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Preview

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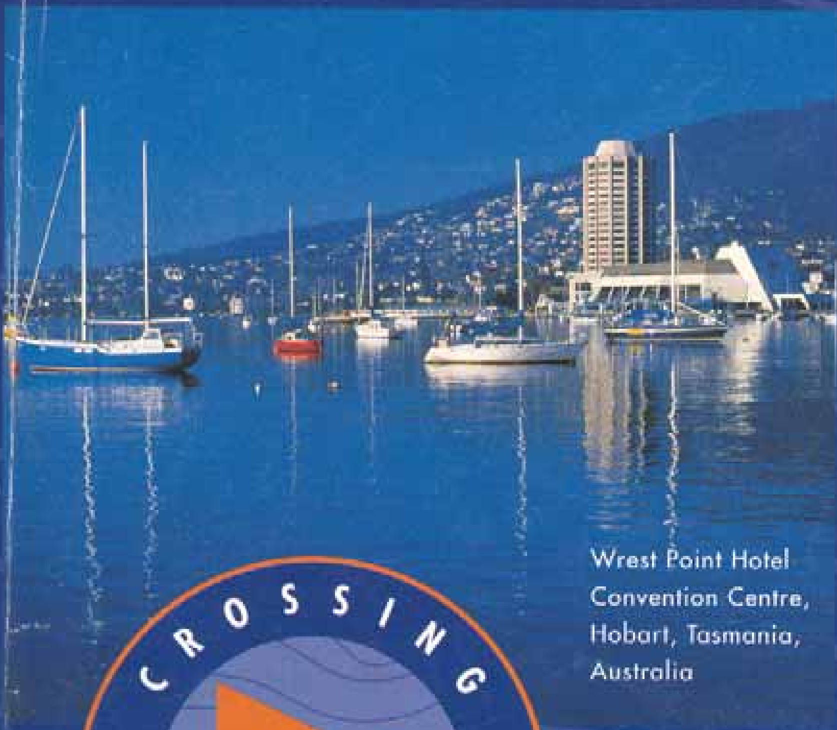
CONFERENCE HANDBOOK

ASEG 13th International Geophysical Conference and Exhibition



Wrest Point Hotel
Convention Centre,
Hobart, Tasmania,
Australia

CROSSING THE BORDERS

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Crossing the Borders

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Conference Handbook

SECTION ONE

Co-hosted by & EAGE

Welcome from Your Conference Committee

It is a great privilege to welcome sponsors, delegates and exhibitors to the 13th International ASEG Conference and Exhibition. We trust this conference will continue a long tradition of excellence, established by previous ASEG Conferences, for the publicizing of advances in geophysical learning and technology. This Conference also represents a break from past practice, in that by virtue of a joint effort between the Victorian and Tasmanian State Branches we elected to stage the Conference outside the traditional large city venues. We acknowledge with thanks the generous support from the Tasmanian Convention Bureau which assisted us in this innovation. It is also a pleasure to welcome our sister organisations the SEG and EAGE who are co-hosting the Conference and have added significant resources in publicity to make this a truly international event.

No conference like this one can succeed without the enthusiastic support of Sponsoring companies. We warmly thank our Principal Sponsor, Western Geophysical, a Division of Baker Hughes. Our four major sponsors, Geosoft Australia, Silicon Graphics, UTS Geophysics and Veritas DGC Australia receive our thanks for their generosity in ensuring the success of the Conference. A further eleven additional sponsoring companies and organisations have added their support, and we thank them also.

Our Conference theme "Crossing the Borders" reflects both our geographical location and the technological trends of our profession, where specialties such as 3D seismic imaging and deep EM sounding which have hitherto been regarded as "petroleum geophysics" or "mining geophysics", are progressively becoming adopted as tools of other branches of geophysics. Out of 199 papers submitted to the conference, we have selected a vigorous programme of 10 Key-note papers, plus 108 verbally-presented and 36 poster papers. Additional professional development for delegates is available from 10 pre-Conference Workshops, and a post-Conference tour of the geology and geophysics of Tasmania's rich (scenically, historically and mineralogically) West Coast mining district.

Our social programme has an Antarctica theme, with the Conference Dinner on Tuesday being held in "Antarctica", complete with a talk from our guest, the explorer Nick Feteris. An evening cocktail party on Wednesday at Hobart's new "Antarctic Dreamworld" furthers this theme. Numerous delegates have told us of their intention to spend holidays in Tasmania before or after the Conference. We wish each of you safe travelling, a professionally-rewarding conference, and for those with the time to spare, a holiday to be remembered.

Michael Asten — Craig Dempsey

Co-Chairmen

Conference Organising Committee

CO-CHAIRMEN	Michael Asten, Flagstaff Geo-Consultants Craig Dempsey, BHP Petroleum
Technical Programme Co-Chairmen	Shanti Rajagopalan, Earth Bytes Pty Ltd Geoff Pettifer, Geo-Eng Australia Pty Ltd
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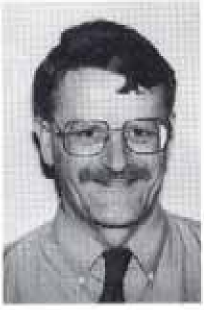
Tasmania Liaison	Jonathan Knight, J.K. Knight and Assocs Pty Ltd, Tasmania
Exhibition	Paul McDonald, Department of Natural Resources and Environment Ron Palmer, Stockdale Prospecting Limited
Finance	Konrad Schmidt, Acacia Resources
Students' Day	Michael Roach, University of Tasmania
Workshops	Hugh Rutter, Flagstaff Geo-Consultants

ASEG President's Conference Address

Noll Moriarty
President, ASEG



Ladies and Gentlemen, welcome to the 13th Conference and Exhibition of the Australian Society of Exploration Geophysicists. It is pleasing to note we are the largest exploration geophysics gathering held on a regular basis in the Asia-Pacific. This conference is being held for the first time in Tasmania. I'm sure that this magnificent location will contribute significantly in your assessment that this is one of the best-yet conferences.

Firstly, we sincerely thank our principal sponsor Western Atlas, major sponsors Geosoft Australia, Silicon Graphics, UTS Geophysics and Veritas DGC. Indeed, all the other sponsors' contributions are gratefully acknowledged. Without sponsor support, this event would not reach its excellent standard.

The theme of the Conference - "Crossing the Borders" - reflects the fact that many geophysicists now are moving from being largely specialist to being multi-skilled and multi-disciplinary. More on this later.

The next four days has an extensive and varied technical programme, covering the entire spectrum of exploration geophysics. There is no doubt the quality of the over 100 papers will be of the usual high technical and scientific standard we have come to expect from our Conferences. A big thank you to all the authors who have given of their time to make this Conference a success.

The extensive trade exhibition is vital to the effectiveness of this conference. The exhibition allows all of us to evaluate the latest products and services, make personal contacts and maybe even have a beer to slake any raging thirst.

Delegates, on your behalf, I extend many thanks to the Conference Organising Committee, headed by co-chairmen Craig Dempsey and Mike Asten. Anyone who has been involved in Conference organisation, knows only too well the massive effort required to attract and co-ordinate the authors, exhibitors, workshops and delegates. To the Committee, thank you and please enjoy the fruits of your hard labour.

I'd like to briefly touch on broader matters.

Firstly, the future direction of our Society. Will it continue to primarily cater for specialist geophysicists, involved in acquisition/ processing/ interpretation of geophysical data? How much should we cater for non-geophysicists that use geophysical data in exploration and production of natural resources. The trend these days is for a team approach to solve our technical challenges, involving contributions from geologists and engineers. I suggest the Society needs to look at how it caters for the geoscientists who use geophysical data.

As you may be aware, the ASEG Federal Executive, with the help of State Branches, is currently reviewing how the Society operates. One facet being examined is how to initiate a membership drive programme. All agree increasing our number of members provides diversity and stimulation. It also provides funds, which can be channelled into worthy areas. One beneficiary of this is the ASEG Research Foundation, which has had its funding from the ASEG doubled in the current year.

The ASEG must improve its service to members, both current and future. It must assist you to broaden your technical spectrum. The ASEG must encourage geoscientists from other disciplines to see the mutual benefits of participating in the Society. This means you need to be active ambassadors for the ASEG.

Enough of the talk - let's all enjoy the next four days and hopefully we'll take home more than the memories of a good time...

Calendar Clips

1998

December 10-12
SEGJ Fracture Imaging Symposium, Tokyo

1999

April 18-21
APPEA Conference ,Perth

April 21-23
Murray Basin Conference, Mildura

Oct 31- Nov 5
SEG Convention Houston

2000

March 12-16
ASEG 14th Conference Perth

Sneak Preview

1999 will be a big year!

- *Conference Round-up*
- *Student Special Edition*
- *Membership Handbook*
- *Your Suggestion*

As always your contributions are welcome.

The SEG, an International Society

Brian Russell
President, SEG

It gives me great pleasure to bring greetings from the Society of Exploration Geophysicists to the Australian Society of Exploration Geophysicists on the occasion of their 13th International Geophysical Conference and Exhibition in Hobart, Tasmania. On a personal note, I have attended all but one of the ASEG meetings this decade, and have been consistently impressed with the quality of the technical sessions and exhibition, not to mention the entertainment. I'm certain that this meeting will match the long tradition of excellence that your previous meetings have set.

I would like to take this opportunity to talk a little bit about the SEG in general, and its relationship with the ASEG. Primarily, I want to discuss the ways in which the SEG has changed over the last few years to make it more responsive to the needs of geophysicists throughout the world.

We have been following the SEG membership figures and several interesting points emerge from considering the trends over the last 14 years. First, as we all know, membership showed a big decline in the late eighties and early nineties, largely due to industry conditions. On the positive side, membership has picked up recently, from a low of 13,309 in 1995 to the current level of 14,228. Second, it is very clear that the ratio of U.S. based geophysicists to non-U.S. based geophysicists has altered dramatically in those 14 years. In 1985, 73% of our membership resided in the U.S. and only 27% elsewhere, whereas in 1998, 62% lived in the U.S., and 38% outside. In addition, the membership outside the U.S. has largely been increasing since 1995.

Along with the increase in international membership has been a change in the responsiveness of the SEG to its international members. My predecessors as President, Rutt Bridges and Fred Hilterman, have done an excellent job of ushering in new programs that are aimed at covering both the U.S. and international areas. Specifically, the DISC (Distinguished Instructor Short Course) was created by Fred's committee, and brings a topical one-day short course to sites around the world. The inaugural course, "Time Lapse Seismic in Reservoir Management" by Ian Jack, was given in 18 different cities around the world, including three in Australia: Perth, Melbourne, and Brisbane. The good news was that these courses were at no charge, as long as you were a member of both the ASEG and SEG. The second course will be entitled "Velocity as an Interpretational Tool" and given by Phil Schultz, in the 1998-99 timeframe.

A second new initiative, brought in by Rutt Bridges and our previous committee, is the Distinguished Educator Program, in which a noted geophysical educator will spend six months at various universities around the world, providing lectures, short courses, needs assessments, and technology and materials transfer. Dr. Robert R. Stewart was chosen to be the first SEG Distinguished Educator. Currently, he is Professor of Geophysics at the University of Calgary and director of the CREWES Consortium. Dr. Stewart initiated the CREWES Consortium while he held the chair in Exploration Geophysics at the University of Calgary an appointment he recently fulfilled and a position that is now held by GEOPHYSICS editor Dr. Larry Lines.

Another way in which we are helping the international community, specifically in the area of geophysical education, is in the Corporations Behind Education, and the Foundation Directed Gifts. To quote from the July 1998 President's Page, by Steven Rutherford:

"Corporations Behind Education. The emphasis of several recent Executive Committees has been to revamp the SEG Foundation to make it more active and effective in fostering and supporting growth in the field of geophysics. Education for members, geophysics students, and even the public is now a major focus in the activities of the Foundation. Under the leadership of Fred Hilterman and Rutt Bridges, an exciting new matching gifts program has been created, the Corporations Behind Education program. This idea has been a tremendous success. To date, more than $500,000 has been contributed to fund SEG scholarships. These funds have been matched by $500,000 transferred from the Society to the Foundation. The net result is a corpus of $1,000,000, the interest on which will fund future scholarships. These scholarships will help ensure the continuity of students entering the field of geophysics."

"Foundation Directed Gifts. The second program allows donors to direct unrestricted funds in the Foundation's general fund toward specific programs (see "Foundation" page in the June 1998 TLE). The SEG Foundation currently has about $6,000,000 in total assets; 42% of this total are donor restricted in terms of how they can be utilized and 58% are unrestricted. At its April 1st, 1998 meeting, the Foundation Board of Directors initiated a program, which allocates up to $1,000,000 of the unrestricted funds to be used to match donor contributions to the following SEG endowment programs:

- SEG Scholarships
- Geophysics Field Camps
- Annual Meeting Travel Grants
- Student Section Dues Fund
- Student Section Video Fund
- Student Section Book Program
- Museum.

Corporations and individuals wishing to endow any of the above programs may do so by donation of one-half of the amount required. The Foundation will provide the remaining one-half from the $1,000,000 in unrestricted general funds allocated to the program. Individual and corporate contributions from $1,000 to $100,000 qualify for matching. Donors will also be able to name the endowed activity.

I encourage you to take advantage of these programs, to help geophysics education in Australia. These programs are open to anybody in the world, and can be directed to any university that you wish.

Another point that I wish to discuss is the makeup of the SEG Executive Committee, which has changed to reflect the increasingly international nature of our society. The 1996-97 committee contained three international members: Australia's own Brian Spies, Ingebret Gausland from Norway, and Eulogio del Pino from Venezuela (as well as Kay Wyatt, Sven Treitel, Rutt Bridges, and Fred Hilterman from the U.S.). The 1997-98 committee included Toshi Matsuoka from Japan, Brian Russell and Larry Lines from Canada, and Steven Rutherford, an American working in London (as well as Rutt Bridges, Karen Christopherson, and Wulf Massell from the U.S.). And our new committee contains Brian and Larry again, and Orlando Chacin from Venezuela (as well as Bill Barkhouse, Angela Stacner, John Castagna and Joel Watkins from the U.S.). This year's SEG executive committee, in conjunction with the Tulsa business office staff, intends to continue the international initiatives of the previous committees.

The SEG is also active in its involvement in international conventions. This involvement can be at one of five levels: from Level I, that simply involves publicity in GEOPHYSICS/TLE, through Level V, which involves major support from our staff in all areas of the convention. Our involvement at this conference is at Level III, which means that we helped with publicity mailings and assisted in the organization of the technical program.

I hope that this brief summary has given you an idea of how the SEG is truly expanding its international role. Our partnership with the ASEG is one that makes both societies strong and reflects the fact that the job of exploration geophysicist is truly international in scope.

Executive Brief

We have a new ASEG secretariat, Glenn Loughrey of Dellaraine Associate Management Services. Unfortunately, an illness forced the closure of Enterprising Events, but we have found an excellent new secretariat at quite short notice. Glenn and his company are based in Brisbane and have extensive experience in providing secretariat services to a diverse group of associations, both in Queensland and nationally. We are confident that his team will provide an excellent service to the ASEG. Phone, fax and mail redirections have been in force and I'm confident we've captured most if not all of the recent communications. My apologies if this has not occurred or if there has been any other problems for the members.

One outcome of the changeover of the membership database, was that it highlighted the number of unfinancial members. Membership is one of our primary sources of income so we are keen to rectify this problem. Hopefully, by the time of this Preview, many members will have rejoined the Society and will be eligible to receive the special conference edition of Exploration Geophysics and the special Airborne EM Exploration Geophysics volume.

On membership and promotion, Noll Moriaty and Nick Sheard were busy at the SEG conference promoting the ASEG to the SEG members from the comfort of our new mobile booth. Publicity flyers detailing the publications and other activities of the ASEG have been printed and will be distributed to SEG conference delegates along with a membership form.

Make sure you drop in at our ASEG booth at the Hobart conference and give us your feedback.

Financial Status:

As at 19th August 1998:

Cheque Account (0080 0044) balance =	$36,678.08
Premium business account =	$60,501.41
Term Deposit CBA Commercial Bill) =	$158,000
Cash Management (Sands 0079 1475) =	$11,817.65
Term Deposit (Sands 5008 4219) =	$40,000
Net Cash:	~$306,996

Robyn Scott
Hon Secretary

PRINCIPAL SPONSOR

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Western Geophysical

Baker Hughes International is a major global oilfield services company, supporting the energy industry in the search for and development of oil and gas reserves. Baker Hughes consists of ten divisions, each of which is a leader in the respective sector of the upstream services industry.

Western Geophysical a division of Baker Hughes is the leading provider of seismic services on land, in deep waters, and across shallow-water transition zones. Services range from proprietary 2-D, 3-D, and 4-D time-lapse reservoir monitoring surveys to the industry's largest inventory of speculative, non-exclusive, seismic data for prospect evaluation. Using powerful parallel computers, seismic data are processed onboard, onsite, and in Western's global network of computer centers.

Baker Atlas (formerly Western Atlas Logging Services) offer a complete range of formation evaluation, downhole seismic, completion, production logging, reservoir monitoring, and geoscience services for petroleum exploration, field development, and production.

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PetroAlliance Services Company Limited is a joint venture formed by Western Atlas International, Inc. and MD Seis International Ltd. to offer advanced petroleum information services in the areas of seismic, well logging, and integrated project services to local and international oil companies operating in the Former Soviet Union (FSU). As a part of this joint venture, Western Atlas provides training for geophysical and wireline crews, management expertise, and data integration services.

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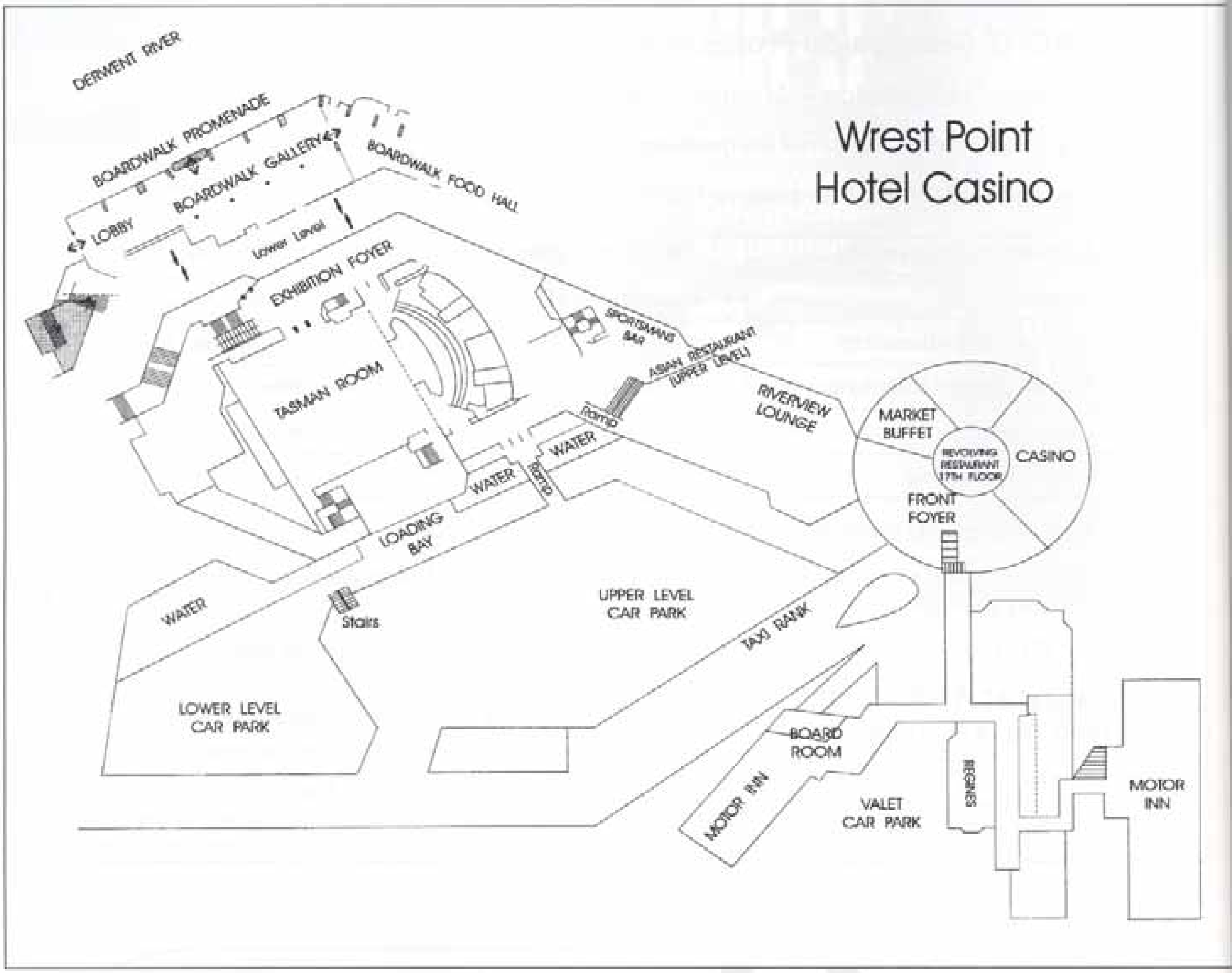

Exhibition Hours

Sunday 8 November
6pm – 8pm

Monday 9 November
9am – 5.30pm

Tuesday 10 November
9am – 5.30pm

Wednesday 11 November
9am – 5.30pm

Thursday 12 November
9am – 2pm

SUNDAY 8 NOVEMBER 1998

2.00PM ONWARDS — CONFERENCE REGISTRATION

6.00 - 8.00PM — "ICEBREAKER" WELCOME RECEPTION IN EXHIBITION AREA

DAY 1 MONDAY 9 NOVEMBER 1998

7.00AM — SPEAKERS' BREAKFAST

9.00AM — OFFICIAL WELCOME TO CONFERENCE AND EXHIBITION

10.00 - 10.30AM — MORNING TEA

	BLACKJACK ROOM **STREAM 1**	DERWENT ROOM **STREAM 2**	MAIN ROOM **STREAM 3**
	MINERAL CASE HISTORIES: TASMANIA & VICTORIA	**PETROLEUM CASE HISTORIES: SOUTH EAST AUSTRALIA**	**AIRBORNE EM**
10.30AM	Application of Detailed Ground Magnetics for Gold Exploration in NE Tasmania ***M Roach***, T Chalke	Keynote Address: ***Doug Schwebel***, Department Manager – Exploration Department, ESSO Australia Limited **Changes in Exploration Activity over the Life of the Gippsland Basin**	Keynote Address: ***Brian Spies***, Director, CRC for Australian Mineral Exploration Technologies **Crossing the Borders: Advances in Airborne EM**
11.00AM	Regional Geophysics of the Housetop Granite Area – NW Tasmania ***M LeClerc***, M.Roach, D.Leaman	Seismic Stratigraphic Extrapolations from a Single Well in the Strahan Sub-basin, Western Tasmania and the Application to Hydrocarbon Exploration ***W. Lodwick***, V.Passmore	How to find Localised Conductors in GEOTEM Data ***P.Wolfgram***, M. Hyde, S. Thomson
11.30AM	Lessons from a Case Study of Geophysical Interpretation in western Victoria ***D.Moore***, S.Maher	The Continental Margin off East Tasmania and Gippsland: Structure and Development using New Multibeam Sonar Data ***P.Hill***, N.Exon, J.Keene, S.Smith	Recent Results in South-Eastern Australia from the Latest Developments in Towed Boom HEM Systems R. Henderson, ***M. Smith***, M.Rangott

DAY 1 MONDAY 9 NOVEMBER 1998 continued

	BLACKJACK ROOM STREAM 1	DERWENT ROOM STREAM 2	MAIN ROOM STREAM 3
12.00 - 1.30PM	LUNCH		
	LOGGING / PETROPHYSICS	**EM INTERPRETATION (I)**	**MINERAL CASE HISTORIES: OVERSEAS (I)**
1.30PM	Application of Neural Networks to Identify Lithofacies from Well Logs ***Y.Zhang***, H.Salisch, J.McPherson	Conductivity-Depth Transformation of Slingram Transient Electromagnetic Data ***J.Reid***, P.Fullagar	Keynote Address: ***Terry Crabb***, CEO, Australian Geophysical Surveys **Crossing the Borders: Exploration issues overseas**
2.00PM	Acoustic Velocities as a Function of Effective Pressure in Low to Moderate Porosity Shaly Sandstones, Part 2 – Implications for Hydrocarbon Exploration ***A.Khaksar***, C.Griffiths	Reduction of the Layered Earth Response in Transient Electromagnetic Data for Mineral Exploration ***M.Sykes***, U.Das	The Fiji Airborne Geophysical Survey Project ***P.J.Gunn***, B.Rao, G.Singh, I.Hone
2.30PM	Estimating the Effects of Pore Geometry and Pore Fluid Species on Elastic Wave Velocity Dispersion in Rocks Using Microstructural Models ***A. Endres***	Measurement of Static Shift in MT and CSAMT Surveys J.Macnae, ***L.Lay***, L.Weston	Exploring the Solomon Islands with Airborne Geophysics ***P.Swiridiuk***
3.00 - 3.45PM	AFTERNOON TEA		
	LOGGING, GROUNDWATER & ENVIRONMENTAL GEOPHYSICS	**PETROLEUM CASE HISTORIES: 3-D SEISMIC**	**MINERAL CASE HISTORIES: OVERSEAS (II)**
3.45PM	Recent Advances in Borehole Resistivity Logging ***K.Strack***, O.Faini, A.Mezzatesta, L.Tabarovsky	Brown Bassett 3-D Seismic Survey: Solving a Complex Statics Problem D.Rimmer Presenter: ***G.Hofland***	Geophysical Exploration for Gold in Gansu Province, China W.Guo, ***M.C.Dentith***, J.Xu, F.Ren
4.15PM	Groundwater Geophysical Studies in the Katherine Region ***G.Humphreys***, D.Chin, M.Jamieson, D.Foo, R.Sinordin A.Knapton	A Depth Imaging Case History from the North Sea Using a Phased Velocity Modelling Approach T.Dunbar, B.Davis, ***G.Hofland***	Geophysics of the Porgera Gold Mine, Papua New Guinea ***J.Levett***, K.Logan
4.45PM	Minesite Groundwater Contamination Mapping ***G.Buselli***, H.Hwang, K.Lu	3D Seismic Surveying for Coal Mine Applications at Appin Colliery, NSW ***P.Hatherly***, B.Zhou, G.Poole, I.Mason, H.Bassingthwaighte	Applications of TEM in Taiwan ***C.S.Chen***
5.15 - 6.15PM	EXHIBITION HAPPY HOUR		

DAY 2 TUESDAY 10 NOVEMBER

Time			
7.00AM	SPEAKERS' BREAKFAST		
9.00AM	EXHIBITION OPENS		
	BLACKJACK ROOM	**DERWENT ROOM**	**MAIN ROOM**
	STREAM 1	**STREAM 2**	**STREAM 3**
	ELECTRICAL METHODS OFFSHORE & EM INVERSION	**SEISMIC PROCESSING CASE STUDIES**	**AIRBORNE GAMMA SPECTROMETRY (I)**
8.30AM	Marine Self Potential Exploration ***G.Heinson***, A.White, S.Constable, K.Key	Cape Ford-1, An Example of the Consequences of True Amplitude Processing for Inversion to Acoustic Impedance and Porosity Prediction ***M.Rauch***, P.Woods	Keynote Address: ***Robert Grasty***, Exploranium Limited **Crossing the Technological Borders in Airborne Gamma-Ray Spectrometry – An Historical Perspective**
9.00 AM	Electrical Sea-Floor Investigations – Direct Current and Frequency Sounding Methods ***N.Schroeder***, V.Rybakin	The Greenshank Anomaly – An AVO Case History ***M.Rauch***, E.Collins	Improved NASVD Smoothing of Airborne Gamma-Ray Spectra ***B.Minty***, P.McFadden
9.30 AM	Fast Inversion of Electromagnetic Array Data ***B. Singer***, E. Fainberg	Simple versus Complicated Seismic Processing in the Exmouth Sub-Basin ***G. Duncan***	Reducing Statistical Noise in Airborne Gamma Ray Spectra ***J.Hovgaard***, R.Grasty
10.00 - 10.30AM	MORNING TEA		
	POSTERS (I)	**VELOCITY MODEL BUILDING (I)**	**AIRBORNE GAMMA SPECTROMETRY (II)**
10.30AM	A Shallow Subsurface Investigation of a Site at Winnererramy Bay, Sydney ***M.Lackie***, K.Gohl	Keynote Address: ***Oz Yilmaz***, Managing Director, Paradigm Geophysical **From Conversion to Inversion**	Mapping of a Granite Batholith using Geological and Remotely Sensed data, the Mount Edgar Batholith, Pilbara Craton ***P.Wellman***
11.00AM	Time-Varying Effects in Magnetic Mapping: The Concept of a Magnetic Amphidrome ***FEM(Ted) Lilley***, A.Hitchman, L.Wang	Tomographic Velocity Model Building for Pre-Stack Depth Migration ***P.Whiting***	Noise Reduction of Aerial Gamma-Ray Surveys ***B.Dickson***, G.Taylor
11.30AM	Magnetotelluric Exploration of the Eyre Peninsula Electrical Conductivity Anomaly ***A.White***, G.Heinson, S.Constable, P.Milligan, F.E.M. Lilley, H.Toh	Creating Image Gathers in the Absence of Proper Common-Offset Gathers ***G. Vermeer***	An Integrated Framework for Interpolating Airborne Geophysical Data with Special Reference to Radiometrics ***S.Billings***, D.FitzGerald

DAY 2 TUESDAY 10 NOVEMBER continued

	BLACKJACK ROOM STREAM 1	DERWENT ROOM STREAM 2	MAIN ROOM STREAM 3
10.30AM - 12 NOON **POSTER DISPLAY CONTINUED** **POSTERS WILL BE ON DISPLAY BETWEEN THE HOURS OF 9.00AM - 5.00PM DAILY ON THE STAGE IN THE TASMAN ROOM.** **POSTER PRESENTERS WILL EACH GIVE A ONE MINUTE 'ADVERTISEMENT' FOR THEIR POSTER IN THE BLACKJACK ROOM BETWEEN 10.30AM - 11.00AM ON THE DESIGNATED DAYS OF PRESENTATION.** **POSTER PRESENTERS WILL BE AVAILABLE ON THE STAGE TO EXPLAIN THEIR POSTERS BETWEEN 11.00AM - 12 NOON.**	The "Coast-Effect" at Micropulsation Frequencies, and its Implications for High-Resolution Aeromagnetic Surveys ***P.Milligan***, A.Hitchman, F.E.M.Lilley The TEMPEST Airborne EM System ***R.Lane***, C.Golding, A.Green, P.Pik, C.Plunkett The International Campaign on Intercomparison Between Electrodes for Geoelectrical Measurements ***K.Lu***, J.Macnae Seismic Constraints on EM Modelling by Detailed Travel Time Inversion ***I.Kirby***, K.Gohl Improving Conductivity Models Using Ontime EM Data ***D. Sattel*** Reflection Models and Ramp Response for Downhole TEM Data ***L.J.Cull***, M.Asten, J.P.Cull Automated Interpretation of Geophysical Borehole Logs via Multi-Parameter Discrimination ***P.K.Fullagar***, B.Zhou, G.N.Fallon 2.5-D Inversion of Deep Transient Electromagnetic Sounding with Grounded Sources ***Z.Lin***, K.Vozoff, G.Smith Simulation of Strong Ground Motion for Australian Intra-Plate Earthquake Using Green's Function Method ***C.Sinadinovski***, K.F.McCue, M.Somerville, T.Muirhead, K.Muirhead		

DAY 2 TUESDAY 10 NOVEMBER continued

Time	Blackjack Room – STREAM 1	Derwent Room – STREAM 2	Main Room – STREAM 3
12.00 - 1.30PM	LUNCH		
12.00 - 1.00PM	PETER WATSON 'REALISATION' LUNCH		
	COAL & GEOPHYSICS IN MINES	**VELOCITY MODEL BUILDING AND DMO**	**ELECTRICAL AND ELECTRODE POTENTIAL**
1.30PM	High-Precision Continuous Deformation Monitoring of Mine Structures ***R.Gwyther***, M.Gladwin, M.Mee	The Application of Reflection Tomography and Interval Velocity Analysis to Achieve Accurate Depth Conversion of Subtle Structures: A Case Study ***R.Taylor***, D.Kelly, N.Fisher, A.Canning	The Behaviour of Mise-a-la-Masse Anomalies in an Anisotropic Half-Space near a Vertical Contact ***N. Uren***, P.Li
2.00PM	Examination of the Gravity & Electromagnetic Survey Methods Applied to Coal Exploration in the Area of the Southern Gunnedah Basin O.Nakano, E.Ishii, N.Ozawa, B.Mullard, ***J.Beckett***, D.Robson, A.Willmore	Building Velocity Models for Pre-Stack Depth Migration ***R.Bloor***	Applied Potential Modelling of Simple Orebody Structures ***S.Greenhalgh***, S.Cao
2.30PM	Application of Microseismic Monitoring to Characterise Geomechanical Conditions in Longwall Mining ***X.Luo***, P.Hatherly	Comparing Equalized and Dealiased DMO on Field Data ***C.Beasley***, E.Mobley	Normalisation of Electric Potential for a Buried Electrode under a Conductive Overburden ***M. Asten***
3.00 - 3.30PM	AFTERNOON TEA		
	NEW FRONTIERS IN OIL EXPLORATION	**POTENTIAL FIELD INTERPRETATION TECHNIQUES (I)**	**MINERAL CASE HISTORIES: AUSTRALIA (I)**
3.30PM	The Use of Computer Algebra for Obtaining Exact Solutions to Simple Seismic Reflection Models ***B. Hartley***	A New, Rapid, Automated Grid Stitching Algorithm S.Cheesman, ***I.MacLeod***, G.Hollyer	Geophysical Investigations of the Titania Prospect ***P. Eagleton***
4.00PM	A Comparison of Omega-X, PSPI and Explicit Alogarithms for Post-Stack Migration ***C.Notfors***	Naudy Based Automodelling with Trend Enhancements ***D.FitzGerald***, R.Almond	Geophysical Response of the Silver Swan Nickel Sulphide Deposit Western Australia ***W.Amann***, R.Pietila
4.30PM	The Contribution of High Quality Aeromagnetic Survey Data to Hydrocarbon Exploration ***I.Kivior***, D.Boyd	The Use of Fractal Dimension Estimators for Enhancing Airborne Magnetic Data ***T.Dhu***, M.Dentith, R.Hillis	A Comparison of High Density Ground Magnetic Surveys and Low Level Aerial Magnetic Surveys in a Near Surface Noise Environment: A Cobar Case History ***P.W.Basford***, N.A.Hughes
5.00 - 6.00PM	EXHIBITION HAPPY HOUR		
7.00PM	CONFERENCE DINNER		

DAY 3 WEDNESDAY 11 NOVEMBER 1998

Time	Stream 1	Stream 2	Stream 3
7.00AM	SPEAKERS' BREAKFAST		
9.00AM	EXHIBITION OPENS		
	BLACKJACK ROOM	**DERWENT ROOM**	**MAIN ROOM**
	STREAM 1	**STREAM 2**	**STREAM 3**
	EXTENDING GEOPHYSICS	**ANISOTROPY**	**ELECTRICAL & EM CASE STUDIES (1)**
8.30AM	Neutron Radiography: A Technique to Support Reservoir Analysis ***M.Middleton***, I.Paszit	Keynote Address: ***Rolf Klotz***, Manager R & D, Western Atlas **Seismic Imaging in Anisotropic Media** ***R.Klotz***, S.Downie, S.Leng Ng	Keynote Address: ***N.Sheard***, Chief Geophysicist, MIM Exploration **MIMDAS – A New Direction in Geophysics** ***N.Sheard***, T.Ritchie, J.Kingman, P.Rowston
9.00AM	Geologists and Geophysicists: Getting them on the Same Planet ***A.J. Willocks***, B.A. Simons	Inversion of Velocity Field and Anisotropic Elastic Parameters for Layered VTI Media ***R.Li***, P.Okoye, N.Uren	An Application of Reverse Coupling to Increase Signal Strength Beneath Conductive Sediments-Miitel Mine, Kambalda, WA ***J.Elders***, A.Wellington
9.30AM	The Australian Stress Map ***R. Hillis***, J. Meyer, S. Reynolds	Polarisation Analysis: What is it? Why do you need it? How do you do It? ***N.Hendrick***, S.Hearn	The Delineation of Coronet West by Detailed Underground DHEM ***P.Mutton***
10.00 - 10.30AM	MORNING TEA		
	POSTERS (II)	**PRE-STACK DEPTH MIGRATION**	**CROSSING TECHNICAL FRONTIERS IN MINERAL EXPLORATION (I)**
10.30AM	Self-Demagnetisation Corrections in Magnetic Modelling: Some Examples ***W.W. Guo***, M.C.Dentith, Z.X.Li, C.M.Powell	Pre-Stack Depth Migration Experience in Less Complicated Geological Environments ***G.Williams***, B.Gosling, S.Hollingsworth	Keynote Address: ***Pat Quilty AM***, Director, Antarctic Division **Geophysics as Centrepiece: Its role in the Australian Antarctic Territory**
11.00AM	Application of the Discrete Wavelet Transform to the Interpretation of Magnetic Anomaly Data ***R. Bird***, T.Ridsdill-Smith, R.Dietmar Muller, M.Pilkington	Pre-Stack Migration Using the Equivalent Offset Method ***J. Bancroft***	A new Drillhole Targeting Tool – Case Histories Showing Discrete AEM Response Associated with Gold Mineralisation, Eastern Goldfields, Western Australia ***P. Lemming***
11.30AM	An Analysis of the Broken Hill Exploration Initiative Petrophysical Database ***P. Ruszkowski*** Airborne Geophysical System at the Geological Survey of Finland ***M. Kurimo***, M.Airo	MITAS, Migration Input Trace Aperture Selection ***M. Marcoux***, C.Harris, S.Bickel	Mapping Dykes Using Surface and Downhole Seismic Methods ***B. Evans***, M Urosevic

DAY 3 WEDNESDAY 11 NOVEMBER 1998 continued

	BLACKJACK ROOM STREAM 1	DERWENT ROOM STREAM 2	MAIN ROOM STREAM 3
10.30AM - 12 NOON **POSTER DISPLAY CONTINUED** **POSTERS WILL BE ON DISPLAY BETWEEN THE HOURS OF 9.00AM - 5.00PM DAILY ON THE STAGE IN THE TASMAN ROOM.** **POSTER PRESENTERS WILL EACH GIVE A ONE MINUTE 'ADVERTISEMENT' FOR THEIR POSTER IN THE BLACKJACK ROOM BETWEEN 10.30AM - 11.00AM ON THE DESIGNATED DAYS OF PRESENTATION.** **POSTER PRESENTERS WILL BE AVAILABLE ON THE STAGE TO EXPLAIN THEIR POSTERS BETWEEN 11.00AM - 12 NOON.**	Utilisation of 256 Channel SAEI Radiometric Data to Improve the Quality of Radiometric Pixel Imagery for Exploration ***D. Calandro***, G.Reed Applications of Gravity and Magnetic Block Modelling ***S.Roberts*** The Development and Calibration of a GPS-Based Gravity Data Acquisition System ***W. Featherstone***, D.Bilick, R.Hackney, M.Dentith High Precision Gridding of Gravity Data ***A. Murray*** Levelling Marine Potential Field and Bathymetry Data, a New Approach ***R. Seikel***, M.Morse Towards Better Geophysical Modelling of the Hamersley Iron Province – I: Magnetic Petrophysics ***W.W.Guo***, Z.X.Li, M.C.Dentith, C.M.Powell A Geophysical Case Study of the Ashmore Kimberlite Cluster, North Kimberley Province, Western Australia ***J.Sumner***, P.Wilkes, J.Robins, R.Ramsay NORMAG: Development of a GPS – Ground Magnetometer System ***K.Mayes***, J.Cook, M.Sharry A New Drillhole Targeting Tool – Case Histories Showing Discrete AEM Response Associated with Gold Mineralisation, Eastern Goldfields, Western Australia ***P. Leeming***		

DAY 3 WEDNESDAY 11 NOVEMBER 1998 continued

12.00 - 1.30PM	LUNCH		
12.15 - 2.15PM	DERWENT RIVER LUNCH CRUISE		
	BLACKJACK ROOM STREAM 1	**DERWENT ROOM** STREAM 2	**MAIN ROOM** STREAM 3
	MAGNETIC METHODS & CASE STUDIES	**PETROLEUM CASE HISTORIES: INTERNATIONAL**	**INDUCED POLARIZATION**
1.30PM	Geophysical Signatures of the Iron Duchess and Iron Princess Deposits, Middleback Range Area, South Australia ***M.Dentith***, T.Dhu, G.Bubner, R.Hillis	Hydrocarbon Potential in Indian Deep Waters ***R.Singh***, S.Rawat, K.Chandra	Radial Resistivity/IP Surveys using a Downhole Transmitting Electrode ***S. Mudge***
2.00PM	Remote Determination of Magnetic Properties and Improved Drill Targeting of Magnetic Anomaly Sources by Differential Vector Magnetometry (DVM) ***D.Clark***, P.Schmidt, D.Coward, M.Huddleston	"The First Year of First Oil" from Azerbaijan, a Former Soviet Union Republic: The Development of a South Caspian Giant Oil Field ***M.Hession***, T.Redshaw, J.Gorman	Electromagnetic Coupling for Tensor Reconnaissance IP Surveying ***T. Grant***
2.30PM	The Magnetic Daily Variation in Australia: Dependence of the Total-Field Signal on Latitude ***A.P.Hitchman***, F.E.M.Lilley, W.H.Campbell, F.H.Chamalaun, C.E.Barton	Ocean-Bottom Seismograph and Conventional Reflection Surveys in the Petrel Sub-Basin: an Integrated Seismic Study ***A.Goncharov***, C.Collins, P.Petkovic, T.Fomin, V.Pilipenko, B.Drummond, C.Lee	To Remove EM Coupling from IP Data In-Situ ***J. He***
3.00 - 3.45PM	AFTERNOON TEA		
	GEOPHYSICS IN NSW	**POTENTIAL FIELD INTERPRETATION TECHNIQUES (II)**	**EM INTERPRETATION (II)**
3.45PM	Positive Impacts and Future Direction of Discovery 2000 ***D.Robson***	Multiscale Edge Analysis of Potential Field Data ***N.Archibald***, P.Gow, F.Boschetti	Modelling the 3D TDEM Responses using the 3D Full-Domain Finite-Element Method Based on the Hexahedral Edge-Element Technique ***F.Sugeng***
4.15PM	The Palaeozoic Koonenberry Fold and Thrust Belt, Far Western NSW: A Case Study in Applied Gravity and Magnetic Modelling ***N.Direen***	Separation Filtering of Aeromagnetic Data Using Filter-Banks ***T.Ridsdill-Smith***	Modelling the EM System Response of Geological Complexity Accurately ***A.Raiche***, F.Sugeng, Z.Xiong
4.45 - 5.45PM	EXHIBITION HAPPY HOUR		
7.00 - 9.00PM	ANTARCTIC COCKTAIL PARTY		

DAY 4 THURSDAY 12 NOVEMBER 1998

Time	Blackjack Room – Stream 1	Derwent Room – Stream 2	Main Room – Stream 3
7.00AM	SPEAKERS BREAKFAST		
9.00AM	EXHIBITION OPENS		
	MINERAL CASE HISTORIES: AUSTRALIA (II)	**OIL EXPLORATION: TOMOGRAPHY**	**ELECTRICAL & EM CASE STUDIES (II)**
8.30AM	Structure of the Highly-Mineralised Late-Archaean Granitoid-Greenstone Terrain and the Underlying Crust in the Kambalda-Widgiemooltha area, Western Australia, from the Integration of Geophysical Datasets ***M.House***, M.Dentith, A.Trench, D.Miller, D.Groves	Keynote Address: ***Stewart Greenhalgh***, Head of Department, Geology & Geophysics, University of Adelaide **Limitations of Geotomography** ***S. Greenhalgh***, T. Gruber	Geophysical Characterisation of the Region Around a Longwall Coal Mine Electrical Properties at Appin, NSW ***K.Vozoff***, O.Engels, S.Lintker, G.Poole, P.Hatherly, X.Luo
9.00AM	Mapping Australian Geology Under Cover: A Model Study Applied to the Boulia and Springvale 1:250 000 Map Sheet, Queensland ***T. Mackey***, P.J.Gunn, A.Meixner, D.Blake	A High-Frequency Downhole Sparker Sound Source for Crosswell Seismic Surveying ***S.Bierbaum***, S.Greenhalgh	Examples from a new EM and electrical methods receiver system ***A.Duncan***, P.Williams, G.Turner, B.Amann, T.Tully, K.O'Keefe
9.30AM	The Nature of the Basement to the Kimberley Block, North-Western Australia ***A.Meixner***, P.J.Gunn	A Later Arrival-Based Inversion Scheme to Recover Diffractors and Reflectors T.Gruber, ***S.Greenhalgh***	An Historical Perspective on the Discovery of the Wilga Zn-Cu Orebody ***S.Rajagopalan***, S.Haydon, F.Lindeman, D.Barr
10.00 - 10.30	MORNING TEA		
	POSTERS (III)	**MINERAL EXPLORATION: RIM & TOMOGRAPHY**	**RUGGED TERRAIN GEOPHYSICS (I)**
10.30AM	3D Seismic Survey in Reclaimed Land ***M.Minegishi***, N.Aoki, T.Matsuyama On the Relation Between the Stacking Process and the Resolution of a Stacked Section in a Crosswell Seismic Survey ***J.Matsushima***, S.Rokugawa, T.Yokota, T.Miyazaki, Y.Kato	Weighted Tomographic Imaging of Radio Frequency Data ***G.A.Pears***, P.K.Fullagar	Keynote Address: ***Stephen Mudge***, Chief Geophysicist, RGC Exploration Pty Ltd **Crossing the Borders: from Plains to Rugged Terrains**
11.00AM	Browse Basin Transect: Refraction Profiling Using Ocean Bottom Seismometers with Applications to Tectonic Evolution ***J. Sayers***	Radio Frequency Tomography Trial at Mt. Isa Mine ***B.Zhou***, P.K.Fullagar, G.N.Fallon	Mapping the Range Front with Gravity – are the Corrections up to it? ***M.Flis***, A.Butt, P.Hawke
11.30AM	Random Noise Attenuation Using Forward-Backward Linear Prediction Filter ***Y. Wang***	IP Tomography Test Survey in the Barrier Main Lode, Broken Hill, Australia ***H.Katayama***, K.Yokokawa, T.Suzuki, E.Arai	The Gravity Terrain Correction – Practical Considerations ***D. Leaman***

	BLACKJACK ROOM STREAM 1	DERWENT ROOM STREAM 2	MAIN ROOM STREAM 3
10.30AM - 12 NOON POSTER DISPLAY CONTINUED POSTERS WILL BE ON DISPLAY BETWEEN THE HOURS OF 9.00AM - 5.00PM DAILY ON THE STAGE IN THE TASMAN ROOM. POSTER PRESENTERS WILL EACH GIVE A ONE MINUTE 'ADVERTISEMENT' FOR THEIR POSTER IN THE BLACKJACK ROOM BETWEEN 10.30AM - 11.00AM ON THE DESIGNATED DAYS OF PRESENTATION. POSTER PRESENTERS WILL BE AVAILABLE ON THE STAGE TO EXPLAIN THEIR POSTERS BETWEEN 11.00AM - 12 NOON.	Continental Affinity of an Oceanic Plateau: Deep Seismic Profiling of the Agulhas Plateau, SW Indian Ocean ***K.Gohl***, M.Seargent, G.Uenzelmann-Neben Accuracy and Limitations of the Near-offset P-wave NMO Velocity Estimation in Transversely Isotropic Media ***P. Okoye***, N.Uren, J.McDonald Integration of Borehole Image and Seismic Data to Enhance Structural Interpretation ***T. Mahmood*** Otway Basin Deep Structure ***A.Moore***, H.Stagg The Effect of Multiple Removal on AVO Analysis ***R. Van Borselen***	CONTINUATION OF STREAM 1 Seismic Stratigraphic Explorations from a Single Well in the Strahan Sub-basin, Western Tasmania and the Application to Hydrocarbon Exploration ***W.Lodwick***, V.Passmore	CONTINUATION OF STREAM 1 The Continental Margin off East Tasmania and Gippsland: Structure and Development from New Multibeam Sonar Data ***P.Hill***, N.Exon, J.Keene, S.Smith Acoustic Velocities as a Function of Effective Pressure in Low to Moderate Porosity Shaly Sandstones, Part 1 – Experimental Results ***A. Khaksar***, C. Griffiths
12.00 - 1.30PM	LUNCH		
	CROSSING TECHNICAL FRONTIERS IN MINERAL EXPLORATION (II)	**OIL EXPLORATION: TOMOGRAPHY & GEOCHEMISTRY**	**RUGGED TERRAIN GEOPHYSICS (II)**
1.30PM	Seismic Methods for the Detection of Kimberlite Pipes ***M. Urosevic***, B. Evans	A New Method for Crosswell Reflector Imaging ***J.Zhe***, S.Greenhalgh	Magnetization Mapping in Rugged Terrain ***M.Pilkington***
2.00PM	Interpretation of Controlled Geogas Measurements for Mineral Exploration Purposes ***L.Malmqvist***, K.Kristiansson	Crosshole Acoustic Velocity Imaging with Full-Waveform Spectral Data: 2.5-D Numerical Simulations ***B.Zhou***, S.Greenhalgh	The Calculation of Magnetic Components and Moments from TMI: A Case Study from the Tuckers Igneous Complex, Queensland ***P.Schmidt***, D.Clark
2.30PM	Feasibility Studies of TFMMIP and TFEM Surveying with Sub-Audio Magnetics ***D.Boggs***, J.Stanley, M.Cattach	A Thermal Maturation Study of the Carnarvon Basin, Australia and the Northern North Sea, Europe ***J.Samuelsson***, M.Middleton	Resistunce Geoelectric Scanning on Parts of Abydos Cemetery Region, Sohag Governorate, Upper Egypt ***Ahmed El-Mahiudi***
3.00PM	AFTERNOON TEA		
2.00PM	EXHIBITION CLOSES		
3.30PM	CLOSING CEREMONY		
4.00PM	AWARDS FOR BEST PAPER AND BEST EXHIBITOR		
4.30 - 6.30PM	FAREWELL COCKTAIL PARTY		

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CROSSING THE BORDERS

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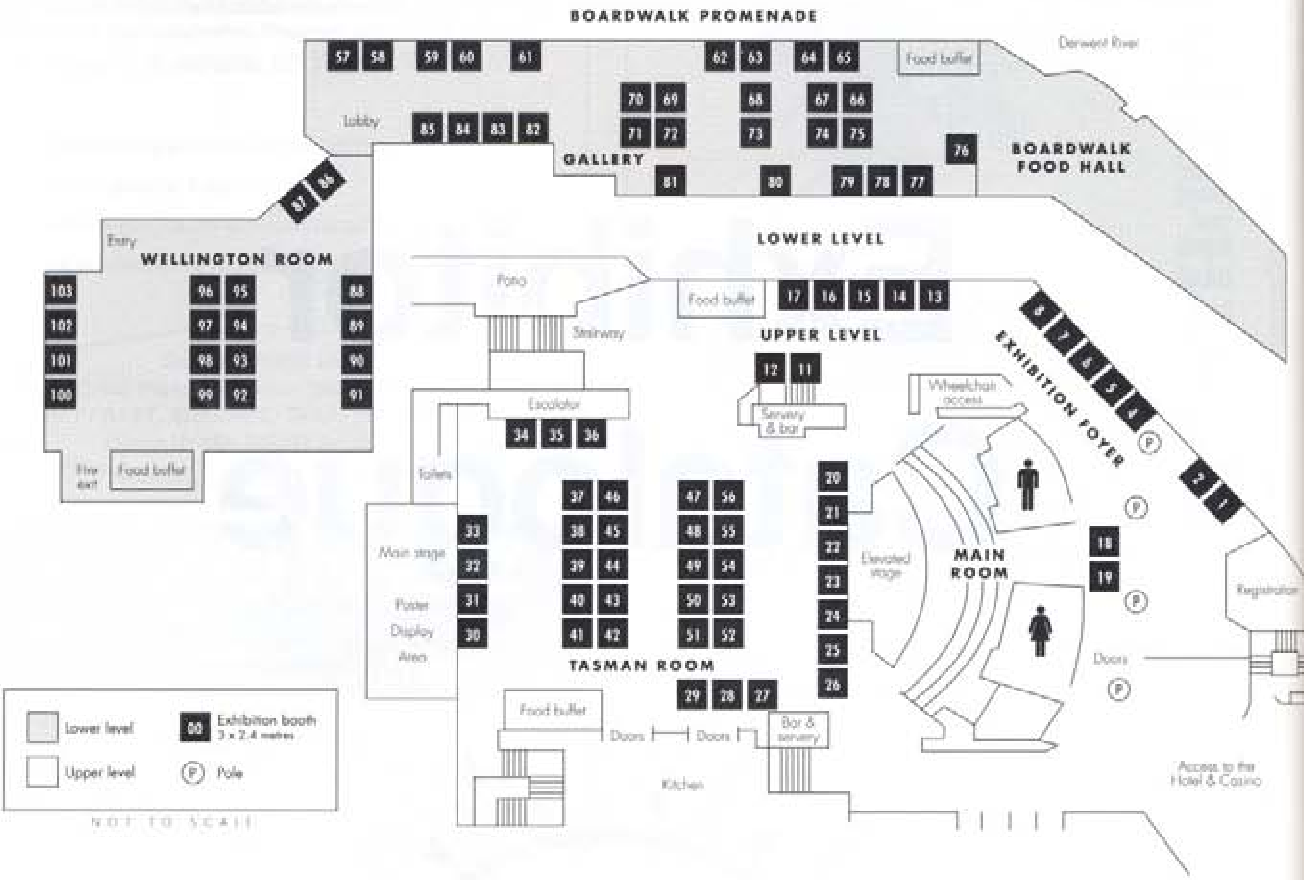

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Curtin Geophysics - The Department of Exploration Geophysics specialises in education and research in Minerals, Groundwater and Petroleum Geophysics. In 1998 the Department has 14 Staff and 130 Students. Since the inception of a geophysics program at Curtin, over 300 persons have been awarded degrees at all levels. The Department is a member of three CRCs; APCRC, CRCAMET, CMTE, with an annual operating budget of $2.1 million.

DESMOND FITZGERALD & ASSOCIATES PTY LTD **BOOTH 42**

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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.

ER MAPPER **BOOTH 86 & 87**

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Contact: Andrew Grace

Earth Resource Mapping - ER Mapper Australian owned multinational Earth Resource Mapping Pty. Ltd. develops and markets ER Mapper - the industry standard for both mineral and petroleum exploration professionals involved in image processing and mapping. The latest release, ER Mapper 6.0 is a fully bundled licence that allows people to perform surface gridding, merge magnetic, gravity and radiometric data into a single image and create stunning maps for interpretation and presentation.

ELECTROMAGNETIC IMAGING TECHNOLOGY BOOTH 74

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Contact: Andrew Duncan

ElectroMagnetic Imaging Technology Pty Ltd (EMIT) develops systems and software for mineral exploration geophysics and groundwater investigation. Products include the state-of-the-art 'SMARTem' PC-based EM and electrical geophysical receiver system, the newly-developed 'Maxwell' EM Interpretation Software for Windows and 'Filament' Fixed-Loop EM Modeling Software.

ENCOM TECHNOLOGY PTY LTD BOOTH 11 & 12

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Contact: Edward Tyne

Encom Technology (offices in Sydney, Melbourne & Perth) has an established reputation for innovation and leadership in exploration software, services and training. Our consulting and data services and Encom GIS and geophysical software are used by mineral and petroleum explorers around the globe. On demonstration at the 13th ASEG Exhibition: ModelVision LE/SE, ModelVision PRO, AutoMag, Noddy, EM Vision, EM Flow, IP Vision, ER Mapper, GPINFO, Discover, EarthMap, MapInfo.

ENGINEERING COMPUTER SERVICES PTY LTD BOOTH 60

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Email: prh@ecsaus.oz.au
Website: www.minex.com
Contact: Pat Hillsdon

ECS International Pty Ltd (ECSI) ECSI was formed in 1996 as an employee owned company. ECSI employs 36 staff in Australia, 16 of whom are shareholders. ECSI was set up to provide an employee ownership and took over the business of Engineering Computer Services (ECS). ECS was established in 1966 and is owned by the company MD and a number of associates.

ECSI took over the business and clients of ECS, and has signed agreements with ECS to:

- Lease the ECS office building.
- Market the ECS product range of software and pay royalties to ECS.

ECSI markets the MINEX software product, to the world mining and exploration industries. MINEX is a comprehensive geology to mining package which is used by such clients as Shell, Exxon and Mitsubishi. MINEX is primarily used by coal companies to plan and organise their geology and mining engineering. The coal market is varied globally. ECSI also markets geophysical software:

- AGP an airborne geophysical processing. mapping and interpretation system;
- Downhole geophysical logging data base and interpretation system

as part of the Minex system;

- SIPS high resolution seismic interpretation system with links to the Minex geological data base for direct input in the generation of the structural model.

ECSI client base is worldwide, with clients in Australia, North America, South America, Middle East, South Africa and Thailand. The ECSI systems are used on Sun and Silicon Graphics workstations and also on PC's using the NT operating system.

Since its commencement in November 1996, ECSI has sold copies of software to companies in Japan, Colombia , Canada, Indonesia and is currently negotiating sales to Jordan and the UK.

EXPLORANIUM LIMITED BOOTH 70

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Contact: Edward McGovern

Exploranium is one of the world's leading suppliers of Gamma-Ray Spectrometers used in Airborne, Land Vehicle and Ground for geophysical and environmental applications. The spectrometers offered are from consoles used with large volumes of detectors (up to 64L) to full 256 channel handheld spectrometers with assay and nuclide identification modes of operation. Exploranium also produces the very popular KT-9 Magnetic Susceptibility Meter used for the measuring of this physical property in rocks and soil materials.

EXPLORATION CONSULTANTS AUSTRALIA PTY LTD BOOTH 92

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Contact: Nicola Wright

Exploration Consultants provides a complete geoscience consultancy service for those seeking to explore for hydrocarbon and mineral resources. The company's expertise ranges from the very earliest planning of seismic exploration programs through to reserves evaluation and economic analysis. Exploration Consultants has a worldwide staff of over 180 specialists in such areas as the quality control of seismic and navigation data acquisition, seismic data processing and interpretation, and integrated geological and geophysical studies at basin, block and prospect scales.

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Contact: Roger Henderson

Geo Instruments is a leader in the Asia-Pacific regions for the sales, rental and servicing of geophysical equipment and software, and in the provision of airborne surveys including HEM. Geo Instruments also manufactures hand-held magnetic susceptibility and conductivity meters, and a new version of TEM which can be seen at our booth for the first time.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA — BOOTH 1

(a Division of the Department of Minerals and Energy)
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Contact: Dr D F Blight
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Contact (for booth logistics): Andrew Goss
Phone: 08 9222 3719
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The **Geological Survey's** role in enhancing the geological framework 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 — BOOTH 64 & 65

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Contact: Andrew Davis

Geophysical Technology Limited GTL provides geophysical services for mineral exploration; industrial and military decontamination; and geotechnical engineering. Its full service capability ranges from project design and management; to data acquisition and processing; to interpretation and modelling. The 'one-stop shop' offering includes the TM-4 magnetometer; Sub-Audio Magnetics; TM-4e EM system; and dual-sensor aeromagnetic system.

GEOTERREX-DIGHEM PTY LTD — BOOTH 13, 14, 15 & 16

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Geoterrex-Dighem Pty Limited operates in the airborne and ground geophysics market place, providing data acquisition, processing and interpretation services of superior quality to the natural resources industry. As part of the CGG group, Geoterrex-Dighem has extensive experience internationally. Geophysical surveys have been successfully conducted throughout the world in the search for precious metals, base metals, diamonds, uranium, groundwater, coal, oil and gas, as well as for geological mapping, engineering site investigations and land management/salinity assessment. Geoterrex-Dighem offers $\text{GEOTEM}_{\text{DEEP}}$ and DIGHEM EM, the leading edge in airborne electro-magnetic surveys, and also act as agents for GEM Magnetometers, GEONICS, ABEM, Mala & Iris Instruments.

GEO-X SYSTEMS LTD - ARAM DIVISION — BOOTH 81

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Contact: Kevin Pelletier

Geo-X Systems Ltd. is the Canadian based manufacturer of the ARAM24 seismic recording system. The ARAM24 has established a worldwide reputation as the "System of Choice" for complex 3-D. With the unrivalled flexibility of "network telemetry", simplified cable design, and Windows N/T operating system the ARAM24 sets the standard for deployment efficiency among the multi thousand-channel 3-D cable systems.

GMA EUROPE LTD — BOOTH 85

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Email: brobinson@gmacalgary.com
Website: www.gmacalgary.com/
Contact: William Verkaik

GMA isn an International software developer that specialises in geophysical modelling, seismic interpretation plus petrophysical applications for PC and UNIX. Starting out in Calgary, Alberta in 1982, GMA now has four offices world-wide. GMA Europe, as one of those offices, has been providing sales and support services for five years now and is responsible for the UK, Europe, the Middle-East and Australia. Visit us at Booth 85 for a demonstration of our software.

GREEN MOUNTAIN GEOPHYSICS **BOOTH 80**

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Contact: Schelly Olson

Green Mountain Geophysics develops high quality geophysical software for seismic exploration. Our acquisition planning, target-based survey optimisation, project management, geometry, and refraction statics applications are regarded as the most reliable and easy to use in the petroleum industry. We support a cross-platform philosophy, developing applications that span from the PC to distributed workstation networks.

GUARDIAN DATA SEISMIC **BOOTH 24**

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Email: gdsperth@gds.com.au
Website: www.gds.com.au
Contact: Bryan Robertson

Guardian Data Seismic was established in Australia in 1984 and specialises in supplying data recovery, data archiving and data and document management solutions to the Resource Industry. The company employs over 100 staff and has 9 centres operating in 6 countries, handling all media types and formats from analogue sheets to IBM3590 and DD2.

GX TECHNOLOGY **BOOTH 78**

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GX Technology Corporation is a leading provider of customised solutions for the oil and gas E&P industry, focusing especially on the risk-reduction benefits derived from velocity, depth and time modeling. GXT's new-generation product line, EarthWave, and the expertise of one of the largest prestack depth imaging teams in the industry, provide oil company E&P teams with a complete range of solutions for their depth-related challenges. GXT is headquartered in Houston, Texas and has regional offices in London, Paris, Calgary and Beijing.

HAMPSON-RUSSELL SOFTWARE SERVICE **BOOTH 73**

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Hampson-Russell Software Services Ltd. was established in 1987 by Dan Hampson and Brian Russell. The headquarters are located in Calgary, Alberta, Canada and we currently have two other regional offices in London, England and Houston, Texas. Present company size is 30 employees worldwide. Hampson-Russell Software is a geoscience software developer. Products include AVO (amplitude vs. offset analysis), STRATA (3-D seismic inversion), GEOSTAT (for geostatistical analysis), GLI3D (3-D refraction statics), PRO3D (3-D AVO analysis program), and EMERGE (our new 3-D multi-attribute analysis and reservoir parameter prediction program).

INSTITUTE OF GEOLOGICAL & NUCLEAR SCIENCES LIMITED **BOOTH 72**

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We are New Zealand's largest geoscience research and consultancy organisation. Our 200 scientists work for private and government organisations around the globe specialising in: resource exploration, structural evolution, and development, natural hazards and, isotope technology applications. Our passive and active source seismologists form one of the biggest geophysical teams in the Southern Hemisphere. Institute seismic processing staff develop, utilise and promote specialist software, GLOBE Claritas, an interactive seismic data processing package. Visit us at Booth 72 and our web site at www.gns.cri.nz

JASON GEOSYSTEMS AUSTRALIA **BOOTH 35**

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Contact: Gary Klomfass

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

KEVRON GEOPHYSICS **BOOTH 30**

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Kevron Geophysics Pty Ltd specialises in data acquisition and processing of high resolution aeromagnetic gradiometer and multichannel radiometric surveys. The company owns and operates six aircraft, four Shrikes, a Cessna 404 and a Cresco 750. The Cresco, powered by a turboprop engine, has an outstanding performance in rugged terrain and in flying detailed low level surveys.

LANDMARK GRAPHICS BOOTH 39, 40 & 41

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Landmark
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Landmark Graphics Corporation is the leading supplier of integrated information systems and professional services to the energy industry. Landmark delivers the widest breadth of integrated exploration and production solutions across the oil field life cycle - enabling petroleum companies to find, produce, and manage oil and gas reserves more effectively. Headquartered in Houston, Landmark is a wholly-owned subsidiary of Halliburton Company, and has 50 offices around the world, with systems installed in more than 80 countries. Landmark's worldwide Web site can be accessed at http://www.lgc.com

MAGELLAN GPS SYSTEMS BOOTH 77

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Magellan GPS Systems is the Australian distributor for all Magellan GPS and Communication products from low cost hand-held GPS to real time centimetre accuracy GPS and GLONASS. Magellan GPS Systems has a complete range of products covering communication, navigation and precision navigation. Magellan has offices in Perth, Sydney and, Victoria and dealers in all other states. Our professional staff includes Surveyors, Engineers and Marketing Specialists as well as one of the few Magellan Approved and trained service centres in the world.

MINERALS AND PETROLEUM VICTORIA BOOTH 82 & 83

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Natural Resources and Environment

Minerals & Petroleum Victoria is a division of the Department of Natural Resources & Environment. The Department is mid way through a six year $25.5 million program of large scale airborne geophysical surveys, gravity surveys, geological mapping, seismic surveys and drilling to promote exploration. Examples of recently acquired aeromagnetic, gravity and other exploration data are on display at our booths.

MINERAL RESOURCES TASMANIA BOOTH 99

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MINERAL RESOURCES TASMANIA

Mineral Resources Tasmania (MRT) is the first point of contact for organisations or individuals seeking geoscientific information about Tasmania or the adjacent waters. MRT staff have an excellent knowledge base and our library, accessible by the public, holds open-file data and reports on all exploration activities. Exploration and mining tenements and royalties are administered by MRT.

NEURAL MINING SOLUTIONS BOOTH 71

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Neural mining solutions

Neural Mining Solutions Limited NMS is a geoscience software provider based in Sydney, Australia. Our focus is to provide the resource industries with neural network software to aid in the analysis and optimisation of their resources. Given the high stakes and intense competition within all areas of the resource industries (and current volatility in commodity markets), informed business decisions on the acquisition, exploration and exploitation of prospects is essential. Currently we have products tailored for the mining and environment industries that deliver the following tools: - cluster and anomaly analysis - Correlation analysis - Relationship explorer - Fuzzy search capabilities - Potential field mapping and modelling functions. Prospect Explorer (for the mineral exploration industry) is a revolutionary new software tool, using NMS patented technology, designed to help the explorationist automate the detection of potential prospects from multi-component survey data, using state-of-the-art neural analysis techniques. At present the software packages run on Windows NT and handle gridded data sets of geophysics, geology, geochemistry and other remotely sensed data.

PARADIGM GEOPHYSICAL BOOTH 66, 67 & 75

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Contact: David Cox

Paradigm Geophysical
THE SEISMIC DATA ANALYSIS COMPANY

As a leader in seismic data analysis and the largest international independent developer of exploration and production software, Paradigm Geophysical provides you, our customer, with complete product suites for processing, inversion and interpretation of data, as well as high quality geophysical services and support. Our partnership with our customers, combined with our diversified experience in earth modelling technologies, has led us to pioneering work in the industry. This work includes the development of innovative, depth-based technologies, volume-based interpretation and model building, as well as easy access to third-party data models. We are committed to continue doing what we do best - providing leading edge production-oriented solutions that transform data into knowledge.

PC DESIGN **BOOTH 61**
(ROBERTSON GEOLOGGING LIMITED)

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Contact: Paul Clemence

Robertson Geologging is the world's leading supplier of slimhole geophysical logging equipment. As part of its continuing commitment to research and development the company is pleased to announce the launch of its next generation of logging systems: the RG-Micrologger_ and the RG-Videologger_. Full details can be found on our Website http://www.geologging.com

PETROCONSULTANTS **BOOTH 25 & 26**
DIGIMAP /ASB

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The Petroconsultants Group, together with PI/Dwights as part of the IHS Energy Division are the world's largest supplier of international exploration and production data. Petroconsultants Digimap maintains an Australia-wide shotpoint and bathymetric database, and has developed REDEEM, a proprietary system for scanning and reconstituting seismic data. Digimap works closely with ASB to produce gazettal data packages.

PETROSYS PTY LTD **BOOTH 18 & 19**

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Email: support@petrosys.com.au
Website: www.petrosys.com.au
Contact: Mike Brumby/Volker Hirsinger

Petrosys are an established supplier of E&P computing systems with offices in Australia, the USA, and Europe. Specific functions of Petrosys applications include mapping, data management, analysis of interpreted seismic, and digitizing. There are over 330 users of Petrosys software distributed across more than 105 sites in some 23 countries.

PETROLEUM TECHNOLOGY **BOOTH 89**
MINCOM PTY LTD

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Petroleum Technology Mincom (PTM) has been providing software and consulting services for 17 years including: GEOLOG: Multi-well storage, manipulation, and display software, Synthetics, Petrophysics, Cross-sections, correlations etc. Stratlmagic: Revolutionary software for a truly geological understanding of 3D seismic data employs Neural Network technology.

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Pitt Research are airborne geophysics data specialists. We specialise in high-quality aeromagnetic and radiometric data processing, image processing, mapping and interpretation services for ultra-detailed, helicopter and fixed-wing surveys. We have geophysical data distribution agreements with various industry and government agencies, and manage the WANT Database, a data broking scheme for multi-client airborne geophysical surveys operating in WA and the NT.

PGS AUSTRALIA PTY LTD **BOOTH 93, 94, 95, 96, 97 & 98**

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Petroleum Geo-Services is a technologically focused oilfield service company principally involved in the business of acquiring, processing, managing and marketing 3D and 4D marine seismic data. PGS also provides floating production, storage and offloading systems, data management solutions, 4D reservoir monitoring, characterisation studies and other specialised geophysical and production related services.

PRIMARY INDUSTRIES AND **BOOTH 59**
RESOURCES SOUTH AUSTRALIA

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Website: www.pir.sa.gov.au
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Primary Industries and Resources South Australia (PIRSA) now encompasses: Mines and Energy Resources, Agricultural Industries, Fisheries, Aquaculture, 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.

QUEENSLAND DEPARTMENT OF MINES & ENERGY — **BOOTH 76**

DEPARTMENT OF MINES AND ENERGY

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Contact: Jim Beeston

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 rigorous 'client-focussed' promotion.

ROBERTSON RESEARCH AUSTRALIA PTY LTD — **BOOTH 57 & 58**

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RG ROBERTSON GEOLOGGING

Robertson Research Australia Pty Ltd specialises in land, marine 2D and 3D, and transition zone seismic data processing services on either an exclusive or non-exclusive basis. Interpretative processing services (AVO analysis, inversion, petrophysical log analysis and pre-stack depth migration) are also provided at our Perth based office. We offer workstation interpretation services for both 2D and 3D seismic with full integration to other disciplines. Specialised studies involving sequence stratigraphy, structural geology, basin modelling and non-exclusive reports are also offered. Visit us at stands 57 and 58 for full details of the services offered by the Robertson Group.

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Schlumberger Oilfield Services

Schlumberger Oilfield Services provides a complete range of integrated services to help oil and gas companies efficiently find and produce hydrocarbons in a safe and environmentally responsive manner. At the ASEG conference, Wireline & Testing will be exhibiting the latest logging technology. GeoQuest will be displaying an integrated reservoir characterisation platform (from seismic to simulation) and, with Geco-Prakla, will present the Australian Power House where large quantities of seismic and well data can be stored and remotely accessed. Geco-Prakla will be displaying advanced 3D seismic acquisition and processing technology as well as the latest open file Australian seismic data.

SCINTREX PTY LTD — **BOOTH 22 & 23**

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SCINTREX PTY LTD

Scintrex is a geophysical company that undertakes contract surveys and consultancy, and rents, repairs and sells Scintrex instrumentation. The geophysical methods include induced polarisation, MIP and MMR, proton and cesium magnetometry, resistivity, physical properties, gravity with microgravity, Heligrav and GPS elevation options, SIROTEM and VLF and borehole logging.

SEISMIC MICRO-TECHNOLOGY INC — **BOOTH 68**

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Website: www.seismicmicro.com
Contact: Pam Huddleston

Seismic Micro-Technology develops software for geoscientists and engineers involved in exploration and production: The KINGDOM Suite is a tightly integrated suite of software applications. Applications run concurrently in our virtual display area. Applications include: 2d/3dPAK (seismic interpretation), SynPAK (synthetic seismograms), TracePAK (post-stack data processing), VuPAK (3D visualization), and ModPAK (modeling).

SOCIETY OF EXPLORATION GEOPHYSICISTS — **BOOTH 79**

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Website: www.seg.org
Contact: Paul Hummel

The Society of Exploration Geophysicists (SEG) (founded 1930) has 15,000 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.

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Contact: Brett Merritt

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Email: umag@ozemail.com.au
Website: www.ultramag.com
Contact: Phil McClelland

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Email: rchisholm@auslog.com.au
mreveleigh@auslog.com.au
Contact: Rick Chisholm & Mike Reveleigh

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WORLD GEOSCIENCE CORPORATION **BOOTH 2**
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Tel: 08 9273 6400
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Contact: Bill Witham

Since 1977, **World GeoScience Corporation** has been a leading airborne geophysical survey operator. The company has sales offices in Perth, Houston, London, Jakarta and Rio De Janeiro. Airborne magnetic, radiometric, electromagnetic and laser fluorosensor surveys are offered for mineral, hydrocarbon and groundwater applications. R & D is focused on airborne geophysical hardware & software development.

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Zeh Graphic Systems (ZEH) pioneered colour raster plotting and developed systems to drive the world's first colour electrostatic plotter, which was introduced by Versatec in 1982. Since then, ZEH has installed over 3000 systems worldwide, and has established three main offices in Houston (Texas), London (England) and in Singapore.

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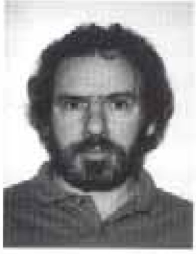
Zonge Engineering and Research Organisation (Aust) Pty Ltd specialises in providing ground electrical and electromagnetic geophysical survey services to the mining and exploration industry. Zonge has based itself on design and manufacture of unique geophysical equipment, providing interpretive services supported by data processing and modelling software developed in house. Surveys conducted by Zonge include IP, TEM, NanoTEM, CSAMT, and AMT.

Preview

SECTION THREE

Co-hosted by & EAGE

Editor's Desk — ASEG 13th Conference Preview



It is likely that many of the conference attendees will not get around to reading this editorial until after the event and that is as it should be. There are plenty of better things to read and do in Hobart. The concept of Conference Preview was born in 1994 in Perth and was the brainchild of the then editor Geoff Pettifer. He found that advertisers preferred to spend their marketing dollars at the Conference and a Conference Preview gave them that opportunity.

It also gives those members unable to attend a flavour of the Conference and particularly the Exhibition. The Exhibitor's Guide has become a de-facto directory of geophysical service companies and has an 18 month shelf life. Special thanks to Mark Dransfield who looked after the Conference side of this issue.

If you do happen to read this at the conference then one of the 'better things' I would ask you to do is to speak with members of standing committees and the Federal Executive about your Society. Feedback is important to all of these people. I note that there have been less than 10 Letters to the Editor since my involvement with Preview began.

One thing that the Publication Committee has discovered is that you can't give too much notice to advertisers and subscribers. Renewal inquiries from libraries start as early as July for the following year. Conference advertising rates are also required long before the event. This year we have worked with the Publishers and will be able to provide information in a more timely manner than in the past.

Enjoy the conference!
Henk van Paridon

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ASEG 1998 Silver Membership Certificates

The following members have been awarded Silver Certificates in recognition of 25 years association with the ASEG. Names have been identified by comparing the current membership list with that published in The Bulletin of the ASEG Vol 4 No 4 (Dec 1973). Clearly it is possible that some names have been missed due to difficulties in matching 'common' names, or changes in name through marriage or deed poll. Any member who believes they are in this category should contact the Koya Suto via the Federal Secretariat with their details.

Name	Surname	City	State
Lubo	Acimovic	Pymble	NSW
Max	Allen	Curtin	ACT
Jim	Allender	Unley	SA
James	Anderson	Bicton	WA
John	Ashley	Ardross	WA
Mike	Asten	Richmond	VIC
John	Blumer	North Sydney	NSW
David	Boyd	Wattle Park	SA
Graham	Boyd	Belair	SA
Allan	Brash	South Melbourne	VIC
Frank	Brassil	Evatt	ACT
Roald	Brotherton	Brisbane	QLD
Anna	Challis	Kings Cross	NSW
Stephen	Collins	Warrawee	NSW
Terry	Crabb	Jandakot	WA
Joe	Cucuzza	Montmorency	VIC
Roger	Deakin	Warana Beach	QLD
John	Denham	Elong Elong	NSW
Sandy	Dodds	Eastwood	SA
Tony	Doe	Bundoora	VIC
Hugh	Doyle	Queenscliffe	NSW
Lawrence	Drake	La Paz	Bolivia
Graeme	Drew	Auchenflower	QLD
Terrence	Fern	Royal Exchange	NSW
Wolfgang	Fischer	Paddington	NSW
Bernie	French	Koongamia	WA
Gary	Gibson	Bundoora	VIC
Peter	Gidley	Castlecrag	NSW
Stewart	Greenhalgh	Adelaide	SA
Stewart	Gunson	Mount Pleasant	WA
John	Hall	Adelaide	SA
Sydney	Hall	St Lucia	QLD
Robert	Harvey	Lower Templestowe	VIC
Peter	Hatherly	Kenmore	QLD
Ian	Hawkshaw	West Pennant Hills	NSW
Richie	Huber	Brisbane	QLD
Richard	Irvine	Mid-Levels	Hong Kong
Stephen	Jeffrey	Victoria Park	WA
Graham	Jenke	Belmont	WA
Laszlo	Kevi	Lemon Tree Passage	NSW
David	King	Forestville	NSW
David	Leaman	Hobart	TAS
John	Lean	West Pennant Hills	NSW
Andre	Lebel	Mahogany Creek	WA
Terry	Lee	Canberra	ACT
David	Lemcke	Annandale	QLD
Ted	Lilley	Canberra	ACT
Ian	Lilly	Monash Park	NSW
Frank	Lindeman	Southbank	VIC
Roderick	Lovibond	Adelaide	SA
Ken	McCracken	Mittagong	NSW
Noel	Merrick	Sydney	NSW
Mike	Middleton	Goteborg	Sweden
Graham	Miller	Karrinyup	WA

Name	Surname	City	State
Andrew	Mutton	Brisbane	QLD
Peter	Napier	Rijswijk	N'land
Ken	Nielsen	Dunolly	VIC
David	O'Neill	Cherrybrook	NSW
John	Parker	St Georges	SA
Bill	Peters	Ardross	WA
Geoff	Pettifer	Morwell	VIC
Graham	Pilkington	Valley View	SA
Eddie	Polak	Lyons	ACT
Bruce	Preston	Fairlight	NSW
Art	Raiche	Sydney	NSW
Bob	Raper	Castlecrag	NSW
Bob	Richardson	Newport	NSW
Bob	Richardson	Rosny Park	TAS
Doug	Roberts	Adelaide	SA
Dave	Robson	St Leonards	NSW
Brian	Rumph	London	UK
Richard	Schroder	Lutwyche	QLD
D.E.	Searle	Brisbane	QLD
Michael	Sexton	Canberra City	ACT
Mike	Shalley	Dulacca	QLD
Raymond	Shaw	Mosman	NSW
Brian	Spies	Sydney	NSW
John M.	Stanley	Armidale	NSW
Kim	Stanton-Cook	Collaroy	NSW
Les	Starkey	West Perth	WA
Barry	Taylor	Kensington Park	SA
Devin	Trussell	Melbourne	VIC
David	Tucker	Glen Osmond	SA
Rod	Tuson	Laguna	NSW
Edward	Tyne	Milsons Point	NSW
Keeva	Vozoff	North Sydney	NSW
Michael	Watts	Milan	Italy
John	Webb	Daw Park	SA

Preview Deadlines – 1998/99

December	**November 15**
February	**January 15**
April	**March 15**
June	**May 15**

Industry Briefs

GeoQuest and Guardian Data Form Data Management Services Alliance

GeoQuest and Guardian Data Seismic have signed an alliance designating Guardian Data Seismic as a preferred partner for seismic transcription services for GeoQuest customers. The alliance will enhance GeoQuest's seismic data management offering, providing customers with expert teams to recover and transcribe their seismic data onto more modern media. Then the media can be accessed near line using GeoQuest's SeisDB® seismic trace storage and archival system for a total data management solution.

Initially, services from the alliance will be combined in GeoQuest's Australian Data Center that offers E&P data management outsourcing to Australian oil and gas companies. The center scheduled to open in August will safely manage all E&P data, using modern database technology and approved standards.

Guardian Data Seismic established in Australia in 1984 supplies data recovery, data archiving and data management solutions to E&P companies. GeoQuest and Guardian Data Seismic currently work together in Milan, Italy providing data management solutions for Agip.

Baker Hughes and Western Atlas Complete Merger

Baker Hughes Incorporated recently announced that the merger of Baker Hughes and Western Atlas had been completed following approval by the shareholders of Baker Hughes and Western Atlas Inc. The transaction is valued at approximately $4.8 billion, including the assumption of approximately $1.3 billion in debt.

Max L. Lukens, Chairman and Chief Executive Officer of Baker Hughes said "In bringing Baker Hughes and Western Atlas together, we have combined Baker Hughes' leadership in recovery with Western Atlas' leadership in discovery."

Baker Hughes' oilfield divisions will be organised into two operational groups that will be focused on product and service technology leadership, and systems development. One group will be composed of Western Geophysical, Baker Atlas (formerly Western Atlas Logging Services) and INTEQ .The second group, will include Baker Oil Tools, Baker Petrolite, Hughes Christensen, and Centrilift.

The company will have approximately 35,000 employees worldwide, including over 16,000 based outside of the United States.

Book Review

The Garchy 1995-1996 Electrode Experiment: Technical Report

G Clerc, G Petiau and F Perrier, editors

April 1998; 229 pages

The CNRS in France organised a large scale 1-year field experiment to evaluate the wide variety of electrodes used for the different kinds of electrical geophysics. They recently produced a complete report on the results which should be of interest to many ASEG members who use electrodes.

It was a carefully controlled year-long field and laboratory evaluation of almost every known electrode type available. The report consists of nine chapters and three appendices beginning with the scientific issues, ten pages on the physics and chemistry of electrodes, and a 20-page description of the practical realisations, before going into a detailed description of the experiments. Results and data analysis are described in the following two chapters. Chapter 7 then describes the SP field and soil analysis at the site, observations of effects of artificial 'rain', and results from using various clay mixtures to improve and stabilise contact. Chapter 8, by Lu and Macnae of the CRC for AMET, describes their tests of capacitive electrodes. Finally there is a chapter summarising the recommendations emerging from the experiment. The appendices list the participants (20 people from nine countries), tell how to get copies of the data, and give a detailed design description of a low noise broad band electrode for MT measurements. The report makes effective use of colour photos and data plots where they are advantageous.

The work was done in the context of increasing quantitative use of EM data with little more than anecdotal knowledge about the behaviour of electrodes, except for the landmark 1980 paper of Petiau and Dupis. There is of course a wide range of requirements, from the short-term needs of CSAMT to very long term geomagnetic monitoring and depth sounding. Some electrodes were designed for use on the sea floor. Emphasis in this experiment was on the 'longer period' applications having periods of 60 seconds and longer. There were many surprises. Some of the more expensive Cu/CuSO4 electrodes were among the noisiest. Reproducing construction does not guarantee reproducible behaviour.

The study was summarised in the paper 'A one-year systematic study of electrodes for long period measurements of the electric field in geophysical environments', by F E Perrier et al in J. Geomag. Geoelectr., 49, 1677-1696, 1997. The full report may be available from Dr F E Perrier, Laboratoire de Geophysique, B P 12, 91680 Bruyeres-le-Chatel, France.

K Vozoff
harbourd@ozemail.com.au
July 1998

Proceedings Of The Workshop On Airborne Geophysics

Editor: Colin V. Reeves

Until the financial crisis of 1992 India was essentially closed to mineral exploration by foreign companies, because all major minerals were reserved to the State. However, since that time the economy has been substantially opened up to foreign investment by successive governments and an increasing number of Australian, Canadian and other companies now seeking out exploration prospects in India.

Most of these companies utilize airborne geophysical data in project generation and project scale exploration and naturally will wish to apply a similar approach in India.

This volume is a useful introduction to the status of airborne geophysics in India. It is jointly published by the Association of Exploration Geophysicists, India and the International Institute for Aerospace Survey and Earth Sciences, The Netherlands (ITC) and comprises papers presented at a workshop on airborne geophysics held in Hyderabad, India in November, 1996. This was well attended, with considerable interest from foreign geophysicists wishing to gain a first-hand appreciation of the status of airborne geophysics in India and the availability of data. Representatives of several airborne geophysical contractors were also on hand hoping to generate business in India, which at the time had not permitted contractors to fly surveys for exploration companies in India.

The papers fall into two categories:-

(1) seven papers by authors from various Indian government agencies reviewing the magnetic, radiometric and EM surveys carried out in India.

(2) ten papers by Western authors presenting recent advancements in data acquisition, processing and interpretation.

While material in the latter papers is technically interesting and well documented, most of it has been presented elsewhere and has appeared in various journals and other publications, so the main value of this publication to Australian geophysicists lies in the Indian papers.

These discuss the works carried out by the National Geophysical Research Institute (NGRI), the Airborne Mineral Surveys and Exploration (AMSE) Wing of the Geological Survey of India (GSI), the National Remote Sensing Agency (NRSA), Atomic Minerals Division (AMD) of the Department of Atomic Energy, and the Oil and Natural Gas Corporation (ONGC), the government agencies who collectively have flown almost all airborne geophysical surveys in India. The emphasis is on an historical perspective.

Maps showing the areal coverage of the surveys flown by the different agencies are included (although in many cases the figures are too small for detail to be recognised) and in most cases basic survey specifications are provided. Each agency also provides information on the development of equipment and processing techniques over the last few decades. From this it is apparent that limited government funding in recent years has restricted the amount of new data acquired, with the result that over 30% of the country has not yet been flown and most coverage is by high-altitude, wide line spacing surveys with relatively poor resolution.

A number of papers also summarise aspects of the interpretation of the data and provide examples of successful applications to mineral, oil and uranium exploration.

One issue highlighted at the workshop was the lack of an integrated airborne magnetic map of India, comprising all existing regional and detailed surveys stitched together. Data is held by a number of different government agencies and the usefulness of a county-wide aeromagnetic "stitch" has only belatedly been recognised, but a proposal to commence this work was presented at the workshop. It is a pity that the offer by ITC and other groups with considerable experience in such projects to jointly work on this project was not actively pursued, as the expertise of these organisations would ensure that a quality compilation was produced quickly and become available for regional interpretation.

The publication is available from either:-

ITC
P.O. Box 6
7500 AA Enschede
The Netherlands

or

Association of Exploration Geophysicists,
Centre of Exploration Geophysics
Osmania University
Hyderabad 500 007
India

at a cost of US$100.

The publication is hardcover, nicely bound and has a good index, but for the price it is disappointing that many of the figures have poor resolution, being scanned images in most cases. However it is an essential reference for any company or consultant working in India.

R.J. Irvine
July, 1998

Expansion of Australia's Geomagnetism Program

The Australian Geological Survey Organisation is expanding its geomagnetic observatory program in response to the many statements of support submitted by users to a recent review. The expanded program encompasses:

(1) maintenance of the six mainland observatories (Canberra, Gnangara, Charters Towers, Alice Springs, Learmonth, and Kakadu);

(2) continued operation of the magnetic observatories at Mawson station in Antarctica and Macquarie Island in the sub-Antarctic;

(3) upgrading of the Antarctic variometer station at Casey to observatory standards, and continued support for the variometer station at Davis (run by the Australian Antarctic Division);

(4) expansion of ground surveys from annual occupations of 11 "super" repeat stations to 1.5-yearly occupations of 17 stations covering a wider geographical range;

(5) collaboration and regular exchanges visits with Indonesia's geomagnetic observatory group.

The expanded program will improve the accuracy of both the regional (AGRF) and global (IGRF) magnetic field models over our region as well as provide better data services to the solar-terrestrial physics and space weather communities.

Charles Barton
AGSO Geomagnetism
cbarton@agso.gov.au

Calendar of Events

1998

Dec 10-12
SEGJ/SEG/ASEG 4th Int. Symposium Fracture Imaging, Tokyo

The technical sessions will cover "Fracture Detection, Imaging, and Characterization" and "Underground Heterogeneity."

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Phone/Fax: +81-3-3774-5858
http://wwwsoc.nacsis.ac.jp/segj/meeting/is4/.
In Australia email: mcdonald@geophy.curtin.edu.au

1999

April 18-21
APPEA Conference & Exhibition Perth Concert Hall

Contact: Lynda Gordon or Lyn Alexander
Tel: 02 6247 0960
Fax: 02 6247 0548
Email: appea@appea.com.au

April 21-23
Murray Basin Conference ,Mildura .

Hosts AIMM, GSA, AIG, Theme Rutile, Zircon & Ilmenite.

Contact Rebecca Norton
Tel 03 5332 6864 Fax 03 5333 6516
Email: goodingg@rats.agvic.gov.au

October 31 - November 5
SEG Convention Houston

Call for Papers
www.seg.org/seg99

2000

March 12-16
Australian Society of exploration Geophysicists
14th Conference and Exhibition, Perth

"Exploration Beyond 2000"

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ASEG Branch News

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The Queensland branch has had two technical meetings in recent months. In August four students gave presentations relation to their research projects. An interesting variety of topics were covered, ranging from seismic stratigraphy of Moreton Bay to Earthquake geophysics. The speakers were Simon Coombs (UQ) Matthew Kay (UQ), Mike Winter (UQ-Quakes) and Trinetta Herdy (QUT).

In September, Randall Taylor presented his paper titled "Reflection tomography and interval Velocity Analysis to achieve Accurate Depth Conversion of Subtle Structures: A case Study". This paper will be presented at the Hobart Conference.

Natasha Hendrick has been organising a student barbeque for Wednesday, 14 October at UQ. This will be a social "meet the industry" night. There will be a number of informal presentations by industry geophysicists and some live music to follow.

New South Wales

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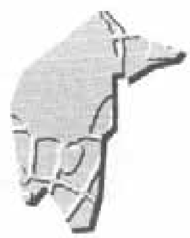
The third Wednesday of each month continues to be the time for the NSW Branch regular meetings at the Rugby Club (near Circular Quay). An assortment of topics has been presented from geotechnical applications of geophysics to petroleum structural interpretation. The next meeting will be held on 21 October with speakers Geo Instruments and Geoterrex / Dighem, on airborne EM.

Timothy Pippett
NSW Branch President

ACT



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The Victorian Branch held its AGM on the 7th of April at which the 1998-1999 committee was elected (see committee listing in June Edition of Preview). The only tussle was for the position of Student Representative - it was felt by all members present that this keenness on the part of the students to serve the ASEG should be rewarded so both nominees, Trudi Hoogenboom and Roger Hurren, were elected to the committee!

The AGM was followed by a philosophical presentation by Mark Dransfield, BHP Research, entitled "Potential Field Searchlights", in which Mark described the interaction between the earth and potential field instruments, such as magnetometers, gravimeters and gravity gradiometers, imagining the instruments to be searchlights lighting up the earth.

The following month on the 19th of May, Andrew Long, PGS Seres, spoke on "3D Seismic Imaging Using Vertical Cable Technology" which showed how 3D reservoir imaging can be improved by using a more complete range of azimuths.

A special meeting was called on the 4th of June to take advantage of the visit by the distinguished geophysicist, Sven Treitel, to Melbourne. Sven Treitel presented some interesting problems in Exploration Geophysics, such as non-unique inversion of geophysical data, which have stayed with us despite advances in geophysical technology. The meeting attracted a large audience and included ASEG members who wished Sven Treitel to autograph their copies of "Digital Signal Processing"!

The "Industry Night", held on the 16th of June, organised to disseminate information about the current state of geophysics in Victoria, was one of the best attended meeting in recent years. Representatives from Universities, Government, Petroleum and Mineral Exploration Companies, Geophysical Software Companies and Geophysical Consultants, presented information about educational opportunities, research, survey programmes, exploration activities, and geophysical services available in Victoria.

Ian Jack, BP Exploration, and SEG Distinguished Lecturer, presented an excellent workshop on "Time Lapse Seismic in Reservoir Management" on the 8th of July, which was attended by over 50 members. The meeting was sponsored by BP Exploration.

Suzanne Haydon, Geol. Surv. Victoria, presented a poster on the 11th August which explained the making of the Omeo Geological Map. Her interpretation of high-resolution aeromagnetic and aeroradiometric data was integrated with geological mapping to produce a geological map consistent both with outcrop geology as well as with geophysical facts! A laudable achievement and one well worth following. Suzanne's keen listeners drank wine from John Gehrig's winery at Oxley!

Victorian Branch members took a break in September. The Students' Night, at which students will present results of their Honours research, is scheduled for October. And of course, the 1998 ASEG conference will be held in November.

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1998 Qld ASEG Golf Classic

Dependable as ever, the Queensland winter sun was shining on July 15 for the 2nd Annual Qld ASEG Golf Classic. As they say – "Beautiful One Day, Perfect the Next" (ed. Guess who's the ex South Aussie). This year the Golf Classic was held at the Nudgee Golf and Country Club and the general opinion of all players was that the course was in magnificent condition.

As with last year the Classic was played as a four ball ambrose team event commencing with a shot gun start. For the uninitiated this means all teams start at the same time and so far as the theory goes all teams should finish at the same time. More on that later.

The round of golf progressed as it should, with all participants enjoying the opportunity to show off their golfing prowess or enjoy a nice walk, whichever the case may be. By mid afternoon the golf had been played and all teams were in the clubhouse enjoying the refreshments. All teams that is, except the Velseis Processing team. We are still trying to determine whether they were playing the same course or for that matter, the same game as everyone else. As mentioned earlier, one of the objectives behind a shotgun start is for all players to finish at about the same time. The Velseis Processing team took about half as long again as every other team. Mind you, on a time per shot basis Velseis Processing were probably quite good, as they played twice as many shots as anybody else.

Their processing is better than their Golf!! - The Velseis Processing Team.

Winners of the 1998 ASEG Golf Classic - Rio Tinto.

The boys from Geco-Prakla.

On to the results: the winner (on a countback) of the Schlumberger Geco-Prakla perpetual trophy for the best net score in the 1998 Qld ASEG Golf Classic was the Rio-Tinto team. Second place went to MIM Exploration and third place went to last year's winning team, BHP Coal. Obviously Velseis Processing "won" the wooden spoon.

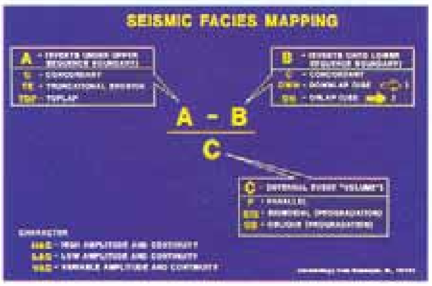
During the day, a number of "nearest the pin", "longest drive" and similar competitions were run and a few noteworthy winners of these were: Fiona Duncan from Velseis Processing – Nearest the Pin on the 1st hole, Ruth Reeve from Veritas DGC – Longest Ladies drive on the 2nd hole, Justyn Hedges from Oil Company of Australia - Nearest the Pin on the 3rd hole and Jack Brown from Geco-Prakla – Straightest Drive on the 11th hole. Congratulations to all prizewinners.

A hearty thankyou goes out to all sponsors, without whom the Golf Classic could not proceed. Thankyou also to the many people who assisted with running the Golf Classic. Lastly, thankyou to all players for assisting in making the 1998 Qld ASEG Golf Classic a most enjoyable day and see you all next year.

Grant Asser

OIL COMPANY OF AUSTRALIA
Schlumberger Geco-Prakla
Velocity Data
VERITAS
Santos
VELSEIS PROCESSING
VELSEIS
Landmark

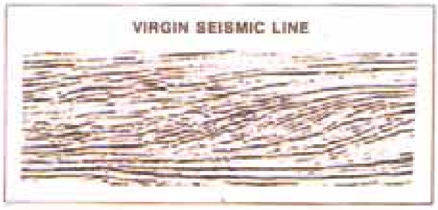
The Beautiful Queensland weather - enjoyed by the Silicon Graphics Team.

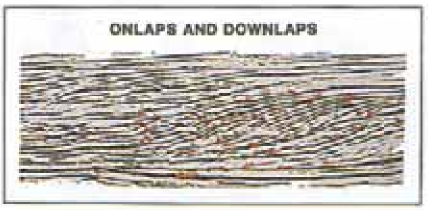


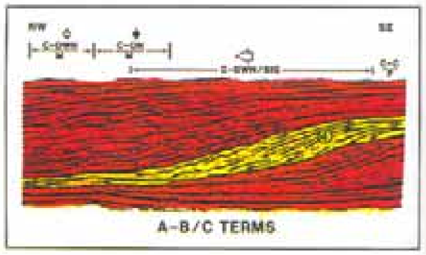
Rob Kirk

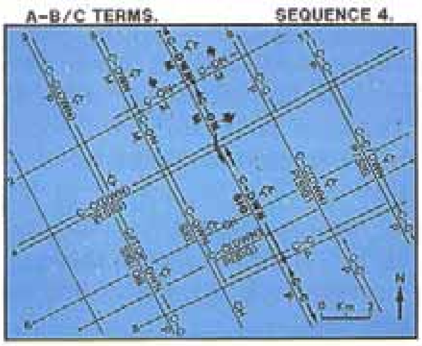
Facies Mapping

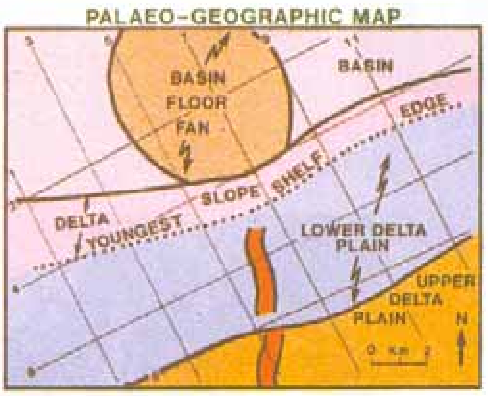
An oft-neglected map is the seismic facies map. This attempts to map the 3D seismic geometries within a sequence. It is quick and easy to do and provides a very useful link between the geologist and geophysicist. The "A-B/C" scheme is a simple but effective method of mapping geometries (Fig 1). The "A" term refers to what is happening just under the upper SB. The "B" term refers to what is happening down onto the lower SB, while the "C" term lumps all the intervening events together. Initially you might A-B/C map the entire third order sequence and then refine the maps by A-B/c mapping individual systems tracts.











This series of figures looks at how we may make a seismic facies map (SFM). These are prograding Tertiary carbonates in Western Australia (Fig 4). In Figure 5 using red we pick all event terminations (after picking out faults, multiples, flatspots, etc.!) (You could set up a red fault on Landmark that you draw the terminations with.)

Figure 6 shows the A-B/C terms for sequence 4. Note I have already broken out two units - one being the prograding facies while the other is the basal mound facies. (I am already thinking about a depositional model.) On Figure 7, each line's A-B/C terms are posted on a map, parallel to a line so that all directions can be represented. Bear in mind that dip facies can be quite different to strike facies, as seen here. You often have "facies misties". On Figure 8 we now map the swathes of A-B/C terms. Note that onlaps are closed arrows while downlaps are open arrows. The final SFM is seen in Figure 9. When we can calibrate the SFM with well data we can attempt to produce a palaeogeographic map (Fig 10). We may use this to comment on reservoir distribution or seal competency (or to help explain the distribution of an anomalous velocity package!)

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Airborne geophysical signatures of localities of epithermal gold deposits in Fiji

By P.J. Gunn, T. Mackey and A. Meixner
Australian Geological Survey Organisation

Introduction

On June 2 1998 the results of the Australian Agency for International Development (AusAID) funded Fiji Airborne Geophysical Survey Project were released. This project, which involved the acquisition of approximately 160 000 line kilometres of aeromagnetic, airborne gamma-ray spectrometric and digital elevation data, was designed and managed by the Australian Geological Survey Organisation (AGSO). The data were acquired 80 metres above the land and sea surface with 400 metre line spacings onshore and 800 metre spacings offshore. The Australian company Kevron Pty. Ltd. was contracted to perform the acquisition and processing. The primary objectives of the survey were to provide databases to stimulate mineral and hydrocarbon exploration in Fiji and to allow refinements to the geological mapping of Fiji. AGSO produced 1:250 000 scale interpretations of the data which revised and extended the known geology of Fiji and identified areas considered to have enhanced potential for mineral and hydrocarbon prospectivity. The Fiji Mineral Resources Department (MRD) is the Fiji Government agency responsible for the archiving, distribution and ongoing usage of the products of the project.

During AGSO's interpretation activities it was noted that localities of known epithermal gold occurrences in Fiji have distinctive geophysical signatures that can be recognised in the airborne geophysical data. The object of this paper is to present and explain these signatures as it is considered that they can be used as templates to identify localities prospective for undiscovered epithermal gold deposits both in Fiji and other areas with similar geological settings.

Background information on the geology of Fiji and epithermal gold deposits

Figure 1 shows that Fiji is located along the circum-Pacific "Ring of Fire" which is the intrusive/volcanic belt hosting most of the larger epithermal gold and porphyry copper gold deposits in the world. The igneous activity in this belt is the result of subduction processes. In the case of Fiji the present geometry of subducting plates has been complicated by a reversal of the subduction process associated with the development of a spreading centre in the North Fiji Basin. Figure 2 shows inferred plate tectonic reconstructions which explain the development of the island arc systems which comprise Fiji and its environs.

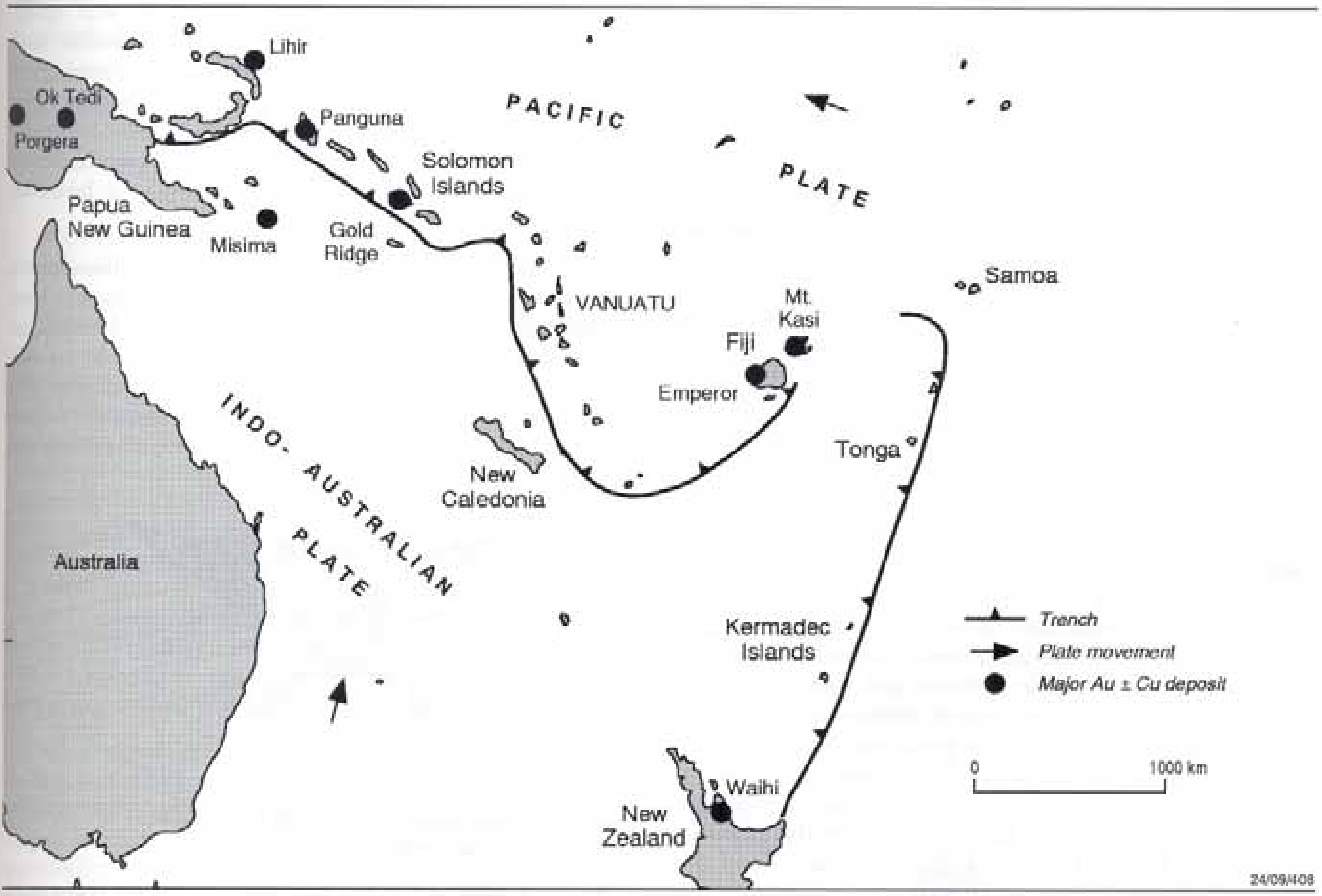


Figure 1. Location of Fiji.

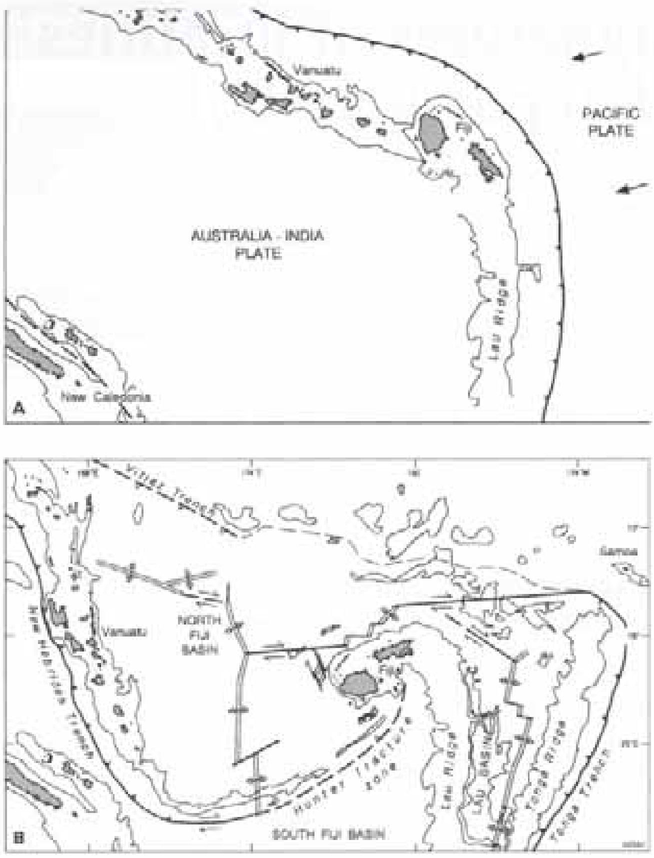


Figure 2. Plate tectonic reconstructions of the Fiji region based on Hathaway (1993): A c.10 ma., B present.

Figure 3a shows the commonly accepted model for the developments of island arc systems. The model involves the development of stratovolcanoes above intrusive plutons resulting from thermal processes associated with subduction of oceanic crust. Detachment of oceanic crust at the point of initial subduction can preserve slices of oceanic crust as ophiolite wedges. Figure 3a illustrates the situation inferred in Vanuatu, the island arc system adjacent to Fiji, prior to arc reversal in the area. Figure 3b illustrates the present situation in Vanuatu that has resulted from a reversal of the subduction direction. It should be noted that a new line of intrusive centres is being developed above the now subducting sheet. It is probable that the development of Fiji has followed a similar process - albeit one that has been complicated by a degree of rotation associated with the opening of the North Fiji Basin.

It is important to understand how the above, basically simple, processes lead to the geological development of island-arc complexes such as those that comprise the islands of Fiji. Central to this understanding is the fact that the main building units of these complexes are the intrusive plutons and their associated volcanic products. These systems build the island-arc systems on a floor of ocean crust. The plutonic systems and their associated volcanic products tend to occur in alignments parallel to subduction zones and to show petrologic differentiation that ranges from the tholeiitic series closest to the point where subduction commences through the calc-alkaline series to the alkali series most distal from the point of subduction. Figure 4 shows a model for an island arc intrusive volcanic complex. This consists of an intrusive stock, which does not reach the surface, overlain by a vent

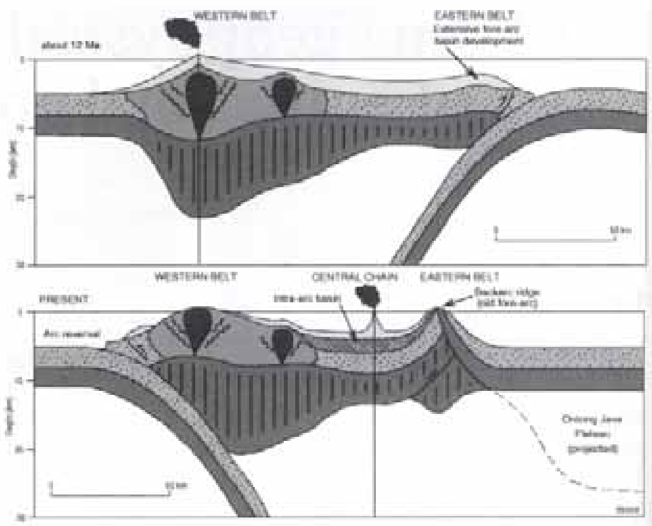


Figure 3. Sections illustrating the evolution of the Vanuatu island arc system.

system through which lavas and pyroclastic material are transmitted to the surface where they are deposited in a series of sub horizontal layers around the vent in a manner that can form a stratovolcano. Dykes, sills and volcanic plugs may be intruded into the section above the intrusive stock. Erosion of the volcanic and intrusive material creates the primary source of sedimentary rocks in island arc systems although reef growth sometimes contributes substantial carbonate components. The simple system described above can however be complicated by metamorphism due to burial and thermal effects and pressure associated with the interactions of different plates along the subduction zone. These plate interactions can also result in folding, faulting, tilting and uplift. Overprinting of intrusive and volcanic episodes and extension can further complicate the geological assemblages of island arc systems. Despite this complexity, it is commonly possible to identify relatively simple geological situations similar to the one illustrated in Figure 3a and to use this recognition as a basis for geological and geophysical interpretations.

Figure 4, after Colley and Flint (1995), illustrates a model showing how porphyry copper-gold and epithermal gold deposits can be genetically related to the intrusions that build island arc systems. It should however be noted that, while Figure 4 indicates the development of a stratovolcano, such features are not an essential component in the development of epithermal

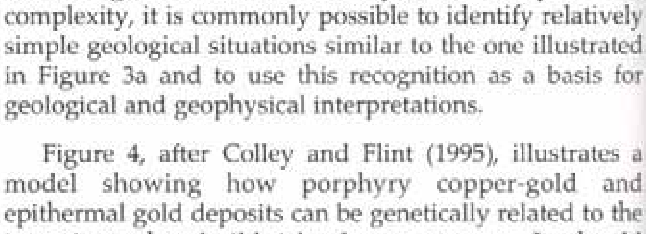


Figure 4. Geologic setting of epithermal gold and porphyry copper-gold deposits (after Colley and Flint, 1995).

gold and porphyry copper-gold deposits. These deposits can be formed without the actual development of a volcano. Disseminated copper and gold mineralisation may be precipitated from fluids associated with the emplacement of the intrusive stock in the country rock above, flanking, and in the upper portions of the stock. Such "porphyry" copper-gold deposits cannot be economically mined unless extensive erosion of the overlying volcanic material occurs. Magmatic gases and hydrothermal fluids ascending above the intrusive stock, via fractures and fumaroles, may mix with meteoric or connate fluids to precipitate gold in what are termed "epithermal" deposits. Some epithermal gold deposits are spatially associated with a central vent above an intrusive stock and some are located in fractures or small local vents which proximal to, but not necessarily vertically above, the intrusive stock. Porphyry copper-gold and epithermal gold deposits tend to be associated with calc-alkaline and alkaline suites of rocks. Fiji contains several known porphyry copper and epithermal gold deposits (Colley and Flint, 1995). This is to be expected given Fiji's island arc setting.

The system illustrated in Figure 4 is simple and idealised. Despite the fact that rock associations in such systems are frequently considerably more complex, especially when multiple phases of intrusion occur, the model of Figure 4 is appropriate for understanding the likely geophysical responses of the units comprising the system illustrated and for the subsequent recognition of such responses in Fiji. These responses are discussed in the following section in the context of how they can be used to identify localities where epithermal gold deposits may occur.

Expected regional geophysical responses of intrusive volcanic systems that may host epithermal gold deposits

The components of the model of Figure 4 and their possible geophysical responses are as follows.

The intrusive stock. This may be magnetic and thereby cause a discrete magnetic anomaly. If multiple phases of superimposed intrusion occur, this anomaly may exhibit concentric zoning or even more complex subdivisions. As the plan sections of such intrusions tend to be circular or ellipsoidal, the observed anomalies commonly have such outlines as well. Contact metasomatic effects may produce a magnetic annulus, due to magnetite concentrations in the country rock surrounding the intrusion. The intrusions do not always contain significant concentrations of magnetite and it is possible that they will be imaged as magnetic lows relative to adjacent country rock if the country rock contains greater concentrations of magnetic minerals. Destruction of magnetite by alteration processes associated with fluid flow may create local magnetic lows in the magnetic responses of the intrusions and the country rock.

The intrusion of stock-like bodies is an essential factor in the formation of most epithermal gold deposits. The identification of such intrusions in a particular area at depth is thus a favourable regional indicator for the possibility of an overlying epithermal gold deposit. It is important however that erosion has not stripped off the cover sequence, such as genetically related volcanic and pyroclastic rocks, in which any epithermal gold deposit is likely to be located. Such erosion is not completely negative from an exploration viewpoint as it may expose rocks with porphyry copper potential.

The volcanic system. This consists of the assemblage of volcanic and pyroclastic rocks together with any dykes and sills developed in volcanoes above the intrusive stocks. Figure 4 shows such a volcano consisting of a central vent that has resulted in the formation of a caldera. It is possible to have multiple vents. Calderas are not always formed. If calderas do form they tend to be circular. Vents may contain plugs of solidified volcanic material such as that illustrated in Figure 4. Vents may also be associated with the formation of ring dykes and radial fracture systems.

The volcanic and pyroclastic material ejected from the volcano (shown as "younger volcanics subaerial and submarine" in Figure 4) consists of irregular (both in thickness and in plan), superimposed sheets of volcanic rocks such as lavas, tuffs and agglomerate. The magnetic characteristics of these units are extremely variable due to different cooling histories and compositions at different localities. Often it is only possible to outline such units in the magnetic data on the basis of their textural character rather than their bulk magnetic response. Airborne spectrometric gamma-ray responses (ternary, potassium, thorium and uranium) are however extremely useful for mapping the surface outlines of exposed volcanic units on the basis of variations in their radioelement concentrations.

Vents are commonly evident as magnetic lows. There are several possibilities for this response. It may simply be due to a physical hole. It could be due to the destruction of magnetite in and around the vent system due to alteration processes. It could also be due to a magnetic effects of a plug of weakly magnetic or reversely magnetised rock in the vent. Some vents are marked by central magnetic highs whish are due to plugs of magnetic rock. These central highs are often surrounded by magnetic lows which may be caused by the factors listed above. Ring dykes can add doughnut shaped magnetic highs to the magnetic signatures of vent systems. If a caldera is developed it will be visible in digital elevation models unless its topographic expression is destroyed by erosion.

The identification of a vent system associated with calc-alkaline or alkaline volcanic rocks allows exploration efforts for epithermal gold deposits to be focussed in the locality of the vent.

The epithermal gold deposits. These do not have a direct geophysical expression. Specific localities where such deposits may have formed can however be indicated by airborne geophysical data. As shown in Figure 4 such deposits are developed in vein systems in or proximal to volcanic vents. These veins are the result of precipitation of gold from fluids that have ascended from the underlying stock via fractures and faults. Such fractures and faults van be visible in airborne magnetic data by virtue of displacements of magnetic units and destruction of magnetite by mineralising fluids and weathering along the plane of the fault or fracture.

Alteration processes may locally enhance the potassium content in the country rock adjacent to epithermal gold deposits and such elevated local potassium concentrations can often be recognised in images of potassium values determined from the airborne gamma-ray spectrometric data.

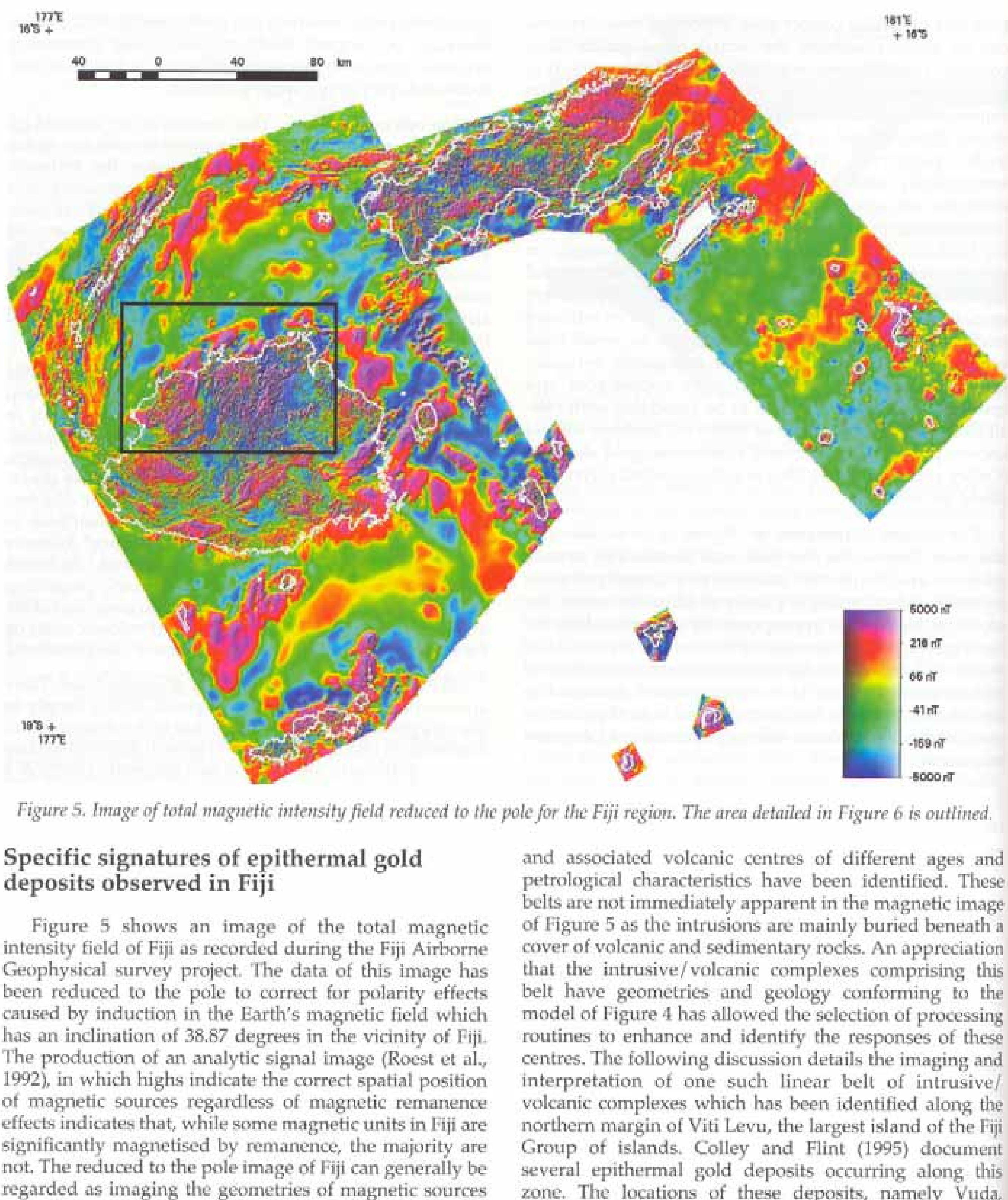


Figure 5. Image of total magnetic intensity field reduced to the pole for the Fiji region. The area detailed in Figure 6 is outlined.

Specific signatures of epithermal gold deposits observed in Fiji

Figure 5 shows an image of the total magnetic intensity field of Fiji as recorded during the Fiji Airborne Geophysical survey project. The data of this image has been reduced to the pole to correct for polarity effects caused by induction in the Earth's magnetic field which has an inclination of 38.87 degrees in the vicinity of Fiji. The production of an analytic signal image (Roest et al., 1992), in which highs indicate the correct spatial position of magnetic sources regardless of magnetic remanence effects indicates that, while some magnetic units in Fiji are significantly magnetised by remanence, the majority are not. The reduced to the pole image of Fiji can generally be regarded as imaging the geometries of magnetic sources according to the principles of magnetic induction as applying in a situation with a vertical inducing field i.e. the image is giving a good general indication of the positions and shapes of the magnetic sources of the area.

A detailed description of the AGSO 1:250 000 scale interpretation of these data is given by Gunn et al. (1998). Gunn et al. conclude that, apart from the linear anomalies in the northwest extremity of the survey area, which are likely to be due to slices of ophiolitic rocks, virtually all the magnetic responses observed are due to intrusive/volcanic complexes such as described in the preceding sections. Several linear belts of intrusive centres and associated volcanic centres of different ages and petrological characteristics have been identified. These belts are not immediately apparent in the magnetic image of Figure 5 as the intrusions are mainly buried beneath a cover of volcanic and sedimentary rocks. An appreciation that the intrusive/volcanic complexes comprising this belt have geometries and geology conforming to the model of Figure 4 has allowed the selection of processing routines to enhance and identify the responses of these centres. The following discussion details the imaging and interpretation of one such linear belt of intrusive/volcanic complexes which has been identified along the northern margin of Viti Levu, the largest island of the Fiji Group of islands. Colley and Flint (1995) document several epithermal gold deposits occurring along this zone. The locations of these deposits, namely Vuda, Tuvatu, Vatukoula and Raki Raki, which are hosted by shoshonitic volcanic assemblages, are shown in Figure 6. Vatukoula is a major deposit originally containing approximately 8 million ounces of gold. The Tuvatu deposit is currently undergoing a feasiblity study.

The geophysical indicators of the intrusive/volcanic systems that formed these deposits are as follow:

Gravity data (Figure 6a). The data from this image corresponds to the gravity contours of Figure 12 of Colley and Flint (1995) and represents terrain-corrected Bouguer gravity data processed to suppress long wavelength and shallow sources over Viti Levu. The acquisition and processing of these data is described by the Metal Mining Agency of Japan (1993). The significance of these results is that isolated gravity highs appear to be indicating the gravity effects of deep, dense intrusions beneath the epithermal gold deposits.

Total Magnetic Intensity (Figure 6b). This image, which has been illuminated from the west, does not clearly indicate the magnetic effects of the intrusive bodies indicated by the gravity data. The image of Figure 6a is dominated by the erratic high frequency magnetic effects of the shoshonitic volcanic assemblages which host the epithermal gold deposits. The magnetic effects of the underlying intrusions are only evident in this image by vague general increases in the field values in the vicinity of the intrusions. The image of Figure 6b is showing the high frequency magnetic effects of the surface and near surface volcanic material superimposed on the broader magnetic effects of the buried intrusions. It is only when the effects of the volcanic material are removed by a filtering process, such as the upward continuation illustrated in Figure 6c, that the magnetic responses of the buried intrusions become obvious. While the image of Figure 6b can be used to map individual volcanic units, the vertical gradient image of the magnetic field (Figure 6d) proved more useful for this task.

By carefully inspecting the image of Figure 6b it is possible to identify features expected to be characteristic of the localities of epithermal gold deposits The Vuda vent system appears as a circular magnetic low containing a central high. The Tuvatu epithermal deposit appears to be located in an east-west trending fault adjacent to a small circular magnetic high with a central low which collectively may be indicating a vent. The Vatukoula deposit is located adjacent to the Tavua Caldera in a locality where east-west trending and northeast trending faults indicated in the data appear to intersect. The Tavua Caldera is evident as a magnetic low.

Upward continued total magnetic intensity (Figure 6c). When a magnetic field is recalculated at a higher level the magnetic effects of thin discontinuous and sub-horizontal magnetic sources are suppressed relative to the magnetic effects of bodies with significant width and depth extent. In the image of Figure 6c where the field has been computed at a level of 500 metres above the ground surface (in contrast to the field shown in Figure 6b which was measured 80 metres above the ground surface) the magnetic effects of the surface volcanic material have been suppressed to the extent that three major magnetic anomalies corresponding to the gravity anomalies in northern Vitu Levu have become evident. It appears that the intrusive bodies underlying the Vuda, Tuvatu, Vatuloula and Raki Raki epithermal gold deposits are both dense and magnetic relative to the material into which they are intruded.

The upward continuation data shows a distinct magnetic low corresponding to the vent system manifesting as the Tavua Caldera. The intrusive centre associated with the Raki Raki epithermal system shows a similar (albeit offshore) central low. No clear central low is associated with the intrusion underlying the Vuda and Tuvatu deposits however both the gravity and upward continued magnetic data indicate an elongation of this feature and it is possible that it sources several relatively smaller vents such as those associated with the Vuda and Tuvatu areas rather than a major single vent such as the one causing the Tavua Caldera.

Vertical Gradient of the total magnetic intensity (Figure 6d). The vertical gradient processing has enhanced the magnetic effect of high frequency magnetic anomalies relative to the effects of broad low frequency magnetic anomalies such as are caused by deeper sources. The processing of Figure 6d is particularly useful for the mapping of individual volcanic units on the basis of textural characteristics. The vertical gradient processing also simplifies the recognition of fine detail such as fault and fracture systems. Vent systems such as Vuda, Tuvatu and Tavua which have surface expressions can be recognised in the derivative data.

Ternary radiometric image (Figure 6e). The ternary gamma-ray image is an excellent tool for the mapping of surface geology if care is taken to identify effects caused by variations in weathering and areas where transported material has been superimposed on bedrock. The image of Figure 6e shows that the areas corresponding to the Vuda, Tuvatu and Tavua vents have elevated counts in all radioelements. The principal vent in the Raki Raki area is offshore so no comments are possible for this area.

Potassium Image (Figure 6f). In the image of the equivalent potassium ground radioelement concentrations of Figure 6f it can be noted that the vicinities of the Vuda, Tuvatu and Tavua vents all correspond to localised areas with potassium values amongst the highest evident in the data. These can be assumed to be due to potassic alteration caused by fluids associated with the formation of the epithermal gold deposits.

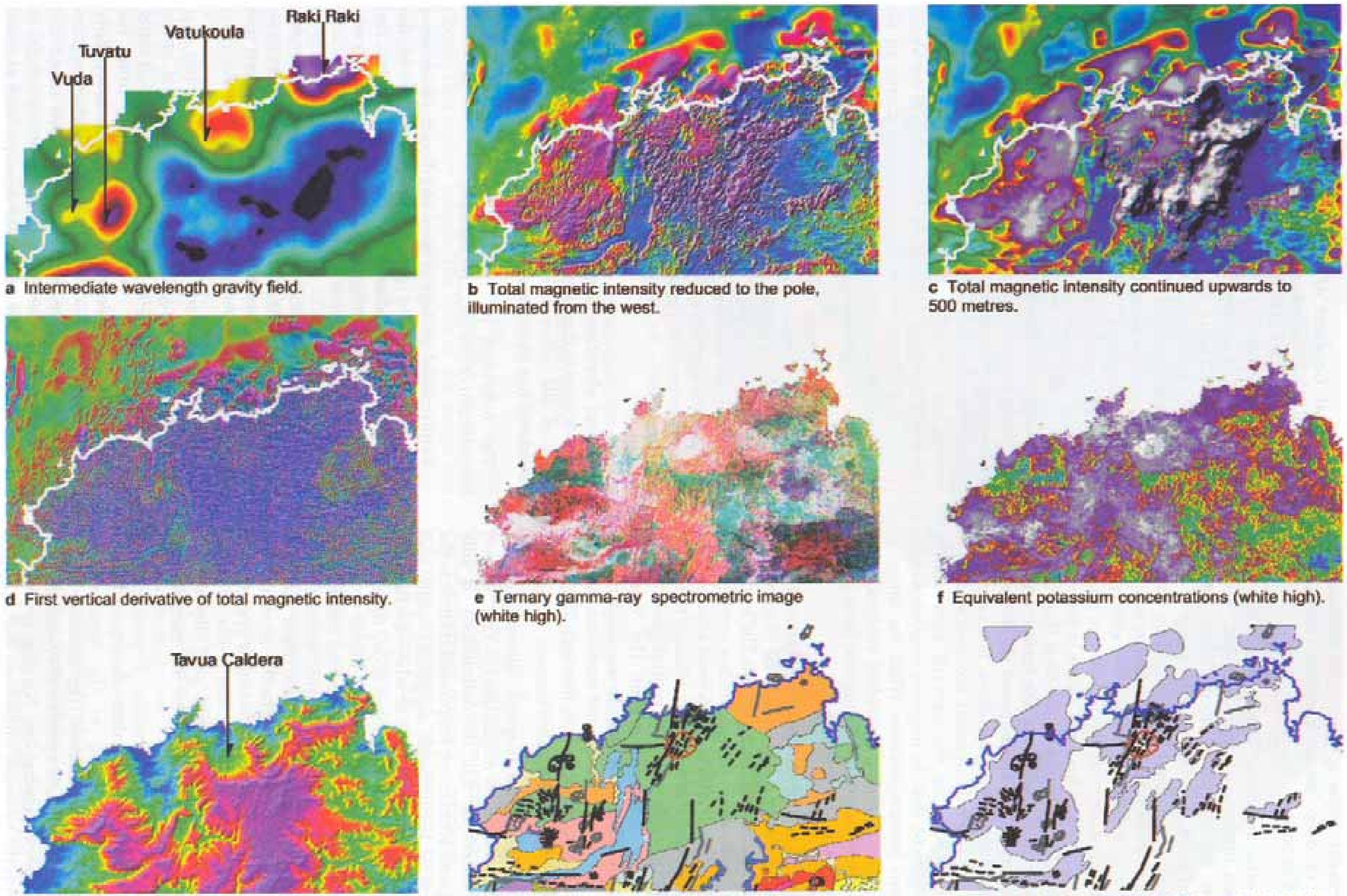
Digital elevation (Figure 6g). The Tavua Caldera is clearly evident in the digital elevation image of Figure 6g. None of the other epithermal gold deposits being considered has an obvious topographic expression.

The following images summarise the geological intepretation of the geophysical data:

Surface solid geology (Figure 6h). Figure 6h shows a detail from the solid geology interpretation of the geophysical data produced by Gunn et al. (1998). The interpretation has distinguished different volcanic flows, structure and localities of vents.

Positions of major subsurface intrusions (Figure 6i). Figure 6i, a detail from the interpretation of Gunn et al. (1998), indicates the outlines of subsurface intrusions that have not reached the surface.

It appears significant that the intrusive centres that appear to be sourcing the epithermal deposits under discussion occur in a line and at regular spacings. It could be envisioned that they have resulted from the contemporaneous ascent of magma in a series of regularly spaced convection cells formed above a subducting plate of oceanic lithosphere. Some workers have raised the possibility of the importance of major transform faults in the localisation of epithermal gold deposits. Such features are not markedly evident in the area being considered although a significant northeast trending fault zone does appear to intersect the Tavua Caldera.



a Intermediate wavelength gravity field.

b Total magnetic intensity reduced to the pole, illuminated from the west.

c Total magnetic intensity continued upwards to 500 metres.

d First vertical derivative of total magnetic intensity.

e Ternary gamma-ray spectrometric image (white high).

f Equivalent potassium concentrations (white high).

g Digital elevation.

h Detail from the surface solid geology interpretation of Gunn et al. (1998). Different volcanic units, structure and vents have been identified.

i Detail from the interpretation of Gunn et al. (1998) showing locations of major subsurface intrusive stocks.

Figure 6. Details of the a belt of intrusive /volcanic complexes associated with epithermal gold deposits in northern Viti Levu. The locations of the deposits (Vuda, Tuvatu, Vatukoula and Raki Raki are indicated on several images.

Concluding Remarks

This paper has discussed geophysical responses associated with epithermal gold deposits in a limited area of Fiji. The area presented has the greatest known concentration of such deposits and is the best documented in terms of such deposits. The airborne geophysical data of the Fiji Airborne Geophysical Survey Project contains responses in other areas of Fiji, not known to contain epithermal gold deposits, which are similar to the responses noted to be associated with the known deposits.

The data and images of the results of the project and the interpretation report of Gunn et al. (1998) can be obtained from:

Bhaskar Rao (Director) Mineral Resource Department, Fiji, Private Mail Bag, Suva, Fiji, Tel: +679 381 611, Facsimile +679 370 039. Email: brao@mrd.gov.au.

Acknowledgements

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Abstracts

SECTION FOUR

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List of Abstracts by Session

Name of presenter only

Monday 9 November 1998

Tuesday 10 November 1998

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Alphabetical Index of Speakers

MINERAL CASE HISTORIES: TASMANIA & VICTORIA

Application of Detailed Ground Magnetics for Gold Exploration in NE Tasmania

M. Roach, T. Chalke

Abstract

Gold mineralisation in north-east Tasmania occurs mainly within structurally controlled quartz veins hosted by the Ordovician to Devonian Mathinna Group, a thick sequence of proximal to distal turbidites. In a few small zones where thin magnetic units are present within the stratigraphy structures can readily be identified from airborne magnetic data but in most areas both stratigraphy and structure cannot be delineated even from high-resolution helicopter aeromagnetic data. High resolution ground magnetic surveys have been conducted over a number of areas of historical gold production. In all cases, these surveys have been successful in mapping subtle stratigraphic magnetic features with amplitudes of only a few nT which appear to result from the slight difference in magnetic susceptibility between mudstone and sandstone dominated units. Most of these features are not apparent in the airborne magnetic data. In many images cross-cutting structural features are clearly apparent and many of these closely correspond to areas of historical gold workings. In some areas zones of alteration adjacent to structural features are also marked by areas of magnetite destruction. High resolution magnetic data has proven to be a very effective tool for mapping stratigraphy and structure in the Mathinna Group and in some cases for the direct detection of zones of alteration and gold mineralisation.

MINERAL CASE HISTORIES: TASMANIA & VICTORIA

Regional Geophysics of the Housetop Granite Area - NW Tasmania

M. LeClerc, M. Roach, D. Leaman

Abstract

The Housetop granite is a composite Devonian granitic body in NW Tasmania. It intrudes into a region of complex geology including Proterozoic sedimentary rocks, Cambrian sediments and volcanics, Ordovician clastics and limestones and is extensively overlain by flat-lying Tertiary basalt. The Housetop Granite is spatially associated with a variety of mineralisation types including tin-tungsten bearing magnetite skarns and sulphide vein deposits. Most major Devonian granitic intrusions in Tasmania are characterised geophysically by areas of little or no magnetic response and strongly negative residual Bouguer anomalies. In contrast, the Housetop Granite is spatially associated with a major broad positive magnetic anomaly and only a minor negative gravity anomaly. Previous geophysical interpretations have suggested that the granitic rocks were the source of the magnetic anomaly and that the granite was anomalously dense when compared to other Tasmanian granitoids. Newly acquired petrophysical data indicates that the Housetop granitic rocks are neither anomalously dense or magnetic. Modelling based on this new data suggests that the granitic rocks are relatively thin and that they are underlain by an east-dipping highly magnetic unit which is interpreted as a body of Cambrian ultramafic rocks with physical properties similar to ultramafic rocks which crop out elsewhere in western Tasmania. These geophysical models support recently proposed thin-skinned structural models for northern Tasmania.

MINERAL CASE HISTORIES: TASMANIA & VICTORIA

Lessons from a Case Study of a Geophysical Interpretation in Western Victoria

D. Moore, S. Maher

Abstract

This paper compares the predictions and results of the Victorian Initiative for Minerals and Petroleum drilling programme, mostly over the Horsham 1:250 000 map sheet area of western Victoria. Sixteen holes were drilled beneath thin cover of the Cainozoic Murray Basin at targets identified in Moore's (1996) geological interpretation of the airborne magnetic and ground based gravity data. This integrated interpretation divided the region into the Stawell and Glenelg Zones. The Stawell Zone metaturbidites and metabasalts form the eastern edge of the Lachlan Fold Belt. The Glenelg Zone included weakly metamorphosed andesites of the Dimboola Subzone, greenschist to amphibolite facies metaturbidites and metavolcanics of the Miga Subzone and amphibolite grade rocks of the Ozenkadnook Subzone. All were deformed in the 500 Ma Delamerian Orogeny. Drilling depths were estimated both from magnetic modelling and previous drilling in the region. Drilling targeted basement depths between 30 m and 250 m. Where magnetic modelling was the main depth control, basement depths were within 20% of predicted depths, slightly more reliable than those estimated from nearby drilling. Of the sixteen holes, nine intersected the predicted lithologies and another three intersected lithologies that substantially agreed with the predictions. While four drill holes intersected quite different lithologies to those predicted, no major geological reinterpretation was needed. The drilling intersected both Cambrian continental island arc volcanic rocks and Upper Proterozoic metasedimentary basement, strengthening the temporal and tectonic correlations between western Victoria and western Tasmania. The study showed that a careful interpretation can give a reliable indication of the basement, even in areas of total cover. Integrating geological and geophysical data and using standard geological logic and techniques, like drawing sections to test plan interpretations, are powerful aids. Drilling complemented the interpretation by providing samples that could be used to test the interpretative hypothesis.

PETROLEUM CASE HISTORIES: SOUTH EAST AUSTRALIA
KEYNOTE ADDRESS

Changes in Exploration Activity over the Life of the Gippsland Basin

Douglas A Schwebel

Abstract

With more than three decades of exploration and development operations, the Bass Strait provides a unique opportunity to gain a historical perspective of the various phases of exploration and development, and changing technologies within a producing basin. Exploration history within the Gippsland Basin can be subdivided into three periods. The initial period of frontier exploration in the Gippsland Basin (1960 - 1975) is one in which the large, easy to recognise structural traps were identified and tested to establish a proven resource base. This phase of exploration activity was marked by the acquisition of regional geophysical surveys and low fold, coarsely spaced 2D seismic data. Wildcat drilling successfully tested large traps and resulted in the discovery of significant oil and gas reserves, thereby establishing the Gippsland Basin as Australia's most prolific oil and gas province. The second exploration phase (1975 - 1990) is defined as a period of consolidation, when new exploration technologies provided the means to improve the understanding of the basin's hydrocarbon system. During this period, exploration activity was directed at evaluation of smaller structural traps and non-conventional plays. The introduction of 3D seismic and workstation interpretation techniques provided the opportunity to evaluate more subtle structural traps and improve the definition of fault and stratigraphic plays. The current era of exploration activity (1990 +) is defined as the mature phase, where synergies between exploration and development activities provide a means to evaluate successively smaller exploration targets. Greater importance is placed on technical risk mitigation and lower cost evaluation methods. Improved 3D seismic data quality and the use of techniques, such as visualisation and seismic modelling, have provided tools to better predict the range of potential outcomes. With over 30 years of exploration activity including the recording of 150,000 line kilometres of seismic and the drilling of over 150 exploration and appraisal wells, the Bass Strait illustrates the cycles through which a producing hydrocarbon basin passes during its life. It also illustrates how the application of new technologies and an evolving understanding of the basin's hydrocarbon system can impact on exploration and development programs.

PETROLEUM CASE HISTORIES: SOUTH EAST AUSTRALIA

Seismic Stratigraphic Extrapolations from a Single Well in the Strahan Sub-basin, Western Tasmania and the Application to Hydrocarbon Exploration

W. Lodwick, V. Passmore

Abstract

The Strahan Sub-basin of the Sorell Basin, offshore Western Tasmania was penetrated by the Cape Sorell-1 well in 1982. This well penetrated to a depth of 3506 metres and live oil shows were recorded at around 3000 metres. The seismic coverage over the area is of good quality and of sufficient density to establish stratigraphic correlations. This paper demonstrates the application of stratigraphic interpretation methods, develops models of deposition and facies change away from the well and identifies prospects for hydrocarbon exploration. Cape Sorell-1 penetrated Cainozoic and Mesozoic (Cretaceous) sediments. The bulk of the sedimentary section beneath the well is thought to be Mesozoic. Starting from the known rock types in the well, depositional models were built using the structural information extracted from the sequence interpretation and analogues taken from the literature. Facies changes within each sequence were then estimated from detailed interpretation of the seismic character. Seismic attributes were used extensively in this process. Finally, a number of models were made and the oil industry analysis of structure, size, source, seal and reservoir applied to the definition of leads and prospects.

PETROLEUM CASE HISTORIES: SOUTH EAST AUSTRALIA

The Continental Margin off East Tasmania and Gippsland: Structure and Development using New Multibeam Sonar Data

P. Hill, N. Exon, J. Keene, S. Smith

Abstract

The continental margin facing the southern Tasman Sea off south-east Australia is of high petroleum and geological significance because it contains Australia's richest oil province, the Gippsland Basin. Exploration activity in the region has concentrated on the shelf of this basin. Off Tasmania the upper margin is host to important deep-sea trawl fisheries, and regional geophysical data suggest some long-term petroleum potential. In early 1997, 20,000 km of the margin were surveyed by the Australian Geological Survey Organisation, in co-operation with Scripps Institution of Oceanography and the University of Sydney. The SeaBeam 2000 multibeam sonar system of the US RV Melville was used to map the topography and character of the seafloor in unprecedented detail. The SeaBeam 2000 is a 12 kHz, 121-beam echo-sounder that collects both bathymetry and backscatter (sidescan) data across a swath of width about 3.4 times the water depth. The survey also collected 3500 km of magnetic and gravity profile data. The margin off Gippsland is dominated by a large embayment 100 km across and floored by an ESE-trending chasm, the Bass Canyon, which is 60 km long and 10-15 km wide. The canyon has cut down about 2 km into the margin and is bounded to the north and south by very steep inner canyon walls 1000 m high. Sediments transported down the canyon debouch at its mouth, at ~4000 m depth, and spread onto the abyssal plain via a network of distributary channels and levees. Sediment from the shelf is channelled into the entrance of Bass Canyon by three major, deeply-incised tributary canyons and a number of smaller ones. Bass Canyon has probably acted as a conduit for clastic sediment to the deep sea floor since break-up at ~80 Ma. Seismic profiles over the Bass Canyon complex show that canyon erosion has exposed sections of almost the entire Gippsland Basin sequence down to the Early Cretaceous and underlying basement. Numerous suitable dredge and core sampling sites in the canyons have been identified for a geological sampling program. Off east Tasmania, the survey showed the margin to be generally steep and rugged, with relatively little sediment having been deposited on the

continental slope, except in narrow rifts, since break-up. The adjacent abyssal plain is commonly underlain by 2 km of sedimentary section. The continental slope is cut by an extensive system of canyons, some more than 30 km long and 500 m deep. Large fault blocks on the lower slope show structural trends consistent with a NW-NNW rift direction and NE-ENE transfer direction. The upper slope appears to be underlain by a subsided Miocene carbonate shelf. Volcanics, of probable late Cainozoic age, are fairly widespread on the seafloor off north-east Tasmania. Such volcanic terrain includes a number of scattered cones, the largest 450 m high.

AIRBORNE EM

Keynote Address

Crossing the Border: Advances in Airborne EM

Brian Spies

Abstract

Airborne electromagnetics has had a fascinating history since it was first flown in Canada 50 years ago. In the 1950s and 1960s, AEM was responsible for at least US$10 billion of mineral discoveries in Canada, a country geophysically blessed by recent glaciation. AEM crossed the borders to Australia in 1957, with very disappointing results. At the time it was not generally recognised that, with the relatively high-frequency systems then in use, the almost ubiquitous conductive regolith cover would produce a large "geological noise" response which dominated subtle signals from the bedrock. It was not until the 1970s that Australian geophysicists tested time-domain ground EM systems that could penetrate through thick regolith cover, and developed advanced instrumentation (SIROTEM) and interpretation techniques. These were later exported back to the then frequency-domain dominated USA and Canada. The first discovery attributed to AEM in Australia was the Que River deposit in Tasmania, using a helicopter AEM system in 1972. But Tasmania is relatively resistive, and a more advanced technology is needed for most of the mainland. Current AEM research is focused on wider bandwidths, larger transmitter moments, and reducing noise levels to penetrate through the regolith layer. The intense research in AEM in Australia culminated in the AEM 98 conference in Sydney in February 1998, which saw large numbers of northern Americans "crossing the borders" to see what the Australians were up to. The third "crossing the border" theme related to AEM is the border between geophysics, geology and geochemistry. Geophysicists traditionally view AEM profiles with the objective of finding a late-time anomaly indicative of a good conductor at depth (the 'drill here' approach), a procedure especially difficult in areas of complex regolith variability. Geologists, on the other hand, are quite comfortable using geophysical maps to solve geological problems, as evidenced by the widespread use of aeromagnetics and radiometrics. Explorationists have recently recognised that substantial exploration benefits arise from being able to map within the regolith to track hydrogeological features driving secondary enrichment. Increasingly it is becoming more difficult to separate bump hunting and geological mapping in the exploration context. Both are intimately related, and when used by the geologist give feedback into how AEM can best be interpreted.

AIRBORNE EM

How to find Localised Conductors in GEOTEM Data

P. Wolfgram, M. Hyde, S. Thomson

Abstract

Orebodies, mineralised zones, faults, folds, contacts, etc. may represent localised electrical conductors that create airborne electromagnetic (AEM) responses of interest to explorationists. However, typical AEM datasets in conductive regimes exhibit numerous features besides those of interest and it is left to the interpreter to identify the ones that are of significance to the interpretation task at hand. Synthetic data can be used to illustrate typical effects of host medium and conductive overburden on target responses, and how these might be identified in the presence of noise such as variations in aircraft ground clearance. Although an understanding of the complex anomaly features is possible, analysing large data sets will require rapid methods of pinpointing anomalous areas and allowing the user to employ visual correlation over a map to aid in the interpretation. Different transformations of the data can enhance different features of interest to the explorationist. The conductivity depth transform (CDT) maps broad conductive zones and their depths - it is less suitable for detecting localised conductors. The stationary current image (SCI(tm)) on the other hand indicates areas where electric currents become trapped in localised conductive features such as isolated bodies, faults, folds, etc. The SCI emphasises structural features because it is optimised for lateral contrasts in electrical conductivity.

AIRBORNE EM

Recent Results in South-Eastern Australia from the Latest Developments in Towed Boom HEM Systems

R. Henderson, M. Smith, M. Rangott

Abstract

The Hummingbird EM system is a fully digital, five frequency, coaxial and coplanar towed boom system which has many unique features including measuring only 6.5 metres in length, weighing only 190 kilograms and being detachable into three sections for easier transportation. Magnetometer and spectrometer measurements can be obtained at the same time as the EM with the sensors for both magnetics and EM contained in the rigid boom. Results are presented in the traditional options of profiles, contours and images. The use of differentially corrected GPS makes for excellent resolution of the position of anomalies and of structural deformation of both conductive and resistive formations. Results from surveys recently conducted in NSW, Indonesia and Vanuatu verify these attributes. In particular, a magnetic/electromagnetic survey over the copper prospect at Burraga in NSW produced substantially new information on the continuity and structure of bedrock conductors compared to a previous HEM survey and has delineated new targets for further exploration. The contoured colour image of resistivity computed from the coplanar 6.6 kHz coil displays the distribution and character of conductive and resistive units. NE-SW faults and NW-SE faults evident in the data are known to be

important structural controls. The magnetic data for the same area acquired with the HEM system show strong magnetic responses, both normally and remanently magnetised, with effective mapping of structure and lithology. The one-day Hummingbird EM survey rapidly mapped key geological features of an exploration property where ground access problems have restricted past ground geological and geophysical work. Measurements on drillcore of electrical conductivity and magnetic susceptibility have assisted in the understanding of the HEM survey results over the complex geological setting of the Burraga style mineralisation.

LOGGING / PETROPHYSICS

Application of Neural Networks to Identify Lithofacies from Well Logs

Y. Zhang, H. Salisch, J. McPherson

Abstract

Neural networks are physical cellular systems which can acquire, store, and utilise knowledge obtained by experience. They have a number of performance characteristics in common with biological neural networks or the human brain. They can simulate the nervous systems of living animals which work differently from conventional computing and analyse, compute and solve complex practical problems using computers. Studies show that neural networks can be used to solve a great number of practical problems which occur in modelling, predictions, assessments, recognition, and image processing. Especially, neural networks are suitable for application to problems where some results are known but the manner in which these results can be achieved is not known or is difficult to implement; or where the results themselves are not known. Lithofacies are geological definitions within a formation. The determination and assessment of lithofacies is of major significance in petroleum exploration and development. Lithofacies need to be recognised in order to evaluate the distribution of sand bodies and find potential hydrocarbons in a basin. In cored intervals of boreholes, lithofacies can be determined by using core descriptions. In uncored intervals it is not possible to identify lithofacies. However, well logging provides information in a continuous manner which can be used, in many cases, to identify lithofacies in cored and uncored intervals. This paper presents an application of neural networking to identify lithofacies from well logs in a lithologically complex formation. Only conventional well logs were available for this study. Nonetheless it was possible to establish an identification network of lithofacies by integrating error back propagation and self-organising mapping algorithms. This network was applied to identify lithofacies in six wells. The results indicate that it is possible to identify lithofacies from conventional well logs by using neural network techniques. Neural networks have a potentially large application in petroleum exploration and development.

LOGGING / PETROPHYSICS

Acoustic Velocities as a Function of Effective Pressure in Low to Moderate Porosity Shaly Sandstones, Part 2 - Implications for Hydrocarbon Exploration

A. Khaksar, C. Griffiths

Abstract

Hydrocarbon production may cause changes in dynamic reservoir properties including pressure and fluid saturation. Understanding the magnitude of such variations is essential for the exploration of new reserves and optimising the performance of existing fields. Laboratory measurements of acoustic properties of representative rock samples, simulating in situ pressure and fluid saturation, provide a useful guide for calibrating and interpreting seismic and sonic log data. A petro-acoustic study was carried out to investigate factors influencing acoustic properties of Cooper Basin sandstones. This study integrated field data and petrography with laboratory measurements of acoustic properties of representative rock samples. In a previous paper (Abstract - this volume) we highlighted experimental data; here we elaborate on implications of these results in predicting rock property and pore fluid type from sonic logs and seismic reservoir monitoring. Analysis of data from acoustic measurements at ultrasonic frequency on samples from the Cooper Basin reveals that the pressure dependency of the Cooper Basin rocks is very large. The velocity-pressure relationship obtained from laboratory data is consistent with the sonic log anomaly observed in partially pressure-depleted reservoirs in the Cooper Basin. A method is proposed to correct the sonic log reading for pressure variation in the study area. At in-situ reservoir pressure Vs and Vp are strongly correlated and dry and water-saturated samples show significantly different velocity ratios (Vp/Vs). The Vp/Vs ratio is not affected by porosity and clay content and therefore has potential as a gas indicator in the region. The strong stress sensitivity and the distinct Vp/Vs values for dry and water saturated Cooper Basin cores suggest that the dynamic changes in pressure and saturation of the reservoir rocks may also be detectable from acoustic impedance or travel time at seismic and sonic log frequencies.

LOGGING / PETROPHYSICS

Estimating the Effects of Pore Geometry and Pore Fluid Species on Elastic Wave Velocity Dispersion in Rocks Using Microstructural Models

A. Endres

Abstract

Numerous laboratory studies have been performed to determine and quantify the phenomena that affect elastic wave velocities in porous rocks; these results have been used in the interpretation of seismic data and acoustic well logs. However, it has become apparent that significant velocity dispersion can occur in liquid saturated rocks between the ultrasonic frequencies (100 kHz-1 MHz) used in laboratory measurements and the lower frequency bands used in reflection seismology (10 Hz-500 Hz) and well logging (approximately 10 kHz). If geophysicists are to quantitatively interpret exploration

data on the basis of petrophysical laboratory results, it is imperative that the nature of the dispersion mechanisms be understood. Two mechanisms that are commonly used to explain the elastic wave velocity dispersion in liquid saturated rocks are Biot dynamic poroelasticity and local (or squirt) flow. Recent work by Endres and Knight provides the basis for a consistent comparison of the effects of these two dispersion mechanisms, using inclusion-based models to explicitly describe the pore structure in porous media. Systematic modelling performed in the current study has revealed that the relative magnitude of the dispersion due to these two mechanisms is strongly dependent on the pore structure and pore fluid properties. The Biot mechanism produces greater velocity dispersion than the local flow mechanism when the pore shape spectrum consists primarily of spherical pores or the pore fluid bulk modulus is small. Dispersion due to the local flow mechanism is greater than that produced by the Biot mechanism when there is sufficient difference between the high and low frequency pore fluid pressure conditions within the pore space. This condition occurs when sufficient cracks (i.e., low aspect ratio pores) are present or the pore fluid bulk modulus is adequately large.

EM INTERPRETATION (I)

Conductivity-Depth Transformation of Slingram Transient Electromagnetic Data

J. Reid, P. Fullagar

Abstract

Approximate conductivity-depth transformation has become popular for presentation of transient electromagnetic (TEM) profile data. Many different schemes have been published, the majority of which deal with data acquired using the coincident-loop and central-loop configurations. TEM surveys for mineral exploration or groundwater studies, however, sometimes employ the 'slingram' configuration, in which the receiver is located outside the transmitter loop. Accordingly, a conductivity-depth transformation has been developed for slingram impulse-response TEM data. The depth assigned at each delay time is the depth to the physical current maximum in a half-space with conductivity equal to the apparent conductivity at that time. Apparent conductivity is almost always dual-valued, but it is possible nonetheless to select a unique apparent conductivity for the purpose of depth transformation: only one apparent conductivity at each delay time is compatible with downward diffusion of current. The unique apparent conductivities selected in this manner do not always define a smooth conductivity versus time curve. An automated procedure has been developed to edit the errant apparent conductivities in such cases. The conductivity-depth transformation yields a valid qualitative portrayal of the actual variation of conductivity with depth when applied to theoretical slingram data for layered-earth models. Conductivity-depth pseudo-sections generated from field data show good correspondence to known geology, and may be generated in a fraction of the time required for least-squares inversion.

EM INTERPRETATION (I)

Reduction of the Layered Earth Response in Transient Electromagnetic Data for Mineral Exploration

M. Sykes, U. Das

Abstract

The transient electromagnetic (TEM) response of a conductive mineral deposit can often be measured only in a narrow (late) time interval due to the masking effects produced by a conductive geological environment. A new multi-receiver technique is presented which will enable better use to be made of TEM survey data for mineral exploration. We consider a finite loop of current (or a vertical magnetic dipole) on the surface of the earth and compute the vertical magnetic and tangential electric fields anywhere on the surface, either inside or outside the loop. The contribution of the transient fields associated with the currents in the earth layers to the measured response is, to a large degree, removed from the measurements by combining the responses in a specific manner given in the paper. The combination of the measured fields results in a derived quantity which is related only to scattered, non-layered contributions. Synthetic results obtained for a 3-D conductive body in a homogeneous host medium below a conductive overburden yield a significant reduction in the layered earth response and a consequential relative increase in the anomalous response of the body. A benefit of the reduction of the layered earth response is that the signal from a conductive target body may be observed earlier in time and a more complete analysis of its decay curve can be made. It is expected that application of the technique will result in the detection of ore bodies, which would have otherwise remained undetected.

EM INTERPRETATION (I)

Measurement of Static Shift in MT and CSAMT Surveys

J. Macnae, L. Lay, L. Weston

Abstract

Controlled source audio-frequency magneto-telluric (CSAMT) surveys have found frequent application in mineral exploration, and there have also been a number of attempts to use magneto-telluric (MT) soundings in the same application. The advantages of CSAMT over conventional EM lies in its ability (through measurements of the electric field) to discriminate resistive as well as conductive zones, and in its depth-of-penetration capability. Static shift is however the bane of magneto-telluric (MT) and CSAMT soundings. It severely distorts any depth calculations and deteriorates the resolution of conductivity structure inferred from scalar CSAMT measurements. Static shift also significantly restricts the MT-method in its use for geological studies of the upper and lower crust; and its application to mineral, hydrocarbon, and geothermal resource exploration. Theoretical investigation using modelling has shown that measurements of an Inductive Source Telluric Field (ISTF) may closely predict and thus potentially remove the static shift at MT and CSAMT stations. Applications of the method in the field require the set-up of a low-power transmitter local to the survey line. This

transmitter is then used, with the main survey electrodes, cables and receiver, to collect additional data to be used for corrections. The collection can be run in parallel with the MT or CSAMT data acquisition, and requires little additional survey time. Initial tests of the concept in field studies near Sydney and over a skarn prospect in the Parkes vicinity proved very encouraging. The 'along-line variation' indicative of static shift was reduced by the correction by a factor of about 5 in the Parkes case, and the 'corrected' CSAMT section appeared smooth and regular as opposed to having the vertical striping typical of static problems.

MINERAL CASE HISTORIES: OVERSEAS (I)
KEYNOTE ADDRESS

Crossing the Borders: Exploration Issues Overseas

Terry Crabb

Abstract

During the current economic downturn, with commodity prices low and access to land creating more risk for explorers, many Australian exploration companies have cut back exploration budgets, have laid off staff, and are prioritising projects. Some companies have refocused their exploration efforts overseas. The reduced number of line kilometres being flown by the exploration industry in Australia has resulted in fierce competition amongst airborne contractors, pushing prices way below reasonable levels. A number of airborne contractors have started up in the last five years, attracted by the exploration upswing. World-wide, the number of aircraft providing high quality magnetics and radiometrics has doubled over this period. What is happening in Australia is being replicated around the world. Pricing of international contracts has followed a similar trend dropping well below the US$10.00 per line kilometre mark in Africa and South America Aerodat in Toronto proved to be the first airborne contractor fatality, and if this trend persists, additional contractors will fail. During this time, Governments have stepped in and are contracting out the flying of large portions of potentially mineral rich ground. AGSO and state governments in Australia are being matched by Namibia, Morocco, Argentina, and Denmark - all following the exploration initiative so successfully promoted by South Australia in 1995. Whilst access to land is causing major problems here in Australia; other countries like South Africa, Argentina, Greenland, Hungary, India and Namibia are opening up. Government data initiatives, software and hardware developments, professional societies, education options, R & D, conferences and meetings around the globe, plus cultural diversity, logistical support, infrastructure and safety concerns for explorers overseas are all assessed with a view towards what may be happening by the end of this millennium.

MINERAL CASE HISTORIES: OVERSEAS (I)

The Fiji Airborne Geophysical Survey Project

P. J. Gunn, B. Rao, G. Singh, I. Hone

Abstract

The Australian Agency for International Development (AusAID) funded Fiji Airborne Geophysical Survey Project acquired 162,967 line kilometres of airborne magnetic, radiometric and digital elevation data over all the main islands of Fiji plus substantial portions of adjacent sedimentary basins. The objective of the survey was the creation of a public domain database to stimulate mineral and petroleum exploration as well as providing a basis for land use, environmental, geo-hazard and geothermal studies. Analysis of the data for Vitu Levu indicates two north-east trending zones of intrusive centres that appear to be related to known mineralisation. The northern zone is recognised as containing distinct gravity and magnetic highs interpreted to be due to deep intrusive stocks that fed volcanic centres. The volcanic centres, which have close spatial associations with epithermal gold deposits, are variably evident as circular magnetic lows, presumably due to magnetite destruction, potassium count rate highs, interpreted as due to potassic alteration and circular topographic features reflecting volcanic topography. The Vatukola epithermal gold deposit which occurs in this belt exhibits all these features. The southern belt of igneous activity, which contains the Namosi porphyry copper deposit, is characterised by a gravity low in which the intrusion associated with Namosi causes a diffuse circular magnetic anomaly, a potassium count rate high and a topographic expression. Intersecting fault systems can be noted to occur at the locations of both Vatukola and Namosi. The airborne data has been used to produce a solid geology interpretation for the survey area in which the characteristics associated with the known mineralisation have been used to highlight areas of particular prospectivity. As surface volcanic cover in many portions of the study area obscures potential mineralising intrusive centres it has been necessary to apply various high cut filtering processes, in particular the upward continuation technique, in order to suppress the magnetic effects of the volcanic rocks relative to the magnetic effects of the intrusive centres.

MINERAL CASE HISTORIES: OVERSEAS (I)

Exploring the Solomon Islands with Airborne Geophysics

P. Swiridiuk

Abstract

The Island of Guadalcanal occurs as an 's' shape with each end twisted along the en echelon chain axis of the Solomon Islands primary fractured arc. The regional geology of Guadalcanal consists broadly of Mesozoic gabbroic and ultrabasic basement with Tertiary intrusives and sedimentary cover, and Quaternary volcanics. Helicopter borne magnetic and radiometric surveying was completed over 405 sq. km. on four tenements adjoining Gold Ridge. Topographic variations of sea level to 2400m within the survey areas necessitated a Squirrel helicopter platform enabling a "Tight Drape" survey of

30m sensor height and 100m line spacing. The objective of the survey was to delineate known gold-copper porphyry and epithermal style mineralisation events as well as being used as a primary exploration tool for the detection of new ore deposits and structurally favourable sites. Transfer fault structures and dilatant zones were identified from magnetic and terrain model data enhancements. This helped identify favourable sites for volcanic centres to develop with accompanying hydrothermal activity, alteration and mineral deposition. Porphyry prospects in the mountainous southern weather coast are coincident with magnetic features which correlate with IP anomalies. An intense magnetic anomaly on the side of Mount Popomanesu is interpreted as an intrusive at the contact between gabbro and Kavo greywacke beds where skarn occurrence is likely. A major porphyry or volcanic event at Sutakiki is evident as a magnetic anomaly core intrusive with an outer halo of magnetite and potassium destruction 2km in diameter and coincident with a topographic depression. Magnetic ring dykes are evident within the collapsed dome suggesting remnants of post volcanic collapse activity. Controlling mechanisms for widespread mineralisation near the Gold Ridge deposit appears related to a partially collapsed 10km diameter strato-volcano which is evident from both the digital terrain model and Radarsat images. An inner 5km diameter halo of potassium anomalies are directly coincident with anomalous gold and copper. Other volcano occurrences evident from the Radarsat and magnetic data and from hot spring locations along strike of the island indicate the presence of a magmatic arc which is a likely control of most of the mineralisation that exists on the island. Digital terrain model data has been extremely valuable in generating a drainage map to enable accurate location of follow-up sampling as GPS usage is restricted due to mountainous terrain and a dense forest canopy.

LOGGING, GROUNDWATER &
ENVIRONMENTAL GEOPHYSICS

Recent Advances in Borehole Resistivity Logging

K. Strack, O. Faini, A. Mezzatesta, L. Tabarovsky

Abstract

In locating hydrocarbons in a borehole, electrical logging techniques play a key role since they can distinguish between oil and water saturated rocks. During the past 5 years, numerous new electrical logging technologies were developed based on integrating state-of-the art geophysical technology into borehole logging. The technologies selected for this presentation include shallow imaging devices as well as deep array resistivity tools and a through casing resistivity device. Geophysical hardware design, acquisition principles, data processing and interpretation result in better measurements and better signal-to-noise ratio which translate directly into more hydrocarbon reserves. 3D numerical modelling that has only recently become available supports all phases of tool design and interpretation. Here, using case histories, we illustrate how geophysical concepts go hand in hand with the advances in electronics and information technology to get better hydrocarbon reserve estimates. Two major hardware changes are the major contributing factors: small signal measuring devices such as the sigma delta converter and resulting multi-sensor arrays providing multiple depths of investigation. The electronic advances lead to a hybridisation of the receiver amplifier and A/D circuitry. As a result, the STAR resistivity imager now measures calibrated values, which allow one to successfully compare image button measurements with a micro resistivity log. Data processing starts with the acquisition of the complete waveform, which is then stacked for signal-to-noise ratio improvement and inverted to obtain the best possible match between the measurements and the synthetic curves. In addition, the inversion gives numerous quality indicators, which allow the comparison between different inversion runs. Two-dimensional inversion delivers not only a two-dimensional distribution of the formation parameters but also statistics that are essential for estimating the reliability of the results. In a more complex environment such as dipping beds, deep invasion and thin beds more complex models are used on a selective basis. Array resistivities from array induction and array laterolog tools can be interpreted with higher vertical resolution. In most cases this even results in an increase in hydrocarbon reserves. Case histories for different tools and applications clearly show the benefits of the new concept of integrating multiple resistivity logs interpretation.

LOGGING, GROUNDWATER &
ENVIRONMENTAL GEOPHYSICS

Groundwater Geophysical Studies in the Katherine Region

G. Humphreys, D. Chin, M. Jamieson, D. Foo, R. Sinordin, A. Knapton

Abstract

The Northern Territory Government is under pressure from the horticultural and cattle industries to develop land for fruit-growing and improved pasture. Around Katherine, local geology is dominated by the Tindal Limestone, a thick sequence of Cambrian sediments known to host high-yielding aquifers. Water bores drilled recently have been tested at yields approaching 100 litres per second. The limestone is underlain by Cambrian-aged Antrim Plateau basalt. The potential for high bore yields is dependent on the thickness of limestone beneath the regional water table, and the geophysical methods investigated were intended to map depth to the top of the basalt. With an increasing number of bores drilled, definition of the regional water table is improved and data modelling is enhanced. Aeromagnetics were flown by CRAE in 1992, and the results merged with regional magnetic data by them and later by Normandy in an unsuccessful mineral exploration program. The imagery showed a number of significant faults, which were assumed to control the depth to basalt. Many of these faults were detailed with one or two ground magnetic traverses. One fault system west of Katherine on Manbulloo station is closely associated with the King River and after test-drilling was shown to have significant down-throw (and hence water potential) to the north-east of the fault. Ground magnetics has been used successfully south-west of Katherine, where faulting and inclined contacts have been used to determine controls on hydrogeology. A number of joint DC Schlumberger and Sirotem II soundings have shown little electrical contrast between the limestone and the underlying basalt. A hyper-saline layer at the base of the basalt can usually be located, and chemical analyses are being conducted to

determine whether this water is fossil sea-water. Using this as a target horizon will be valuable only if the basalt can be shown to be a consistent thickness over a defined area. Occasionally, a saline aquifer exists between the basalt and the limestone, but this is not sufficiently common to be diagnostic. Other electrical methods tried have included self-potential profiling and single-loop TEM profiling, but none has proven conclusive to date. Gamma logging of bores is routine for investigation bores and is essential in areas of lost circulation. It provides a better regional correlation than drillers' geological logs, and is less subjective. Caliper logs are also used to locate fracture zones within the limestone, to optimise screen settings. Magnetic susceptibility is being tried to seek the fractured and scoriaceous layers in basalt.

This investigation began as a regional mapping project, and has been refined to finer scale as data have accumulated. The availability of spatial analysis tools has enabled a complex 3-dimensional geological model to be developed. Inputs to the analysis have included the groundwater databases of the NT Natural Resources Division, AGSO/AUSLIG 9-second digital elevation model, drilling and geophysical data from AGSO, NTGS and mineral explorers. Recent advances in understanding the hydrogeology of the Katherine region have been possible only with access to complex digital data sets. Geophysics has been successful in defining and refining hydrogeological environments, thus contributing to better estimates of the success rate and potential yield of bores. Regional data analysis using groundwater, topographic and land-system data have allowed better regional interpretation of the groundwater supplies. Improved land management and land-use planning will be implemented to ensure sustainable development in the region.

LOGGING, GROUNDWATER & ENVIRONMENTAL GEOPHYSICS

Mine-site Groundwater Contamination Mapping

G. Buselli, H. Hwang, K. Lu

Abstract

A number of electromagnetic and electrical methods have been applied jointly to map groundwater contamination near mine-site landforms. The main methods being investigated are transient electromagnetic (TEM) and direct current (DC) resistivity soundings, DC profiling, self potential (SP), and induced polarisation (IP) measurements, combined with any existing hydrogeological and hydro-geochemical data. At the tailings dam of the disused Brukunga pyrite mine in South Australia, reaction of groundwater with the tailings causes the formation and discharge of sulphuric acid. Geophysical methods have been investigated to determine whether they can be used to characterise variations in depth to watertable and map preferred groundwater flow paths through the tailings dam. The results of the geophysical surveys show that it is difficult to determine any preferred channels of groundwater flow from SP profiling data alone, but TEM and DC sounding measurements have enabled accurate determination of watertable levels and aquifer resistivity. The shallowest and most resistive part of the aquifer occurs in the south-east of the site, and we deduce that a possible source of fresh groundwater enters the site here. It has been recommended that efforts to reduce acid formation in the tailings dam should concentrate on reducing this inflow of groundwater.

PETROLEUM CASE HISTORIES: 3-D SEISMC

Brown Bassett 3-D Seismic Survey: Solving a Complex Statics Problem

D. Rimmer

Abstract

This paper presents a seismic processing case history of a 3-D seismic survey from West Texas in the United States. The seismic data were acquired in an area of very poor seismic data quality due to the severe surface topography and the large variation in near surface geology. The near surface is made up of higher elevation mesas with compression wave velocity of 4100 m/sec and lower velocity valleys with compression wave velocity of 2900 m/sec. The near surface causes large, rapidly varying statics in the reflected seismic energy, and poor data quality after stack. Without statics correction there is no coherent reflected signal after stack. The key to processing was the statics solution, both reflection statics and refraction statics. The key to the refraction statics was picking the far-offset traces for refracted energy that came from a layer with higher velocity than the near surface. The key to the reflection statics was using a maximum power method. Maximum power reflection statics worked well in this area of poor data quality. The data was successfully processed producing coherent, interpretable data in the zone of interest.

PETROLEUM CASE HISTORIES: 3-D SEISMC

A Depth Imaging Case History from the North Sea Using a Phased Velocity Modelling Approach

T. Dunbar, B. Davis, G. Hofland

Abstract

Building an accurate velocity model can be a very time consuming step in the quest for an optimum depth migrated image. Various constraints, such as time and expense, force compromises in the quality of the velocity model and the subsequent depth image. This paper suggests using a phased approach to velocity model building, which employs fast simple techniques in areas of relatively simple geology, and more robust modelling techniques where the geology is more complicated. The accuracy of the model is constantly validated to ensure that the current model building technique is not introducing an unacceptable amount of error. We demonstrate our velocity modelling technique by showing a case history from the North Sea. Business drivers introduced significant time constraints to the project. Using the phased velocity modelling approach, we were able to reduce the cycle time by an estimated 4 months, and provide a depth imaging solution which addressed business issues, potentially saving $16 m in future costs.

PETROLEUM CASE HISTORIES: 3-D SEISMC

3D Seismic Surveying for Coal Mine Applications at Appin Colliery, NSW

P. Hatherly, B. Zhou, G. Poole, I. Mason, H. Bassingthwaighte

Abstract

Modern underground coal mining requires detailed knowledge of geological faults and other geological features. A fault of throw greater than a seam thickness of about 3 m can cause enormous delays to mine production. BHP Coal has been using 2D seismic surveying for some time to map structures with throws down to about 5 or 6m but in an effort to obtain better resolution (mainly through seismic coverage), 3D seismic surveys are now being undertaken. For this application, the strength of 3D seismic surveying lies in the ability to establish the continuity of subtle features from one bin section to the next. Maps of the interpreted horizons allow very small features to be seen. Attribute analysis adds further structural and lithological information to the interpretation. The present indications are that 3D seismic surveying is set to become a key tool in coal mine exploration.

MINERAL CASE HISTORIES: OVERSEAS (II)

Geophysical Exploration for Gold in Gansu Province, China

W. Guo, M. C. Dentith, J. Xu, F. Ren

Abstract

Gansu Province is in north central China. The Province is rich in mineral resources with more than 100 known deposits, containing a variety of commodities, and of a number of different styles. However, gold reserves in Gansu were insignificant until the mid-1980s when developments in geochemical exploration techniques led to the discovery of over 40 new deposits. These geochemical methods play a key role in gold exploration in Gansu, particularly during reconnaissance exploration. Geophysics tends to be used as a tool to follow-up in prospective areas. The role of geophysics in gold exploration in Gansu can be illustrated using a number of case studies. The deposits described here are at Liba, Huaxi, Liziyuan, Nanjinshan and Xiaoxigong. These deposits are of different type, and this results in different geophysical methods being effective in each case. The Liba and Huaxi deposits occur in sedimentary rocks. They are structurally controlled and sulphides are associated with mineralisation. Ground magnetic surveys are useful for mapping the mineralised structures and stratigraphy. However, the IP method is badly affected by conductive cover. The deposit at Liziyuan is also structurally controlled but occurs in altered granodiorite. Sulphides are again associated with mineralisation. Mineralised bodies within granodiorite are associated with coincident IP and geochemical anomalies. However, in this case ground magnetic data are ineffective. The Nanjinshan deposit occurs within high-grade quartzitic metasediments and again structural control is evident. Sulphides scattered within quartz veins are associated with the mineralisation. The resistivity method is effective for determining positions and depth extensions of gold-bearing quartz veins. In the Xiaoxigong deposit, borehole geophysical methods were very useful during the evaluation of the deposit. Geophysical logging was able to efficiently identify the mineralised sections. Mise-a-la-masse potential and IP data were able to determine the spatial distribution of mineralisation. Drill hole measurements of potential, using a surface source, helped to find blind mineralisation adjacent to the drillhole.

MINERAL CASE HISTORIES: OVERSEAS (II)

Geophysics of the Porgera Gold Mine, Papua New Guinea

J. Levett, K. Logan

Abstract

The giant gold deposit of Porgera, located in the Enga Province in highland Papua New Guinea, had a 1997 reserve of 82.6 Mt at 4.4g/t, or 11.6 Moz. The high grade mineralisation, most of which has now been mined out, is associated with quartz-roscoellite veining along the Romane Fault Zone (zone VII). Early prospecting in the late 1930's discovered alluvial gold in the Porgera valley. From 1964 to 1983 the Waruwari deposit was defined by east-west drilling and in 1983 the Romane Fault mineralisation was discovered using north-south drilling. While geochemistry and drilling have been credited with the discovery of zone VII, geophysics has played an integral part in defining the extent of the Porgera Intrusive Complex and if used earlier in the exploration process may have led to the discovery of zone VII before more than 200 drill holes were put into the deposit. Geophysics has been used extensively in Porgera's exploration program to target buried intrusives. Some of the most successful tools used have been airborne magnetics to map the intrusives, along the contact of which mineralisation is associated, IP and radiometrics have defined the extent of the hydrothermal system, the Romane Fault Zone is shown in K/Th ratio and a combination of 3D magnetic modelling and AMT has defined the system at depth in the latest round of work.

MINERAL CASE HISTORIES: OVERSEAS (II)

Applications of TEM in Taiwan

C. S. Chen

Abstract

Three case studies, based on the results of a large dataset of SIROTEM soundings, demonstrate the applications of TEM in Taiwan. The transmitter-receiver array used was the in-loop configuration with the dimensions of the square transmitter loops varying from 20 m to 400 m on one side for effective exploration depths between 20 m and 500 m. Occam's smooth model inversion was employed to reduce the temptation to over-interpret the data and to eliminate arbitrary discontinuities in simple layered models. The inverted results were filtered and then organised into both depth slice and cross sections to study the 3D geo-electric structures of the survey area. The first case study is located on the south-western coast of Taiwan. The 3D resistivity images show fresh-water saturated sand and/or gravel sediments in the northern part of the survey area, while a widespread sea-water intrusion is evident in the south. These findings are supported by more than 140 wells. The second case study is located in eastern Taiwan. Based on the TEM sounding results, one predominant electrical discontinuity can be recognised in the Longitudinal Valley which agrees well with the known suture trace on the surface between the

Philippine Sea and the Eurasian plates. The third case study is in the urbanised Taipei Basin. The 3D resistivity images display basement topography and trace the probable faults of Taipei Basin. These findings are supported by more than 180 wells. Therefore, TEM surveys can work around the urbanised city where ambient electrical noise is high, and open spaces limited.

ELECTRICAL METHODS OFFSHORE & EM INVERSION

Marine Self Potential Exploration

G. Heinson, A. White, S. Constable, K. Key

Abstract

Self Potential (SP) exploration, which is commonly used on land, may be extended offshore. At the seabed, seawater has a reduction-oxidation (redox) potential of +200 to +400 mV. With increasing depth through the sediments, bio-geochemical factors produce an anoxic environment with a redox potential of between -100 to -200 mV. A conducting medium, such as a mineral vein, will act as a short circuit and the return current in the seawater and sediments produces an SP anomaly. Alternatively, fluid flow through faults offshore may also generate a measurable electro-kinetic self potential. Marine SP measurements show significantly lower noise levels than land measurements, due to the uniform marine environment and low contact resistance of the electrodes, so that anomalies of a few tens of microvolts or less can be differentiated from noise. Recently, marine SP measurements south of Eyre Peninsula, South Australia and Rose Canyon, San Diego, California have been made. In both cases, a series of horizontal electrode dipoles were towed close to the seafloor in depths of up to 100 m to measure the electric potential gradients. A proton-precession magnetometer was also towed at the surface in the Eyre Peninsula experiment. The major source of noise is from ocean swell and waves, which may be minimised by coherent stacking of signals, and by band-pass filtering. South of Eyre Peninsula, SP anomalies of magnitude 100 mV/m and width 2 km were observed on a number of traverses perpendicular to the trend of an onshore mylonite zone. Little correlation exists between the SP and magnetic data, suggesting that the SP sources are either non-ferrous minerals such as graphite, or due to the electro-kinetic effect of groundwater flow through the fracture zone.

ELECTRICAL METHODS OFFSHORE & EM INVERSION

Electrical Sea-Floor Investigations - Direct Current and Frequency Sounding Methods

N. Schroeder, V. Rybakin

Abstract

In sea-floor investigations seismic methods are normally the most successful tools for unmasking the geological problems below the sea-bottom. However, in some geological situations it is very difficult to obtain useful seismic signals. Oil prospecting in areas where the sedimentary rocks are covered by plateau-basalts, and geotechnical investigations in shallow waters where the sea bottom is covered by thick layers of gaseous mud, are two examples where the seismic methods often give unusable results. Today marine electro-prospecting based on both direct current (DC) and frequency sounding (FS) methods is also used as a tool in the investigation of sea bottom composition. DC and FS methods have been successfully developed for shallow water investigations. The parameters of the equipment used in such kinds of marine searches usually allow investigators to obtain significant results for depths of up to 100 meters. The research presented aims to adapt DC and FS methods for shallow water prospecting to the problems of mapping the sedimentary rocks buried by hundreds or thousands of meters of plateau-basalts as in the case study in the Faroe Island waters.

ELECTRICAL METHODS OFFSHORE & EM INVERSION

Fast Inversion of Electromagnetic Array Data

B. Singer, E. Fainberg

Abstract

An inversion algorithm usually includes modelling and optimisation components. In turn, the optimisation part of the algorithm requires evaluation of Frechet derivatives with respect to the model parameters. As a result, traditional inversion algorithms imply multiple simulation of the model response. Unless a powerful computer is used, only a limited number of the model parameters can be found. Quite often practical needs far exceed the limitation on the number of parameters that can be used even on a powerful computer. Besides requiring a significant computer resource, a large number of unknown parameters also results in a large number of models satisfying the data. For interpretation of the electromagnetic data in a realistic geological environment, it is beneficial to use an inversion algorithm satisfying the following criteria: (1) The algorithm should allow for an adequate presentation of the geological situation. In particular, this means that the number of independent parameters describing the model can be large (from many hundreds to tens of thousands). (2) The algorithm is preferably based on a direct inversion approach avoiding multiple simulation of the model response. (3) The algorithm may use a simplified earth model. The model should be described using parameters that can be found with a smaller degree of uncertainty compared to the full 3-D conductivity distribution. We outline a number of algorithms that can be used as a practical tool for interpretation of 3-D electromagnetic data. A choice of the particular algorithm is determined by the type of the data to be inverted and the thin sheet model that adequately represents the geological situation. Computation on a numerical grid of about 104 nodes typically takes a few minutes per period when run on a PC. Similar algorithms can be used for inversion of time-domain and controlled source data. We present examples of inversion of the areal magneto-telluric response. The inversion is targeting conductance of the subsurface and deep inhomogeneous layers.

SEISMIC PROCESSING CASE STUDIES

Cape Ford-1, An Example of the Consequences of True Amplitude Processing for Inversion to Acoustic Impedance and Porosity Prediction

M. Rauch, P. Woods

Abstract

The Cape Ford-1 well is located in the Bonaparte Basin, Block WA-128-P, offshore Western Australia. Prior to drilling the well a comprehensive AVO and acoustic impedance inversion study was performed. Input for inversion to acoustic impedance was a CDP stack generated from true amplitude processing gathers, time horizons of relevant reflectors, and a low-frequency velocity trend calculated from neighbouring well data.

The Turtle-2 well is located up dip from the Cape Ford-1 well, and was used for phase matching and calibration purposes. Turtle-2 log acoustic impedance values were converted to porosity values and extrapolated down dip to the Cape Ford-1 well. Average porosity in the Tanmurra formation sands at the Turtle-2 location was 12%. Predicted porosity at the Cape Ford-1 location was 25%, in comparison to a total porosity of around 10% encountered in the well. Cape Ford-1 well logs indicated the presence of hydrocarbons.

A class-3, hydrocarbon saturated sandstone with low total porosity usually displays a small zero offset reflection coefficient and a large increase in amplitude with offset. A class-3, hydrocarbon saturated sand with a high total porosity shows a medium to large zero offset reflection coefficient and a smaller increase in amplitude with offset. The inverted acoustic impedance value of a true amplitude stacked trace at the top of a low porosity sand will diverge much more from the zero offset reflection coefficient than would be the case of high porosity sand. Therefore, in order to minimise errors when predicting porosity, only the zero offset reflection coefficient should be used for acoustic impedance inversion. This explains the discrepancy between predicted and observed porosity values at Cape Ford-1.

This paper shows synthetic modelling results using both low porosity and high porosity sandstones. Each synthetic data set was inverted to acoustic impedance, first by using the true amplitude processed CDP gathers and second by using the zero offset reflection coefficients. Our modelling indicates that the use of true amplitude processed data with large changes in amplitude with offset are unreliable for porosity prediction. The seismic data around Cape Ford-1 was again inverted to acoustic impedance using only the rear offset stack. These results are compared with the previously performed inversion to acoustic impedance results.

SEISMIC PROCESSING CASE STUDIES

The Greenshank Anomaly - An AVO Case History

M. Rauch, E. Collins

ABSTRACT

The Greenshank anomaly straddles the border between WA 246 P and WA 1 P, in the Dampier Sub basin on the North West Shelf of Western Australia. It is located approximately 70 km northwest of Dampier and 25 km northwest of the Stag Oilfield.

Seismic data over the Greenshank anomaly displays a series of high amplitude events, dipping basinward near the centre of a northeasterly trending fault block. These anomalous amplitudes were correlated from regional seismic control to the lower M. australis Sandstone within the lower Cretaceous. Pre-drill seismic interpretation, AVO and acoustic impedance studies over the anomaly suggested the presence of a stratigraphic trap that comprised either a high porosity brine filled sand, or a hydrocarbon saturated low acoustic impedance sand. However, the drilling of Greenshank 1 in June 1996 encountered a low acoustic impedance shale with minor gas shows beneath a higher velocity cemented claystone at the level of the seismic anomaly. The higher acoustic impedance lower M. australis Sandstone intersected below the shale was very poor quality and water wet.

A post-drill AVO study was conducted to explain the difference between the observed AVO behaviour and the well results. Synthetic forward AVO modelling was performed using the Greenshank-1 measured sonic, density and synthetic shear sonic data. This study showed that the fluid factor anomaly is caused by the low acoustic impedance shale above the reservoir and not the sand as interpreted pre-drill. The acoustic impedance and Poissonís ratio in the shale decreases relative to the overlying high acoustic impedance claystone unit, resulting in a positive AVO anomaly.

Keywords: AVO, Synthetic AVO modelling, Greenshank Anomaly, Greenshank-1, M. australis Sand

SEISMIC PROCESSING CASE STUDIES

Simple versus Complicated Seismic Processing in the Exmouth Sub-Basin

G. Duncan

Abstract

Seismic data quality in the deep water regions of the Exmouth Sub-basin, Western Australia is generally excellent. Both the temporal and lateral resolution are very high, allowing the identification of fine geological detail. These deep water data contrast with the data quality over much of Australia's offshore exploration and producing regions, where multiples, velocity inversions, poor reflectivity contrasts and sea floor reefs and channels seriously degrade data quality. A quite different approach to seismic data processing is required for processing seismic data from the deep water Exmouth Sub-basin than is normally used for the more noisy areas of offshore Australia. Rather than concentrating on processes that improve the signal-to-noise ratio of the data, it is more important to concentrate on processes that do not distort the seismic wavefield. In processing seismic data recorded in 1994 in the Exmouth Sub-basin, many processes typically applied to seismic data did not lead to any improvement in quality. In fact, it proved to be quite difficult to find processes that actually improved the quality of the data. It was found that the results of processing were very susceptible to the type of deconvolution applied to the data. Conventional trace-by-trace prestack deconvolution was found to introduce reverberations, degrading the quality of the final migrated section. A shot averaged deconvolution process was found to produce vastly superior results than trace-by-trace deconvolution. Other processes such as shot domain F-K filtering, trace summation and F-K demultiple were found to have little effect on the quality of the final section. These processes, however, can introduce subtle distortions of the wavelet, and hence should only be used if it can be demonstrated that they produce noticeable improvements. The final sequence used to process the data was extremely simple, and consisted of: (1) gain recovery; (2) large gate trace equalisation; (3) shot averaged deconvolution; (4) one pass velocity analysis; (5) NMO, mute and stack; and (6) migration followed by bandpass filtering. Probably much of the deeper water regions of Australia could benefit from the use of a very simple processing sequence such as presented in this paper.

AIRBORNE GAMMA SPECTROMETRY (I)
KEYNOTE ADDRESS

Crossing the Technological Borders in Airborne Gamma-Ray Spectrometry - A Historical Perspective

Robert Grasty

Abstract

Airborne gamma-ray spectrometry commenced in the late 1960's, primarily for uranium exploration. Since the mid-1970's, the method has been applied extensively in support of geological mapping and mineral exploration. In 1997, it is estimated that in the western world, between 3 and 4 million kilometres of airborne gamma-ray surveying were carried out. These surveys, normally flown at a height of approximately 120 m above the ground, typically utilise between 30 and 50 litres of NaI detectors with 4 or 8 litres of shielded detectors for monitoring variations in atmospheric radioactivity. In the 1960's, airborne gamma ray spectrometry was a qualitative prospecting technique, principally for uranium exploration. The equipment was insensitive and tended to be susceptible to spectral drift. Cylindrical detectors with up to seven photo-multipliers tubes (PMTs) on each detector made the daily checks of the equipment both time consuming and difficult. In the 1970's, the development of large volume prismatic detectors with just one PMT made the operation of the equipment much easier. These 10 x 10 x 40 cm (4 x 4 x16 inch) prismatic detectors could also be packed more efficiently into rectangular boxes containing 4 detectors.

The early gamma ray spectrometers generally recorded three or four spectral windows. These windows were used to monitor 40K gamma-rays at 1460 keV, 214Bi gamma-rays at 1760 keV from the uranium decay series, and 208Tl gamma-rays at 2615 keV from the thorium decay series. A total count window was also used to monitor overall levels of radioactivity. Modern spectrometers record at least 256 channels of spectral data in the range 0 - 3 MeV, together with the three standard windows. A cosmic ray window which records all incident particles above 3 MeV is also used to monitor cosmic ray increase with aircraft altitude above sea-level. All modern spectrometers are energy stabilised so that gamma-rays of the same energy always fall into the same channel. This is achieved by continuously monitoring one of the prominent gamma-ray peaks from potassium or thorium.

Standardised procedures for converting the airborne gamma-ray measurements to ground concentrations of potassium, uranium and thorium were developed in the late 1970's mainly through large government uranium exploration programs such as those carried out in the United States and Canada. These procedures were developed because many aircraft with different detector volumes were involved in these national programs. In 1991, the International Atomic Energy Agency (IAEA) produced a practical guide to airborne gamma ray surveying which was based on the Canadian and United States standards. More recently a guide to the technical specifications for airborne gamma ray surveys was published by the Australian Geological Survey Organisation in co-operation with state governments and industry. An essential part of calibrating an airborne spectrometer is to determine the system stripping ratios. These stripping ratios are the ratios of the counts detected in one window to those in another window from pure sources of the potassium, uranium and thorium. Four or five large concrete calibration pads, typically 8 m across and with known concentrations of the three radioactive elements were initially used to establish these spectral ratios. However, these pads are difficult and expensive to build. Nowadays, four small concrete pads, 1m x 1m x 30 cm and weighing approximately 700Kg are used to determine the stripping ratios for both ground and airborne spectrometers. Experiments have shown that these small pads give the same calibration constants as the much larger and more expensive aircraft calibration pads and have proved to be an effective and inexpensive way of calibrating both ground and airborne gamma-ray spectrometers.

Airborne sensitivities are determined from flights at different altitude over a calibration range whose ground concentrations are measured with a calibrated portable gamma-ray spectrometer. These flights are also used to derive exponential factors to correct for changes in the airborne count rate with aircraft altitude. The IAEA has produced guidelines for setting up such an airborne calibration range.

In compiling the airborne gamma-ray data to produce maps of the ground concentration of potassium, uranium and thorium, one of the most difficult problems to overcome is the presence of radon and its decay products in the atmosphere. Radon is a member of the uranium decay series and, being a gas, can diffuse out of the ground. Under certain climatic conditions and in some parts of the world the effect of radon and its gamma ray emitting decay products can be significant and cause serious errors in the measurement of ground concentrations of uranium.

One of the first methods to correct for atmospheric radon was through the use of small secondary detectors placed on a lead shield and thus partly shielded from radiation from the ground. These secondary detectors are usually known as 2pi or upward looking detectors as they respond principally to radiation from the half space above the aircraft. Nowadays, it is common practice for these upward looking detectors to be located inside the main detector package immediately above the main crystals. With this configuration, the main or downward looking detectors act as the shield to ground radiation and the extra weight of lead is unnecessary. More recently, a spectral ratio technique has been used to estimate the contribution of radon decay products in the air. This technique relies on differences in the ratios of two 214Bi gamma ray peaks at 609 and 1760 keV for radon decay products in the air and the ground. This technique has proved to be particularly successful in Australia. However, it is has proved to be difficult to apply this technique in the northern hemisphere due to the interference of 137Cs gamma radiation at 662 keV from atomic weapons testing.

Many of the earlier gamma ray surveys were not calibrated, simply being presented as count rates in the potassium, uranium and thorium windows. Recently, procedures have been developed to "back-calibrate" these older data sets so that they can be combined into regional maps. Many older airborne surveys have now been back-calibrated.

One of the main limitations of the airborne gamma-ray spectrometric method has been due to the statistical nature of the gamma ray counting process. Even with the large volume NaI detectors currently used, the count rates from the individual radio-element windows are low and result in significant errors in measuring ground concentrations, particularly uranium. Recently there have been major advances in reducing the statistical errors in the window measurements by utilising the full 256 channels. This has resulted in more reliable measurements of the ground concentration of potassium, uranium and thorium.

Airborne gamma ray spectrometer systems can also be used for environmental monitoring. Radioactive debris from the Russian nuclear satellite Cosmos 954 was successfully located by airborne gamma ray spectrometry. They have also been used for mapping radioactive contamination from the Chernobyl nuclear accident and for mapping radioactive plumes from nuclear reactors.

AIRBORNE GAMMA SPECTROMETRY (I)

Improved NASVD Smoothing of Airborne Gamma-Ray Spectra

B. Minty, P. McFadden

Abstract

Noise-adjusted singular value decomposition (NASVD) is a spectral component analysis procedure for the removal of noise from gamma-ray spectra. The procedure transforms observed spectra into orthogonal spectral components. The lower-order components represent the signal in the original observed spectra, and the higher-order components represent uncorrelated noise. Noise is removed from the observed spectra by rejecting noise components and reconstructing the spectra from lower-order components. A synthetic dataset has been used to obtain new insights into the NASVD method. The dataset is based on an airborne survey over the Jemalong Plains area, NSW. The estimated ground concentrations of potassium (K), uranium (U) and thorium (Th) were spatially filtered and then used to synthesise airborne spectra using simulated Poisson noise. These spectra include a background component based on typical aircraft and cosmic background, and a simple model of the distribution of atmospheric radon. The application of NASVD smoothing to this dataset gives a much greater reduction in U concentration errors than that normally experienced. Careful investigation suggests that the reason for this is that the Jemalong Plains dataset exhibits high correlation between U and Th, and because the survey was flown on a day of low and near constant atmospheric radon concentration. If the dataset is modified by either adding spectra derived from an anomalous U/Th source, or by including atmospheric radon variations typical of most airborne surveys, then the large reductions in U concentration error are no longer achieved. Tests on the synthetic data suggest that the smaller the variation in spectral shape within the input signal, the greater the noise reduction. This is used to develop an improved implementation of the NASVD method that can be applied to large survey datasets. Instead of processing the survey data by flight, the entire survey database is sorted into clusters on the basis of similarity in spectral shape, and the NASVD method is applied to these clusters. This typically halves the K, U and Th fractional errors compared with those obtained when the data are processed according to flight. This increases the amount of geological information that can be extracted from enhanced images of the processed data.

AIRBORNE GAMMA SPECTROMETRY (I)

Reducing Statistical Noise in Airborne Gamma Ray Spectra

J. Hovgaard, R. Grasty

Abstract

There are three main noise reduction methods which are being used to process airborne radiometric data. In one method, potassium, uranium and thorium spectra are computer fitted to the measured spectra. The other two methods are the Maximum Noise Fraction (MNF) method and the Noise Adjusted Singular Value Decomposition (NASVD) method which are designed to extract the real spectral components present in the data. These spectral components are then used to reconstruct each measured spectra with reduced noise. In all three methods, it is important to consider the statistical noise on each channel. It is shown that due to this noise, principal component (PC) analysis is unable to extract the real spectral components present in the data. However, a modified version of the PC method can be used as an effective noise reduction technique. The NASVD method can be used not only for noise reduction but also to extract the real spectral components, since all channels in all spectra are scaled to approximately the same absolute noise level. In the MNF noise reduction method, the same channel number is assumed to have the same noise level throughout the survey area which is only valid in areas where the radioactivity levels are constant.

POSTERS (I)

A Shallow Subsurface Investigation of a Site at Winnererramy Bay, Sydney

M. Lackie, K. Gohl

Abstract

Winnererramy Bay is located near Mona Vale, Sydney, on the southern shores of Pittwater. The site is approximately 6 Ha in area and mostly open land. The land is essentially estuarine sands and muds over a sandstone basement which has in recent times been used for the dumping of concrete blocks, machinery, domestic waste and whole car bodies. The objective of this study, aside from the tuition of students, was to assess the shallow sub-surface of the area using a number of geophysical techniques. A seismic refraction survey was carried out using a 24 channel Geometrics Strataview R48 Seismograph using either a hammer or shotgun source. Three distinct layers were detected; a dry unconsolidated sand generally 3 m thick overlying a wet unconsolidated layer 30 to 60 m thick on top of a sandstone basement. The depth to basement was greater in the west of the site, towards the centre of an infilled fluvial channel system. The depth to basement determined from a 100 m loop SIROTEM 3 survey correlates quite well with the seismic results. The results from various Schlumberger Array resistivity soundings tended to concur with the three layers identified by the seismics but the thickness of the second layer was quite variable (1-100 m), primarily due to very noisy data resulting from problems with getting enough current input. A detailed (2m line spacing) magnetic survey was done using a G-858 caesium vapour magnetometer. The survey revealed many dipole anomalies, these being associated with shallow buried ferrous objects, the most common being reinforced concrete. In the north of the area, where a training trotting track has been established since 1974, the occurrence of such anomalies was considerably less. A Geonics EM31 was used to conduct a FDEM survey (5m grid) over the site. The western edge of the site is bounded by a storm-water drain and the data delineates it with a significant increase in conductivity close to the drain. In the south of the site a linear feature is also observed, its cause not obvious.

POSTERS (I)

Time-Varying Effects in Magnetic Mapping: The Concept of a Magnetic Amphidrome

F. E. M. Lilley, A. Hitchman, L. Wang

Abstract

Superimposed upon the main part of Earth's magnetic field, which is steady over the duration of a magnetic survey, is a smaller part which fluctuates with time. The removal of this time-varying part is a major objective of survey data reduction, and is especially important in the case of modern aeromagnetic surveys which are of high resolution. In this paper known aspects of behaviour of the time-varying part of Earth's magnetic field are reviewed, and the concept of an ideal magnetic amphidrome is introduced. The term is taken by analogy with its use in physical oceanography. A magnetic amphidrome is a place where fluctuations with time of the total magnetic field, as measured by a total-field survey instrument, are always nil. Parkinson's concept of a 'preferred plane' for magnetic field changes enables an especially simple description of a magnetic amphidrome. An amphidrome will occur when the normal to the preferred plane is parallel (or anti-parallel) to the direction of the steady total magnetic field for that place. Case histories of measurements of the fluctuating magnetic field in Australia show examples of approximate magnetic amphidromes. In this sense Australia is quite 'amphidrome rich', especially near its southern coastline. A numerical model of the electrical conductivity of Australia, set in its surrounding seas, is used to predict amphidromes regionally. This paper is part of the CICADA project (Clarifying Induction Contributions to Aeromagnetic Data).

POSTERS (I)

Magneto-telluric Exploration of the Eyre Peninsula Electrical Conductivity Anomaly

A. White, G. Heinson, S. Constable, P. Milligan, F. E. M. Lilley, H. Toh

Abstract

The Eyre Peninsula Anomaly (EPA) is a major linear electrical conductivity structure in the middle to lower crust that has been mapped by EM methods from the southern coastline to about 500 km inland. Conductance of the anomaly is between 3,000 and 10,000 S, due to either saline fluids in a fracture zone or from mantle-derived graphite deposits. The strike of the anomaly follows the trends of other tectonic structures, such as the mylonite shear zone to the east and banded iron formations. However, there is no surface geological expression of the EPA, and no conductivity anomaly associated with the

mylonite zone, despite the presence of economic quantities of graphite. A correlation between the EPA and a broad 30 mGal gravity anomaly suggests that the high conductivity is associated with extensional-faulting in the crust and mantle upwelling, possibly related to marginal rifting at the time of break-up of Australia and Antarctica. In April-May 1998, the SWAGGIE (Southern Waters of Australia Geo-electric and Geomagnetic Induction Experiment) project took place. On land, 23 recording magnetometers were deployed in an array across the southernmost part of Eyre Peninsula with spacing of less than 5 km, to delineate the position and depth of the EPA. At the same time, 18 seafloor magneto-telluric sites were occupied in three linear arrays; two parallel to the edge of the continental shelf and one perpendicular, extending across the shelf to the abyssal plain. These land and marine instruments were deployed for 50 days, sampling at 0.1 Hz. An additional 10 seafloor magneto-telluric sites were obtained using a high-frequency system with a sample rate of 25 Hz over a two-day deployment. The main objectives are to investigate the marine extent of the EPA and its depth and conductance, which will improve our understanding of the tectonic evolution of southern Australia.

POSTERS (I)

The 'Coast-Effect' at Micro-pulsation Frequencies, and its Implications for High-Resolution Aeromagnetic Surveys

P. Milligan, A. Hitchman, F. E. M. Lilley

Abstract

The geomagnetic phenomenon known as the Coast Effect usually refers to the enhancement of the vertical component of geomagnetic fluctuations with proximity to the coast (or, more precisely, with proximity to the continental slope). It has been well defined by many studies of several continental margin types for longer periods (in the range of several minutes to many hours), but has not been measured at the shorter periods representative of micro-pulsations (a few seconds to several minutes). Measurements of the total magnetic field, as produced by airborne magnetic surveys, also display a coast effect, as the vertical magnetic component provides a significant input to the total-field in the Australian region. Micro-pulsations have a range of amplitudes, from fractions of a nT to several nT. As their spectrum overlaps that of near-surface ground magnetic sources, as measured by aeromagnetic surveys, their detection and removal are highly desirable to avoid false interpretations of the data. For most magnetic surveys, a single base-station is used to monitor the time-varying component of the total field, with its data subtracted from those of the survey. Thus, errors can be introduced into aeromagnetic survey data if the spatial non-uniformity of time variations is not taken into account, particularly for coastal surveys. It is more important to quantify the shorter-period variations for such surveys, as their spatial variability is less likely to be removed by tie-line levelling. Time variations in three orthogonal components of the geomagnetic field have been measured along a profile perpendicular to the east coast of Australia, extending from several hundred kilometres inland to near Durras on the coast, with one sea-floor site on the continental shelf. Canberra Magnetic Observatory also lies on this profile. High-resolution ring-core fluxgate sensors were used in the field instruments, with a sampling interval of 5 s, and data were recorded for two weeks. Thus, the coast effect from periods of a few tens of seconds to the daily variation has been well defined. It is frequency dependent, and the implications for airborne magnetic surveys are discussed.

POSTERS (I)

The TEMPEST Airborne EM System

R. Lane, C. Golding, A. Green, P. Pik, C. Plunkett

Abstract

The TEMPEST airborne EM System has been developed by the Airborne EM Systems group at the CRC AMET. It is a towed bird, time domain system. A medium power version has been operated in a Trislander aircraft, and a high power version is planned for a Skyvan aircraft. The transmitter produces a square wave of user-defined duty cycle and base frequency, free from the effects of variation in pulse width. The towed bird contains a 3 component receiver coil set. A high speed 'streaming' acquisition system records up to 150,000 samples per second as well as performing preliminary processing functions to assist the operator with quality control. A range of sensors record the attitude and motion of both the aircraft and the receiver coils, allowing improved monitoring and correction for changes in the transmitter-ground-receiver geometry. Data reduction algorithms have been developed or modified to take advantage of the range of sensors present and the bandwidth of the received signals. Examples of data acquired during initial TEMPEST surveys are presented.

POSTERS (I)

The International Campaign Comparing Electrodes for Geoelectrical Measurements

K. Lu, J. Macnae

Abstract

In many applications of electrical geophysics, the electrodes used to detect signal seem to be an important source of noise. To identify which electrodes were most stable for electric field measurements, an international campaign to evaluate electrodes for long-term monitoring of the telluric field was held at Garchy, France between April 1995 and April 1996. More than fifty electrode pairs from around the world took part in the campaign. Most of the electrodes were metal-electrolyte designs, but with different construction details. The inter-comparison was carried out through laboratory and field experiments. The results of the experiment showed a surprising variation between the performances of different electrodes. Stability as determined in a brief laboratory experiment proved to be an excellent predictor of long-term field stability. Instabilities of differing qualitative character were noted over the year. Linear drift may be caused by gradual changes in ground contact, leaking of electrolyte, or the changing of chemical concentration of electrolyte within the electrodes. Sudden onset of transient noise, which could be as large as 20 mV, is likely to be an electrochemical process such as reaction charge release and accumulation within the electrodes. Other physical causes of drift could be attributed to mechanical contact problems. Of metal electrodes, stainless steel is by far the best.

POSTERS (I)

Seismic Constraints on EM Modelling by Detailed Travel Time Inversion

I. Kirby, K. Gohl

Abstract

A comparison of seismic refraction models and time-domain airborne electromagnetic (AEM) conductivity-depth images has been conducted for an area in the Eastern Goldfields, Western Australia. The principal aim was to determine the concurrence of the models, suggest reasons for any differences, and to investigate the validity of using velocity models as possible constraints on the geometry of geologic structures for refinement of the AEM images. Seismic first arrival data from a deep crustal reflection survey were used to produce 2D refraction velocity-depth models for both P-waves, and where apparent, S-waves. A Poisson's ratio model was also generated. Modelling was achieved with a 2D ray tracing program allowing for horizontal and vertical velocity gradients, with an automatic inversion performed using a damped least-squares method applied to the residuals of modelled travel times with respect to the observed data. Along much of the transect there was general concurrence between the AEM and seismic models, with the following exceptions. In areas where lateral geologic structure varied rapidly, AEM models tended to be significantly smoothed, an inherent restriction of the resolution of the AEM method as well as a limitation of 1D inversion used in AEM modelling. In the presence of a thick conductive overburden AEM was not able resolve the occurrence of bedrock. In areas with a thin, highly conductive overburden, AEM models differed significantly from the velocity models, probably due to the influence of 2D and 3D effects. It was found that velocity models may assist to refine AEM conductivity images where 1D inversion of AEM data cannot not closely resolve the actual geology, such as in areas of rapid lateral structural variation.

POSTERS (I)

Improving Conductivity Models Using On-Time EM Data

D. Sattel

Abstract

Modelling of data from half-sine time-domain airborne EM systems is traditionally limited to the period following the transmitter turn-off, the off-time data. The joint use of on-time and off-time data widens the resolvable range of conductivities. Using a half-sine waveform with a base frequency of 25 Hz and a pulse width of 4 ms, conductivities and conductances as low as 0.5 mS/m and 0.02 S, respectively, become resolvable. Also, with the constraint of on-time data, automated modelling becomes more stable as noise at late time is less likely to be confused with signal. Conductivity-depth sections of QUESTEM-450 (Lane et al., 1998) data from Forrestania, Western Australia were modelled using a layered-earth inversion (LEI) and a current imaging technique. The known mineralisations, including massive sulphides and a banded iron formation, are indicated by the off-time data. For both methods, additional use of on-time data led to a model improvement.

POSTERS (I)

Reflection Models and Ramp Response for Downhole TEM Data

L. J. Cull, M. J. Asten, J. P. Cull

Abstract

Very conductive ore bodies are difficult to detect using standard TEM techniques. Eddy currents are established at the surface of these bodies to oppose the flux associated with the primary field in accord with Faraday's law of induction. These eddy currents persist with negligible losses when the primary field is removed, consistent with the very high conductivity of the body. Consequently during the off time dB/dt remains close to zero and signal levels at the surface are negligible. However an examination of the primary field, or ramp response, rather than the secondary field, will often show sudden changes in amplitude consistent with interference effects from a multiple source. Ramp response data obtained for highly conductive targets have now been interpreted using models based on multiple filaments. The results are consistent with conventional interpretations based on filament theory and also with models based on a reflection of the primary field at the conductor surface.

POSTERS (I)

Automated Interpretation of Geophysical Borehole Logs via Multi-Parameter Discrimination

P. K. Fullagar, B. Zhou, G. N. Fallon

Abstract

An automatic interpretation tool, LogTrans, for geophysical borehole logs was developed during a recent CMTE/AMIRA project: The Application of Geophysics to Mine Planning and Operations. 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 and can be understood as an extension of scatter plot interpretation from two to multiple dimensions. The rock classes may be distinguished by lithology, grade, mechanical properties, or any combination of characteristics. Interpretation entails two stages: statistical characterisation, involving determination of the centroids (means or medians) and ranges (standard deviations or 'spreads' between specified percentiles) of the distributions of each petrophysical parameter for each class, based on a representative control data set; and categorisation, in which multi-parameter data are assigned, at each depth point, to the 'most likely' rock class, as judged from the control data statistics. The LogTrans approach is fast and intuitive. It has been applied successfully to logging data sets collected from a number of Australian and overseas mines. Prediction accuracy in excess of 90% has been achieved in several cases.

CROSSING TECHNICAL FRONTIERS
IN MINERAL EXPLORATION (I)

A New Drillhole Targeting Tool - Case Histories Showing Discrete AEM Response Associated with Gold Mineralisation, Eastern Goldfields, Western Australia.

P. Leeming

Abstract

High bandwidth airborne electromagnetics (AEM) techniques can be used for mapping regolith, estimating depth to bedrock and isolating discrete AEM response potentially associated with alteration and mineralisation. Data were collected over several known gold deposits, including Sunrise-Cleo, Keringal, Golden Delicious, and Beasley Creek in the Laverton area. Gold prospects at Lake Gidji and Eight Mile Dam north-east of Kalgoorlie, and the Lake Cowan area near Higginsville, all in salt lake environments, were also flown. AEM interpretation relies on layered earth inversion techniques (Sattel, 1997). A three-layer model has proved useful in the Eastern Goldfields with a conductive layer sandwiched between a thin resistive surficial layer and resistive bedrock. Inversion models do not perform as well in areas of extreme (high or low) conductance. However, using an integrated interpretation methodology, limitations of the inversion models are easily recognised and discrete AEM response can be spatially differentiated with reference to known structural geology. Layer 1 coincides with hardpan, alluvium and colluvium, layer 2 corresponds with the intervening saprolitic layer and layer 3 is the resistive bedrock. Systematic interpretation of particular data sets including layer 2 conductance (thickness times conductivity), bedrock topography, regolith thickness and conductivity-depth sections permits the mapping of regolith. Transported versus erosional and residual environments can be clearly differentiated thereby predicting drilling conditions, the depth of cover and the geochemical sampling environment. Features such as Tertiary palaeo-channels and palaeo-lacustrine environments can be clearly recognised. Discrete bedrock highs which may be caused by silicification, quartz veining and carbonate alteration can be identified. Preferential weathering or thickening of regolith along shear zones, where argillic, chloritic and potassic alteration may accompany gold mineralisation along prospective geological structures can also be targeted for drill testing.

POSTERS (I)

2.5-D Inversion of Deep Transient Electromagnetic Sounding with Grounded Sources

Z. Lin, K. Vozoff, G. Smith

Abstract

Deep transient electromagnetic sounding using a grounded-wire source has seen increasing use in geophysical exploration during the last decade. This method is sometimes called LOTEM. One of difficulties with LOTEM is data interpretation. Typically, the data are interpreted with layered-earth models even though that data often arise from multidimensional earths. This paper shows an effective two-dimensional (2-D) interpretation method for LOTEM. Numerical solutions to the forward problem are based on finite difference methods in frequency domain. The results are transformed into time domain using a digital filter method. The inversion methods are based on damped least-squares techniques. Partial derivatives are calculated using perturbation and sensitivity equation approaches. The former is theoretically simple and numerically stable, but it can be computationally expensive. The latter is more efficient because it takes advantage of certain unique features of the finite difference method to construct an efficient algorithm for the accurate calculation of partial derivatives. The solutions use the singular value decomposition (SVD) of the Jacobian matrix and a variety of stabilisation methods. Inversion programs have been tested with two sets of synthetic data. The first synthetic data came from a 2-D rectangular conductor in a uniform halfspace. The inversion results show that inversion with a single transmitter cannot produce fast convergence. Multi-transmitter setting and joint inversion can improve both the convergence rate and accuracy. The second set of data was used to do a feasibility study for the detection of the resistivity distribution in coal seams. Modelling results illustrate that conductive parts (relative to highly resistive original coal) can be easily defined, but resistive parts need multi-transmitter setting to delineate. The main limitations of the method are that the geometry of the model must be specified in advance and that the technique should be used interactively, with models constrained by geological information.

VELOCITY MODEL BUILDING (I)
KEYNOTE ADDRESS

From Conversion to Inversion

O. Yilmaz

Abstract

The old way of seismic data analysis involves processing, imaging and interpretation — all in the time domain, conducted sequentially. This sequence is then followed by time-to-depth conversion. The new paradigm for seismic data analysis involves processing in time, followed by inversion for earth modelling and imaging in the depth domain, conducted concurrently. Simply put, the old way involves interpretation in time followed by conversion to depth. The new paradigm involves inversion for earth modelling in depth. With the new paradigm, interpretation is implicit to earth modelling in depth — by the time you've completed analysis of your data, you also have done your interpretation. Note that processing refines the data you acquire, whereas inversion creates knowledge — an earth model in depth and an earth image in depth. Also note that a measure of uncertainty about the information is as important as the information itself — you have it in depth, not in time. To conduct seismic data analysis with the new paradigm, you need to integrate systems for processing, interpretation and inversion. Results of conventional processing — stacking velocities, CMP gathers and CMP-stacked data, and results of time-domain interpretation — time structure maps, are downloaded to an inversion system for earth modelling and imaging in depth. Estimation of structural models is largely based on traveltime inversion methods, and that of stratigraphic models is based on amplitude inversion methods. When combined, the structural and stratigraphic models

constitute seismic representation of an earth model in depth. The structural model is used to derive an earth image in depth. Finally, the seismic representation of an earth model in depth needs to be transcribed into petrophysical representation — a reservoir model. Note that inversion is the agent of integration — it moves you from time to depth domain. Estimation of an earth model can be done in two different manners — structure-dependent and structure-independent. I shall present case studies for earth modelling and imaging in depth using appropriate combinations of inversion methods.

VELOCITY MODEL BUILDING (I)

Tomographic Velocity Model Building for Pre-Stack Depth Migration

P. Whiting

Abstract

It is now commonly accepted that pre-stack depth migration is the best method available for accurate imaging. However, this technique is only used in relatively extreme circumstances. The implementation of pre-stack depth migration is restricted by relatively high costs and turnaround times, as well as its sensitivity to errors in the interval velocity / depth model. For a pre-stack depth migration project to be successful, a reliable interval velocity / depth model is essential. Multiple iterations of pre-stack depth migration are often required to achieve a sufficiently reliable model. Obviously, this iterative nature contributes significantly to higher costs and turnaround times. Reflection tomography has been considered, in recent years, as a potential method for finding a reliable velocity model more easily. This method has also been held back due to its own generally high costs and turnaround. Reflection tomography normally requires interpretation of many reflectors on pre-stack data. This is time consuming and prone to error. Also, in efforts to simplify the overall procedure, the inversion itself has sometimes been compromised. A reflection tomography algorithm has been developed that does not require manual picking of events and does not compromise the inversion process. The scheme depends on a method of tracing reflected raypaths that does not require reflector definition and that allows automatic picking to be successful. It also utilises entropy constraints in a subspace inversion with stages of decreasing model space smoothing. The aim of this inversion is to help ensure that reliable velocity models are created and that local minima are avoided. This approach to reflection tomography is quite automated and has been applied successfully to many datasets from Australia and around the world. Two examples from offshore Australia demonstrate that the velocity models resulting from this reflection tomography algorithm clearly improve the results of pre-stack depth migration.

VELOCITY MODEL BUILDING (I)

Creating Image Gathers in the Absence of Proper Common-Offset Gathers

G. Vermeer

Abstract

Current velocity model building techniques have been developed specifically with the parallel geometry in mind. In this geometry it is possible to create common-offset gathers, to migrate individual gathers, and then to analyse move out in the image gathers directly as a function of offset. In actual practice, well-sampled 3D common-offset gathers with constant azimuth are not available, not in land data acquired with the orthogonal geometry or other crossed-array techniques, and not even in data acquired with the parallel geometry. Therefore, alternative data gathers have to be sought which are suitable for migration and which still allow migration velocity analysis. The method proposed in this paper is based on an extension of the notion of minimal data set, being a single-fold alias-free data set, suitable for migration. Examples of minimal data sets are common-offset gathers with constant azimuth and cross-spreads. However, proper minimal data sets cannot always be constructed, or, in other cases, minimal data sets do not extend across the whole survey area. This requires the construction of pseudo-minimal data sets. Each pseudo-minimal data set is an approximation of a minimal data set; their number should be equal to the fold count. In the parallel geometry the pseudo-minimal data sets are still close to common-offset gathers. These gathers can be used directly for velocity analysis. In other geometries, the pseudo-minimal data sets encompass a wide range of offsets. Then it is necessary to determine from all traces in a pseudo-minimal data set which trace is the imaging trace, and what is its offset. A possible technique to determine this offset is the vector-weighted diffraction stack. The proposed data gathering and velocity-analysis technique needs further research and testing for the best results.

AIRBORNE GAMMA SPECTROMETRY (II)

Mapping of a Granite Batholith using Geological and Remotely Sensed data: the Mount Edgar Batholith, Pilbara Craton

P. Wellman

Abstract

The gamma-ray spectrometric data over an exposed granite batholith contain detailed information on its structure and composition. The information is poorly displayed in the conventional red-green-blue or hue-saturation-intensity colour-space images. Variation diagrams should be prepared showing the relationship between K, Th and U, and the rocks separated into granite types with different evolution paths in K-Th-U space. The data should be displayed as a map showing the distribution of each granite type, and for each granite type a map showing the distance along the average evolutionary path, and a map showing the deviation of the observed concentrations from this average evolutionary path. None of the other geological or geophysical techniques compete with gamma-ray spectrometry in resolution and reliability in displaying the structure and composition of the Mount Edgar Batholith. The use of rock sample geochemistry, petrography, air photo interpretation, field observations, structural studies, and Landsat-5 Thematic Mapper data enhanced for geology, did not adequately map the batholith. The magnetic survey gives a wealth of internal detail within the batholith, however subdivisions of the batholith based on magnetic texture and amplitude of short-wavelength magnetic anomalies sometimes relate with other datasets and sometimes do not, presumably because of the effects of redox changes. Spectrometry is

the best mapping tool over other exposed batholiths of the Pilbara Craton, both the relatively-deformed more-mafic batholiths and the more-felsic batholiths composed of discrete intrusions.

AIRBORNE GAMMA SPECTROMETRY (II)

Noise Reduction of Aerial Gamma-Ray Surveys

B. Dickson, G. Taylor

Abstract

Two methods of reducing noise in aerial survey data have been evaluated as to their performance on a set of laboratory measured spectra and a section of an aerial survey. The techniques are applied to the spectral data before subsequent processing to determine potassium, uranium and thorium concentrations. The Maximum Noise Fraction (MNF) method was found to be most effective at removing noise from U and Th signals, reducing noise in U by a factor of 3.5 and Th by 1.5. No technique investigated gave an effective noise reduction for K. The MNF technique requires that a measure of the noise be obtained and this is best done using the differences of adjoining spectra along flight lines. Parameters such as the number of spectral channels to use in the analysis and the number of MNF components to retain in reconstructing the smoothed spectra were investigated and we recommend keeping around 40 MNF components to ensure minor spatially-related signal is retained and using spectral data in the range 200 to 3000 keV.

AIRBORNE GAMMA SPECTROMETRY (II)

An Integrated Framework for Interpolating Airborne Geophysical Data with Special Reference to Radiometrics

S. Billings, D. FitzGerald

Abstract

New processing techniques for airborne radiometric data make use of the information contained in all 256 channels of a radiometric spectrum, improving the final quality obtained. However, visualisation and interpretation of the processed data require interpolation to a regular grid and current methods for doing this are generally unsatisfactory. We highlight alternative interpolation techniques (kriging, radial basis functions, tension splines, smoothing splines) that overcome many of the disadvantages of existing methods. These techniques are formulated in a common mathematical framework and can be used for exact or smooth interpolation of the processed data. The resulting grids can be made to inherit certain desirable characteristics, such as smoothness or minimum variance. Further, the framework generates a continuous model of the data that can be updated rapidly when the image is visualised at different scales. Until recently, the main impediments to the application of the technique to large geophysical surveys have been the computer memory and effort needed to solve the resulting matrix equations. We describe some recent advances that reduce the computational requirements to acceptable levels. We describe an extension to the usual multi-channel technique that, during processing, preserves the original signal (as embodied in the 256-channel spectra) for as long as possible. We show that better images can result if the spectral components are gridded and the spectra reconstructed at the grid points. The reduction to standard 4-channel count-rates and conversion to ground concentration occur in the final processing step.

COAL & GEOPHYSICS IN MINES

High-Precision Continuous Deformation Monitoring of Mine Structures

R. Gwyther, M. Gladwin, M. Mee

Abstract

Recently developed high-precision strain monitoring systems have been operated successfully for more than four years in the Bulli basin, to provide long term monitoring of strain variations induced by longwall mining operations 400 m beneath the Cataract Reservoir. The system was installed to confirm the predictions of safety margins in the mine design, and provides direct and real time measurement of the deformations induced by the rock caving during long wall extraction sequences. The observations indicate that, at the measurement depths of approximately 100 m, horizontal strains of order 100 microstrain are locally associated with the progression of the longwall. Furthermore, mining induced horizontal strains at distances of about 1 km ahead of the longwall pattern are only approximately 10 microstrain at the measurement depth. The total mining cycle was accompanied by significant rotation of the principal strain axes with time. Unexpected changes in stress orientation could have devastating effects on design performance of an underground workings. The feasibility and value of direct measurement of induced strain in real time as mining occurs has been demonstrated, and allows modification and optimisation of the mine plan without compromise of chosen safety margins. Results have enabled modifications to panel geometries with resultant increases of 5% in coal extraction.

COAL & GEOPHYSICS IN MINES

Examination of the Gravity & Electromagnetic Survey Methods Applied to Coal Exploration in the Area of the Southern Gunnedah Basin

O. Nakano, E. Ishii, N. Ozawa, B. Mullard, J. Beckett, D. Robson, A. Willmore

Abstract

The New South Wales Department of Mineral Resources (DMR) and the Japanese New Energy and Industrial Technology Development Organisation (NEDO), have entered into a Joint Coal Exploration Research Agreement aimed at developing advanced coal exploration technologies with particular emphasis on geophysical technologies. As part of the first year's project an investigation into the applicability of gravity and transient electromagnetic geophysical methods for coal exploration was undertaken. The Caroona coal prospect has a resource of high quality multi-seam coal lying within relatively complex geology. While significant drilling has been undertaken in the area, a number of aspects of the geology cannot be adequately identified by drilling. The area is known to contain thrust faulting and igneous intrusions. The coal seams are covered by 40-80

m of alluvial materials which can reduce the seismic energy transmission for conventional seismic surveys. Trial gravity and electromagnetic surveys were undertaken to test the potential of these geophysical methods and to supplement the seismic data. The aim was to provide a much better estimate of the bedrock-alluvium interface and to define the distribution of intrusions and faulting. The field work involved undertaking a gravity and electromagnetic survey along a 3.5 kilometre traverse which coincides with a seismic survey line (L972) in the Caroona area. It is believed that the integration of these geophysical methods has facilitated the extrapolation of geological models derived from the seismic interpretations. Combined with a philosophy of close space sampling, integration of geophysical methods has the potential to revolutionise coal exploration. The regional geophysical coverage which can be provided by these techniques is extremely cost effective and will assist the evaluation and modelling of areas involving complex geology. In the Caroona area the preliminary results have shown that the gravity and electromagnetic data has defined the alluvium thickness and structural zones.

COAL & GEOPHYSICS IN MINES

Application of Microseismic Monitoring to Characterise Geomechanical Conditions in Longwall Mining

X. Luo, P. Hatherly

Abstract

To characterise the geomechanical conditions and responses to underground coal mining in different geological settings, we have undertaken microseismic monitoring at two longwall mines. Our work has concentrated on major concerns of the mines such as the patterns of induced fracturing in the roof and floor, the effect of geological faults and the possibility of water and methane gas inflows. Our results have comprehensively defined the fracture patterns. Applications for microseismic monitoring also exist for the mapping of hydraulic fracture growth in reservoir engineering and the data can be used for the study of shear wave anisotropy in fractured media.

VELOCITY MODEL BUILDING AND DMO

The Application of Reflection Tomography and Interval Velocity Analysis to Achieve Accurate Depth Conversion of Subtle Structures: A Case Study

R. Taylor, D. Kelly, N. Fisher, A. Canning

Abstract

Reflection tomography and interval velocity analysis (IVA) is applied to a 2D seismic line in the Surat Basin - an area where the primary goal is achieving reliable depth conversion of low relief structures, in seismic time, in the presence of near surface velocity anomalies and subtle lateral velocity gradients. The technique, using commercially available velocity analysis and Pre-Stack-Depth-Migration (PSDM) software, represents a potential solution to problems which have challenged previous workers. We demonstrate that reflection tomography can resolve shallow velocity anomalies by using as input the moveout errors of deeper horizons from an initial pass of PSDM. Significantly, reflection energy from the near-surface layer is not required to resolve its velocity. When the shallow velocity model is determined, the interval velocity analysis of subsequent layers becomes stable and a more refined velocity model may be constructed. Several iterations of PSDM and reflection tomography are generally required before running a final pass of PSDM. The example seismic line contains three wells which are used to judge the quality of the final depth migration. The results demonstrate that it is possible to extract accurate lateral velocity information inherent in high fold CMP gathers from land data containing shallow velocity anomalies or residual static errors. A lateral velocity gradient causing an apparent pull of up of 26 metres between wells B and C is successfully resolved. The example demonstrates the predicted formation tops of Well C would have been accurate to around +/- 5m if reflection tomography and interval velocity analysis had been applied in place of a regional velocity function derived from nearby well data.

VELOCITY MODEL BUILDING AND DMO

Building Velocity Models for Prestack Depth Migration

R. Bloor

Abstract

Prestack depth migration can provide good images in areas with significant lateral variations of velocity. However, for a prestack depth migration to be successful we require an accurate velocity model. The building of such a velocity model is a difficult process. Initially we use methods based on updating velocities from standard velocity picks but applied to migrated image gathers. These methods are generally applied in a layer stripping manner and work well in areas where lateral velocity variations are slow, and can be continued into areas of relative complexity, but convergence to an accurate model can take many iterations. As complexity increases, these velocity picking methods become less reliable. We increase the reliability of these methods by searching around the predicted velocity for a better model. It is not uncommon to find optimum results ranging from half the predicted change of velocity to about one and a half times the predicted change. These are then combined to produce the current estimate of the velocity model. Significant elevation change or steep dips complicate the whole procedure and reduces the chances of success using the method described above. However, if the nature of the velocity variations in the overburden is understood, the details of the velocity model can be recovered from the relative behaviour of imaged offset planes. This is essentially a tomographic approach and can be approached manually or by using more automated methods. Generally speaking we have found these methods are quicker to converge if we work on local regions of the model driven by an interpretation. Such local approaches do pose the problem that we may overlook shallow variations until we are deeper in the model, so we require the flexibility to either work locally or on more parts of the model simultaneously. Combining these methods, we can build adequate velocity models for many different structures.

VELOCITY MODEL BUILDING AND DMO

Comparing Equalised and De-aliased DMO on Field Data

C. Beasley, E. Mobley

Abstract

Several techniques are known for improving the response of DMO when input seismic data are spatially irregularly sampled. Equalised DMO (EQ-DMO) is designed to overcome irregularities in the output dip spectrum of the DMO operator that occur as a result of irregular sampling in source, receiver, offset, or azimuth. De-aliased DMO is designed to overcome irregularities due to binning the DMO operator. In this paper we review these two distinct algorithms and compare pre-stack and post-stack results to determine their relative merits. EQ-DMO derives from the simple concept of normalising the CMP stack by dividing by the fold or some function of the fold. DMO is essentially a selective stack over all possible dips, so by analogy, division of each dip component by its respective fold equalises DMO. Applying EQ-DMO either on individual common offsets or as a component of full DMO and stack minimises phase and amplitude distortions related to irregular spatial sampling. Since some dip components may be absent in sparsely sampled data, particularly within individual common offsets, one might expect EQ-DMO to work better for offset groups than for individual offsets. Field data examples generally confirm this result. De-aliased DMO improves 3-D DMO when the DMO operator does not fall exactly on cell centres. A common and economical way to deal with this problem is to bin the DMO operator, i.e., stack the traces generated by the operator into the nearest bin centre. Binned operators can be effective but also suffer in that their trajectory - the path from source to receiver - is aliased. Sampling the operator onto the grid rather than simply binning it de-aliases the trajectory. This procedure is effective even for sparsely sampled data. As costs are always a concern, it is natural to ask which of these processes is most effective. We conclude that the best practice is to apply both EQ-DMO and de-aliasing procedures; however, one or the other alone may achieve significant benefit as well and be cost effective on a particular field data example.

ELECTRICAL AND ELECTRODE POTENTIAL

The Behaviour of Mise-a-la-Masse Anomalies in an Anisotropic Half-Space near a Vertical Contact

N. Uren, P. Li

Abstract

The mise-a-la-masse method has been successfully modelled in detailed studies of anomalous conductors in otherwise homogeneous media. Vertical contacts form common geometries in galvanic studies when describing geological formations with different electrical conductivities on either side. However, previous studies of vertical discontinuities have been mainly concerned with isotropic environments. In this paper, we deal with the effect on mise-a-la-masse anomalies due to a conductor near a vertical contact between two anisotropic regions.

The integral equations used for the mise-a-la-masse potential in anisotropic half-spaces have been established. The Green's function was obtained using the reflection and transmission image method in which five images are needed to fit the boundary conditions on the vertical interface and the air-earth surface. We have established a new method to calculate the value of the integrals for the anisotropic case. This new method uses a one-dimensional analytical integral followed by another multi-dimensional integral evaluated numerically.

By means of this approach the solutions provide a relatively complete description of mise-a-la-masse anomalies in an anisotropic half-space with a vertical contact. The examples we were given clearly show the effects of a vertical contact between media with different resistivity tensors. This forward modelling technique will be very useful in confirming field interpretations.

ELECTRICAL AND ELECTRODE POTENTIAL

Applied Potential Modelling of Simple Orebody Structures

S. Greenhalgh, S. Cao

Abstract

In applied potential or mise a la masse surveys current is injected into an orebody in one drillhole and the resulting electric potential is measured as a function of depth in another drillhole or as a function of horizontal position over the ground surface. The crosshole measurements are intended to establish the continuity or otherwise of the conducting ore. One can imagine the situation where metallic ore is encountered in both holes, but it is not known whether the holes intersect the same continuous orebody, or whether it is broken between the holes, or whether the intersections are of different ore surfaces. Alternatively, ore is intersected in only one hole and the question is what can one infer from DC electrical measurements about the extent of the conductor between the two holes. In this paper we present a formulation for calculating the electrical potential distribution in an inhomogeneous 2-D or 3-D earth for any number of current electrode sources or sinks. Numerical modelling has been carried out for various classes of ore body structure, to understand the effects of conductor continuity, depth, thickness, dip and irregularity on the applied potential response. The effect of current electrode placement inside and outside the conductor, was also studied. It is possible from the shape and amplitude of the potential profiles to partially discriminate between continuous, terminating and faulted conductors. The modelling is especially useful as an aid to interpretation of field measurements and in the design of applied potential surveys.

ELECTRICAL AND ELECTRODE POTENTIAL

Normalisation of Electric Potential for a Buried Electrode under a Conductive Overburden

M. Asten

Abstract

Electric-field surveys using surface transmitter electrodes suffer reduced sensitivity where the host rocks and targets of interest are screened by a conductive overburden. Increased sensitivity to conductive targets is achieved by placing transmitter electrodes in the basement via drillholes. However the interpretation of electric potential data where transmitter electrodes are buried beneath conducting overburden is complicated by both the geometry of the transmitter-receiver configuration, and by strong perturbations of electric potential due to the conductive overburden. The geometric normalisation (apparent resistivity) function for buried electrodes under a 2-layer earth is developed using an image method. Application to model data computed for a basement conductor, and to field data obtained with a "radial-IP" configuration, shows how a conductive overburden can cause false apparent basement conductors if an incorrect homogeneous-earth normalisation is used. Normalisation using the 2-layer function gives improved identification of subtle conductive inhomogeneities in the earth. Geometric normalisation (apparent resistivity) functions may suffer from instabilities when receiver electrodes are close to a transmitter electrode. In such cases, stripping (i.e. subtraction) of a layered-earth geometric function gives better results than normalisation (i.e. division) by the function.

NEW FRONTIERS IN OIL EXPLORATION

The Use of Computer Algebra for Obtaining Exact Solutions to Simple Seismic Reflection Models

B. Hartley

Abstract

The usage of computer algebra is in its infancy in many fields but is likely to increase as the speed and practicability of computer generated analytical solutions improves. This paper discusses the use of computer algebra to solve ray-tracing problems in simple seismic reflection models. The classical two-point problem, of finding ray travel times as a function of source receiver distances for multi layer models, does not have a complete explicit solution except in the simplest of cases or where unrealistic assumptions are made. Approximation methods have therefore been adopted to obtain numerical solutions. Such methods, however, have the disadvantage of sometimes requiring remodelling and recalculation if parameters are altered. If analytical solutions can be found, they could incorporate parameters of the model as variables and the expressions only need re-evaluation rather than a complete re-determination. The re-evaluation would be based on exact expressions and not on approximations such as are used now.

Exact parametric solutions can be derived for three-dimensional models with multiple layers having different acoustic velocities, with reflections and refraction at interfaces according with Snell's Law. These solutions have been generated using subroutines from the Maple computer algebra system and simulates three-dimensional ray tracing through acoustic media and the interactions with interfaces. These subroutines model ray transmission through a uniform medium, and model the reflection or refraction at interfaces. The solutions result in the generation of long expressions, which evidently could not be reasonably found by hand calculation. The symbolic algebra give travel time, ray position and ray direction as parametric equations using initial ray direction as the parameters. When a numerical receiver position is entered travel time and ray-path solutions are returned by solution of the parametric equations.

The subroutines are general and could be used to generate mathematical expressions for other simple earth models. For more complex models the analytical solutions may yield very long expressions. Geophysicists will find further applications for computer algebra packages for problems, which are currently solved by numerical and approximate methods.

NEW FRONTIERS IN OIL EXPLORATION

A Comparison of Omega-X, PSPI and Explicit Algorithms for Post-Stack Migration

C. Notfors

Abstract

Three widely used frequency domain algorithms for post-stack migration are the omega-x, PSPI and explicit algorithms. They differ in speed and accuracy with omega-x being the least accurate and fastest. PSPI is the slowest and less accurate than the explicit algorithm. The explicit algorithm is the most accurate of the three.

NEW FRONTIERS IN OIL EXPLORATION

The Contribution of High Quality Aeromagnetic Survey Data to Hydrocarbon Exploration

I. Kivior, D. Boyd

Abstract

Aeromagnetic surveys have been flown for fifty years as one of the methods providing information for hydrocarbon exploration. The method was generally regarded as a reconnaissance tool looking for major structures. The adage that the strength of a chain is in its weakest link is as true in geophysical surveys as in other fields of human activity. Major advances have been made in the last decade in the quality of aeromagnetic data so that low amplitude anomalies arising from magnetic bodies within the sedimentary section can now be measured with sufficient precision to provide information about the geology of the sedimentary rocks associated with hydrocarbon accumulations. This presents a challenge to the interpreter, for better interpretation procedures to take full advantage of the high quality magnetic data. Recent developments in computer technology, instruments, processing and interpretation of the earth's magnetic field have significantly extended the scope of aeromagnetic surveys as a tool in the exploration for hydrocarbons. The new approach used in the analysis and interpretation of aeromagnetic survey data over sedimentary basins allows interpreters to fully utilise information carried by the magnetic field data. The high quality experimental aeromagnetic survey flown over part of the Eromanga and Cooper Basin shows that magnetic layers in the sedimentary rocks make this an appropriate area for exploration by detailed aeromagnetic surveys. By applying new interpretation techniques it is now possible to make full use of the high quality digital magnetic data. It is possible to delineate major structures within a weakly magnetic basement, to follow magnetic horizons within the sedimentary section, to pick out fault and joint patterns within the sediments, to detect possible hydrocarbon alteration zones and to compute the

thickness of the sediments. The obtained results are comparable with those derived from seismic survey data. The aeromagnetic method is very effective to interpolate between widely spaced seismic lines which are used to tie the magnetic interpretation to the stratigraphy. After completion of the experimental research we have successfully conducted work over several basins including those in low latitudes, rugged terrains and volcanic provinces.

POTENTIAL FIELD INTERPRETAION TECHNIQUES (I)

A New, Rapid, Automated Grid Stitching Algorithm

S. Cheesman, I. MacLeod, G. Hollyer

Abstract

Traditional methods of stitching two separate grids together (such as manually adjusting values on neighbouring grids, levelling to an existing low-resolution grid or using various weighting schemes to merge grids) can produce smooth final products but the process is time-consuming and costly. Research into grid stitching techniques recently led to the development of automated methods that address several main challenges, such as determining how to select a path along which overlapping grids can be joined. A new algorithm, called grid suturing, uses Fourier analysis to deconstruct the errors along the join path into a sum of functions with different spatial wavelengths, and applies corrections that propagate smoothly into the grids by a distance proportional to the individual wavelengths. Measures are taken to minimise "Gibbs" type phenomena, and prevent interference between separate join sections in close proximity. Both normal and "postage-stamp" grid stitching is handled. Corrections can be weighted to apply to just one grid in cases where the other is considered to be of higher quality. Optionally, local trends may be removed. The result of this automatic and rapid algorithm is a merged grid that is seamless across boundaries-regardless of the different wavelengths of features along the join path. The method also maintains the integrity of the original data.

POTENTIAL FIELD INTERPRETAION TECHNIQUES (I)

Naudy Based Automodelling with Trend Enhancements

R. Almond, D. FitzGerald

Abstract

Recent years have seen a revival of interest in automatic interpretation of magnetic anomalies. This has resulted partly from a dramatic increase in the quantity and quality of aeromagnetic data, and partly from the development of the "improved Naudy" technique by Shi (1993) (referred to here by the term Naudy). Application of a reliable automatic interpretation method to large aeromagnetic datasets as part of processing allows contractors to produce preliminary maps of structure and depth on a routine basis. This can be done in much the same way as maps of first vertical derivative. In addition the application of the Naudy technique on an individual line basis allows the interpreter to generate preliminary models rapidly for subsequent refinement by specialised modelling programs. This can reduce much of the setting up time traditionally associated with modelling lon detailed lines of data. One critical parameter that is n determinable directly from the Naudy method is tl strike of the body. In parallel with the development of a effective Naudy tool DFA has introduced a tren detection method. We describe the use of trend data t provide strike control during Naudy processing. Bod strikes are inferred before the Naudy scanning takes plac thereby increasing the precision of the interpreted mode by adding a third dimension. Trends corresponding t shallower and deeper structures are handle independently. Further refinements optionally allow plate-like bodies and a full inversion to better fit th observed data. Simple two dimensional "dyke" model are constructed with attributes of strike, dip, width, depth and susceptibility. We show examples of the use of th Naudy method to provide a rapid fully automati preliminary structural analysis and depth to basemen map of a large petroleum exploration area. The map shows how secondary near-surface fracturing can be seen in the magnetic data. It also shows how pre-application of strike in an area where trends are well defined can significantly improve overall results.

POTENTIAL FIELD INTERPRETAION TECHNIQUES (I)

The Use of Fractal Dimension Estimators for Enhancing Airborne Magnetic Data

T. Dhu, M. Dentith, R. Hillis

Abstract

Airborne magnetic data is routinely enhanced by amplitude based filters such as horizontal and vertical derivatives. Texture is defined as the spatial distribution of amplitudes over region. Textural analysis provides a possible alternative method of data enhancement. This paper investigates the potential of using fractal dimension for quantifying texture and highlighting textural contrasts in airborne magnetic data. Profiles have been created by combining theoretical data with fractal dimensions (FD) of 1.1, 1.3 and 1.5. Estimates of FD using the semi-variogram and variation methods clearly distinguish between sections of the profiles with different theoretical FD. Fractal dimension estimates made on a real airborne magnetic profile, using the variation method, clearly define two regions of visible textural contrast. A series of other variations in the estimated FD suggests that the method is able to resolve subtle contrasts that are not easily detected visually. The semi-variogram method of FD estimation is not able to resolve the obvious textural contrasts in real data highlighting the need for further study of this methodology. The variation method has been used to estimate FD on a series of airborne magnetic profiles. This profile data was then gridded to generate an image of FD that moderately improves structural resolution. Whilst more work needs to be carried out, it is obvious that estimates of FD do detect textural contrasts in both theoretical and real data, and that this information can be used to enhance aeromagnetic data.

MINERAL CASE HISTORIES: AUSTRALIA (I)

Geophysical Investigations of the Titania Prospect

P. Eagleton

Abstract

Titania is a gold mineralised system containing the Oberon Resource in the Tanami Desert region of the Northern Territory. It represents a difficult exploration environment. It is completely covered with a blanket of transported material which includes a lacustrine clay layer and a shallow very saline watertable. The mineralisation occurs in non-magnetic stratigraphy mainly in a package of medium to fine grained metasediments and altered basic intrusives. Ground and airborne magnetic surveys have been conducted over the prospect. The detailed airborne survey has been useful in better defining the more magnetic regions surrounding the prospect as well as shallow weak magnetic anomalies such as an interpreted palaeo-channel located in the southern region of Titania. Gravity has been used extensively. In the deeper unoxidised zones the densities of the fine grained metasediments and intrusives are similar and higher than the coarser grained metasediments. In the shallow oxidised regions the intrusives have a lower density than the fine grained metasediments. The presence of sulphides particularly at Oberon in the finer grained metasediments can substantially increase densities. Orientation surface TEM gave very limited depth penetration. Orientation downhole TEM provided little additional information and could not effectively map sulphide concentrations. The applied potential surveys using a surface dipole to measure chargeability and potential gradient were useful in mapping more conductive and chargeable zones resulting from different stratigraphy and lithological variations such as sulphide and graphitic content. Gravity is the most effective method in mapping the stratigraphy associated mineralisation by its good correlation with residual gravity highs. The applied potential method is a useful method to complement gravity where drillholes are available. It can provide greater certainty to residual gravity anomalies that may be indicating mineralised stratigraphy.

MINERAL CASE HISTORIES: AUSTRALIA (I)

Geophysical Response of the Silver Swan Nickel Sulphide Deposit Western Australia

W. Amann, R. Pietila

Abstract

The Silver Swan is a massive sulphide, high grade (14%) nickel deposit, located on the basal contact of an Archaean komatiite, 43 kms north east of Kalgoorlie, Western Australia. Its high conductivity contrast with the host rock has allowed down hole electromagnetic techniques to be most useful for directing deep drilling. Due to the deposit's high grade and the role geophysics has played in its exploration this paper should be very interesting for geoscientists involved in massive nickel sulphide exploration.

MINERAL CASE HISTORIES: AUSTRALIA (I)

A Comparison of High Density Ground Magnetic Surveys and Low Level Aerial Magnetic Surveys in a Near Surface Noise Environment: A Cobar Case History

P. W. Basford, N. A. Hughes

Abstract

Exploration in the Cobar Basin for base metal and gold mineralisation is heavily dependent upon high quality magnetic data. Most of the major mineral deposits in the district have some relationship to magnetic material (magnetite and/or pyrrhotite), with most deposits having a recognisable aeromagnetic signature. A challenge to using magnetics as a targeting tool in the Cobar Basin is the extensive occurrence of maghemite, a highly magnetic mineral, occurring in sheet wash areas or in drainage channels, generating spurious anomalies and masking basement responses. In the search for economic mineralisation, discrete aeromagnetic anomalies are routinely followed up with ground magnetic surveys to better define the source (basement magnetic material or maghemite), thus delineating the drill target. Ground magnetic data suffers from the high frequency, high amplitude effect of near surface maghemite pebbles. Following work by Stanley and Sertsrivanit (Sertsrivanit, 1986 & Stanley et al 1992), high density ground magnetic data collection has been used in the Cobar district to aid in discriminating and removing the response due to near surface maghemite. The work undertaken by Sertsrivanit and Stanley concluded that if the response of the maghemite pebbles could be adequately sampled, then it is possible to remove their effect. To achieve this, data is collected at a very high density along lines (20-50cm), with lines spaced nominally 10 to 20m apart. Although the data is adequately sampled along the line it is clear that there is aliasing in the across line direction for compact, near surface 3D sources. Since it is impossible logistically to collect data on an equal grid interval at high density spacing (i.e. 0.5m by 0.5m grid), a non-linear 2D median filter is used to process the data to attenuate the essentially random signal generated along the lines by maghemite pebbles. Sertrisvanit's work concluded that the best signal-to-noise ratio attainable was from high density sampling with the sensor close to the source (less than 1m). The best signal-to-noise ratio for aeromagnetic data collection was concluded to be at altitudes of 60 to 70m, with the worst to be for a detector located 10 to 20m above the surface, the altitude of detailed helicopter and specialist fixed-wing aircraft. A recent high density low altitude aeromagnetic survey (20m line spacing, 3.5m along line sampling and 25m flight height, thus essentially un-aliased) was flown over the same area as a high definition GRI ground magnetic survey. The two data sets contain the same essential features, however, there is more definition in the non-filtered low altitude aeromagnetic data.

EXTENDING GEOPHYSICS

Neutron Radiography: A Technique to Support Reservoir Analysis

M. Middleton, I. Pazsit

Abstract

Dynamic neutron radiography is a method to image fluid flow in porous media, based on the tendency of neutrons to be preferentially attenuated by hydrogen. Fast neutrons with energies of several MeV can be produced by particle accelerators, and are suitable for detecting fluids in rock samples of 0.15 to 0.30 m thick. Slow (thermal) neutrons with energies of about 0.03 eV are produced by nuclear reactors, and are ideal for imaging fluid flow in rock samples in the order of 0.01 m thick. Thermal neutrons are attenuated by an exponential law, which relates the incident intensity of a neutron beam to the transmitted neutron beam via the bulk density of the rock in the neutron path, the bulk neutron attenuation coefficient in the neutron path, and the thickness of the rock in the neutron path. These exponent terms can be linearly related to the components making up the rock the volume fraction of fluid 1, the volume fraction of fluid 2 and the volume fraction of the rock matrix. Knowing that the sum of the fluid volume fractions is the rock's porosity, an estimate of the relative fluid saturation can be made. These are the principal economic quantities required for either a hydrogeological or petroleum reservoir. Examples of water infiltration and petroleum imbibition into the Visings" Sandstone, Sweden, are provided to illustrate the application of the technique.

EXTENDING GEOPHYSICS

Geologists and Geophysicists: Getting them on the Same Planet

A. J. Willocks, B. A. Simons

Abstract

The results of new detailed airborne geophysical surveys over Victoria have been lauded by industry as being a great incentive to increase mineral exploration in the State. These data become especially useful when combined with new semi-detailed geological mapping. The Geological Survey of Victoria has now developed a new methodology to integrate geological mapping with the interpretation of the geophysical data to produce a single composite understanding of the rocks and their relationships. It has required a reappraisal of the way geologists and geophysicists map, both together and separately, and additional training to make the process work. Sufficiently detailed data acquired prior to the geological mapping allows a fully integrated interpretation, using the available geophysical and geological data, to produce maps which reflect both geological and geophysical reality. Previously, geologists and geophysicists worked in partial or complete isolation. Too often geophysicists gave geologists lineament/line maps which bore little resemblance to geological reality, lacked credibility and were almost immediately discarded by geologists as being 'unhelpful'. The new process requires geologists and geophysicists to work as a team to reconcile all the geophysical and geological observations to produce an accurate, integrated geological map. It demands that the geologist understands the geophysical responses and the geophysicist understands the geology. Both need to acknowledge the limitations inherent in each method. Presenting the results provides a further series of challenges to the mappers, interpreters, managers and cartographers. We have also yet to integrate the mineralisation history into this mapping process. Meeting these challenges to produce a full and accurate understanding of the geology and geophysics, rather than of one or the other, is essential to ensure increased exploration success.

EXTENDING GEOPHYSICS

The Australian Stress Map

R. Hillis, J. Meyer, S. Reynolds

Abstract

The Australian Stress Map project has compiled 275 quality ranked stress orientation analyses for the Australian Continent, approximately doubling the number of analyses from those in the 1992 World Stress Map compilation. Most new data are from borehole breakouts. Regionally, maximum horizontal stress (sH) is oriented 050°-060°N from New Guinea along most of the North West Shelf, rotating to 090°-100°N in the Carnarvon Basin. A broadly north-south sH orientation is observed in the Amadeus Basin, and also in the Bowen Basin. However, in the southern half of the continent a broad east-west sH trend is observed in the Cooper-Eromanga Basins, Yilgarn Block and Flinders Ranges. In south-eastern Australia sH is oriented 120°N. The rotation of stresses along the North West Shelf and from east-west in the Yilgarn Block to north-south in the Amadeus Basin can be explained in the context of the heterogeneous plate boundary forces acting along the convergent plate boundary to the north of Australia. However, plate boundary forces can not explain the rotation of sH from east-west in the Cooper-Eromanga Basins to north-south in the Amadeus Basin, which may be linked to second order influences on the stress field. The vertical stress gradient in the Bonaparte and Cooper-Eromanga Basins increases with depth, and is around 20 MPa/km at 1 000 m, attaining 23 MPa/km around 3 000 m depth. The Amadeus Basin displays an overburden gradient of 25 MPa/km that is little affected by depth. In situ measurements in hard rock terranes suggest a higher average overburden stress gradient of 27 MPa/km. Leak-off pressures suggest that sh is the least principal stress (60-70% of sv) in the Bonaparte and Cooper-Eromanga Basins. Hence in neither basin is the stress regime one associated with reverse faulting (where sH > sh > sv). Consideration of the frictional limits to faulting suggests that, if in a state of incipient faulting, the stress regime is approximately on the boundary between the normal (sv > sH > sh) and strike-slip (sH > sv > sh) faulting environments in the Bonaparte Basin and strike-slip in the Cooper-Eromanga Basins. Applications of the stress data include modelling plate tectonic driving forces, assessing seismic hazard/fault reactivation trends, mine and wellbore stability, and fluid flow directions in the subsurface. For example, hydraulic fractures induced for geothermal exploitation of hot-dry-rock in the Cooper-Eromanga Basins would tend to be vertical, and not, as previously suggested horizontal.

ANISOTROPY
KEYNOTE ADDRESS

Seismic Imaging in Anisotropic Media

R. Klotz, S. Downie, S. Leng Ng

Abstract

Anisotropy, which is the variation of the seismic velocity with propagation direction, and ray-bending have largely been ignored in the formulation of present day data processing methodologies. Examination of some synthetic data models which include these two effects reveals exactly how we would expect recorded seismic data to behave in their presence. Conventional hyperbolic normal moveout (NMO) corrections are seen to significantly over estimate the data movement required at steep reflection angles. Steep reflection angles are associated with both steeply dipping events and the far offsets at shallow reflection times for gently dipping events. Since the late 60's (Taner & Koehler 1969) numerous authors have proposed various schemes to improve the accuracy of moveout corrections. Most of these schemes relied on a Taylor series expansion, to 4th or a higher order, honouring Snell's law. While such equations are considerably more accurate for mid-range reflection angles, they are extremely poor estimates near the critical reflection angle of the medium's highest interval velocity layer. We introduce anisotropic moveout (AMO), a more direct, economical and precise solution of Snell's law. AMO is an extended form of NMO which incorporates the effects of ray-bending, anisotropy and an accurate moveout solution for refracted data arrivals beyond the critical reflection angle. Results from synthetic models processed with AMO are compared with NMO. Some Australian data examples with NMO are compared with AMO, to show how it is possible to extend the usable offset range. This provides better resolution in the velocity analyses as well as producing gathers which are more suitable for amplitude versus offset (AVO) analysis. In the late 80's Lynn et al in an article 'Where are the Fault Planes' demonstrated how severely prestack FK migration results were degraded by ignoring ray-bending and anisotropy. The fault plane reflections, which are reflected at steep angles needed significantly higher velocities to image properly. The AMO equations can be used to replace the NMO equations which are part of the imaging conditions in prestack Kirchhoff time migration. This substitution transforms Kirchhoff into an accurate anisotropic curved-ray migration which can simultaneously image fault planes and near flat reflectors with the same velocity.

ANISOTROPY

Inversion of Velocity Field and Anisotropic Elastic Parameters for Layered VTI Media

R. Li, P. Okoye, N. Uren

Abstract

Numerical modelling studies have been used to devise a way to recover the average P-wave velocity field and the following anisotropic elastic parameters for layered transversely isotropic media: the vertical P-wave velocity, the vertical S-wave velocity, the P-wave anisotropy (e) and the near-vertical P-wave anisotropy (d). Horizontally layered models comprising transversely isotropic materials with vertical symmetry axes (VTI materials) and isotropic materials were used in computer simulation experiments. It is difficult, even under ideal conditions, to obtain average values of e and d experimentally from multi-layered media. Hence in our numerical simulations, these were obtained by inversion of transmission data. A new double precision inversion code has been developed to invert traveltime data to recover the average elastic parameters e and d. The average vertical P and S-wave velocities were directly determined from traveltime data. Subsequently, using the average parameters to the top and to the bottom of a layer of interest, the interval parameters of that layer were recovered using a new least-squares algorithm. From the individual parameters for each layer, we may also compute the overall average velocity field and parameters for the whole multi-layer model. Comparison of the inversion results with directly calculated averages indicated that such multi-layered media can be described as a single layer VTI medium except at large incident angles. Simple relationships between the individual and overall average layer parameters were found. A good knowledge of both the individual layer and the overall layer anisotropic parameters, and velocity field may lead to improved seismic data processing and hence, more accurate data interpretation. We expect that this will result in a significant enhancement in seismic resolution and delineation of reservoir volume estimates.

ANISOTROPY

Polarisation Analysis: What is it? Why do you need it? How do you do It?

N. Hendrick, S. Hearn

Abstract

For several decades single-component seismic reflection has been the primary geophysical tool for hydrocarbon exploration and development. This conventional scalar approach has achieved a high degree of maturity and future enhancements are likely to be increasingly subtle. Significantly more information can be recovered from the seismic wavefield if it is recorded and analysed as a vector quantity. Consequently multi-component reflection techniques are emerging as the next frontier for seismic exploration.

Polarisation analysis is arguably the fundamental multi-component processing concept. It involves the computation of parameters which describe the particle motion vector associated with propagating seismic energy. These polarisation parameters can be utilised to selectively reject unwanted noise events (e.g. out-of-plane energy), extract pure compressional and shear wavefields, and recover information relating to fracturing, porosity and lithology. Such applications of polarisation analysis have been widely reported in the geophysical literature. In addition, considerable information has been provided on the mathematics of estimating polarisation parameters. However, there is little, and sometimes conflicting, information regarding data preparation for, and limitations of, polarisation analysis. The primary aim of this paper is to provide a practical guide for using polarisation analysis, with reference to real data experiences.

Pre-processing prior to polarisation analysis is aimed at stabilising particle motion without distorting inter-component relationships. We demonstrate practical issues relating to a typical pre-processing scheme

incorporating amplitude equalisation, bandpass filtering and velocity filtering.

We clarify the available options for polarisation analysis by identifying three broad algorithmic approaches, and comment on the advantages and disadvantages of each. The simplest approach involves the visual inspection of the particle motion hodogram. The second approach produces automated instantaneous polarisation estimates. The most commonly used approach involves the visual inspection of the particle motion hodogram. The second approach produces automated instantaneous polarisation estimates. The most commonly used approach involves estimation of the average particle motion over a specified data window. Careful consideration must be given to window design as this controls the compromise between stability and resolution.

Current developments involving multi-channel, multi-component processing concepts have the potential to alleviate some of the limitations associated with the widely used single-channel polarisation analysis techniques.

ELECTRICAL & EM CASE STUDIES (I)
KEYNOTE ADDRESS

MIMDAS - A New Direction in Geophysics

N. Sheard, T. Ritchie, J. Kingman, P. Rowston

Abstract

Array style geophysical exploration in base metal exploration has been a dream for some time. MIMEX in conjunction with Refraction Technology have realised this dream and developed, built, trialed and are currently routinely surveying using a multi-channel distributed acquisition ground geophysical system. The system was designed to be modular and produce high quality data from array style measurements. It can use any sensor type and with suitable software, produce detailed interpretative products with increased resolution and better depth penetration than any current commercial system. The goal is to produce 3D geology interpretations based on 3D discretised physical property block models with as much spatial resolution and property accuracy as possible - and do this at lower operating costs by current standards. A detailed system specification was started in February 1995 and building of the prototypes began in April, 1995. The initial field trials in Dallas USA were undertaken in December 1995 with an Australian shakedown in September, 1996. The first field unit operating with 32 channels was commissioned for survey use in June, 1997. The system has been designed with no theoretical upper channel limit, although each unit is expected to have about 100 channels which is largely limited by field logistical constraints. The system, named MIMDAS - MIM Distributed Acquisition System, can collect the following data: controlled source electromagnetic data, spectral and non-linear induced polarisation data, magnetometric induced polarisation, controlled source magneto-telluric data, natural field magneto-telluric data and standard electromagnetic data. The system can collect other data sets such as seismic if required. The system is based upon single channel distributed acquisition boxes (DAS boxes) that collect 19/24 bits (depending on sampling frequency) of non-aliased linear data with a band width of 0 - 20 kHz. These data are relayed to a truck mounted central recording unit (CRU) via local area network (LAN) cables. Each distributed acquisition box is accurately synchronised and the data are stored in each unit, streamed into the CRU and recorded either during acquisition or at the end of each event. The acquisition software allows interrogation of each box or any sensor and can display raw data as it arrives. The data are processed on site and field plots produced. All raw time series data are kept allowing reprocessing. For controlled source surveys at least one channel is devoted to accurately monitoring the input current into the transmitting source. These current data are then used to deconvolve the input data and produce data from computed waveform styles. The distributed system avoids multiplicity of cables attached to sensors and the inherent distortion and noise. It also means expandability of units/sensors is limited only by logistics and computer power. The current monitor removes the requirement of a 'good' transmitter, as it produces data from the theoretical clean waveforms used in interpretation packages. The data from each channel is collected simultaneously which offers considerable noise cancellation benefits. The time series data allows simple signal processing procedures to remove cultural noise, which when combined with selective stacking routines and other remote reference noise cancellation schemes produces very high quality data. Considerable area or line kilometres of quality data can be captured rapidly. Concurrent to the production of MIMDAS a considerable effort was made to enhance and create software which enables quality interpretation. This has resulted in a product which allows a 3D style interpretation which was the aim of the project.

ELECTRICAL & EM CASE STUDIES (I)

An Application of Reverse Coupling to Increase Signal Strength Beneath Conductive Sediments-Miitel Mine, Kambalda, WA

J. Elders, A. Wellington

Abstract

Downhole electromagnetics (DHEM) is the principal geophysical tool used at Kambalda Nickel Operations for the detection and delineation of sulphidic ore zones. The case study presented here is from Miitel, a relatively new mine site which expects to begin production by January 1999. Exploration at Miitel is a challenging proposition as mineralisation occurs in discrete blocks which due to limited drilling are not yet well defined. For this reason, most holes drilled at Miitel are surveyed with DHEM to increase the investigation area and to assess the size of intersected conductors. DHEM logging at Miitel faces a significant problem. Exploration targets are not only overlain by a conductive overburden but are also overlain by a layer of thick pyrrhotitic sediments, positioned 100m into the hanging wall. The consequence is a low amplitude response from the target and substantial overburden interference at the target area, below the sediments. These effects increase the signal-to-noise ratios and increase the ambiguity in interpretation. In DHEM logging, usually the optimum transmitter loop position is where coupling is maximal with the target and minimal with all other conductors. Typically this is accomplished by placing the transmitter loop in a normal coupled position where the field lines traverse a path from the centre of the loop

through the hanging wall side of the target ore horizon. Reverse coupled loops couple poorly with the sediments because field lines couple through the foot wall beneath them, while still coupling well with the targeted ore blocks. Logging results from a surface drillhole at Miitel used both normal and reverse coupled transmitter loops to test the effectiveness of this non-conventional survey design. The results demonstrate how reverse coupling can successfully be used in this adverse environment to overcome the effects of amplitude reduction, current channelling, and drive delay thus improving data quality and interpretation reliability.

ELECTRICAL & EM CASE STUDIES (I)

The Delineation of Coronet West by Detailed Underground DHEM

P. Mutton

Abstract

The Coronet Nickel mine is located at Kambalda, 60km south of Kalgoorlie in Western Australia. The ore shoots currently being mined extend to depths of up to 600m below the surface. Extensional exploration beyond the existing mine reserves from underground drilling platforms is routinely used to discover ore shoots outside existing reserves. This drilling is expensive, and limited drilling positions often provide poor drilling angles. Such holes however, make excellent geophysical platforms, and the highly conductive nickel sulphide orebodies provide excellent geophysical targets. The intersection of a significant thickness of high tenor massive nickel sulphide west of existing reserves prompted an extensive underground drilling program. This yielded numerous, poor intersections, and the extent of the economic mineralisation remained unknown. Further drilling would have been very expensive and was only possible at very poor drill angles. Downhole electromagnetic (DHEM) surveying of the initial holes however, confirmed the presence of many conductors, and modelling resulted in the development of a very detailed and highly constrained geological model. On the strength of this model and the geological information, a decision was made to develop out to this ore shoot named Coronet West. This decision was proved correct when ore was intersected within 1m of the position predicted by the DHEM. Subsequent mining has shown the ore shoot to be comparable in size and attitude to that predicted by the geophysics model.

POSTERS (II)

Self-Demagnetisation Corrections in Magnetic Modelling: Some Examples

W. W. Guo, M. C. Dentith, Z. X. Li, C. M. Powell

Abstract

Self demagnetisation, also referred to as shape demagnetisation, occurs within any magnetised body. In the case of weak to intermediate magnetism ($k < 0.1$ SI and/or $Jr < 10$ A/m), its effect is insignificant and can be neglected in magnetic forwarding modelling. However, such effects are important when modelling bodies with strong magnetism. The effects of self demagnetisation in magnetic modelling are considered in a few publications, but very few detailed case studies have been presented. In this paper, we present three examples of magnetic modelling illustrating the importance of the phenomenon when source bodies are highly magnetic. The first example concerns a magnetite iron deposit. In this case accounting for self demagnetisation in terms of a single, simple body is sufficient to recognise that discrepancies between observed and calculated magnetic anomalies are due to self demagnetisation of the orebody. The second example, a volcanic-hosted iron deposit, demonstrates that ellipsoidal models are applicable as a satisfactory approximation of modelling for the equi-dimensional and/or lens-like bodies. The third case, an ultramafic-hosted nickel and copper deposit, demonstrates that under favourable conditions applying demagnetisation corrections can help to identify the effects of mineralisation within a larger anomaly.

POSTERS (II)

Application of the Discrete Wavelet Transform to the Interpretation of Magnetic Anomaly Data

R. Bird, T. Ridsdill-Smith, R. Dietmar Muller, M. Pilkington

Abstract

Magnetic data have become essential to resource exploration and are often digitally enhanced to facilitate their interpretation. For example, production of horizontal and vertical derivatives is common, and quantitative interpretation methods such as Euler deconvolution and analytic signal calculation utilise these derivatives. These methods can be used to invert magnetic anomaly data in both two- and three-dimensions to retrieve magnetic source positions and depths. In turn, the results can provide strong constraints on geologic interpretations. However, derivative calculations are most commonly conducted in the Fourier domain and the resultant dataset is susceptible to corruption with high-frequency noise. This noise is accentuated when derivatives higher than first-order are calculated. Therefore, magnetic source position and depth solutions calculated using these derivatives can be adversely affected. As an alternative, we utilise the discrete wavelet transform method developed by Ridsdill-Smith and Dentith (1998) to calculate horizontal and vertical derivatives. Source positions and depths are then calculated (e.g., Euler deconvolution) and compared with solutions derived using previous, standard techniques. Sample magnetic data for this study are from the North West Shelf of Australia.

POSTERS (II)

An Analysis of the Broken Hill Exploration Initiative Petrophysical Database

P. Ruszkowski

Abstract

An analysis of the Broken Hill Exploration Initiative petrophysical database reveals that most lithologies display a bimodal magnetic susceptibility distribution. This bimodality represents sub-populations of each lithology into those that have ferromagnetic minerals absent or present. Iron in the weakly magnetic sub-population is incorporated into the paramagnetic silicate minerals e.g. Fe^{2+}, whereas similar lithologies, which are

strongly magnetic, contain more Fe^{3+} in magnetite. Further graphing and analysis of magnetic susceptibility values show a regional increase in magnetite formation in amphibolites with metamorphic grade as the Broken Hill orebody is approached. This is supported by an overall increase in density of the amphibolites as metamorphic grade increases. Graphs of magnetic susceptibility versus Koenigsberger ratio (Q) reveal that most lithologies show three distinct sub-populations with little difference between outcrop and drillcore values. 1) Low susceptibility, low remanence (46% of population). 2) Low susceptibility, high remanence (42% of population). 3) High susceptibility, high remanence (11% of population). There is a notable absence of a fourth population with high magnetic susceptibility and low remanence. It is concluded that most highly magnetically susceptible rocks sampled have a significant component of remanence (NRM) to affect magnetic field modelling. From outcrop data there is a general remanent declination trending towards the North and a preferred inclination of between -45 to -90 degrees (near vertically upward). As these directions are generally near the earth's present magnetic field the effect of remanence generally enforces the present day field. Anisotropy data generally reveals a very slight anisotropic susceptibility.

POSTERS (II)

Airborne Geophysical System at the Geological Survey of Finland

M. Kurimo, M. Airo

Abstract

The Geological Survey of Finland (GTK) is one of the leading geological organisations in Europe. GTK employs some 800 people, including 350 geoscientists. GTK is overseen by the Ministry of Trade and Industry and its main goals are: 1) to maintain, update and distribute geological information in Finland and 2) to research and develop new exploration technology and methods. Practical applications meet the everyday needs of the mining and construction industries.

GTK has had a wide experience of aero-geophysical surveying since 1951 when it started systematic airborne geophysical mapping. The First National Mapping Program was completed in 1972. The Second Program commenced in the same year using a terrain clearance of 30-40 m and a line spacing of 200 m. Today, almost the whole country is covered and the data is available to the public both as printed maps and numerically. GTK also offers its expertise for customer world-wide. Over 150 000 line kilometres were surveyed during 1997 for different clients.

The airborne geophysical instrumentation is installed in the fixed-wing DHC Twin Otter aircraft. During the manufacturing of the Twin Otter several modifications were made to its electrical systems in order to reduce the electrical noise levels. The geophysical equipment includes two caesium magnetometers at wing tips and automatic compensation system, EM dual frequency unit, frequencies 3125 Hz and 14368 Hz, vertical coplanar coil configuration, coil distance 21 m and a gamma-ray spectrometer with 8 downward and 2 upward looking NaI crystals for a total of 41 litres. Other instrumentation includes: GPS-navigation unit with ability of real time DGPS, radar altimeter, barometer, thermometer, accelerometer and sferics monitor. The flight path is recorded to normal VHS video. The measurement units installed in the aircraft are connected to each other by a local area network (LAN). On the ground there is the magnetic reference station and reference GPS receiver.

The high-resolution multi-sensor aero-geophysical measurements can be utilised in bedrock mapping, exploration and environmental studies. Several different cases are introduced.

Systematic high-resolution aero-geophysical surveys in Finland benefit from regional to detailed scale investigations. Due to their wide areal coverage the airborne surveys are used to map large scale structures and tectonic boundaries within the basement on a regional scale. Interpreted in combination with regional petrophysical data, they are particularly efficient at characterising structural and lithological variations and deformation style.

Aero-geophysical surveys have been found to be effective in outlining polluted surroundings of dumping areas and, related to gravity and topographic data, in detecting groundwater reservoirs.

Integrated interpretation of aero-geophysical, petrophysical, geochemical and geological data have yielded good results in base metal prospecting. A bedrock mapping project in Ghana during 1997 was financed by The World Bank/IDA NDF and consisted total of 130 000 line kilometres. In this project the Birrimian volcanic belt was mapped to identify target areas for the exploration of gold and base metals.

An aeromagnetic offshore survey for oil prospecting in Norway investigated the advantage of the two magnetometer horizontal gradiometer system in an area where sub-nanoTesla anomalies have an important role in interpretation.

Aero-geophysical surveying for mineral exploration in Portugal was performed to gain accurate and detailed geophysical information by rapid data processing. The survey used all the geophysical instrumentation at 100 m line spacing and 35 m mean terrain clearance. The raw data was processed immediately after every flight and in a few hours preparatory data and maps were available.

An EM survey for sea ice thickness was carried out by flying separate lines along waterways and measuring EM anomalies with an exact terrain clearance with laser and radio altimeter. The target area was on the Pechora and Kara Seas on Northern Russia. A two-layer model was interpreted and the upper layer, i.e. the thickness of ice was achieved with better than 10 cm accuracy.

POSTERS (II)

Utilisation of 256 Channel SAEI Radiometric Data to Improve the Quality of Radiometric Pixel Imagery for Exploration

D. Calandro, G. Reed

Abstract

The cornerstone of the South Australian Exploration Initiative (SAEI) was the flying of broad - acre aeromagnetic surveys over areas of shallow, prospective bedrock. Between 1992 and 1995, 1 million line kilometres of aeromagnetic and radiometric surveys were flown, at

100 and 400 metre line spacing. Not only were the four windows corresponding to total count, potassium, uranium and thorium recorded, but also the full 256 channel spectrum. However, only the conventional four channel data and pixel imagery were utilised. Both digital located ASCII data and hardcopy pixel imagery products were produced from these datasets. However, due to the lack of geological information that could be derived as a result of the poor quality of radiometric pixel imagery and general lack of understanding, radiometrics was under-utilised as an exploration tool. SAEI 256 channel radiometric data has been subjected to a Principal Components analysis processing technique. This process identifies all statistically significant spectral shapes which can then be utilised to determine new potassium, uranium, and thorium windows. The result of this processing has been, in most cases, a dramatic reduction in the noise content of radiometric pixel imagery, particularly the uranium channel as the procedure utilises all of the counts in the spectrum, thus displaying more geological detail than is possible via the conventional three window method. As more geological information is being displayed in these data sets than ever before, this processing technique will lead to a greater understanding of SAEI radiometric data, and will increase the viability of SAEI radiometric data as a valuable exploration tool.

POSTERS (II)

Applications of Gravity and Magnetic Block Modelling

S. Roberts

Abstract

In complex geological environments, the earth may be more easily represented by a block model than by an aggregate of three dimensional polyhedra. Also, changes to that model are often more easily accommodated when a block model is used. Software has been developed to compute the gravitational and magnetic fields of complex three dimensional block models. The models are represented as a list of prisms, each with homogeneous physical properties, contained within a user defined number of voxel frameworks. By minimising the number of prisms required to define the model, storage requirements and computation time is minimised. The software uses digital terrain models of varying complexity to clip the extents of the model. Consequently, it can be used to compute the complete Bouguer correction for gravity data, which incorporates terrain effects. A similar technique can be used to remove the magnetic field variations attributable to terrain from aeromagnetic data, where the background rocks are magnetic. In both cases, spatially variable physical rock properties can be incorporated into the computations. Examples of both types of processing are given. Overburden overlying complex palaeo-terrain is often the source of gravity anomalies that can mask the gravity signatures of basement geology. Using available geological data which may include outcrop boundaries, drill hole logs or earth models obtained from the interpretation of electrical or electromagnetic data, detailed block models of the overburden can be constructed. Once the terrain corrected gravity field of the overburden is removed from the data, the residual data is predominantly attributable to basement density variations. Examples from Charters Towers and Kalgoorlie are given. Complex geological models are readily converted into block models. In this format they are easily visualised, and the gravity and magnetic fields of the model can be computed. Examples from the Renison tin mine, Tasmania, and Cargo, New South Wales, are given.

POSTERS (II)

The Development and Calibration of a GPS-Based Gravity Data Acquisition System

D. Bilick, W. Featherstone, R. Hackney, M. Dentith

Abstract

This paper describes the development and calibration of a vehicle-based gravity acquisition system, which is positioned in three dimensions using kinematic GPS (Global Positioning System) measurements. The GPS antenna is mounted on a moveable arm, which can be fitted to any ground-based vehicle, and continuously tracks kinematic GPS data to yield positions relative to a geodetic base-station. For each gravity measurement, the arm is swung into position above the gravimeter and the height measured to allow an exact determination of the three-dimensional position of that measurement. The sensitivity of a modern gravimeter coupled with the vertical gradient of gravity at the Earth's surface dictates that the precision of the vertical co-ordinate is the most important. However, the least accurate aspect of any GPS-based gravity survey is the co-ordinate transformation from GPS ellipsoidal heights to Australian Height Datum heights. This is calibrated in the field by connecting to existing vertical benchmarks surrounding the survey area, then applying a correction to the co-ordinate transformation wherever appropriate. This approach also ensures that the computed gravity anomalies are fully compatible with existing gravity data. The results of preliminary tests in the Perth metropolitan region show that the prototype system allows for the computation of accurate gravity anomalies, and is more efficient than other ground-based gravity surveys.

POSTERS (II)

High Precision Gridding of Gravity Data

A. Murray

Abstract

A new technique of multiple pass gridding has been developed using the minimum curvature method which will practically allow high precision gridding to be performed on any gravity station distribution. Gravity data interpretation usually involves the compilation of several separate datasets of widely differing observation (point value) spacing. Traditional one pass gridding techniques often demand a compromise between achieving a high frequency response in areas of dense observations while avoiding high frequency noise or ringing in areas of sparse coverage. This compromise may be side-stepped by piecewise gridding of the area and feathering the grid pieces together or by using a triangulation technique; however, both these methods will introduce spurious artefacts into the frequency response which will hamper a unified interpretation of the area. The gridding method which best suits the well defined

behaviour of a gravity field is the minimum curvature technique; unfortunately, this method is particularly sensitive to the cell size chosen for the gridding in relation to the observation spacing. If the cell size is less than one sixth of the station spacing obvious boxing and ringing effects become evident in images or contours based on the derived grid. The best results are obtained when the cell size lies between one third and one fifth of the observation spacing. The ideal gridding technique will effectively approximate this spacing everywhere within the area being gridded notwithstanding even extreme variance in the observation spacing. This new technique of multiple pass gridding combines the original observed data with cell values from the previous pass filling any gaps in the original dataset. This additional 'pseudo-data' holds the grid constant in areas of sparse data while the cell size is progressively refined to make full use of the dense data. This method has been thoroughly tested using data in the Broken Hill area which ranges in observation spacing from 25 metres to 7 kilometres! Images of this area with an 80 metre cell size show an excellent frequency response and are aesthetically pleasing. This technique has also been employed to grid the Eastern Goldfields region of Western Australia, the Lachlan Fold Belt in New South Wales and the Cooper Basin in South Australia. The Cooper Basin data derive from a miscellany of surveys carried out in the 1960s using various control points and position datum. The discrepancies of about 1 milligal between these surveys become immediately obvious when gridded using this high precision technique.

POSTERS (II)

Levelling Marine Potential Field and Bathymetry Data, a New Approach

M. Morse, R. Seikel

Abstract

The levelling of marine potential field and bathymetry data has been a difficult and often time consuming problem. As part of the Australian Geological Survey Organisation's (AGSO) Timor Sea Project, a major upgrade of the marine ship-track potential field and bathymetry data which have been acquired on the north-west Australian margin since 1963 has been undertaken. AGSO and Desmond Fitzgerald and Associates have developed new techniques for correcting crossover and other errors in these data, thereby enabling the production of high quality images for interpretation. Typical marine data compilation may include Government Surveys, open-file company data and foreign surveys. The wide range of data sources and variable navigation accuracies inherent in data of different vintages result in crossover errors being a dominant feature of any grid created from such unlevelled data. Images produced from such data are difficult to interpret as they are dominated by linear features which coincide with ships' tracks. To integrate such data into a more usable form for accurate geological interpretation required the development of a new levelling methodology. Firstly in adapting the crossover based levelling techniques familiar in aeromagnetics data processing the survey cruises are split into "straight" segments. Then these segments are compressed to other segments of the survey or other segments of other surveys to produce a crossover network. Sandwell and Smith's World Gravity Image was recognised and used as a regional reference onto which individual surveys were least square fitted. As a final stage the surveys are compiled into one large survey and the crossover based levelling technique called loop closure was performed. Particularly bad fitting segments were edited normally. The bathymetry and magnetic data are levelled differently to the gravity data because regional reference is not normally available. Such data is levelled using a combination of crossover based loop closure levelling techniques and filtering technologies such as de-corrugation and micro-levelling. The offshore data are gridded in conjunction with existing onshore databases to produce a suite of images of Bouguer anomaly, magnetic anomaly, and bathymetry/topography. These grids have been filtered and manipulated to produce various derivatives and composites to enhance the interpretability of the data. Enormous improvements upon the usefulness of the original data-sets have resulted from this approach.

POSTERS (I)

Simulation of Strong Ground Motion for Australian Intra-Plate Earthquakes Using Green's Function Method

C. Sinadinovski, K. F. McCue, M. Somerville, T. Muirhead, K. Muirhead

Abstract

Seismic records of Australian intra-plate earthquakes show different characteristics in frequency content, peak acceleration and duration, when compared with events from inter-plate regions. In the situation of an insufficient number of quality strong motion records of intra-plate earthquakes at short distances, synthetic seismograms are used for testing of structural behaviour. The near-field synthetic records of likely intra-plate earthquakes are considered, with a typical strong ground motion duration of several seconds. In this approach a Green's Function method is used to simulate a large earthquake by summation in time of a number of smaller earthquakes or sub-events. Each sub-event is given a slightly different time origin to represent the propagation of a rupture along a fault plane. The magnitude 2.3 aftershock of the 29 December 1989 Newcastle earthquake recorded on one of the rock sites was used as sub-event in this study, to simulate the main shock of magnitude 5.6. Additional validation studies for events recorded elsewhere in Australia are reported. The initial results of the study show that the synthetic near-field seismograms produced by the Green's Function method are realistic, and can be used to represent ground motion during typical Australian intra-plate earthquakes.

POSTERS (II)

Towards Better Geophysical Modelling of the Hamersley Iron Province - I: Magnetic Petrophysics

W. W. Guo, Z. X. Li, M. C. Dentith, C. M. Powell

Abstract

The Hamersley Iron Province of Western Australia contains extensive banded iron formations (BIFs) and large iron deposits. The investigation of magnetic properties of the Hamersley BIFs, iron ores and other rocks is the first step towards a better magnetic anomaly interpretation

over the province. Different from any other rock, BIF is characterised magnetically by high susceptibility, strong anisotropy, high natural remanent magnetism (NRM) (or high Q value) and strong self-demagnetisation effects. These factors make the features of BIF-related magnetic anomalies very complicated, as illustrated by our theoretical models. Five hundred and seventy-four oriented samples and some industrial drill cores were collected from the province for petrophysical and palaeomagnetic analyses. Some magnetic petrophysical results obtained so far are summarised below.

The five main iron formations of the Hamersley Group all show a similar distribution pattern of mean bulk susceptibility (MBS) - a logarithmic bimodal distribution. This means that each iron formation has two major susceptibility groups. For the Brockman Iron Formation, however, the MBS of the Joffre Member BIFs exhibits a logarithmic normal distribution, whereas that of the Dales Gorge Member BIFs shows a similar distribution to the BIFs in the Hamersley Province as a whole. The Weeli Wolli, Joffre, Dales Gorge and Mount Sylvia BIFs have the highest susceptibility. The Boolgeeda BIF has intermediate susceptibility but it is still higher than that of the iron ores and other non-BIF rocks. The Marra Mamba BIF has the lowest susceptibility, which is even lower than the iron ores and dolerite dykes. Iron ores have intermediate susceptibility. Brockman martite-microplaty haematite ores have slightly higher susceptibility than Marra Mamba martite-goethite ores. Fresh dolerite and Cheela Spring Basalt have variable susceptibility. Other rocks are low in susceptibility.

The Dales Gorge, Joffre and Weeli Wolli BIFs have strong anisotropy of magnetic susceptibility (AMS) with well-developed bedding-parallel or sub-bedding-parallel magnetic foliation. Some haematite ores, the Boolgeeda BIF and the Mt. McGrath haematite conglomerate have low AMS with recognisable sub-bedding-parallel magnetic foliation. Other rocks, including the badly weathered BIFs of the Marra Mamba Formation, are generally isotropic.

With respect to the current horizontal, the natural remanent magnetisation (NRM) direction of the Joffre, Mount Sylvia and Weeli Wolli BIFs are almost totally scattered. However, a basin-wide north-west-up post-folding NRM direction from the Boolgeeda BIFs, and a north-westerly sub-horizontal post-folding NRM direction from the Marra Mamba and Dales Gorge BIFs, can be recognised. Martite-microplaty haematite ores of the Tom Price, Paraburdoo and Channar deposits, and the Barrett-Lennard haematite conglomerate, have a north-westerly sub-horizontal NRM, while the NRM of the Mount Whaleback ores lies in the north-west direction with a positive inclination around 55°. NRM of Marra Mamba surface martite-goethite ores generally has a north-westerly sub-horizontal Fisher-mean direction, but the difference between the Fisher and vector means is large. Dolerite dykes and Cheela Springs Basalt have a relatively high NRM intensity, but the directions are scattered. NRM of other units has a low intensity and is insignificant for magnetic modelling. Weathering and lightening have greatly affected the magnetic properties of some of the surface samples. Reasonable estimation of the characteristic susceptibility and NRM of BIFs from the data gathered from surface samples remains a crucial problem for achieving better magnetic anomaly interpretation, which is the aim of the next stage of the study.

POSTERS (II)

A Geophysical Case Study of the Ashmore Kimberlite Cluster, North Kimberley Province, Western Australia

J. Sumner, P. Wilkes, J. Robins, R. Ramsay

Abstract

Since 1980, airborne radiometric, magnetic and electromagnetic (DIGHEM) surveys, and ground magnetic, electromagnetic (SIROTEM, EM-34, GEM-2A), and gravity surveys have been employed in kimberlite exploration in the North Kimberley Province of Western Australia. However, none of the regional surveys have yet been able to detect a kimberlite cluster prior to discovery by traditional indicator-mineral sampling. The discovery in the Beta Creek project, by Striker Resources N.L., of two new diamondiferous kimberlites (Ashmore 1 and 2) beneath surface concentrations of chromite, provides a site to characterise the style and dimension of their geophysical response. The Ashmore 1 and 2 pipes intrude Proterozoic Warton Sandstone and each have a surface area of approximately 0.5 hectares. The diatremes consist of magmatic cores surrounded by sandstone/kimberlite breccias. In the upper section, weathering has reduced the kimberlite to kaolinite clay and the pipes are overlain by up to 20m of slightly silicified sandy overburden. Detailed gravity and frequency domain EM surveys demonstrate that a 0.5mGal low and increased conductivity are the results of the weathering of the near surface kimberlite. The underlying fresh kimberlite consists of several intrusive phases, some of which produce strongly positive magnetic anomalies. The results of the study to be presented in this paper demonstrate that coarsely spaced airborne surveys are unlikely to detect the small, commercially significant kimberlites that occur in the North Kimberley. Geophysics is best applied to the generation of drill targets, from high resolution airborne and ground based surveys, after indicator mineral sampling has detected prospective areas.

POSTERS (II)

NORMAG: Development of a GPS - Ground Magnetometer System

K. Mayes, J. Cook, M. Sharry

Abstract

Recent advances in GPS technology have enabled the development of a low-cost ground magnetometer system with the potential to completely supersede traditional grid based magnetic surveys. No longer is there the inconvenience of having to stop to take each reading, relying on a constant walking pace or the hassle of using topofil. The processing for all of which assume the operator is walking a perfectly straight line along a pre established grid which is rarely the case. A system that is GPS positioned enables the operator to tailor the survey while in progress. A few infill lines or extensions to the survey can easily be accommodated. The system uses off-the-shelf components, and only the back-pack is manufactured. This has the advantage that equipment can simply be hired to add a second field system, or

maintain production when a field break-down occurs. The Geometrics G-858 caesium magnetometer was chosen because of its high sensitivity and excellent in-field display of the recorded magnetic profile. The GPS unit is a Trimble Pro XL/XR 12 channel model, with positional accuracies that are reliably 0.5m. A key component of the system is the 32bit Windows based software used to process and integrate the magnetic and positional data. After the initial calibration at the beginning of the day, the simplicity of the system is such that only two keys need be pressed. One for the start of a line and another for the end of a line. Consequently field crew training is easy, the potential for operator error is minimal, and field production rates are high. The system offers significant improvements in both survey quality and productivity. The magnetic data is acquired faster, more accurately and at less cost, all of which are highly desirable outcomes. It can be easily adapted to record a multiplexed signal of MMR and magnetics to give similarly high-resolution resistivity. This paper describes the development of the Normag system together with case studies derived from some of the several thousand line kms of data already acquired in Australia, Africa, Europe and America.

PRE-STACK DEPTH MIGRATION

Pre-Stack Depth Migration Experience in Less Complicated Geological Environments

G. Williams, B. Gosling, S. Hollingsworth

Abstract

Depth migration differs from time migration in that it images seismic data correctly in the presence of lateral velocity changes. However, for mild lateral velocity gradients we often use time migration for reasons of cost and stability; the time spent deriving an accurate velocity field and the increased sensitivity of depth migration to the velocity field make depth migration more difficult to apply. For these reasons, depth migration has often only been used when time migration is perceived to fail to image the data properly. Very often, this means that depth migration is only used in particularly difficult and complex geological environments. Unfortunately, in these environments, depth migration is often disappointing because either the ray paths diverge causing the subsurface not to be illuminated by the recording, or our current model building techniques are inadequate for such complicated cases. For example, many model updating techniques assume the starting model is either close to the correct answer, or it is slowly varying or flat horizons exist. Experience in the Browse Basin and the North Sea has shown that pre-stack depth migration can be used to improve imaging substantially in comparatively simple geological environments. In the case of the Browse Basin, rugged seabed topography can cause imaging problems throughout the data that can be addressed successfully with pre-stack depth migration. It is worth noting that in this context no well information or geological model from an interpreter was necessary; building the model became almost entirely a velocity picking exercise. In many parts of the North Sea a chalk layer with gentle dips lies above the oil and gas bearing targets. The chalk has an interval velocity that is typically twice that of the overburden and the underlying strata. Consequently, the gentle dips at the top and bottom of the chalk are sufficient to cause image distortion at the reservoir level that can only be corrected using pre-stack depth migration. In these cases, pre-stack depth migration can be viewed as a tool to obtain better images and higher resolution rather than a tool to obtain an image at all.

PRE-STACK DEPTH MIGRATION

Pre-Stack Migration Using the Equivalent Offset Method

J. Bancroft

Abstract

A method of prestack time migration is presented that is simpler, faster, and provides better velocity information than conventional Kirchhoff methods. It is based on prestack Kirchhoff time migration and can be applied to both 2-D and 3-D data. The method is divided into two steps, a gathering process that forms common scatterpoint (CSP) gathers and an imaging process using a Kirchhoff migration performed independently on each CSP gather. The CSP gathering process sums input traces into equivalent offset bins in each CSP gather with no time shifting. The equivalent offset is defined by an exact hyperbolic simplification to the double square root (DSR) equation of prestack time migration. A CSP gather is similar to a CMP gather as both contain offset traces, and both represent a vertical array of scatterpoints. CSP gathers can be formed at any arbitrary location, have high fold in their offset bins, and have a much larger offset range due to the gathering of all input traces within the migration aperture. After the CSP gathers have been formed, conventional velocity analysis estimates accurate prestack migration velocities. The high fold and large offsets of the CSP gather provide better focusing for improved velocity analysis. The imaging process collapses each CSP gather into a single migrated output trace. It is performed as a Kirchhoff process, which consists of scaling, filtering, normal moveout (NMO) correction, and stacking. Significant computational savings result from delaying arithmetic operations on the input samples until after a CSP gather has been formed. This space-time domain method is suitable for uneven geometries, may be adapted to migrate from topography, enables velocity analysis at random locations, and permits prestack migration of a 3-D volume into an arbitrary 2-D line. The method is also used to prestack migrate converted-wave (P-S) data and to compute residual statics before NMO correction.

PRE-STACK DEPTH MIGRATION

MITAS: Migration Input Trace Aperture Selection

M. Marcoux, C. Harris, S. Bickel

Abstract

Depth migration images using the Kirchhoff method are shown improved by applying "surgical" muting after migration moveout and before summation. The aperture construction we describe is fundamentally different from controlled illumination. In controlled illumination, the aperture control is based on structural and velocity depth models. In migration input trace aperture selection, it depends on the appearance of the migration corrected

data set, analogous to reflection surfaces that after summation determine the reflector event. Reflection event surfaces, pre-moveout, are surface referenced recordings whereas the reflector event surfaces, post-moveout, are subsurface referenced. For significant output after the sum, the reflector event surfaces must have stationary regions. Muting selects the stationary zones that are usually observed as "flat spots". Non signal and a significant amount of aliasing can be removed. The size and amplitude of flat spots are a reflector-localised measure of the depth, reflectivity and region of the reflector about the output "point" that accounts for the reflection recorded.

CROSSING TECHNICAL FRONTIERS
IN MINERAL EXPLORATION (I)
KEYNOTE ADDRESS

Geophysics as Centrepiece: Its role in the Australian Antarctic Territory

Pat Quilty AM

Abstract

Geophysics has had a key role in the Australian National Antarctic Research Expeditions (ANARE) since their inception and, indeed, the entire system of government of the Antarctic depends on the spirit of scientific co-operation as was exercised during the International Geophysical Year of 1957/58. The preamble to the Antarctic Treaty refers to the '... co-operation on the basis of freedom of scientific investigation as applied during the International Geophysical Year.' Geophysics, specifically the search for the South Magnetic Pole to test Gauss' dipole hypothesis, was a major justification for voyages of exploration in the mid 19th century and was an important quest into the early days of this century. Most current Antarctic research areas depend on a geophysical foundation. Geophysics is seldom conducted as a discipline for its own sake but as a subject contributing to resolution of major scientific questions such as what are the cratonic units and boundaries constituting the Antarctic continent, nuclear test ban monitoring, why Antarctica has so few earthquakes, and documentation of our few active volcanoes. Australian Antarctic stations conduct observatory programs in seismology (including Nuclear Test Ban Monitoring) and magnetics, and with the advent of refined satellite positioning systems and interest in global change issues, geodesy has emerged as a rejuvenated focus. Recent budget decisions have thrown into doubt the ability to continue some of these activities. There is immense scope for expanded field geophysics programs especially in aeromagnetic and gravity surveys both onshore and offshore, and seismic surveys offshore for global change and broader scientific value. Australia is still a minor contributor to these programs but offshore seismic programs have become more important in recent years. Because of the great area, small number of workers, the cost of programs and lack of obvious client group, there are major gaps in our geophysical understanding of the Antarctic, and major questions have yet to be defined and answered.

CROSSING TECHNICAL FRONTIERS
IN MINERAL EXPLORATION (II)

Mapping Dykes Using Surface and Downhole Seismic Methods

B. Evans, M. Urosevic

Abstract

Seismic methods are commonly used for the detection of faults in the exploration and production of coal. The use of surface seismic methods for the delineation of vertical structure, such as the imaging of dykes, is not used in industry because seismic waves transmit from the surface down to horizontal reflection surfaces, and reflect back up to the surface. Consequently, where sub-vertical structures such as dykes occur, the surface seismic method fails. Seismic methods can be applied using different source-receiver geometries. Their ability to image dykes may therefore depend upon on the geometry used, the dyke thickness and the seismic wave propagation mode in relation to dyke composition and internal structure. The use of surface seismic methods makes it difficult to distinguish between faults/fractures and very thin dykes (1-2m in thickness) when a dyke's thickness is less than the seismic wavelength. Consequently, borehole seismic methods have to be used to detect the presence of dykes. This paper presents some results from a research project which is attempting to use both surface and downhole seismic to detect dykes. The paper shows how a sub-vertical dyke of some 40 m thickness and associated faulting was imaged using surface seismic methods. The alternative approach of going downhole with seismic sources and receivers (borehole seismic profiling), showed that dyke sides can also be successfully imaged at depth, and that in future, it should be possible to produce an image of both sides of a dyke, in its correct orientation, using existing boreholes.

MAGNETIC METHODS & CASE STUDIES

Geophysical Signatures of the Iron Duchess and Iron Princess Deposits, Middleback Range Area, South Australia

M. Dentith, T. Dhu, G. Bubner, R. Hillis

Abstract

Outcropping deposits of iron ore occur throughout the Middleback Ranges in central South Australia. Several of these deposits are currently being mined. Since 1995 BHP Steel has been actively exploring for new reserves. The work described here was carried out to characterise the geophysical signature of two deposits of different type to assist in exploration for similar deposits concealed by cover. The first deposit, Iron Duchess, is typical of the deposits in the southern part of the study area. The other deposit, Iron Princess, is unusual in its geological setting, but is most significant in that it is the only blind deposit known in the area. The iron ores of the Middleback Range area formed by supergene enrichment of the magnetite-rich BIF. The enrichment process involves dissolution of gangue minerals and partial or total replacement of magnetite by haematite and martite. All deposits, where a stratigraphy can be recognised, occur within fold structures where the original rock types were structurally thickened and exposed by weathering. Shear zones are also commonly associated with mineralisation. Density measurements indicate that iron ore in both the studied deposits had a

density greater than the host rocks. However, the ore was more susceptible than the host at Iron Princess, but less magnetic than the host at Iron Duchess. Remanent magnetism was random in both deposits. Interpretation of aeromagnetic data showed this to be an efficient means of mapping stratigraphy and structure, although significant processing, notably the use of automatic gain control, was required to make the best use of the data. Gravity surveys showed both deposits to be associated with clear positive anomalies. In contrast, ground magnetic data are much less useful for direct detection of ore bodies due the variability of magnetic responses.

MAGNETIC METHODS & CASE STUDIES

Remote Determination of Magnetic Properties and Improved Drill Targeting of Magnetic Anomaly Sources by Differential Vector Magnetometry (DVM)

D. Clark, P. Schmidt, D. Coward, M. Huddleston

Abstract

The induced magnetisation of a magnetic source is proportional to the ambient magnetic field and varies in response to natural geomagnetic variations, such as diurnal changes, storm fields and pulsations. In contrast, the remanent magnetisation is independent of changes in the ambient field. The local perturbation of the geomagnetic variations arising from a subsurface magnetic body can be determined by simultaneous monitoring of geomagnetic variations at two sites: one within the static magnetic anomaly associated with the body and another at a remote base station. Total field measurements can only provide a qualitative indication of the relative contributions of remanent and induced magnetisation to the anomaly. Monitoring of all three field components at the on-anomaly and base stations, however, allows the components of the second order gradient tensor of the anomalous pseudo-gravitational potential to be determined. This tensor depends only on the source geometry and the measurement location and is independent of the nature (remanent or induced), magnitude or direction of the source magnetisation. Without making any assumptions about source geometry or location, the Koenigsberger ratio (Q), the direction of remanence and the direction of total magnetisation can be obtained from the components of this tensor. This information can constrain magnetic modelling prior to drilling and remove a major source of ambiguity in magnetic interpretation. The direction to the centre of a compact source can be determined directly from diagonalisation of the tensor. Values of Q constrain the magnetic mineralogy of the source and the remanence direction can discriminate sources of different ages or geological histories. Thus the method can also alleviate the geological ambiguity that afflicts magnetic interpretation. Field trials of differential vector magnetometry (DVM) at several sites, including the Tallawang magnetite deposit, New South Wales, have demonstrated the validity of the proposed in situ method. However, a number of technical difficulties must be resolved before this method can be used routinely. Accurate characterisation of departures from mutual orthogonality of the components measured by each vector sensor, and the relative orientation of the anomaly and base station sensors, are crucial to the successful implementation of the method.

MAGNETIC METHODS & CASE STUDIES

The Magnetic Daily Variation in Australia: Dependence of the Total-Field Signal on Latitude

A. P. Hitchman, F. E. M. Lilley, W. H. Campbell, F. H. Chamalaun, C. E. Barton

Abstract

The quiet daily variation, denoted Sq, occurs as a background signal during magnetic surveying. The morphology of Sq is dependent on a number of factors, particularly latitude. Type curves that describe the latitudinal dependence of the horizontal and vertical components of Sq on a global scale appear in many texts. This paper describes a recent compilation of global Sq curves for the total magnetic field, which is the component of most relevance to magnetic mapping. An analysis is then made of total-field variations from a north-south line of stationary recording magnetometers which operated across central Australia as part of the AWAGS experiment of 1989-1990. These data are analysed for information on the magnetic daily variation across the Australian continent, particularly its latitudinal variation. Observations cover a full year and their analysis is divided into four seasons to show variation with season as well as latitude. The observed data show a minimum in the total-field signal in the geomagnetic latitude band 20deg. - 30deg., in support of the global Sq total-field curves. There is also clear evidence in the AWAGS data for the path of the Sq focus across Australia, identified by an amplitude minimum in the daily variation of the horizontal magnetic north component. The band in which the total-field Sq variations are generally reduced is termed the total-field 'doldrums'; this band is on the equator-side of the path of the Sq focus.

PETROLEUM CASE HISTORIES: INTERNATIONAL

Hydrocarbon Potential in Indian Deep Waters

R. Singh, S. Rawat, K. Chandra

Abstract

Deep water exploration is a natural step forward to assess and accrete the hydrocarbon reserves to add to the endowment after having accomplished this task to a certain extent along the continental shelf areas of India. Oil and Natural Gas Corporation Limited of India (ONGC) has made gradual but steady progress in the deep waters beyond 200m isobath exploring hydrocarbons, acquiring multi-channel seismic data and other geo-scientific data in recent years. Hydrocarbon potentiality in the deep water areas of known offshore basins viz. Kutch, Bombay, Kerala-Konkan, Cauvery and Krishna-Godavari is analysed in this paper. The evolution of these polycyclic basins was initiated as intracratonic rifts in divergent margin set-up at different geological times. Later these basins acquired pericratonic character evolving through typical syn-rift and post-rift phases. The recently acquired seismic data corroborates the extension of identified lineaments in deep water area differentiating the deep sea basinal region into segmented linear ridge-depression complexes. The sedimentary thickness in these deep sea basins varies between 2 and 8 km, with areas of higher thicknesses being near the shelf break and in areas beyond 2500m water depth in the proximity of various river mouths in different basins. The hydrocarbon potential of deep waters of India covering about 1.4 million sq. km of the Indian offshore is estimated to be between 5.0 and 9.0 billion tonnes of oil and oil equivalent gas. Analysis of about 70,000 km seismic data has helped in identifying and mapping the geological features like submarine fans, turbidites, build-ups, wedge-outs, growth fault related roll-over anticlines and other structural features for hydrocarbon prospectivity in these basins. These prospects range in size from 10 to 600 sq. km area in water depth from 300 to 2000m. The average prospect size is about 200sq. km in the western offshore and about 20sq. km in the eastern offshore. Exploration of these will help in establishing a resource base for future energy supply of India.

PETROLEUM CASE HISTORIES: INTERNATIONAL

"The First Year of First Oil" from Azerbaijan, a Former Soviet Union Republic: The Development of a South Caspian Giant Oil Field

M. Hession, T. Redshaw, J. Gorman

Abstract

On November 7, 1998 Azerbaijan will have been exporting oil to the "West" for one year.

The first development in one of the world's most significant hydrocarbon provinces is now establishing a track record. The exported oil comes from the Gunashli-Chirag-Azeri field complex which is located 85km south-east of the Apsheron Peninsula in the South Caspian Sea. More than 12 billion BOE are trapped within an elongate, north-west to south-east trending anticlinal Pliocene reservoir, which is approximately 40 km in length. Sparse pre-existing well data and 2D seismic data gave limited insight into the likely reservoir performance of this huge structure. An accelerated development program resulted in the first 3D acquisition in the region. Post processing and data analysis during an initial 2-year period have achieved various degrees of success in this unique oil province.

The interpretation has been predominantly geophysical making the acquisition and processing of good quality seismic data critical for accurate drilling depth predictions. Much of the geophysical effort has been directed towards amplitude and coherency analysis plus AVO prediction and correct depth positioning. A brief overview of techniques used is presented in this paper.

The geological knowledge of the reservoir formations has been improved through the study of cores in appraisal wells, which have been gathered using soft sediment coring techniques. Challenges include hole stability and accurate pore pressure prediction in top/intermediate hole sections teeming with mud volcanoes and shallow gas. The present and future will see the use and application of pre-stack migrated seismic data to allow better structural imaging, depth conversion and detailed investigation into encouraging seismic amplitude variation. The seismic work program will continue to be directed at the optimised management of the reservoir as the first developed segment heads towards plateau.

PETROLEUM CASE HISTORIES: INTERNATIONAL

Ocean-Bottom Seismograph and Conventional Reflection Surveys in the Petrel Sub-Basin: an Integrated Seismic Study

A. Goncharov, C. Collins, P. Petkovic, T. Fomin.
V. Pilipenko, B. Drummond, C. Lee

Abstract

Refraction/wide-angle seismic studies with ocean-bottom seismographs (OBSs) in the Petrel sub-basin were a part of a broader OBS survey undertaken by AGSO along 5 profiles on the Australian North West Shelf. The project provided velocity information to better constrain the depth conversion of AGSO's regional deep reflection profiles on the Shelf. One of the main scientific goals of this project was to understand better the origin of

reflectivity seen in the conventional reflection data, particularly in the deep crust. Other objectives of the survey were to identify the base of the sedimentary section; identify major intra-crustal boundaries, and particularly the crust-mantle boundary; and estimate S-wave velocities. The OBS data were recorded with a 100 m shot interval and were therefore not spatially aliased with respect to prevailing velocities and frequencies. This enabled the utilisation of seismic digital processing techniques not normally used to process data recorded with refraction/wide-angle observation geometries. F-k filtering, which was used in a non-conventional fashion to enhance signal/noise ratio, and depth migration of wide-angle reflections are particularly important.

Prominent reflectivity seen in the conventional reflection data at two-way times (TWT) greater than 4 s does not correspond to any velocity increase imaged by refraction/wide-angle techniques. On the other hand, the most significant velocity increase which occurs at the Moho does not produce high-amplitude near-vertical reflections. Interval velocities estimated from the conventional reflection data at TWT greater than 2 sec appear to be up to 1 km/s lower than those derived from the OBS data. If the first are used to depth convert reflection data, then depth to seismic boundaries in the centre of the basin at TWT 6-9 s would be underestimated up to 2 km. Seismic reflection and refraction techniques are complementary to each other, and both are required to fully interpret the data.

INDUCED POLARIZATION

Radial Resistivity/IP Surveys using a Downhole Transmitting Electrode

S. Mudge

Abstract

The sensitivity and resolution of surface resistivity/IP surveys is severely restricted by the conductivity and thickness of overburden material. An electrode array, using a buried transmitting electrode, has been devised to increase the sensitivity and resolution of surveys conducted in these environments. The transmitting electrode is located below the conductive overburden, in a drillhole, and voltage and chargeability measurements are made on the surface along survey lines radial to the drillhole. Reconnaissance resistivity/IP surveys using the electrode array were conducted in the Cambro-Ordovician Mt Windsor Volcanics near Charters Towers in Queensland, an area covered by the electrically conductive Late Tertiary Campaspe Beds, and demonstrate the effectiveness of the array for detection of anomalies from buried base metal targets. Data were acquired from several surveys conducted around a series of adjacent drillholes to provide a continuous coverage across the prospective area. The data from individual radial traverses show the sounding response of the ground as well as the ground response along the profile. A method for removing the sounding response, which is local to each drillhole, from each radial traverse has been devised so that the data from each traverse can be merged into a continuous data set.

INDUCED POLARIZATION

Electromagnetic Coupling for Tensor Reconnaissance IP Surveying

T. Grant

Abstract

IP/resistivity surveying is well established as an important tool in the exploration for sulphide mineralisation. The most common survey configurations used today are the dipole-dipole and gradient arrays. In comparison, the bipole-dipole or 'reconnaissance IP' (RIP) array is relatively unknown and unfamiliar. However, this survey configuration is often worth considering because it offers important advantages for exploring large areas in a rapid and cost effective manner.

With the use of large fixed transmitters, and potentially large transmitter-receiver separations, it is important to consider electromagnetic (EM) coupling effects for the RIP array. This study presents numerical modelling results for a simulated frequency-domain RIP survey over a conductive half-space.

EM coupling for 'vector' mode calculations (using measurements from a single transmitter) exhibit a fairly simple behaviour of increasing phase with increasing distance from the transmitter. The EM coupling phase response has the same sign as a normal IP response. However, EM coupling for 'tensor' mode calculations (using measurements from two separate, near orthogonal transmitters) exhibit a more complex behaviour with regions around the transmitters having both positive and negative phase responses. This theoretical EM coupling behaviour is demonstrated in actual field measurements.

Importantly, modelling results indicate the standard frequency domain EM coupling removal scheme known as '3-pt de-coupling' or 'phase extrapolation' is as effective for the RIP array as it is for the dipole-dipole and gradient arrays. That is, even though the EM coupling response is more complex spatially for the RIP array, in typical resistivity environments, it is not too severe for careful application of the phase extrapolation technique, which requires good quality data particularly at the lower frequencies.

INDUCED POLARIZATION

To Remove EM Coupling from IP Data in Situ

J. He

Abstract

IP is an effective method for metal ore finding, however EM coupling in low electric resistance areas such as the western area of Australia has reduced much of its effectiveness. The nature of EM coupling difference between time-domain and frequency-domain has been interpreted in the article firstly. It is pointed out that EM coupling could be removed from IP easily in the frequency-domain under strong EM coupling. We also provide two methods for the removal of EM coupling from IP: coupling cutting and dual-frequency coherency demodulation. The former cuts the component mainly composed of EM, the latter removes active and negative EM by themselves. The two methods can retain the IP component very well, but the latter is a unique feature of

Dual-IP. The author has taken a Dual-IP instrument to Australia and Malaysia in 1996. Some in-situ tests were carried out, and valid IP data were acquired. Dual-IP technology has been widely used in continental area of China. Some representative cases are listed in the article.

GEOPHYSICS IN NSW

Positive Impacts and Future Direction of Discovery 2000

D. Robson

Abstract

The New South Wales Government Discovery 2000 Exploration Initiative (Discovery 2000) will continue to provide the products for companies to further develop their exploration strategies. In its first four years this program has been very successful and exceeded many of its original goals. Overall State-wide mineral exploration activity has increased by 60% with total annual expenditure now over $100 million. One of the successes of the Discovery 2000 program has been to encourage both mineral and petroleum explorers into "new" areas, not previously considered to be prospective. Within the Discovery 2000 mineral project areas there are 160 new Exploration Licences (EL's). This covers about 21% of all ground under EL's in the State. Sixty-seven companies, ranging from majors to juniors, have taken out exploration titles. Petroleum exploration has more than doubled and is at the highest level of activity for over 30 years. This is particularly evident in the Darling Basin where there is significant potential for large gas bearing structures. The Discovery 2000 information systems projects are close to completion. The world-class Digital Imaging Geological survey System (DIGS(r)) is now operational and provides rapid retrieval of company exploration data. Over half a million documents (text and maps, both black and white and colour) have been scanned and indexed. Geoscience Data Packages on CD-ROM have been released over all of the Discovery 2000 mineral areas. These packages contain all available geophysical imagery, geological and geochemical data. A feature of these packages is a first-pass interpretation of the geophysical data.

A sum of $10 million is be spent over the next 2 years. New areas being considered for airborne geophysical and gravity surveys including the Cobar / Nymagee area , the Gilmore Structure and along the Peel Thrust. With the help of the Discovery 2000 initiative, New South Wales is increasingly being recognised as an attractive target for mineral and petroleum resources development.

GEOPHYSICS IN NSW

The Palaeozoic Koonenberry Fold and Thrust Belt, Far Western NSW: A Case Study in Applied Gravity and Magnetic Modelling

N. Direen

Abstract

Geophysical modelling combined with recent geological mapping indicates that the Koonenberry belt of far western NSW is a Mid Palaeozoic fold and thrust system. This new interpretation relies upon the different petrophysical and structural attributes of four distinct tectono-stratigraphic packages.

Package 1 comprises mixed, multiply deformed, Late Neoproterozoic - Late Cambrian rift and continental margin sequences. Package II comprises Late Cambrian - Early Ordovician mixed carbonate-siliciclastic facies, and has been subjected to two minor and one major deformation event. Package III contains fluvial-lacustrine red beds and volcanics with one major and one minor set of folds. Package IV is the Late Devonian Mulga Downs Group, a generally flat-lying fluvial cover sequence with restricted folding. Fault kinematics are constrained by analysis and modelling of geophysical data, which indicate across-strike repetitions of various sequences. High spatial frequency magnetic linear features require steep surface dips, but listric character is demanded by lower frequency magnetic anomalies which are best fitted by sub-horizontal bodies at mid-crustal depths. Detailed analysis shows many anomalies are skewed to the east near the positions of suspected faults. However the major Koonenberry Fault is a west-dipping back-thrust. These features strongly suggest that the Koonenberry belt is a west-vergent thrust package that detaches in the mid-crust. The principle fold-thrust deformation occurred during the Silurian, prior to deposition of package III, and probably corresponds to the Benambran event in the Lachlan Fold Belt. This deformation overprints a Late Cambrian event that has deformed Package I. These conclusions indicate that the Koonenberry Belt is a zone of overlap between the Lachlan and Delamerian Orogens.

POTENTIAL FIELD INTERPRETATION TECHNIQUES (II)

Multi-scale Edge Analysis of Potential Field Data

N. Archibald, P. Gow, F. Boschetti

Abstract

Mapping the three-dimensional distribution of rock properties from potential field data is a difficult and arduous task, with inherent ambiguity remaining a major problem. We apply a combination of automated interpretation procedures, based on multi-scale wavelet analysis and three-dimensional visualisation methods, to attempt to extract geometrical information from potential field datasets, and display this information in an easily understandable and intuitive way. The resulting visualisations are similar to 'worm' maps commonly produced by interpretation of aeromagnetic data, but are defined in three dimensions.

The techniques are tested on a series of synthetic and observed datasets, of varying complexity and scale. The tests show both the effectiveness of the technique as an aid to the geological interpretation of potential field maps and in its use for providing constraints on the three-dimensional geology.

The results of the testing on synthetic datasets show that for certain geometries there is an intuitive relationship between 3D edge location and shape, and subsurface geometries. Such relationships prove particularly robust even under 'noisy' conditions where fine scale features (i.e. the response of laterites in magnetic datasets) mask the coarser scale features that characterise the broader geological picture.

Three real datasets at different scales have been analysed. These include the Western Australian gravity dataset (representing the terrane-scale), aeromagnetic data covering a 1:100,000 scale map sheet from central Victoria,

and a mine camp-scale aeromagnetic dataset from a mineralised greenstone terrane in Western Australia. The results produce different information at different scales. At the continent-scale the multi-scale edges allow discrimination of different tectonic styles, and comparison of the significance of crustal-scale structures. At the district to mine camp scale the edges can be used for geological mapping purposes such as to map subtle changes in sedimentary sequences, map alteration patterns, and constrain pluton geometries at depth.

POTENTIAL FIELD INTERPRETATION TECHNIQUES (II)

Separation Filtering of Aeromagnetic Data Using Filter-Banks

T. Ridsdill-Smith

Abstract

Filter-bank transforms analyse the local frequency content of a signal. This information can be used to design matched filters that adapt to local properties of the data. Matched filters can be applied to aeromagnetic data to separate the responses of depth-varying magnetic layers and are known in this case as separation filters. The performance of filter-bank separation filters is demonstrated on two synthetic data sets, each with a deep and shallow magnetic layer with differing amounts of depth variation. The modelled data were analysed with a Gaussian filter-bank and conventional global Fourier methods. The Gaussian filter-bank method was more effective than the Fourier method when the depth to the layers was highly variable because the filter-bank was able to adapt to the changing local frequency properties of the data. The numerical accuracy of the Fourier method helped it perform better when the layers were at approximately constant depths because the observed data closely fitted the Fourier model. These results give a preliminary indication that the filter-bank approach to separation filtering provides an effective method for separating the anomalies of magnetic layers that vary significantly in depth. The method also automatically produces crude depth estimates of the layers which may be useful as a first-pass interpretation.

EM INTERPRETATION

Modelling the 3D TDEM Responses using the 3D Full-Domain Finite-Element Method Based on the Hexahedral Edge-Element Technique

F. Sugeng

Abstract

The finite-element method (FEM) has been used as a powerful method for solving complex modelling problems in electromagnetics. The straightforward approach in the conventional finite-element method to electromagnetic problems is to apply the FEM to Maxwell's equations directly and solve for the electric or the magnetic fields. Each component of the electric and magnetic fields is approximated independently using the basis function assigned at the element corner nodes. The method works well for some applications. However, the presence of inhomogeneous conductivity in earth structures implies that at the inter-element interface the normal component of the field is discontinuous and the tangential component of the field must be continuous. In this situation, where it requires an inherent constraint in the electric or magnetic fields, the approach used in the conventional finite-element method is not appropriate.

The use of the edge-element based FEM addresses these problems. It takes the whole vector of the field components in the approximation as one entity instead of independently and formulates the problem in terms of the electric or magnetic field components tangential to an edge of the element, guaranteeing continuity of the tangential components and allowing the normal component to jump at the element interfaces. The edge-element vector basis function is also constructed specially to be divergence free and hence in quasi-static approximation it satisfies the divergence free condition of the electric and the magnetic fields within each element.

An efficient and accurate 3D full-domain finite-element program was developed based on the hexahedral edge-element technique to calculate the TDEM responses of complex 3D geological structures. The results show that the program is capable of modelling complex 3D structures and works well at high conductivity contrasts (up to 100,000:1).

EM INTERPRETATION

Modelling the EM System Response of Geological Complexity Accurately

A. Raiche, F. Sugeng, Z. Xiong

Abstract

For many years, EM modellers were amongst the strongest proponents of the flat earth society because geological complexities such as topography, irregular bedding, dipping faults, curving boundaries and high conductivity contrast were too difficult to model. Using an edge-element method, we have been able to model these effects for 3D models for contrasts as high as 1 million to 1. We have also used conventional finite-element methods to model these effects for 2D models activated by 3D sources. The question is: are these results right?

Simpler models such as multiple thin sheet structures with arbitrary orientation and multi-block models in layered hosts continue to remain useful for a variety of modelling tasks. These are based on integral equation and hybrid methods. By applying programs based on different mathematical algorithms to similar structures, we are able to establish regimes of accuracy for each. Eventually, this should allow us to establish empirically derived discretisation criteria for model building. We describe the scope of our five major programs and present an example of cross verification against a simple model.

Accurate modelling must also account for EM system effects such as transmitter waveform, stacking algorithms, receiver windows and system geometry. We show an example of using a program to compare the resolution capability of helicopter and fixed wing AEM systems plus an example of the errors of not modelling the transmitter orientation correctly. Finally, we discuss issues relating to the use and development of modelling software.

MINERAL CASE HISTORIES: AUSTRALIA (II)

Structure of the Highly-Mineralised Late-Archaean Granitoid-Greenstone Terrain and the Underlying Crust in the Kambalda-Widgiemooltha area, Western Australia, from the Integration of Geophysical Datasets

M. House, M. Dentith, A. Trench, D. Miller, D. Groves

Abstract

The highly mineralised (Au, Ni) Kambalda-Widgiemooltha area comprises typical late Archaean granitoid-greenstone sequences, and is situated within the Kalgoorlie Terrane of the southern Norseman-Wiluna Belt in the Yilgarn Craton of Western Australia. In the Kambalda-Widgiemooltha area high-resolution aeromagnetic data, two deep seismic reflection profiles and gravity data are available to examine the geophysical signature and three-dimensional structure of this important area. The Kambalda-Widgiemooltha area is divided, from west to east, into three fault-bounded domains, the Coolgardie, the Kambalda and Parker Domains. Lithological associations and structural features defined by the aeromagnetic data substantiate the division of the study area into three north-north-west-trending domains, and indicate that each domain consists of two, approximately equal-width, sub-domains. A four stage deformation sequence is recognised from the aeromagnetic data which includes early recumbent folding and thrust repetition (D1), regional north-north-west folding and imbrication (D2), transcurrent movement on major north-north-west shear zones (D3), and the formation of late north-north-east and north-west-trending lineaments (D4). Two deep (20s TWT) seismic reflection profiles across the Coolgardie and Kambalda Domains reveal a three-layered crust beneath the study area. The upper layer, which includes the greenstone belt, is generally unreflective in the upper 5 km, becoming more reflective towards its base at 7.5 to 10 km depth. The lower part of this layer is more reflective and comprises a felsic unit that could be a continuation of the greenstone belt stratigraphy, attenuated basement, or rift-related sedimentary rocks. Domain-bounding faults are interpreted as listric structures that have allowed the partial imbrication of the domains during regional deformation. The middle layer extends to between 23 - 27 km and it is characterised by moderate to strong, variably dipping reflections. It is interpreted as an imbricate sequence of granitoids and gneisses. A more homogeneous, but weakly reflective, character is indicative of the lower crustal layer. East-dipping truncating reflectors at the western margin of the study area suggest that this layer is younger than the upper and middle layers and may, therefore, represent the late-tectonic external granitoids. The Moho is not imaged, but a general decrease in the number of reflections indicates that the crust is about 35 km thick.

MINERAL CASE HISTORIES: AUSTRALIA (II)

Mapping Australian Geology Under Cover: A Model Study Applied to the Boulia and Springvale 1:250 000 Map Sheet, Queensland

T. Mackey, P. J. Gunn, A. Meixner, D. Blake

Abstract

The Australian Geological Survey Organisation has produced an interpretation of aeromagnetic, gravity and available outcrop and drill information for the Boulia and Springvale 1: 250 000 map sheets that cover the area where units of the prospective Mount Isa Inlier plunge southward beneath a cover of flat lying Cambrian and younger sediments. A methodology has been developed for this interpretation which could be used as a basis for a nation-wide study of "Australia under cover". The prime basis of the interpretation was aeromagnetic data which maps magnetic basement units beneath the generally magnetically transparent cover units. Magnetic images map magnetic units and the starting philosophy of the magnetic interpretation was to produce an initial "magnetic source map". To assist this task various processing and enhancements, and enhancements of the geophysical and geological data were prepared as GIS layers. The interpretation was produced as a GIS overlay. The outlines of magnetic sources (together with depths, depth extents and dips where possible) were estimated on the basis of the laws of magnetic induction assisted where appropriate by reference to compilations of model magnetic body responses. The magnetic source map can be regarded as a fact map, that could be produced by any competent physicist with no knowledge of geology. The geological stage was reached when, as far as possible, geological identifications were assigned to the magnetic sources and structure and the distribution of non magnetic units was inferred. The stage of geological identification used ancillary information such as outcrop geology, drill information and gravity data plus geological reasoning based on forms, associations and amplitudes of the magnetic sources. Structure was deduced from the geometrical relationships of sources. As well as defining the continuation of the units of the Proterozoic Mount Isa Inlier, the interpretation also defined the thickness of the overlying Cambrian Georgina Basin sediments in the area thereby providing a guide to the petroleum prospectivity of the area. Previously unknown volcanic units were identified within the Georgina basin sediments plus a series of intrusive features that appear to have traversed the Georgina basin section so that their tops are close to the present day land surface. The intrusions have dimensions and characteristics similar to kimberlite pipes.

MINERAL CASE HISTORIES: AUSTRALIA (II)

The Nature of the Basement to the Kimberley Block, North-western Australia

P. J. Gunn, A. J. Meixner

Abstract

Interpretations of aeromagnetic data to define the nature of the basement beneath the sediments of the Kimberley Basin of north-western Australia are complicated by the magnetic effects of the extensive hotspot related Hart Dolerite and Carson Volcanics and related feeders which occur within the sediment section of the Kimberley Basin.

The magnetic effects of these sources can however be suppressed by upward continuation and stabilised downward continuation to reveal what appears to be a largely granitic basement to the area. Computer modelling has defined the geometry and density and magnetic characteristics of what may be a remnant of an ophiolite slice emplaced under the south-eastern margin of the Kimberley Block during subduction related to the convergence of a Kimberley "micro-continent" with the main Australian continent. Linear gravity lows over the Kimberley Block may define granites formed as a result of the subduction process. Five north-east trending zones of differing lithologies can be identified in the basement on the basis of differing characteristics in their associated magnetic and gravity fields. A conjugate dyke-filled fracture system, apparently related to Devonian-Carboniferous rifting processes has been superimposed on the area. Suites of these fractures are located over areas interpreted as junctions between zones of different lithologies in the basement.

OIL EXPLORATION: TOMOGRAPHY
KEYNOTE ADDRESS

Limitations of Geotomography

S. Greenhalgh, T. Gruber

Abstract

Much has been published in the literature on geo-tomographic techniques, but little is known about their basic limitations or usage guidelines. For example, what image resolution can one expect for a given experiment geometry? In particular, various implicit or explicit assumptions are left unquestioned and their potential impact on inversion results remain unknown.

Most inversion methods, based on a chosen forward model, are actually search algorithms for a global minimum in a non-linear, high dimensional function space. Mathematical techniques for true non-linear inversion are widely available. However, the high dimensionality of the function domain makes them, at this point of time, infeasible for application in seismic tomography. Instead, linearised minimisation is frequently used in iterative minimisation schemes, with the assumption that a global minimum or a minimum sufficiently close to the real world situation can be found.

The high dimensionality of the function space also makes it impossible to rigorously analyse such inversion schemes in terms of convergence, stability and predictability. Consequently, the reliability of inversion results is not well understood and largely neglected in the seismic tomography literature.

The synthetic experiments reported here illustrate the serious effect that inadequate spatial sampling and noise have on image reconstruction. Even minor errors, due to rounding and inaccuracies in forward modelling, get greatly amplified in the tomograms. The results obtained enable a better understanding of the sensitivities and limitations of tomographic inversion.

OIL EXPLORATION: TOMOGRAPHY

A High-Frequency Downhole Sparker Sound Source for Crosswell Seismic Surveying

S. Bierbaum, S. Greenhalgh

Abstract

Traditionally seismic exploration techniques have not been widely used in hard rock mining and exploration environments. To facilitate faster and more accurate shallow high-resolution seismic surveys a high-frequency electric discharge (sparker) seismic source was developed. The main design requirements of this source were that it (1) achieve rapid downhole firing, (2) fit down surface diamond drill holes (70mm diameter), (3) provide similar energy level and frequency content to a seismic detonator so as to produce useful sharp signals over a distance up to 200 meters, and (4) it should be highly repeatable and reliable. The sparker system consists of a surface control and power source, winch cable and depth encoder, and a downhole probe. The 22kg downhole probe, which has a diameter of 60mm and length of approximately 3m, produces a discharge energy output of 480J. The innovation with this sparker is that the 60F, 5000V discharge capacitor is contained within the downhole probe, thus overcoming the problem of significant power loss through the high resistance of the cable and the effects of inductance experienced by other surface capacitor arc discharge sources. The sparker described does not include a discharge chamber, but instead relies on the saline conditions of a fluid filled borehole to enable explosive plasma bubble formation to occur. Initial field tests in the hard rock environment of Kambalda, Western Australia, provided some very encouraging results. The ability of the sparker to operate in a borehole under hydrostatic heads in excess of 250m and to produce clear received signals at distances in excess of 100m was demonstrated. The output signal of a single shot of the sparker compared very favourably with that produced by a seismic detonator under the same conditions. The firing rate in the field was found to be approximately 5 shots per minute. Repeatability of the signal was excellent.

OIL EXPLORATION: TOMOGRAPHY

A Later Arrival-Based Inversion Scheme to Recover Diffractors and Reflectors

T. Gruber, S. Greenhalgh

Abstract

Seismic tomography techniques based on first break time inversion are a convenient way to recover velocity fields. However, these techniques only use a small fraction of available seismogram data. Migration uses entire reflection seismograms but stops short of actual inversion, using a summing/averaging method. The result is a smeared image of diffractor points, which makes it difficult to recover weaker events. In this paper we develop a seismic inversion technique to recover diffractors and reflectors from full waveform seismograms by direct inversion, rather than a migration based approach. We choose a simple, idealised modelling scheme to highlight the basic advantages and limitations inherent to this class of inversion techniques, and derive

several important and generic guidelines applicable to the design and development of full-waveform-based inversion algorithms. We propose a modelling scheme for diffractions, reflections and refractions in an arbitrary velocity field. By using a source-wavelet estimation method, we linearise the forward model and are able to obtain a diffractor/reflector field recovery scheme that is based on standard iterative matrix inversion. Our investigation reveals that the algorithm provides super-resolution of the structure compared to the time-of-flight tomography and requires only a surprisingly small number of sources and receivers for successful operation. However, like all super-resolution systems it is highly prone to noise capture, where noise is any system unknown. In our case this translates into inaccuracies in the a priori velocity field estimate and the seismic wave shape/amplitudes. Our experiments show that the background velocity field needs to be known with an unrealistic accuracy of better than one percent, suggesting that this class of linearised inversion schemes is unsuitable for real-world data sets. The scheme highlights the pitfalls of any full waveform inversion approach. Without adequate amplitude/phase calibration, and velocity control, waveform dynamics can be mis-inverted to produce spurious structures.

ELECTRICAL & EM CASE STUDIES (II)

Geophysical Characterisation of the Region Around a Longwall Coal Mine: Electrical Properties at Appin, NSW

K. Vozoff, O. Engels, S. Lintker, G. Poole, P. Hatherly, X. Luo

Abstract

In order to predict surface Long Offset Transient Electromagnetic (LOTEM) survey response at Appin, NSW, models were run based on resistivity logs of the sedimentary section, from surface through to the coal measures. These gave the surprising prediction that the 3m Bulli coal seam would have a pronounced effect on the response in spite of its 400-500m depths, and thus mining of the seam should also be easily observed from surface. What is more, the effects of draining gases from the seam should be easily resolvable by repeat measures. However, LOTEM measurements repeated one year apart over the Appin Colliery showed effects ten times larger than could be explained by either of these other two mechanisms. The explanation is that the stress release with the mining led to subsidence extending over a thickness of at least 200m above the seam. Resistivity is greatly increased in the subsidence zone due to a drainage of water. This picture is in complete accord with repeated seismic reflection surveys and monitoring of microseismic events along the same line. The surveys were also a demonstration of the (DMT-patented) distributed EM field acquisition concept. They showed that very large volumes of multi-channel data can be acquired rapidly and economically using a seismic - like field system,. Such data are essential to multidimensional inversion and interpretation. The LOTEM measurements were carried out by HarbourDom Consulting and DMT (DeutscheMontanTechnologie) with support of the German Government, BHP and ACARP. The seismic work was done by BHP Coal, Collieries Division, and the microseismic work by CSIRO DEM. A more complete report will be prepared in the near future.

ELECTRICAL & EM CASE STUDIES (II)

Examples from a new EM and Electrical Methods Receiver System

A. Duncan, P. Williams, G. Turner, B. Amann, T. Tully, K. O'Keefe

Abstract

The SMARTem Electrical Methods Geophysical Receiver System has evolved during the last three years as a flexible new tool for TEM, IP and other electrical geophysical survey methods. This paper presents a brief description of that instrument and several case studies undertaken recently in Australia. First prototyped in mid-1995, the SMARTem receiver is now increasingly used in mineral exploration and ore delineation geophysics. Based on a rugged PC with a familiar operating system and programmed in a high level language, its aim is to increase the value of the data obtained in electrical geophysical campaigns. In addition to carrying out geophysical tasks in a graphics-rich environment it functions as a digital storage oscilloscope and spectrum analyser. SMARTem has been used in fixed-loop, moving-loop, borehole (conventional and 3-component) and underground surveys in both direct-trigger and crystal-synchronised modes. TEM data from Leinster and Kambalda in Western Australia illustrate the use being made of SMARTem in the exploration for nickel deposits in Western Australia. Data is typically collected in or around existing mine infrastructure where electrical interference from power grids and other sources is significant. Signal and data processing strategies have been developed and optimised to allow data of the desired quality to be collected at good rates of production. At Honeymoon Well, Western Australia, SMARTem work has been carried out over the Wedgetail Deposit - a popular site for tests of TEM instrumentation. Fixed-loop and moving-loop TEM data from the site is presented to illustrate this instrument's performance in the mapping of this very difficult geophysical target. Recently, SMARTem borehole TEM data has been collected underground at Mount Isa in the exploration for new Deep Copper ore bodies. Examples of data sets and processing results are discussed.

ELECTRICAL & EM CASE STUDIES (II)

An Historical Perspective on the Discovery of the Wilga Zn-Cu Orebody

S. Rajagopalan, S. Haydon, F. Lindeman, D. Barr

Abstract

The Wilga and Currawong Zn-Cu massive sulphide deposits lie within Silurian volcanics in the Limestone Creek Graben in a rugged and remote region of north-eastern Victoria. In the early seventies, Western Mining Corporation Ltd. followed up soil sampling geochemical anomalies with IP surveys. But drill holes, sited to test geochemical and/or IP anomalies, intersected disseminated pyrite and, in some cases, stringer chalcopyrite but no massive sulphides. No convincing EM anomalies could be confirmed from early EM surveys (Crone shootback on ground and frequency-domain in the air). In 1977-78, a Transient Electromagnetic survey was initiated after an extended trial using the Russian MPP0-1 system showed that the ground coverage was much better

than expected. The initial 50 m moving loop TEM survey over the Wilga Prospect revealed an elevated value at the last station on the last line. The survey was extended revealing a strong anomaly which was drilled and massive sulphides intersected (25.5 metres of 4.10% Cu, 0.46% Pb, 7.28% Zn and 31.5 g/t Ag). The deposit at Currawong, about 4 km to the NE of Wilga, was discovered after the 50 m loop TEM was replaced with 100 m loop TEM. The Wilga deposit consists of a single ellipsoidal lens giving a reserve of nearly 4 Mt grading 3% Cu, 6.2% Zn and 23 g/t Ag. The Wilga and Currawong deposits are both pyrite-sphalerite-chalcopyrite massive sulphides. The Wilga orebody was mined from 1992 till 1996 by Macquarie Resources in partnership with Denehurst Limited. The anomalous geochemistry, IP and gossanous zone at Wilga occur near the crest of a ridge and lie updip of the deposit. Detailed drilling at Wilga showed that it is a blind deposit, buried to about 80 m and lying parallel to the slope of the hill. The first unsuccessful drill-hole at Wilga, which was located on geochemical indications, missed the deposit by only 10 m. Both Wilga and Currawong are genuine geophysical discoveries. The prospective area was defined by geochemistry but both deposits were found by following up TEM anomalies after numerous drill holes sited to test geochemical anomalies failed to intersect massive sulphides.

POSTERS (III)

3D Seismic Survey in Reclaimed Land

M. Minegishi, N. Aoki, T. Matsuyama

Abstract

Recently our 3D seismic experience in a difficult area in Japan revealed many serious problems in the actual applications. Those include data processing artefacts caused by inevitable irregularities of acquisition geometry and much lower frequency content than existing 2D seismic results. For further investigations of those problems, a 3D seismic data set was acquired with more complete acquisition geometry in an old Japanese oil field at the end of 1997. The 3D area size of about 9 sq. km was decided to be appropriate for a target depth of 2km and the given survey budget. The area is mostly rice fields in reclaimed land and characterised by fewer constraints on 3D seismic survey, availability of well information, and complex geological structure. The acquisition was intended to be in excess of usual specifications for production 3D seismic so that the surveys with various kinds of geometry could be simulated by partial selection of the data. The survey was successfully carried out with vibrator sources except for a failure to get permission from one land owner. However, the obtained data show the very complex nature of the wavefield partly because of reclaimed land. Especially, strong ringing wave trains required suppression at the earlier stage of data processing. Their characteristics were investigated and the relationship between the dominant frequency and the situation of the previous lake was recognised. Many approaches have been taken to suppress them. However, the results show that the amplitude distortion introduced at the ringing suppression caused a poor mapping image of steep dip reflections. The experience suggested that the original amplitude of reflected signals should be maintained after suppression of the ringing. Special treatment of the reflection amplitude during the suppression processes resulted in a better image. After preconditioning the data optimally in such ways, more accurate evaluations and compensations for geometry imprint were conducted with confidence.

POSTERS (III)

On the Relation Between the Stacking Process and the Resolution of a Stacked Section in a Crosswell Seismic Survey

J. Matsushima, S. Rokugawa, T. Yokota, T. Miyazaki, Y. Kato

Abstract

This paper describes the effect of source/receiver geometrical arrangements on the lateral resolution when implementing the diffraction stacking process in crosswell seismic survey. Diffraction stacking with stacking velocity analysis is equivalent to the Kirchhoff prestack time migration except for performing stacking velocity analysis. Basically, the resolving power of seismic data depends on the dominant frequency of the recorded wavelet and average velocity of the medium. It is proposed that lateral resolving power is controlled by source/receiver geometrical arrangements. To obtain a better understanding of the concept of the seismic lateral resolution, the problem of seismic imaging is approached from the viewpoint of interference of equi-travel time planes. Suitable source/receiver geometrical arrangements in homogeneous media are discussed. These studies are illustrated on a numerical simulation model, in which the zero phase Ricker wavelet is used and homogeneous and isotropic media are assumed. The following conclusions can be obtained. Firstly, source/receiver sampling at a constant interval influences the lateral resolution. The use of a coarser interval results in worse lateral resolution. Secondly, it is important for better lateral resolution to arrange source/receiver points at an constant angle toward imaging point. Especially, this is important when the array length becomes long. If the position of the target is known in advance, the source/receiver point has only to be arranged as mentioned above toward the target. However, generally the position of target is unknown. In this situation, it is one of the solution plans to choose the most suitable source/receiver points in the case of stacking process in each imaging point. Thirdly, the use of a large aperture is effective in improving lateral resolution.

POSTERS (III)

Browse Basin Transect: Refraction Profiling Using Ocean Bottom Seismometers with Applications to Tectonic Evolution

J. Sayers

Abstract

Ocean bottom and land seismometers were deployed along a 720 km transect extending from the onshore Kimberley to the Argo Abyssal Plain. The refraction traverse is coincident with deep reflection seismic lines recorded to 16 seconds two-way-time. Refraction first breaks, coupled with gravity data, were modelled to provide a section 950 km long and 70 km in depth. Enhancement of the raw refraction data was achieved using bandpass and F-K filtering as well as trace mixing.

P-wave component first arrivals were detectable out to 310 km and coherent phases present to 660 km. Large offset first arrivals constrained the base of crust as well as providing some evidence of layering within the mantle. Whilst confidence of mantle generated arrivals was good on only five of the stations, gravity and strong coherent reflections provided further constraints across the whole transect. The crust thins rapidly over a 50 km section from 37 to 25 km with the Moho bowing upwards. The area of thinning is coincident with upper crustal discontinuities; block faulting extends from the Mesozoic Basins into the lower crust and fault reactivation is demonstrated. The shelf break is also coincident with the western side of an area where the lower crust thins from an average 16 km to 6 km. A pod at the base of the crust, immediately eastwards of the discontinuities, has a velocity of 7.0 - 7.1 km/s which may be indicative of diorite to gabbro composition. The lower crust thickens to 24 km here implying possible underplating. Lower crustal extension initiated in the Lower-Middle Jurassic was primarily responsible for controlling the development of the margin at this location during the Mesozoic as demonstrated by a direct relationship between lower crustal thinning and Mesozoic depocentres. The lower crust may have undergone brittle deformation as demonstrated by the presence of possible shear planes interpreted on several deep reflection seismic lines. A deepening of the simple to pure shear transition zone may be characteristic of passive margins. Extension initiated and facilitated magmatic emplacement, the process by which the crust was thickened.

POSTERS (III)

Random Noise Attenuation Using Forward-Backward Linear Prediction Filter

Y. Wang

Abstract

Random noise attenuation (RANNA) processing is commonly implemented by linear prediction filtering in the spatial domain. This paper presents an up-to-date version of RANNA technology, which designs a filtering operator by means of transient-free formulated, forward-backward linear prediction (FBLP). Conventionally, the filter for the random noise attenuation is designed by minimising the squared errors over an infinite length, being greater than the range of available data. The zero-trace padding outside the design gate causes `transient errors', as one assumes implicitly that those zero-traces were `alive'. This problem is overcome in this paper by using a transient-free formula (without zero-trace padding), which minimises the squared residues within the design gate rather than over an infinite length of data. The conventional method designs the filter by a forward prediction. It is improved in this paper now by performing the prediction not only in one direction but in both forward and backward directions. In this manner, the new version RANNA designs the filter by minimising both the forward and backward prediction residues simultaneously, and is intended for a better prediction of linear events with spatial amplitude variation, by overcoming the lateral mixing in the conventional one direction prediction scheme.

POSTERS (III)

Continental Affinity of an Oceanic Plateau: Deep Seismic Profiling of the Agulhas Plateau, South-West Indian Ocean

K. Gohl, M. Seargent, G. Uenzelmann-Neben

Abstract

The Agulhas Plateau, south-west Indian Ocean, exhibits particular characteristics among the oceanic plateaux as it is believed to consist of Cambrian and Proterozoic continental fragments as well as of large areas of overthickened oceanic crust. Plate tectonic reconstructions infer that the plateau had a key central position during the initial opening of Gondwana. Since the Miocene, its topographic relief has played an important role in directing the Antarctic deep sea current and the warm Agulhas Current. To address questions regarding its origin, composition, and lithospheric structure, a deep seismic refraction and reflection survey was recently conducted across the plateau using ocean bottom seismometers (OBS), a 2400-m long streamer, and a powerful air-gun source. The sedimentary deposition pattern was mapped in a high-resolution reflection survey across the flanks and top of the plateau. This poster reports on the development of a lithospheric model of the Agulhas Plateau and its margins by integrating structural data from the seismic reflection surveys with deep sounding refraction/wide-angle reflection recordings and gravity anomaly data. A velocity-depth model is produced which maps the crust-mantle boundary and distinct zones of oceanic and continental origin. Furthermore, an attempt is made to show the effect of magmatic events on the sedimentation processes.

POSTERS (III)

Accuracy and Limitations of the Near-offset P-wave NMO Velocity Estimation in Transversely Isotropic Media

P. Okoye, N. Uren, J. McDonald

Abstract

The accuracy and limitations of the near-offset P-wave NMO velocity estimation in transversely isotropic media have been studied using numerical and physical modelling. An expression for the near-offset P-wave NMO velocity for a single horizontal reflector in a vertically transversely isotropic layer has been previously obtained and in which ao and d respectively represent the vertical P-wave velocity and the P-wave critical anisotropy at oblique angles. The expression is presented as being valid for any degree of anisotropy. The accuracy of this expression is subject to practical testing in this paper. Single layered horizontal models were used to carry out the numerical modelling studies. A computer program which calculates P-wave NMO velocities in transversely isotropic media was used. This program uses the exact ray and phase velocity equations in generating velocity functions to be used in ray tracing; it is known to give accurate results. Using the elastic parameters for measured anisotropy in sedimentary rocks, the near-offset NMO velocities are computed and results are compared with values obtained using the above expression. The degree of anisotropy varied from very weak to strong and contrasting velocity functions

were used in numerical modelling simulations. Phenolite materials with contrasting velocity functions were used to simulate transversely isotropic media with vertical axes of symmetry in physical modelling tests. Experimental reflection data were collected and velocity analysis was conducted for near-offset traces, and the NMO velocity determined by the maximum stack response. The elastic parameters, ao and d, of the phenolite materials were recovered by an iterative inversion of first arrival travel times. These parameters were used to estimate the near-offset P-wave NMO velocity in phenolite using the NMO expression and also with our computer program. The NMO velocities obtained from these two methods were compared to that obtained from velocity analysis of the experimental seismic data. These comparisons enabled the validity of the above expression in the limit of small offsets, to yield accurate P-wave NMO velocity, to be tested. Results obtained indicate that the accuracy of the near-offset P-wave NMO equation depends on the nature and degree of anisotropy encountered in a given area, and is not valid for all degrees of P-wave anisotropy.

POSTERS (III)

Integration of Borehole Image and Seismic Data to Enhance Structural Interpretation

T. Mahmood

Abstract

Two types of images are used in the petroleum industry, electrical and acoustic. These images are of high resolution, acquiring detailed sub-surface geological information. This information is typically complemented with other datasets e.g., core, seismic, well logs, etc., for sedimentological, petrophysical and structural interpretation. Electrical images provide resistivity variations in rock texture, fluid saturation and mineralogy, whereas acoustic images record acoustic impedance contrasts related to density and porosity. These images generally provide high confidence in the interpretation of faults and fractures, depending upon the image type and quality, as fractures and faults show different acoustic or resistivity properties from the host rock. Fractures and faults are commonly discordant to bedding planes, planar to non-planar and usually continuous around the borehole. These can be interpreted on workstations, as conductive or resistive features on the electrical borehole images. Integration of borehole and seismic data allows for the interpretation of seismically resolvable fractures and faults. Scale of investigation is the main problem with integrating high-resolution image data or high-density dips obtained from images with the seismic data. To plot the manually picked bedding, fractures and faults dip data on top of seismic data, the dip data is filtered and upscaled using a stereoplot-based technique. The filtered dip results are then plotted as apparent dips in the correct orientation, overlaid on the well trajectory, at the same horizontal and vertical scales as seismic sections. Integration of borehole and seismic data allows confident seismic interpretation and seismically resolvable faults can be traced towards their tip. Damage zones can also be identified from borehole images and incorporated with seismic data to evaluate reservoir compartmentalisation.

POSTERS (III)

The Evolution of the Otway Basin in Light of New Deep-Seismic Data

A. Moore, H. Stagg

Abstract

The north-west-trending Otway Basin straddles Australia's south-eastern margin for some 500 km from Cape Jaffa in South Australia through Victoria to the north-western tip of Tasmania, and covers an area of 150 000 sq. km. The basin is a component of the Southern Rift System that developed between Australia and Antarctica from the Late Jurassic. Interpretation of its evolution has long been a contentious subject. In particular, the timing and extent of rifting, and the azimuth(s) of extension, have all been matters subject to disagreement. These disagreements may have resulted from the complex regional setting of the basin within a dominantly strike-slip margin. The Australian Geological Survey Organisation (AGSO) has acquired a range of innovative data sets in the basin to enhance understanding of its tectonic framework, its history, and its petroleum potential. In 1994-5, AGSO acquired a regional grid of more than 3400 km of deep-seismic data (16 s record length) across the basin offshore, from relatively unextended crust in the north-east to oceanic crust in the south-west. These data image the structural foundations of the Otway Basin, with strong deep crustal and Moho reflections being present on most lines. The basin developed as an intra-cratonic rift in eastern Gondwana from the Tithonian, as the crust between Antarctica and Australia extended. Initially, the rift was dominated by SE-SSE extensional transport, which produced WSW-trending extensional half-graben (e.g. Crayfish Platform, Robe Trough, Torquay Sub-Basin) and NW-trending oblique extensional features such as the Penola and Ardonachie Troughs. Sinistral relative lateral motion between the plates continued through the Cretaceous and into the early Palaeocene. Intra-basinal structural complexities were introduced where irregularities in the plate boundary alternately locked-up or released, causing local transpression or transtension. Late Maastrichtian transpression caused intense left-lateral shearing in the north-western part of the basin. While it is generally accepted that break-up of Australia and Antarctic occurred in the Cenomanian (ca 96 Ma), the extended strike-slip history of the Otway Basin meant that emplacement of oceanic crust adjacent to the basin did not take place until the latest Cretaceous and early Tertiary. That is, the effective 'break-up unconformity' is the major erosional event that terminates the Upper Cretaceous Sherbrook Group. There is no requirement for changes in direction of plate movements prior to the Eocene.

POSTERS (III)

The Effect of Multiple Removal on AVO Analysis

R. Van Borselen

Abstract

Removal of free surface multiples from seismic reflection data is an essential pre-processing step before pre-stack migration and post-migration amplitude analysis. Conventional multiple suppression methods such as predictive deconvolution and differential move-out filtering are based on rather general characteristic differences between primaries and multiples. Since the

underlying assumptions are often not met in the field, the effectiveness of these methods can be limited: too much multiple energy is passed while too much primary energy is rejected. Wave-equation based surface-related multiple removal is a data driven method that requires no a priori information about the subsurface. Using the measured data itself, all surface-related multiples are predicted and subtracted from the multiple-contaminated data in a least square sense. Since AVO attributes, such as slope and intercept, are extremely sensitive to amplitude deviations, preservation of the amplitude characteristics is a key ingredient for successful application of amplitude inversion techniques. In this abstract, the effect of different multiple removal techniques on amplitude versus offset (AVO) analysis is investigated. Post-migration amplitude analysis is conducted on a Gulf of Mexico data set after application of three different multiple removal methods: a differential-moveout based method in the f-k domain, in the Radon domain, and a wave-equation based surface-related multiple removal method. Results show that amplitudes of primary events are affected by multiple removal methods based on differential moveout. Using a surface-related multiple removal method, primary events remain unaffected, allowing optimal application of amplitude inversion techniques.

POSTERS (III)

Seismic Stratigraphic Extrapolations from a Single Well in the Strahan Sub-basin, Western Tasmania and the Application to Hydrocarbon Exploration

W. Lodwick, V. Passmore

Abstract

The Strahan Sub-basin of the Sorell Basin, offshore Western Tasmania was penetrated by the Cape Sorell-1 well in 1982. This well penetrated to a depth of 3506 metres and live oil shows were recorded at around 3000 metres. The seismic coverage over the area is of good quality and of sufficient density to establish stratigraphic correlations. This paper demonstrates the application of stratigraphic interpretation methods, develops models of deposition and facies change away from the well and identifies prospects for hydrocarbon exploration. Cape Sorell-1 penetrated Cainozoic and Mesozoic (Cretaceous) sediments. The bulk of the sedimentary section beneath the well is thought to be Mesozoic. Starting from the known rock types in the well, depositional models were built using the structural information extracted from the sequence interpretation and analogues taken from the literature. Facies changes within each sequence were then estimated from detailed interpretation of the seismic character. Seismic attributes were used extensively in this process. Finally, a number of models were made and the oil industry analysis of structure, size, source, seal and reservoir applied to the definition of leads and prospects.

POSTERS (III)

The Continental Margin off East Tasmania and Gippsland: Structure and Development using New Multibeam Sonar Data

P. Hill, N. F. Exon, J. B. Keene, S. M. Smith

Abstract

The continental margin facing the southern Tasman Sea off south-east Australia is of high petroleum and geological significance because it contains Australia's richest oil province, the Gippsland Basin. Exploration activity in the region has concentrated on the shelf of this basin. Off Tasmania the upper margin is host to important deep-sea trawl fisheries, and regional geophysical data suggest some long-term petroleum potential.

In early 1997, 20,000 km^2 of the margin were surveyed by the Australian Geological Survey Organisation, in co-operation with Scripps Institution of Oceanography and the University of Sydney. The SeaBeam 2000 multibeam sonar system of the US RV Melville was used to map the topography and character of the seafloor in unprecedented detail. The SeaBeam 2000 is a 12 kHz, 121-beam echo-sounder that collects both bathymetry and backscatter (sidescan) data across a swath of width about 3.4 times the water depth. The survey also collected 3500 km of magnetic and gravity profile data.

The margin off Gippsland is dominated by a large embayment 100 km across and floored by an ESE-trending chasm, the Bass Canyon, which is 60 km long and 10-15 km wide. The canyon has cut down about 2 km into the margin and is bounded to the north and south by very steep inner canyon walls 1000 m high. Sediments transported down the canyon debouch at its mouth, at ~4000 m depth, and spread onto the abyssal plain via a network of distributary channels and levees. Sediment from the shelf is channelled into the entrance of Bass Canyon by three major, deeply-incised tributary canyons and a number of smaller ones. Bass Canyon has probably acted as a conduit for clastic sediment to the deep sea floor since break-up at ~80 Ma. Seismic profiles over the Bass Canyon complex show that canyon erosion has exposed sections of almost the entire Gippsland Basin sequence down to the Early Cretaceous and underlying basement. Numerous suitable dredge and core sampling sites in the canyons have been identified for a geological sampling program.

Off east Tasmania, the survey showed the margin to be generally steep and rugged, with relatively little sediment having been deposited on the continental slope, except in narrow rifts, since break-up. The adjacent abyssal plain is commonly underlain by 2 km of sedimentary section. The continental slope is cut by an extensive system of canyons, some more than 30 km long and 500 m deep. Large fault blocks on the lower slope show structural trends consistent with a NW-NNW rift direction and NE-ENE transfer direction. The upper slope appears to be underlain by a subsided Miocene carbonate shelf. Volcanics, of probable late Cainozoic age, are fairly widespread on the seafloor off north-east Tasmania. Such volcanic terrain includes a number of scattered cones, the largest 450 m high.

POSTERS (III)

Acoustic Velocities as a Function of Effective Pressure in Low to Moderate Porosity Shaly Sandstones, Part 1 - Experimental Results

A. Khaksar, C. Griffiths

Abstract

Compressional and shear wave velocities were measured as a function of effective pressure on a set of cores from gas producing reservoirs in the Cooper Basin in South Australia. The aim of this study was to investigate the relationship between the stress sensitivity of acoustic velocities and geological and petrophysical characters of low to medium porosity shaly sandstones. The suite of samples consists of 22 core plugs from depths between 1917 m to 2564 m with helium porosity ranging from 2.6% to 16.5%. The samples are mainly fine to medium - grained sublitharenite. The echo-pulse technique was used to measure ultrasonic velocity and attenuation in dry and fully water-saturated cores under effective pressures of 5 MPa to 60 MPa. Experimental results show that compressional and shear wave velocities increase non-linearly with effective pressure. The influence of pressure was more pronounced below 40 MPa for both compressional and shear wave velocities. The rapid increase of wave velocities with effective pressure between 5 MPa and 40 MPa is attributed mainly to the closure of low aspect ratio pores such as micro-cracks and loose grain contacts within the rock framework. Compressional wave velocity in dry samples shows stronger pressure sensitivity, whereas there is no significant difference between the stress dependency of shear wave velocity in dry and water saturated samples. There is a positive correlation between change in velocity with pressure and core porosity and permeability. However, this association is weak and diminishes with increasing effective pressure. The pressure dependence of acoustic velocity in the Cooper Basin samples are not related to total clay content, but samples with a greater amount of pore filling and grain-coating clay particles appear to be less pressure sensitive at dry condition. Cooper Basin sandstones show higher-pressure sensitivity when compared to data from other studies.

MINERAL EXPLORATION: RIM & TOMOGRAPHY

Weighted Tomographic Imaging of Radio Frequency Data

G. A. Pears, P. K. Fullagar

Abstract

The radio imaging method is utilised in mines and oil fields to obtain detailed geological information between drill holes or mine roadways. When radio waves are transmitted through the ground at a fixed frequency, variations in absorption as the transmitter-receiver geometry changes are indicative of variations in conductivity of the geological section. With operating frequencies typically between 103 and 106 kHz, radio frequency electromagnetics (RFEM) is intermediate in range and resolution between low frequency electromagnetics used in exploration and high frequency ground penetrating radar (GPR). At many metalliferous mines, the ore is characterised by high conductivity contrasts and well defined boundaries. Radio tomography between holes or mine roadways has a role to play in orebody delineation, but standard SIRT reconstruction produces unrealistic smooth images. In order to generate tomographic images with sharp boundaries, a weighted SIRT algorithm has been developed. A 'clamping weight' has been designed to fix the absorption coefficient at the low (host) value in regions which do not attenuate the radio signals, thereby localising high absorption into discrete zones. A 'central weighting' has also been introduced to concentrate high absorption towards the centre of the image in an attempt to compensate for the sensitivity of the acquisition system to variations in conductivity close to the receiver or transmitter. The weighted tomography has been tested on simulated cross-hole radio frequency data, as well as data collected from the Levack mine, Canada. Generally, the inclusion of weights in tomographic reconstructions has produced more realistic images of the geology. For the synthetic data sets, the resulting tomograms resembled the true model more closely than the standard SIRT images. For the Levack data set, the weighted tomography improved the definition of a mineralised lens.

MINERAL EXPLORATION: RIM & TOMOGRAPHY

Radio Frequency Tomography Trial at Mt Isa Mine

B. Zhou, P. K. Fullagar, G. N. Fallon

Abstract

A cross-hole RFEM (Radio Frequency Electromagnetic) tomographic survey was conducted at the Mt. Isa Copper Mine in 1995 as part of a CMTE/AMIRA project investigating the application of geophysics in metalliferous mines. The primary objective of the survey was to evaluate the capability of RFEM for orebody delineation, in a section of the mine where a correlation had previously been established between conductivity and copper grade. An absorption tomogram constructed from the limited 52.5 kHz data set demonstrated that RFEM has potential in this environment for resolving orebody boundaries and establishing ore continuity between drill holes. The calculated absorption coefficients on the tomogram lie between 0.94 and 5.165 dB/m, consistent with laboratory absorption measurements on rock samples from the survey site. The continuity of the foot wall orebody, paralleling the Paroo Fault, was not well represented in the tomogram, due to low ray coverage in the corner of the image. However, a simple amplitude mask, depicting only the less attenuated ray paths, provided evidence for continuous ore between the holes. This provides encouragement for efforts to combine amplitude masking with tomography.

MINERAL EXPLORATION: RIM & TOMOGRAPHY

IP Tomography Test Survey in the Barrier Main Lode, Broken Hill, Australia

H. Katayama, K. Yokokawa, T. Suzuki, E. Arai

Abstract

In the both domestic and overseas mineral exploration projects of the Metal Mining Agency of Japan (MMAJ), much drilling has been conducted in order to acquire drilling cores which are routinely used for geological logging and laboratory analysis. However drill holes

themselves are seldom used as an exploration tool except for occasional geophysical logging such as resistivity, self-potential and induced polarisation (IP). Therefore the MMAJ has been developing an IP tomography data acquisition system since 1992 for the purpose of effectively utilising drill holes, reducing exploration cost and improving accuracy of geophysical exploration. This system is based on time-domain measurement and adopts a pole-dipole electrode configuration to avoid coupling effects. It consists of a transmitter, receiver, personal computer, controller, non-polarisable electrodes, ground cables and borehole cables, and has the following advantages: 1) It acquires 10 data sets of resistivity and chargeability simultaneously. 2) It acquires very accurate data because of an operational amplifier at an electrode site in the borehole cable and the relay box. 3) It acquires the data automatically through the controller, computer and relay boxes. In 1997, the MMAJ conducted an IP tomography test survey in order to examine the applicability of the system for mineral exploration in the Barrier Main Lode which is located north-east of Broken Hill, NSW, Australia. The accuracy of the acquired data was excellent because of the high sensitivity of the system and lack of interference with the power line and other utilities. The data was analysed with an inversion technique based on the alpha centres method and the non-linear least square method. Although the reconstructed resistivity is lower than that obtained by the previous electrical logging, the reconstructed image is consistent with the result of ground electrical data and geophysical logging. The ore body is shown as a low resistivity in the resistivity image, and as a high chargeability in the chargeability image. The system was confirmed to be able to effectively recognise an ore body under the conductive overburden.

RUGGED TERRAIN GEOPHYSICS (I)
KEYNOTE ADDRESS

Crossing the Borders: From Plains to Rugged Terrains

S. Mudge

Abstract

We often assume that the Earth is flat and that all geophysical surveys are conducted on a flat survey plane, just as many geophysical text books suggest. However the surface of the Earth is often rugged, and the effect of this rugged surface depends directly on the height of the survey above the ground. Mountainous areas have always provided a challenge for both airborne and ground surveys, and for the processing and interpretation of the survey data. For example, airborne surveys in these terrains suffer variable terrain clearance between adjacent survey lines as the aircraft attempts to 'hug' the terrain. This combined with the undulating survey surface, causes data levelling problems and distorted anomalies which often lead to erroneous interpretations of the survey data. Problems associated with airborne surveys conducted in rugged terrains are, in recent times, becoming evident in the low-level surveys now being conducted with agricultural aircraft over seemingly undulating terrains: the close proximity of the survey aircraft to the gently undulating terrain produces the same terrain induced problems as experienced in mountainous terrains. All ground geophysical methods are strongly affected by rugged terrain. For these surveys, it is often possible to use the rugged terrain to advantage by obtaining multiple 'views' of a buried source by surveying several slopes of the terrain around the target source. In addition, EM loops and galvanic electrodes can also be judiciously located on the terrain to obtain a more accurate definition of a buried anomalous source. Explorers are also demanding more accurate interpretations of data from rugged terrains in order to resolve target responses from the distorted responses measured in these terrains. To this extent modern 3-dimensional computer modelling software can now accommodate survey data from an undulating survey surface and the geophysical responses of geologically complex undulating terrains can now be computed. Rugged terrains present new challenges to survey design, survey operations, data processing and interpretation, and modelling of the survey data. As a consequence of this there is now an urgent requirement for high resolution digital terrain models for survey design and for accurate reduction, interpretation and modelling of all geophysical survey data. Techniques developed for rugged terrain environments can also be applied to underground and open-pit mine environments.

RUGGED TERRAIN GEOPHYSICS (I)

Mapping the Range Front with Gravity - are the Corrections up to it?

M. Flis, A. Butt, P. Hawke

Abstract

The currently used gravity data reduction procedures were formulated in the petroleum industry and have not changed since the 1930's. Simplifications needed to facilitate data reduction by hand have remained, in spite of the cheap and powerful computer processing that is now in common use. Corrections such as the Free Air Correction still use a linear relationship with height, even though the full latitude and height dependent formula is simple and available. More significantly, the Simple Bouguer Correction is still being used routinely in spite of the significant errors it introduces by assuming an infinite "Bouguer slab" and that the density of all rocks in the survey area can be approximated by one value. The result is that most gravity data is over or under corrected. The Complete Bouguer Correction, incorporating a full terrain correction, is rarely applied, and only then when the topography is extreme. Yet it is this correction which promises to deliver an accuracy in data processing and presentation commensurate with the accuracies currently being achieved in data collection in the field with DGPS and modern gravimeters. The availability of high resolution Digital Terrain Models and faster terrain correction software certainly allows these corrections to be applied routinely. Even more rarely used is a variable density model. Obtaining such a model is still plagued by problems and is the next major hurdle to be overcome. Density models may be classified into three types: assumed, statistical, and inferred. Assumed densities are typically based on measurements of hand specimen samples and extended to the entire survey area. Statistical density models are based on minimising the correlation between topography and gravity whilst inferred densities are derived from a transformation of the actual gravity data. The Hamersley Basin of Western Australia is a hostile environment for the gravity method. Precipitous cliffs of high density banded iron formations abut low

lying plains of unconsolidated sediments. Exploration for iron is focused on this topographically challenging range front. The strict application of the Complete Bouguer Correction coupled with a variable density model allows the gravity method to be used as a direct detector of iron deposits in spite of the obvious problems.

RUGGED TERRAIN GEOPHYSICS (I)

The Gravity Terrain Correction - Practical Considerations

D. Leaman

Abstract

The revival in gravity methods stimulated by the availability of reliable positioning and, more importantly, elevation estimation using relatively low cost GPS methods has transferred the focus on survey accuracy and precision from elevation errors to those implicit in the complete topographic correction. The terrain correction has commonly been ignored in low relief terrain since the error in doing so has usually been much less than that related to errors in elevation accuracy. It is now possible to specify and observe gravity surveys which can yield a precision of 0.01 to 0.03 mGal in the Bouguer anomaly in production practice. Unfortunately even quite minor aberrations in local topography may generate errors in excess of 0.1 mGal and no tight specification is justified unless it also demands detailed description of the local terrain, outlines how to avoid problems, and requires calculation of such corrections as are necessary. This will require a change in observer culture. There is no doubt that the terrain correction is now the major source of deficiency in gravity survey data bases. The methods used for calculation of the terrain correction also need review and care since digital terrain models are not necessarily of adequate precision or reliability for calculation of the effects close to the observation point. Small features, which cannot be defined by digital terrain models, and which need either careful description or avoidance by operators, must be considered. Two important rules must be observed if the terrain correction, or its absence, is to be satisfactorily calculated or justifiably ignored. Firstly, any object subtending more than five degrees at the meter, regardless of its distance from the meter, must be described and compensated. Secondly, terrain calculations must extend to the radius at which, or beyond which, there is no topographic feature which might generate an effect more than half the claimed or desired accuracy specification for the survey.

CROSSING TECHNICAL FRONTIERS IN MINERAL EXPLORATION (I)

Seismic Methods for the Detection of Kimberlite Pipes

M. Urosevic, B. Evans

Abstract

The results of a seismic experiment conducted in Northern Territory over known kimberlite pipes are shown. A very low reflectivity sedimentary sequence and unfavourable near surface conditions resulted in poor quality surface seismic data. The delineation of the external kimberlite pipe shape at depth, based on the principle of using the P-wave reflections which terminate against the pipe flanks, is not simple. However, by a combined analysis of P and S-reflected waves the pipe shape and its structure may be recoverable from seismic data. In this experiment, most of the seismic energy produced by an explosive charge at a shallow depth generated shear and guided waves rather than P-waves. Totally refracted P, S and guided waves generated additional wave modes in a kimberlite pipe which are used to precisely determine pipe location and its diameter. We also show that single borehole imaging has a potential for the delineation of the external pipe form and structure. The use of such unconventional seismic methods may be the solution for assisting an economic assessment of individual kimberlite pipes in the Northern Territory.

CROSSING TECHNICAL FRONTIERS IN MINERAL EXPLORATION

Interpretation of Controlled Geogas Measurements for Mineral Exploration Purposes

L. Malmqvist, K. Kristiansson

Abstract

Based on studies of the mechanism responsible for the transportation of radon in the bedrock during the late 1970s it was found that this mechanism also carried important information about concealed mineral deposits. Extremely small amounts of matter from depth is transported to the ground surface by a carrier gas. This matter is sampled in a controlled manner in situ and it has been demonstrated in numerous tests and in commercial exploration projects over the last 10 years that important unique information can be extracted from these fingerprints. It has been found that a correction factor for the flow properties in the underlying bedrock at site must be introduced. These correction functions have been possible to establish due to the large amount of data now available from different parts of the world and due to the fact that a large number of elements are measured under equal conditions in real time at each site. It has also been found that these flow corrections are different for the different elements of interest in mineral exploration. It seems also possible to extract general information about the depth to the target. Based on an ideal model, an apparent depth estimate can be calculated. Information from a number of exploration projects from the activity of the last 15 years has been retrospectively analysed and a surprising good agreement with now available ground truth found.

CROSSING TECHNICAL FRONTIERS IN MINERAL EXPLORATION (II)

Feasibility Studies of TFMMIP and TFEM Surveying with Sub-Audio Magnetics

D. Boggs, J. Stanley, M. Cattach

Abstract

The Sub-Audio Magnetics (SAM) technique measures parameters related to electrical and magnetic characteristics of the sub-surface. A galvanic and / or electromagnetic source is used to excite current flow within the sub-surface. Measurements are taken with a rapid sampling, total field magnetometer while continuously traversing within the survey area. By selecting the transmitted waveform appropriately,

magnetic signals related to separate physical phenomena become distinguishable and can be observed within the measured magnetic field variations. Signal processing techniques are then used to obtain the following measurements: Total Magnetic Intensity (TMI), Total Field Magnetometric Resistivity (TFMMR), Total Field Magnetometric Induced Polarisation (TFMMIP), Total Field Electromagnetics (TFEM). The measurements indicated are used to map variations in sub-surface resistivity, chargeability and magnetic properties. While software and hardware limitations have previously restricted measurements to the TMI and TFMMR parameters, ongoing development of acquisition and processing software now allows all four parameters to be measured, potentially from a single survey. Application of the SAM method to the Flying Doctor Lead / Zinc / Silver deposit showed that the mineralisation produced significant anomalous responses within the TFMMR, TFMMIP and TFEM parameters. Surface TFMMR and TFMMIP data are transformed to equivalent Magnetometric Resistivity (MMR) and Magnetometric Induced Polarisation (MIP) data, removing the data's dependence on the direction of the Earth's ambient magnetic field direction. A survey over an unexploded ordnance (UXO) test site showed that Total Magnetic Intensity (TMI) and transient electromagnetic (TFEM) data may be simultaneously acquired and used to locate these types of targets.

OIL EXPLORATION: TOMOGRAPHY & GEOCHEMISTRY

A New Method for Crosswell Reflector Imaging

J. Zhe, S. Greenhalgh

Abstract

Imaging seismic reflectors with crosshole tomographic data is not normally done due to the lack of a proper imaging method. We introduce here a new method for tomographically imaging reflectors. The scheme first picks up traveltimes of each reflected event from common-shot gathers. It then uses the picked times to image the reflecting interfaces according to a very important principle: two reflection points from the same interface that produce reflection pulses on two neighbouring receivers have the same tangent line. The same scheme can be used for surface reflection or crosshole data, but the latter requires some special processing to separate upgoing and downgoing waves. This paper will show how to apply the scheme in tomographic surveys. Traveltimes of each reflection event are initially read from a common-shot gather tomographic seismic section. Then each pair of traveltimes from neighbouring traces is processed in sequence. The isochronal curves are calculated from the two traveltimes. A common tangent to the two isochronal curves is then found and a reflection segment is defined. In this way, all traveltimes are processed in pairs and a straight or curved interface, corresponding to the locus of tangents, is reconstructed to map the reflecting interface. The processing difference between surface seismic reflection data and tomographic (crosshole) seismic reflection data is that the crosshole data contains downgoing waves as well as upgoing waves. So the program has to decide if a reflection event comes from above or below the source. Then the program processes the data to obtain the reflector orientation. This imaging method can handle multiple layers and curved interfaces for an arbitrary 2D velocity distribution.

OIL EXPLORATION: TOMOGRAPHY & GEOCHEMISTRY

Crosshole Acoustic Velocity Imaging with Full-Waveform Spectral Data: 2.5-D Numerical Simulations

B. Zhou, S. Greenhalgh

Abstract

This paper focuses on the question of full-waveform inversion and the use of crosshole full-waveform spectral data. We examine the differences in effectiveness of each form of data (real, imaginary, amplitude, phase and Hartley spectra) and determine which is best for imaging the velocity distribution. By 2.5-D numerical simulation for three models, we found that, except for the principal phase data, the monochromatic real, imaginary, amplitude and Hartley spectra can be used to image the targets between boreholes by full-waveform inversion; the real and imaginary spectra produce nearly the same quality of images. The images obtained from the amplitude data exhibit more artefacts than the others. The inversion of the Hartley spectral data gives the best image of all. By computing the data misfit functions, we found that the profile of the misfit function of the principal phase data is more complicated than the others. For example, some discontinuities or fluctuations occur in the neighbourhood of the true solutions. The complexity of the misfit function may be the main cause for the failure to satisfactorily image with the principal phase data alone: local minima capture the misfit function during the attempted global optimisation.

OIL EXPLORATION: TOMOGRAPHY & GEOCHEMISTRY

A Thermal Maturation Study of the Carnarvon Basin, Australia and the Northern North Sea, Europe

J. Samuelsson, M. Middleton

Abstract

The suppression of vitrinite reflectance can cause a problem for the oil industry if not properly considered. The scope of this paper is to emphasise the errors that suppression could lead to in estimating the heat flow and transformation ratio of hydrocarbons. Two cross-sections from the Carnarvon Basin, North West Shelf, Australia, are modelled in order to study the effect of suppressed vitrinite reflectance in a sedimentary basin. The results are adopted to a modelled profile across the northern North Sea. The modelling implies that neglecting the suppression effect of the vitrinite reflectance could lead to the heat flow being erroneously estimated by as much as 60% (42.5 mW / sq. m instead of 68 mW / sq. m). As a result the timing of hydrocarbon generation may be miscalculated and the source rock maturity will be underestimated. Erroneous predictions of the transformation ratio of hydrocarbons could be with as much as 60-80%.

RUGGED TERRAIN GEOPHYSICS (II)

Magnetisation Mapping in Rugged Terrain

M. Pilkington

Abstract

Magnetisation mapping aims to derive a map of the surface magnetisation (or equivalently, susceptibility) distribution to assist in geological mapping through a more precise delineation of magnetisation boundaries and providing a map of magnetisation levels that can be directly related to rock properties. The mapping surface can be either the crystalline basement or, where overburden thickness is small, the ground topography. When the mapping surface and the survey altitude are both constant, magnetisation mapping reduces to a downward continuation of the observed magnetic field. Draped-survey flying in rugged terrain presents problems for magnetisation mapping due to variable sensor altitude and changing ground topography. Changes in the depth to the magnetic sources leads to variable attenuation of the magnetic anomalies. If the dominant wavelengths of the ground topography are comparable to changes in magnetisation, then topographically induced anomalies will be indistinguishable from the effects of magnetisation changes. Therefore, the standard magnetisation mapping approach is modified in order to address these problems: 1) the varying sensor height is dealt with by using an approximate equivalent geometry from which the magnetic data can be more easily inverted; 2) the change in ground elevation is overcome by using an iterative inversion procedure that takes into account the varying source-to-observation distance; 3) finally, a correction is applied that accounts for errors introduced by the transformation of geometries. This approach is demonstrated on a recent aeromagnetic survey of the Tatla Lake region, British Columbia, Canada.

RUGGED TERRAIN GEOPHYSICS (II)

The Calculation of Magnetic Components and Moments from TMI: A Case Study from the Tuckers Igneous Complex, Queensland

P. Schmidt, D. Clark

Abstract

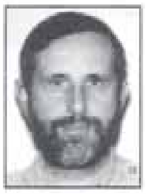
This paper re-examines some largely forgotten methods that are eminently adaptable to modern computing environments. The methods were originally formulated before the advent of electronic computers and do not appear to have been fully developed, or given the attention they deserve. It is apparent that if an anomaly is small with respect to the geomagnetic field (which is usual), components of the anomaly can be derived from total magnetic intensity (TMI) observations, or indeed, any other component irrespective of its direction. For large anomalies an iterative method enables estimates to converge on accurate solutions. Furthermore, for an isolated anomaly integrals of first order moments of the components yield information such as the direction and magnitude of the total anomalous magnetic moment of the source. However, earlier suggestions that integrals of second order moments of components yield information on location of magnetisation centres, analogous to the centre of mass the gravity case, appear to be flawed. Several improvements are proposed that, i) compensate for the finite nature of survey areas, ii) correct for the departure from a true potential field of total magnetic intensity (TMI) anomalies and iii) correct previous misconceptions regarding second order moments of components. Examples of the application of the methods are derived from a survey flown by Aerodata over the Tuckers Range area of north Queensland. This survey was chosen because the magnetic properties of the lithologies giving rise to the magnetic anomalies have been thoroughly studied. The selected areas contain many anomalies showing effects of magnetic remanence of reverse polarity. The results of the methods used herein agree well with those expected from the measured magnetic properties and magnetic modelling. It seems that magnetic interpretation could be significantly augmented by developing these methods to their full potential and incorporating them in commercial packages. Future enhancements of these techniques could include mapping the lines-of-force which we believe would be of great benefit to magnetic interpretation in rugged terrains, especially in low magnetic latitudes.

Authors' Biographies

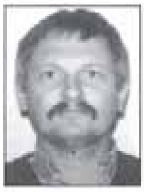
SECTION FIVE

Co-hosted by & EAGE

Meri-Liisa Airo is a geophysicist and research scientist in aeromagnetic interpretation and magnetic petrology.



Richard Almond received a B.Sc. (Hons.) degree in Physics from the University of Edinburgh in 1969. In 1970, after a brief sojourn in the Niger Delta with Seismograph Service Ltd., he joined the former Bureau of Mineral Resources where he worked in a wide variety of roles until 1987. Between 1987 and 1991 he worked as an I.T. consultant for Paxus Corporation. Since 1991 Richard has worked as an independent consultant specialising in developing I.T. solutions for the geoscience industry. The Potent gravity and magnetic interpretation package was developed as part of this work.



William Amann graduated from Monash University in 1978 with a B.Sc. in Geology. He worked for Geoterrex for two years before taking a long term contract position with Chevron Resources where he helped develop and operate a multimode electromagnetic survey system. This is where he developed a strong interest in electromagnetic methods and instrumentation. After studying the spectral IP response of gold deposits at The Kalgoorlie School of Mines he spent two years with Shell Minerals before taking a permanent position with WMC. He started with Outokumpu in 1996 and is a member of the ASEG, SEG and is Chairman of the WA branch of the AIG.

Naoshi Aoki is a Geophysicist. He received his B.Sc. (1993) in Geoscience from Chiba University, Japan. He joined JAPEX Geoscience Institute Inc. and worked on seismic data acquisition and data processing. He moved to Japan Petroleum Exploration Co. in 1994. He was in charge of seismic interpretation works in domestic oil and gas exploration project for 3 years. Currently, he has been working at the Technology Research Center of Japan National Oil Corporation since 1997.

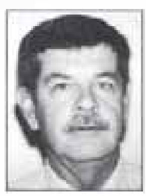
Nick Archibald has extensive experience in the application of geological expertise to problems in exploration and mining. He is an Honours Graduate in geology from James Cook University of North Queensland. He completed his Ph.D. at UWA, where his thesis investigated the structural - metamorphic evolution of a portion of a greenstone terrain in the Eastern Goldfields of Western Australia. He was subsequently employed as a Research Fellow at Monash University where he worked on a project at Broken Hill. Since 1993, Nick has devoted considerable time to a strategic collaboration with the CSIRO Division of Exploration and Mining resulting in the formation of Fractal Graphics.

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 majored in Physics, Geology and Geophysics at the University of Tasmania before entering post-graduate study at Macquarie University in 1972. After excursions into magneto-tellurics and DC electrical methods he gained a Ph.D. in geophysics on the topic of using micro-seismic waves as a tool for studying sedimentary basins. In 1977 he took up a two-year appointment lecturing and coordinating an M.Sc. (geophysics) programme at Ahmadu Bello University in Nigeria. He then 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 a decade, initiated the 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 Co-Chairman of the ASEG Conference 1998.

John Bancroft obtained a B.Sc. (1970) and M.Sc. (1973) from the University of Calgary and a Ph.D. (1976) from Brigham Young University. He has developed software for the seismic processing industry and has specialised in the areas of static analysis, velocity estimation, and seismic migration. John is a faculty member of the University of Calgary, a Senior Research Geophysicist with the CREWES Project, and an Instructor for the SEG. 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. John is a member of ASEG, CSEG, SEG, EAGE, IEEE, and APEGGA.

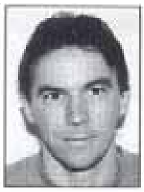
Paul William Basford graduated with B.Sc. (Hons.) in Geophysics from the University of Adelaide in 1992. He joined Pasminco Exploration in 1993, where he worked in Cobar, Broken Hill, South Australia and Queensland. From 1995 to 1997 he was based in Tasmania working in the Mt. Read Belt. He is currently employed as a Senior Geophysicist responsible for geophysical activities in Cobar and Tasmania.

Craig Beasley General Manager, Geophysical R & D Western Geophysical. Craig joined Western Geophysical in Houston in 1981 after receiving his Ph.D. in mathematics and served in several capacities in both the Computer Sciences and Geophysical Research and Development departments. He is currently General Manager of Research and Development.



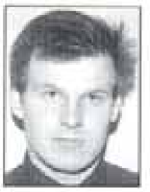
Jeff Beckett graduated from the University of New South Wales in 1976, with a B. Sc., (Geology). Since 1981 he has worked in the Coal & Petroleum Geology group of the Geological Survey of New South Wales. Jeff is currently based in the Hunter Valley as Principal Geologist for the Northern Region. Jeff has responsibility for coal resource assessment, landuse planning and project assessment in the Hunter and Gunnedah Basins.

Samantha Bierbaum graduated from the University of South Australia and is currently completing a Ph.D. at the University of Adelaide. Her research interests include hard rock seismology, seismic source development and earthquake seismology. She is currently a member of SEG, ASEG, EAGE and AGU.

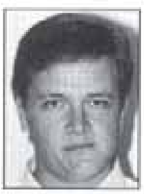


Stephen Billings was born 20 August 1970 in Australia and received the B. Sc. degree from La Trobe University in 1991 and a B. Sc. (Hon) degree in Theoretical Physics from The Australian National University in 1992. In 1994 he received a Graduate Diploma in Resource and Environmental Science from the Australian National University and commenced a Ph.D. in Agriculture at the University of Sydney in 1995. His current research interests include environmental geophysics and the development of efficient techniques for the processing of irregularly sampled geophysical data, particularly airborne gamma-ray spectrometry.

Robert Bird received his B.Sc. (Hons.) in Geology from the University of Western Ontario in 1983 and then proceeded into the petroleum industry in Canada (working with CGG and Dome Petroleum) prior to pursuing graduate studies. He received a M.S. (1991) and a Ph.D. (1994) in Marine Geology and Geophysics from the Graduate School of Oceanography, University of Rhode Island. Dr Bird was a Visiting Fellow and Research Scientist with the Geological Survey of Canada from 1994 to 1997, and then he joined the Tectonics Special Research Centre at the University of Western Australia to continue his research in tectonics and geophysics.



Robert Bloor studied Mathematics at the University of Cambridge, England, graduating in 1990. He then moved to Leeds, England to study for his Ph.D. in Geophysics. His Ph.D. examined near surface effects in exploration seismic data and means of correcting for them. He received his Ph.D. in 1994. At the beginning of 1994 he was employed by Western Geophysical in London as a Research Geophysicist. In August 1996 he was promoted to Senior Research Geophysicist in the London research group and in June 1998 he was transferred to the Houston research group. Professional interests cover seismic data processing and specifically imaging.



David Boggs received a B.Sc. with Honours in Geophysics and the University medal from the University of New England in 1991. He was subsequently employed as a geophysicist with Geophysical Technology Limited (formerly the Geophysical Research Institute). During this time his activities have involved undertaking and supervising geophysical survey work as well as development of geophysical software. David is currently undertaking Ph.D. research into the development of the Sub-Audio Magnetics technique while continuing to do part-time work with Geophysical Technology.

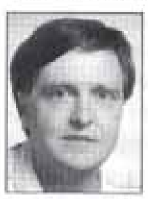
Goachino Buselli Jock received a B.Sc.(Hons.) degree in physics in 1967 and a Ph.D. in 1972 from the University of Adelaide, South Australia, and is now a principal research scientist at the CRC AMET in Sydney. For over 26 years, he has worked on problems in electromagnetic geophysics related to minerals 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.

Domenic Calandro graduated in 1993 with a B.Sc. in Geophysics from the Flinders University of South Australia. He is currently employed as a Geophysicist with the Mineral Resources Group of Primary Industries and Resources South Australia where he manages and coordinates the processing of Airborne Magnetic and Radiometric data acquired through the South Australian Exploration Initiative, Broken Hill Exploration Initiative and company surveys. His expertise covers data acquisition, processing and interpretation of both ground and airborne geophysical data.

Anat Canning received a B.Sc. (Mathematics) from the Hebrew University, Israel in 1980. From 1981 to 1989 she worked at the Institute of Petroleum Research and in 1987 she gained an M.Sc. in Geophysics from the Tel Aviv University. Anat moved to the Houston Advanced Research Center in 1990 where she spent 5 years. In 1993 she was awarded a Ph.D. in Geophysics from the Rice University in Texas. At present Anat is employed as a Research Scientist with Paradigm Geophysical. She is a member of SEG.

Stephen Cheesman Employment History: 1991-1993 University of Toronto, Research Associate in Geophysics Division. 1993-1996 Private Consultant, Software Developer for Geophysical Application for GSC and industry, 1997-Present Geosoft Inc., Research Geophysicist supporting Software Development. Academic History: University of Toronto, Ph.D. in Geophysics 1989, Post-Doctoral Studies with Geological Survey of Canada (GSC) at Pacific Geoscience Centre developing a new marine EM surveying system. 1991. Professional Interests: The development and implementation of novel numerical analysis methods for exploration geophysicists. Involved in the continuing development of the marine EM surveying system and enjoys the occasional research cruise.

Chow-Son Chen ASEG and SEG active member since 1984, Associate Professor of Geophysics, Institute of Geophysics, National Central University of Taiwan. Major area of interest is geophysical prospecting, with emphasis on electromagnetic method. B. S. in physics, 1974, National Normal University, Taiwan; M. S., 1978, and Ph. D. in geophysics, 1989, National Central University, Taiwan. Researcher at Institute of Industrial Technology and Research, 1979-1984. Faculty member at National Central University, Taiwan. Authored 10 refereed publications, 1 in SEG journals and 1 book.

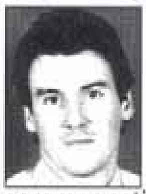


David Clark obtained a B.Sc. (Hons I) majoring in Physics from Sydney University in 1974 and an M.Sc. in Geophysics from Sydney University in 1983. Since 1978 he has worked in the Rock Magnetism Group of CSIRO Exploration and Mining and its precursor Divisions and is currently a Principal Research Scientist. His research interests include application of magnetic property data to interpretation of magnetic surveys, magnetic petrology, potential field modelling and development of a method for remote determination of magnetic properties of buried magnetic sources.

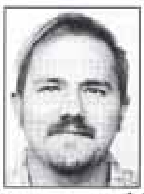
Ed Collins is a Senior Geophysicist with Apache Energy Limited. He graduated from Curtin University in 1988 with a B.Sc. and Honours degree in Geophysics. In 1989 he joined BHP Petroleum in Melbourne, working as an Exploration Geophysicist in the Northern Australia Division. In 1993 he joined Hadson Energy Limited (now Apache Energy Limited), where he contributed to several hydrocarbon discoveries including the Stag, Legendre, and Caribou Fields. His experience primarily includes data interpretation in the Carnarvon, Bonaparte, Browse and Arafura Basins, the Exmouth Plateau, and Timor Sea. Ed is a member of the ASEG, SEG, and PESA.

Terry Crabb a native of Adelaide SA and an Adelaide University graduate, is currently CEO of Australian Geophysical Surveys, based at Jandakot Airport, WA. Crabb has worked throughout Australia, as well as in USA, Canada, Iran, Phillipines, Burma, South Africa and Argentina. He has worked in Government and in the Geophysical contracting industry, and is currently completing his MBA. Crabb is actively involved with the ASEG, and is a member of SEG, PESA , AIP and a fellow of the AusIMM.

Buzz Davis is a staff geophysicist with Landmark Graphics involved in building velocity models and depth imaging. Before joining Landmark, Buzz was an interpreter and seismic processor for Amoco in New Orleans and Houston. Member of SEG, B.Sc. Geophysical Engineering - Colorado School of Mines

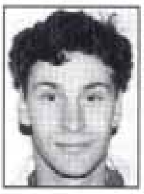


Michael Dentith is Head of the Department of Geology & Geophysics at The University of Western Australia. His research interests include the geophysical signatures of mineral deposits, alternative means of processing and enhancing aeromagnetic data and the seismicity of south-west Western Australia. He is a member of the ASEG, SEG, AGU and GSA.



Trevor Dhu graduated B.Sc. (Hons.) from the University of Adelaide in 1996. He is currently studying for his Ph.D. at Adelaide University with research on textural based enhancement of airborne geophysical data. Trevor has also worked on a casual basis 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 and SEG.

Bruce Dickson obtained his M.Sc. from Wellington University and received a Ph.D. from Imperial College, London in 1973. He moved to Australia where he has been working in CSIRO on a variety of aspects of application 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.

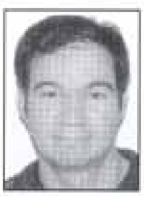


Nick Direen is currently undertaking a Ph.D. in geophysics at the Centre for Ore Deposit Research (CODES) at the University of Tasmania. He received his B.Sc. (Hons.) from the University of Tasmania in 1995 for his thesis "Geophysical modelling of the Longford Basin, northern Tasmania". His present research involves tectonic modelling derived from the integration of potential field models, structural geology and seismic data. He is presently applying these methods to determine the Volcanic Hosted Massive Sulphide prospectivity of Palaeozoic basement in western NSW, SA, Victoria and Tasmania. This has involved a lot of "border crossing".

Thad Dunbar is staff geophysicist with Amoco (UK) Exploration Company. He is currently involved with interpretation/evaluation of several projects in the North Sea. In the past, he has been involved in several offshore lease sales in the Gulf of Mexico. He has a B.S. in Mathematics from Tulane University graduating in 1983. From 1983 to the present he has worked with Amoco Production Company.

Andrew Duncan received a B.Sc. (Hons.) in geophysics at Monash University where his main interests were in electrical geophysics and inversion techniques. After graduating in 1986 he took on a research fellowship at Monash during which time he developed EM interpretation software, researched data acquisition techniques and taught a course on remote sensing to undergraduates. In 1989 he joined World Geoscience Corporation and was responsible for development of airborne EM systems. He participated in the development of the Questem and Saltmap airborne EM systems and developed algorithms for the acquisition and processing of EM and magnetic data. In 1994 he formed ElectroMagnetic Imaging Technology (EMIT) and has been developing new instrumentation and software for EM geophysics and groundwater exploration since that time. EMIT released the SMARTem receiver system in 19985.

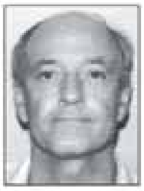
Guy Duncan completed his B.Sc. in geophysics from Curtin University in 1985 and a Post Graduate Diploma in petroleum geophysics in 1986. From 1987 to 1991 he worked for BHP as a research scientist at their laboratories in Newcastle where he was involved in the in-seam seismic, cross-hole seismic and VSP methods. He took three years leave of absence from BHP in 1991 to undertake Ph.D. studies at the University of Melbourne which he completed in 1994. He is currently working for BHP in their petroleum division based in Melbourne, involved in seismic processing, depth imaging and amplitude versus offset studies. He is a member of the SEG and the ASEG.



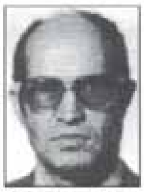
Peter Eagleton received his B.Sc. in geophysics from the University of Sydney after finishing his studies in 1983. He then worked as a field geophysicist for Geoterrex for three years in places around Australia and Africa. He followed this with a stint at I.P.S. Radio and Space Services as a Physicist . He completed a Dip. Ed. at The University of Technology majoring in science in 1990 and taught science courses in Sydney. He returned to mineral exploration by working as a sub-contractor for Surtec Geosurveys conducting geophysical surveys around Australia and Papua New Guinea. He joined North Flinders Exploration in 1993 as an internal geophysical consultant and for the next five years has worked with exploration teams in the Northern Territory. He is an active member of the ASEG.

Julie Elders graduated in 1993 from the Colorado School of Mines with a B.S. in Geophysical Engineering. Since then she has been working as a mine geophysicist for WMC Resources' Kambalda Nickel Operations, Kambalda, WA.

Anthony Endres received his B.S. (1977) from Michigan Technological University in mathematics, his M.S. (1979) from Texas A&M University in applied mathematics, and his Ph.D. (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 in Hydrology at the University of Western Australia. His research interest include the use of rock physics in geophysical interpretation and the application of geophysical methods to hydrogeological and geotechnical problems.



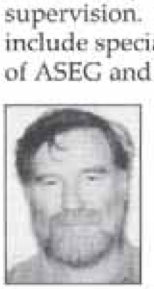
Brian Evans Dip. E.E. (L'pool), M.Sc. Geophysics (WAIT) and Ph.D. Geophysics (Curtin). He was an instrument engineer with GEC-Elliott (London), after which he worked for GSI amongst other seismic companies. He was a geophysical consultant for 8 years, when he returned to the education arena at WAIT in 1983. He operates a small experimental seismic crew and is active in the APCRC and CMTE2 developing new techniques for petroleum and mining applications. His present area of interest is pore pressure prediction while drilling. He is a member of the ASEG, SEG, SPE, IEE and author of the SEG book' 'Seismic Data Acquisition in Exploration'.



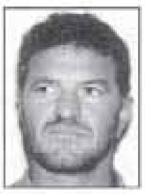
Edward Fainberg received his M.S. (1963) in physics from State University of Turkmenia, his Ph.D. (1969) in physics and mathematics from Institute of Physics of the Earth, and his Doctor of Sciences Diploma (1982) from Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation with the Russian Academy of Sciences. He is working for the Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation and United Institute of Physics of the Earth, both with the Russian Academy of Sciences, since 1970. He is a professor of the Russian Academy of Sciences (1983) and head of the Laboratory of Electromagnetic Modelling. His scientific interests are mainly focused on global and regional deep electromagnetic explorations. The area of his most recent interest is application of the electromagnetic methods for environmental research.

William Featherstone holds a first-class Honours degree in Geophysics and Planetary Physics from the University of Newcastle-upon-Tyne and a Doctorate in Geodesy from the University of Oxford. He is currently Associate Professor of Geodesy and leads the Geodesy Group in the School of Spatial Sciences, Curtin University of Technology. His research interests include physical geodesy, gravimetric geoid determination, satellite positioning, map projections and co-ordinate systems, and has published widely in all these fields. Will is also a Fellow of the Royal Astronomical Society, President of the Australasian Surveying and Mapping Lecturers' Association, Federal Councillor of the Institution of Surveyors, and Chair of the International Association of Geodesy's Study Group on Synthetic Modelling of the Earth's Gravity Field.

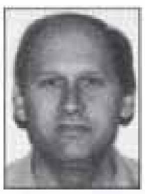
Nigel Fisher graduated from Imperial College, University of London with a B.Sc. (Mathematics) in 1970 and an M.Sc. (Geophysics) in 1971. He was awarded a Ph.D. in Mathematics from the University of Queensland in 1981. From 1982 to 1994 he worked for various seismic processing contractors including a period as Digicon's Brisbane centre manager. In 1995 he established a consultancy specialising in seismic processing supervision. In 1997 these services were expanded to include specialised seismic processing. Nigel is a member of ASEG and PESA.



Desmond Fitzgerald With over 20 years experience in the minerals industry, Des has a range of interests in the technical software and instrumentation hardware areas. Chairman: Mindata Pty Ltd, GeoJAG Australia, International Monitoring Systems, Director: Techbase Australia Pty Ltd; ISS Pacific P/L. As Principal of Desmond FitzGerald and Associates, Des co-wrote the Intrepid geophysics processing and mapping software product. Current extensions are rewriting the Australian National Gravity data handling for AGSO and also developing automatic interpretation methods for mineralised targets. The Mindata business is committed to sensor development and data collection for mining and water applications.



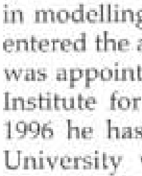
Marcus Flis graduated from the University of Adelaide with a B. Sc. (Hons.) in 1979. He was employed by CRA Exploration from 1980 to 1989, principally in the search for base metals. In 1985 Marcus was awarded an M. Sc. from the University of Utah for research into IP effects in TEM. From 1989 to 1995 he explored for gold in W.A., the N.T., and Greece for Newcrest Mining Ltd. He is currently the Principal Geophysicist and Manager - Exploration of Hamersley Iron Pty. Ltd based in Dampier, W.A.. Marcus is a member of the ASEG, the EAEG, and the SEG.



Peter Fullagar holds an M.Sc. in Applied Mathematics and Earth Sciences from Monash University and a Ph.D. in Geophysics from the University of British Columbia. He worked for Western Mining Corporation in Australia for 12 years, serving as Exploration Geophysicist, Research Geophysicist, Geophysical Research & Processing Manager, and Chief Geophysicist. While with WMC he worked in petroleum exploration as well as mineral exploration, and also developed an interest in the application of geophysics in mines. In 1993 he became the inaugural Chair of Borehole Geophysics at Ecole Polytechnique in Montreal. In Canada he initiated research into the application of radar and radio imaging for orebody delineation at Inco mines in Sudbury. He returned to

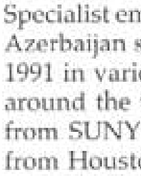
Australia in 1994 to join the CSIRO/CMTE in-mine geophysics research team in Brisbane, and was project leader for AMIRA Project P436, "The Application of Geophysics to Mine Planning and Operations", which was sponsored by seven major mining companies. He is currently Director of Fullagar Geophysics Pty Ltd, a member of the MINSERVE consulting group based in Brisbane.

Karsten Gohl received his Diploma in Geophysics from the University of Hamburg in 1987 and his Ph.D. in Geophysics from the University of Wyoming in 1991. As a postdoctoral research fellow at the University of Uppsala, he further increased his expertise in modelling/inverting of deep crustal seismic data. He entered the area of marine and polar geophysics when he was appointed as research fellow at the Alfred Wegener Institute for Polar and Marine Research in 1992. Since 1996 he has been lecturer in geophysics at Macquarie University with research emphasis in terrestrial and marine shallow subsurface and deep crustal seismic applications.



Alexey Goncharov holds a Ph.D. degree in Geophysics from the St-Petersburg Mining Institute in Russia. He has worked at that institute for a number of years as a Senior Research Scientist and Associate Professor in Geophysics. Teaching geophysics to students was his primary occupation in 1989-1994. His research interests are mostly in studying the structure of the crust and upper mantle by various seismic methods. He started his work processing and interpreting seismic data from the Baltic Shield, later he was involved in the seismic part of the unique super deep drilling project on the Kola peninsula in Russia. In 1994, he joined AGSO where his research interests outgrew the bounds of Precambrian crust and he expanded his original seismic orientation to petrological interpretation of seismic data.

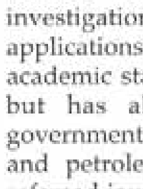
John Gorman has been the Applications and Systems Specialist employed by Landmark Graphics with AIOC in Azerbaijan since 1997. He has been with Landmark since 1991 in various technical support and training capacities around the world. He graduated with a B.S. in Geology from SUNY Oneonta, NY in 1977 and an MBA in 1989 from Houston Baptist University. Prior to Landmark, he spent three years processing seismic data with Seiscom-Delta, and nine years with BP Exploration (Houston) as an exploration geophysicist.



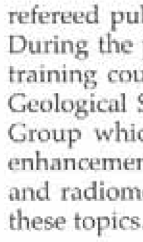
Todd Grant graduated from the Montana College of Mineral Science & Technology with a B.Sc. in Geophysical Engineering in 1987. He then graduated from the University of Utah with a M.Sc. in Geophysics in 1990, where his work focused on numerical modelling and interpretation of electrical and electromagnetic methods. Todd spent two years with CRAE exploring for gold and base metals in Western Australia and three years with Newmont Mining exploring for gold on the Carlin Trend in Nevada USA. Since 1995, he has been working for Rio Tinto in Western Australia. He is a member of the ASEG and the SEG.

Bob Grasty was born in London England in 1939 and received his B.Sc. in Physics and his Ph.D. in Geophysics at Imperial College, London in 1964. After moving to Canada in 1968 he joined the Geological Survey of Canada and became head of the airborne geophysics section in 1985. His main interests have been in developing airborne gamma-ray survey techniques particularly specialiszing in the calibration and interpretation of the data. Bob has worked with industry and government organisations both abroad and in Canada and has frequently served as a consultant to the International Atomic Energy Agency. He was the leader of a team that successfully located radioactive debris from the crashed Soviet nuclear satellite (COSMOS 954) in northern Canada in 1978. In 1995 he took early retirement from the Geological Survey to become chief scientist at Exploranium, a company specialising in the manufacture of radiation detection systems.

Stewart Greenhalgh is the Douglas Mawson Professor of Geophysics and Head of the Department of Geology & Geophysics at the University of Adelaide. He obtained B.Sc. (Hons. I), M.Sc. and D.Sc. degrees , with a geophysics major, from the University of Sydney, and a Ph.D. degree 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, but has also worked at other universities, with government agencies and as a consultant in the mining and petroleum industry. He has published over 120 refereed journal articles on various aspects of theoretical and experimental geophysics. He is a member of SEG, EAGE, SSA, AGU and ASEG.

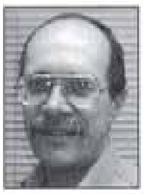


Peter Gunn has worked as a full time employee for 14 different corporate organisations and has worked as a consultant for 35 other organisations. This has involved working on location in 19 countries. He has four graduate qualifications and has published 43 refereed publications and edited two thematic volumes. During the past five years he has led 22 workshops and training courses. He is currently head of the Australian Geological Survey Organisation's Geophysical Mapping Group which specialises in the acquisition, processing, enhancement and interpretation of airborne magnetic and radiometric and gravity data as well as researching these topics.



Wanwu Guo completed his B.Sc. (Hons.) degree in Exploration Geophysics at the Changchun College of Geology, China in 1982. He was employed as an Exploration Geophysicist and Project Geophysicist in western China by the Bureau of Geology and Mineral Resources of Gansu Province (BGMRGP) during 1982-1989, working on mineral deposit exploration, regional geophysics and basin analysis. He received his M.Sc. in Geodynamics and Seismology from the Seismological Institute of Lanzhou (SIL), the China State Seismological Bureau in 1991. He joined SIL as a Research Geoscientist involved in crustal geophysical studies, tectonophysics and earthquake prediction from 1992 to 1995, and meanwhile as an

Honorary Geophysicist with BGMRGP participating in research projects of mineral deposit exploration and prediction. He will soon complete his Ph.D. at the University of Western Australia in Geophysics. He is a member of the ASEG, SEG, AGU and GSA.

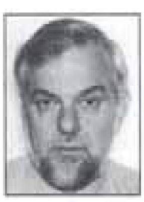


Ross Gwyther is a research geophysicist with CSIRO Exploration and Mining in Brisbane. He is currently managing an earth strain research project in minescale geophysics, and is responsible for monitoring and analysing surface strains and tilts arising from longwall coal mining in the Bulli basin, and the maintenance of field installations. He has previously worked for 15 years in earth strain studies investigating earthquake processes in California.

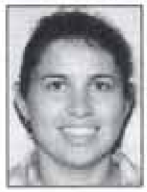
Bruce Hartley joined the Department of Exploration geophysics at Curtin University in 1994. He has been working on the attenuation of multiple reflections as well as developing interests in new mathematical methods for use in Geophysics. The work being presented here is an outcome of research in multiple attenuation where accurate time distance relationships are required to improve multiple prediction and enhance their attenuation. He has broad scientific interests including anisotropic wave propagation in seismic exploration and the measurement of natural radioactivity, particularly optimised measurement of radon and its decay products.

Peter Hatherly is a Principal Research Geophysicist with CSIRO Division of Exploration and Mining. Working through the Cooperative Research Centre for Mining Technology and Equipment he is mainly involved in the development of geophysical methods for use in coal and metalliferous mining. Current interests include high resolution 3D and VSP seismic methods, microseismic monitoring and geotechnical evaluation of rock types using geophysical logs. He holds a B.Sc. (Hons.) from the University of Sydney and a Ph.D. from Macquarie University.

Graham Heinson completed a B.Sc. (Hons.) in Geophysics from the University of Edinburgh in 1987, and a Ph.D. from the Australian National University in 1991 under the guidance of Dr F.E.M. (Ted) Lilley. He then moved to Flinders University in Adelaide where he is currently a Lecturer and Queen Elizabeth II Research Fellow. His research interests are in marine geophysics, particularly electromagnetic methods. He is a member of ASEG, AGU and EEGS.

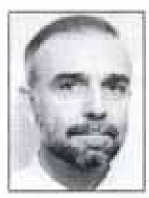


Roger Henderson is a Senior Geophysicist with 30 years experience in many parts of the world. He holds an M.Sc. from Sydney University and was a lecturer at Macquarie University in Sydney from 1968 until 1971, after which he spent three years in the UK as a geophysicist, first with Hunting Geology and Geophysics and then Barringer Research of Canada. He then moved to Toronto with 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, and has held the position ever since. Roger has published on a range of subjects, in Geophysics, Geoexploration, Australian Journal of Science, and Exploration Geophysics. He has twice been President of the Australian Society of Exploration Geophysicists and Co-Chairman of two of its conferences. For his dedication to the society 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 an Australia-at-large Rhodes Scholarship and spent a year researching seismic waveguides within the Department of Engineering Sciences at The University of Oxford. On her return to Australia Natasha started working in the Special Projects Group with Digicon Geophysical Ltd. She spent two years working with PSDM, velocity model building and wave-equation datuming projects. In 1997 Natasha returned to the University of Queensland to begin her Ph.D. on "Applications of Multi-Component Processing in Exploration Seismology". She has been awarded an APA[Industry] Scholarship and the APPEA K.A. Richards Memorial Scholarship. Natasha is currently a member of the ASEG Qld Branch Committee.

Michael A. Hession was the Chief Geophysicist of A.I.O.C. in Baku seconded from British Petroleum. Before joining A.I.O.C. in January 1996, Dr. Hession worked on exploration and development projects in the Gulf of Mexico, Indonesia, Norway, Vietnam and Canada. Dr. Hession graduated with a Ph.D. in geophysics from University College Wales in 1987. He recently joined Woodside Petroleum Pty. in Australia.



Peter Hill is a research scientist (geophysicist) in the Petroleum and Marine Division of the Australian Geological Survey Organisation in Canberra. He graduated from the Australian National University with a B.Sc., and subsequently completed a B.Appl.Sc. (Geology) at the University of Canberra and an M.Sc. at the ANU. He joined AGSO's marine geoscience group in 1983, and has since worked on projects researching the development of the Australian continental margin, mostly using AGSO's research vessel Rig Seismic for data acquisition. He has also had considerable involvement in SW Pacific marine geoscience, including the use of swath-mapping techniques. He is now working on tectonic, petroleum and multibeam seafloor mapping projects in the SE Australia region.

Richard Hillis is a senior lecturer in exploration geophysics at the University of Adelaide. He graduated B.Sc. (Hons.) from the Royal School of Mines, University of London in 1985, and Ph.D. from the University of Edinburgh in 1989. After research positions at Flinders University, Adelaide, and at the British Geological Survey, Edinburgh, Richard joined the University of Adelaide in 1992. His main research interests are in contemporary stresses and sedimentary basin dynamics. Richard is a member of AAPG, AGU, ASEG, EAGE, GSA, GSL, PESA and SEG.

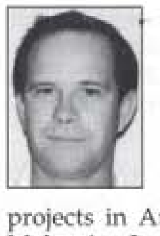
Adrian Hitchman completed studies in applied Physics at the Capricornia Institute of Advanced Education in 1981 before undertaking a B.Sc. (Hons.) in Geophysics at the University of New England. On completion, he began work as a geophysicist at the Bureau of Mineral Resources where he collected and prepared magnetic field data for periodic updates of the Australian Geomagnetic Reference Field (AGRF) model. In 1991 Adrian completed a Graduate Diploma in Education and became a Science/Maths teacher. He is now undertaking Ph.D. research at the Australian National University, investigating interactions between electromagnetic induction in the Earth and total-field magnetic survey data. Adrian is a committee member of the ACT ASEG branch and also a member of the SEG and EAGE.

Gregg Hofland is a senior geophysicist with Landmark Graphics, specialising in velocity modelling for depth conversion and depth imaging. Prior to Landmark, he spent several years working on seismic modelling products with Western Atlas Software and Sierra Geophysics/Halliburton. Hofland has bachelor's and master's degrees in Geophysics from the Colorado School of Mines, and is a member of the SEG and the Denver Geophysical Society.

Greg Hollyer Brief Employment History: 1988-91 Special Projects Geophysicist, BHP Minerals Intl. 1991-1995 Senior Technical Writer, software industry. 1995-1996 Senior Geophysicist and Technical Communicator, Geosoft Inc. 1996-Present Manager. Academic History: Queen's University- B.Sc.- Geophysical Engineering 1986, Queen's University- M.Sc.- Geophysical Engineering 1991, York University- Certificate in Technical and Professional Writing 1994. Professional Honors and Awards: Presentation Award, Borehole Geophysics Symposium, 1991. Professional Society Affiliations: SEG Member - NO Association of Professional Engineers, Professional Interests: Geoscience data processing and analysis methods, Software developments and deployment, Technical and scientific communication.

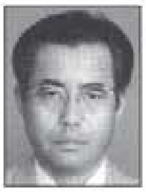
Michael House received his B.Sc. (Hons., 1991) in geology and Ph.D. (1996) in geophysics from the University of Western Australia. He then commenced working with RGC Exploration Pty Ltd as an exploration geophysicist searching for gold, base metals and mineral sands. He currently works with Goldfields Exploration Pty Ltd in Kalgoorlie.

Jens Hovgaard was born in Denmark in 1961. In 1989 he receiving his M.Sc. in electrical engineering from the Technical University of Denmark (DTU) where he continued working as a research engineer developing models for nuclear well logging tools. In 1992 he joined the Danish Emergency Management Agency and was responsible for developing and implementing a Danish airborne gamma-ray system for monitoring nuclear fall-out in case of a nuclear accident. Between 1994 and 1997 Jens was project leader of a Nordic research program (Nordic Nuclear Safety Research) on emergency response systems. As part of this program, he chaired the planning committee for an international field exercise, Rapid Environmental Surveying Using Mobile Equipment (RESUME 95) that was held in Finland in 1995. In 1998 he was awarded his Ph.D. degree in airborne gamma-ray spectrometry from DTU.



Gary Humphreys has an Engineering degree from the University of Western Australia and a Graduate Diploma in Applied Geophysics from W.A. Institute of Technology (now Curtin University). He worked with Scintrex in Perth as a contractor/consultant for 14 years, with projects in Australia and Asia (including China, Japan, Malaysia, Laos and Pakistan), specialising in mineral exploration, groundwater studies and technical training. He joined the Water Resources Division of the Power and Water Authority in Darwin in 1993, and leads a team in the application of geophysical techniques to groundwater exploration and evaluation. The Division recently moved into the Department of Lands, Planning and Environment. Current interests include integrating geophysical and groundwater data sets, sounding methods and estimating groundwater quality and quantity with surface and borehole geophysics. He is a member of ASEG, SEG, EAEG and IAH.

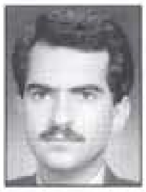
Marina Hyde has worked with Geoterrex-Dighem and Encom Technology during 1996-98. Some of the research on localised conductors originated from Marina's course work at Macquarie University, where she has recently obtained her M.Sc. in Geoscience.



Eiji Ishii graduated with a B.E. from Akita University in 1974. He worked for Osaka Soil Test Laboratory from 1974 to 1976. He completed a M.E. in mining geology from Akita University in 1980. He has since worked at Suncoh Consultants Co., Ltd. as a geophysicist. He is a member of SEGJ and ASEG.

Hiroyuki Katayama obtained his B. Sc. (1994) in the resistivity method and his M.Sc. (1996) in numerical modelling experiment of TEM from Kyoto University. He has been employed as a geophysicist by Metal Mining Agency of Japan since 1996, and engaged in domestic mineral exploration and technical development.

Damian Kelly received a B.App.Sci (Hons.) from the University of Queensland in 1984 and a Graduate Diploma in Applied Finance and Investment from the Securities Institute of Australia in 1997. He worked for BHP Petroleum for nine years as a geophysicist engaged in seismic data acquisition and interpretation projects in a variety of Australian onshore and offshore basins. Since joining Oil Company of Australia in 1994 as a senior geophysicist, he has been involved in a number of successful Surat Basin exploration and development drilling programmes. He is a member of PESA, ASEG, SEG and SPE and is an Associate of the Securities Institute of Australia.



Abbas Khaksar graduated from the University of Tehran, Iran in Exploration & Mining Engineering in 1990 and received an M.Sc. degree in Petroleum Geology and Geophysics from the University of Adelaide in 1994. From 1990 to 1992 he worked in phosphate and potash exploration for the Iranian Ministry of Mines and Metals. Currently, he is a Ph.D. candidate at the National Center for Petroleum Geology and Geophysics at the University of Adelaide. His Ph.D. research is concerned with the petrophysical evaluation of well logs with particular interest in the influence of pressure and saturation on acoustic properties of reservoir rocks. He is a member of ASEG, PESA, EAGE and the London Society of Petrophysicists.

Ian Kirby graduated with B.Sc. (Hons.) in geophysics from Macquarie University in 1998. His Honours thesis was on seismic constraints on EM modelling by detailed travel time inversion. During his studies he has been employed by Coffey Partners International Pty Ltd on a casual basis, largely involved with geophysical investigations for geotechnical projects.

Irena Kivior obtained her Eng. M.Sc. (1976) in ore geology from the Academy of Mines and Metallurgy in Cracow. Prior to coming to Australia in 1980, she worked as a mathematician. For two years she worked in ore exploration. From 1982 to 1990 she worked with ETSA on the geophysical and geochemical properties of coal. Irena undertook her Ph.D. on geophysical interpretation of the Polda rift and deep crustal studies based on potential field data at the University of Adelaide (1990-1996). She presently conducts her postdoctoral research on deep crustal studies. In 1997 Irena established Archimedes Consulting, which specialises in the analysis and interpretation of aeromagnetic data for petroleum exploration.

Rolf Klotz received a B.Sc. Geology, Adelaide University 1978, B.Sc. (Hons. 1st class) Geophysics, Adelaide University 1979 and has 19 years experience working for Western Geophysical (now a division of Baker Hughes) in Singapore, Houston, Perth and Adelaide. Positions held: Marine Analyst, Marine Processing Group Leader, Research Geophysicist, Senior Computer Programmer, Senior Research Geophysicist, and Research & Development Manager. USA Patents awarded: Modified Residual Migration, and Equalisation DMO. Recipient of Litton Industries Advanced Technology Award in 1993. Active membership in SEAPEX and ASEG.

Maija Kurimo Project manager of airborne geophysical surveys in Finland and in special projects abroad. Geological Survey of Finland (GTK) operates with two aircraft performing airborne geophysical mapping in Finland and commercial surveys abroad. Kurimo has also been involved with interpretation and image processing of airborne geophysical data.

Mark Lackie did his undergraduate degree at Melbourne University and then completed a Ph.D. at Macquarie University in 1989. He then worked at the CSIRO EM (or was that Exploration Geoscience or DEM or Mineral Physics) until 1994 when he fled the structural upheavals to Macquarie University. Mark is currently enjoying being a lecturer in geophysics.

Richard Lane received a B.Sc. (1983) with Hons. 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 as Managing Geophysicist for the Product Development Division. He was appointed Program Leader for the Airborne EM Systems Program of the CRC AMET in 1997.

Leharne Lay graduated from Macquarie University in 1997, with an honours degree in geophysics. During her honours year she worked closely with the Cooperative Research Centre for Australian Mineral Exploration Technologies, from whom she received an Honours scholarship. She was awarded the University Medal for the research work on which this paper is partly based. Following graduation, Leharne was employed as a processing geophysicist with Goldfields Exploration in Kalgoorlie. Currently she is employed by PGS Tensor in Perth.

Margaret LeClerc graduated from the University of Tasmania with a B.Sc. in Geology and Geophysics (1995) and B.Sc. (Hons.) in Geophysics (1996). She is now based in Perth, and has been employed as a Geologist with Great Central Mines Ltd and Johnson's Well Mining N.L. for the past 2 years. She has worked on a fly-in fly-out basis in the north-eastern goldfields, on both mine based and regional exploration programs.

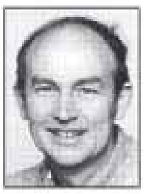
David Leaman received a B.Sc. (Hons.) and Ph.D. from the University of Tasmania. From 1966 to 1981 he worked for the Geological Survey of Tasmania on many applied geophysical, hydrological and structural projects. Since mid 1981 he has been a consultant specialising in the application of gravity and magnetic methods to the appraisal of structural setting and control of ore deposits, coal and petroleum basin studies, and basin evolution. He has wide experience within Australia and is visiting senior lecturer in Geophysics and tectonics at the Centre for Ore Deposit and Exploration Studies at the University of Tasmania. He is a member of ASEG, SEG, EAEG, PESA and GSA.

Pru Leeming Graduated from the University of Melbourne with a B.Sc. major in Geology in 1976. Commenced work in the mineral exploration industry with Newmont by supervising gold, tin and basemetal projects in Victoria, Tasmania, the Kimberley and Pilbara regions, of Western Australia, northern NSW and north Queensland. Experience gained offshore included work at the Emperor Gold mine in Fiji, several epithermal gold prospects in New Zealand and the Pyrite Belt, in southern Spain. After completing an M.Sc.MSc in Mineral Exploration at Rhodes University, South Africa, Pru joined Freeport to work in gold exploration in the Murchison of Western Australia. The next four years were spent working in the gold mining industry at Karonie gold mine, in the Eastern Goldfields with Freeport/Normandy and the Fortnum gold mine in the Glengarry Basin, with Homestake. After working south of the Golden Mile at Kalgoolie for several months with Homestake, Pru joined World Geoscience Corporation to work on regional geophysical interpretation and mapping projects in India, Oman, Indonesia and the Eastern Goldfields. Currently she is working on the application of AEM to regional mapping and drillhole targeting with the Product Development Division of World Geoscience.

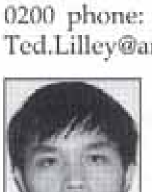
Jennifer Levett After gaining a B.Sc. (Hons.) in geophysics at The University of Sydney in 1994, Jennifer Levett joined Placer Exploration Ltd. and since then has primarily been working in Papua New Guinea. Her work has mostly involved exploration around the Misima and Porgera minesites. Jennifer is now working for Placer Dome Exploration in Canada.

Ruiping Li received B. Sc. (1984) and M.Sc. (1988) in Physics at Wuhan University, China. From 1984 to 1985, employed by the Department of Applied Physics, Hunan University, China, as an assistant lecturer. From 1988 to 1995, worked at Radar Academy, China, as a lecturer. Currently, is a Ph.D. student in the Department of Exploration Geophysics, Curtin University of Technology. Research work is concerned with seismic in multi-layered transversely isotropic media.

Zheng-Xiang Li is a Senior Research Fellow, and an ARC QEII Fellow since 1995. He obtained his B.Sc. in geology from Peking University in 1982, and Ph.D. in palaeomagnetism and tectonics from Macquarie University in 1989. He joined the University of Western Australia in 1990, and has since established a palaeomagnetism laboratory there. He is now a member of the Tectonics Special Research Centre. His research interests include palaeomagnetism and global tectonics, and the application of palaeomagnetism and rock magnetism to resource exploration. Currently running a MERIWA project on the timing and genesis of iron ore deposits in the Hamersley Province.

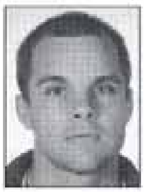


F.E.M. Ted Lilley grew up in Hobart, and was educated at Hutchins School. Upon leaving he was awarded a cadetship in geophysics by the Australian Atomic Energy Commission. He studied science at the University of Sydney, graduating B.Sc. (Hons.). After experience in aeromagnetic surveying with the Bureau of Mineral Resources (now the Australian Geological Survey Organisation), he undertook graduate study in geophysics at the University of Western Ontario, Canada, where he graduated M.Sc. and Ph.D Postdoctoral work on the dynamo theory for the cause of Earth's magnetic field followed at the University of Cambridge, England, before he returned to the Australian National University, where he is now a Senior Fellow in the Research School of Earth Sciences. He has worked particularly in geomagnetism, and on measurements of natural electromagnetic induction in the Earth. Dr F.E.M. (Ted) Lilley Research School of Earth Sciences Australian National University Canberra, ACT 0200 phone: (02) 6249 3406, fax: (02) 6249 0738, email: Ted.Lilley@anu.edu.au

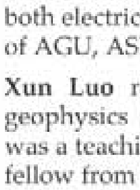


Zhihong Lin received his B.Sc. (1983) in geophysics from Chengdu Institute of Geology, PRC and his M.Sc. (1986) in nuclear physics from China Institute of Atomic Energy. He recently submitted his Ph.D. thesis in geophysics to Macquarie University. From 1986 until 1991 he worked on application of nuclear techniques at CIAE. Between 1992 and 1995 he worked on the application of LOTEM to hydrocarbon exploration and EM modelling and inversion. He currently works at the CRC for Australian Mineral Exploration Technologies. He is a member of SEG and ASEG. His main interests are radiometrics, EM modelling and inversion.

William Lodwick is a geophysicist with nearly 20 years of experience in the acquisition, processing and interpretation of seismic data. Bill started his career in the oil industry in 1974 during summer holidays, gained a B.Sc. in Physics in 1978 and has worked in the USA, Singapore, Australia and Indonesia. Bill is currently the Principal Geophysicist for the Bureau of Resource Sciences (Department of Primary Industry and Energy) in Canberra where he participates in advice to government on policy, promotion of hydrocarbon exploration in Australia and the interpretation of seismic data in support of acreage releases.

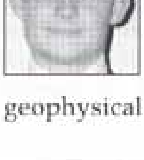


Keiran Logan completed his B.Sc. degree with the University of Sydney in 1984, majoring in geophysics and applied mathematics. After initial employment with CRA in late 1984, he joined Placer Pacific Limited in early 1985 as the geophysicist responsible for surveys in Australia, Asia and the Pacific. He is currently a senior geophysicist with Placer Pacific Limited coordinating a team of geoscientists on Placer owned projects and mines in PNG and Asia. He is also completing a Ph.D. in geophysics at the University of Sydney. Keiran is an active member of the ASEG, SEG and AGU.



Kanglin Lu received his B.S. (1984) and M.S. (1987) in hydrogeology from the China University of Geosciences (Wuhan), and submitted his Ph.D. thesis in geophysics to Macquarie University in March 1998. Before joining CRC AMET as a Ph.D. student, he worked at Xiangtan Mining Institute. He is currently working with CSIRO. His research interests include instrument development, noise reduction techniques, and numerical modelling of both electric field and groundwater flow. He is a member of AGU, ASEG and SEG.

Xun Luo received a B.S. (1982) and M.S. (1987) in geophysics from the Chengdu College of Geology. He was a teaching assistant from 1982 to 1984 and a research fellow from 1987 to 1990 with CCG. From 1990 to 1994 he studied at the Victoria University of Wellington, New Zealand and received a Ph.D. in 1994. Since then he has worked as a research scientist and a senior research scientist with Division of Exploration and Mining, CSIRO, Australia. His research interests are in mining induced seismology, mine scale geophysics, mining geomechanics and crustal seismology. He is an Honorary Professor of Chengdu Institute of Technology, an Honorary Professor of Changsha Institute of Mining Research and an Honorary Research Fellow of Central Queensland University. He is a member of AGU, NZGS and ASEG.



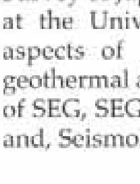
Timothy Mackey received his B.Sc. (Hons.) degree in geophysics from Monash University in 1993. In 1994, he joined the geophysical mapping section of the Australian Geological Survey Organisation. He has worked in image processing, contract supervision, airborne geophysical data processing and digital GIS interpretation and integration of potential field geophysics and geology. Timothy has worked on several major geophysical interpretation projects, including Fiji, Mount Isa, Goulburn, offshore Otway Basin and the southern Joseph Bonaparte Gulf.

Ian N. MacLeod Brief Employment History: 1978-1986 Paterson, Grant and Watson (PGW) Limited 1986-Present Geosoft Inc. Academic History: Queen's University- B.Sc.- Geology and Physics 1978 Professional Honors and Awards: Professional Society Affiliations: SEG Member, -YES Canadian Exploration of Geophysical Society, Australian Society of Exploration Geophysicists, South African Geophysical Association. Chairman, Technical Program - Exploration 97 Professional Interests: Use of micro-computers and graphics techniques to enhance and present geophysical and geochemical data.

James Macnae Professor James Macnae leads the EM Interpretation and High-Resolution Geophysics programs within the Cooperative Research Centre for Australian Mineral Exploration Technologies. He has supervised numerous research students at Macquarie University over the past six years, and led several AMIRA research projects. While his main research interests have involved the development of conductivity-depth imaging, approximate modelling and inversion for EM data, he has research interests in most sectors of exploration geophysics. He has had over 25 years experience in mineral exploration as a consultant and geophysical contractor. Outside of geophysics, Jim sings with the Sydney Philharmonic Choirs and coaches the local U9 T-Ball and soccer teams.

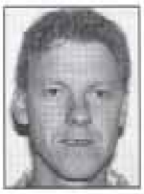
Tariq Mahmood received his B.Sc. (Applied Geology) in 1988 and an M.Sc. (Structural Geology) in 1990 from Punjab University Pakistan. He worked as a Research Officer at the Centre for Integrated Mountain Research in Pakistan before commencing studies at the NCPGG. His research towards and M.Sc. in Petroleum Geology and Geophysics has been supported by an AIDAB scholarship with extension of his work towards a Ph.D. supported by the APCRC. Tariq is a member of PESA, ASEG and AAPG.

Lennart Malmqvist Current positions: Professor. Dept. of Physics University of Lund, Sweden. Semtech Resources AB, Chairman. *Former positions:* Boliden Mineral AB, Chief Geophysicist. Boliden AB, Technical Director, Vice President.



Jun Matsushima Research assistant Engineering Research Institute, Faculty of Engineering, The University of Tokyo, 2-11-16, Yayoi, Bunkyo-ku, Tokyo 113-8656, Japan. Phone: +81-3-3812-2111 ext. 7718 Facsimile: +81-3-3813-5772 e-mail: mjun@gpl.t.u-tokyo.ac.jp Jun received a B.A. and M.A. (1995) in engineering from the University of Tokyo. From 1995 to 1996 he worked at the Geological Survey of Japan. Since 1996 he has been research assistant at the University of Tokyo. His interests include all aspects of the crosswell seismic method applied to geothermal and heterogeneous problems. He is a member of SEG, SEGJ, Japan Soc. for Computational Engineering and, Seismological Soc. of Japan.

Takashi Matsuyama is a geophysicist, Technology Research Center of Japan National Oil Corporation. Takashi graduated from Tokyo University in 1994 with a B.S. degree in geophysics. He joined Japan National Oil Corporation (JNOC) in 1994. He was assigned to Technology Research Center in 1997. His current interests are 3D seismic modelling, rock physics and geostatistics analysis.



Tony Meixner completed a degree of Bachelor of Science majoring in geology at the Australian National University in 1991. The following year he studied honours at the Research School of Earth Sciences, ANU, involving the three dimensional kinematic modelling of the magnetic field of the southern Bonaparte Gulf. At the beginning of 1996 he began employment in the Geophysical Mapping section of the Australian Geological Survey Organisation. Since that time he has been involved with the modelling of potential field data as an aid to the interpretation of regional data sets.

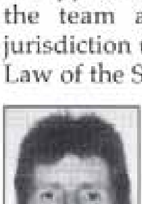
Mike Middleton completed a Ph.D. at the University of Sydney in 1978. He has worked for CSIRO, ECL (Australia), Geological Survey of W.A., and as a private consultant. From 1990 to 1993 he was Adjunct Associate Professor in the Department of Exploration Geophysics at Curtin University of Technology. Since 1993, he has been Nordic Professor of Petrophysics at Chalmers University of Technology, Sweden. He is a member of ASEG, SEG, and AGU.

Peter Milligan graduated from The Flinders University of South Australia in 1975 with a B.Sc. (Hons.) in Geophysics and Geology, and a Diploma in Education. He subsequently completed a Ph.D. degree in Geophysics at Flinders University. Since 1974 he has taught science and mathematics in South Australian high schools before joining the then Bureau of Mineral Resources, Geology and Geophysics (now the Australian Geological Survey Organisation) in 1985, initially with the Geomagnetism Section. From 1986 he has worked with the Airborne Group of the Minerals Division, where he is now a Senior Geophysicist. Research interests are in the fields of Geomagnetism and its applications to airborne magnetic surveys and in image processing of geophysical data. He is currently Treasurer of the ACT local branch of ASEG.

Masato Minegishi is an assistant manager, Technology Rresearch Centre of Japan National Oil Corporation. Masato graduated from Hokkaido University in 1986 with a master's degree in geophysics. He joined JAPEX Geoscience Institute Inc. (JGII) in 1986. After seismic data acquisition, data processing, and R&D works in JGII, he moved to Japan Petroleum Exploration Co. (JAPEX) in 1989. After seismic interpretation work, he was in charge of a seismic imaging research project for 3 years. He was assigned to Technology Research Center of Japan National Oil Corporation in 1996. Currently his interests are 3D seismic modelling, elastic inversion, wavefield separation, and geostatistics analysis.

Brian Minty received a B.Sc. (1976) from Rhodes University, a B.Sc. (Hons.) (1977) in geophysics from the University of the Witwatersrand, an M.Sc. (1982) in exploration geophysics from the University of Pretoria, and a Ph.D. (1997) from the Australian National University. He worked for the Geological Survey of South Africa for 5 years before emigrating to Australia to work for Hunting Geology and Geophysics Ltd. He currently works as a senior research scientist for the Australian Geological Survey Organisation in Canberra, Australia. His research interests relate mainly to the acquisition, processing and interpretation of airborne magnetic and gamma-ray spectrometric data.

Aidan Moore graduated from Trinity College, Dublin University, with an Honours degree in Geology, with subsidiary Physics. He joined the Australian Geological Survey Organisation (AGSO) in 1987 after more than twenty years in seismic acquisition and interpretation, and prospect assessment on land and offshore with oil companies in West Africa, the British Isles and Australia. After doing regional structural mapping and basin prospectivity assessments in areas including offshore Tasmania, the Arafura Sea, the Philippines, and South Pacific areas, he is now attached to the team assembling Australia's claim to offshore jurisdiction under the United Nations Convention on the Law of the Sea.

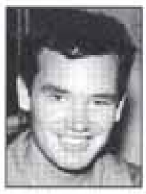


David Moore has been a Senior Geophysicist with the Geological Survey of Victoria for the past three years. After graduating from the Australian National University in 1968, he became a geologist, first with Geopeko Ltd, and then with the Australian Atomic Energy Commission, the Northern Territory Geological Survey and BHP Minerals. His work ranged from strategic analysis, through prospect evaluation to mine production geology. Since 1990, he has been interpreting regional geophysical data sets in ways that are meaningful to geologists. He is a member of the ASEG, AIG and the GSA.

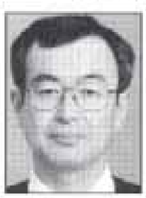
Stephen Mudge graduated from the University of New England in 1975 with a B.Sc. in Physics and Geophysics and in 1976 completed a B.Sc. (Hons.) in Geophysics. He joined Geopeko Ltd in 1977 to work throughout Australia on numerous base-metal, gold and uranium exploration projects which included a period with Austirex Aerial Surveys. Since 1981 he has been with RGC Exploration Pty Ltd where he is currently Chief Geophysicist and responsible for the Group's geophysical exploration for base-metals, tin, gold and heavy mineral sands throughout Australia, Asia, South-West Pacific and South America. He has held several positions in the ASEG and is currently a member of the ASEG Research Foundation and author of the Excitations articles in PREVIEW. He is a member of ASEG, AIG, SEG, EAEG and AusIMM.

Brad Mullard has been employed in the exploration and mining industry for the past 18 years. He currently holds the position of Assistant Director (Coal and Petroleum) with the New South Wales Department of Mineral Resources. Brad has overall responsibility for the assessment of the State's fossil energy resources and provides strategic advice to Government in the areas of development proposals, State energy infrastructure and land use. He is actively involved in promoting development opportunities in the State for both coal and petroleum and has overall responsibility for implementing the petroleum component of the Government's Discovery 2000 program which aims to attract increased exploration activity to NSW.

Alice Murray graduated from the University of Western Australia with a B.Sc. (Hons.) in Physics in 1968. She worked at the Mundaring Geophysical Observatory for a short time before obtaining a permanent position with the Bureau of Mineral Resources in Canberra in 1969. After a year in the Operations Branch she transferred to the Regional Gravity Section of the Geophysics Division. During the next ten years she established the National Gravity Database Computer System and supervised a contract to digitise gravity data which was held in analogue form in company reports. During this time a number of gridding and 3D modelling techniques were developed. With the end of the systematic 11km surveying of the continent in 1973 BMR's gravity surveying was reduced to sporadic detailed surveys along seismic lines and maintenance of the national base station network. She supervised 4km in-fill surveying of the Eastern Goldfields and Lachlan areas in the late 1980s. In the 1990s gravity has become an important tool in mineral exploration mainly due to accurate positioning with GPS. In 1997 Alice assumed leadership of the National Gravimetry Project in the Minerals Division of AGSO and produced the Gravity Map of the Australian Region and digital grid.



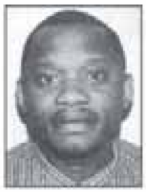
Paul Mutton completed his B.Sc. in Geophysics at Curtin University in 1994. After working as a field geophysicist for WGC he returned for Honours in 1996. He has been working at WMC's Kambalda Nickel Operations since 1996 as a mine geophysicist for several of the underground nickel mines. Here he works with the mine geologists in production, extensional, and additional drilling programs in and around the mines.



Osamu Nakano received a B.Sc. in geophysics in 1974 from Hokkaido University. Since 1974 he has been working for Dia Consultants Co., Ltd. as a geophysicist. He is currently the project leader for integrating geophysical technology using high resolution seismic, gravity and electromagnetic surveys for coal resources. He is a member of SEGJ and ASEG.

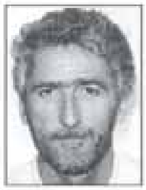
Carl Notfors Regional research manager Veritas DGC Asia Pacific Ltd. Employment History: 1978-81 GECO, 1981-84 Aramco, 1984-89 Digicon, 1989-90 Seres A/S, 1990-present Veritas DGC. Academic History: M.Sc. petroleum prospecting, Norwegian

Inst. of Technology. Society affiliations: SEG, EAGE. Professional interests: Seismic Data processing.



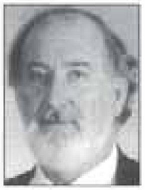
Patrick Okoye received his B.Sc. (1984) in physics and astronomy, and an M.Sc. (1989) in applied geophysics from the University of Nigeria , Nsukka. From 1986 to 1988 he was employed by the Department of Physics, University of Nigeria. Between 1988 and 1991 he lectured at the Federal Polytechnic, Oko, Nigeria. In 1994 he received a Ph.D. in exploration geophysics from Curtin University of Technology in Western Australia. His Ph.D. work was in the area of reflection seismics in anisotropic media with particular interest in lateral or spatial resolution. Currently his research work involves anisotropic parameter determination and migration. He is a member of SEG and ASEG.

Glenn Pears graduated with a B.Sc. (1st Class Hons.) in physics from the University of Queensland. This was followed by an M.Sc. research degree, also carried out at the University of Queensland, which examined the ability to invert cross-hole radio frequency data using approximate inverse mapping (AIM) techniques. This project was supported by CSIRO and the Noranda Technology Centre. In May, 1997, Glenn was employed by World Geoscience Corporation Pty. Ltd. as an Interpretation Geoscientist and forms part of the Petroleum Exploration Consulting group within WGC. Glenn is an associate member of the ASEG with professional interests in all aspects of geology and geophysics.



Mark Pilkington received an M.Sc. from the University of Leeds in 1979 and a Ph.D. from McGill University in 1985, both in Geophysics. After working for Urquhart Dvorak in Toronto he joined the Geological Survey of Canada in Ottawa in 1987. Since then he has worked on interpretation methods for potential field data, using fractal earth property models in inversion and investigating the geophysical characteristics of terrestrial impact craters.

Chris Powell obtained his Ph.D. degree from the University of Tasmania and his first class Honours from the University of Queensland. He joined the Department of Geology and Geophysics at UWA in January 1990 and was Head of Department for five years. Previously he was Head of the School of Earth Sciences at Macquarie University. In 1996 he submitted a successful application for an ARC Special Research Centre and became the Director of the Tectonics Special Research Centre in January 1997. His principal areas of research are in field-based structural geology and tectonics. In recent years his work has branched into field-oriented sedimentology and palaeomagnetism, with the aim of reconstructing Australian and global palaeogeography.



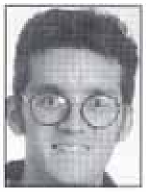
Pat Quilty AM Professor Patrick Quilty is the ANARE Chief Scientist with the Antarctic Division of the Department of the Environment. He is a geologist, with qualifications from the Universities of Western Australia and Tasmania. He has worked in academia (University of Tasmania, Macquarie University), in industry with West Australian Petroleum (WAPET). He participated in both the Deep Sea Drilling Project and the Ocean Drilling Program. He has been senior vice-president Royal Society of Tasmania (Governor is president), president of the Association of Australasian Palaeontologists, and vice-president of the Scientific Committee on Antarctic Research (SCAR) and chaired the organising committees for XX SCAR (1988), in Hobart. He has published over 140 scientific papers. He has four species, a range of nunataks and a bay named in his honour. He received the Royal Society of Tasmania Medal (1996), US Antarctic Services Medal (1974), was Distinguished Lecturer for the Petroleum Exploration Society of Australia (1986) and is Honorary Research Professor at the University of Tasmania. He was speaker in the North American Speaker series for 1998/99. He first visited Antarctica in 1965/66 with the University of Wisconsin and has made about 14 other working trips south in addition to accompanying many tourist overflights. In 1997 he was awarded Membership of the Order of Australia (AM) in the Queen's Birthday Honours List, and inaugural Distinguished Alumnus from the University of Tasmania.

Art Raiche During the 1960's, Art Raiche worked for the US defence industry on problems associated with anti-submarine warfare, EM compatibility, gas dynamics and other such anti-social topics whilst pursuing a Ph.D. in theoretical nuclear physics at night. Upon completion he migrated to Australia in 1970. A year later, he joined the yet to be created CSIRO Mineral Physics division even though no one including the chief knew what that meant. Over the past two decades he has led seven AMIRA projects in EM modelling and inversion. A former Doberman breeder, he now studies and plays Japanese honkyoku on the shakuhachi.

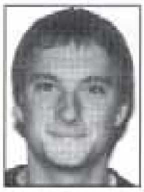
Shanti Rajagopalan studied Mathematics and Exploration Geophysics graduating with an M.Sc. (Tech) degree from Osmania University in 1984 and a Ph.D. from the University of Adelaide in 1989. She worked at the National Geophysical Research Institute in India and the Bureau of Mineral Resources in Canberra before returning to the University of Adelaide to lecture in 1992. Shanti worked for CRA Exploration (later Rio Tinto Exploration) from 1995 till end 1997. She is currently a consultant geophysicist. She specialises in applying the aeromagnetic method to mineral exploration. Shanti is the current President of the Victorian Branch of the ASEG. She is Assoc. Editor of Geophysics and the Co-Chairman of the Technical Programme at this conference.

Marianne Rauch is Manager of the Integrated Geoscience Department (Australia) with CGG. She graduated from Karl Franzens University, Graz, in 1985 with a Ph.D. in Geophysics. In 1988 she immigrated to Australia where she worked at Curtin University in the Department of Geophysics. Since 1991 she has been involved in integrated geoscience studies such as AVO, synthetic modelling and stratigraphic inversion to acoustic impedance. Marianne is a member of the ASEG, PESA, and EAGE.

Terry Redshaw graduated in Applied Mathematics in 1979 and completed his Ph.D. in Numerical Analysis in 1982, both from the University College of Wales. He then joined Western Geophysical. Dr. Redshaw joined BP in 1985 where he spent several years in BP's R&D groups working on seismic processing and migration. For the past 2 years he has been leading BP's Seismic Modelling and Rock Property Team.

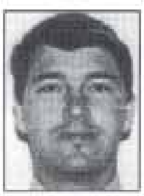


James Reid received his B. Sc. (1991) and M. Sc. (1994) in Geophysics from the University of Sydney, Australia. He is currently a Ph.D. student at the Cooperative Research Centre for Australian Mineral Exploration Technologies, Macquarie University, Sydney, working on approximate models for interpretation of airborne electromagnetic data. He is a member of ASEG and SEG.



Thomas 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 doctor of philosophy at the University of Western Australia.

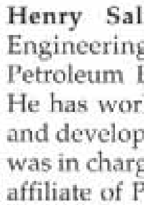
Dan Rimmer has over 17 years experience processing and modelling seismic data. He came to Landmark four years ago as a ProMAX trainer. He spent the one year as the ProMAX product geoscientist within the development group and as technical advisor for ProMAX AVO. He spent the last year as a technical consultant to the marketing department. Before coming to Landmark, Dan spent thirteen years with Marathon Oil Company, eleven years in their research center in Denver, and two years in Houston. He specialised in depth imaging, 2D and 3D seismic modelling, wavelet processing, AVO, VSP and processing in difficult data areas. Dan has a B.S. in physics from California State University at Northridge and a M.S. in Geophysics from the Colorado School of Mines.



Samuel Roberts graduated with a B.Sc. (Hons.) degree in Geophysics from the University of Adelaide in 1989. He spent several years working for Geoterrex Pty Ltd in the Ground Geophysics department before joining RGC Exploration Pty Ltd in 1993. He is currently employed as Geophysicist at RGC where he contributes to the gold exploration programme in WA. He is a member of the Australian Society of Exploration Geophysicists (ASEG).

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 B.Sc. (joint major of geology and physics) 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 Bureau of Mineral Resources (BMR - now the Australian Geological Survey Organisation). 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. David's interests are potential field modelling and low latitude magnetics. He is a member of ASEG.

Brian Russell holds a BSc. in Geophysics from the University of Saskatchewan, Canada, and an MSc. in Geophysics from the University of Durham, England. He started his career in 1976 at Chevron Standard in Calgary as an exploration geophysicist and also worked for Chevron Geosciences in Houston. He then worked for Teknica Resource Development as a senior explorationist, Veritas Seismic as a research and training geophysicist, and Veritas Software as vice president of marketing and training. In 1987, Brian co-founded Hampson-Russell Software Services Ltd. along with Dan Hampson, and is currently vice president of that company. Hampson-Russell Software develops interpretive processing software for the international exploration industry, specializing in inversion and modelling programs. Brian also presents courses on new geophysical technology throughout the world for Hampson-Russell, as well as other training organizations. Brian has been very active in both the CSEG and the SEG. He was Technical Co-Chairman of the 1989 joint CSEG/CSPG convention, and President of the CSEG in 1991. During 1993/94, he was Second Vice President of the SEG and is a past Chairman of The Leading Edge editorial board. He was also Technical Co-Chairman of the 1996 SEG meeting in Denver, Colorado. Brian is currently president of the SEG for the 1998-99 term. He is also registered as a professional geophysicist in the province of Alberta and is a member of many other geoscience organizations.

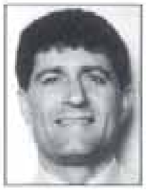


Peter Ruszkowski graduated with honours from London University in 1990. He worked for several years as a geophysical analyst for Western Geophysical in their London branch until the draw to Australia became too strong. Upon emigrating to Sydney in 1993 he soon found work as an analyst in an energy efficiency consultancy, later taking the job of geophysicist in Discovery 2000 of the New South Wales Geological Survey.

Henry Salisch has a B.E. degree in Geological Engineering and did his postgraduate studies in Petroleum Engineering at the University of Oklahoma. He has worked with Schlumberger in log interpretation and development from 1954 to 1977. From 1977 to 1986 he was in charge of well log research at Intevep, the research affiliate of Petroleos de Venezuela. In 1986 he joined the University of New South Wales in Sydney, Australia where he is in charge of teaching and research in petrophysics at the Centre for Petroleum Engineering. He is a member of SPE, SPWLA, EAGE and Pi Epsilon Tau.

Jörgen Samuelsson received a M.Sc. in civil engineering in 1991 at Chalmers University of Technology, Gothenburg, Sweden and in 1994 he graduated with a M.Sc. in petroleum exploration. He has since been a scholar of the Nordic Energy Research Program. In 1997 he received a Lic. Eng. degree in petroleum geology and is currently working on his Ph.D. doing basin modelling.

Daniel Sattel received his Vordiplom from Universitaet Karlsruhe, Germany in 1986 and an M.Sc. from Oregon State University, U.S.A. in 1990, working on the interpretation of seismic refraction data. After graduating from a postgraduate course in hydrogeology at Universitaet Tuebingen, Germany in 1991 he did a Ph.D. in geophysics at Macquarie University modelling and interpreting EM data. He is currently working for World Geoscience Corporation in Perth involved in airborne EM research, development of modelling software as well as occasional interpretation jobs with the EM field crew.



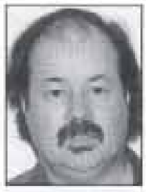
Jacques Sayers graduated with a B.Sc. (Hons.) from the University of Tasmania in early 1985 and joined SAGASCO Resources Ltd the same year, as a petroleum geophysicist. He worked in the Cooper-Eromanga Basins and subsequently joined new ventures, assessing acreage in Australasian basins. In 1990, he joined Digicon Inc.(UK) where he worked on 3D acquisition projects in the offshore Gulf Coast, Malaysia and Nigeria. He obtained an M.Sc. (Geophysics) from the University of Durham (UK) in 1993. Jacques returned in late 1993 to Australia where he obtained short term onshore seismic processing and environmental geophysics contracts. In July 1994 he joined the marine petroleum division of the Australian Geological Survey Organisation where he has worked on North West Shelf regional projects. He is a member of ASEG and PESA.

Phillip Schmidt graduated with a B.Sc. (Hons.) in 1973 from the University of New England in geophysics and with a Ph.D. in 1977 from the Australian National University, specialising in palaeomagnetism. He then spent 2 years in Canada at the Earth Physics Branch of the Dominion Observatory, Ottawa, on a National Research Council of Canada Postdoctoral Fellowship, returning to Australia in 1978 to take up a position with CSIRO in Sydney as a Research Scientist. He is now a Senior Principal Research Scientist and head of the Rock Magnetism group in CSIRO Exploration and Mining. His research interests include the application of palaeomagnetism to geological problems, the integration of rock magnetism and palaeomagnetism and the application of magnetic methods to exploration.

Douglas A Schwebel graduated from Sydney University in 1973 with a B.Sc. (Hons.). He subsequently was awarded a Ph.D. in Geology from Flinders University of South Australia. After completing his Ph.D., Doug joined SAOGC in Adelaide in 1978 as a Petroleum Geologist, working predominantly in the Cooper Basin. In 1980 he joined Esso Australia. During his 18 year career with Esso, Doug has held various positions in Exxon affiliated companies in Australia, Indonesia and the US. He is currently the Exploration Manager for Esso Australia.

Raymond Seikel received a B.Sc. (Hons.) degree in Physics from Deakin University in 1981. From there he joined the Exploration department of BHP's Minerals Division. Ray was involved on various software developments by the Geophysics Group including the in-house geophysical processing system PITS. In 1991 Ray joined Desmond FitzGerald and Associates with an agreement from BHP to further develop and commercialise PITS which is now known as Intrepid. Current work includes marine and terrestrial gravity processing and interpretation software.

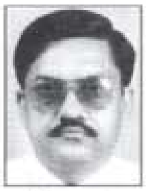
Michael Sharry graduated from the University of Queensland with a B.App.Sc. Geophysics in 1993. He worked with Solo Geophysics based out of Mt. Isa until 1996. He then commenced work with North Limited in Western Australia where he is currently exploring for gold. His interests include signal processing and high resolution electrical geophysics. He is also studying externally for his M.Sc. from Curtin University.



Nick Sheard Why I became a Geophysicist: I came to Australia for a years' break between school (in Wales) and University in the UK. I got a job with Mac Phar Geophysics as an IP Field Assistant in Kalgoorlie. This was great fun and highly educational for a Welsh country boy. I got a place at Flinders University in South Australia (1969) and after a false start of one year I buckled down and managed a B.Sc. (Hons.) (1974). I finally got a job with the BMR (AGSO - now) and worked in Papua New Guinea doing Seismic and Magnetic Observatory work - 3 years. I returned to Australia (Canberra) and worked in the Airborne section doing Airborne Magnetic and Radiometric Surveys all over Australia (5 years). Private enterprise beckoned and in 1981 I joined Carpentaria Exploration Company (wholly owned MIM subsidiary). I worked with them in Adelaide and Perth doing fairly standard geophysical exploration for gold and base-metals. For 2 years I left to join CRAE at Broken Hill but finally rejoined MIM Exploration to take up my current position as Chief Geophysicist - supervising global geophysical exploration and our current R & D initiatives (1991). Moved to Brisbane from Mt. Isa in December, 1992, as Chief Geophysicist where we started to build and develop some ground and airborne geophysical techniques in collaboration with third parties. In January, 1998, I was appointed as General Manager of Technical Services for MIM Exploration Pty Ltd. Family - wife Diane and three teenagers (2 girls and a boy), dog and a cat. Interests fishing, and following cricket and Rugby Union with particular generosity shown to others by losing bets when Wales is playing.

Cvetan Sinadinovski has a doctorate in seismic tomography and geophysical imaging from the Flinders University of South Australia. He has worked as a visiting fellow in USA and Europe, and as a software specialist in Sydney and Adelaide. Currently is employed as a professional officer in the Australian Geological Survey Organisation in Canberra. Member of ASEG, AIG, and AEES.

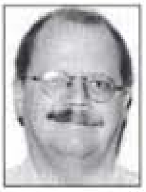
Bension Singer received his MS (1971) in physics from Moscow State University and his Ph.D. (1981) in physics and mathematics from Russian Academy of Sciences. From 1977 to 1991 he worked as a junior, later as a senior research scientist for the Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave Propagation in Moscow with Russian Academy of Sciences. Since 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 CSS 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.



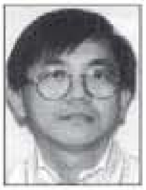
Ravi Singh Ph.D. (Physics) from IIT, Kanpur on the work "Acoustic properties of disordered binary alloys". More than 17 years experience in various fields of geophysics related to petroleum exploration and development in different tectono-stratigraphic frameworks of Indian sedimentary basins. Developed expertise in subtle trap exploration in deep water regimes as well as gas hydrate exploration. His pioneering work in gas hydrates could establish Indian subcontinent in the global map of clathrate reserves. Could map locales of expected giant hydrocarbon reserves in the Arabian Sea off west coast of India in around 900m water depth. The author could also has an interest expertise ion the fractal analysis of the paleo/recent structural inversions. About 10 research papers to his credit published/presented in journals/seminars of national/international repute.

Mike Smith has worked as Chief Geophysicist or Exploration Manager for public companies throughout Australia and the Western pacific region as well as in Europe and South America. He has over 25 years experience in exploration for a wide range of commodities and deposit styles. He holds an M.Sc. from Sydney University and gained initial geophysical experience at the Bureau of Mineral Resources. He spent 14 years with Exxon Minerals Company based in Sydney, Perth, New York and Madrid with responsibilities for the design, implementation and interpretation of ground and airborne surveys in many countries. In August, 1985 Mike joined Austpac Gold NL as Exploration manager of the company's gold exploration programs in PNG, Solomon Islands, Vanuatu, Fiji and New Zealand, later expanding these activities to Japan, the Philippines and Bolivia. In March 1996 he joined Geo Instruments as Manager for Marketing and Sales of helicopter-borne electromagnetic, magnetic and radiometric surveys. Mike served three terms as President of the Australian Institute of Geoscientists (AIG), and is currently a Councillor. He is a former Vice President and Treasurer of ASEG and has served on many conference and symposium organising committees.

Brian Spies is Director of the Cooperative Research Centre for Australian Mineral Exploration Technologies (CRC AMET), a collaborative joint venture of seven government, academic and industry partners developing new geophysical techniques optimised for exploration in Australia. Brian has a B.Sc and Grad. Dip (Univ. New South Wales, 1970 and 1971), and a Ph.D. in geophysics (Macquarie University, 1980). He held various posts in minerals exploration in Australia (BMR) and USA, and worked in oilfield research and management from 1984 to 1996 (Arco Oil and Gas Company, and Schlumberger-Doll Research) in seismology, non-destructive testing, and reservoir characterisation before returning to his native Australia in 1996. Brian is very active in promoting the science and profession of geophysics, and led the transition to electronic communication and publication in the SEG. He serves on numerous committees, has held many editorial positions, and is the author of 80 publications and 8 patents. He was awarded Life Membership in the SEG in 1996, and is a member of the ASEG, EAGE, EEGS and AGU.



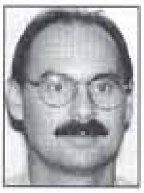
Kurt Strack is chief scientist for Western Atlas Logging Services (WALS). Kurt joined WALS in 1992 as manager of the Resistivity Product Line and Advanced Scientific Research Department, supporting logging-tool development and interpretation through computer modelling. He received a Ph.D. from the University of Cologne, Germany, and an M.Sc. from Colorado School of Mines. Kurt has worked over the past 20 years as a geophysical consultant, university researcher and teacher, and as R & D manager in the geothermal and logging industry, and has produced over 100 publications. His main interest is integrated geophysics, inversion, technology transfer, and project development (complete systems). He is a member of SPE, AAPG, ASEG, DGG, BDG, SEG, SPWLA and EAGE. As a former Fulbright scholar, Kurt has received numerous international rewards and is presently SPE Distinguished Lecturer 1998/1999 on Through-Casing Resistivity (E-mail: kurt.strack@waii.com)



Fred Sugeng is Senior Research Scientist of CSIRO, Division of Exploration & Mining. Currently, he is a member of CRCAMET Mathematical Modelling Project. His primary research interest has been the application of the finite-element method as the geophysical modelling tool. He has developed a 2.5D and 3D Electromagnetic computer modelling program to model complex topography and geology using a new finite-element technique. Dr. Sugeng received his master degree from Technische Hochschule Darmstadt, Germany in Mechanical Engineering and he holds a Ph.D. in Mechanical Engineering from the Hochchule des Bundeswehr Hamburg, Germany. His work experiences before he was involved in geophysical modelling, included working in Germany as fluid-mechanic Research Engineer designing Pumps, Compressors and Gas-turbines for the DECHEMA Inst., REXROTH Corp., and the Defence Dept. In 1983 he came to Australia and worked as Research Fellow in non-Newtonian fluid - mechanics at the Sydney University and in 1985 he joined the CSIRO Mathematical Modelling Group.

Peter Swiridiuk is a geophysical consultant who spends much of his time working on South Pacific Islands projects with Western Pacific Gold. He received his B.Sc. (Hons.) in Geophysics and Dip.Ed. (Mathematics) mid way through 1990 from the University of New England. He then joined the De Beers organisation for six years based in Melbourne where he helped in the search for diamond bearing rocks in WA, SA and NT. After De Beers he began a consulting career based in Brisbane where he now searches for gold, base metals as well as diamonds utilising a variety of airborne and ground geophysical techniques.

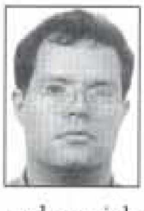
Michael Sykes Graduated from the W.A. Institute of Technology in 1981 with a Bachelor's degree in Physics and worked with GSI as a processing seismologist before returning to WAIT to complete a Graduate Diploma in Education in 1983. Worked as a secondary school teacher for too many years before enrolling (part-time) in Honours (Remote sensing) at Curtin University in 1994. Currently working towards a Ph.D. in the area of 3-D electromagnetic modelling and signal enhancement under the supervision of Umesh Das.



Randall Taylor graduated from the University of Queensland in 1982 with a B.App.Sci. (Hons.) in Geophysics. Initial employment was with AAR Ltd involving seismic data acquisition and interpretation projects in central Queensland and Hainan Island. After joining Santos Ltd, in 1987 he was engaged in successful exploration projects in the Eromanga, Browse and Carnarvon Basins. This work mainly comprised 2D and 3D seismic interpretation. In 1994 he joined OCA Ltd as a Senior Geophysicist where he has been responsible for exploration activities in the Otway Basin and development drilling in the Eromanga Basin. He is a member of, ASEG, SEG, EAGE and PESA.

Stephen Thomson started out in geophysics at Queen's University at Kingston. After several years spent practising exploration geophysics with Geoterrex, he went back to school to obtain his M.BA. This was followed by several more years in Europe where he learned how large companies use innovation to be successful. Since 1996 he has been back at Geoterrex-Dighem where he presently directs business development for fixed wing airborne EM.

Milovan Urosevic received a B.Sc. in exploration geophysics in 1980 and a M.Sc. in geophysics in 1985 from the University of Houston. He has worked for the oil industry since 1980, in the areas of seismic data processing and interpretation. He joined Curtin's research group in 1991. His research interests are in multi-component seismology, seismic anisotropy and fracture detection. He is a member of SEG and ASEG.



Roald Van Borselen received his M.Sc. (1991) and Ph.D. (1995) in technical geophysics from the Delft University of Technology, The Netherlands. Since 1995, he has been working for Amoco production company in 3D imaging. His interests are wave theory, seismic inversion and special processing. He is a member of SEG.

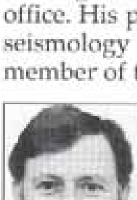
Gijs Vermeer received an M.Sc. in Applied Mathematics from the Technological University of Delft (TUD) in 1965. He spent nearly 30 years with Shell, both in research and in operations. Since 1991 he worked with Shell Research on fundamentals of seismic data acquisition. In February 1997 he started 3DSym - Geophysical Advice, a company specialising in 3D survey design and analysis. He is the author of 'Seismic Wavefield Sampling' published in 1990 by the SEG. His main interests are seismic data acquisition and seismic data processing, and their interrelationships. He is a member of EAGE, SEG and CSEG.

Yanghua Wang received his B.E. (1983) from Changchun University of Science and Technology, M.Sc. (1994) from Monash University, and Ph.D. (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 has been working as a senior research geophysicist for Robertson Research International since 1997. His research interests includes seismic wave theory, modelling and inversion, tomography, and signal processing. He is a member of ASEG, EAGE, and SEG, and a fellow of the Royal Astronomical Society.

Peter Wellman obtained an M.Sc. from Victoria University of Wellington, a Ph.D. from ANU, and has since worked at the Bureau of Mineral Resources, now the Australian Geological Survey Organisation. He has worked on the reduction and interpretation of gravity, magnetic, and gamma-ray spectrometric data, with a main interest in province-wide interpretation and in data integration with geology.

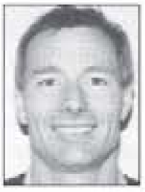
Antony White graduated from Imperial College, London in 1965 with a B.Sc. (Hons.) in physics. He then studied in the Department of Geodesy and Geophysics, University of Cambridge, where he completed a Ph.D. in geophysics under Sir Edward Bullard. He subsequently spent 4.5 years at Scripps Institution of Oceanography in California as a post-graduate research geophysicist. In 1972 he moved to the School of Earth Sciences of the Flinders University of South Australia where he is currently a Senior Lecturer and Head of Department. His research interests lie in the fields of continental and marine electromagnetism.

Peter Whiting received a B.Sc. in geophysics and mathematics from the University of Sydney in 1984, an M.Sc. in geophysics from Macquarie University in 1989 and a Ph.D. in Mathematics from the University of Sydney in 1994. Peter worked in various positions for GSI/HGS between 1984 and 1993 in both Sydney and Perth. Since 1994 he has been with Veritas DGC (formerly Digicon) and is now the Regional Technical Manager based in their Singapore office. His prime areas of interest are general exploration seismology and specifically imaging. He is an active member of the ASEG, SEG and EAGE.



Richard Gareth Williams received his Ph.D. 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 Europe, Africa and Middle East division of Veritas.

Alan Willmore graduated in 1988 with a B.Sc. in geology and geophysics from the University of Sydney, and is currently working towards his M.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 B. Sc. (Hons.) in geology in 1975 (the first year of geology graduates from LaTrobe). 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 airborne geophysical surveying to geological mapping.

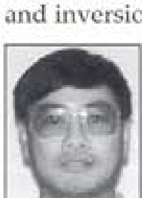
Peter Wolfgram obtained his geophysical training at the Universities of Munich and Toronto and has specialised in electromagnetic exploration methods. Since joining Geoterrex-Dighem in 1992 he has coordinated the R&D activities in Sydney and enjoyed working on the development of the GEOTEMDEEPTM system. More recent R&D projects are still secret but nonetheless a source of constant excitement about the possibilities of airborne EM.

Oz Yilmaz Educational Data: B.S. in Geology with Geophysics Option from University of Missouri-Rolla in 1970, M.S. in Geophysics with research in rock physics and earthquake seismology from Stanford University in 1972, and Ph.D. in Geophysics with research in exploration seismology from Stanford University in 1979. Professional Data: 25 years in the seismic industry – acquisition, processing and interpretation, and research and development responsibilities at Turkish Petroleum, Western Geophysical, Schlumberger, and now Executive Vice President and Chief Technology Officer of Paradigm Geophysical. Aside from publications on all aspects of seismic data analysis, he wrote a book entitled Seismic Data Processing, which was published by the Society of Exploration Geophysicists in 1987 and became the all-time best seller in the geophysical literature. The book is used in academia as the standard textbook, and as the main reference on the subject in the seismic industry. Now, he is working on the second edition and preparing a second book on seismic inversion. Services to Professional Societies: Oz is a member of SEG and EAEG, was Vice-President of SEG for the 1993-94 term, and was the SEG 1996 Spring Distinguished Lecturer. He has taught a course on 3-D Seismic Exploration as part of the Continuing Education Program of SEG and served as an Associate Editor of Geophysical Prospecting of EAEG. He organised the 1994 SEG/EAEG Summer Workshop on Earth Modelling and Imaging in Depth, and the Istanbul 1997 SEG International Conference and Exposition. Awards and Honors For his contributions to the science of geophysical exploration: Oz was honored by the Society of Exploration Geophysicists in 1991 with the Virgil Kauffman Gold Medal Award, and by the European Association of Exploration Geophysicists in 1992 with the Conrad Schlumberger Award. He was also honored with Special Commendation Award by the Technical University of Istanbul in 1992. For his contributions to the geophysical profession in a global manner, his biography has been included in Who's Who in the World, 1998 edition.

Yujin Zhang received a B.Sc. (1983) and an M.Sc. (1989) degree in petrophysics from Daqing Petroleum Institute P. R. China. He taught and did research in petrophysics at the Daqing Petroleum Institute from 1983 to 1994. He then joined the research staff of the Centre for Petroleum Engineering at the University of New South Wales in Sydney, Australia, where he is presently working on his Ph.D. His major research areas are petrophysics, formation evaluation, reservoir characterisation, log interpretation and application of neural networks for formation evaluation. He is a member of SPE and SEG.

Jingping Zhe received his B.S. (1982) in Computer Sciences from Xian Jiaotong University, P. R. China and M.S. (1994) in Geophysics from The Flinders University of South Australia. He currently is studying for a Ph.D. at the University of Adelaide. He had worked for Xian Geophysical Research Institute for 8 years as a computer programmer for geophysical application software before working for Pitt Research Pty Ltd for 2 years as a researcher and computer programmer. His research interests include acoustic and elastic seismic forward modelling and migration, and resistivity modelling and inversion.

Bing Zhou received B.Sc. (1982) and M.Sc. (1989) degrees in geophysics from Chengdu University of Technology (CDUT, formerly Chengdu College of Geology), China. From 1990 to 1991, he worked at the Institute of Geology & Geophysics for the Earth's Interior, CDUT. As a visiting scholar, he joined the Seismology Group at Flinders University of SA in 1992 and at the International Centre for Theoretical Physics, Trieste, Italy in 1994. He was involved in seismic tomography and synthetic modelling for the 3D lithosphere. Now, he is a candidate for the Ph.D. at Adelaide University. His research interests are in geotomography, wave equation modelling and inversion, and the structure of the earth's interior.



Binzhong Zhou received his B.Sc. (1993) and M.Sc. (1986) in geophysics from Chengdu Institute of Technology (CDIT), PRC. He received a Ph.D. 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 Ggeological Services in Adelaide. In 1993, he joined Lincoln College at Oxford University as a research fellow in geophysics and Elf Research Centre in London as a consulting research fellow. In 1995, he moved to Brisbane and joined the Mine Scale Geophysics Group in CSIRO Division of Exploration and Mining as a research geophysicist. 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.