Examples based on synthetically modelled data show that significant multiple content can be removed by using this new migration technique. The velocity models used for these examples are reasonably complex which enables the new technique to be tested quite rigorously. In most, if not all, depth migration procedures the resultant image quality is dependent on an accurate velocity model. A slightly inaccurate velocity model was used with the new procedure which still resulted in a reasonably accurate depth migrated section.

DRYLAND SALINITY AND FARM PLANNING (2)

The application of the TEMPEST broad-band AEM system for land management in landscapes characterised by a thick, very conductive, regolith

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Lake Toolibin, located some 250 km SE of Perth in the wheatbelt of WA, is a recognised RAMSAR wetland currently threatened by rising groundwater and increased salinity. These problems, accompanied by rapidly expanding salinity within the Lake Toolibin recovery catchment, prompted an investigation into the potential of new airborne geophysical technologies as tools for providing information relevant to its management. A SALTMAP AEM survey of the lower part of the catchment highlighted some constraints associated with high base frequency (495 Hz) systems when trying to fully characterise the conductivity structure of environments exhibiting high conductances. In the lower catchment, drilling indicated the presence of a thick, very conductive regolith comprising both in-situ saprolite and palaeochannel sediments. These materials occupy a significant proportion of the lower catchment and, where present, their conductances limit the quantitative interpretation of inverted SALTMAP data. In mid-'98, the lower part of the Toolibin catchment was flown by the TEMPEST AEM system - a broad-band, low base frequency (25 Hz), time-domain EM system. This paper discusses its potential for quantifying conductivity structure in areas of high conductance. A 1D layered earth inversion of the TEMPEST data yields a good approximation to the conductivity structure defined from borehole conductivity logs and ground EM data. In contrast to the SALTMAP data, for areas where conductances are in excess of 10 S, the observed spatial patterns provide a more reliable indication of variations regolith thickness and conductivity. The TEMPEST data suggest that areas with the highest conductances, largely confined to the valleys, are constrained in part by the geology (particularly dykes) and structure. This is effectively demonstrated through a combination of the airborne magnetics and a series of interval conductivities, the latter showing a change in average conductivity with depth. This compartmentalisation is likely to reflect a complex interaction between lithology, structure, groundwater flow and processes of deep weathering. In the near surface transported materials, contrasts in the observed conductivity structure indicate significant variations in the hydraulic conductivity of palaeochannel sediments, a feature also noted in the SALTMAP data.

Utilising the DIGHEM Helicopter-borne EM / Magnetic / Radiometric system for salinity and water resource mapping in the Chapman Valley, WA

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A helicopter-borne electromagnetic / magnetic / radiometric (DIGHEMV) survey comprising 2170 line-km of data was carried out over the Chapman Valley, near Geraldton, WA in October 1997 as part of the National Dryland Salinity Program. The purpose was to evaluate the usefulness of airborne geophysical surveys, particularly EM, in determining the three dimensional variability of saline or fresh groundwater in the regolith. The survey collected five frequencies of EM, 256 channels of radiometric data, high sensitivity magnetic data and terrain data simultaneously. A number of data presentation methods were used to display the three-dimensional results from the EM data. These included conductivity maps overlain on air photographs and Sengpiel Conductivity-Depth Sections. Two methods of interpreting the data were utilised. The first used semi-automated techniques based on textbook models of salinity development, utilising EM, radiometric and soil data, topography, magnetic structural data, and drainage patterns resulting in a derived "Salinity Hazard and Groundwater Resource" map. The second method involving interpretation by local research personnel treated individual focus areas on a case by case basis. The second method led to more valuable and applicable results.

Airborne radiometric and magnetic data contributes to the mapping and understanding of soil: Lake Toolibin and Chapman Valley case studies

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Conventional soil mapping relies on air photo interpretation to extrapolate field experience, but information embedded in the photos (usually colour 1:25 000) varies enormously depending on time of acquisition and land usage. Further more, most mapping in Western Australia has been at a reconnaissance level and so map units often embrace large areas with considerable variability. Consequently it is difficult to retrieve, quantify and test knowledge inputs. Airborne radiometric data, on the other hand, provides something like a million times less data per unit area of land than the usual photography. However the information is accurately geo-referenced, uncorrupted by vegetative cover and is therefore much easier to manipulate and interpret. Field experience in the Toolibin catchment, and a desk-top analysis of similar data for the Chapman Valley area, shows that a great deal of soil information, at paddock scales, can be extracted when radiometric pixels are associated with landscape and geological setting. The potential for automated rule-based mapping of soil properties grows as evidence for setting is extracted from soil landscape and geological maps and classifications of magnetic and elevation data. Factors limiting automated rule-based mapping include:

- Inadequate elevation data.
- Clustering of soil properties at spatial scales smaller than radiometric pixels
- Inadequate rules

Some rules, appropriate to particular settings, are already obvious, others will require a better understanding of geomorphology and pedogenisis. Indeed, radiometric and magnetic data help to provide such insights.

EM INTERPRETATION (1)

Imaging and identification of thick electrical conductors using conductance and differential conductivity parasections of TEM data

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Moving-loop TEM data can be transformed to an approximate depth image (parasection) using a range of 1D algorithms. The SPIKER algorithm for computing conductivity-depth images (parasections) from profiles of in-loop time-domain EM data is extended to provide differential conductivity vs depth, and integrated conductance vs depth. Optimal imaging of deep conductors, especially if under conductive overburden, is achieved by use of 2D filters on the EM data prior to transformation, and by imaging of the conductance parameter. Modelling studies of thick conductors such as paleochannels under transported cover, and weakly-conducting alteration zones within basement, demonstrate how parasections improve ability to interpret such geology, and also provide cautionary examples of apparent conductivity artefacts generated in the parasections by the edges of conductive bodies.

Analytical computation of EM field components in a uniform half-space

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Analytical expressions for the electromagnetic field components at an arbitrary location in a half-space are presented for a vertical magnetic dipole source on the surface of the earth. The Hankel transforms required in the computation are enumerated using expressions based on the modified Bessel functions of the first and second kind. For surface electromagnetic fields, the Bessel function expressions are shown to consistently produce results that are up to four orders of magnitude more accurate than the results commonly obtained using digital filters. In addition, initial speed tests reveal that considerable computational time is saved compared with the use of numerical routines based on digital filters. It is expected that the increased speed and accuracy of the analytical solution will find application in forward modelling and inversion routines where a half-space is considered to be a suitable model and Hankel transforms need to evaluated many times.

Airborne bathymetry via inversion of electromagnetic frequency soundings and conductivity depth imaging using "EM Flow"

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This study examines the application of airborne electromagnetic (AEM) methodologies to determine bathymetry in shallow seawater. Conductivity sections have been generated from a recent helicopter-borne DIGHEMV survey (operating vertical coaxial and horizontal coplanar transmitter-receiver coil geometries) of lower Port Jackson, Sydney Harbour. The sea depth ranges from about 1 to 30 m. Acoustic bathymetric soundings and marine seismic survey provide the true seawater layer thickness and depth to bedrock over most of the EM survey region. This complimentary data can be used to evaluate the accuracy of airborne electromagnetic bathymetry and the efficacy of inverted 1D conductivity sections and rapid EM interpretation schemes such as EM Flow for obtaining conductivity-depth images for shallow seawater overlaying marine sand sediments and sandstone. For 1D inverted conductivity sections, the seafloor sediment thickness was also constrained by marine seismic data. The inversion constructs layered conductivities which satisfy the AEM data to an accuracy consistent with the observational uncertainties. Inverted frequencies ranged from 328 to 55 300 Hz. Resolution of the sea depth was only fair when inversion was unconstrained. However, an accuracy of ~10% of depth was achieved when sea water and seafloor conductivity were specified a priori. Differences and similarities between stitched 1D inversions and approximate conductivity-depth images derived from "EM Flow" are well illustrated by this dataset.

RESERVOIR GEOPHYSICS (2)

Delineation of reservoir boundary using AVO analysis

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Keutapang Formation is a group of sedimentary rocks consisting of sandstone with shale intercalation. It was deposited in the coastal environment during Middle Miocene age in the north Sumatra Basin. The thickness of the formation is in range of 500-1300 m.

In the sandstone reservoir, hydrocarbons were trapped within the porous zone. In this rock formation the top of the porous zone could be identified as the source of AVO anomaly. By applying Shuey's (1985) equation to the AVO anomaly parameters of velocity of P wave Vp, ΔVp (velocity contrast of two layers), ρ (density), $\Delta\rho$ (density difference of two layers) and σ can be estimated by the Marquardt inversion.

The relationship between ρ and Vρ for water-filled sand shale sequences is explained by Gardner et al. (1974) equation. The difference between the derivative and the equation itself is defined as the fluid factor.

Application of the fluid factor to the field where Keutapang sandstone located gives a significant change in values. These changes also shown by the value of P wave velocity and density for each CDP location. The prospective reservoir is located in the area of high value compared to the surrounding area.

Borehole data in the area shows the comformable result to the predicted zone, therefor the method has given a satisfactory result in estimating the zone of interest for further delineation of reservoir boundary.

Using multi-attribute transforms to predict log properties from seismic data

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In this paper, a new method for predicting well log properties from seismic data is described. The analysis data consists of a series of target logs from wells which tie a 3-D seismic volume. The objective is to derive a multi-attribute transform, linear or non-linear, between a subset of the attributes and the target log values. The selected subset is determined by a process of forward step-wise regression, which derives increasingly larger subsets of attributes. In the linear mode, the transform consists of a series of weights, which are derived by least-squares minimisation. In the non-linear mode, an artificial neural network is used. Cross-validation is used to estimate the reliability of the derived multi-attribute transform.

This method is applied to a real data set. We see a continuous improvement in prediction power as we progress from single-attribute regression to linear multi-attribute prediction to neural network prediction. This improvement is evident not only on the training data, but more importantly, on the validation data. In addition, the neural network shows a significant improvement in resolution over that from linear regression.

The effect of low velocity channel lenses on amplitudes, imaging and depth conversion

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A number of Tertiary channels with anomalous velocities have been identified from seismic data acquired on the northwest shelf of Western Australia. The presence of these channels has several important implications to the explorationist. Seismic reflections beneath these channels typically show time sags and amplitude striping (due to earth lenses), as well being poorly imaged (when stacking velocities are interpolated across the channels). An examination of isovelocity profiles from closely spaced velocity analyses shows that good stacking velocities are generally anticorrelated with lateral changes in average velocity. This is due to the widths of the channels (500-1000 m) being less than a spread length. In the case of channels that have anomalously low velocities, the stacking velocities can be up to 200 m/s or 6-7% faster below the channels than they are in velocity profiles outside of the channels. This is inverse to the average velocity decrease of 1% due to channel fill, and as such has important implications for the depth conversion process. The presence of reflection amplitude fluctuations, by factors of 2 to 4 fold on near offset traces, corresponds to fluctuations seen in downgoing waves in nearby walkaway VSP's. In addition, the correlation of high downgoing wave amplitudes with relative delays in arrival times indicates that high amplitude striping may be due to low velocity earth lens effects rather than reverberation. The correction of such events will probably require estimation of small lateral changes in the 3D velocity field with accuracy not available today. This paper will address the effect that high frequency isovelocity curvature has on the seismic response, and the implications these have on the processing and interpretation sequence. Examples of steps taken to address these issues will be given; including decreasing the velocity sampling interval, the use of Pre-stack Depth Migration to improve imaging, and the importance of editing and smoothing in the creation of a regional velocity field for depth conversion.

New plays in the Browse Basin - NW Australia

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The outer NW Browse basin has been explored for some time, but with only modest returns. More recent discoveries at Cornea and Gwydion in the inner Browse basin region have helped dispell the gas prone concerns and the new Gazette areas are being closely examined for new application potential.

The Veritas data set shows a wide variety of potential play styles, together with frequent DHI features. Our poster paper shows the main structural elements and plays styles seen in the region together with a number of seismic examples of exciting looking leads that may contain the regions next Giant Oilfield.

DRYLAND SALINITY AND FARM PLANNING (3)

Parna petrophysics- implications for its detection using airborne geophysics and their potential application for land management in western NSW

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Parna, comprising an aeolian sediment of clay size, forms a significant component of the regolith developed in the Lachaln Fold Belt of western NSW. These materials blanket parts of the contemporary landscape and, in places, they form surficial deposits in excess of 8 m thick. Parna has significance both from an exploration and land management perspective. Recent studies have suggested that parna constitutes a significant store and source of soluble salts. This paper describes the mineralogical and petrophysical characteristics of parna, making specific reference to materials adjacent to the type section at Marinna, near Junee, which is located in the Murrumbidgee catchment. Rising water tables and dryland salinity have been identified as major concerns to the overall health of this catchment. Therefore information on the distribution and movement of salt within the upper reaches of this catchment is important, as is the role of parna in controlling these dynamics. Results from multiparameter borehole geophysical studies indicate that parna is characterised by sub-horizontal variations in conductivity and natural gamma. These properties are attributed to contrasts in the porosity and permeability of these materials and to variations in their composition. Significant vertical conductivity contrasts have been noted between parna and underlying saprolite, with the results from EC1:5 measurements and downhole induction logs suggesting that conductivity is controlled by the soluble salt content of these materials. Ground EM surveys (EM 31) suggest that areas covered by parna may exhibit marked lateral variations in average conductivity, but that such variations are attributable to differences in the thickness and conductivity of those materials. Where relatively thick accumulations of parna occur, we might expect to map its distribution with an airborne EM system. TEMPEST AEM data from an area around Junee are currently being investigated to ascertain whether the distribution of significant accumulations of parna could be determined. The radiometric response of these materials is also considered.

Interpretation of geophysics for salt hazard identification and watershed management, Western Australian case studies

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A 'salt hazard' is an area where factors may act to produce a discharge of saline water causing a scald at the surface. The factors related to the salt stored beneath the surface, a source of water, an increase in recharge and an impedance to groundwater flow. The factors used to identify these areas were based on a standard rule of identifying changes in transmissivity particularly of the regolith or near surface geology. The process of salt hazard identification involved setting up models of salinity and then identifying areas based on the models, using geophysical and other data sets. In regions with little available data, the acquisition of airborne geophysics provided accurate data at high resolutions over a relatively short period of time across many catchments. The geophysical data was used to gain an understanding of hydrogeological processes in order to identify areas of potential discharge. The magnetics in conjunction with the electromagnetics was used to map geological and regolith structures important to groundwater movement, such as dolerite dykes and reactivated faults. The radiometrics in conjunction with the topography was used to gain understanding of soil properties and surface water movement. Sandplain seeps were identified from the use of radiometrics. The use of 'salt hazard' maps provided farmers and farm planners with a map of likely discharge points and causes. The salt hazards were an intermediate step that lead towards a targeted farm plan. This enabled existing and potential saline areas to be addressed, so that the water shed management design and implementation was more effective. Case studies across the wheatbelt of Western Australia include Trayning, Wyalkatchem, Moora and Toolibin.

The National Airborne Geophysics Project (1997-1999)

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In late 1996 the National Dryland Salinity Program, Agriculture Fisheries and Forestry Australia (AFFA), AGSO and other States (WA, NSW, QLD and VIC) and Federal agencies became involved in a National Project assessing the role of airborne geophysics for farm and catchment planning. Five Catchments were selected within Australia, Balfes Creek (QLD), Liverpool Plains (NSW), Willaura (Vic), Toolibin and Chapman Valley (WA). The SALTMAP system of World Geoscience was flown in Balfes Creek, Willaura and Toolibin, while the helicopter mounted Geoterrex-DIGHEM system was flown at Chapman and Liverpool Plains. Magnetics and radiometrics were also acquired.

Twenty six conclusions and nine recommendations are contained within the National report. Further conclusions and recommendations are contained within the Toolibin and Chapman Valley Reports. The dot points below paraphrase some of the more important conclusions.

- Airborne data is complex and requires significant interpretation to enable widespread community use,
- Airborne geophysical data can be correlated with many of the relevant physical properties of the catchments, especially in wheatbelt terrain,
- Airborne geophysics significantly improves our knowledge and understanding of catchments - soils, geology, salt store, groundwater systems and salinity risk. However, it does not accurately map salinity near the soil surface.
- Airborne geophysics is best used in conjunction with a series of other datasets including digital elevation models, aerial photography and information about watertable depth and quality to ensure optimal farm and catchment planning.
- Airborne geophysical data helps government agencies and consultants provide relevant advice at a farm and paddock scale which is not currently possible due to the regional nature of currently available datasets,
- Airborne geophysics may be cost-effective, especially in areas where detailed management plans are being developed. Cost of data acquisition and interpretation depends on the size of the area surveyed (the larger the area the cheaper per unit) and the line spacing of the survey (cost increases with tighter line spacing). Indicative costs are $3 - $7/ha.

NEW METHODS

Underground tests of the high frequency seismoelectric method at the Lynx Mine, Canada

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Field trials of a Soviet inspired seismoelectric method at an underground zinc mine in BC, Canada, have demonstrated its effectiveness and confirmed some of the claims by the inventors of the method. The deposit investigated is a massive sulphide orebody principally made up of sphalerite, grading about 15% Zn in the area investigated. This deposit is a difficult target for standard geophysical techniques as it is virtually indistinguishable from the andesite/rhyolite host rock to these methods. However, we were able to demonstrate that the massive sulphide ore produces high frequency electromagnetic emissions when a strong seismic wave passes through the orebody.

An explosive seismic source (less than 1 kg) and wide bandwidth, 1-5000 kHz, EM sensors connected to a computer data acquisition system were used to produce and collect the seismoelectric signals. Our experiments show that there was a substantial increase in high frequency EM activity when seismic waves passed through the orebody. Thus, EM signal arrival time and shot point location could be used to locate the source of the EM signals. To demonstrate this capability shotpoints were placed around a known portion of the orebody in order to image the extent of the ore zones. A two dimensional image of the zones creating the EM signals was constructed from data gathered at 14 shot positions. The location and extent of a large anomaly in the image corresponds well with the drill-inferred position of the orebody. Another smaller anomaly appears to be coincident with the known location of a pillar of ore left behind by previous mining.

A new Australian airborne gravity system

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In June 1997, Australian Geophysical Surveys commenced a research an development project to build an airborne gravity system. The initial project target was to achieve a 1 milligal measurement accuracy whilst in a hovering helicopter.

By February 1999, this project target was achieved, and in May 1999 it was decided to expand the project target to enable measurement of gravity from moving airborne platform, preferably a fixed wing aircraft, whilst maintaining the same 10 mm/s2 accuracy.

System test procedures are explained and test flight results of the prototype are reviewed.

The effectiveness of the system in detecting both mineral and petroleum exploration targets is evaluated using modelling software.

Alternative airborne gravity systems are reviewed, with the latest open file information being summarised.

Maximum noise fraction method reveals detail in aerial gamma-ray surveys

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Low-noise images of the U/Th ratio can be obtained from aerial gamma-ray survey data by using the maximum noise fraction (MNF) method, which applies statistical linear algebra operators to most of the 256 channel raw spectral data of a survey. With reduced noise, U/Th data may be better used to map geological variations and explore for minerals such as U, Th and Sn. Data from a small (120 line-km) survey in north Queensland are used to demonstrate the method and confirm the reliability of the detail in the U/Th map. The map is compared with those derived using conventional processing methods and using noise adjusted singular value decomposition (NASVD). Statistical tests of selected areas and profile displays show all methods produce similar U/Th ratios on a broad scale, but only the MNF method enables small-scale features to be identified. A small dam in the study area, which being water-filled has low count-rates, gives anomalously high U/Th ratios. This dam is seen in the conventionally processed U/Th image as a small area of high ratios, is difficult to see in the NASVD image, but is shown with its correct size and shape in the MNF image.

The development of non-contacting electric field sensors for IP measurements

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There a number of commercially available non-contacting electrode systems in use for resistivity. These systems are designed to work in arid or rigid (concrete/tarmac) areas where ground contact is a problem These devices all operate at a very high frequency (typically hundreds of kiloHertz) to ensure that capacitive coupling to ground is large. In a research project at Macquarie University with support from AMIRA P460 and the Collaborative research Program of the ARC, we investigated whether it was possible to make electric field measurements with a non-contacting electrode at the low frequencies and long periods of conventional IP systems.

While calculations showed that the calculated capacitance-to-ground of a 1m2 electrode was sufficient to make signal measurements provided that a pre-amplifier with an input impedance of the order of 100 GW could be built. This was easily achieved, and signals from an IP transmitter easily detected. However, the expected signal was swamped by noise in much of the observed data.

The key to developments of a successful capacitive electrode lay in suggestions from Yves Lamontagne and Gordon West that active guarding was required to the sensor shield and its attached preamplifier from signals of atmospheric origin. These signals include wind blown charge (carried on dust and other microscopic particles); and variations in the strong (typically 100 V/m) earth to ionosphere electric field. With complete shielding/guarding protection of a small capacitive electrode, we were able to make excellent resistivity measurements and limited IP measurements using a conventional IP transmitter and sensors insulated from the ground.

The main problem affecting successful IP measurements was temperature drift of the electronic preamplifiers. In most instrumentation the electronics is contained in one enclosed location and at the same temperature and balancing between each half of a preamplifier can be achieved over a wide temperature range. The distributed halves of a preamplifier located at each electrode are often at very different temperatures (for example if one is in the sun and the other in the shade). Further research to minimise this remaining source of noise would be needed before routine IP measurements could be made with non-contacting electrodes.

EM INTERPRETATION (2)

The effect of magnetic anomalies on transient electromagnetic data

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The effect of magnetically polarisable material on transient electromagnetic responses is discussed using data calculated for a layered-earth model and a sphere in free-space. Results from the layered-earth models indicate that step-response measurements with the UTEM system will be moderately affected by the magnetic permeability (m) of the surface layer for values above 1.1 times the free-space value (m0). Impulse response data recorded by the SIROTEM system are indicated to be fairly insensitive to high magnetic permeability values. Although QUESTEM on-time data are affected by magnetic induction, effects are likely to be confused with the much stronger primary-field response. Singular value decomposition analysis of layered-earth and sphere responses shows TEMPEST data to be sensitive to magnetic permeability variations exceeding 0.2 m0, but only for sizeable structures.

TEMPEST data acquired crossing a banded iron formation related magnetic anomaly of 8 000 nT were found to be devoid of any indication of magnetic induction. The anomaly was modelled with a dike-shaped polygon with a magnetic permeability of 2.0 m0. The absence of any corresponding anomaly in the TEM data suggests a high proportion of remanent magnetism or susceptibility anisotropy. The electromagnetic responses caused by dragging the receiver coils through the associated magnetic gradient is removed by the stacking process, but is retrievable from the streamed data.

IDM Solver for 3-D modelling of electromagnetic field

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The Iterative Dissipative Method (IDM) is based on a special property of the Green's function of the electromagnetic field. It was shown by Fainberg & Singer (1980) that the iterative-perturbation process applied to an integral equation for the electric current can always be made convergent. An introduction of a modified Green's function significantly improves contraction properties of the equation kernel and accelerates convergence of the iterative sequence. The corresponding integral equation was derived by one of the authors (1988) and became a basis for the Modified IDM (MIDM).

The MIDM can be used for calculation of the electromagnetic field with the only restriction that the geoelectric inhomogeneities are located in the energy dissipating environment. The frequency range, anisotropy, external sources, and other parameters of the electromagnetic problem do not restrict application of the MIDM.

On a finite numerical grid, the integral equation is reduced to a system of linear equations. For a numerical algorithm to be robust, the system should be preserve the contraction properties of the continuous equation. We show that a numerically robust algorithm can be developed using a projection technique. A practical implementation of the approach requires integration of the Green's function over "source" and "receiver" cells. An algorithm of quadruple horizontal integration was previously developed and used in a number of thin sheet IDM codes.

We have developed a 3-D solver based on the MIDM combined with the projection techniques. Testing shows that the MIDM iterative sequence converges at the theoretically predicted rate. In particular, the convergence rate does not depend on the numerical grid used for computation.

Efficient solution of full domain 3D electromagnetic modelling problems

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Electromagnetic modelling of 3D conductive targets using staggered grids results in matrix systems that are severely ill conditioned and unsuitable for many iterative solvers. Either a minimal residual solver, MINRES, or a restarted biconjugate gradient stabilised solver, BiCGSTAB(l), can be used to bring the solution to convergence. The BiCGSTAB(l), method, combining the bi-conjugate gradient method with a restarted minimal residual correction, is very efficient in solving the matrix system arising in our applications. To speed up the solver further we employ various preconditioning techniques. The use of a symmetric Jacobian preconditioner greatly improves the convergence of the MINRES method. In homogeneous regions where the divergence of the electric field is zero the Maxwell equations reduce to vector Helmholtz equations with decoupled components. These Helmholtz equations can be readily approximated by central differences, resulting in diagonally dominant matrices that can be used as preconditioners for the original curl curl equation of the staggered grid. The diagonals of the Helmholtz equation can also be used as a Jacobian preconditioner, which is superior to Jacobian preconditioning using the diagonal elements of the original curl curl equation. Numerical results have demonstrated the efficiency of these approaches.

3D VSP survey design, data processing and interpretation

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3D VSP data quality and success rate can be significantly improved by pre-job survey designing. Modeling methods such as reflectivity methods, ray-tracing methods and finite difference/element methods are useful tools in understanding the relationship between the acquisition geometry and the acquired data. By comparing modeling results of various source-receiver configurations, an optimal borehole seismic survey geometry can be obtained.

The source-receiver configuration of a borehole seismic survey is very different from that of a surface seismic survey. Unlike the surface seismic data, borehole seismic data contain both the downgoing and upgoing compressional and shear waves. Various methodologies, e.g. multi-component processing techniques, have been developed to separate and enhance these different waves. Depending on the objectives of a borehole seismic survey, the separated wavefields undergo further processing.

Borehole seismic data provide a unique opportunity of measuring the far-field source signature and calibrating the surface seismic data from time to depth domain. Borehole seismic data in general have more high-frequency contents than surface seismic data and can yield higher resolution imaging of the subsurface structures. With an appropriate survey design, AVO and anisotropy effects can be directly quantified.

SEISMIC SURVEY DESIGN

Implications of marine seismic survey design on acquisition efficiency

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The efficiency of an open water marine 3D survey is a non-linear function of survey design parameters, and can vary by factors of 3 - 5 for a given survey area. To expedite selection of time and cost efficient survey parameters, a 3D/2D acquisition model has been developed, calibrated and utilised over the last 3 years. In addition to aiding survey design, the model can be used to (i) benchmark survey costs, (ii) evaluate acquisition tenders, (iii) evaluate the effectiveness of non-proprietary (multi-client/joint) surveys, and (iv) encourage efficient 2D/3D survey sizes.

The most important output of the model is a realistic estimate of the time required to acquire the survey data, given a survey design and a vessel's in-water capabilities. Generally, efficient designs will minimise vessel sail kilometres. The 3D model accommodates operational efficiency, relative cost and geophysical design parameters including survey size, maximum cross-line width, average in-line line length, acquisition direction, cross-line bin size, in-line shot spacing, maximum offset, number of sources and steamer length.

Design efficiencies are analysed by computing a survey efficiency factor for important parameters over sensible ranges. Operational parameter ranges must be calibrated to seasonal and area conditions, and documented capabilities. Rates are market-determined and available from a tendering process. Efficient survey parameters that fulfil target level in-line fold requirements will tend to (i) maximise the number of CDP lines per vessel pass, (ii) maximise average in-line line length and survey size, (iii) maximise acquisition cross-line bin width, (iv) utilise trace interpolation over trace acquisition, (v) minimise time between shots, and (vi) maximise streamer length.

This model has been used to select designs that take advantage of available technology and survey environment, whilst meeting data quality objectives.

Environmentally sensitive 3D land geophysical survey design - a case study

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This paper deals with the impact of geophysical parameters on the environment and suggests ways of reducing this impact. Specifically this paper deals with the design process of a land vibroseis 3D survey in Australia and analysis of 4 different geophysical designs which have been proposed to shoot this survey. The biggest factors in determining the environmental footprint of a seismic survey are determined by the source and receiver line spacing, fold and the size of the survey area. The size of the survey and the receiver and source line spacing are mainly determined by the geophysical objectives of the survey. The required fold is determined by a variety of issues including the geological sequence, the source to be used and ambient noise environment. In general, the deeper the target, the larger the survey and the wider the source and receiver lines can be spaced. The size of the survey is a combination of the image area combined with the migration aperture and \the fold aperture. The size of the survey was made optimal by data trials and by theoretical analysis. The source and receiver line spacing combined with the shooting methodology determine the fold at the target. Different shooting methodologies are discussed including two cross-swath geometries and two "conventional" geometries. Potential acquisition footprints were evaluated by forward modelling and observing the effects of different source and receiver patterns on synthetic frequency slices after NMO and DMO. The logistics of shooting the different geometries wore analysed and the environmental impact determined. As a result of the geophysical analysis an optimum survey size and source and receiver spacing could be. determined. Analysis of the environmental impact of the geophysical designs led to the selection of a "cross-swath" geometry. The cross-swath geometry reduces traffic within the prospect area. This means that less line preparation such as bulldozing and brush. cutting is required which reduces the environmental impact.

DRYLAND SALINITY AND FARM PLANNING (4)

The use of ground EM systems to accurately assess salt store and help define land management options for salinity management

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The ability to rapidly and accurately determine the vertical and spatial distribution in soil salinity at a farm or paddock scale is extremely important for land managers and researchers involved in managing land salination. Knowledge of current (shallow) soil salinity levels is required to make informed short-term management decisions as to what pasture, crop or tree species will be the most productive, or should be grown to minimise surface soil salination. Prognosis of future (deeper) salinity development is required for longer-term management. Hence, characteristics of regolith salt store and groundwater depth are essential information. The vertical distribution of salt throughout the regolith is also very important at the regional scale and for calibrating larger-scale airborne EM mapping systems.

Accurate site assessment using soil sampling and laboratory analysis is time consuming, expensive and can be highly variable because of large spatial variability compared with sample size and practical sampling density. Clearly, an accurate and efficient system of salinity mapping using portable ground-based geophysical instruments is required.

The Geonics EM38 and EM31 instruments have been routinely used to map soil salinity. Recently, automated, ground-based data acquisition and real-time mapping systems have been developed. In the past, most use has been made of the instruments' relative readings. However, continued calibration in variable terrain will allow for more practical and absolute use to be made of readings.

The Geonics EM34 and EM39 instruments have also been used to determine salinity profiles to depth; however, usually in experimental situations. They have the potential to replace deep drilling (EM34) and drill-sample assay (EM39), and have been used to evaluate airborne EM systems.

We have reviewed the use of the four Geonics instruments for salinity investigations and present over thirty calibrations with soil salinity from various terrains in southwestern Australia and compare them with calibrations from eastern Australia. We found that the instruments are reliable and the information they generate is reproducible. In all situations studied, salinity was the dominant contributor to EM response. However, soil type, moisture and temperature can have secondary contributions, which may be more important when EM is used to assess and predict plant response to salinity. We show that for practical purposes ground-based EM can be confidently used in salinity mapping.

Mineralogical and petrophysical properties of the regolith at Broomehill, WA - implications for mapping salinity using AEM data

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The regolith developed over the granite-gneiss terrains of southwestern Australa is recognised as a significant respository of soluble salts. The distribution of this salt and its mobilisation has significant implications for the management of dryland salinity in this region. Regolith materials developed over these granite-gneiss rocks are both varied and complex. They are commonly characterised by high porosities but relatively low permeabilities. However, at local scales, these characteristics exhibit marked variation both horizontally and vertically and are influenced by changes in mineralogy and structure. Variations in the nature and distribution of these materials impacts significantly on the distribution of salts in the landscape and, by implication, is likely to have a significant bearing on the observed response in AEM data.

In this study we examine factors controlling regolith conductivity structure in the Broomehill area, WA. By reference to drill core, and associated downhole and ground geophysical data sets we note that regolith electrical structures are controlled by a complex interaction between lithology, structure, regolith type and thickness, salt (mainly NaCl) content and distribution, water content and hydraulic conductivity. Stitched 1D layered earth inversions of SALTMAP AEM data produce a coherent set of conductivity maps for the study area. This suggests that 1D inversions do not constrain the identification of lateral changes in the gross conductivity structure. However, in areas of very high conductance, a few problems resulting from a limited system bandwidth were identified. Whilst general associations are apparent from the AEM data, for example valleys being associated with a thicker, more conductive, regolith profiles, similar relationships can be observed with more localised EM anomalies in other parts of the landscape. These results suggest that care be taken when interpreting AEM data when from a land management perspective.

IP/DC RESISTIVITY

The 2D smooth model inversion applied to dipole-dipole IP/resistivity data

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The results of an IP/Resistivity survey using a dipole-dipole array, and presented as a pseudosection, require experience and a certain amount of imagination to produce an interpretation which even then has doubtful reliability. The recent availability of the 2D Smooth model inversion process has dramatically improved the ability to understand and interpret this type of exploration data. But how robust are the algorithms and how reliable are the results? Three commercially available inversion processes are examined and evaluated. The three software packages are applied to field data from three different geological environments located overseas and in Australia. The results of the inversions are presented.

The similarities and discrepancies are discussed relating them to the geological environment of the field data and the initial parameters used to guide the inversion.

EM coupling removal from time-domain IP data

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EM coupling of frequency domain induced polarisation (IP) data has been the subject of many studies, and a number of "de-coupling" procedures have been devised. However, there has been far less emphasis on coupling in the time domain, the normal approaches being to wait until late times and assume the EM contribution is insignificant or, less frequently, to invoke a Cole-Cole model to account for the EM coupling response. In this paper time domain IP data are de-coupled by subtracting the best-fitting EM half-space decay. Analytic expressions are derived for the mutual coupling of parallel electric dipoles on a uniform half-space; these and their derivatives provide a basis for inversion of the transient voltages. The application of the new procedure is illustrated on dipole-dipole IP data from the Yandal greenstone belt of Western Australia.

Depth of investigation for Schlumberger, Wenner and Dipole-Dipole Array over homogeneous, anisotropic and inclined half-space in DC resistivity methods

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In this paper the depth of investigation is computed over a homogeneous anisotropic and inclined earth for different values of dip and anisotropy coefficient in Schlumberger array, Wenner a configuration and Dipole-Dipole (Parallel Dipole) arrangement. Based on potential formula for a homogeneous anisotropic earth model , several equations were derived for calculation of potential difference (dVp1p2) over inclined layers in above arrays. Normalized Depth of Investigation Characteristics (NDIC) function arises of double integration of dVp1p2 (potential due to a thin layer) divided by triple integration of dVp1p2 (total potential). Then a code was developed to calculate NDIC. In this code I used Gauss-Legender numerical integration method for double and triple integration. The various parameters such as anisotropy coefficient, dip of layers, orientation and distance between potential electrodes and current electrodes can influence the result. Depth modification coefficients for these arrays have been summarized in several tables. It will be see when the dips of layers lay between 0 and 16 degrees the depth of investigation decreases by increasing of anisotropy coefficient, and from the dips equal and greater than 17 degrees depth of investigation increases by increasing of anisotropy coefficient.

PETROPHYSICS

Opaque mineralogy and rock magnetism - The missing link

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Rock magnetic measurements play an important role in quantitative magnetic interpretation and there is increasing awareness of the role of remanence and anisotropy of magnetic susceptibility.

Correlation between opaque mineralogy and rock magnetic properties is the key to understanding the effects of processes such as diagenesis and metamorphism. The interaction of bulk chemical composition, oxygen fugacity and grain size can only be established by careful petrographic studies of opaque oxide textures supported by microprobe analysis.

Correlation of blocking temperatures and opaque mineralogy is often the key to understanding the processes. For example, CRM acquired during low grade metamorphism often has very high unblocking temperatures and stable, single component remanence.

The benefits of integration of opaque oxide mineralogy and rock magnetic properties are illustrated using drill core data from Hamersley Basin BIFs. Fractal interpretation of detailed susceptibility logs provides a clear picture of variability at the micro mesoband scale and is used to select representative samples for petrography and rock magnetism so that subtle effects are not missed. It is best to do some petrographic interpretation first, then select samples for rock magnetism measurements.

The results show good correlation between opaque mineralogy and rock magnetic properties and a catalog of typical opaque oxide textures and their rock magnetic properties has been produced. The effects of diagenesis and low grade metamorphism and late stage magnetite recrystallization are clear. However, at a local scale, there is considerable variability and the underlying processes are clearly complex. Opaque oxide mineralogy and rock magnetism studies on closely spaced samples would be needed to investigate these effects and to try to understand the reactions involved

Towards grade estimation via automated interpretation of geophysical borehole logs

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Economic benefits can flow from geophysical logging at all stages of the mining cycle. The most commonly cited benefit is substitution of diamond delineation drilling with cheaper percussion or reverse circulation drilling in cases where geophysical logs can substitute for core. This approach can deliver an attractive direct saving in drilling costs (and time) if drill meterage is unchanged, or a potentially greater indirect benefit from better resource delineation if more holes are drilled within the original drilling budget. Operational advantages of logging include data objectivity, speed of interpretation, and reduced core handling and analysis costs.

Substitution of diamond drilling with percussion drilling is not always feasible. However, the amount of core drilling which can be foregone in favour of more economical drilling plus logging expands enormously if grade can be reliably inferred from petrophysical logs. For some ore systems a close correlation can exist between a petrophysical parameter and grade, e.g. between natural gamma activity and uranium grade, or susceptibility and iron grade. More commonly, individual petrophysical grade estimates are less reliable than assays, but the overall correlation with grade may still be adequate for discrimination between grade ranges, e.g. ore versus waste, or low grade versus high grade. In order to exploit the potential for petrophysical grade estimation in these cases, efficient means must be found to infer grade ranges from borehole logs.

An automated interpretation tool, LogTrans, was developed for geophysical borehole logs during a recent CMTE/AMIRA Project. LogTrans performs rapid analysis of multi-parameter logs and expedites presentation of interpreted results in a form meaningful to mining engineers and geologists. The LogTrans algorithm exploits the contrasts in petrophysical signatures between different "classes" of rock, distinguished by lithology, grade, mechanical properties, or a combination of characteristics. Interpretation entails two stages: statistical characterisation, based logs and core-based data from a set of control holes, and discrimination, during which depth intervals are assigned to the rock class with petrophysical signature "closest" to the measured signature.

In this paper we present two examples of petrophysical grade estimation, one from a coal mine and one from a base metal underground operation.

MIGRATION (2)

Tomographic velocity model updating methods for prestack depth migration in practice

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Radon transform and its inversion are the base of modern tomographical techniques which are applicable to image situations where generalized line integrals of a function are available as the collected data, such as the traveltime in seismic tomography. Collecting and organizing data to serve as generalized line integrals of a function for the application of tomography methods is one of the critical aspects to the success of tomography applications.

It is well known that the Prestack Depth Migration (PSDM) is very sensitive to the velocity - depth structural model and tomography methods are widely accepted as a powerful tool in building and updating the velocity model for PSDM.

It is also commonly acknowledged that offset consistency is a key criterion for the QC of the result from PSDM. This is based on the observation that images from different offsets will be identical to one another if the velocity used in PSDM is correct. Therefore, the flatness or curvature of the moveout of reflection events within CRP gathers is a measure of the accuracy of the velocity model being used by PSDM. On the other hand, measurement of the flatness can be used as the perturbation for the velocity model updating procedure. When tomography methods are employed as the tool for updating the velocity model, the measure of flatness of the reflection events is usually organized into a summation of traveltime delay distribution along a ray path. Therefore, how the flatness of the reflection events is measured is of great importance to the application of tomography methods.

In this paper we analyze three ways of measuring the flatness:

1) measurement based on the hyperbolic moveout assumption, 2) measurement based on non hyperbolic moveout assumption, and 3) measurement based on image divergence in common offset planes. With real world data we will show the results of their application to PSDM processing in practice.

Geophysical applications of equivalent offset migration (EOM)

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The principles of equivalent offset migration (EOM) are extended to prestack migration of converted waves, VSP's and vertical marine cables, anisotropic prestack depth migration, and migration to zero offset. Combinations of these processes are also possible such as anisotropic prestack depth migration of converted wave that have been acquired on a rugged surface. In each application, the fundamental principles of gathering the data before NMO correction is maintained and more accurate velocities are estimated after the prestack migration gathers have been formed.

Equivalent offset migration was initially designed as a prestack time migration that provided an intermediate step in prestack Kirchhoff migration by forming prestack migration gathers. The gathers are formed before NMO correction and are insensitive to velocities. However, after their formation, accurate prestack migration velocities may be obtained by conventional techniques such as semblance analysis. The prestack migration is completed by applying conventional NMO correction along with the appropriate scaling and filtering associated with Kirchhoff migration. Delaying the computations of antialias filtering etc. allows the gathers to be formed rapidly with simple summation.

Prestack time migrations equate the double-square-root equation that defines the traveltimes of source and receiver raypaths, with a hyperbolic equation that defined the same traveltime for a colocated source and receiver. The equivalent offset is defined in the hyperbolic equation and used to define the offset for the samples in each input trace as they are mapped into the prestack migration gathers of each migrated trace.

Prestack depth migration uses the source and receiver traveltime maps for each input trace to define the corresponding traveltime and depths for all migrated traces. These times and depths are also used to define an equivalent offset to form prestack migration gathers. Anisotropic traveltimes may be included in the computation of traveltime maps for a more refined focussing of the seismic image.

Geohazard information from conventional seismic data in deep water areas

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The deep water off the North West Shelf of Australia allows recording of high quality near sea bed reflectors uncontaminated with water layer multiples. Near offset traces are extracted from conventional marine seismic data and processed to recover amplitude beyond ghost frequencies. The near sea reflectors are then scaled to band limited reflectivity using the ratio of the averaged ocean bottom multiple amplitude divided by the squared averaged ocean bottom primary amplitude. The reflectivity in turn, may be inverted to acoustic impedance and interpreted to identify possible hazards (shallow gas or hydrates for example) for drilling operations. This data, combined with multibeam bathymetry, is a cost effective substitute for conducting a standalone high resolution seismic drill site survey.

In addition, sea bottom shear velocity can be estimated from the full fold gathers and the zero offset reflectivity. This involves using a liquid to solid Zoeppritz model for reflection amplitude calculation and using the far offset reflectivity from the CDP gathers. The square of the sea bottom shear velocity is determined from the change in compressional impedance at the sea bottom interface and the differences in reflectivity between zero offset and other pre-critical angle offsets. The accuracy of the shear velocity estimate is proportional to the reflection angle separation between amplitude measurements. The shear velocity, compressional velocity change and zero offset reflectivity can be combined to estimate sea bottom shear strength. These additional measurements will improve mechanical predictions of sea bottom rock strength for top hole drilling, anchor handling and facilities construction.

MULTI-COMPONENT AND 4D

Diffraction stacking with stacking velocity analysis - its application to a surface seismic survey in an active fault area

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In this paper, a new type of data processing method called "diffraction stacking method with stacking velocity analysis" is presented. This method is a kind of prestack migration methods. One of the biggest advantages of this method is that data processing can be performed without apriori information of velocity structure.

The conventional processing of surface seismic reflection data processing is modified as follows.

1. In the case of conventional surface seismic reflection data processing (CDP stacking method), the amplitudes of observed data are stacked along the reflection pattern. In other words, stacking processing is performed at common reflection point. On the other hand, in the case of diffraction stacking method with stacking velocity analysis, the amplitudes of observed data are stacked along the diffraction pattern. In other words, stacking processing is performed at common diffraction point.

2. Stacking velocity analysis (the main element of conventional surface seismic data processing) can be a useful tool for detecting the pattern of a scattered wavefield. It may be regarded as a kind of matching against characteristic patterns (e.g., the hyperbola pattern caused by reflection events in a CDP ensemble). In this paper, stacking velocity analysis is modified for detecting a pattern caused by diffraction events. Final stacked records can be obtained based on results of stacking velocity analysis. This proposed data processing was applied to surface seismic field data obtained in an active fault area and it was found that this poposed method produced a better stacked section than conventional CDP stacking method.

Time-lapse 3-D seismic physical modelling

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Seismic physical modelling is used to study the effects of seismic wave propagation in isotropic and anisotropic media, and to improve methods of data acquisition, processing and interpretation. Until recently, the use of unconsolidated sands for seismic physical models had been unsuccessful due to the lack of control or understanding of the natural variations that occur throughout the models. Our research has allowed many of the drawbacks to be overcome.

The use of sands allows fluids to be incorporated into the models for the first time, providing a much more realistic analogue of hydrocarbon reservoirs, and presents an opportunity to expand the role of seismic physical modelling. The computer controlled modelling system allows repeatable acquisition, which makes it an ideal environment to study some of the time variant characteristics of reservoirs that occur with production. This is demonstrated with a model whereby the migration of kerosene and air is monitored with time-lapse surveys. Time-lapse 3-D (or 4-D) seismic is becoming increasingly important in the management of hydrocarbon production, yet there is a lack of model data to support some of the fundamental conclusions being made. Subtle anomalies on difference sections may in fact be artefacts of the different acquisition footprints or manufactured from the complex data processing that is necessary to allow comparison of legacy data sets.

The ability to perfectly repeat data acquisition on sand models bypasses these problems such that any anomalies seen on difference sections can be directly attributed to changes that have occurred within the model. The development of TL3-D seismic physical models will also provide a number of other advantages, which are:

1. Inexpensive, real seismic data.
2. The absence of complications from seasonal or climate factors.
3. Rapid data turn around in a matter of days, rather than having to revisit an area years later.
4. Potential to control the changes within the model and compare the seismic interpretations against the known changes.
5. The ability to deliberately change acquisition parameters to test the effect on the resultant seismic difference sections.

A Comparison of multi-component wavefield separation techniques

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Conventional single-component seismic imagery has, in the past, provided acceptable resolving power in many standard hydrocarbon exploration applications. However, seismic exploration is increasingly focusing on more subtle hydrocarbon traps. In this environment, multi-component technology is generating widespread interest. Significantly more information can be recovered from the seismic wavefield if it is recorded and analysed as a vector quantity. Arguably the most important potential application of true vector- processing for seismic exploration is the decomposition of the seismic data into its constituent wavemodes (e.g. P, S, surface waves). The resultant sub-surface images should yield improved structural and geological interpretation.

A number of multi-component wavefield separation techniques, including the Integrated Wavefield Separation Algorithm (IWSA), Spectral Matrix Filtering (SMF), Controlled Direction Reception (CDR) filtering and Wave-Equation-Based decomposition, will be examined. Such approaches to wavefield separation can utilise both slowness and polarisation information inherent in the vector data. All are true multi-trace vector-processing methods capable of overcoming limitations associated with the traditional and more widely investigated single-trace vector-processing algorithms.

A brief theoretical review of each technique will be accompanied by discussion of practical issues associated with implementation of the method. Wavefield separation applied to both synthetic and real two-component data will be compared.

INVERSION

Bayesian inference applied to joint inversion of contemporaneous data

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Geophysical inversion in practice becomes a balance between pragmatism and theory. Although the problem is frequently nonunique and ill-posed, much effort is expended on the construction of models for the subsurface physical property distribution. Frequently, prior information and measured data errors are not explicitly incorporated into the inversion procedure. The constructed model may satisfy the data to a specified tolerance, but the interpreter has little quantitative measure of the confidence level for the existence and magnitude of individual model features. The inference theory of Backus provides a framework for analysis of inversion results for linear problems. This theory, based on Bayes' theorem, can be generalised to nonlinear problems and is used to create quantitative measures of confidence that can be ascribed to model results. The total error includes theoretical errors introduced in the modelling procedures as well as measurement errors. These errors can be quantified by a probability density function describing the statistical properties of the data and the effects of approximation in the forward modelling problem. Bayes' theorem allows a probability density function to be defined for the elements of the model. These probability density functions provide information about the value of model elements and the degree to which each is resolved. This paper demonstrates the use of Bayesian inference applied to contemporaneous geophysical measurements incorporating prior information about the physics and expected properties of the model. The contemporaneous data considered are audio frequency magneto-tellurics, induced electromagnetic field measurements and induced polarisation. Using inference theory, the probability density function of one type of data can be improved by attempting to predict its values using the other observed data types. A combined dataset that spans the largest part of the model space is then used in the inversion procedure.

Crosswell seismic tomography without ray tracing

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A tomographic inversion algorithm was applied to invert four crosswell seismic surveys acquired in the Glenn Pool field, Oklahoma. Instead of calculating the raypaths and traveltimes explicitly by standard ray tracing, this algorithm uses a finite-difference eikonal equation solver and minimises the traveltime differences between the observed and calculated P-wave traveltimes in a least square sense. The model is updated by an SIRT-like algorithm. A dynamic -trimmed median filter is applied to the gradient after each iteration. Three constructed velocity tomograms showed good correlation with each other as well as with the sonic logs. However, certain anisotropy artefacts due to the interpreted shale layers were also identified from the residual traveltime maps. This study demonstrated the great potential of crosswell seismic imaging in reservoir development.

A.D.I. plus interpolation - Accurate finite-difference solution of 3-D wave-equation migration

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Conventional 3-D wave-equation migration using an alternating direction implicit (A.D.I.) finite-difference method separates the 3-D downward extrapolation operator into two 2-D operators. While the A.D.I. technique affords computational efficiency, known errors in positioning steeply dipping reflectors result. This paper develops a so-called ADIPI algorithm — A.D.I. plus interpolation — to preserve the accuracy of the original extrapolation operator in the stable implicit finite-difference solution. This method still exploits the efficiency of the A.D.I. technique, that solves two tridiagonal systems recursively. The final accurate solution is obtained by a simple interpolation between the intermediate solution, resulted from the latter A.D.I. extrapolation, and the original unextrapolated wave field.

CASE HISTORIES (NICKEL) (1)

Comparison of frequency-domain and time-domain surface-to-borehole EM data on a nickel prospect

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With the purpose of testing a frequency-domain 3-component downhole EM prototype, surface-to-hole FEM data were recorded in a borehole where similar data in time-domain were already available. The Nivala test site, located in central Finland, is a nickel prospect owned by Outokumpu Mining Oy. It features a conductive (5-50 Ωm) serpentinite body including a small subsurface nickel mineralisation. The intrusion is embedded in resistive country rock (mica gneiss, 5 000 Ωm). Approx. below 250 m from the surface the northern rim of the serpentinite body is anomalous in conductivity showing also a nice polarity according to 3-D magnetometry.

Though the transmitting loops used in the two experiments are located on opposite sides of the serpentinite, the FEM and TEM measurements show remarkable concordance and, subsequently, inversion by current filaments give very good agreement, FEM complementing the information given by TEM.

Borehole TEM was recorded with the Geonics 3-component Protem instrument, giving schoolbook anomalies in two barren boreholes. Filament inversions locate the center of the current pattern in the NW contact of the intrusion. The origin for the anomaly could be either Ni ore or very conductive inclusion of serpentinite at the edge of the intrusion.

Surface-to-hole FEM was recorded in one of these holes with the 'SlimBoris' prototype of IRIS Instruments, designed for multiple downhole EM configurations. This system uses a 3-component receiver probe with either a surface or a downhole transmitter in the range of 35 Hz - 9 kHz.

The measured field at each frequency is normalised by low frequency data. Further conditioning consists in removing the residual 'regional' trends, so that the final data 'asymptotize' to zero on both sides of the anomalies.

The final data have been inverted by equivalent dipoles and filaments. Closed rectangular filaments or magnetic dipoles are used to represent a vortex effect, whereas open electric bipoles or dipoles are used to represent a galvanic effect.

All the inversions place the model between the two drillholes. For the in-phase components, the best fit is obtained with a closed rectangular filament, whereas, for the quadrature field, only open filaments give relevant results. This feature is strong diagnostic of a dominant galvanic effect on the quadrature field (the galvanic/vortex ratio is by nature stronger in quadrature than in phase).

Despite a resistive country-rock, a galvanic effect can be produced here by currents induced in the serpentinite, then channeled into a more conductive zone in electrical contact with the intrusion, either more conductive serpentinite or ore. Downhole FEM thus confirms and complements the interpretation given by TEM.

The role of geophysics in the discovery and delineation of the Cosmos Nickel Sulphide Deposit, Leinster Area, W.A.

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Cosmos is a typical Kambalda-style, komatiite-hosted, highly conductive and magnetic, massive pyrrhotite-pentlandite sulphide deposit. It is located approximately 40 km south of the Mt. Keith nickel mine in the northern Yilgarn Craton of Western Australia. It was discovered in mid-1997 using a combination of geological, geochemical and geophysical exploration techniques during routine evaluation of a prospective ultramafic belt. The discovery hole was the initial test of a short strike-length, late-time transient electromagnetic (TEM) anomaly in an area that had previously been partially drill tested by other companies. The original moving-loop TEM anomaly, recognised on two 150 m spaced lines, was defined in detail using a large, fixed transmitter loop survey. Modelling of the late-time fixed-loop data indicated that the source was a steeply east dipping conductor at about 50-75 m depth. Ore-grade massive nickel sulphides were intersected in the predicted position in the first diamond hole drilled to test the conductor. The limited depth extent of the conductor suggested by the modelling was confirmed by subsequent drilling and downhole TEM surveys. Detailed ground and aeromagnetic data subsequently collected over the deposit defined the host ultramafic well, but did not clearly distinguish the magnetic massive sulphide zone. The significance of the Cosmos TEM surveys was their ability to quickly and accurately focus drilling on the small but high-grade massive sulphide lens within the much larger mineralised halo.

The Maggie Hays and Emily Ann Nickel Deposits, Western Australia: A geophysical case history

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Geophysical techniques played a significant role in the discovery of the Emily Ann massive nickel-sulphide deposit and extensions to the Maggie Hays deposit, which are associated with komatiitic olivine cumulate ultramafic rocks, in an Archaean greenstone belt located about 500 km east of Perth, Western Australia.

Detailed aeromagnetic surveys were used to outline komatiitic rocks and structures. Physical property measurements on drill core showed the mineralisation to be highly conductive and magnetic. Trial induced polarisation, audio magnetotelluric and time-domain electromagnetic (TEM) surveys indicated that latter had the most potential for detecting the nickel-sulphide mineralisation.

The Maggie Hays deposit comprises both disseminated and massive nickel-sulphides concentrated at the base of an ultramafic unit between 200-500 m below the surface. A limited moving-loop TEM survey in 1992 located an anomaly immediately north of the main part of the deposit. Diamond drilling of this anomaly failed to discover extensions to the deposit or explain its source. In 1995, a fixed-loop TEM survey delineated an excellent response confirming the earlier moving-loop anomaly, which when drilled, resulted in the discovery of the Maggie Hays North zone at 100 m below the surface.

A moving-loop TEM survey resulted in the discovery of the blind, high-grade Emily Ann nickel-sulphide deposit 3 km north of the Maggie Hays deposit, at a depth of 120 m. Downhole TEM surveys aided delineation diamond drilling of the deposits with the location of extensions of mineralisation.

High-powered, late-time moving-loop TEM, with fixed-loop TEM follow up, is currently being used routinely to explore for additional deposits. However, the highly conductive overburden response obscures the signal from bedrock conductors, which are often represented only as low-amplitude, late-time anomalies. Geophysical targeting is further complicated by the close proximity of highly conductive barren banded iron formation-hosted massive sulphides. Trial airborne EM surveys have detected Maggie Hays North, but not Emily Ann and probably not the Maggie Hays main zone.

within the impedance cube helps to establish correlations between wells in order to interpolate reservoir properties.

RESERVOIR GEOPHYSICS (3)

Geometry of the oil pool in the rough range trend, Western Australia

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A study involving re-interpretation of existing multi-channel seismic reflection data indicate that the Birdrong sandstone reservoir has been compartmentalised by two main fault systems that are orthogonal. The fault systems are the east-west trending transfer faults and the north-north-east trending wrench (strike-slip) and normal faults. The results suggest that the discovery well, Rough Range-1, was drilled into just one of the compartments, which probably had not extended far enough to contain hydrocarbons because of structural control on closure. Because of the thinness of the reservoir unit (~10 m) being investigated, a small fault with an offset equivalent to the reservoir thickness would be enough to displace the hydrocarbon pool. Furthermore, structures have leaked extensively, that is the hydrocarbon reservoir has been breached, and probably now is mostly dry. Any remaining oil and gas accumulations would appear to be in isolated channel sands within fault-enclosed compartments. Structural reactivation in the Late Miocene has opened up faults and provided conduits, which have allowed any accumulated hydrocarbons to migrate to adjacent compartments and up into younger sequences. Any migrated oil could be contained within the younger sequences or, possibly, escape to the surface and be lost via the large network of inter-connecting faults. Further investigations may be required but we strongly suggest that reservoir partitioning is responsible for the form of the subsurface geometry of the hydrocarbon pool in the Rough Range trend.

Moving to a layered impedance cube, advantages of a 3D stratigraphic inversion

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Amplitude variations on seismic data depend on impedance contrasts and bed thickness interference effects. For fine layers, interference patterns can become predominant, making accurate picking of fine layers on seismic sections questionable, also amplitude and time maps are unable to describe the properties of layered reservoirs. Only modelling techniques taking into account a priori information, tuning effects, and geological and petrophysical constraints are suitable to interpret seismic data in terms of layers and impedance.

CGG proposes a unique program TDROV, which converts 3D migrated seismic data into acoustic impedance, by inverse modeling. Starting with a simple macromodel, the program is able to produce a finely stratified broadband impedance model by iteratively updating the current impedance model on a global basis. The updating results from volumetric impedance pertubations and strata interface deformation. which are accepted/rejected according to the Metropolis algorithm implemented within a Simulated Annealing schedule. The resulting impedance model may be validated by comparison with well logs since they are riot input explicitly into the program.

In the case study we present here, this technique in particular allows the user to perform qualitative and/or quantitable reservoir characterization. The endproduct of the inversion consists of automated maps of the space-variant acoustic impedance of the strata. Cut-off techniques were used to isolate the heterogeneous bodies in the 3D volume without any horizon picking in particular the blocked and layered representation of the traces

Optimised reservoir characterisation workflow using multi-attributes classification - a case study on the Wandoo field, NW Shelf, Australia

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Grid-guided volume attributes and 3D volume seismic transforms integrated through multi-dimensional seismic classification algorithms provide new inputs for the seismic interpreter to rapidly. converge towards a 3D seismic facies hypothesis fitting a solid structural framework. We illustrate the approach with the 75 millions barrels Wandoo field from the Australian NW Shelf. At the Barremian target sands level (600 m), the structural framework of the field is complex and of low seismic fold, with high frequency noise and multiples.

From the onset, seismic interpretation was performed in multi-attribute 3D visualisation environment. Modelbased noise attenuation techniques were used to pre-process the input seismic volume to facilitate the time structural interpretation of regional reflectors. Newly developed grid-guided volume attributes based on orthonormal polynomial trace reconstruction captured subtle lateral differences in seismic facies that were not represented on the observed wiggle trace. Multi-dimensional geostatistical (Fisher, Contextual Bayesian) and Neural Network classification algorithms were used to produce a set of class and probability maps from all volume attributes generated on the reservoir interval. Calibration of the. derived classes for facies and fluids was performed using a priori information from well mesurements.

Simultaneously with the grid-guided approach, the entire seismic volume was transformed into a set of 3D seismic facies attributes (texture, edge enhancing and termination cubes) to enhance both lateral and horizontal discontinuities. The 3D classification algorithms were used to integrate the information content of multiple attribute cubes into a single probability volume. The latter was displayed in 3D visualisation space to track voxels of given seismic facies and automatically extract 3D fault surfaces. These results were validated by additional exploration wells not included in the initial study. Further well trajectories could then be planned in 3D visualisation space to reach potential targets with a higher degree of confidence.

Better, Faster Decisions through Collaborative Volume Interpretation

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"Collaborative Volume Interpretation" unleashes the creativity and knowledge of E&P Asset Teams - delivering value in the form of faster and better decisions. Repeatedly, we have observed the impact of leveraging 3D visualization, seismic attributes and collaboration technology as an enabler for greater productivity and a more in depth understanding of the subsurface. Case studies will be used to illustrate the technical and business impact of Collaborative Volume Interpretation from the desktop to large-scale immersive environments.

The "Surface Interpretation" paradigm has served the E&P business well, since before the dawn of the interpretation workstation. Surface Interpretation establishes the structural/stratigraphic framework of the subsurface, and is a cornerstone of traditional E&P workflows. The initial approach of manually "interpreting on the media" (e.g. paper, glass, film) has steadily given way to the workstation environment, where skilled craftspeople pick horizons, faults and tops, aided by automated tools. While 3D seismic data is commonly interpreted, the Surface Interpretation approach generally entails interpreting on 2D panel views of seismic, supported with generally rudimentary 3D visualization options.

The emerging "Volume Interpretation" paradigm not only provides a full 3D visualization/interpretation environment, but also introduces the concept of region or voxbody interpretation, based upon character similarity and connectivity. Volume Interpretation strongly leverages well-based information - fusing it with multiple volumes of attribute, multi-component and multi-vintage seismic data for an integrated conceptual model of the subsurface. This multi-volume approach supports tailoring of seismic data for specific interpretation objectives, such as seismic impedance for reservoir delineation, similarity attributes for fault sealing and structure impact and energy/amplitude attributes for hydrocarbon detection.

The value of Volume Interpretation is maximized through the use of collaborative technologies that enable E&P professionals to see and work in "the same subsurface". Collaborative "connection tools" allow asset team members to view and interact within the same application, either locally or in a global setting, providing access to the best available knowledge base. By visually fusing geophysical, geological and reservoir information in a shared surface/subsurface context, asset teams are able to focus their knowledge to make better, collaborative decisions. Furthermore, by breaking away from the typical linear and "siloed" E&P workflow approach and enabling collaboration, productivity is improved - resulting in faster decisions.

SEISMIC ANISOTROPY (1)

Stress induced anisotropy: the effects of stress on seismic wave propagation

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The stress field within the Earth is a first order geophysical property and an important controlling factor on the microscale structure of rocks. The dynamic nature of the Earth's stress field is a result of tectonism, uplift and extension. However, stress-induced phenomena are also influenced and complicated by remanent stress-history effects. The resultant anisotropic sedimentary layers present within the Earth allow their interpretation using the seismic method. Interpretation objectives include the determination of in situ stress directionality, fracture orientation and support the delineation of hydrocarbon reservoirs. Stress has the potential to affect most petrophysical rock properties.

The effects of stress history on the acoustic and elastic properties of artificially manufactured sandstones have been investigated in the laboratory using ultrasonic techniques. Homogeneous mixtures of quartz sand and epoxy resin were allowed to harden under the application of different forming stress magnitudes. This was followed by unloading under anisotropic stress conditions satisfying uniaxial strain criteria. The resultant sandstones exhibited azimuthal velocity, amplitude and Poisson's ratio changes with a 90-degree periodicity. Pronounced, well-defined shear-wave splitting was also prevalent. As the manufacturing (forming) stress was increased the average velocity of all body waves decreased, attenuation increased and the percentage anisotropy increased.

The azimuthal anisotropy was consistent with the symmetry of the anisotropic stresses during unloading. The severity of the anisotropic trends favoured an interpretation focussing on microcrack development. Thus, acoustic trends including shear-wave splitting were accounted for by the formation of intergranular microcracks in the plane orthogonal to the maximum stress during unloading. As the forming stress was increased, so too did the length of the unloading path. It is postulated that this in turn induced a higher density of aligned microcracks, inducing a larger, controllable, acoustic anisotropy.

A technique is presented for the preparation of anisotropic sandstones, which is a simple method for building models of known anisotropy. These developments offer a new approach to research into stress-induced phenomena and their implications for seismic interpretation.

Analysis of higher order moveout in terms of vertical velocity variation and VTI anisotropy

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The standard approach to NMO for reflection seismic data uses a second order equation. However, this is only correct for a constant velocity, isotropic earth model. In the more general case, the moveout equation contains higher order terms,

$$t^2 = t_0^2 + \frac{x^2}{v^2} + \alpha\, x^4$$

The effect of higher order terms is small at shorter offsets but becomes rapidly more important with increasing offset. Modern recording geometries often use longer offsets, with 6 km common. At these longer offsets, the higher order terms are important. Use of 4th order NMO can allow longer offset reflection energy to be included in the stack. In turn, this can yield better multiple suppression and better amplitude versus offset analysis.

Practical analysis of seismic data exhibiting 4th order NMO effects has been undertaken. The first approach was initially to pick the 2nd order term on moderate offset data and then to scan the full offset range for the 4th order coefficient, a. However, practical measurement of the 2nd order coefficient often requires using offsets where moveout is influenced by higher order terms. Since measurement of the 4th order coefficient is sensitive to the 2nd order coefficient, a false measurement can prevent correct refinement by being locked in a wrong solution. Instead it is necessary to simultaneously pick 2nd order and 4th order coefficients in order to flatten gathers and obtain accurate velocity measurements.

Vertical velocity variation and VTI anisotropy can both cause 4th order (and higher) NMO effects. Consequently, it is difficult to interpret the 4th order coefficient directly in terms of either vertical velocity variation or VTI anisotropy. A method has been developed which uses the second order term to predict the vertical velocity variation component of the fourth order effect. Once this component has been removed, the remaining fourth order effect can be interpreted in terms of VTI anisotropy.

Inversion technique for transverse isotropy with a tilted symmetry axis

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Computer simulation experiments and numerical modelling studies have been used to recover the P-wave anisotropic elastic parameters for transversely isotropic media with a tilted symmetry axis (TTI media). These parameters include P-wave velocity along the axis of symmetry a0, S-wave velocity along the axis of symmetry b0, the P-wave anisotropy e, and the near-vertical P-wave anisotropy d. The angle of tilt in such media also has been recovered.

The Levenberg-Marquardt method is utilised in carrying out the iterative inversion to recover the elastic parameters and angle of tilt y using a set of transmission data. This paper presents the 2-D case in which the vertical plane through the survey line contains the anisotropic axis of symmetry.

The method was tested numerically on single layer models created with published anisotropic parameters having a range of tilt angles from zero to 90°. Traveltimes were computed using in-house software based on computed ray velocity (group velocity) functions. The traveltime data were inverted to recover the elastic parameters and the tilt angles of the symmetry axis. Results obtained are in good agreement with model parameters.

In order to evaluate the performance of the inversion scheme in practice, random noise was added to the model data. The inversion algorithm proved to be robust and good results were obtained in the presence of noise. VSP field data were also successfully processed using the inversion program. The software includes options of constraining parameters to improve inversion accuracy.

Elastic parameter recovery from field data may be used to improve the accuracy of pre-stack depth migration, depth estimation and reservoir volume estimations. Currently, VSP data must be recorded with dip direction for inversion with this 2-D software. Extension to the general 3-D case is currently being planned.

Experimental observation of wave propagation along interfaces in anisotropic media

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Anisotropy is not always taken into account in seismic exploration. With the advent of modern high precision seismic equipment the effect of velocity anisotropy has become more evident. It has been found that the effects of anisotropy can cause serious problems in data processing. Therefore, further work is required to better understand anisotropy and the way in which it affects the propagation of waves at the earth's surface and at an interface. In seismic exploration, waves may pass through, be propagated along or reflected from an interface. At the ground surface these may manifest themselves as ground roll, Rayleigh waves or Love waves and at deeper interfaces as Stoneley waves when specific conditions are met. Love waves are observed only when there is a low velocity layer overlying a high velocity substratum. In order to investigate the propagation of these types of waves, a series of experiments were conducted. The first set of experiments dealt with surface waves at a liquid-solid interface. Both isotropic and anisotropic materials were used and Rayleigh waves and Love waves were produced. In the second study interface refractions at a solid-solid interface were investigated, where materials on either side of the interface differed, with at least one being anisotropic. No complete theory of the propagation of such signals is known when either or both of the layers are anisotropic and measurement is needed to investigate that propagation. This research compares the bulk anisotropic properties with those manifested at the surface. This research used the Physical Modelling System at Curtin University Department of Exploration Geophysics. Focusing ultrasonic transducers were used as both source and receivers, and models were constructed using isotropic plastics and anisotropic phenolite.

WAVELET TRANSFORMS

Wavelet estimation of a local long memory parameter

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There are a number of estimators of a long-memory process' long-memory parameter when the parameter is assumed to hold constant over the entire data set, but currently no estimator exists for a time-varying long-memory parameter. In this paper we construct an estimator of the time-varying long-memory parameter that is based on the time-scale properties of the wavelet transform. Because wavelets are localised in time they are able to capture the time-varying statistical properties of a locally stationary long-memory process, and since wavelets are also localised in scale they identify the self-similarity scaling behaviour found in the statistical properties of the process. Together the time and scale properties of the wavelet produce an approximate log-linear relationship between the time-varying variance of the wavelet coefficients and the wavelet scale proportional to the local long-memory parameter. To obtain a least-squares estimate of the local long-memory parameter, we replace the time-varying variance of the wavelet coefficient with the sample variance of the wavelet coefficients computed over the so-called 'cone of influence.' That is, we use only those wavelet coefficients whose time index falls within the support of the wavelet basis function in order to compute the local sample wavelet variance. To test the empirical properties of our estimator we perform a number of Monte Carlo experiments. We find the wavelet-based estimator of the local long-memory parameter to have empirical properties similar to other wavelet-based estimators of the long-memory parameter for globally stationary long-memory processes. For processes where the long-memory parameter suddenly changes, the wavelet-based estimator again performs well, only exhibiting an elevated positive empirical bias at points in time right before the long-memory parameter increases, and a negative bias immediately after the change. The wavelet-based estimator of the local long-memory parameter is demonstrated using vertical ocean shear data.

Inferring Geological Structures Using Wavelet-Based Multiscale Edge Analysis and Forward Models

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The location and characteristics of irregularities commonly carry most of the information found in signals. In geophysical potential-field datasets irregularities are the product of contrasting properties of the sub-surface rocks. The analysis of gravity and magnetic images faces the limitation imposed by the inherent non-uniqueness of potential field problems. Useful information can be obtained only with the use of appropriate a priori information. The common assumption that geological units are sharply bounded by faults and other geological contacts suggests that irregularities in geophysical potential-field images correspond to irregularities in the sub-surface rocks, and this relationship has been the basis for many forward and inverse modelling systems (Jessell 1999).

The detection and visualisation of these irregularities at different scales of resolution (multiscale edges) greatly enhance the interpretability of images. Researchers in geophysical inversion at the CSIRO Division of Exploration and Mining have developed a set of tools for the analysis and processing of potential field data using wavelets for detection and manipulation of multiscale edges. The results of this processing are viewed in modern graphics environments as an enchancement to aid interpretation. In order to train interpreters to use this new visualisation tool forward modelling has been used to generate multiscale edges from synthetic models. In this way the multiscale edges can then be compared to subsurface structures. This also allows a better understanding of possible ambiguity in signatures from the interference between two or more causative sources. An atlas of forward-modelled potential-field responses has been developed by Monash University using NoddyTM software (Jessell 1981, Jessell & Valenta 1996). The synthetic models for over a 150 different geological structures have subsequently been analysed using the multiscale edge-detection technique. By comparing synthetic multiscale edge responses with responses from real datasets an understanding of the 3-D geological structure can be developed. The detection and discrimination of different source type, depth to source, dip direction and contact relationships can be successfully modelled using this technique.

CASE HISTORIES (NICKEL) (2)

Electromagnetic methods applied to exploration for deep nickel sulphides in the Leinster Area, Western Australia

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Nickel-sulphide deposits lying at the base of the regolith usually give strong, readily interpreted, surface time-domain electromagnetic (TEM) anomalies. In the Leinster area of Western Australia much of the prospective stratigraphy has been covered by TEM surveys and the strong anomalies have been drill tested. Deep nickel sulphides may be economic if they occur close to existing mining and processing infrastructure, but targeting the subtle TEM responses of these bodies requires skilful application and interpretation of TEM surveys. Conductive regolith can mask the response of deep nickel-sulphide orebodies to surface TEM systems. IP effects and other geological noise originating in the regolith can make recognition of weak bedrock anomalies difficult. Taking a slingram or out-of-loop reading can minimise regolith effects, and give a better response from sub vertical bedrock conductors than in-loop readings. Downhole electromagnetic (DHEM) surveys in reconnaissance drill-holes increase the effective penetration depth of TEM, and can assist surface TEM interpretation in a prospect area. Despite weak surface TEM anomalism, DHEM surveys of deep drill-holes can yield precise information about the position and conductivity of nickel sulphide systems.

Horses for (conductive) courses: DHEM and DHMMR

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DHEM surveys have been routinely used in exploration programs for nickel sulphides in the Yilgarn Craton of WA and they have generally been successful in defining the massive sulphide zones within the deposits. Recently, some DHMMR surveys have been carried out at a well-drilled deposit located in the Agnew - Wiluna Greenstone Belt. These surveys did not respond well to the massive sulphides, but did locate some previously undefined matrix sulphides in close association with the massive sulphides. Although generally of lower grade, matrix sulphides may make a more attractive target than the massive sulphides because of the much larger tonnages involved.

The massive sulphides of pentlandite, pyrrhotite, etc are excellent conductors, have a plate-like form and thus provide a good target for EM techniques. However, it appears that their thinness makes them relatively poor current gatherers and thus they gave little if any MMR response. The matrix sulphides have a similar composition and an elongated strike length, but have a 'blocky' form in cross-section. In geophysical parlance, they could be described as 'cigar' or 'sausage' shaped. Such shapes make relatively poor targets for EM, but are excellent current gatherers and are thus very applicable to MMR. And the several DHMMR surveys carried out have defined a zone of matrix sulphides close to the top of the massive zones. The fact that the DHMMR did not see the massive sulphides, suggests that the matrix sulphides, although of lower sulphide content and thus presumably less conductive, effectively gather all of the energising current to the near exclusion of the massive sulphides. As well as responding to a quite different target, the results also suggest that the DHMMR is capable of detecting sulphides at a greater distance from the hole than the DHEM.

Mineral potential evaluation based on airborne geophysical data

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A high-resolution helicopter-borne magnetic, electromagnetic and radiometric survey has been completed over the entire Bathurst Mining Camp in Eastern Canada. The goals of the survey were to characterize the geophysical response to massive sulfide deposits in the camp, to determine the physical properties of sulfide and host rocks, and to interpret airborne and ground geophysical data. A prediction model, based on the differences between the distribution functions of geophysical survey data of the study area and of mineralized zones, has been developed to identify exploration targets for Volcanogenic Massive Sulfides (VMS) deposits. This has been used to produce a mineral potential map, which has been evaluated by applying a cross validation analysis using 37 known VMS deposits in the camp. From the results of the cross validation we would have Adiscovered@ 15 (41%) of the 37 deposits if we had selected the 1% of the study area (40km^2) in the potential map which represents the highest relative potential for VMS deposits. Similarly, if the top 5% area had been selected as the target area, then 21 (57%) of the 37 deposits would have been Adiscovered@. In summary, we expect that 46% of all new discoveries of VMS deposits in the Bathurst Camp will be within the 1% range in the prediction map. Best prediction results are obtained when all three types of geophysical data are used: magnetic, electromagnetic and radiometric. As most orebodies in the Bathurst Camp are associated with coincident magnetic and electromagnetic anomalies, the usefulness of the magnetic and electromagnetic data could be expected. Although the radiometric data are not directly associated with orebodies, they have to be included in the prediction model as they reflect the geology of the area.

MIGRATION (3)

Comparison of diffraction tomography to Kirchhoff Migration

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Crosswell seismic diffraction tomography is a new waveform inversion algorithm and has a great potential for producing higher-resolution images than the conventional traveltime tomography. The objective of this paper is to identify the inherent relationship between diffraction tomography and Kirchhoff migration. Both of them can be considered as multi-dimentional inverse scattering problems. However, it is found that crosswell diffraction tomography inverts for the low-wavenumber components of the velocity scattering potential, while Kirchhoff migration inverts for the high-wavenumber components. To achieve the highest image resolution, both low-wavenumber components and high wavenumbers should be recovered; this means that diffraction tomography and wave-equation migration should be integrated in order to obtain the full-wavenumber spectrum images.

Pre-stack imaging - Time or depth?

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Scattering points in the earth result in diffraction surfaces in seismic data. The better the shape of these surfaces are matched in the processing the more accurate the resulting image. More complicated earth models give more complicated diffraction-shapes. The NMO-DMO processing-sequence assumes straight ray-paths and thereby constant velocity. Appending zero-offset migration to the sequence, to effect pre-stack time migration is an improvement, but the constant velocity assumption of the first 2 steps still limits the accuracy of the total solution. Non-hyperbolic Kirchhoff pre-stack time migration is a better approach and does not assume straight ray-paths. In cases where the velocity varies only mildly in the spatial direction the Kirchhoff approach will often give as good results as pre-stack depth migration. Non-hyperbolic Kirchhoff time-migration uses travel-time tables computed with ray-tracing through an interval velocity model rather than using rms velocities and the double square-root equation. This gives improved diffraction shape matching in situations with large vertical velocity variations. For complicated geology pre-stack depth migration is required. Kirchhoff pre-stack depth migration uses travel-time maps computed through a spatially varying velocity model. Accurate pre-stack depth migration requires an accurate velocity model and the use of automated reflection tomography has been found to produce velocity models of the required detail. In this paper we demonstrate the 3 above mentioned imaging methodologies on several 2-D and 3-D data sets.

Fast Kichhoff migration in the wavelet domain

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Aeromagnetic and gravity signatures, and circumstantial geological evidence, are interpreted in terms of a late Lower Cambrian c.1240 km-diameter multi-ring structure centred 50 km northwest of Deniliquin, southeastern Australia, within pre-Lachlan Fold Belt basement.

Magnetic basement 2-4 km deep and bodies 11-12 km-deep define the 220 km-diameter "Deniliquin structure" which includes a central 17 km-deep high-density magnetic body. A circular de-magnetised zone and relicts of a gravity low surround this centre. Low seismic velocities and gravity modelling suggest basement fracturing.

Gravity lows due to troughs of later sediments, and overlapping magnetic anomalies, as well as arcuate features beneath the Adelaide Fold Belt suggest a multi-ring structure. Younger rocks obscure the eastern multi-ring but basement ring patterns are inherited into their trends. Some later faults are tangential.

Narrow de-magnetised zones, narrow zones of later turbidite-hosted vein quartz-Au deposits, locations of depocentres, magnetic bodies and rare alkaline igneous rocks all suggest the existence of related radial fault zones ("master faults") which extend to distances of 950 km within the basement. Deep reflection seismic profiling can locate them.

It is suggested that the Deniliquin structure originated beneath sea, causing the main event in the Delamerian Orogeny at ~514 Ma but prior to emplacement of allochthonous mafic-ultramafic masses older than 513 Ma. At this time, there is no known faunal passage from confirmed Early into Middle Cambrian strata. It is suggested the event also triggered ~30 Ma of igneous activity and tectonism in southeast Gondwanaland and possibly at its antipode.

Though unproven, a large meteorite impact is the most likely origin for the Deniliquin structure. Entry of seawater into the hot central cavity may have caused rapid expulsion of mantle-derived mafic-ultramafic "allochthons" over Victoria, Tasmania and other places, the first event in the Lachlan Fold Belt and comparable elements in Tasmania.

A comparison of indirect and direct near surface velocity measurement for velocity model building and pre-stack depth migration in an area of shallow carbonate overburden

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Hydrocarbon exploration in the Carnarvon Basin of the Australian Northwest Shelf has often been hindered by the effects of a shallow carbonate overburden, frequently producing significant ray path distortion with resultant seismic time image degradation.

This paper will compare the results of pre-stack depth migration using near surface velocity models created from indirect and direct measurements in an area of shallow carbonate overburden. The indirect method uses inversion of stacking velocities to generate an initial model followed by reflection tomographic updating. An alternative velocity model is created using the direct measurement of the near surface velocity field using refraction tomography (diving waves).

The rate of change of velocity and thickness of the shallow carbonate layer is difficult to measure directly as well control across the Carnarvon Basin is low and few of the older wells have any reliable sonic logs through this layer. Even modern wells have only poor near surface information due to inherent difficulties with cement bond and no returns during drilling. Well target depth prognosis is difficult in some areas and prospect depth conversion needs to include wider ranges than often used in order to encompass many of the well results. Frequently wells have come in off prognosis due to local velocity variations which are counter to that obtained from regional well control.

Several schemes have been adopted to try to make the best use of regional stacking velocity information for depth conversion and velocity model building. However, all these methods suffer from the problem of low fold in the shallow section where high velocities, ranging from 2000 m/s to 3600 m/s over the shallowest 200 m/s, are not uncommon.

Depth migration has recently been introduced by several companies exploring in the Carnarvon basin to help solve the problems of seismic imaging and regional velocity control. Results have certainly been encouraging and several examples of improved seismic images exist. However, the final quality of the depth migration image depends to a large degree on the accuracy of the input velocity model. Stacking velocities tied to well control are often used to build the initial velocity model, followed by either layer stripping, coherency inversion or reflection tomography to improve the velocity model. One commonly used method is to measure the depth delays in deep data after pre-stack depth migration and to assume that these delays are due to errors in the near surface velocity field. Reflection tomography is then used to update the near surface velocity layer. This indirect method of generating a near surface velocity field has been used on several 2D and 3D pre-stack depth migration projects with some success. Results seen by the author have included mild to moderate lateral variations in near surface velocity of up to 100 to 300 m/s per km, including some mild vertical velocity inversions of up to 200 m/s.

Data from recent 2D and 3D surveys over the WA-246-P exploration permit were used to compare depth migration results using velocity models created from indirect measurement using reflection tomography and direct measurement using diving wave refraction tomography for the near surface velocity field. The existing 2D and 3D time migrated data showed good data quality over much of the permit, but exhibited regions of poor data quality in a fault shadow over the main prospect. Initial trials using diving wave refraction tomography produced a near surface velocity field showing vertical velocity inversions of up to 800 m/s and strong lateral velocity variations of up to 500 m/s per km.

This paper will compare the results of pre-stack depth migration using velocity models created from indirect (reflection tomography) and direct (refraction tomography) measurement of the near surface velocity field in an area of shallow carbonate overburden.

The eventual goal is to combine the refraction tomography with reflection tomography so that it is not necessary to define a hard boundary at the base of the near surface high velocity layer. The base of the near surface carbonates is usually a gradational change in lithology and therefore occurs within a section of weak reflections and is very difficult to pick directly from seismic. It would therefore seem more useful to be able to use a gradational change from near surface velocities to deeper subsurface velocities by using the two velocity derivation methods (refractions and reflections) together.

SEISMIC MULTIPLES

Practical implementation of interbed multiple attenuation

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Interbed multiples are frequently a problem at target levels in seismic data. These multiples are often generated in high velocity layers, and consequently have little differential moveout compared to the primaries with which they interfere. In addition, statistical methods such as predictive deconvolution frequently fail to remove these multiples (for example as a result of geological complexity) or else they attenuate primary energy beyond a level that is considered acceptable. In such cases the only remaining approaches to attenuating the multiples are based on modelling and subtraction.

This paper describes one such method, which uses primary reflections in the data themselves to predict interbed multiples via a technique analogous to that used to predict surface multiples. The paper concentrates on the practical aspects of the method and is illustrated with synthetic and real data examples. It is shown that reasonable predictions of interbed multiples can be obtained provided great care is taken at every stage of the data preparation. Although presently in its infancy and computationally very expensive, it is envisaged that the method will find its place in future processing flows when alternative algorithms are not successful.

Predictive deconvolution for non-random reflectivity sequences

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Predictive deconvolution is one of the most widely used of all seismic processes. Perhaps because it has become a 'standard' over the past three decades, there has developed a tendency to overlook the basic assumptions of the method. One fundamental assumption is that sedimentary geology is non-cyclic, resulting in a reflectivity function which is random. In real sedimentary basins, however, this assumption is often violated. It is perhaps not surprising, then, that predictive deconvolution sometimes fails dismally.

One published approach for overcoming this problem is to apply a pre-filter which attempts to correct for reflectivity non-randomness prior to deconvolution. Here we investigate an alternative approach where the non-randomness is accommodated in the predictive deconvolution algorithm itself. An initial estimate of the prediction error filter is based on the standard random reflectivity assumption, with the modified solution being obtained iteratively. The degree of non-randomness to be incorporated into the solution can be estimated using well-log data, or by trial and error.

A series of synthetic trials based on log data from several Australian basins suggests that the algorithm has the potential to significantly reduce the errors implicit in conventional spiking deconvolution. The paper will include comments on methodology, and will discuss performance of the algorithm on synthetic and real test data.

Seismic preconditioning before autoconvolution based multiple attenuation

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Multiples are seismic events that have undergone more than one reflection. If these events are not removed from seismic sections, they can be misinterpreted as primaries or interfere with them, thus confusing the sub-surface structural information used in interpretation.

The 3-D multiple moveout (MMO) and Iso-stretch radial (ISR) transforms are used to pre-condition data so that multiple events on a trace become periodic and the wavelet is stationary in each ISR trace. Wavelets are, however, stretched differently in ISR traces. These transforms aid in the attenuation of multiples by the autoconvolution method.

Using autoconvolution to predict multiples, a statistically optimised filter is derived based upon the characteristic wavelet. This filter is then applied to attenuate all surface related multiples in one pass, as if the multiple amplitudes form a geometric series. Successive applications may be used for further optimisation.

A further pre-conditioning method, as an extension to the 3-D ISR and MMO transforms, has been devised. This transform makes the wavelet of the same event constant, from trace to trace, across the record. This enables traces to be stacked into one, as all traces have the same multiple content after pre-conditioning. Optimal modelling of the multiple sequence is derived from this single stacked trace. Subsequently removal from individual traces is achieved with a dramatic improvement in processing time.

The performance and potential commercial applications of these methods have been evaluated and tested on Western Geophysical's Gulf of Mexico data set, previously used by the SEG to test multiple attenuation techniques. Successful surface multiple attenuation has been achieved with the techniques presented, where other traditional methods have been less successful. The new techniques in this paper are not computer intensive and do not require velocity analysis prior to their application.

REGOLITH (1)

Using AEM data to map Palaeo to Mesoproterozoic lithology and structure in areas of complex regolith and topography.

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Palaeo-and MesoProterozoic sediments in some highly prospective parts of Australia are often lacking in significant magnetic susceptibility contrasts.. As a result, their mapping by magnetics is difficult and confusing. Where these rocks are weathered, and where they are characterised by a complex regolith including transported overburden and a varied vegetation density, the application of other mapping technologies such as radiometrics or remote sensing may also be difficult. In this paper we examine the potential of electromagnetic methods for mapping in such settings. Specifically we describe results from the processing and interpretation of a regional GEOTEM 75 Hz data set to aid the mapping of complex structures and lithology in the Western Succession of the Mt Isa inlier in Northern Queensland. The survey area , comprising some 12 000 line-km, covers folded and faulted Mesoproterozoic sedimentary rocks of the McNamara Group which are unconformably overlain in the west by Cambrian sediments of the Georgina Basin The study area extends northwards for some 100 km from the Lady Loretta Zn-Pb-Ag deposit, and is prospective for other base-metal deposits. We give particular attention to the potential of image processing based methods for enhancing and displaying subtle contrasts in the conductivity of essentially non-magnetic sediments which include dolomitic, siliceous and carbonaceous siltstones, laminated shales, sandstones, conglomerates and limestones. We show that RGB colour composites of the AEM data reveal structure and stratigraphic variations that have not been identified in previous mapping. Besides looking at the effectiveness of these images for displaying useful information, we also examine the value of transforming the data to CDI's for enhancing structural and stratigraphic detail.

The gravity - borehole residual extraction and modelling technique utilised in this study has general application to mining, petroleum and basin studies where a large amount of reliable depth control is available to constrain the layered earth gravity model, giving new impetus to the use of high resolution gravity.

Electrical structure of the regolith in the Lawlers District, W.A.

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The Lawlers district lies within the Eastern Goldfields Province of WA and encompasses a number of working gold mines. It has a variably conductive complex regolith, overlying a granite-greenstone basement and was one of several areas used in a recent AMIRA project (P407) whose aim was to improve the effectiveness of airborne electromagnetics in Australia.

Part of the area was flown with the SALTMAP AEM system, with some ground EM follow up and physical property measurements on samples collected from the open cut mines. The work showed that, although the regolith may have as many as six separate units overlying the basement (i.e. colluvium/alluvium, ferricrete, mottled zone, saprolite, saprock and possibly a palaeochannel), the electrical and EM data were only able to resolve three distinct layers. However, this structure provided a good fit to more than 70% of the AEM data. Areas of poor fit included ridges of resistive greenstones where the responses were close to the system noise level and a block of data affected by problems with the data acquisition. The SALTMAP data were interpreted after applying a 1D inversion and the CRC's CDI process. The results were comparable, but there were some differences with perhaps the most significant being that the CDI was about 100 times faster.

Thus at Lawlers, the resulting vertical electrical structure may be collectively classified as a resistive (~100 Ω) surface layer of colluvium/ alluvium/ ferricrete (0-30 m thick), a conductive (~10 Ω) intermediate layer of saprolitic materials and/or sediments (0-100 m thick), overlying a uniformly resistive (~1000 Ω) basement. The work has identified several avenues for improving the collection and interpretation of AEM data: one example being the importance, and difficulty, of correctly removing the effect of the primary field.

Simplified electrical structure models at AEM scales

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Fixed wing AEM data in Australia commonly exhibit numerous local responses, most of which have been attributed to regolith inhomogeneities rather than the isolated conductive targets of sulphide exploration. To define the regolith structures affecting AEM data several steps are needed. The first involves selecting a geological mapping scale matched to the scale of an AEM system. Generally, any confined conductive target cannot be detected at a distance more than a few times its lateral dimensions. With a nominal transmitter altitude of 120 m, this would set (say) a 30 m or 40 m minimum size on any structure likely to produce an anomaly. Sensitivity analysis indicates that an AEM system is insensitive to features located more than 200 to 300 m from the system. Long narrow features can however gather current and be detectable. A mapping scale was therefore indicated in the range between 1:10 000 and 1:100 000.

In the Lawlers district of WA, the electrical structure generally consisted of 3 layers, specifically a thin, moderately resistive layer of alluvium/colluvium overlying a thick (commonly 30 to 50 m) conductive layer of saprolite/sediments, overlying a relatively resistive basement. One or both of the upper layers are absent in some areas.

Seven important structures were identified at Lawlers at the scales suggested above. Drillhole data, ground and airborne EM, and ground resistivity, were used to define vertical and lateral variations of importance within this overall layering scheme. The electrical structures were classified as 1) Layer (locations far from lateral inhomogeneity), 2) Contact, 3) Wedge, 4) Variable basement topography, 5) Variable surface topography, 6) Lateral inhomogeneity and 7) Palaeochannel model. Geological and physical reasoning constrain the permissible geometry and dimensions of each of these structures.

When AEM data in map form is interpreted by a geologist or geophysicist using other constraints (derived e.g. from drilling, magnetics, radiometrics etc.), it is possible to attribute an appropriate model from the above set to virtually every local anomaly observed in the survey. Once this is done, the slow process of modelling and interpreting individual responses may be attempted, in particular to distinguish bedrock target responses from those due to regolith structures.

Geological constraints on regolith electrical structures: Lawlers, Western Australia

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Interpretation of AEM data from the Lawlers District, W.A., indicates that areas of complex regolith cover are characterised by marked variations in electrical conductivity. Analysis of these data, coupled with ground EM, petrophysics and drill hole geology indicates that conductive zones lie within the regolith, usually between a thin, relatively resistive, surface layer and a resistive basement. The conductive layer is commonly associated with the saprolite and to a lesser extent with alluvium in palaeochannels and drainage sumps. Combined interpretation of the AEM with aeromagnetic and field data suggest that the conductivity structure exhibits a strong lithodependence. Structure is also important. 1D Layered earth inversions and CDI's showed that the conductivity and thickness of regolith materials (predominantly saprolite) varied with lithology. For example, the felsic volcanics located in the NE margin of the survey area are characterised by a thick, poorly conductive saprolite. This contrasts with a thinner, more conductive saprolite developed over adjacent mafic lithologies. Somewhat surprising, were the electrical characteristics of the ultramafic units which appeared to be similar to those of the felsic volcanic units, suggesting thick, relatively resistive, materials. This behaviour is at odds with that reported in other studies concerning the electrical properties of weathered ultramafics in other environments. At Lawlers, significant gold occurrences appear to lie at the boundary of resistive (silicified?) areas identified in the AEM data , an important conclusion if it can be generalised. The Lawlers study suggests that differences in the regolith electrical properties of the saprolites can be attributed to the complex interplay between the manner in which particular lithologies weather, the character of the resulting regolith in terms of porosity and permeability, and to variations in the soluble salt content and quantity of the saturant waters. The "EM response map" of the Lawlers area is further complicated by a the presence of transported cover which appears to impose a cross cutting conductivity structure over that of the underlying saprolites.

CASE HISTORIES (GENERAL) (1)

Base metal discovery at the Hill 800 Prospect, Victoria

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The Hill 800 Prospect is located northwest of Licola in the eastern highlands of Victoria. It was discovered in 1994 and is currently being explored by Mount Wellington Gold N.L. as a volcanic hosted massive sulphide prospect in the Cambrian Jamieson Volcanics. Soil geochemical data show high gold values in an oxidised and altered cap near the top of Hill 800 and high copper values in altered volcanics to the south and west of the hilltop. The best assay values in drillholes are 37 m @ 3.16 g/t Au from 0.5 m, and 6 m @ 1.1% Cu from 253 m.

The gold and copper mineralisation currently detected at Hill 800 does not have a significant geophysical response. The airborne magnetics and radiometrics, airborne frequency-domain electromagnetics (DIGHEM), airborne radar (AIRSAR), ground magnetics, fixed-loop time-domain electromagnetics (SIROTEM), and induced polarization surveys have been useful for regional geological mapping.

The regional magnetics show a highly magnetic source beneath Hill 800. This has been modelled as an intrusion that comes to within a hundred metres of the surface, so it is a likely source of the alteration fluids. Induced polarization results have accurately predicted pyrite enrichment (+/-gold). A drilling target was defined from a 3-D model of inverted 100 m line-spaced data. The induced polarization chargeability anomaly was associated with high resistivity, and when drilled, was found to be caused by disseminated sulphides (pyrite). SIROTEM data show subtle high conductivity at late times in an as-yet-untested area. A downhole magnetometric resistivity survey indicates a conductive source off-hole at about 400 m depth in this area.

The rugged terrain and harsh weather conditions have required the use of geophysics, but in some cases resulted in degraded data. Many different methods have been trialled, but only the recent re-visualisation of the induced polarization data has resulted in a successful drilling target from geophysics.

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Aeromagnetic imaging of gold mineralised structures in Archaean greenstone and granite terranes northwest of Kalgoorlie, Western Australia

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Low-level, high-resolution aeromagnetic surveying (flight line spacings ~50 m, mean terrain clearance 20-50 m) has proven to be extremely useful for imaging magnetic rock units and mineralised structures in all of Centaur Mining and Exploration Limited's gold mining and exploration project areas. These areas include gold in tholeiitic basalts and dolerites (Mt. Pleasant, Grants Patch and Ora Banda), gold in high magnesian basalts and ultramafic rocks (Zuleika and Carbine), and even gold in granites (Woodcutters). Regional gold mineralisation trends follow the NW striking greenstone fabric that is defined by stratigraphy, ductile shear zones and necking lineations. A NW trend in mineralisation also sits in granite, following the axis of the Scotia-Kanowna dome. The Woodcutters prospect area occurs along this granite trend and is approximately 6 km from the nearest greenstone belt. All of these gold mining centres occur where the regional mineralisation trends cross through favourable host rocks and are coincident to i) flexures in the greenstone belt, and/or ii) NE striking zones of late-stage brittle-ductile faulting. The late-stage faults have small offsets and weak magnetic signatures, and therefore present a challenge for aeromagnetic imaging. At Woodcutters, the aeromagnetic data clearly show sets of east-west trending late-stage faults that link up with the main mineralised fault zones to produce a rhombic shaped block that is ~2 km wide and is rimmed by weak to strong gold mineralisation. Improvements in airborne magnetic data quality, navigation and image processing, combined with affordable acquisition costs (<$7 per line km), have enabled imaging of very subtle magnetic responses to more accurately track rock units, map the regolith and identify key mineralised structures at prospect scale. GIS integration of this magnetic imagery with a sizeable geological and geochemical database has provided a better understanding of the existing ore bodies and is helping to further narrow the exploration focus on well defined target areas.

Geophysical surveys at the Nkomati Mine, Mpumalanga, South Africa

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Nkomati Mine, a joint venture between Anglovaal Mining and Anglo American, exploits a magmatic Ni-Cu-Co-PGE massive sulphide deposit associated with the Uitkomst Complex, in Mpumalanga, South Africa. The mineralisation consists of flat-lying massive sulphides, which are magnetic, dense and conductive and geophysics has been used to assist the exploration program for further resources. Methods that were tried include surface magnetics, gravity and controlled source audio magnetotelluric (CSAMT) surveys, plus drillhole electromagnetic (DHEM) and drillhole magnetometric resistivity (DHMMR) surveys.

The downhole methods were the most effective for the deep targets. Because of the highly conductive nature of the sulphides, standard impulse type time domain DHEM did not give good results until transformed into step type data, however strong responses were obtained from some innovative frequency domain measurements. Since all of the holes were vertical, no useful cross component data could be collected and the location of the sources suffered from radial symmetry. In contrast, the DHMMR was able to resolve on which side of the hole the conductors lay.

The CSAMT successfully defined the disseminated and massive mineralisation at depth, but the removal of static effects was a major problem and in some cases spurious responses were produced due to source location. The surface magnetics and gravity were useful for outlining relatively shallow mineralisation outside of the main complex. Qualitative interpretation, and modelling of the gravity and magnetic data, showed a good correlation with the CSAMT results.

SEISMIC METHODS

Direct Hydrocarbon indicators at the Macedon-Pyrenees Field

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There are examples of hydrocarbon accumulations in the Exmouth sub-basin that exhibit anomalous amplitude and AVO behavior which are related to the presence of hydrocarbons. These include the Scarborough gas field, the Jupiter and Vinck gas discoveries, and the Macedon-Pyrenees oil and gas field. In these cases, the pre-drill recognition of anomalous amplitude behaviour aided the decisions to drill the discovery wells. In the case of the Macedon-Pyrenees oil and gas field, high seismic azmplitudes caused by gas were recognised pre-drill within the Windalia Radiolarite unit. This unit overlies the Barrow Group reservoir section at the Macedon-Pyrenees field. The mapping of gas-related seismic 'brightening' of the Windalia Radiolarite unit provided an independent check on the depth conversion of the structure and was a key factor in promoting the structure as a drillable prospect. Since the discovery well, seismic brightening of the Windalia Radiolarite has been recognised over a number of other fields. This fact provides an indication that valid structural closure exists at the Barrow Group, and the possibility of the presence of hydrocarbons. Further seismic analysis has concentrated on the recognition of gas-related brightening and amplitude variation with offset (AVO) behaviour of the Barrow Group reservoir sands. This work has been carried out to aid exploration in other parts of the WA-155-P exploration permit and in surrounding areas of the Barrow and Exmouth sub-basins. The results of an acoustic impedance study utilising well data have shown that the Macedon sands sub-unit of the Barrow Group should brighten significantly when charged with gas. AVO modelling using recorded P-wave and S-wave data has shown a change in AVO behaviour between Macedon sands filled with gas, and similar sands filled with brine. Detailed reprocessing of seismic data across the Macedon-Pyrenees field has been carried out to see whether the modelled behaviour of gas-filled Macedon sands could be recognised on the seismic data. Seismic data quality has been improved significantly through reprocessing and a strong relationship can now be seen between seismic brightening and gas-filled Macedon sands.

Wide angle reflectivity-another amplitude dimension

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Deep water reflection seismic data contains high signal to noise ratio returns from pre-critical reflection angles of 60 degrees and beyond. Wide angle reflections contain information not available in conventional 0 to 30 degree seismic data and they can be used to improve structural images and subsurface property estimates. These reflections add a third dimension to the two-dimensional reflectivity model that underpins conventional AVO analysis. The viability of such reflections was confirmed 3 years ago in a NW Shelf deepwater walkaway VSP that also revealed significant accompanying earth transmission effects.

Acquisition of wide angle reflections in 1 km of water at 3 km target depths is achieved with a streamer length of about 5 km. Processing wide angle amplitudes into subsurface reflectivity has required extensions to several processing applications including amplitude recovery (divergence, elastic/inelastic earth transmission), reflection angle estimation, velocity analysis, and deconvolution. Qualitative use of the wide angle information is achieved by creating wide angle stacks to complement zero offset projection stacks and 0-30 degree stacks.Quantification of wide angle reflectivity is proceeding with improvements to AVO gradient estimation and with weighted stack inversions for independent estimates of density, compressional and shear velocity changes across reflector interfaces. Translation of these event responses into petrophysical properties can be achieved by existing modelling codes or by attribute analysis.

The rewards for recovery of wide angle reflectivity have been reduced resource uncertainty in deep water acreage due to increased confidence in the detection of amplitude anomalies and in the translation of amplitude responses into subsurface causes. A significant remaining challenge is to detect and compensate for earth transmission effects induced by small scale lateral earth heterogeneity without altering estimates of the earth reflectivity.

Depth Fold Illumination - shedding new light in difficult data areas

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For years geophysicists have used CDP fold diagrams to estimate subsurface coverage prior to seismic acquisition. These diagrams can be misleading when exploring in areas of significant structure or velocity variation because the fold coverage diagram is based on the seismic array alone and typically does not incorporate the earth model.

Features such as moderate structural dip, lateral velocity variations, vertical compaction gradients, gas clouds, and diapirs all cause distortions in the seismic image. These distortions also affect subsurface fold coverage; creating areas of focused energy and shadow zones.

A new technique, called DepthFold Illumination, has recently been developed which incorporates the earth model in fold coverage diagrams. High-density 3D forward ray tracing is used to estimate seismic coverage at depth. This technique has many uses; such as:

- Improve seismic acquisition parameters.
- Determine if 3D prestack depth migration is appropriate for a given data area.
- High-grade areas selected for AVO analysis.

This paper explains the DepthFold Illumination technique and shows several examples of how DepthFold Illumination is being used by companies to make faster, more accurate business decisions.

SEISMIC ANISOTROPY (2)

Determination of the average and interval elastic parameters in multi-layered transversely isotropic media: physical modelling approach

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Physical modelling facilities and anisotropic inversion techniques have been used in this research to recover the average and interval elastic parameters and average P-wave velocity field information in layered transversely isotropic media. The elastic parameters recovered are the vertical P-wave velocity ($\alpha 0$), the vertical S-wave velocity ($\beta 0$), the P-wave anisotropy (ε) and the near vertical P-wave anisotropy (δ). Experimental models constructed with isotropic and anisotropic modelling materials with vertical axis of symmetry were used in acquiring transmission data. Inversion codes developed in-house at the Department of Exploration Geophysics, Curtin University were used to invert travel time data to recover the average elastic parameters e and d. The average vertical P and S wave velocities $\alpha 0$ and $\beta 0$ were determined from first arrival times observed from physical modelling experiments. These velocity values were used as input to the inversion program that recovered the average elastic parameters. The interval parameters for each particular layer were recovered by another inversion program that utilised the elastic parameters of the multi-layered model.

Physical modelling transmission data obtained from experiments indicate that the effect of the transducer size needs to be considered. Inconsistencies in d values recovered from the two layer models and the interval elastic parameters e and d recovered from the three layer models indicate that corrections must be applied to compensate for the large size of the Piezoelectric transducers. The accuracy of the inversion results was observed to decrease as the ratio of the transducer width to the model thickness increased. When the ratio of the thickness of the model to the size of the tranducers is not large enough, the size effects of the transducer must be accounted for. Numerical modelling also demonstrated the effects of transducer size on the recovered elastic parameters. Point size transducers were successfully used to overcome the transducer size effects, and hence, obtain more accurate results. The accurate recovery of the elastic parameters when applied to walkaway VSP data will permit accurate depth imaging and reservoir volume estimates.

Attenuation measurements in the South Sydney Basin

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From the coal exploration results in the South Sydney basin, it is known that gas may be present throughout the sedimentary sequence but in varying concentrations. This has been highlighted by recent results obtained from the full waveform sonic logging. To examine the variations in more detail, several VSP surveys were selected at different localities for the attenuation studies. The quality factor Q has been estimated using a pulse broadening method (Hatherly, 1986). Beside an average Q estimate for the first 500 m of the sediments down to the exploration target which is the Bulli seam, an interval Q measurement for the three major units was also established. Consistent values of Q were obtained throughout the study.

Measurements of the attenuation values for the sub-weathering layer were also made using refracted waves from the surface seismic data. The pulse broadening method is particularly suitable for Q estimation via refraction arrivals because unlike interval VSP measurements, the computations are made across the same layer. Still, the refraction and VSP results are in very good agreement. Furthermore, the attenuation results correlate very well with the results obtained from the full waveform sonic data.

In a structurally disturbed area characterised using surface seismic sections and the multi-offset VSP imaging results, the attenuation measurements over the depth interval 50-350 m show very low Q-values of only 12-15. Higher values of 25-30 were estimated for the same interval in undisturbed zones. In all of the measurements, the underlying Bulgo sandstone had higher Q-values (45-53) than the overlying units.

There are major implications for these measurements with respect to gas drainage programs prior to coal extraction, gas release during mining and the planning of seismic exploration in the area.

REGOLITH (2)

Geological constraints on electrical structures identified in Gilmore Fault Zone TEMPEST AEM data - implications for exploration in an area of complex regolith cover

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The Gilmore Fault Zone, located in the Lachlan Fold Belt of western NSW, is a major NNW-trending structure that may have a significant role in localising mineral fluids in the region. Recently, TEMPEST AEM data were acquired over the area, with a view to developing its mineral potential by better understanding the geophysical expression of porphyry and epithermal Au and Au-Cu mineral systems characterised by a complex regolith cover. Analysis of these data showed that areas of regolith cover are characterised by marked variations in electrical conductivity. Their combined interpretation with aeromagnetic and field data, suggests that the observed conductivity structure exhibits a strong lithodependence. More conductive areas are commonly associated with volcanic rocks. Structure is also significant in controlling EM response. A combination of ground and downhole electrical geophysics and drill hole geology indicates a variable vertical conductivity structure, with more conductive zones commonly associated with the saprolite and with transported cover, including parna and alluvial materials in buried palaeochannels. Initial results suggest that variations in the electrical properties of the regolith may be attributed to a complex interplay between the manner in which particular lithologies weather, alteration zoning, and the character of the resulting regolith in terms of porosity and permeability, and to variations in the quality and quantity of groundwaters. Modelled responses for the TEMPEST data show that a 1D layered earth inversions and/or CDI's are effective at describing the gross conductivity structure for the area. From a mapping perspective, information from the TEMPEST system complements data from other airborne geophysical data sets, most notably magnetics, by providing new insights into geometry of regolith-fresh rock interface and variations in regolith thickness. The characterisation of buried alteration and mineralisation using airborne EM techniques is also discussed.

Automatic merging of gridded airborne gamma-ray spectrometric surveys

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Older airborne gamma-ray spectrometric survey data were often presented in units of counts per second. These data values are dependent on survey and equipment parameters such as detector volume, survey height, and the window energy limits used to measure the gamma radiation. Thus, data values on adjacent surveys may not be directly comparable. This is a critical problem for the interpretation of data over large areas, as it is difficult to reliably relate radiometric signatures in one survey area to those in another.

The conventional solution to this problem is to 'back-calibrate' the data from older surveys to ground level concentrations of the radio-elements. This requires a linear transformation of the data that incorporates both a scaling (to accommodate detector volume, flying height and window widths) and a base-level shift (to accommodate inadequate background removal). The usual method of determining these scale and shift parameters is through field measurements using a calibrated portable spectrometer. However, because field work is expensive, an alternative solution is sought.

An alternative approach is to use the differences between gridded survey data values in those areas where the surveys overlap to automatically estimate a base-level shift and scaling factor which, when applied to one of the surveys, minimises the differences in the overlap region. In this way an un-calibrated survey can be merged with a survey already calibrated to elemental concentrations of the radio-elements. Surveys can then be sequentially merged (or 'levelled') to produce regional compilations of the data. A similar approach has been used for many years to level aeromagnetic data. However, this sequential approach tends to propagate joining errors and introduce regional trends into the merged data.

A new method overcomes this problem by considering the levelling of all of the grids in the regional compilation as a single inverse problem. Using a two-stage approach, the best base-level shift and scale for each survey grid is estimated. The first stage estimates the best relative shift and scale for each overlapping grid pair which, when applied to one of the pair, gives a least-squares fit to the grid values in the overlap area. The second stage uses the relative shift and scale parameters to estimate an absolute shift and scale for each grid that both honours the relative shift and scale parameters (in a least-squares sense) and brings each grid to the same absolute level as one or more base grids. The method works well as long as the data in the overlapping survey areas has a reasonable dynamic range.

OARS - A new system for mapping surface mineralogy simultaneously with airborne geophysics

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The Operational Airborne Research Spectrometer (OARS) is a novel hyperspectral profiling reflectance spectrometer developed by CSIRO and World Geoscience Corporation (WGC) to examine alternative means of collecting and delivering exploration data, based on the principles of reflectance spectroscopy. OARS is a component of CSIRO's long-standing "Airborne Mineralogy" Concept.

OARS can be integrated with other geophysical instruments, principally airborne magnetics and radiometrics, and can be flown simultaneously on exactly the same flight lines. It will measure ground reflectance spectra from contiguous 8m pixels from an altitude of 80m.

After data processing, interpolated images of relative mineral abundance will be reconstructed using GPS positioning data to produce a variety of mineralogical maps.

OARS consists of a downward and an upward-looking spectrometer each covering some 190 spectral channels in the visible to short-wave infrared range, with an average spectral resolution of 10nm. This wavelength range allows OARS to map most species of phyllosilicates, clays, sulphates, carbonates and iron oxides, that occur in alteration zones, the regolith and host rocks. Green and dry vegetation are also mapped. A CCD camera allows monitoring of the flight path while flight attitude sensors and GPS are used for geo-location.

The instrument was first tested in late '98. Subsequent test surveys in early '99, over a more challenging geological area in NW Australia, verified its ability to deliver new mineralogical data.

CASE STUDIES (GENERAL) (2)

Geophysical signatures associated with the Gossan Hill Deposit

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The Archaean Gossan Hill VHMS deposit occurs within a sequence of steeply dipping felsic lavas, tuffs, volcaniclastics and sediments of the Warriedar Fold Belt in the Yalgoo-Singleton Greenstone Belt. This greenstone belt lies within the Murchison Province of the Yilgarn Craton, Western Australia.

The Gossan Hill deposit is 4 km to the south of the Scuddles orebody and has a primary sulphide resource of : 4.92 Mt grading 4%Zn and 2.3%Cu. Zinc mineralisation occurs as discrete tabular bodies (Panels A, B and C).

The main copper mineralisation occurs as lenses stratigraphically below the zinc, with associated pyrite and magnetite.

Gossan Hill was discovered in 1971 by Aztec geologists during a regional base metal exploration program. In mid-1997 it was decided to undertake a series of bench marking geophysical surveys to characterize the orebodies prior to mine development. These surveys were also designed to assist in the exploration for any undiscovered lenses and panels of zinc and copper mineralisation respectively. These benchmarking surveys included a wide array of techniques with the primary focus being on fixed loop and down hole electromagnetics to target stringer or massive mineralisation. The stringer mineralisation, typically pyrrhotite, is used as a vector to massive primary zinc (sphalerite) mineralisation whilst massive magnetite and pyrite and associated pyrrhotite which are directly associated with the copper mineralisation.

The aim of this paper is to not only discuss the "classical" geophysical signature(s) of the Gossan Hill deposit but to also highlight several unexpected and interesting responses encountered. For example one unexpected response was the presence of a horizontal conductor in the fixed loop data over C-panel as opposed to the expected vertical conductor, which has been attributed to a thin matrix of native copper at the base of oxidation.

Numerous other survey techniques or configurations were also acquired including downhole magnetics, petrophysical logging, moving loop EM, detailed gravity and Dighem surveying and these will also be discussed.

Physical properties of the Lawlers regolith, WA

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The regolith in the Lawlers district, WA, can be classified as a number of geologically identifiable layers. Saprolite commonly forms one of the thickest and least dense of these layers, and appears by far to be the most porous material encountered in the section. Porosity derived from many samples averaged 37.8%. The solid constituents of saprolite are not solely clay, but rather it is an extremely weathered rock type with a retained fabric that supports its structure. Physically it behaves as a clayey sand. While the constituent clays (predominantly smectite over mafics and ultramafics, and kaolinite over felsics) are inherently conductive, the immense porosity predicts that the measured conductivity of saprolite in-situ should be dominated by the salinity of the local groundwater, even if contained fluids are only slightly saturated.

Previous work by Palacky has suggested that the conductance and/or conductivity of the saprolite layer is different over different lithologies, . However, physical property measurements indicate that the conductivity of saprolite cannot uniquely be used to determine parent lithology; physical property studies indicated overlaps in properties for metasedimentary, felsic, mafic and ultramafic saprolites and also overlying palaeochannel clays. Provided that groundwater conductivities are not too variable, diagnostic onductance differences however may occur, particularly since the saprolite layer over felsic lithologies is usually reported to be thinner than that developed over mafics or ultramafics

Below the saprolite layer, a saprock layer is defined that contains the transition from virtually unweathered bedrock to heavily weathered saprolite. This transitional layer retains much of the structural strength and density of bedrock, and thus has very similar seismic velocity to bedrock. Its conductivity however, is far greater than that of the bedrock: possibly reflecting the influence connected conductive paths marking the passage of fluids, during the weathering process.

Above the saprolite, regolith materials have much lower porosities and higher densities. They also tend to be lower in conductivity than the saprolite. The geological processes of surface and mid level ferruginisation, accompanied by silicification and deep argillisation all strongly affect measured physical properties.

The geophysical response of the Hercules base metals deposit: A case study from Western Tasmania

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The Hercules volcanic-hosted massive sulphide Zn-Pb-Cu-Ag-Au mineralisation in western Tasmania presents a difficult geophysical target even though it is hosted within highly resistive volcanics. The deposit is made up of a number of small, steeply dipping, ore lenses. Limited petrophysical data indicates the ore to be poorly conductive, non-magnetic, of moderate density and moderately chargeable.

Regional aeromagnetic, airborne electromagnetic and gravity surveys do not appear to identify the mineralisation. Responses from electromagnetic surveys are attributed to the overlying black shale sequence. Mineralisation has been detected from induced polarisation surveys, however, the black shale sequence is often found to be chargeable.

The Hercules deposit lies within the same alteration system as the Rosebery volcanic-hosted base-metals deposit, located approximately 7 km to the north. Mineralisation at Rosebery is contained within larger pods, is more conductive and easier to detect when the overlying black shales are thin or absent.

BOREHOLE MODELLING

Acoustic compression wave velocity modelling in sedimentary sequences

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Layered-clay shale density increases systematically with increasing depth of burial by progressive explusion of pore water:

$$\rho(z) = \rho_0 + (\rho_\infty - \rho_0)(1 - e^{-kz})$$

Using elastic wave propagation theory, this shale density function can be transformed into a shale velocity prediction. Providing shale and water chemistry remain relatively stable, the progressive reduction in shale porosity and contained water also results in systematic changes to shale resistivity.

More general formation (mixed lithology) sonic slowness can be modelled using established log interpretation transforms (the Archie porosity - resistivity and Raymer-Hunt-Gardner porosity - slowness relationships). The difference between measured formation resistivity and predicted shale resistivity is then interpreted in terms of departure of the expected slowness from that of pure shale. When added to the expected shale slowness, the combined slowness shows good agreement with observed sonic log data.

This provides a new technique for prediction of formation velocities. The technique can be used to improve the quality of sonic log data, and can be applied where no sonic data were acquired. Numerous technical and commercial applications result.

Well-site quasi-2D inversion of array resistivity logging data using neural networks and dimensional reduction

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New generation galvanic array tools can provide high resolution resistivity logging data in conductive borehole environment. Fast and accurate interpretation of these array data lead to quick and correct decisions on well completions. Due to the high nonlinearity between the galvanic data and the earth formation, inversion is necessary in interpreting resistivity logging data. A typical array tool data set, however, consists of several tens of measurements at each logging depth, acquired at a dense sampling of 4 cm. Such a large amount of data not only makes inversion-based interpretation very slow, but also makes it impossible to delivery the results to the customers at well site.

In this paper, we develop a quasi-2D well site deliverable inversion algorithm that utilizes trained neural networks as forward modeling engines. We first convert the 2D data into quasi-1D data via numerical focusing. We further simplify the quasi-1D data by performing borehole correction. The numerically focused and borehole effect corrected 2D data are then inverted to provide information about the 2D resistivity structure. We use back propagation neural network to construct the forward modeling engine in the inversion. Synthetic tool responses, which are usually referred to as the training pattern, are first generated over a set of earth models covering a large range of resistivity contrasts and invasion lengths. The earth models used to create the training pattern are input to the neural network as the stimuli whereas the associated responses are used as the desired neural network output. The neural network is then trained to model the tool response. After the training, the neural network is validated and applied in a least square type inversion algorithm. We tested our inversion algorithm on both synthetic and field data. The numerical examples show that the fast inverse algorithm is a useful tool in providing information about the formation resistivity at well site

Effects of outermost boundary on acoustic waves in an artificial cased borehole

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Cement bond evaluation of a cased borehole has been studied extensively by using acoustic techniques. For example, experiments on laboratory scaled models and theoretical treatment including wave field modeling and mode dispersion analysis have been studied. The problem of bond evaluation for a second boundary and even for first boundary to some extent still exists.

In order to understand the effects of cement bond quality on borehole waveforms quantitatively and physically and to scale the sonic tools used in cement bond evaluation, people use a set of artificial cased borehole models to investigate the effects of cement, steel casing and formation on borehole waveforms. Since the model is artificial, the simulated formation is finite and naturally there is an outermost artificial boundary that has an influence on the borehole waves and hence has an influence on sonic tool calibration. So it is important to know how the outermost boundary affects the borehole waves and how we minimize these effects.

In this paper we treat the model for a cased borehole with a finite formation. First the closed form solution was derived, and then the full waveforms and spectra of the model for various formation radius and absorption material were calculated. The numerical results show that when the radius of the simulated formation is larger than 1.5 m, the outermost boundary has little influence on the borehole waveforms with the source receiver spacing between 1.0 m to 1.5 m at typical logging frequency range. While at spacing shorter than 0.5 m with the other conditions unchanged, the outermost boundary influence can not be neglected. In order to absorb the reflected energy from the outermost boundary, solid absorption material is better than a fluid one. The numerical results also show that even when the first and second boundaries are not well cemented, the effects of the outermost formation boundary on the borehole waveforms can not be totally neglected. For low frequency excitation, these effects are negligible. This is explained both in time and in frequency domains. Numerical results also show that low frequency mode waves have a very shallow lateral penetration.

EXPLORATION PHILOSOPHY (1)

GIS mapping of the Cobar region

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Competition for the exploration dollar from other States and overseas has never been greater. Through the New South Wales Government's Discovery 2000 Exploration Initiative, adding "value" to geophysical data is a very necessary component in opening up new areas for exploration. With the releases of high-resolution airborne geophysical data and detailed gravity data over the Cobar / Nymagee region in western NSW, the data have been imported into a Geographic Information System (GIS). This data is the foundation of a Geoscience Database Package which also includes the digital geology, soil types, historical titles, exploration drilling (1 900 points), mineral deposits (480 points), petrological data (5 550 points), stream sediment data (12 350 points), cadastral information and a number of written reports relevant to the area. The package is designed to provide a greater understanding of the geology and structure of the region and operates on both ArcView and MapInfo platforms. The area has been subject to mining in the past and is a target for current exploration. The largest deposits in the Cobar Sheet area are located in deep-water sedimentary rocks of the Cobar Supergroup. These are the deposits at the CSA mine, Elura mine and The Peak gold mine. The deposits display strong structural control, and metahydrothermal processes and deformation may explain the geometry of the deposits. The geophysical data now plays a major role in unravelling the complexities of the Cobar area by allowing the GIS user to integrate and interrogate different datasets. Besides being an essential dataset for effective exploration under cover, the GIS compatibility has already been an important aid to Local Councils, other governments departments and land-care groups.

Systematic spatial analysis as an approach to interpretation of airborne geophysical data

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In the past one to two decades, rapid improvements associated with GPS navigation systems, digital data recording technology and developments in computer technology have contributed to significant improvements in airborne geophysical data acquisition, processing, visualisation and interpretation. As a consequence of these developments, more high quality, well located and larger data sets are being collected. Furthermore, there is a developing trend towards using multivariate geophysical data suites. For example, airborne geophysical surveys for salinity studies routinely use magnetic, radiometric and electromagnetic data in conjunction with a suite of non-geophysical variables. This trend will be accelerated when new multi-instrument platforms such as CERBERUS become fully operational. The new generation of large, multivariate geophysical data suites presents a significant interpretation challenge. In particular, the traditional manual approach to geological interpretation of the data, based on a scientific, yet intuitive, assessment of visual cues, fails to be effective. This paper reports the application of systematic, spatial analysis techniques such as unsupervised classification to a salinity case study in Western Australia. The results are compared with traditional interpretation products for the same case study. It emerges that the information extracted using systematic, spatial analysis enables the interpretation to be significantly more detailed and thus enables new insight into the value and information content of the geophysical data. Indeed, some of the results obtained using the systematic approach could not have been achieved using the traditional, manual interpretation process. In the new millenium, further developments in this 'data mining' approach to interpretation should significantly improve interpretation outcomes and maximise the value of geophysical data.

POTENTIAL METHODS (4)

A low cost ATV towed array magnetometer survey for mapping intrusions in coal fields -Kayuga, Hunter Valley

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Currently available GPS technologies have enabled inexpensive geophysical surveys with data-positioning and navigation in real-time. In April 1999, GTL used real-time GPS with an ATV towed trailer array of magnetic sensors to perform mapping of dykes in the Kayuga Coal Field. The one-man operated trailer system did not require a physical grid set-up prior to the commencement of the survey. Recent improvements to the logging rate of the TM-4 magnetometer have enabled the system to travel at 30 km/hr and with an along-line sample interval of 0.5 m. The system guides the operator along the survey lines by use of a cross-track error bar displayed on the survey computer. The expandable array of magnetic sensors with adjustable height and separation allowed the optimisation of the system for the application. During 1998, the same system was used with eight sensors, 0.5 m apart for the detection of unexploded ordnance in North America. A standard four-wheel ATV was used for the both types of survey. The GTL trailer system enables practical, fast collection of high-resolution accurately positioned magnetic data for a variety of engineering geophysical applications. The GTL trailer system opens new possibilities of covering large areas efficiently and it is an important milestone in achieving effective large-scale surveys.

Interpreting crustal scale features using wavelet-based multi-scale edge analyses of regional gravity datasets

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Multi-scale edge analysis techniques developed by the CSIRO Division of Exploration and Mining enable detailed analysis of potential field data. This edge analysis technique allows differing scales of geological interpretation from a single data-set by looking at broader wavelength structures with increasing levels of upward continuation. The multi-scale edge picking technique has been developed for interpretation of 3D geological features. By simulating ever increasing upward continuations the technique uses wavelets to locate edges at various scales. The results are 3D 'worm' maps showing x,y,z and wavelet amplitude information. These data is then colour mapped according to wavelet amplitude. The actual edge information along with the overall spectral characteristics of an area highlight features in the data not obviously apparent in the raw potential field. Regional gravity data from Western Australia, Tasmania, Gulf of Mexico and Europe have been analysed using this technique. The results increase knowledge of the 3D structure of these terranes. Analysis of data from the Eastern Goldfields of Western Australia has identified a coarse-scale feature transecting the Kalgoorlie Greenstone Belt from SE to NW. This structure is discordant to the overall NNW-SSE trend of the lithologies in the belt but appears to have an influence on the distribution of nickel bearing komatiites and location of major gold mining camps. Furthermore a subtle ridge in the DTM at this location confirms the secondary evidence indicating to a presence of a previously unidentified geological feature. 'Worm' maps produced from offshore gravity data from the Gulf of Mexico reveal distinctive spectral characteristics between geological terranes. For example, the main salt deformation province in the Gulf of Mexico has a different feature density and intensity in the wavelet analyses than the hemi-pelagic mud province to the immediate south.

ELECTRICAL METHODS

Airborne electromagnetic bathymetry of Sydney Harbour

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An electromagnetic survey using the helicopter-borne DIGHEMV system was carried out over lower Port Jackson, Sydney Harbour. The survey area is bounded by a rectangle 5.5 km by 1.0 km covering the main shipping channels and extends from North Head (Manly) down to Bradley's Head and Shark Island. The study served to review the capacity of the DIGHEMV system to provide accurate bathymetry data in shallow seawater down to 30 m, which is the maximum depth of the survey area. The DIGHEMV system operated at frequencies of 385 Hz, 7 200 Hz and 56 000 Hz in a horizontal coplanar transmitter/receiver coil configuration and 900 Hz and 5 500 Hz in a vertical coaxial transmitter/receiver coil configuration. (The 56 000 Hz data was used to determine the transmitter/receiver height above the seawater upper surface and agreed with radar altimeter recordings.) In order to obtain high quality data with optimised signal to noise ratio, rigorous calibration procedures were carried out to ensure data accuracy. These included low altitude profiles over deep seawater of known electrical conductivity, thorough phasing and gaining over very resistive background at a remote site, and high altitude zero level calibrations throughout the survey flights. Twenty seawater conductivity soundings were taken on the day of the airborne survey at various locations in the survey area so that the variation of seawater conductivity with location and depth could be reliably estimated. The two-layer inversion algorithm yields a thickness of the upper layer (bathymetry) which is consistent with known records of depth soundings data from Navy charts and other sources. This study verified the use of airborne electromagnetics as a reliable bathymetric reconnaissance tool that can be used to rapidly survey shallow coastal waters.

Electromagnetic investigation of the Eyre Peninsula conductivity anomaly

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Seafloor and land magnetotelluric (MT) data were collected in the SWAGGIE (Southern Waters of Australia Geoelectric and Geomagnetic Induction Experiment) project in April-May 1998, from 30 seafloor and 23 land sites. The principal objective of the experiment was to delineate the strike and depth of a zone of high electrical conductivity, known as the Eyre Peninsula Anomaly (EPA) in South Australia. Three linear arrays of marine magnetotelluric instruments were deployed across the continental shelf and slope to locate the offshore extension of the EPA on the continental margin, and to image the continental-oceanic lithosphere-asthenosphere transition. A land array of magnetometers was deployed at the same time to better resolve the EPA in southern Eyre Peninsula. Robust remote-reference processing of time-series magnetic and electric data gives good MT and geomagnetic depth sounding (GDS) responses in the bandwidth of 101 to 105 s, corresponding to skin-depths of mid-crustal (10 km) to mantle transition (400 km) range. Initial processing of marine and land data clearly indicates that the EPA is continuous to the edge of the continental shelf, with a conductance greater than 15 000 S confined to a narrow, near-vertical zone. At sites distant from the EPA, one-dimensional MT inversions fit the data well and provide a background conductivity structure for two and three-dimensional forward and inverse modelling of the EPA.

Airborne electromagnetic bathymetry: an overview of several Australian surveys with implications for maritime defence in littoral waters

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The use of airborne electromagnetic (AEM) methods as a rapid environmental assessment tool for measuring seadepth (bathymetry) and sediment properties in shallow water could significantly enhance the capability of the Royal Australian Navy's maritime operations in littoral waters. The areas of defence application which could be supported by current technology include: mine countermeasures operations (route surveying of priority port approaches, mine burial prediction and measuring sediment properties that could influence mine-hunting sonar performance), amphibious operations (bathymetry, shore gradients, sediment properties to support heavy landing craft), hydrographic reconnaissance (complimenting the demanding hydrographic survey effort required to map Australia's extensive area of coastal waters, remote bathymetry sensing of turbid waters) and anti-submarine warfare (localised detection for degaussed submarines, geoacoustic modelling of low frequency sonar propagation). Several surveys have been recently performed to test the AEM technique and assess its defence applicability. The survey data, when combined with other datasets (single and multi-beam sonar and marine seismic reflection) can be used to rigorously test the accuracy of interpretation, inversion and modelling algorithms. The DIGHEMV survey of Port Jackson, Sydney Harbour, provides a useful route survey case study because the bathymetry varies from about 1 to 30 m and the seabed terrain features a rock reef straddled by two shipping channels. The QUESTEM 450 surveys in Geographe Bay and over Cape Naturaliste, W.A, were used to detect a shipwreck (symbolic of localised submarine detection) and to determine the maximum depth of investigation respectively. Combined with accurate ground truth data, the dataset can be used to quantitatively assess the AEM system, contractor data, and the efficacy of layered earth inversion and conductivity-depth imaging software. Conductivity sections can be used to estimate sediment properties and detect shallow bedrock.

RESERVOIR DYNAMICS

Shear wave observation using a down-hole hydrophone array

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We observed Shear waves using a down-hole hydrophone array to a depth of 453 m. The Shear(S-) waves were clear and a polarity reversal was observed when the source was struck from the opposite direction, in both the transverse case and radial case. Even though the tube wave was strong while the sensors were in the cased section, it was very weak in the non-cased part in contrast to the clear S-wave. We generated the S-wave by striking horizontally on one side of a wooden plank with a 4 kg wooden hammer. The PVDF (Poly Vinylidene Fluoride) hydrophone array was used for recording. The hydrophone has not its own directionality. In this observation, the phase of the waves are consistent and they are easily defined. This fact raises a question why hydrophone can detect polarity reversal. One possibility is the presence of anisotropy. The hodograms created from two directional source for the same depth of the hydrophone suggest the presence of the anisotropy. S-waves change the polarization direction due to anisotropy and split. Radial component of the split wave is converted to P-wave at the borehole and detected by hydrophones. A hydrophone array is easy to handle compared to the geophones which needs to be fixed to a borehole wall, and its use speeds up the S-wave measurement in a borehole. Further research is required to clarify these observations.

Magnetic signatures produced by fluid flow in porous sediments

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Laboratory experiments have demonstrated that a magnetic field is created during the displacement of water by oil in a porous medium. This magnetic field is interpreted to be generated by the electrokinetic effect. The results of the experiments are up-scaled to permit modelling of the electrokinetic-magnetic field generated by a producing oil field. Predicted maximum magnetic anomalies (measured at the Earth's surface) near oil wells, where the oil-water contact moves vertically at rates between 1 to 5 m/yr (conventional production rates), are in the vicinity of 1 nT or less. However, in the situation where producing wells have unstable pressure regimes, vertical flow rates can exceed 100 m/yr for short periods; maximum magnetic anomalies in the vicinity of 150 nT are predicted under such conditions. Accepting the interpretation that the electrokinetic-magnetic field is produced by randomly changing current loops in the partially oil-saturated zone (transition-zone) of the reservoir, the observed magnetic field is expected to exhibit time-transient behaviour.

The cause and effects of multilayer-generated guided-waves

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Seismic methods are commonly used by the petroleum industry to obtain reflections from geological boundaries that are prospective for oil and gas production. In the presence of near-surface high-velocity layers (i.e. sea-floor carbonates or basalts), a significant portion of the primary seismic energy is scattered. This results in very poor reflection data as little energy remains to be transmitted down further and subsequently reflected back to the surface. This dispersal of energy is characterised by the generation of guided-wave energy in low-velocity layers underlying the high-velocity overburden, resulting in the dominant horizontal propagation of seismic energy.

Poor reflections beneath carbonates cause a major problem for exploration in Western Australia, yet little research has been done to understand the guided wave phenomenon which mask reflections. Some papers provide mathematical treatise on reverberations while others try to migrate reflectors from beneath the high-velocity layers in an attempt to improve their image. None have properly explained the generation of the guided wave noise phenomenon. During 1998, physical models of high/low velocity layers were built in an attempt to simulate guided waves. Guided waves were simulated to the point that a prescriptive approach to their development was established.

The guided wave data were analysed and it was found that a direct relationship existed between the wave package velocity, dominant frequency and dominant wavelength of the guided waves, to the thickness of the low-velocity layer.

In this paper, an empirical formula is presented to estimate the interval velocity of the low-velocity layer, for the case of horizontally layered media. The results of a three-component recording simulation indicate that guided wave propagation is of pseudo-Rayleigh wave particle motion. This implies that the generation of guided waves is not solely due to total internal reflections within the waveguide, but also involves surface wave propagation along the surface of the underlying high-velocity layer. It is proposed that this surface wave refracts energy into the low-velocity layer

at post-critical angles, thus providing additional energy for total internal reflections within the waveguide.

EXPLORATION PHILOSOPHY (2)

Regional aeromagnetic interpretation of Australia and Southern Africa - The identification of several Proterozoic rift related dyke swarms

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In the initial stages of continental rift events, fanning dyke swarms are intruded along three arms oriented at approximately 1200 to each other. Successful rifting commonly occurs along two arms, leaving a third 'failed arm' dyke swarm, intracratonic trough or both.

Seven large dyke swarms have been identified during interpretation of regional aeromagnetic datasets. Each swarm shows different characteristics which give insights into the tectonic environment at the time of intrusion. Four are located in Australia; two in the NE of Arnhem Land, one in Western Australia and one in the Eastern Albany-Fraser Province. Three dyke swarms are located in Southern Africa; one in the Western Kaapvaal Craton, one in the Northern Kaapvaal Craton and one in the Kamanjab Inlier in Namibia.

All the swarms are interpreted as marking the initial stages of continental rift events. The swarms display different tectonic styles:

- The "Kheis", "Waterberg" and "Fraser" dyke swarms are examples of swarms related to a rift system which was subsequently overprinted by an orogenic event.
- Dyke swarms possibly related to the opening of an intracratonic rift are the Damaran rift parallel "Kamanjab" dykes and the Walker Trough subparallel "ArnhemI" swarm.
- The "ArnhemII" swarm fans through 900 and reflects a different crustal stress system to the other swarms.
- The massive "Northampton-Mundine Well" dyke swarm, a remnant of the break-up of Rodinia exhibits an asymmetry reflecting the crustal stress regime during intrusion.

The spatial characteristics of the swarms are determined by the orientation of the rift system and the regional stress field. For example the "ArnhemII" swarm which exhibits a wide fan angle indicates the crust was subject to a lower differential stress at the time of intrusion than the more focussed "Kheis", "Waterberg" and "Fraser" swarms.

The location and orientation of successful rift margins for each swarm is proposed here. 'Passive margin' dykes however have not been observed for any swarm. A standard feature of Proterozoic dyke swarms is that passive rift margins are overprinted by later rifting and/or orogenic events. The orientations of the rift systems identified here are of valuable use in continental reconstruction.

Advances in geophysical/geological mapping in the Lachlan Fold Belt, New South Wales

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Second edition geological mapping in the Lachlan Fold Belt has ushered in a new technological era in New South Wales. The mapping program undertaken by the NSW Department of Mineral Resources includes the interaction of high-resolution airborne geophysical data with geological mapping and ground geophysical surveys. Enhanced imaging of the magnetic, radiometric, gravity and satellite datasets has provided a powerful tool in assisting the mapping process. New standards have been designed for collecting and collating geological and geophysical data in a GIS. This includes ground sampling of radioelement data and magnetic susceptibility data for each geological unit. Additional ground magnetic and gravity traverses with 2.5D computer modelling have assisted with the interpretation of structurally complex geological terrains. The initial results on the Goulburn map sheet have been encouraging, with the identification of a major new prospective area for mineralisation in Silurian volcanics previously mapped as unprospective Ordovician sediments. Improved efficiencies of working in a team environment in the field that include geologists, geophysicists, GIS and cartographic personnel, enable more ground to be covered at a higher resolution with fewer resources.

Potential field evidence for the existence of an Archaean suture zone in the Western Yilgarn craton, Western Australia

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Geophysical evidence supports the existence of a previously undocumented, north-south trending Archaean suture zone within the western Yilgarn Craton. It has been interpreted from government regional aeromagnetic and gravity data, detailed aeromagnetic surveying, and field checking to be about 60 km wide and 800 km along. It abuts against the Lake Grace Terrane in the south, and extends north through the Wheatbelt town of Merredin until it truncates the eastern end of the Narryer Terrane at the northern margin of the craton. It is referred to here as the Merredin Suture Zone (MSZ), but has previously been recognised by others as a geophysical lineament that forms a pronounced boundary between higher magnetisation of the Murchison Terrane and magnetically subdued granite-greenstone terranes to the east (Barlee and Southern Cross terranes). The magnetic outlines of late Archaean granitoid bodies also change shape across the MSZ, from lensoid to the east to more circular to the west. Strong north-south lineations in gravity also highlight the existence of the MSZ as a deep-seated, sub-vertical structural corridor. Remnants of the MSZ are mapped in the magnetics and on the ground as gneissic bands and chains of xenoliths composed of gneiss, meta-sediments and amphibolite sitting in a matrix of granitoid. The Narryer Terrane abuts against the northern end of the MSZ, indicating that it initially formed a transform fault between micro-continents or terranes. Thin-skinned thrusting appears to have pushed the Meekatharra greenstone belt over the gravity lineament that defines the deeper part of the MSZ. This over-thrusting causes the surface trace of the MSZ to become a narrow contact between the Meekatharra and Barrambie greenstone belts. The Windamurra layered ultramafic complex was intruded along the MSZ, and probably favoured it as a zone of lithospheric weakness. The MSZ shows evidence for re-activation under ductile conditions, producing elongation and sinistral dislocation of the Windamurra complex. Large, circular granite plutons imaged in the aeromagnetic data also intruded along the MSZ, and these plutons stitch the Barlee and Murchison terranes in the vicinity of the Bimbijy Homestead and the Cogla Downs Homestead to the north. The Lake Grace Terrane is documented to have docked against the southwestern margin of the proto-Yilgran during the late stages of cratonisation. This NE verging collision caused the Lake Grace lithosphere to be thrust under the southern end of the MSZ. The diffuse nature of the MSZ's high grade rock remnants, secondary ductile deformation, thrusting in the upper crust, and plutonic stitching by granitoids all helped to mask the MSZ from being recognised as a terrane boundary. Interpretation of potential field data and some fieldwork has identified the MSZ as a tectonic corridor, but detailed geological mapping and dating of its remnant rock units is required to properly constrain its tectonic history.

SEISMIC\METHODS IN MINERALS (1)

Seismic refraction inversion of a palaeochannel system in the Lachlan Fold Belt, Central New South Wales

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We assess a method for conducting seismic refraction inversion in a 3-D setting to image the shape and structure of a palaeochannel. The trial survey was conducted over a suspected Tertiary palaeochannel adjacent to the Wyalong goldfields (Lachlan Fold Belt) in central NSW. This work has implications for the control of groundwater migration and dryland salinity studies. The method was conducted using standard multichannel seismic recording equipment and an unconventional 3-D field geometry. Three-dimensional velocity-depth models show a 4-layer sub-horizontal system underlain by high-velocity metasedimentitic basement at a variable depth, ranging from 70 to 170 m. The interpreted palaeochannel is coincident with high magnetic intensity features identified from recent surveys of the region.

Can amplitudes resolve ambiguities in refraction inversion?

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The inversion of seismic refraction data with model-based methods is inherently ambiguous, and artefacts, which are geologically plausible and significant, can be introduced by the algorithms used to generate the starting model. In many cases, the minimum variance criterion of the generalized reciprocal method (GRM) can resolve whether lateral variations in the refractor wavespeeds are genuine, or whether they are artefacts of the inversion algorithm. As an additional constraint, this paper demonstrates that any genuine lateral changes in refractor wavespeed should also have an associated amplitude expression.

Amplitudes are not commonly used in most seismic refraction studies, mainly because the very large geometric spreading component masks any variations related to geology. The amplitude decay is usually much more rapid than the commonly assumed inverse distance squared function, which only applies after the signal has travelled several wavelengths in the refractor.

This study demonstrates that the refraction time section generated through the convolution of forward and reverse refraction traces, shows the same structure on the refracting interface, in units of time, as would be produced by the conventional reciprocal method (CRM) or the GRM. The traveltimes, which are contained within the phase spectra, are added with convolution.

The amplitude spectra are multiplied, which is sufficient both to compensate for the large geometric effects and to facilitate convenient recognition of amplitude variations related to changes in refractor wavespeed. Convolution emphasises these amplitude variations through the squaring of the head coefficients and the convenient inclusion of transmission losses. In general, the higher the refractor wavespeed and/or density, the lower the amplitude.

The results are applicable to the search for massive sulphide orebodies under electrically conductive regoliths, where other traditional exploration techniques, such as electrical and electromagnetic methods, may not be fully effective. These targets would be characterised by an increase in the thickness of the regolith and a decrease in amplitude caused by an increase in the density.

Imaging coal seam structure using 3-D seismic methods

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The mining and export of coal is a major industry in Australia, and the Bowen Basin in Queensland holds a vast reserve of this commodity. The problem in extracting the coal from the ground is knowing the coal seam structure ahead of the mining process. If while mining a coal seam, an unknown fault, unstable roof conditions or a gas pocket are encountered, they can lead not only to equipment damage and down-time, but risk of life to personnel. Currently, coal seams are mapped by borehole information, but these are not detailed enough and expensive. The coal mining industry can benefit greatly from the seismic method, which offers a cost-effective way of continuously imaging the sub-surface. Particularly, the use of 3-D reflection surveying is ideal in geologically complex areas since geology is three-dimensional in nature and modern processing and interpretation methods will allow subtle features to be mapped.

Seismic methods are now becoming more common place in coal seam mining and the Burton Downs colliery in Queensland, Australia is one such mine to take advantage of the technology. With no previous seismic work done in the area, reverse vertical seismic profiling (RVSP) and two-dimensional (2-D) surveys were initially shot. RVSP results showed that the seismic method was viable, imaging the coal seam of interest (VSP to CDP mapping) and provided acquisition parameters for the 2-D surveys. The 2-D lines gave high-resolution images of the coal seams across the mine area, and showed a complex faulting system which included low-angle reverse faulting and normal faulting. The success of the 2-D profiles prompted the acquisition of a three-dimensional (3-D) survey in the northern (Kerlong) area of the mine. After processing the 3-D depth volume, a much more complete structural interpretation could be made.

REGIONAL STUDIES (2)

Basement reactivation and control of Neogene structures in the Outer Browse Basin, North West Shelf

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Basement control on reactivation along the North West Shelf has been broadly postulated, but direct links with Neogene events have yet to be substantiated. One reason for this is that styles of Neogene reactivation and inversion vary around the North West Shelf, and have been found to be tightly constrained to certain areas.

Structural highs, initiated during Late Permian to Early Triassic extension ("Bedout Movement") have strongly influenced the patterns of subsequent Neogene deformation in the Barcoo Sub-basin of Browse Basin. Recent structural and stratigraphic analyses of Cenozoic and Mesozoic horizons in the Barcoo Sub-basin has revealed the strong influence of structures deep within the section upon the location and nature of structures within the Miocene section. In particular NE-SW extensional faults have been reactivated at several times since the early Triassic, with the subsequent formation of inversion structures such as open folds developed in Triassic half graben growth sequences. Reactivation of these Early Triassic extensional faults continued during the Cretaceous and Cenozoic. Minor fault movement is recorded in the Cenomanian-Turonian, whilst more pronounced faulting occurred in the Middle Oligocene and Middle to Late Miocene. The latter was associated with pure strike-slip and transpressional reactivation of NE-SW faults and formation of extensive inversion structures such as the Barcoo and Lombardina-Lynher structures. Other effects of continued motion on these faults can be seen from the location of drape anticlines in the Cretaceous section and the preferential location of shallow marine reefs in the Miocene section directly over the edge of Triassic horsts.

Re-activation of the pre-Permian Najd Fault System and its importance in the oil province of Saudi Arabia

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Structural interpretation covering the Central Saudi Arabia was carried out through Landsat, Radar images and topographic maps. Existing geology maps provide materialized evidence for this study. A strong northwest trending lineament system has been mapped in the region and is interpreted as being related to the reactivated Najd Fault System. Elongate hills, strait-going creeks, offset along valley and ridges, and pull-apart basins are evident, indicating rejuvenation of the Najd transtensional sinistral movement. Geology map shows evidence indicating a northwestward dragging on the sedimentary cover along a NW trending regional lineament in the region which extend from South Ghawar to An Nafud Basin. Northeast trending structures such as Abqaiq-Harmaliyah-Shaybah are related to the Oman-Masirah stress regime. The Ghawar-Khurais-Tinat-Dilam-Dukhan (Qatar) and other north-northwest trending anticlines were reshaped by the rejuvenated Najd stress regime. The northwest trending sinistral Najd Fault was initiated in Precambrian and was reactivated at various times, probably during Paleozoic and late Jurassic times, and continuously, though of variable intensity, from late Cretaceous to the present time. The Carboniferous, Late Cretaceous and Tertiary events are overprinted on one another in the region. The Oman stress regime and the stress regime that is related to oblique obduction of the Masirah Ophiolite are the principal controlling event for the anticline structures in Central Arabia. The effect of the Tertiary orogenic overprint of the Oman-Masirah stress regime in eastern Arabia was to favor a slight renewed movement along the old basement faults such as the Najd Trend. Reactivated Najd system, Oman principal horizontal stress regime and obduction of the Masirah Ophiolite onto the Arabian continent have produced a combined effect on the structures in Eastern Arabian Plate. The Zagros stress regime may have produced little effect in the region.

Crustal structure across the Vulcan Sub-basin from seismic refraction and gravity data

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The attenuated continental crust between the Kimberley Block and the Timor Trough hosts some of the major oil and gas fields in Western Australia. The crustal structure has been interpreted from wide-angle seismic data acquired by the Australian Geological Survey Organisation during 1995/96. Ten ocean-bottom seismometers were deployed along a deep seismic reflection profile aligning NW with exploration wells Fagin and Crane. Data were recorded to offsets of 300 km. A total profile 335 km long and 48 km deep has been developed, by ray-tracing and inversion modelling of the refraction data, and verified by modelling gravity data. The model differentiates 7 crustal and 2 upper mantle layers. The crustal thickness varies between 25 to 30 km, being greatest beneath the Kimberley Block and Vulcan Sub-basin. The velocities within the upper mantle are ~8.1 km/s, while in the lower crust they vary from 5.9-6.2 km/s beneath the Kimberley Block, to 6.4-7.0 km/s elsewhere. Mid-crustal velocities are 5.5-6.2 km/s and 2.0-5.0 km/s in the overlying sedimentary section. Significant lateral variations exist in the lower crust and can be used to infer the limit of the Kimberley Block. A prominent reflector at 6s twt, which is widespread in the region, is not a significant velocity discontinuity. The Moho is not seen on the reflection records, but is a prominent feature in the refraction data. Iso-velocity lines do not necessarily coincide with reflection boundaries, possibly due to decreasing porosity with depth, especially beneath the Cartier Trough.

AEM

The application of airborne EM to minerals discovery: the Canadian camp experience

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Airborne EM (AEM) has been the most successful mining geophysical technique ever developed, with approximately 80 deposits discovered (Witherly-1999) since the early 1950s. Almost 80% of these discoveries have been made in Canada and they can be broken down into three main deposit types; massive sulfides, unconformity uranium deposits and diamondiferous kimberlites.

All three deposit types often tend to occur in relatively close groupings, commonly termed districts or camps. AEM proved particularly effective in screening camps for their endowment of deposits once the existence of a particular deposit type has been established in a camp.

A review of how AEM was applied in the various camp settings shows that early on explorers developed a set of geophysical and geological search criteria which had a strong empirical relationship to the sought after targets. These pathfinders to discovery are termed Geologically Serendipitous Observations (GSOs). Not only did GSOs help guide work in a given camp, they often proved robust enough that they could be applied to new areas with a high likelihood of success.

Historic geophysical literature has tended to focus on the development and evolution of AEM as a stand-alone technology. However, if future endeavors using AEM are to be biased towards success, then it is seen as important to better understand the linkages between AEM technology and the discovery criteria that were developed to guide its very successful use in the camp environments.

Choosing the best AEM system for the target

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There are a number of factors to consider before choosing which airborne electromagnetic (AEM) system to use for seeking a particular style of target. Towed bird time-domain systems offer the advantage of a broad band, high power signal. Compared to frequency-domain systems, depth penetration is excellent but noise levels can be high due to bird motion relative to the transmitter. Helicopter systems have better lateral resolution, the transmitter-receiver geometry is fixed, but the ratio of target response to background is much less due to small transmitter-receiver offsets. Wingtip frequency-domain systems offer better target response to background ratios, but wing motion is an additional noise source.

In this study we use a 3D integral equation program to contrast the responses of a kimberlite pipe and a (sulphide) conductor in a layered earth host for several existing and generic AEM systems. For towed bird time-domain systems, we simulate Geotem 25 Hz, a Geotem 75 Hz and the Tempest 25 Hz system. Is step or impulse response more effective? Which component is most diagnostic?

We also simulate the response of the Dighem, Hummingbird and UTS Geophex systems. What frequencies are best? Is the horizontal coaxial component needed or is the vertical coplanar component sufficient? Lastly we simulate the response of the 2 frequency Geological Survey of Finland wingtip system with horizontal coplanar dipoles as well as a generic 3 frequency system with vertical and horizontal coplanar configurations. In the latter system, we also compute cross components.

It is important to note that this study does not account for the different way in which each system reduces noise levels. In comparing the effects of geometry, altitude, waveforms and components, however, it illustrates the value of modelling programs in trying to get maximum information from money spent on AEM surveys.

Current channelling in time-domain airborne electromagnetic data

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Airborne electromagnetic (AEM) surveys for mineral exploration generate vast quantities of data. Rigorous electromagnetic (EM) modelling of geologically realistic structures is very computationally expensive, and interpretation of local AEM anomalies is usually based on approximate or nomogram methods. These methods typically account only for vortex induction in a conductive target, and are only valid if the host medium containing the target is poorly conductive, or if measurements are made at long delay times.

When a target is either wholly or partly embedded in a conductive host, current channelling may enhance its response in comparison with that due to vortex induction, and the exciting and secondary fields are modified by 'blanking' effects as they pass through the host. The relative importance of current channelling and vortex induction depends strongly on the target and host parameters, the location of the AEM system relative to the target, and on the measurement delay time. In some instances, galvanic currents may dominate the entire target response, and models that account only for galvanic excitation can be applied. At the relatively early times employed in AEM prospecting, it is necessary to account for blanking of the current channelling response by the host medium, imposed as the secondary fields pass from the target to the receiver. Blanking effects can, however, be ignored if modelling is carried out at the resistive limit of the response.

Shallow regolith features, such as palaeochannels, may give rise to observable AEM current channelling anomalies. A field example from the Lawlers area of Western Australia demonstrates that the AEM anomaly associated with a known palaeochannel can be largely explained by the galvanic response of horizontal thin-sheet targets embedded in the overburden of a two-layered earth. The host and palaeochannel parameters required to reproduce the observed anomaly are consistent with those derived from drilling, surface EM and DC resistivity surveys, and petrophysical measurements.

SEISMIC VELOCITIES

A braver approach to seismic velocities in the Taranaki Basin

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The Institute of Geological and Nuclear Sciences recently re-processed offshore Taranaki 1991 seismic data for the Spectrum Exploration/Fletcher Challenge Energy Taranaki Joint Venture. A more detailed stacking velocity analysis, incorporating a 40% interval velocity inversion in the Eocene sequence, resulted in a markedly improved seismic image of the Eocene and deeper reflectors. A dense semblance analysis formed the initial part of the velocity analysis sequence and was followed by interactive constant velocity stack analysis of the velocity inversion, where the weak intra-Eocene reflectors were masked in amplitude by multiples from an overlying strong limestone reflection.

A third, automatic, velocity analysis was performed on the final stack using a combination of semblance and digitised horizon times, producing a horizon-based velocity model with data points every 5 traces (63 m). Prediction of interval overpressures was then possible through the creation of an interval velocity model derived from these velocities. It has subsequently been shown that the calculated overpressures are in good agreement with basin modelling results.

Velocity structure of the Argo and Roebuck Basins, North West Shelf of Australia

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Ocean bottom seismograph (OBS) data have been analysed from a transect across the North West Shelf of Australia extending from the Pilbara Craton to the Argo Abyssal Plain. The data constrain models of the complex tectonic history of the Roebuck and Argo basins by providing velocities to depth convert coincident reflection data, by identifying major intra-crustal boundaries and by determining the depth to basement and base of crust. They also address the anomalous nature of the Argo oceanic crust, the adjacent continent-ocean transition (COT), and the nature and significance of the Bedout High. P-wave and S-wave arrivals were recorded by twenty three OBS and three land stations. The data were analysed by iterative forward modelling of travel times and amplitudes and by inversion for the velocity and interface positions. Waveform inversion was used to model the Poisson's ratio within the crustal layers for stations with good S arrivals. The model shows that the pre-existing 30 km thick continental crust thins to ~10 km across the very sharp COT. Anomalously low velocities in the upper crust of the outer shelf, reflect the thick sequence of Paleozoic sediments and extremely thin crust, part of the Westralian Superbasin. The crust underlying the inner shelf is largely intact and covered by relatively thinner Mesozoic and Cenozoic sediments. The difference in Late Tertiary subsidence behaviour between the inner and outer shelf may be related to differences in lithospheric rheology. The absence of a large number of high relief normal faults in the COT area suggests that this region has subsided largely due to thinning of the lithosphere according to a two-layer stretching model. Velocity modelling and geometrical observations of low angle reflectors imaged in the upper, mid-, and lower oceanic crust near ODP site 765 suggest these features to be real three-dimensional dipping surfaces, probably due to compressional events.

Acoustic structure and seismic velocities in the Carnarvon Basin, Australian North West Shelf: towards an integrated study

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High quality refraction and wide-angle reflection seismic data recorded by ocean-bottom seismographs (OBSs) deployed by the Australian Geological Survey Organisation along a 700 km long transect in the Carnarvon basin effectively supplement results obtained by means of the conventional reflection technology. Velocity information can now be derived from two independent data sets: CDP (near-vertical reflection) and OBS (refraction/wide-angle reflection) data. Generally, CDP-derived average velocities are lower than OBS-derived velocities and this deviation increases with depth: from ~200 m/s at 5 s TWT to ~400 m/s at 10 s TWT. If the CDP-derived velocities are used to depth convert reflection data, then depth to seismic boundaries would be underestimated by 0.5 to 2.0 km respectively. Some prominent local anomalies (where, for example, at 5 s TWT CDP-derived velocities may be up to 400 m/s higher than the OBS-derived) distort this general trend. These would result in ~1.0 km local overestimates of the depth equivalent of 5 s TWT. Co-analysis of the interval velocity field reconstructed from the travel time-based interpretation of the OBS data and the conventional reflection image of the crust in many cases shows their poor correlation. Prominent reflectivity seen in the conventional reflection data at two-way times around 8 s had previously been interpreted as the top of an underplated layer in the crust. However, it does not correspond to any significant velocity increase imaged by refraction/wide-angle techniques. The velocity below that level, estimated from the OBS data, is in the range 6.0-6.5 km/s which is considerably lower than any mafic rock would have under appropriate PT-conditions. On the other hand, a quite significant local velocity increase in the depth range 15-25 km does not produce high-amplitude near-vertical reflections. Only a combination of reflection and refraction/wide-angle techniques provides a clue to a consistent geological interpretation of seismic data. Improved velocity estimation in the crust is crucial for accurate depth migration and for depth conversion of near-vertical reflection data.

In this paper we review the results of National Airborne geophysics project.

SEISMIC METHODS IN MINERALS (2)

The effects of spatial sampling on refraction statics

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The use of seismic refraction data to determine the long wavelength statics correction not adequately addressed by residual statics routines, is widespread. While the importance of accurate traveltimes is well known, the effects of the geophone array on the inversion process are not.

This study used two coincident sets of data recorded with two recording systems at Cobar in southeastern Australia. One system used a 60 m trace interval with end-to-end arrays consisting of 16 detectors, while the other recording system used single detectors, which were 10 m apart.

The temporal resolution achieved with the 60 m groups is poor, and does not accurately measure the thickness of weathering as determined with the data using the 10 m trace spacing. One factor limiting the achieved resolution is the finite length of the geophone array. With extended arrays, the location of the effective receiving point, depends upon the direction from which the seismic signal arrives. For signals traveling in the forward direction, the effective receiving point is the first detector in the array, while for signals traveling in the reverse direction, it is the last detector. For the data used in this study, the forward and reverse traveltimes which are referenced to the same station number, represents a lateral interval of the sub-weathering interface of approximately 100 m, when both the length of the geophone array and the offset distances are added. The traveltime differences of the refracted arrivals over this interval can be up to 20 ms, which implies that an accuracy of only about 10 ms is meaningful with model based inversion methods, unless the effect of the length of the array is accommodated.

An analysis using the generalized reciprocal method, which uses refraction migration in multiples of the array length, shows that a migration distance of one station interval essentially removes the effect of the finite array length, when end-to-end arrays are employed. However, the static then applies to each end of the array, and in the study area, there can be a variation of up to 7 ms in the weathering correction from one end of the array to the other. Therefore, it is necessary to further increase the refraction migration by an additional array length, in order to determine the static in the central region of the geophone array, which is then taken as the static correction for the entire array. Although there is an improvement in the resolution achieved with the 60 m groups, it is still poor, when compared with that achieved using the 10 m single detectors.

Further analysis of the data will be carried out to confirm that the finite length of the 60 m geophone arrays is the significant factor limiting the resolution of the refraction data, rather than the variable signal-to-noise ratios of the data.

Pushing coal seismic to its limits through computer aided interpretation and 3D seismics

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The detection of small structures by reflection seismic surveying is largely dependent on seismic resolution. Based mainly on our visual capabilities, the widely accepted limits for both vertical and horizontal resolution are usually expressed in terms of a quarter of the dominant wavelength criterion. However with 3D seismic surveying and computer aided seismic interpretation it is possible to interpret small structures below these conventional limits. Interactive computer aided interpretation enables us to view our data with different attributes and at scales which facilitate identification of small structures. Accurately picked reflection times (sub millisecond) from a computer can reveal subtle changes in reflection times associated with small faults. 3D seismic surveying allows us to track subtle features from line to line, thus increasing confidence in an interpretation. In this paper, we demonstrate these aspects by using both synthetic data and field data from 2D and 3D seismic surveys from Australian coal mines in the Sydney and Bowen Basins.

Can new acquisition methods improve signal-to-noise ratios with seismic refraction techniques?

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A fundamental issue which impacts on the inversion of refraction data using any method, is the large variations in the accuracies of the traveltime data. These variations are related to the wide range of signal-to-noise (S/N) ratios along the refraction spread, and in turn, are a result of the large amplitude variations caused by geometric spreading. For shallow refraction investigations, the geometrical spreading can be more rapid than the generally accepted inverse of the distance squared function.

At any particular location, a detector will be close to a source point, and the traveltime will be comparatively accurate, because the S/N ratio is high. However, for other shot records, generally in the reverse direction, the source to receiver distance will be much larger, and the accuracy will be greatly reduced. As a result, computations at each detector location are carried out with data which have large variations in accuracies. This adversely effects the quality of the processing using any inversion method.

Most approaches to the processing of seismic refraction data perceive the problem as achieving satisfactory, rather than uniform S/N ratios, and commonly, a simple gain function is applied to adjust amplitudes to a desired level. However, this does not address the issue of the large range in accuracies of the traveltime data due to the variations in S/N ratios.

This study demonstrates that, to a very good first approximation, the convolution of forward and reverse seismic traces, compensates for the large variations in S/N ratios, due to geometric spreading. This facilitates the use of signal enhancement techniques analogous to the common mipoint (CMP) stacking methods which are an integral component reflection seismology. Examples demonstrate the improvements in S/N ratios with stacking of convolved refraction data.

However, in order to achieve suitable data multiplicity or fold, as well as more efficient field methods, it is necessary to employ CMP acquisition techniques, instead of the standard static refraction spread with multiple source points which is the norm in most geotechnical and groundwater investigations. This will require substantial re-capitalization of most shallow refraction operations as very few currently employ sufficient numbers of recording channels or roll along capabilities.

REGIONAL STUDIES (3)

Structural framework of the Mcarthur Basin, Northern Australia interpreted from aeromagnetic data

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The McArthur Basin of Northern Australia has been recognised as containing two distinct rift systems, namely, the Batten Trough which contains the HYC lead-zinc deposit and the Walker Trough. Interpretations of aeromagnetic data indicate that these structures, separated by the Urapunga Fault Zone underwent significantly different extensional processes and as a result have significantly different structural frameworks. The Walker Trough, which developed into a half graben structure, appears to have undergone a relatively simple extensional process framed by north west trending accommodation zones and meridional down to the basin faults. The Walker Trough is underlain by a major magnetic axial dyke whose depth to its top is approximately 12 km. The geometry of this dyke reflects the geometry of the extension in the area. The Batten Trough appears to manifest itself as a series of isolated downfaulted McArthur Group depocentres that have resulted from transtensional movements related to a couple between the Urapanga and Mallapunyah Fault Zones. The Batten Trough area corresponds to a major regional magnetic anomaly apparently resulting from magma emplacement beneath the basin or at the base of the basin's sedimentary section. Extension in the area appears to be reflected in the geometry of this magnetic unit. Previously unknown basin forming fault systems and localised depocentres have been defined.

The nature of the basement to the Cooper Basin region, South Australia

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Analyses of aeromagnetic and gravity data in the Cooper Basin area of South Australia, reveals varied basement lithologies and structure. Most of the observed magnetic responses arise from sources beneath the Cooper Basin sequence. A prominent northeast-trending structural basement grain is evident. Emplacement of a large igneous mass into the upper crust is interpreted beneath the Patchawarra Trough. Interpreted faulting along the southeastern edge of the igneous body resulted in up to 3.5 km of block uplift, coincident with the Gidgealpa and Merrimelia Ridges. A broad and prominent gravity low in the Nappamerri Trough region is attributed to Late Carboniferous Big Lake Suite granodiorite masses, which have intruded Warburton Basin strata. Intense gravity lows within the broader gravity low are attributed to granodiorite cupolas, which became non-tectonic palaeo-topographic highs during Cooper Basin deposition. Another broad gravity low in the Tenappera Trough region is due to a belt of Early Devonian granitoids that have intruded Proterozoic basement. A number of small magnetic anomalies, in the south of the survey, are interpreted as sourced from skarns above and adjacent to the granitoid intrusions. The only magnetic units above Proterozoic basement in the region are the basalts in the Warburton Basin sequence, which coincide with small magnetic anomalies. Depth to magnetic-source modelling correlates well with the known depths of the basalts.

A deep-crustal seismic image through the Bancannia Trough and Koonenberry Zone, New South Wales

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A 160 km regional deep reflection-seismic line was recorded in February 1999 northeast of Broken Hill in western New South Wales. The project was jointly funded by AGSO and NSW Department of Mineral Resources, and the data acquired using the newly commissioned ANSIR equipment.

The seismic line extends in a NE direction from near "Sturt's Meadow" on the Silver City Highway, across the Bancannia Trough and the Koonenberry Zone, and over the far northern Lachlan Fold Belt to near "Yancannia". The profile was designed to help investigate the basement structures which have controlled the partitioning of the Darling Basin into a series of troughs and intervening highs, and to test the model (proposed on the basis of the reflection and refraction profiles farther south) that the Broken Hill Block is an allochthonous upper-crustal thrust sheet.

Acquisition parameters for the survey are discussed by Johnstone & others (this volume). Data quality is excellent. The data show the Bancannia Trough is an easterly-thickening wedge (1.3 to 2.6 s twt) of Darling Basin sediments (?Late Silurian to Early Carboniferous) overlying Cambrian volcanics, preserved between two bounding faults. Reflection events at around 3.5 s (depth ~8 km) beneath the Bancannia Trough are interpreted to be magnetic igneous bodies beneath the trough's basement. On the western side, Neoproterozoic sediments have overthrust the Darling Basin sediments. In contrast, the eastern bounding fault appears to be more vertical, and displays attributes consistent with possible wrench related deformation.

The seismic data show that the Koonenberry Fault is a linear crustal-scale feature, which dips westward at around 60 degrees. At the north-eastern end of the seismic line, a strong linear south-west dipping reflection event is interpreted as the Oleopoloko Fault. As imaged by this regional seismic line, the framework of the crust north-east of Broken Hill appears to be dominated by discrete southwest dipping crustal boundaries (possibly transpressional thrusts). This crustal geometry has implications for the mineral prospectivity of the Koonenberry Zone.

POSTERS

Modelling the airborne electromagnetic response of a vertical contact

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Airborne electromagnetic (AEM) surveying is an important exploration tool because it can map conductivity variation over large areas at a fraction of the cost of ground survey methods. Using rapid, but approximate techniques, large volumes of data may be processed to show the variation of conductivity with depth beneath the survey. These approximate methods work well in regions with horizontal layering but, in certain circumstances, they can imply the presence of false conductors in the vicinity of 2D and 3D structures. By comparing the AEM response of several 2.5D models, each of which contains a lateral conductivity contrast, we show that artefacts associated with conductivity contrasts can imply the presence of a false conductor when flight direction is towards the conductivity high. When flight direction was away from the conductivity high, artefacts associated with the lateral conductivity contrast implied a false resistor. These artefacts were of sufficiently high magnitude that they masked the response of a genuine conductor (0.1 Ωm) at a depth of 50 m. We show that multiple-component data sets utilising the inherent directional dependence qualities of AEM prospecting systems can be used to minimise interpretational errors in the presence of lateral conductivity contrasts.

Geophysical Exploration in the Xi-Cheng Lead-Zinc Orefield, Gansu Province China

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The Xi-Cheng lead-zinc orefield lies in Gansu Province in north-central China. The orefield consists of several separate deposits and more than 200 orebodies in Middle Devonian schist and limestone. Examples include the Changba (Zn+Pb >3.8 Mt), Lijiagou (Zn+Pb >3.2 Mt), Huangchang (Zn+Pb ~1.0 Mt), Dengjiashan (Zn+Pb ~1.0 Mt) and Bijiashan (Zn+Pb >1.0 Mt) deposits. The deposits occur as stratiform and/or tabular forms with ores mainly comprising massive and banded pyrite, sphalerite and galena. The ore contains >8.5% of Zn+Pb, plus associated Ag, Cd, Ga, and Ge. Self-potential, ground magnetic, induced polarisation, resistivity and mise-a-la-masse surveys were carried out in the early stages of exploration in the late 1960s to early 1970s. This paper presents some examples of such surveys over the Changba, Lijiagou and Huangchang deposits. This early geophysical practice showed that: (1) the self-potential method was cheap and effective in rapid reconnaissance for mineralisation below thin cover, but the interpretation of the results was sometimes complicated by the presence of graphite in the host limestone; (2) the ground magnetics was able to define small but recognisable anomalies over shallow concealed mineralisation that contains a small amount of pyrrhotite and/or magnetite, as is often the case; (3) induced polarisation was very useful for mapping mineralisation hosted in schist, but was less useful in areas of graphite-bearing limestone; (4) attempts to use resistivity surveys for mapping mineralisation were largely unsuccessful; (5) mise-a-la-masse surveys were not only useful for determining the horizontal extent of intersected mineralisation in drillholes, but were also able to indicate the presence of other mineralisation in the vicinity of the intersected mineralisation.

A new multi-frequency AEM System

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A fixed-wing airborne electromagnetic system has been designed and constructed in Australia to provide a cost-effective alternative to fixed wing TEM systems and in some cases helicopter EM systems. It consists of horizontal and forward-facing vertical coils mounted outboard of the wings of a Cresco 750 STOL aircraft. The transmitter coils on one wing tip and the receiver coils on the other, at a spacing of 15.5 metres, measure maximum and minimum coupled geometries for each coil set. The transmitter is capable of outputting a range of frequencies, up to 5 at any one time, from a very low 100 Hz up to 20 000 Hz or more to permit the user to choose the most optimum frequencies for the particular requirement.

The coil mounts have been constructed of the latest, high-strength yet light weight materials to provide the most rigid frame to keep noise due to displacement as low as possible. Up-to-date DSP electronics allow the best possible signal to noise to be achieved. A magnetometer and spectrometer are operated together with the EM equipment. As the aircraft is capable of low-flying in flat terrain and also has good terrain following capability due to its powerful engine, the applications for this system are extensive and include kimberlite search, massive sulphide delineation and regional lithogical and structural mapping.

A new distributed acquisition system for ground TEM

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ARTEMIS is a new ground TEM system which employs the concept of distributed acquisition whereby a number of receivers can be deployed to make simultaneous TEM measurements in the same background noise environment. Special circuitry has been devised so that each receiver detects the transmitter pulse remotely for synchronisation. This avoids the need to use connecting cables which are logistically inconvenient and, furthermore are a source of unwanted common mode noise. The lack of cables also makes it easier for the receivers to be deployed in any desired array. Each receiver is an entirely independent entity without the need for a separate receiver console and is light and compact. It comprises a three component sensor with inbuilt pre-amplifier and other necessary electronics, and its own data storage facility. Communication for harvesting data is via a standard PC which also serves as the medium to input the receiver and transmitter locations, and receiver set up parameters, and display these together with various measures of data recording quality. Special software has been written to provide these screen displays and format the data as required for interpretation packages. A truly unique feature of ARTEMIS is its ability to record the transient components as the magnetic field as well as the traditional derivative of the field. The well known advantages of measuring the total magnetic field are thus realised. Digital signal processing undertaken in real time also allows ARTEMIS to obtain the best possible signal to noise. This together with the B-field measurement enables the dynamic range to be extended by 1 or 2 orders of magnitude over that of other TEM systems. Otherwise all of the desirable features of the many years of development of SIROTEM have been retained and in many cases improved upon. The wide bandwidth of the receivers permits measurements for a range of applications from shallow environmental projects to deep mineral surveys.

Passive seismic profiling of the Moon

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We have attempted to verify the following conjecture on field data recorded on the Apollo missions to the Moon:

By cross-correlating noise traces recorded at two locations on the surface, we can construct the wavefield that would be recorded at one of the locations if there was a source at the other.

Based upon previous research that very long time-series and a spatially white distribution of random noise events would be necessary for the conjecture to work in practice, we decided to examine one month of continuous passive seismic recording from a lunar seismogram at the Apollo 16 landing site. The Moon presents an environment free from cultural noise, however, the unique transmissivity characteristics of the outer crust mean that the constant barrage of small meteorites on the lunar surface and tidal-related moonquakes are causing a constant flux of internally reverberating energy that was thought to be appropriate for testing our conjecture.

The results indicate that a seismogram can be constructed for the predominant lunar reflecting boundaries, and the method has potential implications for commercial applications of passive seismic monitoring in the exploration industry.

Victoria revealed: stripping off the cover to show the basement features

Bruce A. Simons

As a result of new detailed geological mapping, airborne geophysics andgravity surveying, the Geological Survey of Victoria has compiled the regional geology of the Tasman Fold Belt in Victoria. A critical part of this was to draw for the first time, a map of the Palaeozoic basement geology for the entire state, including the offshore areas where data wasavailable. This map was to integrates as far as possible the available data ¾ magnetic, gravity, radiometric and seismic geophysical data, with geological mapping by our own mapping teams and mapping and data compilations from other adjoining states. The aim was to produce a map that made sense of the geology at the 1:500 000 regional scale, including the continuation of that geology into the adjacent states. The map was easy to read and that, once the reader was familiar with the concepts, is intuitively understandable, with only minimal reference to the legend. This

paper looks at some of the processes used to achieve those goals and highlights the key advances in geological understanding the map has made. These include:

- the definition of the major structural zones in Victoria and their bounding faults,
- the stratigraphic, structural and tectonic links with New South Wales, Tasmania and South Australia,
- the links between basement features and post-Palaeozoic cover rocks, particularly the hydrocarbon-bearing areas, and
- the tectonic development of the Victorian part of the Tasman Fold Belt System.

The solid geology map makes a significant contribution to the current debate in the earth science literature on the tectonic development of the Lachlan Fold Belt.

Geophysical signatures of porphyry copper mineralisation in Victoria

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Most occurrences of porphyry-type copper mineralisation in Victoria are within the Lachlan Fold Belt in eastern Victoria. Chalcopyrite, chalcocite and pyrite are the main ore minerals. Gold and molybdenum are sometimes present. The mineralised, Silurian-Devonian intrusions are located on either side of the Buchan Rift. Most of the mineralised intrusions are intermediate in composition and tend to be magnetic. The magnetic method is successful in most cases in isolating the intrusion but not the mineralisation. The IP method was successfully used to locate the sulphides. However, most IP anomalies were probably caused by pyrite, which is present in larger concentrations and is more widespread than the economic sulphides. Supergene chalcocite also contributes to IP anomalies.

Thursday's Gossan is the first porphyry copper style deposit identified in western Victoria. The Ordovician porphyry system is located within the Mt. Stavely Volcanic Complex at the intersection of tectonic-scale faults. Porphyry style Cu-Ag-Mo-(Au) mineralisation is hosted by undeformed, weak to strongly phyllic altered, low-K, dacitic, subvolcanic porphyries and surrounding sediments and volcanics. Supergene enrichment of copper occurs as chalcocite in sediments, volcanics and intrusions. However, the copper mineralisation in the Thursday's Gossan system is low grade and uneconomic.

Electrical surveys in the 1970s indicated moderately high chargeable responses (caused by disseminated pyrite and chalcocite mineralisation) and conductive responses (due to massive pyrite) coincident with anomalous copper geochemistry. Airborne EM surveys in the 1990s. identified a conductivity high which probably reflects the presence of high groundwater salinity within the deeply weathered zone of the alteration system, rather than disseminated sulphides at depth. This weathered zone is also associated with a gravity low of 2 mGals. Magnetic surveys over the prospect area were less definitive. The bulk of very prospective but weakly magnetic subvolcanic dacite porphyries cannot be distinguished from the non-magnetic sedimentary rocks.

Drape corrections of aeromagnetic data using wavelets

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Aeromagnetic surveys are commonly flown at a constant height above the terrain to minimise the magnetic effects of variable terrain clearance. This is known as drape flying. However, in mountainous regions it is often not operationally feasible to perform a drape survey. Instead, the survey is flown at a constant barometric height and the draped magnetic data is calculated numerically using a level-to-drape continuation operator. Existing techniques for this calculation include the chessboard and Taylor-series methods. An alternative method described here, based on the wavelet transform, approaches the problem by representing the continuation integral using a family of wavelet basis-functions localised in both space and frequency. This allows the generation of a set of coefficients that can be efficiently applied to the wavelet transform of the signal. The wavelet approach can be used for both 1D and 2D signals. If the drape surface is closer to the ground than the barometric survey height, a major difficulty in the drape correction is the control of noise. This is achieved in the wavelet domain by using a locally-adaptive, exponential noise-reduction filter which can be designed based on the wavelet coefficients. The method can be extended in some cases to generate draped images below the ground surface that can be used to sharpen images of magnetic basement in sedimentary basins. The wavelet method is compared to conventional techniques with data from the Edge Hills region in Canada and the Browse Basin in Western Australia. In this study, the wavelet approach combined with the exponential smoothing filter produces sharper images than either the chessboard or Taylor-series methods.

Reduction-to-the-pole of regional magnetic data with variable field direction, and its stabilisation at low inclinations

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A method for reducing a grid of total field magnetic data to the pole, where the field and magnetisation directions vary, was published by Arkani-Hamed in 1988. He called the method differential reduction-to-the-pole (DRTP) because the variations in direction are treated as perturbations about mean directions and the problem is solved iteratively. There appear to be advantages in applying this (or a similar method) to large regional magnetic grids, particularly at low magnetic latitudes. Nevertheless, it appears to have been rarely used. There are two problems with DRTP. Firstly, the algorithm calls for 12 two-dimensional arrays (5 real and 7 complex) so an implementation capable of dealing with a 4000 x 4000 data grid on a PC or small workstation requires careful coding. Secondly, as noted by Arkani-Hamed, the method is unstable at low inclinations where, like the standard wavenumber-domain method, it selectively amplifies noise (as well as anomalies) in the magnetic north-south direction. The problem of low inclination stabilisation is addressed using a similar technique to that used in Geosoft's MAGMAP to stabilise its wavenumber-domain RTP filter. This introduces a pseudo-inclination into the denominator of the filter transfer function, which is increased from the true inclination in order to reduce the amplification of north-south wavenumbers. It is not obvious that this modification should work with the DRTP algorithm because of the iterative corrections being applied, but tests with synthetic data show that it has a very similar behaviour to the uniform direction algorithm. As an example of its use the low-inclination DRTP is applied to a large regional magnetic dataset from Brazil, where the inclination varies from -40° to +20°.

Wavelet transform-based derivative calculation for use in the interpretation of magnetic data via Euler deconvolution

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Magnetic prospecting is one of the most common geophysical techniques, and is used in oil and mineral exploration, as well as in hydrogeological and archaeological applications. Interpretation of magnetic data often involves using algorithms such as Euler Deconvolution, which estimates the depth to the top of the source of an anomaly. Euler deconvolution uses the first horizontal and vertical derivatives of the total intensity of the magnetic field, which can be calculated using the Fast Wavelet Transform (FWT).

The FWT algorithm decomposes the signal into high and low frequencies, by passing the input through an analysis filter. The high frequency output is then decomposed into high and low frequency bands. This algorithm continues up to a maximum decomposition level. The FWT of the original signal is obtained by concatenating the high-pass coefficients from all levels of decomposition with the final low-pass coefficients. The original signal can be reconstructed using the inverse FWT from the high- and low-pass coefficients by convolution with synthesis filters. Horizontal and vertical derivative operators can be diagonalised in the wavelet domain, meaning that the derivatives can be calculated using fast algorithms.

Denoising methods associated with wavelet analysis can be adapted for the removal of geological noise. Assuming geological noise has higher frequency components than the signal, the noise can be removed by thresholding the high-pass coefficients at each level of the wavelet decomposition of the signal. Two denoising algorithms were used in this investigation. The first method involves noise removal based on the expected energy of noise within the profile, and the second method removes noise based on statistical parameters.

Properties of wavelets such as symmetry govern which wavelets produce superior derivatives. Other wavelet-based properties, such as the level of decomposition used in the wavelet transform and the order of wavelet used, influence the quality of derivatives produced.

Geophysical evidence for crustal fluids in a region of active continental convergence - the South Island of New Zealand

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A geophysical image of the current deformation of the continental Australian/Pacific plate boundary has been obtained, as part of the continental dynamics project SIGHT (South Island GeopHysical Transects), from refraction/wide-angle reflection seismic data and magnetotelluric data recorded in the central South Island of New Zealand. The transpressive plate boundary is marked by the Alpine Fault along which 480 km of strike-slip motion and 90 km of convergence has occurred in the past 6.4 My. On the Pacific plate, where most of the deformation is taken up, the plate boundary is accompanied by low seismic P-wave velocities and high electrical conductivity. Although geologic constraints rule out lithologic variations in the crust, the spatial similarity of the magnetotelluric and seismic velocity anomalies suggests a common origin. A viable explanation is the presence of aqueous fluids. A likely source for these fluids is dehydration of hydrous minerals during metamorphism, and meteoric water may possibly contribute to the observations. Interconnectivity of these fluids could account for the observed high conductivity, and stress in the crust could result in enhanced pore pressures that are sufficient to reduce seismic velocities. The presence and distribution of crustal fluids in this active convergent continental margin may also have important implications for mineralisation in old inactive tectonic regimes in Australia.

Influence of anisotropic elastic parameters on seismic imaging : numerical and physical modelling studies

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The wavefront curvature in an anisotropic medium is significantly influenced by the elastic parameters d* (near-vertical P-wave anisotropy), e (P-wave anisotropy) and g (SH-wave anisotropy). The effects of changes in these elastic parameters on the size of the Fresnel-zone have been studied using numerical modelling techniques and measured anisotropy of real sedimentary rocks. Ray paths for a P-wave gather above horizontal reflectors with tilted axis of symmetry and contrasting velocity characteristics were also studied in order to determine how changes in elastic parameters affect the reflection point dispersal, and hence smearing effect in stacked seismic data. Anisotropic migration of synthetic and physical modelling data was also carried out to demonstrate the effect of using inaccurate elastic parameters, and hence, wrong velocity functions in migrating seismic data.

Numerical modelling results strongly indicate that the anisotropic elastic parameters significantly affect the size of the Fresnel zone, which determines the spatial resolving power for unmigrated seismic data. The magnitude of ray path distortion and reflection point dispersal is found to vary with the value and sign of the elastic parameter d*. Ignoring anisotropy or using incorrect elastic parameters in migration will lead to wrong depth estimation and spatial mispositioning of reflection events.

Experimental seismic data obtained using physical modelling demonstrate that anisotropy can significantly affect the spatial resolving power of seismic waves. The extent of these effects depends on the wavefront curvature which is influenced by the elastic parameters and orientation of the symmetry axis. These observations indicate that the imaging of reflection events from the base of thick shale sediments will be affected by anisotropy.

Precise GPS Measurements for Regional Gravity Surveys – the AGSO Experience

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AGSO has developed two methods of conducting vehicle based regional gravity surveys using the Global Positioning System (GPS) to obtain quick and cheap positions and heights to an accuracy of less than 10 cm. The first method, best suited to surveys where there is good vehicular access, uses one vehicle dedicated to the base GPS receiver and usually two or three roving vehicles taking the gravity observations. Each 1:100 000 map sheet of the survey area is divided into six cells of approximately 20 km by 20 km. The base GPS occupies a suitable site near the middle of the cell and the rovers take gravity and GPS measurements until all sites within the cell have been occupied. The corner sites of each cell become node points and are used as gravity and GPS ties with adjacent cells. This method creates a strong, regularly shaped network of GPS measurements between the bases and forms the backbone of the GPS survey. The second method is suited to surveys where vehicular access may be limited, e.g. along isolated roads, and uses two or more vehicles working in a leapfrog fashion. One vehicle occupies a known position and acts as the base GPS receiver. The other vehicles act as rovers and survey around the base vehicle at distances up to 15 km. One of the rovers then becomes the base GPS receiver and the previous base becomes a rover, leapfrogging the new base to occupy new sites. The bases are used as ties for the gravity loops and are tied together by a network of GPS measurements. Networks created by this method tend to be irregularly shaped because the location of the bases is chosen for accessibility rather than by pre-planning. The networks from both of these methods are tied to the existing geodetic control by occupying trig points for horizontal control, and survey benchmarks for vertical control.

Practical overview of HEM data processing

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The theory of frequency-domain helicopter electromagnetic (HEM) surveys is relatively straightforward, but in practice there are many issues to deal with, both in hardware development and in the software to handle the data processing and analysis (DPA).

This paper gives an overview of standard HEM data processing and analysis techniques. This is not new technology, and is intended only to fill a perceived gap in the literature by summarising existing basic DPA procedures for typical HEM datasets.

Assuming that the inphase (IP) and quadrature (Q) data for each frequency has been calibrated to parts per million (ppm) during data acquisition, the main procedures are as follows.

DATA PROCESSING

- Apply standard geophysical pre-processing techniques such as parallax (lag) corrections.
- Remove non-geological noise from the raw data using appropriate filters.
- Apply drift corrections (zero level corrections). Remove system and instrumentation drift from all EM channels.
- Archive data and analysis results along with proper documentation.

DATA ANALYSIS

- Calculate apparent resistivities and depths.
- Pick anomalies for conductive target body location and analysis. Requires an EM interpreter, but automatic picking provides a first pass.
- Analyse anomaly targets. Calculate apparent conductances and depths to conductors.
- Presentation of results; various combinations of:
    - Standard geophysical maps - survey lines etc.;
    - Apparent resistivity and depth maps;
    - Profile maps of IP, Q, resistivity, anomalies, often superimposed on resistivity or other maps;
    - Classified anomaly symbol maps with annotations (e.g. ID letters, apparent depths, etc.), often superimposed on resistivity or other maps;
    - Detailed multichannel profile plots for each survey line.
    - Conductivity depth sections.
    - Anomaly report.

Detailed ground magnetics as an exploration tool in Central Victoria

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The Castlemaine goldfield has an extensive history of mining, with at least 173 tonnes of gold produced since 1851. Gold mineralisation occurs within quartz veins hosted by the thick monotonous sequence of Ordovician marine turbidites named the Castlemaine Supergroup.

The Geological Survey of Victoria has flown detailed regional scale magnetic and radiometric surveys, which cover large areas of Victoria. The high-resolution aeromagnetic data successfully defines the presence of granite, basalt, and magnetic dykes in the Castlemaine area. Where magnetic dykes are present, structures can also be identified in the airborne dataset. The absence of magnetic marker beds, and low susceptibility contrast between lithologies in the Castlemaine Supergroup, means that the Ordovician bedrock creates little or no magnetic contrast in the airborne data. In addition, the detailed scale of lithological variations within the Castlemaine Supergroup cannot be resolved in the airborne magnetic data. A high-resolution ground magnetic survey (850 line-km) was conducted over a trial area near Vaughan, in an attempt to resolve the small amplitude magnetic variations caused by lithological changes within the Castlemaine Supergroup. The area is covered by detailed geological mapping and includes some known gold mineralisation. The data were collected using 10 m line spacing, and 0.5 m along line sample spacing, at 0.75 m above ground level. Similar survey specifications were employed in trial surveys in the Bendigo Goldfield in Victoria. In both cases, the high-resolution ground magnetic surveys have successfully mapped the subtle stratigraphic magnetic features associated with lithological changes, and in some places have proven useful in delineating areas of alteration associated with gold mineralisation.

Targeted exploration initiative South Australia (TEISA); unlocking the secrets

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A range of new airborne geophysical data sets have been generated for the Southern Gawler Craton, Yorke Peninsula, Peak and Denison Ranges, Stuart Shelf and Adelaide Geosyncline through the Targeted Exploration Initiative.

Designed to unlock to secrets beneath the cover over areas of potential, TEISA has adopted a strong partnering emphasis with industry and AGSO. Consultation with industry during the planning stages of TEISA identified acquisition of high resolution airborne geophysical data and regional gravity data as high priorities.

In 1999, PIRSA and AGSO flew surveys totalling in nearly 300 000 line-km flown at a line spacing of 400 m with company's infilling at a line spacing of 200 m.

Four contractors were awarded the acquisition and processing over separate blocks enabling an excellent forum for observing the various individual acquisition and processing methodologies. As a result nearly 75% of South Australia is now covered by high resolution airborne geophysical data.

As part of TEISA, AGSO flew approximately 122 000 line-km covering the Proterozoic rocks of the Adelaide Geosyncline plus portions of the flanking Stuart Shelf and the Curnamona Craton.

Magnetic and radiometric data from the surveys have been merged with data from adjoining company and government surveys to produce 1:250 000 and 1: 100 000 scale pixel images. NASVD processed 256 channel radiometric data coupled with excellent digital terrain data are providing an excellent tool for regolith and geological mapping.

Prior to TEISA, airborne coverage over the target areas mainly consisted of one mile BMR data, which offered little in detail, nor did it provide adequate information at prospect scale.

Data acquired through the Targeted Exploration Initiative, has given rise to renewed interest by explorers. Previous under explored or neglected ground due to a lack of data considered unprospective by explorers, are now taken up with exploration licences.

High-resolution seismic imagery of palaeochannels near West Wyalong, NSW.

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Two high-resolution 2-D seismic surveys were carried out over palaeochannels near West Wyalong, NSW using an IVIä mini-vibrator. The first aim of these seismic surveys was to map in detail the profile of the palaeochannels. The second aim was to establish the regolith stratigraphy within the channels and evaluate the techniques used for acquiring and processing such data. Short receiver spacings, down to one metre, were used in order to achieve satisfactory resolution of the anticipated shallow targets. The short length of the split spread meant that extra effort was required to eliminate noise close to the source. Paradigm Inc. DISCOä/Focus software allowed interactive tests of processing parameters. A combination of bandpass filtering, spectral equalisation, mutes, and f-k filtering proved effective in suppressing noise and enhancing reflections on the shot records. Refraction statics have been calculated from the first arrivals for all the shots for both lines to reveal the shape of the uppermost layers. Examples of processing tests, as well as the interpreted seismic sections, are presented to demonstrate the effectiveness of high-resolution seismic techniques in imaging regolith stratigraphy and buried palaeochannels. Preliminary results, when tied to borehole data, indicate possible palaeo-erosion surfaces and maghemite gravel-filled palaeochannels to 10 m depth. Saprolite and bedrock interfaces are apparent, indicating palaeotopography with relief exceeding 100 m.

Exploring the Kanmantoo Trough using detailed targeted exploration initiative South Australia aeromagnetic and radiometric data

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Primary Industries and Resources South Australia's Targeted Exploration Initiative has provided an exciting opportunity to acquire detailed 200 and 400 m line spaced aeromagnetic and radiometric data for portion of the Kanmantoo Trough on the eastern side of the Mount Lofty Ranges, South Australia. This data has provided valuable insights into the geology and structure of Cambrian, Kanmantoo Trough metasediments, metavolcanics and igneous bodies that are possibly related to base and/or precious metal mineralisation.

Previous 1.6 km line-spaced data has been replaced by Targeted Exploration Initiative 200 and 400 m line spaced data in the Mannum to Swan Reach area. A solid geology interpretation of covered metasediments, metavolcanics and igneous bodies has allowed much clearer delineation of geological relationships and tectonic features, indicating significant potential for structural and/or stratigraphic traps for mineralising fluids.

Targeted Exploration Initiative South Australia data has also been useful in solving several geological problems that have arisen from recent field mapping. Radiometric data processing has allowed the delineation of several distinct phases of granitic gneiss intrusion related to the Rathjen Gneiss body. Further processing should allow differentiation of other igneous bodies in the same area.

Imaging spectrometry: more than the theory offers

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Spectroscopy is the production and observation of the Electro-Magnetic (EM) spectrum and all methods of recording and measuring for the identification of spectrally distinct and physically significant features of a material. This method of research has been applied to a range of disciplines including geology, botany, environmental studies as well as oceanography. Those regions of the EM spectrum of interest for the discrimination of geological materials include the VNIR between the wavelengths of 400 nm and 1100 nm which highlights absorption features of the Fe and Mn oxides as well as the rare earths. The SWIR (1100 nm - 2500 nm) is significant for identifying mineralogies such as hydroxyls, carbonates, sulphates, micas and amphiboles.

Palaeochannels, particularly those identified in the Gawler Craton of South Australia have been located previously by drilling and geophysical methods such as gravity and TEM as well as the signature from night time thermal imagery. These channels are defined by such characteristics as the shape, the channel fill, the gradient and facies. Occasionally a visible feature of their presence is a series of interconnecting claypans (clearly seen on Landsat TM) which marks the deepest parts of these channels.

A survey flown by a commercially built hyperspectral scanner (HyMap) with 128 channels covering a wavelength range between 440 nm and 2350 nm is the latest airborne scanning sensor to acquire data from the Tarcoola region in the Gawler Craton. The purpose of the survey was to test the scanning sensor device. Over 20 km of data was acquired with the scanner swath width of 2.5 km at a pixel resolution of 5 m. Spectral analysis of this data showed a vegetation response related to landform and groundwater where two palaeochannels are located. The VNIR and SWIR were analysed separately with results from the VNIR analysis showing the distribution and occurrence of 3 endmembers with distinct spectral responses. These were selected from a library of 15 endmembers compiled from the purest pixels making up the image. The first of these included a kaolinite with a poorly crystalline lattice dominating an area of rhyolite from the Gawler Range Volcanics. A strong "red edge" from a chlorophyll response coincided with modern drainage and the third endmember was a mixed pixel which was due partly to a stressed vegetation response and an iron rich clay. The highest distribution and abundance of this endmember occurred as a wide linear feature across the site of the palaeochannels. The sedimentary sequence as determined from drillhole data were used to verify the presence of the palaeochannels as interpreted from the HyMap analysis.

3-D fluid flow tomography

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Time-lapse three-dimensional (TL3-D) seismic techniques are currently being developed to map hydrocarbon reserves within producing reservoirs, in an endeavour to monitor hydrocarbon flow for their improved efficient recovery. Unfortunately, fluid flow effects are not fully understood since changes in temperature, pressure and fluid type, as well as data acquisition and processing all contribute to the TL3-D seismic response.

Previous research has established the ability to simulate the seismic response to changes in grain-size, sorting and pore fluids within physical models constructed using unconsolidated sand. Following on from that research, this research now enables qualitative and quantitative monitoring of pore fluid distributions within unconsolidated sands, using reflection amplitude and velocity tomography. The controlled temperature and pressure conditions, along with the high level of acquisition repeatability attainable using sandbox physical models, allows the TL3-D response to pore fluid movement to be distinguished from all other effects.

This ability to map pore fluids was then applied to the study of fluid movement within unconsolidated sand. It appears that at high injection rates, hydrostatic flow is exceeded and hydrodynamic flow results. Under these conditions, injected buoyant fluids may track laterally into adjacent pore space. The injected fluids were observed to 'seek' the most permeable pathway, associated with the larger pore space of lower capillary pressure, between regions of high hydrostatic pressure and low hydrostatic pressure. Upon the establishment of a connected fluid flow pathway, there is a dramatic reduction in the efficiency of the drivingfluid.

Daily variation of geomagnetic H-field at equatorial and low latitudes

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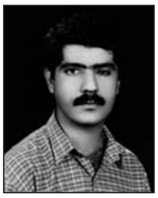
The variations of the geomagnetic H-field in equatorial electrojet (EEJ) regions and non-equatorial electrojet (NEEJ) region have been studied, using the five International Quiet Days of each month for the year 1998. The results of the analysis carried out showed a regular pattern of Sq(H) enhancement at the EEJ regions, peaking around the local noon. On the other hand the variation at the NEEJ region showed a pattern differing slightly from those of the other three stations of the EEJ fields. Correlational analysis results revealed that high significant correlation exists between EEJ field at each of the paired EEJ stations studied, while low insignificant correlation exists between the EEJ fields and the NEEJ field at each of the paired stations of the two separate fields. The diurnal variation so observed was attributed partly to ionospheric plasma irregularities as well as the known dynamo action in the ionosphere. In the NEEJ region, it is suggested that electric field and winds mainly control the phase and randomness on some quiet days. It was also concluded that the variabilities of the current intensities of the EEJ and NEEJ (worldwide Sq) current layer are independent.

Biographies

Section 5



Farhad Abdolahi received his BSc degree in Geology (1993) from the University of Shahid Chamran, Iran and MSc in Exploration Geophysics (1998) from the University of Tehran, Institute of Geophysics, Iran. He is currently working in the Groundwater Exploration Division of Khouzestan Water Power Organisation, Iran. His interest is groundwater exploration in hard formation and karstic areas.

David Annetts received the BSc degree (1989) in Mathematics with Honours in Geophysics, and an MSc (1993) in Geophysics from The University of Sydney. He has worked for CSIRO's Division of Exploration Geosciences as an experimental scientist studying current channelling using electromagnetic scale models and for Geoterrex Pty. Ltd. as a geophysicist with their Ground Geophysics Department. Currently, he is completing a PhD in exploration geophysics at Macquarie University. His areas of professional interest include time-domain electromagnetic prospecting, digital signal processing, programming languages, computer algebra and graphics. He is a member of the ASEG, the SEG, and the IEEE.

Nooruddin Al-Andoonisis earned his first degree (BSc) in Engineering Geology in 1986 from the Faculty of Earth Sciences at King Abdulaziz University, Saudi Arabia and MSc. in Geology in 1992 from the same University. He then attended the Exploration Geophysics Department at Curtin University of Technology where he received a Postgraduate Diploma in Exploration Geophysics in 1996. At present, he is doing PhD studies in the same Department on groundwater prospecting using geoelectrical techniques.

Michael Asten is a consulting geophysicist and Partner with Flagstaff Geo-Consultants, and also holds a part-time academic position as Principal Research Fellow at Monash University. He joined BHP Minerals in 1979 and worked in coal and base-metal exploration in Australia, East Africa and North America, with particular emphasis on geophysical research issues. He has been active in EM research for 14 years, initiated the airborne gravity gradiometer project in BHP, and is author of a short industry course on EM Methods for Geologists. He received the ASEG's Laric Hawkins Award in 1988, is a past Vice-President of the ASEG, an Associate Editor for the SEG, and was Co-Chairman of the ASEG Conference 1998.

John Bancroft obtained a BSc (1970) and MSc (1973) from the University of Calgary and a PhD (1976) from Brigham Young University. He has developed software and specialized in the areas of static analysis, velocity estimation, and seismic migration. John is a faculty member of the University of Calgary and Senior Research Geophysicist with the CREWES Project. He continues to develop a fast prestack migration for conventional and converted wave data, prestack migrated statics analysis, and prestack migration of vertical array data. He received honourable mention for a best paper at the 1994 SEG convention and won the best paper award at the 1995 CSEG National Convention.

Paul Basford graduated with BSc (Hons) in Geophysics from the University of Adelaide in 1992. He joined Pasminco Exploration in 1993, where he worked in Cobar, Broken Hill, South Australia and Queensland. From 1995 to 1997 he was based in Tasmania working in the Mt. Read Belt. In 1997 he moved to Melbourne and worked as a Senior Geophysicist responsible for geophysical activities in Cobar and Western Tasmania. From 1999 he took over responsibilities for geophysics in the Mt Isa Belt, as well as the Project Generation Group.

Don Bennett has been employed as a Technical Hydrologist with Agriculture Western Australia in Bunbury for 9 years. During this period he has been involved with hydrological research into processes and remedies for agricultural dryland and irrigation salinity in southwestern Australia. He has been involved with ground and airborne geophysics, drainage, farm forestry and other high water-use systems research.

Stephen Billings recently completed a PhD in airborne radiometrics from The University of Sydney. Currently he is involved in the helicopter-borne collection of radiometric data with Geophysical Technology Ltd. Stephen's R&D interests include gridding, Fourier transformation and inversion of geophysical data, as well as the development of methods for the detection of unexploded ordinance.

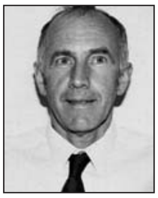
John Bishop has been consulting to the mineral industry for more than twenty years specialising in electrical and electromagnetic methods. He is the principal of Mitre Geophysics Pty Ltd and, with Roger Lewis, a co-director of Applied Geophysical Research Pty Ltd. He has a BSc from the University of Sydney, a PhD from Macquarie University and is a member of ASEG, GSA, AIG, SEG and AusIMM.

Andrew C. Burtt graduated from University of South Australia with Honours in 1992. Employed as a geologist with Primary Industries and Resources (formerly Mines and Energy South Australia) for last 6 years. Worked for the last 4 years on stratigraphy, structure, geochronology and metallogeny of the Cambrian Kanmantoo Trough metasediments, metavolcanics and igneous bodies. For past 6 years has been involved in a GIS compilation of South Australia geology using Arc/Info.

Jock Buselli received a BSc (Hons) degree in Physics in 1967 and a PhD in 1972 from the University of Adelaide. He is now a principal research scientist at the CRC AMET in Sydney. For over 27 years, he has worked on problems in electromagnetic geophysics related to mineral exploration, analogue electromagnetic modelling, and groundwater quality in Australia and overseas. He is a joint holder of patents on the SIROTEM instrument, and has collaborated on the development of SALTMAP, an airborne EM system for mapping near-surface conductivity variations. He has recently investigated new methods for reducing noise contaminating EM measurements and applications of environmental geophysics at minesites. He is a member of SEG and ASEG.

Peter Clark has received his MSc (New England) and did his post-graduate research in potential field gradient measurement and analysis. He now has 15 years geophysical experience, including 12 years in environmental, engineering and UXO geophysics with Geophysical Technology Limited (GTL). Peter specialises in DGPS applications and vehicle mounted systems. He is also working on 3-D computer modelling, spectral analysis and parallel processing for the geophysical detection of hazardous materials. He is a member of AIG, ASEG and SEG (NSG).

Jon Cocker graduated with a BSc (Hons) and MSc (Geophysics, Curtin University) in 1995 and 1998 respectively. He worked as a Research Associate at Curtin University while completing his MSc, working mainly on high resolution seismic processing, before joining WAPET in the Technical Geophysics Team in July 1998. His work involves seismic acquisition and processing, as well as special projects such as pre- and post-stack depth migrations, and investigating, implementing and testing new algorithms (e.g. Band-limited Q compensation, Time-averaged Zero-offset projection, Long-offset NMO formulations and Far-offset AVO).



Duncan Cowan graduated from the University of Nottingham, England with BSc (Hons) in 1963 and a PhD in 1966. He has over 30 years experience in exploration geophysics and geology and has worked on all continents except Antarctica. He works as a consulting geophysicist specializing in interpretation of magnetic, gravity and radiometric data with emphasis on computer techniques for data enhancement, analysis and dataset integration. His research interests include inversion of potential field data, rock and mineral magnetism and kimberlites/lamproites. He lectured at Royal School of Mines, Imperial College, London from 1979 to 1989 and is currently an adjunct research fellow in the Department of Geology and Geophysics, UWA. He is a member of ASEG, SEG, EAGE, IAMG and IMM.

Bruce Craven is a geologist-geophysicist with over 25 years experience in mineral exploration and mining in diverse environments throughout Australasia, Africa and Indonesia. He completed an Applied Science (Honours) degree, majoring in Geology and Geophysics, at the University of Queensland in 1972. Since graduating, Bruce has worked for major resource companies at various locations within Australia and overseas. These companies include Consolidated Gold Fields, MIM, Esso Minerals, Chevron Exploration Company and Asarco Australia [Wiluna Mines] where he held positions of Chief Exploration Geologist and Chief Geophysicist. He joined S.G.C. in 1994 and became a director in 1996.

Tara Deen received her BSc (Hons) from Macquarie University in 1999. Her research involved an assessment of seismic refraction inversion for the delineation of a chosen target. This was done as part of the Gilmore project, in conjunction with AGSO, CRC-AMET, GEMOC and CRC-LEME. Tara is now undertaking a PhD with the University of Sydney. She is a member of the ASEG and SEG.

Michael Dentith is currently Head of the Department of Geology & Geophysics, University of Western Australia. His research interests include the geophysical signatures of mineral deposits, alternative methods of processing and enhancing aeromagnetic data and the seismicity of southwest Western Australia. He is a member of ASEG, SEG, AGU and GSA.

Trevor Dhu graduated BSc (Hons) from the University of Adelaide in 1996. He is currently studying for his PhD at Adelaide University with research on textural-based enhancement of airborne geophysical data. Trevor has also worked for Normandy Exploration since 1996, helping to create and manage their geophysical database. His other interests include potential field geophysics, image processing and automated terrain corrections for gravity data. He is currently a student member of the ASEG, SEG and PESA.

Bruce Dickson obtained his MSc from Wellington University and received a PhD from Imperial College, London in 1973.He moved to Australia where he has been working in CSIRO on a variety of applications of radiation measurements to exploration. His work has covered aspects of uranium grade control, uranium exploration using ground waters, radioactive disequilibrium in uranium deposits and more recently, the understanding and interpretation of aerial gamma-ray surveys.

Peter Elliott graduated with a B.Sc. (Hons) in Geology and Geophysics from the University of Melbourne (1976). He was later awarded an M.Sc. from the University of Melbourne in 1984, and a Ph.D. from Macquarie University in 1997. Peter Elliott has spent the last 8 years working in SE Asia. Most of this time has been spent in Papua New Guinea, and Indonesia. Peter has worked in Indonesia since 1992, and established a permanent branch office in Jakarta in 1996. His work has taken him to interesting locations such as East Timor, Ambon, Kalimantan, Aceh, and many of the other provinces and islands of Indonesia.

Anthony Endres received his BSc (1977) from Michigan Technological University in mathematics, his MSc (1979) from Texas A&M University in applied mathematics, and his PhD (1991) in geophysics from the University of British Columbia. He has been employed as a research geophysicist in the petroleum industry, government laboratories and universities. Dr Endres is currently the Lecturer of Hydrogeology at the University of Western Australia. His research interests include the use of rock physics in geophysical interpretation and the application of geophysical methods to hydrogeological and geotechnical problems.

Will Featherstone is currently Associate Professor of Geodesy and leads the Geodesy Group in the School of Spatial Sciences at Curtin University of Technology. He received a BSc (Hons1) degree in Geophysics and Planetary Physics from the University of Newcastle-upon-Tyne and a D.Phil. in Geophysical Geodesy from the University of Oxford. His research interests include physical geodesy, satellite positioning and coordinate systems, and he has published widely in all these fields. Will is a Fellow of the Royal Astronomical Society and International Association of Geodesy, President of the Australasian Surveying and Mapping Lecturers' Association, and Chair of the International Association of Geodesy's Study Group on Synthetic Modelling of the Earth's Gravity Field.

Professor **Mathias Fink** is a Professor of Physics at the École Normale Supérieure de Physique et de Chimie Industrielles de la Ville de Paris (ESPCI) and at Paris 7 University (Denis Diderot), France. In 1990 he founded the Laboratory Ondes et Acoustique at ESPCI. In 1994, he was elected at the Institut Universitaire de France. His current research interests include medical ultrasonic imaging, ultrasonic therapy, nondestructive testing, underwater acoustics, active control of sound and vibration, analogies between Optics and Acoustics, wave coherence in multiple scattering media and time reversal in geophysics. He has developed different techniques in wave focusing in inhomogeneous media, speckle reduction and in ultrasonic laser generation. He holds twenty patents and he has published more than 180 articles. He received the Silver medal of CNRS in 1995, the Prix FOUCAULT of the French Society of Physics in 1995, The Grand prix de la creativity SNECMA in1994, the Outstanding Paper Award of IEEE Transactions in Ultrasonics in 1992 and his laboratory received the Prize from the magazine : Le Nouvel ECONOMISTE and from the CNRS in 1996. He was the Distinguished Lecturer at the American Acoustical Society meeting in June 1997 (Penn State University) USA.

Nigel Fisher has a BSc (Hons) in Mathematics and an MSc in Geophysics from Imperial College, London. He worked for GSI in London in the early seventies before moving to Australia where he worked in the Mathematics Department, University of Queensland, while undertaking a PhD in Applied Mathematics, which was awarded in 1981. He rejoined the geophysical industry with Digicon in Brisbane in 1982 where he fulfilled a number of technical roles over the following 13 years. In 1995, he established a Consultancy specialising in the supervision of seismic processing. This service was expanded in 1997 to include the provision of seismic processing services, specialising in land data over difficult terrain.

Marcus Flis graduated from the University of Adelaide with a BSc (Hons) in 1979. He was employed by CRA Exploration from 1980 to 1989, principally in the search for base metals. In 1985, Marcus was awarded an MSc from the University of Utah for research into IP effects in TEM. From 1989 to 1995 he explored for gold in Western Australia, the Northern Territory and Greece for Newcrest Mining Ltd. Marcus has been with Hamersley Iron Pty Limited since 1995 and is currently the Principal

Geophysicist with Hamersley Iron Pty Limited, based in Perth, W.A. He is a member of ASEG, EAGE and SEG.

Andrew Foley is currently principal geophysicist with Normandy Exploration and is for all of Normandy's offshore geophysical requirements in addition to those in and around Normandy's Western Australian based mine sites. Andrew graduated from Macquarie University with a BSc (Hons) in Exploration Geophysics in 1988. He joined Surtec Geosurveys in mid-1987 as a geophysicist providing contracting and consulting services to a variety of clients throughout Australia and PNG. In Jan 1991 he joined Normandy Exploration (then Poseidon Exploration) based in their Adelaide office. In Jan 1995 he was promoted to the position of Senior Geophysicist and transferred to Normandy's Perth office. In Dec 1998 he was promoted to his current position of Principal Geophysicist. During his time with Normandy he has been responsible for all aspects of geophysics in both the exploration and in-mine environments in Australia and throughout the world.

Tanya Fomin, a geophysicist has worked with AGSO since 1996. She holds an MSc degree in Geophysics from the St-Petersburg Mining Institute in Russia. Her projects include work on seismic processing and interpretation in the Broken Hill region, ocean-bottom seismograph survey on the Australian North West Shelf.

Li-Yun Fu received a BSc (1985) in Geophysics from China Chengdu College of Geology and his MSc (1992) and PhD (1995) in exploration geophysics from China University of Petroleum. He had been working at China Offshore Oil Exploration & Development Research Center from 1985 to 1989 doing seismic data processing. He did his postdoctoral research in the Department of Engineering Mechanics, Tsinghua University, Beijing from 1995 to 1997 and in the Institute of Tectonics, University of California, Santa Cruz from 1997 to 1999. Now he is a research scientist with CSIRO Petroleum. His research interests include seismic wave modelling and migration, inversion of seismic data, reservoir geophysics, and artificial neural networks. He is a member of SEG, ASEG, AGU and INNS.

Peter Fullagar holds a PhD in Geophysics from the University of British Columbia. He worked in WMC Exploration Division for 12 years, including 3½ years as Chief Geophysicist. During this time he promoted the application of geophysics at Kambalda Nickel Mines. As Chair of Borehole Geophysics at Ecole Polytechnique, Montreal, he introduced radio imaging to Inco nickel mines in the Sudbury Basin. In 1995-96 he was leader of the AMIRA/CMTE P436 in-mine geophysics project, in which borehole logging, downhole radar, seismic, and radio imaging were trialed at seven Australian mines. He subsequently investigated the application of geophysics at Freeport's Grasberg mine in Irian Jaya with Rio Tinto Exploration. He is currently consulting privately to exploration and mining companies.

Stephen Garner joined MIM Exploration in 1997. His research interests are in electrical and electromagnetic methods and signal processing. His current work involves MIM's proprietary distributed acquisition system (MIMDAS). This includes operating system software development, data processing, interpretation, operation/data acquisition and operator support. In 1998, he completed his PhD in the School of Microelectronic Engineering at Griffith University in Brisbane, Australia. Previous work under a National Energy Research Development and Demonstration Council (NERDDC) grant at Griffith University involved the development of the TSIM VLF instrument. This position involved processing software development and field-testing in the central Queensland coalfields.

Jeno Gazdag received his PhD (1966) from the University of Illinois in electrical engineering. Then he joined IBM where he spent 27 years as scientific center staff and project manager. He worked mainly in research and program development in different areas of computational physics. In 1993 he joined the Houston Advanced Research Center, where he conducted research in numerical methods for migration of seismic data. Since 1998 he has been at the Osservatorio Geofisico Sperimentale in Trieste, Italy. His research interest is in 3-D imaging.

Dr Richard George is the senior hydrologist responsible for the management of the Agriculture WA's, Catchment Hydrology Group. The CHG supply NRM Research, Development, Investigation and Education skills to AgWest's Industry and Sustainable Rural Development programs and the WA Community. He has published about 90 significant papers and reports and is recognised nationally as a leading scientist in the in fields of; salinity investigations, catchment processes, landscape evaluation (e.g. catchment geophysics), control and management (particularly engineering and revegetation systems), groundwater modelling and education packaging. He has jointly attracted almost $10M in R&D Funds

John W. Gibson is the Chief Operating Officer of Landmark Graphics Corporation. Since joining Landmark in 1994, John has held other executive positions as well, including vice president of Landmark's Integrated Products Group a Vice-president of technology for the former Zycor Division. He began his career in oil and gas as an exploration geophysicist for Gulf Oil Company. Following the acquisition of Gulf by Chevron, he was manager of geophysical and geological subsurface imaging for Chevron's Oil Field Research Company. He holds a BSc degree in Geology from Auburn University and an MSc degree in Geology from the University of Houston. He is a member of the AAPG, the SEG, and the Geological Society of America.

Adrian Goldberg is an MSc. candidate at Monash University. His project is focussed on the relationship of large fanning dyke swarms to rift systems. He has studied the Gairdner and Botswana Dyke Swarms in detail using aeromagnetic and gravity datasets. He has also conducted AMS and palaeomagnetic studies on the Rehoboth Dyke Swarm in Namibia.

Alexey Goncharov is a Research Scientist who has worked with AGSO since 1994. He holds a PhD in Geophysics from the St Petersburg Mining Institute in Russia. His research interests are mostly in studying the structure of the crust and upper mantle by various seismic methods. In recent years he expanded his original seismic orientation to petrological interpretation of seismic data. His projects include work on seismic interpretations from the Baltic Shield and the super deep bore hole in the Kola peninsula in Russia, velocity and petrological models for the Mount Isa region, and an ocean-bottom seismograph survey on the Australian North West Shelf.

Stewart Greenhalgh is Professor of Geophysics, Douglas Mawson Chair and Head of the Department of Geology & Geophysics at the University of Adelaide. He holds BSc (Hons. I), MSc and DSc degrees in Geophysics/Mathematics from the University of Sydney, and a PhD degree in Geophysics from the University of Minnesota. He has worked in various areas of geophysics, including engineering investigations, coal and petroleum exploration, mining applications and earthquake seismology. He was on the academic staff of Flinders University from 1981 to 1997, where he rose to the rank of Professor. He has spent sabbaticals at Oxford University, University of Minnesota and Western Mining Corporation. Professor Greenhalgh has been a consultant to the mining and petroleum industry, as well as to several government agencies. He has published widely in refereed international journals on various aspects of theoretical and experimental geophysics. He is a member of SEG, EAGE, SSA, AGU and

ASEG and has served on the executive of a number of national scientific committees and professional associations.

Wanwu Guo obtained his BSc (Hons) in Exploration Geophysics from the Changchun College of Geology, China (1982), and MSc in Geodynamics and Seismology from the Seismological Institute of Lanzhou (SIL), the China State Seismological Bureau (1991). He recently submitted his PhD thesis in Geophysics at the University of Western Australia. He was employed as a project geophysicist by the Bureau of Geology and Mineral Resources of Gansu Province during 1982-1989, working on mineral deposit exploration, regional geophysics and basin analysis in western China. He joined SIL as a research geoscientist working on crustal/lithospheric geophysics and geodynamics, tectonophysics and earthquake seismology from 1992 to 1995. He is a member of the ASEG, SEG, AGU and GSA.

Nicholas Gyngell, Geophysicist with RGC Exploration Pty. Ltd. 1994 - 1998 where he was involved in gold exploration in the Kalgoorlie district. Currently he is enrolled at Curtin University completing an MSc in Geophysics (by coursework) in petroleum studies.

Michael Hallett received his BSc with Honours from the University of Sydney in 1988. He was awarded his MSc in Geophysics, Geology and Petrophysics in 1997. Michael is the Senior Technical Geophysicist for DIGHEM surveys at Geoterrex-Dighem Pty Limited and has travelled throughout Australia and to Canada, South America and Indonesia for various geophysical surveys. He is currently involved with on-going improvements in acquisition and data processing for the DIGHEM system for mapping purposes for both land management and mineral exploration purposes.

Dan Hampson received his BSc degree in physics from Loyola College, Montreal, in 1971, and received his MSc in theoretical physics from McMaster University, Hamilton, in 1973. From 1973 to 1975, Dan taught physics and maths in Ghana, as part of the Canadian University Services Overseas program. In 1976, Dan joined Veritas Seismic Processors, where he held a number of positions, including research manager and ultimately Vice President for Research. In 1987, Dan left Veritas and joined with Brian Russell to form Hampson-Russell Software Services, where he has been president to this time.

Bruce Hartley graduated from the University of Western Australia in 1969 with a PhD in physics. His professional appointments include lecturing in Physics at James Cook University, post Doctoral position at the University of Waterloo and Collaborator with the French Atomic Energy Commission. He joined the Department of Exploration Geophysics in 1994 after a career in radiation protection and research into instrumentation for measurement of natural radioactivity. He is currently working on methods of removal of multiples from seismic data.

Dr. Peter Hausknecht received his PhD at LMU University in Munich, Germany working on a project with the CSIRO, Exploration & Mining in Sydney about 'Thermal IR Laser Remote Sensing'. As a senior project scientist at the German Aerospace Research Center near Munich he spent almost 10 years working on satellite and airborne remote sensing subjects focusing on hyperspectral airborne technology. In late 1997 he joined WGC in Perth as the Project Manager for Mineral Mapping Technologies in its Product Development Division and is leading the project team developing hyperspectral Mineral Mapping as a new exploration line.

Suzanne Haydon is a geophysicist with the Department of Natural Resources and Environment in Victoria. Her current projects include the geophysical signatures of base metal mineralisation in Victoria, and a similar project on gold and industrial minerals in Victoria. She graduated from the University of Melbourne, with a BSc. (Hons) in Geophysics in 1993. Suzanne is actively involved with the Victorian Branch of the ASEG, is the current branch Vice-President, and was part of the Conference Organising Committee for the 1998 ASEG conference in Hobart.

Steve Hearn is a Research Scientist with Veritas DGC Australia, and a Lecturer in exploration geophysics at the University of Queensland. He received Applied Science (Hons 1) and PhD degrees from the University of Queensland in 1975 and 1981. Subsequently he has worked for Australian and international seismic companies and as a consultant. He is interested in most aspects of seismology, with current emphasis on multicomponent processing, reflectivity characterisation, and trace inversion.

Roger Henderson is General Manager of Geo Instruments based in Sydney. He holds an MSc from Sydney University and was a lecturer at Macquarie University in Sydney from 1968 until 1971, followed by three years in the UK as a geophysicist, first with Hunting Geology and Geophysics and then Barringer for three years before returning to Australia to join Geoex Pty Ltd of Adelaide as a Director. In May 1982 he became V.P. of Geometrics International Corporation, a subsidiary of EG&G Geometrics of the USA. When G.I.C. was purchased by the Kevron Group of Perth in 1986, Roger was appointed General Manager of the newly formed Geo Instruments. Roger has papers published on a range of subjects, has twice been President of the Australian Society of Exploration Geophysicists and Co-Chairman of two of its conferences and for his dedication to the ASEG he was awarded Honorary Membership in 1994.

Natasha Hendrick graduated from the University of Queensland in 1993 with Honours in Applied Science (Geophysics). She was awarded a University Medal and an Australia-at-large Rhodes Scholarship. Following a year of study at the University of Oxford, Natasha joined the Special Projects Group with Veritas DGC (formerly Digicon Geophysical). Her work included PSDM, velocity model building and wave-equation datuming. In 1997 Natasha returned to the University of Queensland to begin her PhD on 'Applications of Multi-Component Processing in Exploration Seismology'. Her research is funded by an APA[Industry], and she was selected as the 1998 APPEA K.A. Richards Memorial scholar. Natasha is a member of the ASEG Qld Branch Committee.

Fred Herkenhoff obtained BSc and MSc degrees in Geophysics from Stanford University in 1964 and 1966 respectively. He began work for Chevron Research in 1966 and has worked in various technical and geophysical management positions for 6 Chevron operating companies. He has held the position of Chief Geophysicist for Chevron USA Western Region and Caltex Pacific Indonesia and for Wapet since 1996. He maintains technical involvement in 2D/3D seismic acquisition design and in the development and application of new seismic processing and analysis techniques.

Richard Hillis holds the State of South Australia Chair in Petroleum Reservoir Properties/Petrophysics at the National Centre for Petroleum Geology and Geophysics, University of Adelaide. He graduated BSc (Hons) from Imperial College (London, 1985), and PhD from the University of Edinburgh (1989). After positions at Flinders University, Adelaide, the British Geological Survey, Edinburgh, and the Department of Geology and Geophysics, University of Adelaide, Richard joined the NCPGG in 1999. His main research interests are in sedimentary basin tectonics and contemporary stresses in the oil patch. Richard is a member of AAPG, AGU, ASEG, EAGE, GSA, GSL, PESA and SEG.

Adrian Hitchman completed a BSc (Hons) in Geophysics at the University of New England, in 1982. He subsequently began work at the Bureau of Mineral Resources where he collected magnetic-field data for periodic updates of the Australian Geomagnetic Reference Field model. In 1991 Adrian undertook teaching qualifications and became a Science/Maths teacher. He has recently completed PhD research at the Australian National University, where he investigated interactions between electromagnetic induction in the Earth and total-field magnetic mapping data. Adrian is a Committee Member of the ACT ASEG Branch and also a member of the SEG, EAGE and AGU.

Gregg Hofland is a seismic modelling and depth conversion specialist with Landmark Graphics Corp. in Englewood, Colorado. Prior to working for Landmark, he has held similar positions with Western Atlas Software and Sierra Geophysics.

David Howard graduated from Imperial College, London, with a BSc (Hons.) in Physics (1970) and an MSc in Geophysics (1972). Prior to joining the Geological Survey of Western Australia in 1990, he worked in a variety of organizational and geological environments in Britain, Canada, Africa, South America and Australia. After completing an MBA degree in 1993, he held the position of Manager of Planning and Review in the WA Department of Minerals and Energy, followed by a brief period as General Manager of Kevron Geophysics. In August 1997 he returned to the Geological Survey as Chief Geophysicist.

Naomi Kano is a research geophysicist and has worked with Geological Survey of Japan (GSJ) since 1977. His projects are focused on works related to seismic reflection survey.

Pierre Keating received both a BSc (1972) in Engineering Physics and an MSc (1975) in geology from Laval University in Quebec City and a PhD (1987) in geophysics from McGill University in Montreal. From 1974 to 1981, he was a geophysicist for the Quebec Department of Energy and Resources . He was chief geophysicist for ACSI Geoscience Inc. from 1983-1988, when he joined the Geological Survey of Canada. His current research topics are the interpretation and processing of geophysical data and inverse problems. He is a member of SEG, ASEG, AGU, CGU, and the Order of Engineers of Quebec.

Myra Keep is a Lecturer in Basin Tectonics at the University of WA, with a background in structural geology, tectonics and basin analysis. She is currently working on reactivation and inversion on the North West Shelf caused by the plate collision of Australia with the southern margin of the Sunda craton since the Oligocene. Since leaving Mobil in 1995 she has held academic appointments in the UK and Australia.

Anton Kepic has spent the past decade investigating seismoelectric phenomena, gravity gradiometers, in-mine geophysical methods, and developing instrumentation for EM measurement. He participated in the evaluation of various seismoelectric phenomena for use in mineral exploration from 1989 to 1995 whilst earning a PhD in Geophysics at the University of British Columbia. Afterwards, three years were spent at WMC Exploration, and WMC Group Technology as a research geophysicist investigating improvements in-mine geophysics, and geophysical instrumentation. Currently, as a consultant for WMC, advanced borehole TEM/FDEM tools are being developed before moving on to take up a position at Curtin University in late 1999.

Abbas Khaksar is a postdoctoral fellow at the National Centre for Petroleum Geology and Geophysics, University of Adelaide. He received a first class BSc in Mining Engineering-Exploration from Tehran University, Iran, in 1990. From 1990 to 1992 he worked as an explorationist for the Geological Survey of Iran. Abbas received his MSc in Petroleum Geology and Geophysics (1994) and PhD in Petrophysics (1999) both from the University of Adelaide. The topic of his PhD was "a petrophysical study on the influence of effective stress and fluid saturation on acoustic velocities in sandstones". His main research interest is the use of rock physics and log analysis in hydrocarbon exploration and development. He is a member of ASEG, PESA, EAEG and London Petrophysical Society.

Stefan Kleffmann is a recent PhD graduate from the University of Wellington, New Zealand. He has a background in applied Geophysics and Tectonics. Since March '99 he has been a postdoctoral research fellow in the Tectonics Special Research Centre at UWA, and is involved in processing and interpretation of deep crustal seismic data recorded in the Hamersley Province.

Alexander Kritski graduated in 1989 with a BSc degree from the Moscow Institute of Electronics and Automatics (Russia) and joined the Acoustic Institute as an engineer specializing in underwater and ocean acoustics. In 1995 he moved to Australia. He is currently completing his PhD at the University of Sydney. His project "Structure and formation of the Roebuck basin and adjacent shelf off North west Australia" based on a deep seismic dataset provided by AGSO is unravelling the tectonic history of the Northwest Shelf of Australia. His main interests are seismic modelling and underwater acoustics.

Marty Ladyman is a Broomehill farmer with experience in the implementation of geophysics-based on-farm strategies to remedy salt affected land. As a result he has experienced productivity gains and control over his salinity problem. For the past two years he has been managing Agraria Limited, which supplies farm plans to landholders based on multiple data sets.

Yves Lafet has been with Compagnie Generale de Geophysique for a total of 25 years. 15 years of this time has been involved in 3D inversion, His role is currently that of technical supervisor for inversion projects.

Richard Lane received a BSc Hons (1983) in Geology and Geophysics from the University of Melbourne. He began his career with CRA Exploration as a geophysicist in 1984, working on mineral and petroleum exploration projects throughout Australia and South East Asia. In 1997, he joined World Geoscience Corporation as Chief Geoscientist for the Product Development Division. He was appointed Program Leader for the Airborne EM Systems Program of the CRC AMET in 1997.

James Lee has worked at the BHP research laboratories in Newcastle NSW since 1981. His work related to mineral exploration began in the field of airborne infrared spectroscopy and included the deployment of the GER Scanner in an Australian mission in 1987. He was later involved in the joint BHP/CSIRO Airborne Imaging Spectroscopy project. In 1991 he began his involvement with CSIRO in development of high temperature SQUID magnetometers and their deployment in airborne TEM. In this project he was leader of the BHP team responsible for implementation of the airborne system.

Chris Leslie is currently completing a BSc (Hons) from the ANU, Canberra, and the CRC LEME. He is a recipient of a CRC LEME Honours scholarship, and his honours project involves using shallow high-resolution seismic reflection techniques to image buried palaeochannels within the regolith at West Wyalong, NSW. An ASEG Research Foundation student grant has assisted with this task. Chris previously graduated in 1974 as a maths/music teacher, taught maths in a teachers college in Papua New Guinea, and pursued an extended career as an electronics technician.

Min Li is currently a student at University of Sydney, studying for a Masters Degree in Geophysics. She has work experiences with Wiltshire Geological Services on well-logging data management. She has developed an interactive seismic data processing and interpretation software, SeisWin, which has been used by several companies and research institutes.

Ruiping Li received his BSc (1984) and MSc (1988) in Physics at Wuhan University, China. From 1984 to 1985, he was employed by the Department of Applied Physics, Hunan University, China, as an assistant lecturer. From 1988 to 1995, he worked at the Radar Academy, China, as a lecturer. Currently he is a PhD student in the Department of Exploration Geophysics, Curtin University of Technology. His research work is concerned with seismic wave propagation, elastic parameter estimation and moveout velocity corrections in transversely isotropic media.

Andrew Lockwood received his honours in Geophysics from the University of Queensland in 1994, having already completed a BSc in Geology from the Queensland University of Technology. He worked in the geophysics group at Mt Isa Mines for a year before being transferred to field duties in WA. He is now at the University of Western Australia working towards a PhD. His research is concerned with the simultaneous inversion of electromagnetic data with particular reference to the MIMDAS system. The research is funded by an APA(I) grant from ARC with support from MIM and an ASEGRF grant. The project is affiliated with the CEMI at University of Utah. Other research interests include inference theory and electromagnetic modelling.

James Macnae is a Professorial Fellow in the AMET CRC at Macquarie University. He has 30 years experience in mineral exploration in Africa, Europe, Australia, North and South America, and 15 years academic experience (universities of Witwatersrand, Toronto and Macquarie) combined with simultaneous consultancies to many major mining exploration companies. For 12 years he was the research director of Lamontagne Geophysics Ltd (Canada) and managing director for the geophysical contractor Lamontagne Geophysics (Australia). He also spent 3 years as a field geophysicist with Geoterrex.

Timothy Mackey received his BSc (Hons) degree in Geophysics from Monash University in 1993. In 1994, he joined the geophysical mapping section of AGSO. Since then he has worked in image processing, contract supervision and airborne geophysical data processing. He is currently involved with integrated GIS interpretations of geophysics and geology. Timothy has worked on several geophysical interpretation projects, including Fiji, Mount Isa Inlier, Lachlan Fold Belt, Eastern Goldfields, offshore Otway Basin and the Southern Joseph Bonaparte Gulf.

David Maidment completed a BSc (Hons) in Geology at the University of New South Wales in 1991. He spent two years working for UNSW as a research assistant performing geochronological work at the SHRIMP facility at ANU. He joined AGSO in 1994, where his duties have included geophysical interpretation, geological synthesis and GIS development.

Chris Manuel graduated from Curtin University of Technology in 1996 with a first class honours degree in Mineral Geophysics. He then worked as a crew leader for Scintrex Pty Ltd where he undertook the acquisition and processing of various geophysical data from all over Western Australia. In 1998 he obtained an MSc degree in Petroleum Geophysics and is currently undertaking a PhD with research being concentrated on the removal of seismic multiples via seismic multiple migration.

Jun Matsushima, a research geophysicists received a B.E.(l992), M.E. (1994) and Ph.D.(1999) in engineering from the University of Tokyo. From 1994 to 1996 he worked at Geological Survey of Japan. From 1996 to 1999 he worked at the University of Tokyo. Since 1999 he has worked with Geological Survey of Japan. His interests include all aspects of the seismic method applied to geothermal and heterogeneous problems. He is a member of SEG, SEGJ, Japan Soc. for Computational Engineering, Seismological Soc. of Japan.

Jason McKenna graduated from Curtin University of Technology in 1998 with a BSc in Geophysics. Jason is now completing an honours degree in Petroleum Geophysics at Curtin University and is expected to graduate at the end of 1999. His current research involves fluid flow analysis within simulated reservoirs and the time-lapse 3-D response. He is currently a student member of the SEG, ASEG and the AAPG.

Alex McAlpine is Director of Spectrum Exploration Ltd. and has a particular interest in quantitative methods in petroleum geoscience, including basin modelling. Alex worked with Shell International for 13 years, which included assignments in quantitative geophysics research and a loan assignment to the U.K. Department of Energy. From 1992 - 1997 he worked with Fletcher Challenge Energy Taranaki Ltd. on a number of development and exploration projects. Alex holds a PhD from the University of Newcastle upon Tyne in the U.K. and is Vice President of the New Zealand Association of Petroleum Geologists and a National Committee Member of the Geological Society of New Zealand.

Paul McDonald, a geophysicist, has worked with the Geological Survey of Victoria since 1989. His projects include; ground gravity/GPS acquisition, aeromagnetic surveys, geological interpretation and image processing within Victoria. He is a member of ASEG.

Tony Meixner completed his BSc degree, majoring in geology, at the ANU in 1991. The following year he completed an Honours degree at the Research School of Earth Sciences, ANU, involving the three-dimensional kinematic modelling of the magnetic field of the southern Joseph Bonaparte Gulf. At the beginning of 1996 he began employment in the Airborne Geophysics Section of AGSO. During this time he has been involved in a number of interpretation projects, specialising in the modelling of potential field data as an aid to interpretation.

Dr Jayson Meyers, is currently the Manager Geophysics for Great Central Mines and a number of other mining and exploration companies. These companies are actively exploring for and mining a number of different mineral commodities. He has experience in data acquisition, processing, interpretation and geological integration using wide range of geophysical techniques. This experience has led him around the world to work on projects from deep-seismic tectonic studies off of West Africa to hunting for kimberlites in China.

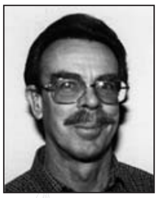
Mike F. Middleton completed a PhD at Sydney University in 1978. From 1979 to 1990, he worked for CSIRO, ECL (Australia) Pty. Ltd., and the Geological Survey of Western Australia. From 1990 to 1993, he worked as a private consultant, and held the post of Adjunct Associate Professor in the Department of Exploration Geophysics at Curtin University. From 1993 to 1998, he held the post of Nordic Professor of Petrophysics at Chalmers University of Technology in Sweden. He was appointed as Professor of Petroleum Geology at Curtin University of Technology in January 1999.

Brian Minty received a BSc (1976) from Rhodes University, a BSc (Hons) (1977) in Geophysics from the University of the Witwatersrand, an MSc (1982) in Exploration Geophysics from the University of Pretoria, and a PhD (1997) from the ANU. He worked for the Geological Survey of South Africa for 5 years before immigrating to Australia to work for Hunting Geology and Geophysics Ltd. He is currently a Principal Research Scientist at AGSO in Canberra, Australia. His research interests relate mainly to the acquisition, processing and interpretation of airborne magnetic and gamma-ray spectrometric data.

Ian Moore joined Western Geophysical as a research geophysicist in 1996 after completing a degree in mathematics at Cambridge University, England, and a PhD in the same subject at Leeds University, England. His main research interest is in multiple attenuation and as such he provides processing and R&D support to regional centres throughout Europe, Africa, the Middle East, the Far East and Australia. Currently, he spends a considerable proportion of his time in Western's Abu Dhabi processing centre in order to concentrate on interbed multiple problems typical of the Middle East.

Tim Munday, leads the AEM Mapping Program within the CRCAMET. Over the past six years he has been working on improved methods for the interpretation of AEM data in regolith dominated terrains. He has a BSc and PhD from the University of Reading, UK.

Marco Nyoni graduated from the University of Southampton, UK, with an Honours degree in Geophysical Sciences, in 1992. He then worked for a geophysical contracting firm for several years, covering groundwater, diamond, mineral exploration and geotechnical projects throughout southern Africa. He is currently, a Senior Geophysicist at Anglovaal Mining Ltd. supervising and interpreting geophysical surveys on various mineral exploration projects. He is studying part-time for a Masters degree (MMET) at Curtin University, Perth. He is an associate member of the SEG and SAGA (South African Geophysical Association).



Derecke Palmer, is a Senior Lecturer in Geophysics in the School of Geology at The University of New South Wales. He graduated from The University of Sydney in 1967 with a BSc (Hons 1). In 1976, he was awarded an MSc on the GRM, a method for processing and interpreting seismic refraction data. In1992, the ASEG awarded him the Grahame Sands Award for Innovation in Applied Geoscience for the GRM. In 1995, the SEG awarded him the Reginald Fessenden Award "for the development of the generalized reciprocal method, one of the most significant innovations in refraction seismology in more than 50 years".

Dr Dogan Perincek has worked for the King Fahd University of Petroleum and Minerals in a joint project with Saudi Arabian Oil Company since 1997. He received his MSc and PhD from the University of Istanbul in 1972 and 1978 respectively. He worked for the Turkish Petroleum Corporation, Mobil Exploration, Geological Survey of Victoria and Western Australia, World Geoscience Co. Ltd. and Robertson Research as a structural geologist and petroleum explorationist. Dr Perincek is currently working as a Geo-consultant. He is a member of the American Association of Petroleum Geologists, Australian Society of Exploration Geophysicists and Petroleum Exploration.

Bill Peters graduated with BSc (Hons) from the University of Western Australia in 1972. He started his career with McPhar Geophysics in Western Australia before joining Anglo American Corporation carrying out various geophysical projects throughout southern Africa. In 1980 he joined BHP in Western Australia, principally working on diamond exploration geophysics. He next worked for Teck Explorations Ltd and DIGHEM Ltd, mainly on helicopter electromagnetic surveys, in Australia and Canada. Since 1985, he has been a principal with Southern Geoscience Consultants, consulting on mineral geophysical projects in Australia and other parts of the world for companies, government agencies and the UN. He is a Member of the ASEG, SEG, AIG, SAGA and a Fellow of the AusIMM.

Peter Petkovic obtained a BSc in geology, physics and mathematics at the ANU in 1971. He worked with the Bureau of Mineral Resources in acquisition, processing and interpretation of data from Australia's first continental margins survey in the 70's. In 1978 he completed a Grad Dip Ed and Grad Dip Curric and then taught mathematics for 10 years. Since 1989 he has worked at AGSO on the development of a long-range radio navigation system, management of processing and software development for marine gravity, magnetic and bathymetry data, development of processing and modelling systems for refraction data, and image processing.

Geoff Pettifer is Principal Geophysicist with Geo-Eng Australia Pty. Ltd. He was formerly in the Victorian Department of Natural Resources and Environment Petroleum Development Unit as Manager Basin Studies and Petroleum Information and the Geological Survey of Victoria as Principal Geophysicist, where his work included developing geophysical methods for fireholes in brown coal. He also worked as a geophysicist in the BMR and the Geological Survey of Papua New Guinea. His interests, experience and current consultancy work cover groundwater, engineering, mining, environmental, regional and basin geophysics, GIS / database and information management. He is a member of ASEG, SEG and PESA.

Timothy Pippett is the Principal and Consulting Geophysicist of Alpha Geoscience Pty. Limited, which he founded in 1997. He has undertaken consulting projects in the environmental, engineering and ordnance fields around the world since that time. His projects include location of buried UXO's around the world, development of a multi-sensor geophysical package for the coal industry and the use of geophysics for environmental and forensic applications. He is a member of ASEG, SEG, EEGS, EAGE and a Fellow of AIG.

Igor Popkov is currently undertaking an MSc in Geophysics at the Flinders University of South Australia. He received his Diploma in Geophysics from the Kazakh Polytechnical Institute in 1992. Igor started his career in the Institute of Exploration Geophysics in Almaty, Kazakhstan, where he worked on seismic acquisition and data processing. From the end of 1992 to 1996 he was a research assistant for a joint project between the Kazakh Polytechnical Institute and the Complex Geophysical Expedition. He is currently a member of ASEG and AGU.

Gabriella Pracilio, environmental geoscientist, has worked with World Geoscience Corporation since 1997. Projects have involved interpreting geophysical and other data sets to identify Salt Hazards for watershed management applications, across various Australian terrains. This includes involvement with the National Airborne Geophysics Project and farmer-funded projects.

Art Raiche is a Chief Research Scientist at CSIRO Exploration & Mining, seconded to CRC AMET, where he is program manager for mathematical geophysics. Over the past two decades, he has originated and led seven AMIRA mathematical EM modelling projects with wide international sponsorship. A former Dobermann breeder, his main outside interest is playing the shakuhachi, an end blown flute of Japanese origin.

J. E. Reid received his BSc (1991) and MSc (1994) in Geophysics from the University of Sydney, Australia, and has recently submitted a PhD at Macquarie University, Sydney. He is currently an Associate Lecturer in Geophysics at the University of Tasmania, and is a member of ASEG, SEG and EEGS. His research interests are in electromagnetic methods applied to mineral exploration and environmental problems.

Thomas Alan Ridsdill-Smith graduated in 1994 from the University of Western Australia with an honours degree in Mathematical Geophysics. From 1995 he worked for two years for World Geoscience Corporation as a geophysicist specialising in potential-field interpretation and processing. Since early 1997 he has been studying wavelets and time-frequency processing of aeromagnetic data as part of his PhD at the University of Western Australia.

David Robson is Chief Geophysicist of the New South Wales Department of Mineral Resources. He graduated from the University of New South Wales with a BSc in 1975, and a Grad. Dip. App. Geophys. in 1976. He then worked with Scintrex for two years before joining the Metalliferous sub-section of the BMR (now AGSO). David spent nearly four years with the BMR where he worked in the Georgetown and Alligator Rivers areas before joining Western Mining Corporation (WMC). With WMC, David was part of the mineral exploration team and worked throughout Australia (in particular the Western Australian goldfields) and the Philippines. In 1994 he joined the Department and has been involved with the Discovery 2000 Exploration Initiative, regional geological/geophysical mapping program and coal exploration. Currently he is the Federal Secretary of ASEG.

Murray Roth is currently Vice President for Exploration and Development Systems, Landmark Graphics Corporation. Murray has been with Landmark for ten years in roles ranging from customer support, through software product/program management, and senior management of software development and product marketing. In his current role, Murray is accountable for the envisioning of new product development and selecting enhancements to existing products, in support of integrated E&D workflows. Prior to joining Landmark, Murray spent 10 years with GSI/HGS in the areas of marine seismic acquisition, marine/land seismic processing, specialty processing (Inversion, VSP) and interactive workstation support. Murray is an active member of the SEG, EAGE and APEGGA.

Hugh Rutter is an experienced explorer in Australia and throughout the world. Clients include most major Australian and several overseas exploration companies. Prior to establishing himself as a Consultant in 1981, he worked for Western Mining Corporation Limited for nine years and BHP, where he was Chief Geophysicist, for five years. At WMC he is credited for contributing to the discovery of the Olympic Dam orebody. He is a Fellow of the AusIMM and Aust. Inst. Geosc.; a member of a number of professional organisations including MICA and the SEG; and is a past President and an Honorary Member of the ASEG.

Ben Sanderson, a 1997 Geophysics graduate from Curtin University of technology is currently completing his Honours in Petroleum Geophysics. He has 7 months land seismic acquisition experience along with a further 6 months in transition zone acquisition, both within Australia and the USA. His current Honours project is aimed at optimising attenuation of surface related multiples from offshore seismic data.

Djoko Santoso received his first degree (Sariana Teknik, 1976) in Geology/Geophysics from Bandung Institute of Technology (ITB-Indonesia), the Post. Grad. Dipi. In Seismology from International Institute of Seismology and Earthquake Engineering Tokyo-Japan (1979), M.Sc. in Geotechnical Engineering from Asian Institute of Technology Bangkok-Thailand (1982). He completed his Doctor of Technology (1990) in Geology from ITB. He has wide range of experience in geological and geophysical exploration activities in Indonesian region. He currently holds the position of Professor in applied geophysics and Vice Rector of the Bandung Institute of Technology. He also has an appointment as Adjunct Professor at the Department of Geology and Geophysics, Texas A & M University, USA and Ajunct Asoc. Prof. At the Department of Exploration Geophysics, Curtin University of Technology, Australia. He is a member of SEG (active member), EEGS, AAPG, IAEG, and AGID.

Daniel Sattel received his Vordiplom from Universitaet Karlsruhe, Germany in 1986, and an MSc from Oregon State University, U.S.A. in 1990, for processing and interpreting seismic refraction data. After finishing PhD studies in geophysics at Macquarie University he joined World Geoscience Corporation in 1996. His current focus is directed on the modelling and interpretation of airborne EM data.

Don Sherlock graduated from the University of WA in 1995 with a first class honours degree in geology. Since graduation he has been employed part time at Curtin University as manager of the Physical Modelling Laboratory while working on a PhD in Geophysics. He is a student member of PESA, ASEG, SEG, and the AAPG.

David Sibley graduated with a BSc (Geology) in 1980 and an MSc in 1983 from Auburn University. After joining Chevron, USA, in 1983, he began work as an exploration geologist in the Gulf of Mexico and later held positions of geophysicist and staff development geologist. He is currently a staff geologist with Chevron Overseas Petroleum Inc. on loan to WAPET. Member: AAPG

Bension Sh. Singer received his MSc (1971) in Physics from Moscow State University and his PhD (1981) in physics and mathematics from Russian Academy of Sciences. From 1977 to 1991 he worked as a junior, later as a senior research scientist for Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave Propagation in Moscow with Russian Academy of Sciences. From May 1993 till November 1995 he was a senior research scientist in the through-casing resistivity project for Western Atlas Logging Services, WAII in Houston, Texas. He joined CSIRO in December 1995 where he currently holds a position of a senior research geophysicist. His scientific interests are mainly focused on development of methods for modelling and inversion of electromagnetic data. He is a member of AGU, SEG and ASEG.

Nigel Smith graduated with a BSc with Honours (Physics) in 1981 from the University of Western Australia. He joined Schlumberger in 1982 and had various assignments as a wireline field engineer. In 1987, he obtained a Post Graduate Diploma in Geophysics from Curtin University. He returned to Schlumberger and held posts as an area geophysicist in Indonesia, Norway and Perth. He joined Wapet in 1997 as a special projects geophysicist and is involved in surface seismic processing and specialist geophysical analyses (wavelet extraction, inversion, AVO studies and depth conversion for example) as required.

Ned Stolz graduated from the University of Adelaide in 1985 with Honours in Geophysics. For the following five years he was employed by CRA Exploration and worked on projects in Western Australia, northwest Queensland and the Northern Territory. Between 1992 and 1997 he completed a PhD at the AMET CRC on the topic of automatic interpretation of EM data. In 1997 he was appointed senior exploration geophysicist at the WMC Leinster Nickel Operation, where he is actively involved in acquisition and interpretation of surface and downhole EM data.

Greg Street, principal scientist has worked with World Geoscience since 1991. Projects included applications of airborne and ground geophysical techniques to a wide range of environmental, groundwater and land degradation investigations throughout the world. Particular projects have included The National Airborne Geophysics Project for the National Dryland Salinity Program in Australia and groundwater exploration projects in Orissa, India and Botswana.

Chris Swain received an MSc in Exploration Geophysics from the University of Birmingham in 1968. He worked for Hunting Surveys for 3 years, then went to the University of Leicester where he obtained a PhD for a geophysical study of the Kenya Rift, leading to a teaching post at the University of Nairobi. From 1984 to 1990 he taught at the University of Zimbabwe, having responsibility for the MSc course in exploration geophysics. He then spent 2 years with the British Antarctic Survey, before joining WMC Resources as Senior Geophysicist with the diamonds group. He is currently an independent consultant.

Michael Sykes graduated form the WA Institute of Technology in 1981 with a BSc degree in Physics, and worked with GSI as a processing seismologist before returning to WAIT to complete a Graduate Diploma in Education in 1983. He worked as a secondary school teacher for too many years before enrolling for Honours in Remote Sensing at Curtin University in 1994. He is currently a PhD candidate working on 3-D electromagnetic modelling and signal enhancement.

Troy Thompson received a BSc Hons (1st class) in Exploration Geophysics from Curtin in 1998. In 1997, he was awarded the Dean's Prize for the most outstanding third year student in the Faculty of Sciences at Curtin, as well as the Australian Institute of Physics Prize. That same year he was awarded the Rio Tinto Field Mapping Prize, the Aus. IMM Bursaries Fund Prize, and was inducted into the Golden Key National Honour Society. He has twice attained membership of the prestigious Curtin University Vice Chancellor's List for the top student of his year. His employment includes vacational work with Santos, WMC Exploration and Mobil. He is a student member of the SEG, ASEG, AusIMM, and Golden Key National Honour Society. He enjoys tennis, hockey and camping. His claim to fame in 1999 was to hike the full length of the Appalachian Trail over a 7-month period.

Greg Turner received a BSc (Hons) in Earth Science from Monash University in 1986 and a PhD in Earth Science from Macquarie University in 1994. He has worked as a research geophysicist at the Australian Coal Industry Research Laboratories, CSIRO Division of Mining and Exploration and the British Geological Survey. He established a production in-mine geophysics team in WMC at Kambalda in 1994 before becoming Geoscience Manager for WMC's technology group in 1997. In 1998 he established SenseOre Services - a company specialising in the use of high-resolution geophysical techniques for mining. He is a member of the ASEG and the AusIMM.

Satohsi Urata, second year graduate student in University of Tokyo, Japan. He majored in geophysical prospecting and received Honorable Mention in SEG/EAGE's inaugural Geo-Applet Contest in 1999.

Nicholas Valleau is Managing Director of Geosoft Australia, based in West Perth. Geosoft provides advanced spatial data processing software for mineral and petroleum exploration. Nick has previously worked for geophysical survey contractors and equipment manufacturers, including Dighem Surveys and Processing Inc. and Geotech, two companies based in Canada. Both specialise in helicopter electromagnetic (HEM) data acquisition and processing. Nick has developed software and published papers on various aspects of PC-based data processing and enhancement as well as esoteric applications of HEM data. Nick graduated as a Geological Engineer from the University of Toronto in 1983.

Dr Bill Verboom is a research officer in AG WEST's Natural Resource Assessment Group. Although this is his first Geophysics related paper, he does have a degree in Chemistry and is an experienced soil surveyor. He has lectured at the University of Zimbabwe and worked as a consultant for many international firms including, BHP, Price-Waterhouse, Dames and Moore, Rio Tinto and EuroConsult.

Julian Vrbancich joined the Defence Science and Technology Organisation (DSTO) at Pyrmont in late 1984 after too many years "post-doc'ing" in Italy, UK and Canberra. He has led a small group studying ELF EM emissions arising from corrosion currents in Royal Australian Navy ships and submarines using undersea instrumentation and geophysical EM numerical modelling methods. Recently, this work has expanded to include the use of airborne geophysical exploration methods, particularly EM, to enhance maritime defence capability in littoral waters. AEM studies were initiated whilst on secondment at the CRCAMET during 1997/98.

Chris Walton completed a Bachelor of Applied Science (Exploration Geophysics) at Curtin University in 1994, he then worked as a processing geophysicist for Western Geophysical in 1995. In 1996 he graduated from the Honours program in petroleum exploration geophysics at Curtin University, and was employed by the University as a research associate during 1997/98. His research involved the acquisition, processing and interpretation of high-resolution seismic surveys over coal seams. Recently, he has begun a Masters at Curtin University looking into the use of the seismic method in delineating coal seams in structurally complex areas.

Xiuming Wang, obtained his BSc and MSc from University of Petroleum of China and Research Institute of Petroleum Exploration and Development in 1984 and 1987, respectively. He received his PhD from Institute of Acoustics of the Chinese Academy of Sciences. He worked in the

Department of Petroleum Exploration of Daqing Petroleum Institute in Northeast China for Applied Geophysics as an Associate Professor from 1991 to 1996, and a Professor from 1996 to the present. He worked in Stanford University for one year. Presently he works in CSIRO Petroleum in Western Australia. His interests include Theory and Application of Elastic Waves and Waveguides, Borehole Geophysics, Rock Physical Measurements and Ultrasonic Measurements.

Yanghua Wang received his BSc (1983) from Changchun University of Science and Technology, MSc (1994) from Monash University, and PhD (1997) from Imperial College, University of London. He worked as a research geophysicist for the Research Institute of Geophysical Prospecting for Petroleum in China from 1983 to 1990. He joined Robertson Research (Australia) as a senior research geophysicist in 1997 and has been the R&D manager since 1998. His research interest includes seismic tomography and inversion, and signal processing.

Brandon Whitcher is a research scientist at EURANDOM, a European research institute for the study of stochastic phenomena. His research involves the extension of wavelet methodology in the analysis of stationary and non-stationary processes, such as characterising persistence in univariate time series, investigating multi-scale covariance in bivariate time series, and estimating time-varying parameters in locally stationary time series. Current applications of interest include hydrology, atmospheric science, geophysics, economics and finance.

R. Gareth Williams received his PhD from Southampton University in 1979. He has worked for Veritas DGC Ltd (formerly Digicon) since 1991 as a Research Geophysicist. From 1985 to 1987 he was Research Manager in the Far East Division and is currently Research and Marketing Manager for the Europe, Africa and Middle East division of Veritas. His main research interests are 4D and seismic imaging. He is a member of the EAGE, SEG, PESGB and the Institute of Physics

Alan Willmore graduated in 1988 with a B.Sc. in geology and geophysics from the University of Sydney, and in 1996 completed a P.Grad.Dip.Comp at Macquarie University. His first exposure to the minerals industry was gained with Placer Pacific, preparing a structural analysis of the Porgera prospect in Papua New Guinea, From 1988 to 1996 he worked for Austirex International, initially as a field geophysicist and later as a data processing geophysicist. Since 1996 Alan has been employed as a geophysicist with the New South Wales Department of Mineral Resources, working with the Department's regional mapping team and coal division.

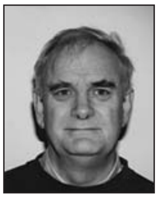
Alan Willocks is a graduate from LaTrobe University with a BSc (Honours) in Geology in 1975. He joined the Geological Survey of Victoria in 1981 and worked as a geophysicist on groundwater, basin studies, engineering projects and later potential field interpretation. He has a keen interest in GIS and information management and joined the department's GEDIS project in 1989 undertaking systems design and database modelling. He is currently Manager Geophysics, coordinating the geophysical component of Victoria's exploration initiative and developing the application of modern high-resolution geophysical data to geological mapping.

Tom Wilson graduated with a BSc (geophysics) from Flinders University in 1998. He is currently performing a hydrogeophysical study of the Clare Valley in South Australia as an Honours project. Tom has been a student member of ASEG since 1997.

Michael Wiltshire established Wiltshire Geological Services in 1969 to provide technical geological services to the petroleum exploration industry. The company began specializing in wellsite management and prospect review services. During these first 10 years Michael realised exploration techniques would be improved if electric log data were more easily available and usable by geologists. Since then WGS has specialized in the acquisition, verification, archiving and distribution of digital log and well summary data to the petroleum exploration industry. The company develops and maintains its own software, purpose built for data recovery, conversion, editing and output.

Ken Witherly obtained his BSc from UBC in 1971 and was employed by Utah Construction and Mining (later BHP) as a field geophysicist. During the next 25 years Ken worked on a variety of exploration and advanced projects throughout North and South America, Africa, Europe, Australia and Asia, exploring for copper, iron, coal, gold, zinc, diamonds and uranium in a variety of deposit settings. In 1999, Ken began a new career as a geophysical consultant, providing cutting-edge technologies to the industry in order to enhance cost-effective discovery performance.

Warwick Wood, a geophysicist with Geo-Eng Australia Pty Ltd, completed his geology degree with a geophysics honours in mid-1998. He has since worked for Geo-Eng on resistivity and seismic surveys for a regional groundwater study in Queensland, and on a seismic/magnetics survey for a dam site investigation in Western Australia. Warwick has commenced an MSc in hydrogeology and has a particular interest in environmental, geotechnical and groundwater applications of geophysical methods.



Derek Woodward, a senior scientist with the Institute of Geological and Nuclear Sciences, Wellington, New Zealand has been undertaking research into exploration geophysics for more than 30 years. Since 1983 he has concentrated on seismic processing techniques, developing innovative modelling and processing procedures. These include new methods for refraction static computations, forward modelling of reflections from stratified sand/silt sequences, and pre-stack migration routines for a variety of shooting configurations and environments.

Zonghou Xiong is a research scientist with the CSIRO Division of Exploration and Mining, working in the Cooperative Research Centre for Australian Mineral Exploration Technologies (CRCAMET). He received his PhD in Geophysics in early 1990 from the Institute of Geophysics at the University of Goettingen, Germany. He was a Visiting Fellowship at the Geological Survey of Canada from November 1990 to March 1992 and a postdoctoral fellow at Department of Geology and Geophysics at the University of Utah from January 1992 to early 1995, when he joined the CSIRO. He is a member of ASEG, SEG, DGG, and AGU.

A N (Tony) Yeates is a senior regional geologist with AGSO, where he started his career after obtaining a BSc (Hons 1) from the University of New England in 1970. His early work involved substantial regional mapping of sedimentary basins. Activities then evolved into more specialised geological and geophysical investigations of fold belts, igneous and metamorphic provinces, and substantial palaeogeographic map compilations. Operational demands then led him to positions in management, marketing and two successful exchanges in the agricultural sector. On return to AGSO, he led NGMA projects and is currently working on the Darling Basin.

Binzhong Zhou received his BSc (1993) and MSc (1986) in geophysics from Chengdu Institute of Technology (CDIT), PRC. He received a PhD in Geophysics at Flinders University of South Australia in 1993. From 1986 to 1989 he was a lecturer in geophysics at CDIT. Between 1991 and 1993, he was a computer software engineer for Wiltshire Geological Services in Adelaide. He was a research fellow in geophysics at Lincoln College, Oxford University and a consulting research fellow at Elf Research Centre in London before he joined the Mine Scale Geophysics Group in CSIRO Exploration and Mining in 1995. His research interests include seismic data processing and interpretation for coal and petroleum industries and applying geophysical techniques to mining problems such as the delineation of deposits and the production of coal and metalliferous ore. He is a member of ASEG, SEG and EAGE.

Dr. Jun Zhou received his BSc and MSc. from the University of Science and Technology of China in 1980 and 1987, respectively. From 1991 to 1994 he was a PhD student at the University of New England, Armidale, Australia. He then worked at the University of New England for three years and joined Western Geophysical in 1997. His interests are in seismic data processing, inversion problems and imaging in particular.