Australian
Society of
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Geophysicists
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Preview

August 1995

Issue No. 57

CONFERENCE HANDBOOK

ASEG 11th Geophysical Conference and Exhibition

In this Issue:

Editor's Desk - ASEG 11th Conference Edition of Preview

Welcome to the 11th ASEG Conference in Adelaide which promises an exciting and diverse technical program. I think our conference programs get better each time, testimony to the vigour and growing maturity of our industry in Australia. A particular welcome is extended to overseas visitors.

Whether this is the first ASEG Conference for you or the latest of many, I am sure you will find much to inspire and extend you in the papers, posters workshops and exhibitions and in that most important ingredient of any conference, the chance to network, to make and renew friendships and acquaintances and to swap ideas and experiences.

Exploration Geophysics and Preview together form a complete technical record of the conference. The Exploration Geophysics Conference volume contains some 60% of the papers presented and the remainder will appear in, and sustain coming issues of our journal. This Conference Handbook issue of Preview contains all paper and poster abstracts, author biographies, exhibitor profiles and the ASEG and SEG President's Conference Addresses as well as our regular newsletter section.

A particularly innovative feature of this conference is the Student Day. The text of presentations to be given are featured in the Preview and will be available on the day to the participants as a reprint. This reprint together with the "Women in Geophysics" reprint (February, 1995) will form part of an ongoing Student Resource kit. Koya Suto and his Promotions Subcommittee have organised the Student Day as part of the ASEG efforts to take up the challenge of Don Pridmore's keynote address at the Perth Conference to promote Geophysics better in the community. ASEG President Kathy Hill and SEG President James Robertson are actively supporting the student day as speakers also.

After a recent drought of colour features in Preview, two colour features this issue is a welcome first. Jason Geophysics (The Netherlands) and Poseidon Geophysics (Botswana) are thanked for their support. Their colour articles on seismic characterisation of reservoirs and 3D aeromagnetics, respectively, ensure something of interest to most ASEG members and an international flavour this issue.

The Preview team welcomes a new Associate Editor, Dr Leonie Jones of the University of Woollongong who, starting next issue, will produce a regular column devoted to geophysics research, education, academia and student news. Leonie can be contacted on
Tel: (042) 21 3013; Fax: (042) 21 4250
or email: leonie_jones@uow.edu.au.

This issue was produced with the assistance of many people, notably Janine Cross, Roger Henderson, Kathy Hill, Rob Kirk, Ciaran Lavin, Steve Mudge, Derecke Palmer and Kerry Slater of the ASEG and Rhonda Hendicott, Natalie O'Sullivan and others from Intermedia, the Conference organisers.

The Adelaide Conference Committee and the Exploration Geophysics Editorial team of John Denham, Richard Facer and Mike Asten have also been working hard to make this conference a success and the thanks of the society go to them.

Thankyou to all concerned and to the numerous contributors.

Enjoy Adelaide and have a good Conference.

Geoff Pettifer, Editor

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Contents Overview

SECTION ONE – Conference Handbook

SECTION TWO – Exhibitor Catalogue

SECTION THREE – Preview

SECTION FOUR – Abstracts

SECTION FIVE – Speakers' Biographies

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Conference Handbook

SECTION ONE

Welcome

It is with great pleasure and pride that we welcome you to the Eleventh Geophysical Conference and Exhibition of the Australian Society of Exploration Geophysicists, one of the premier geophysical conferences held in the world. The conference focus, Increasing the resource, reducing the risk is reflected in the technical program, the exhibition and the future challenges for the industry.

Excellence

For the next three days there will be a choice of over one hundred high calibre technical papers at this award winning convention facility. The papers cover a range of minerals, petroleum, environmental and engineering topics sourced from Australia and overseas, with a balance of case histories and technical developments. New to this conference is a legal forum to discuss issues of land tenure and its ramifications on exploration. This stimulating technical program provides an insight to the health and directions of the industry.

Hands On

A concise workshop program was offered as an adjunct prior to the conference. The variety and relevance of the three sessions ensured that there was something of interest for all attendees.

Innovation

An increased emphasis has been placed on the Poster Sessions so the latest research data and leading edge technologies can be displayed and discussed. We encourage all delegates to attend these sessions.

State of the Art

Explore more than 70 exhibits during lunch, morning and afternoon refreshments and the happy hour. It is fantastic to have again the support of so many exhibitors.

Support

It is not only the delegates, authors and exhibitors who make the conference. Credit and thanks must be given to the conference sponsors. In this tough economic climate it would be impossible to hold such an affordable conference without the valued support of our Principal Sponsor – Western Geophysical, the Major Sponsors (Schlumberger, Digicon, ER Mapper, MESA and World Geoscience) and the various Conference Supporters.

Inaugural

The inaugural "Students Session" is being conducted on Tuesday. This is an opportunity for the Society to promote geophysics to the wider community by targetting secondary school students. The students will be encouraged to consider a rewarding and challenging career in this environmentally responsible and sensitive industry. Take the time to talk to some of these young people during their visit.

Adventure

Don't forget to relax and socialise with other delegates at the welcome reception and farewell cocktails, conference dinner, and the happy hour being held in the exhibition hall. Adelaide is world renowned for its restaurants and wines . . . so enjoy!

We hope that all delegates enjoy the stimulating and rewarding geophysical environment at the conference and exhibition.

Craig Gumley David Tucker
1995 Conference Co-Chairmen

Conference Organising Committee

Co-chairmen	Craig Gumley David Tucker	Santos Ltd Preview Resources
Treasurer	Mike Brumby	Petrosys Pty Ltd
Program Chairman	Danny Burns	Schlumberger Oilfield Australia Pty Limited

Sub-committee chairmen

Terry Crabb	Mines & Energy South Australia
John Hughes	Santos Ltd
Andy McGee	Santos Ltd
Doug Roberts	Boral Energy
Murray Symonds	Western Geophysical Services

The conference gratefully acknowledges the support from the South Australian branch of the ASEG.

ASEG President's Conference Address

Kathy Hill
President
ASEG

Welcome to everyone here from throughout Australia and a special welcome to all of the overseas visitors. We have a truly international conference here in Adelaide. The international President of the Society of Exploration Geophysicists, James Robertson, will be providing a forward looking Keynote address later in the Conference.

On behalf of the membership, attendees and exhibitors I'd like to thank the Adelaide Conference Committee and the many others who have helped in the mammoth task of organising the conference. The Co-chairs, Craig Gumley and David Tucker, have spent many long hours beyond their normal working schedule to ensure the success of the next three days. The resident companies in Adelaide as well as the Mines and Energy Department of South Australia have generously donated the time of their staff.

All of the sponsors including the Principal, Western Atlas, have added essential financial support and are acknowledged in the program. Although I'm sure they've supported the conference for purely altruistic purposes I hope your next business decision considers their public service to geophysical exploration.

The relatively small Adelaide geoscience community must be suffering from "conference fatigue syndrome" with APEA in April and this conference. You've really been the hub this year, Adelaide but I wouldn't be surprised if some of the people who have been involved in both of the conferences look forward to Adelaide as a conference free zone for the next year or so.

In addition the editorial staff, headed by John Denham, have again undertaken the technical review of more than 100 papers with very able assistance of Richard Facer and Mike Asten. Indeed there are probably very few of us here who haven't written, refereed or peer reviewed something in the conference volume of Exploration Geophysics (unless, of course, you missed the deadline). So, if I haven't singled you out for recognition, you are in very good, and abundant, company.

To that effect the ASEG is one of the truly "democratic" organisations, with what must be one of the highest participation rates of any geoscience society of its size. Membership now stands at 1250 as of June 1995, up 12% since the last conference in February 1994. Membership in many other geoscience societies is falling and few could boast that rate of growth.

Why has the ASEG continued to thrive, particularly when other societies are struggling? Part of it no doubt is the mineral industry boom and the special role Australia and Australian Geophysics has in that role. But the reason for its success runs deeper than that. This society comprises a community that is a healthy blend of applied science, research, innovation and pragmatism. We recognise when the elegant solution presents itself and "jury-rig" when necessary.

Also our very diversity is one of the society's strengths. There are individuals in the ASEG who have been involved in research in seismic, potential field, electrical and radar acquisition and processing. They refuse to be pigeon-holed.

At this point I would have liked to present the level of activity for the various areas of geophysical acquisition but am embarrassed to say I can't report just how busy we've been because its almost impossible to gather statistics on all methods. The reflection seismic data industry is the notable exception to the veil of secrecy and I am at a loss to fathom why acquisition statistics are so sensitive to the other contractors. No doubt I will be enlightened during the course of the conference.

Returning to the conference program we see that astonishing level of diversity reflected in the technical program. The program has something for everyone and I urge those of you who might be quite familiar with recent developments in your own area to take the opportunity that the talks this week provide to expand or refresh your range of interests. During my brief sojourn as an academic I found that the talks outside my immediate area of research, rather than those with which I was familiar often triggered a new approach or provided a new point of view. Also it's a healthy exercise for the ego to attend a talk that at least in part goes over your head.

Visit the splendid exhibits and posters, attend the technical sessions and workshops, close those deals but most importantly, learn and have fun.

INCREASING THE RESOURCE
Reducing the Risk

ASEG 11th Conference & Exhibition - Keynote Address

Approaching Year 2000 - Issues for Geophysicists and Goals for SEG

James D. Robertson
President
SEG

During the last several decades, geophysicists have created and commercialized profound technical innovations like 3D seismology and workstation-based geoscience interpretation. These advances have fundamentally changed natural resources exploration and production. The geophysicist today is clearly an equal partner with the geologist and engineer in the discovery and development of hydrocarbons and minerals and, increasingly, in environmental and engineering geoscience. This technical and professional success is noteworthy not only for its scope, but also for its persistence through a period of severe swings in commodity prices and relentless organizational restructurings.

Having crafted success in the midst of turmoil, geophysicists now appreciate that there are fundamentals on which they must focus if they as individual professionals and the profession as a whole are to remain successful into the next century. I offer the following list for your consideration, including in each case a discussion of how the Society of Exploration Geophysicists (SEG) is assisting its members to address each challenge.

Technical Skills

As technical contributors, we must continuously update our technical skills and remain current with the concepts and methods evolving in geophysical science. This maintenance of a core competency is a distinguishing feature of a truly valuable professional. Those who nurture and upgrade their technical base become known as experts who add value, and this attribute brings not just job security but increasing responsibilities and opportunities to work on important projects. Reading technical journals, enrolling in continuing education courses and attentively investigating new vendor offerings are easy to skip when daily deadlines loom, but we should strive to make time for these skill enhancers.

SEG contributes to the maintenance and improvement of technical skills by publishing technical journals and books, organizing technical meetings and workshops and providing continuing education courses for its members. GEOPHYSICS is SEG's reference journal in which approximately two hundred papers are published annually. The Leading Edge (TLE) is the Society's monthly magazine containing news items and articles of general technical and professional interest. SEG sells approximately ten thousand books, videos and slide sets per year that constitute a permanent library of geophysical technology. The Society's meetings and workshops attract ten thousand participants annually. These meetings increasingly are being held outside the United States in order to better serve the Society's international membership. As an example, SEG will be co-hosting the Australian Society of Exploration Geophysicists' meeting in Sydney in 1997, and, on behalf of the 1994-95 SEG Executive Committee, let me note that SEG is very much looking forward to this event. The Society has recently restructured its continuing education program and in 1995 is offering twelve new courses in the five areas of seismic acquisition, seismic processing, seismic interpretation, potential fields and near-surface geophysics.

Professional Communication

Geophysics is complicated and diverse enough that few people can master all aspects of the science. Even fewer people can deeply understand both geophysics and the related technical specialities that contribute to projects of any scope. Consequently, we must exchange information with other geophysicists and with professionals in related fields to become broadly knowledgable about geoscience. The seismic processor interacts closely with the interpreter of the processed data, the reservoir geophysicist has to explain 3D seismic analyses to the rest of the multidisciplinary team managing a producing property, the environmental geophysicist must clearly and fairly outline the advantages and limitations of near-surface geophysics to the hydrogeologist, and we all make presentations and present recommendations to management trained in finance, business administration and other non-technical specialities. It does little good to be an expert if one is unable to communicate one's knowledge to others, and, in turn, to assimilate enough from others to understand how one's expertise fits into an integrated technical solution to a problem.

SEG traditionally has fostered professional communication through its sections, committees, technical meetings, TLE articles, and interdisciplinary projects with other societies like the American Association of Petroleum Geologists (AAPG). There are now twenty-seven societies with which SEG enjoys the section relationship and which are represented on SEG's Council (the Society's ultimate governing body). I am very pleased to note that ASEG and SEG have had this mutually beneficial relationship since 1970. There are thirty-five SEG committees like Research, Development and Production, Continuing Education, Mining, Gravity and Magnetics, etc. that afford the opportunity for individuals with common interests to network and pursue projects that benefit their specialities. SEG and AAPG are currently cooperating to produce two publications: an Atlas of 3D Seismology, and a book of Gravity and Magnetic Case Histories. SEG and AAPG plus the Society of Petroleum Engineers and the Society of Professional Well Log Analysts in recent years have jointly sponsored a series of multidisciplinary conferences called the Archie Conferences to promote interdisciplinary methodologies and teamwork.

Perhaps the most exciting recent development is the establishment in December, 1994 of an SEG Home Page on the World Wide Web. Through Internet, geophysicists around the world are now able to get SEG information and to communicate with each other about Society matters by computer network. For those who want to see what the Home Page has to offer and have a Web browser, the address is http://sepwww.stanford.edu/seg/. There is provision for SEG sections like ASEG to set up their own pages through this SEG electronic bulletin board if a section has an interest.

Business Relationships

As representatives of organizations, we need to understand how our particular companies, universities, government agencies, consultancies, etc. function, and how they contribute to society Each geophysicist should ask who is the customer for my organization's activity. What makes my business entity significant, and how does the business enhance its economic and social value. Are there relationships like strategic partnering with other businesses that can make my organization more profitable and more efficient. We prosper when our employers prosper, and a fundamental for each of us is to look for ways to enhance our organization's technical proficiency, cost avoidance and exposure to business opportunities.

SEG's major direct contributions to business relationships are to sponsor exhibitions at its meetings and to set standards for technical items like seismic tape formats through the SEG Technical Standards Committee. Exhibitions are a forum where vendors can sell their products to clients and demonstrate new products that will bring in more business. Clients in turn can provide feedback to vendors for product development. Owing to the large numbers of geophysicists that attend major conferences like the SEG Annual Meeting, much interaction occurs in a few days, and business relationships between Society members can be built quickly. SEG last year established a new committee called the Exhibitors' Committee which is helping to modify SEG meeting formats to optimize value for exhibitors and customers alike. Also established last year was a Chief Geophysicists' Group that is representing natural resources companies and providing general advice on how to attract geophysicists to Society activities.

Global Workplace

The natural resources business is international, and even those who focus on a small geographic area are affected by global events. The prices of hydrocarbons and minerals are set mostly by worldwide supply and demand, either directly or indirectly through what a competing fuel or substitute material will fetch in the market. Technologies to find and develop natural resources, characterize the near-surface and mitigate earth hazards may be created and perfected in one locality, but they are quickly disseminated outside that area and applied on a global basis. Fax machines and computer networks have brought worldwide, virtually instantaneous communications capability to large numbers of geophysicists, and it is not much of an exaggeration to say that a modern geophysicist lives in a global village. It is undeniable that geophysics both as a profession and a business transcends national boundaries, and each of us needs to appreciate this dimension and view our professional practice as an opportunity to contribute to global and not just local progress.

SEG clearly has been affected by globalization in a major way in the last ten years. In 1983, only 20% of SEG members lived outside the United States. By 1993, that percentage had grown to 34%, representing in absolute numbers an increase from 3600 to 4900 non-U.S. members. It is my belief that SEG will be half U.S. and half non-U.S. by the year 2000. Another measure of internationalization is that SEG has added seven new sections in the last two years, all of which are non-U.S. As a third measure, I had the pleasure of serving on the 1993-94 SEG Executive Committee with a Turkish and a Canadian citizen and on this year's Committee with a Brazilian citizen. Next year's Committee will include an Australian citizen, and I expect that there will never again be an SEG Executive Committee without diverse international representation.

In recent years, SEG has actively developed an ongoing program of joint conferences outside the U.S., mostly in partnership with international SEG sections. The Society's current challenges are to provide the full suite of SEG services like continuing education and distinguished lectures outside the United States, and to develop a funding mechanism to support new members and sections in emerging nations where geophysicists through lack of financial capacity or currency restrictions cannot fully participate in the activities of international professional societies.

Preservation of Research

Geophysics is one of the dominant forces in natural resources management today because business and government leaders in the past focused human resources, money and patient nurturing on geophysical research. Without continual invention of new concepts and methods by research geophysicists, the legions of developers and practitioners in our profession will soon find that there is no more raw material to feed commercial innovations and profitable applications of leading-edge technology. It is likely that the resources currently devoted to geophysical research by traditional supporters like major oil companies, large geophysical contractors and government agencies have fallen below critical mass. Support for geophysical research in the past was strong both because the exploration industry believed in research as a matter of faith and because the last fifty years have been a golden age for scientific research in general, allowing geophysics to benefit as one discipiine in the crowd.

Today, private companies facing flat prices for their products have to control costs to survive, and properly are demanding that expected returns on research investments should be justified by more than wishful thinking. Likewise, given the steadily increasing pressures of global population growth, emerging nation development and environmental management on the world's financial resources, geophysical research is unlikely to draw generous government funding during the next fifty years unless the profession makes a persuasive case for the value of research.

Within SEG, the SEG Research Committee is taking the lead in highlighting the current decline in geophysical research. A special workshop on the topic is scheduled to be held at the SEG Annual Meeting in Houston in October, 1995. Beyond the one workshop, we can all contribute to making the case for research by pointing out and documenting instances where geophysical innovations have directly produced business successes. There is no more compelling argument than a body of published case histories of successful applications of geophysical technology, particularly if many are accompanied by a financial analysis of the positive economic impact of the particular geophysical innovation.

Support for Students

We were all students once and got a helping hand from financial aid, mentoring by somone already in the profession, a summer job, an opportunity to attend a technical meeting at reduced cost and similar assistance. Over the last ten years, there has been a decline in the number of young people studying geophysics in U.S. universities, though there are encouraging signs that the decline is slowing and has reversed in the last couple of years at some schools. The students now in geophysics in universities throughout the world deserve our support as they are the future of the profession's contributions to global society. They are risking that there will be jobs for them when they graduate; we should risk some effort and money on their preparation for long and successful careers.

SEG has traditionally supported students by sponsoring SEG student sections, providing scholarships through the SEG Scholarship Fund and hosting a special student academic reception at the SEG Annual Meeting. This latter event has become very popular in recent years as an occasion where students and faculty can meet both each other and non-academic members of the profession. In 1994, a very generous individual donation to the SEG Foundation enabled the Society to set up a special fund to pay the SEG dues of students in emerging nations. Through this fund, a large number of international students and their faculty advisors are now joining SEG from countries where even the student dues are prohibitively expensive relative to the local cost of living.

In addition to directly helping students, SEG last year took on the challenge of defining a framework for multidisciplinary education that can be used to properly educate students to work in multidisciplinary teams. An SEG grant to the Colorado School of Mines produced a report that is now the basis for a major initiative to find funding for development of a new and significantly different curriculum for university geoscience education.

Public Involvement

The ignorance of the general public at least in the United States about science in general and geoscience in particular is appalling. This is very unfortunate because geoscience understanding at a basic level is essential to properly comprehending the issues in public policy debates on land use, water resources, climatic change, coastal management, building codes in earthquake-prone areas and a host of other natural resources subjects. The public's understanding begins with pre-university education in the geosciences. Those in the profession can encourage pre-university student interest by volunteering to judge science fairs, participating in school visitation programs to explain geological and geophysical impacts on everyday life, influencing school officials to include geoscience education as a standard part of a school's curriculum and talking to civic and social groups. Lack of understanding of geoscience also pervades governmental agencies that make laws and codify and enforce regulations that affect all of us, so don't be shy either about educating a government official.

SEG recently combined its interfaces with the public and the government into a new committee called Public Activities. This group currently concentrates on professional registration of geophysicists in the United States, now a significant issue owing to the growth of engineering and environmental geoscience, and on preservation of U.S. geoscience data, now in some danger of being discarded as U.S. oil companies move their activities overseas. SEG last year also rejoined the American Geological Institute (AGI), which is an umbrella organization of geoscience societies, to support in particular an AGI initiative to influence the way that geoscience is taught in the U.S. at the pre-university level. These public activities are virtually all focused on the United States, and a current topic of discussion in the SEG Executive Committee is whether and how SEG should become involved in similar issues in other countries.

Financial Heritage

Being a geophysicist has been an intellectually and emotionally satisfying career for virtually all of us. In addition, the specialty pays well and has provided the financial means to enjoy a good life. As part of one's generational obligation to give something back to the profession, I hope that every geophysicist will consider some form of financial contribution as a legacy to the future.

SEG provides one excellent mechanism for this investing, and that is the SEG Foundation. The Foundation provides scholarships for students, support for geophysical summer field camps, financial aid for the payment of dues for unemployed SEG members and for prospective members in emerging nations, and general financial support for other worthy charitable, educational and scientific projects. In 1995, SEG launched a new fundraising effort to build the financial resources of the Foundation to a more significant level.

The Foundation is intended to have a global outlook, and a challenge for SEG is to grow the Foundation to a significant worldwide source of funds for geophysics projects.

The SEG Foundation is simply one example of how one might give something back financially to the profession. No matter what form one's financial legacy takes, let me encourage all geophysicists to consider and leave some form of financial heritage to geophysicists of the future.

WESTERN ATLAS

Western Geophysical

Western Atlas International, the oilfield services division of Western Atlas Inc., is a leading supplier of information technology services for the oil and gas industry. The services provided by Western Atlas extend from evaluating the hydrocarbon potential of basins, identifying productive zones, and optimizing hydrocarbon recovery through cost-effective reservoir description and management. Principal clients are the private sector and government-owned oil companies worldwide. Close to 70% of the revenues are generated by operations outside North America.

Western Geophysical

The geophysical division provides comprehensive resources for geophysical exploration and field development. Western's services around the world extend from speculative seismic surveys for prospect evaluation to high-resolution 2-D and 3-D surveys for delineating exploration targets.

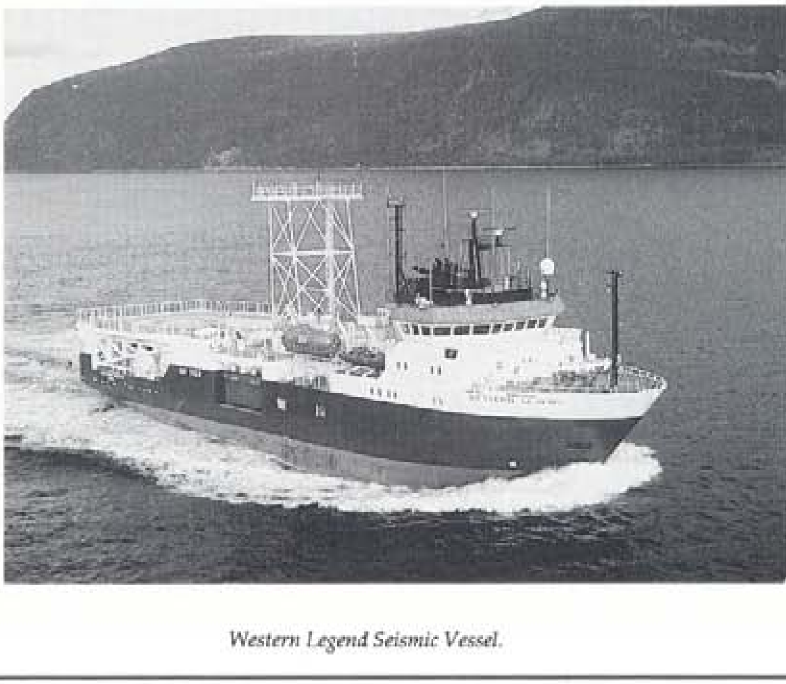
Today, Western is advancing the state-of-the-art in all phases of seismic services through an aggressive combination of geoscientific research, field engineering, and software development. In each global sector, Western is integrating services, expanding service capabilities, and investing in new equipment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

Marine Surveys

To meet the demand for high-resolution 3-D surveys in the coming decades, Western offers a seismic fleet of purpose-built super seismic vessels. The company has recently invested $200-million to produce six new super seismic vessels, designed specifically for today's wide tow requirements. New software has been developed for positioning and navigation control, including the Sargas Differential GPS system and the TotalNet system for the real-time monitoring of source and cable arrays.

Land Surveys

Western Geophysical is investing in telemetry recording systems for acquiring high volumes of data. Improved pre-survey planning and on-site quality control is being achieved through Western's new SPECS system. For vibroseis surveys, Western is equipping more crews with the BBV-60-60, a broadband vibrator that delivers a peak force of 275 kN with minimum distortion.



Western Legend Seismic Vessel.

Transition-Zone Surveys

Western is using a combination of sources, receivers, RF telemetry, and digital Ocean-Bottom Cable (OBC) recording technologies to obtain continuous coverage across transition zones.

Speculative Data

Western has compiled a comprehensive databank of non-exclusive speculative data. Of particular interest in Australia is the company's extensive collection of Carnarvon Basin data.

Data Processing

Western provides comprehensive data processing services through a worldwide network of computer centres. Processing centres in Perth, Adelaide and Melbourne support the Australian and Asian region. These centres have access via ISDN links to Western's main IBM centres in London and Houston, as well as local computer resources. The company also has dedicated client service centres located in China and Brunei.

Western Atlas Omega Seismic processing system.

Western's Geophysical Software Department develops and maintains the seismic software that is used in Western's processing centres and field data processing, and is available for licensing by oil companies. The software library is upgraded on an ongoing basis to enhance subsurface imaging and improve user productivity.

Western offers a full suite of pre- and post-stack 3-D depth imaging tools for complex geological environments. The computations are performed on a network of vector and massively parallel computers that allows data to flow from the secure tape library to the supercomputers and back under the standard tape management system. 3-D velocity modelling is performed with Western's proprietary Pyramid* geological modelling system. Geological information such as seismic analyses, well logs, and interpretations from either Western's or the client's interpretation workstations are integrated to form a single, coherent model of the subsurface geology.

Western's Omega Seismic Processing System is proving itself to be a powerful data processing and quality control tool. The Omega system has been installed aboard many of Western's seismic vessels as well as land and transition-zone crews to support in-field data processing and quality control. The system can output 3-D stack volumes and field acquisition quality control attributes and displays, while maintaining the same data processing production rate as data acquisition.

Research & Development

Western's geophysical research efforts are decentralized with groups located in Houston, London, Denver, and Perth. Research efforts cover a broad range of topics fromtraditional subjects such as data acquisition signal processing, DMO, migration, statics, multiple attenuation, and anisotropy, to new technologies for geological modelling and 3-D visualization. The Data Acquisition R&D group has recently pioneered the OBC and Dual-Sensor technologies and continues to provide innovative solutions for land, marine, and transition-zone data acquisition.

For further information contact:

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Program

Sunday 3 September 1995

Room: Hall E

1800 *Welcome Reception* sponsored by Western Geophysical

Monday 4 September 1995

Room: Halls B & C

0900 *Welcome Address* **Kathy Hill,** ASEG President, Melbourne

0915 *Official Conference Opening*

0930 *Opening Keynote Address* **Ross Adler,** Santos Ltd, Adelaide

1020 *Official Opening of the Trade Exhibition in the Exhibition Hall*

Stream 1 = Hall B
Stream 2 = Rooms 1 & 2
Stream 3 = Hall C
Stream 4 = Rooms 10 & 11

Posters

Posters are mounted on the day of presentation in the Exhibition Hall, adjacent to the Adelaide Convention Centre. Poster presenters will give a short oral presentation during the technical program and will then be available to discuss their posters in the subsequent lunch break.

1030 **Morning Tea in Exhibition Hall**

Time	Stream 1 **Seismic – Case history/Regional**	Stream 2 **Wavefield – VSP**	Stream 3 **Magnetics – Analysis/Interpretation**	Stream 4 **EM/MT – Interpretation**
1100	*Swath-mapping the Australian continental margin: results from offshore Tasmania* **Peter Hill,** Australian Geological Survey Organisation, Canberra	*Shear-wave splitting analysis using a single-source dynamite VSP in the Otway Basin* **Steve Hearn,** The University of Queensland, Brisbane	*Crustal characteristics of graben in South Australia based on regional aeromagnetic and gravity data* **David Boyd,** The University of Adelaide	*A magnetotelluric traverse across the Adelaide Geosyncline* **Francois Chamalaun,** Flinders University, Adelaide
1130	*Evolution and structuring of the Joseph Bonaparte Gulf as delineated by aeromagnetic data* **Peter Gunn,** Australian Geological Survey Organisation, Canberra	*Tube wave suppression in high frequency mine seismic data by singular value decomposition* **Stewart Greenhalgh,** Flinders University of South Australia, Adelaide	*Magnetic mineralogy of the Black Hill Norite and its aeromagnetic and palaemagnetic implications* **Shanti Rajagopalan,** CRA Exploration Pty Limited, Adelaide	**Posters** *A comparison of airborne and ground electromagnetic responses* **Daniel Sattel,** Macquarie University, Sydney *An application of the GEOTEM airborne electro-magnetic method to the study of a salinity affected area in eastern New South Wales* **Michael Hallett** and **Edward Tyne,** Geoterrex Pty Ltd, Sydney *The use of dighem in conductive environments* **Stephen Kilty,** Geoterrex Pty Ltd, Sydney
1200	**Posters** *The Central Officer Basin, South Australia – geophysical results from the NGMA Officer Basin Project* **Jim Leven,** Australian Geological Survey Organisation, Canberra *High resolution aeromagnetic surveying for petroleum in the Western Otway Basin* **Steven Markham,** University of Adelaide *Analogue 3D modelling of the extensional fault systems – examples from the North West Shelf, Western Australia* **Tariq Mahmood,** National Centre for Petroleum Geology & Geophysics, Adelaide	*Huygen's principle versus exploding reflectors – a theoretical and numerical exercise* **Dan Loewenthal,** Tel Aviv University, Israel	*Textural filtering of aeromagnetic data* **Mike Dentith,** University of Western Australia, Perth	

1230 **Lunch in Exhibition Hall**

Time	**Seismic – Wavefield/Modelling**	**Seismic Processing – DMO/Migration**	**South Australia Minerals**	**Magnetics – Processing**
1330	*Detailed elastic modelling to characterise noise contributions to seismic data from the Gippsland Basin* **Jarrod Dunne,** The University of Melbourne	*Suppression of dipping noise and multiples using 3-D pre-stack time migration* **Gareth Williams,** Digicon, East Grinstead, UK	*Geophysics of the Orlando Au-Cu-Bi mine area* **Andrew Foley,** Normandy Exploration Limited, Perth	*An algorithm for reduction to the pole that works at all magnetic latitudes* **Peter Gunn,** Australian Geological Survey Organisation, Canberra
1400	*Hammer-induced seismic investigations in an area of observed anisotropy* **Shane Squire,** Santos Ltd, Adelaide	*A partial DMO operator for use with the stacking velocity function* **Binzhong Zhou,** Oxford, UK	*Interpreting aeromagnetic data in areas of limited outcrop: An example from the Arunta Block, Northern Territory* **David Maidment,** Canberra	*De-warping the Composite Aeromagnetic Anomaly Map of Australia using Control Traverses and Base Stations* **Chris Tarlowski,** Australian Geological Survey Organisation, Canberra
1430	*Variation of stacking velocity in transversely isotropic media* **Patrick Okoye,** Curtin University of Technology, Perth	*3-D Design with DMO modelling* **Judi MacDonald,** Seismic Image Software, Calgary, Canada	*Interpretation and field investigation of some aeromagnetic anomalies from the Abminga Area, South Australia* **Stuart Robinson,** Caldera Resources, Perth	

1500 **Afternoon Tea in Exhibition Hall**

Spectral/Statistical

1530 *Spectral signatures of hydrocarbons* **Jim Dirstein,** Total Depth Pty Ltd, Perth and **Maher Maklad,** Signal Estimation Technology Inc, Calgary, Canada

1600 *Spectral characterisation of reflectivity sequences in the Amadeus, Surat and Bowen Basins, Australia* **Natasha Hendrick,** Digicon, Brisbane

1630 *Reservoir delineation from multi-variate statistical classification: an example from offshore Australia* **Keith Hirsche,** Western Atlas International Inc, Calgary, Canada

Seismic Processing – Velocities

Computer representation of complex 3-D velocity models **Craig Beasley,** Western Geophysical, Houston, USA

Laterally varying velocity estimation **Steven Carroll,** The University of Melbourne

Velocity modelling for depth migration using exact-time migration **Peter Whiting,** Digicon, Brisbane

EM – Case History

Three dimensional structural mapping applications of in-loop transient electromagnetic methods at Maroochydore Copper Deposit, Western Australia **Bradley George,** MIM Exploration, Perth

Deep DHEM exploration at the Isa Mine – the anhydrite prospect **John Jackson,** MIM Exploration Pty Ltd, Brisbane

1700 Happy Hour in the Exhibition Hall – *Sponsored by Australian Seismic Brokers*

Tuesday 5 September 1995

Room: Hall B
Keynote Presentation
0845 *A look back, a look forward and a look sideways* **Robbert Willink,** Boral Energy, Adelaide

Room: Hall C
Keynote Presentation
0845 *A global perspective on developments in electromagnetic prospecting and research* **Michael Zhdanov,** University of Utah, Salt Lake City, USA

Stream 1: Seismic – AVO

0930 *Estimation of limestone reservoir porosity by seismic attribute and AVO analysis* **Djoko Santoso,** Bandung Institute of Technology, Indonesia

1000 *Using variations in amplitude with offset and midpoint to constrain tomographic inversion* **Dylan Mair,** The University of Melbourne

Stream 2: Mining – Seismic Processing

3-D reflector imaging of in-mine high frequency crosshole seismic data **Cvetan Sinadinovski,** Australian Geological Survey Organisation, Canberra

Two step inversion (tomography & pre-stack migration) for high resolution seismic imaging in crosshole or VSP surveys **Ping Zhao,** Curtin University, Perth

Stream 3: EM – Gold

Petrophysical characteristics of BIF-hosted gold deposits and the application of downhole EM to their exploration, with examples from Hill 50 Gold Mine, Mt Magnet, Western Australia **Lisa Vella,** Western Mining Corporation, Mt Magnet

CSAMT and MT investigations of an active gold depositing environment in the Osorezan geothermal area, Japan **Shinichi Takakura,** Geological Survey of Japan, Ibaraki, Japan

Stream 4: SAM – Technique & Analysis

Recent developments in sub-audio magnetics (SAM) **Malcolm Cattach,** Geophysical Research Institute, Armidale

Analytical solutions for the Total Field Magnetometric Resistivity (TFMMR) technique **Nader Fathianpour,** The University of New England, Armidale

1030 **Morning Tea in Exhibition Hall**

South Australia/Northern Territory – Oil/Gas

1100 *Evolution and structuring of the Offshore Otway Basin as delineated by aeromagnetic data* **Peter Gunn,** Australian Geological Survey Organisation, Canberra

1130 *3-D seismic surveying in the Otway Basin* **Noll Moriarty,** Oil Company of Australia, Brisbane

1200 *AVO as an exploration tool in the Penola Trough* **Roderick Lovibond,** Boral Energy, Adelaide

Mining – Tomography

Using seismic data and cross-hole analysis to image fractures **Milovan Urosevic,** Curtin University of Technology, Perth

High resolution seismic tomographic delineation of ore deposits **Shunhua Cao,** The Flinders University of South Australia, Adelaide

Posters

High resolution survey for coal exploration using a newly developed integrated seismic system **Yuzuru Ashida,** Kyoto University, **Eiji Ishii,** Suncoh Consultants Company Ltd, Tokyo and **Osamu Nakano,** DIA Consultants Company Limited, Tokyo, Japan

Potential Field – Analysis/Interpretation

Source component display and potential field interpretation **David Leaman,** Leaman Geophysics, Hobart

L-curve method for the selection of a good regularization parameter and its application to CT for potential field data interpretation **Jun Zhou,** Geophysical Research Institute, Armidale

Application of Euler deconvolution and a neural network system as interpretation aids for three component downhole TEM data **Konrad Schmidt,** Monash University, Melbourne

Minerals – Regional

A regional scale gravity survey of the Southern Cross Greenstone Belt, Western Australia **David Rout,** The University of Western Australia, Perth

Regional geophysics of the Alberton-Mangana Goldfield, Northeast Tasmania **Michael Roach,** University of Tasmania, Hobart

Posters

The use of log residuals and LSfit algorithms on daedalus 1268 airborne scanner data using ER Mapper image analysis system – Kanmantoo, South Australia **Alan Mauger** and **Louise Stathan-Lee,** Mines and Energy South Australia, Adelaide

An integrated geophysical and geological interpretation of the high resolution aeromagnetic survey surrounding the Vaalputs National Radioactive Waste Disposal Site, Bushmanland, South Africa **Luc Antoine,** University of Witwatersrand, Johannesburg, South Africa

On the use of GPS in geophysical surveys **Will Featherstone,** Curtin University of Technology, Perth

1230 **Lunch in Exhibition Hall**

South Australia/Northern Territory – Oil/Gas	Mining – Case Studies	EM Processing	Minerals – Regional Interpretation
1330 *Lake Hope 3D – a case study* **Andrew Oldham,** Santos Ltd, Adelaide	*Combined seismic technology for mine planning – a user's perspective* **Andrew Newland,** BHP Engineering, Wollongong	*Resistivity imaging by time domain electromagnetic migration (TDEMM)* **Michael Zhdanov,** University of Utah, Salt Lake City, USA	*Esoteric and mundane geophysics for diamondiferous pipe exploration* **James Macnae,** CRC-AMET, Sydney
1400 *The integrated use of 3D seismic data, well information and seismic forward modelling – Lake Hope Field Area* **Hege Smith,** Santos Ltd, Brisbane	*A resistivity tomography test survey in the Toyoha Mine, Hokkaido, Japan* **Eiichi Arai,** Metal Mining Agency of Japan, Tokyo	*Higher order spectra in the processing of magnetotelluric data* **Katherine Edwards,** The University of Queensland, Brisbane	*Recent geophysical and geological mapping progress in Eastern Victoria and implications for exploration* **Blair Sands** and **Alan Willocks,** Department of Energy & Minerals, Melbourne
1430 *Regional depth conversion of mapped seismic two-way-times in the Cooper-Eromanga Basin* **Richard Hillis,** University of Adelaide	*Interpretation of rim surveys in underground potash mines* **John McGaughey,** Noranda Technology Centre, Pointe-Claire, Canada		*Interpretation of high quality aeromagnetic data over the Polda Trough* **David Boyd,** The University of Adelaide

1500 **Afternoon Tea in Exhibition Hall**

South Australia/Northern Territory – Oil/Gas	Mining – Techniques/Processing	Aeromagnetic – Gradiometry	EM – Processing/Inversion
1530 *Topography imaging for structural mapping of basins – Otway Basin case history* **Geoff Pettifer,** Department of Energy & Minerals, Melbourne	*A staged genetic algorithm for tomographic inversion of seismic refraction data* **Fabio Boschetti,** University of Western Australia, Perth	*Case history of geological mapping – Ghanzi-Chobe Fold Belt aeromagnetic survey* **Christopher Campbell,** Department of Geological Survey, Lobatse, Botswana	*Conductivity-depth transform of GEOTEM data* **Peter Wolfgram,** Geoterrex Pty Ltd, Sydney
1600 *Tectonic development of the Eastern Officer Basin, Central Australia* **David Hoskins,** University of Adelaide	*Spectral acoustic techniques for joints and fracture characterisation* **George Jung,** Monash University, Melbourne	*Aeromagnetic gradiometers – a perspective* **Mark Baigent,** Kevron Geophysics Pty Ltd, Perth	*Airborne electromagnetic 3D modelling and inversion* **Robert Ellis,** University of British Columbia, Vancouver, Canada
1630 *NABRE (North Australian Basins Resource Evaluation) Phase 1* **NABRE Project Team**		*Aeromagnetic Gradiometry in 1995* **Doug Hardwick,** National Research Council, Ottawa, Canada	*Is full 3-D inversion necessary for interpreting EM data?* **Ned Stolz,** CRC-AMET, Sydney

1930 **Conference Dinner** – Adelaide Festival Centre *sponsored by Digicon*

Wednesday 6 September 1995

Room: Hall B
Keynote Presentation
0845 *Reducing risk through technological innovation: challenges for R&D in the service sector* **Craig Beasley,** Western Geophysical, Houston, USA

Room: Hall C
Keynote Presentation
0845 *Managing exploration risk* **John Main,** CRA Exploration Pty Ltd, Perth

Stream 1 Case History/Interpretation		Stream 3 Minerals – Case History	Stream 4 Ground Water
Attempting to define a subtle trap by seismic attribute mapping of thin sands – a Timor Sea example **David Ormerod,** BHP Petroleum, Melbourne		*The geophysics of the Ernest Henry cu-au deposit (N.W.) Queensland* **Michael Webb,** Western Mining Corporation, Kalgoorlie	*Hydrogeological evaluation of the Keep River Plains* **Gary Humphreys,** Power & Water Authority of Northern Territory, Darwin
An improvement in lithology interpretation from well logs in the Patchawarra Formation, Toolachee Field, Cooper Basin, South Australia **Abbas Khaksar,** National Centre for Petroleum Geology & Geophysics, Adelaide		*The magnetic signature of komatiitic peridotite-hosted nickel sulphide deposits in the Widgiemooltha area, Western Australia* **Louisa McCall,** Central Norseman Gold Corporation, Norseman	*Supplementary ground geophysics for airborne electromagnetic survey over Jemalong-Wyldes Plains area* **Joe Odins,** Department of Water Resources, Sydney

1030 **Morning Tea in Exhibition Hall**

Seismic – Acquisition/Processing	Environmental/Topographical	Minerals – Case History	Radiometrics – Calibration
1100 *Wide-angle reflection profiling – applications for petroleum exploration and crustal studies* **Jannis Makris,** Hamburg University, Germany	*High resolution digital elevation models – a new data source* **Peter Holyland,** Digital Elevation Models, Perth	*Geophysical surveys for strata-bound Outokumpu-type Cu-Co-Zn deposits at Kylylahti, Eastern Finland* **Timo Rekola,** Outokumpu Finnmines Oy Exploration, Outokumpu, Finland	*Radiometric calibration facilities and procedures established for the South Australian Exploration Initiative (SAEI) Airborne Surveys from 1992 to 1995* **Grant Koch,** Mines and Energy South Australia, Adelaide
1130 *Pre-stack processing techniques for multi-source and multi-cable data acquisition* **Gareth Williams,** Digicon, East Grinstead, UK	*Use of magnetics for the location of environmental contamination* **Timothy Pippett,** ADI Services, Sydney	*Exploration for copper-gold deposits, Sultanate of Oman: A case history* **Steve Webster,** Austirex International Ltd, Sydney	*Airborne radiometric calibration: an Australian perspective* **Robert Groves,** World Geoscience Corporation Ltd, Perth
Posters 1200 *A north-south crustal transect through central Australia based on deep seismic reflection profiling* **Russell Korsch,** Australian Geological Survey Organisation, Canberra *Geophysical basement elements map of Australia: implications for crustal tectonism in central and southern Australia* **Russell Shaw,** Australian Geological Survey Organisation, Canberra		**Posters** *The geology, geophysics and mineralisation of Graingers Old Mine and Kohinoor Mine, Kangaroo Island, South Australia* **Suzanne Roberts,** Western Geophysical Australia, Adelaide *A geophysical study of the Koolka Section of the Curnamona Craton, South Australia* **Mohammad Reza Haidarian,** University of Adelaide *A geophysical study of the Malbooma Anorthosite Complex, Gawler Craton, South Australia* **Anna Oranskaia,** Geological Survey of Victoria, Melbourne, **Joanne Hough,** Mines and Energy South Australia, Adelaide and **Shanti Rajagopalan,** CRA Exploration Pty Limited, Adelaide	**Posters** *Continued developments in rapid, multi-modal electromagnetic scattering algorithms* **Ross Groom** and **Peter Walker,** PetRos Eikon Inc, Mississauga, Canada *Simple geological models for 3D magnetotelluric data* **Ted Lilley,** Australian National University, Canberra

1230 **Lunch in Exhibition Hall**

Statics/Surveying	Legal – Native Title	Gold – Case History	Radiometrics – Calibration/Standardisation
1330 *Results of recent seismic acquisition trials and near surface correction comparisons in the Cooper and Eromonga Basins* **John Hughes,** Santos Ltd, Adelaide	*Onshore mining and petroleum exploration ventures – environmental and land access challenges* **David Cole,** Cole Solicitors, Adelaide	*The geophysical signature of the Batman gold deposit Mt Todd project, Northern Territory* **Nigel Hungerford,** Hungerford Geophysical Consultants, Melbourne	*The standardisation of airborne gamma-ray surveys in Australia* **Robert Grasty,** Geological Survey of Canada, Ottawa, Canada
1400 *Can linear inversion achieve detailed refraction statics?* **Derecke Palmer,** The University of New South Wales, Sydney	*Native Title: The Next Horizon* **Ewan Vickery,** Minter Ellison Baker O'Loughlin, Adelaide	*Application of geophysics to the White Devil Gold Deposit, Northern Territory* **Peter Smith,** Pasminco Exploration, Melbourne	*Optimum channel combinations for multichannel airborne gamma-ray spectrometry* **Brian Minty,** Australian Geological Survey Organisation, Canberra
1430 *Precise real time positioning – applications for geophysical operations* **Rod MacLeod,** SAGEM Australasia Pty Ltd, Sydney	*Consultation, exploration and some practical implications* **Noel Bridge,** Normandy Mining Group, Adelaide	*The Mt Leyshon magnetic anomaly* **Michael Sexton,** Normandy Exploration Ltd, Townsville	

1500 **Afternoon Tea in Exhibition Hall**

Seismic – Processing/Multiples	Legal – Native Title Forum	Gold – Case History	Geomagnetic – Micropulsations
1530 *Interactive attenuation of seismic multiples in the radial domain* **Susan Downie,** Curtin University of Technology, Perth	**David Cole,** Cole Solicitors, Adelaide **Ewan Vickery,** Minter Ellison Baker O'Loughlin, Adelaide **Noel Bridge,** Normandy Mining Group, Adelaide	*Geophysical exploration for gold in deeply weathered terrains; two tropical cases* **Ken Witherly,** BHP Minerals, Melbourne	*Short-period geomagnetic variations recorded concurrently with an aeromagnetic survey across the Bendigo Area, Victoria* **Peter Milligan,** Australian Geological Survey Organisation, Canberra
1600 *A method for the removal of long period surface related multiples* **Norm Uren,** Curtin University of Technology, Perth		*Geophysical exploration for epithermal gold deposits – Case studies from the Hishikari Gold Mine, Kagoshima Japan* **Kazuya Okada,** Sumitomo Metal Mining Co Ltd, Tokyo, Japan	*Geomagnetic micropulsations: implications for high resolution aeromagnetic surveys* **Luc Antoine,** University of Witwatersrand, Johannesburg, South Africa

Keynote Presentation

Room: Hall B

1640 *Approaching Year 2000 – issues for geophysicists and goals for SEG* **James Robertson,** SEG President, ARCO International Oil & Gas Co, Plano, USA

1720 **Awards/Presentations**

Room: Hall A

1730 **Conference Farewell** *sponsored by Schlumberger Oilfield Australia Pty Limited*

Exhibitor Catalogue

SECTION TWO

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In a shared booth with the Australian Minerals Foundation, ASEG is displaying available publications and a five year business plan for the ASEG. Information concerning the Society, its activities and the 12th ASEG Conference in Sydney in 1997 will be available. Enquiries about ASEG membership and its benefits are welcomed.

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Contact: Richie Huber

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EarthWare Systems was formed in May 1993 by Dave Johnson to provide advice to government and industry on geoscientific information systems and to undertake development and application of computer techniques.

Principal areas of specialisation include visualisation, three-dimensional imaging, metadata systems and geographic information systems.

EarthWare Systems is the sole Australian agent for Core Software Technology's ImageNet software which has been adopted by ACRES to support their Digital Cathalogue.

EarthWare Systems also markets and supports SpyGlass visual data analysis tools. EarthWare Systems' MINESCAN software system incorporates the three-dimensional imaging techniques provided by SpyGlass Dicer/Slicer.

ELECTROMAGNETIC INSTRUMENTS INC **Booth 100**
PO Box 463
El Cerrito CA 94530
Tel: +1 510 232 7997
Fax: +1 510 232 7998
Contact: Betsy Llosa

EMI designs, manufactures and operates a growing line of innovative geophysical field instrumentation and software for subsurface electromagnetic exploration and monitoring. In its designs, EMI strives to break the technical and cost limitations of existing field equipment and correspondingly holds several patents on its technology. Recent examples of EMI's success with this strategy are the hybrid MT-CSAMT systems (MT-1 and Stratagem) and the state-of-the-art 24 bit IP system (IP-24). EMI operates its equipment in production environments around the world and continually puts this experience back into their designs. Currently, EMI's instrumentation is used in sixteen countries worldwide.

ENCOM TECHNOLOGY PTY LTD **BOOTH 2**
PO Box 422
MILSONS POINT NSW 2061
Tel: (02) 957 4117
Fax: (02) 922 6141
Contact: Peter Gidley

Encom Technology is a software developer and service organisation for the mineral and petroleum exploration industry. Encom supports the industry from its offices in Sydney, Melbourne and Perth. Key business activities include:

- **Software Applications** – ModelVision, EM Vision, GPINFO, DISCOVER
- **Tape Services** – Tape archiving, reformatting, translation and recovery
- **Data Services** – Petroleum and Mineral permits, AUSLIG, ACRES, AGSO
- **ER Mapper** – Distributor in NSW, ACT and Victoria
- **Mapping** – Digitising, data reformatting, colour scanning, plotting
- **Encom Geoscience** – Integrated geophysical interpretation projects
- **Communications** – Multi-platform network and hardware support
- **Computer Hardware** – Sun, Silicon Graphics, PC, Novell, peripherals

Encom's experienced professional staff of geophysicists, geologists and software developers can complement your organisation's team.

ENERGY AND MINERALS VICTORIA **BOOTH 11**
115 Victoria Parade
FITZROY VIC 3065
Tel: (03) 9412 7862
Fax: (03) 9412 7803
Contact: Alan Willocks

Energy and Minerals Victoria is a division of the Department of Agriculture, Energy and Minerals. Its mission is to facilitate exploration for and development of the State's mineral and petroleum wealth. The Department is undertaking a three-year $16.5 million program of large scale airborne geophysical surveys, geological mapping, seismic surveys and drilling. The Department with its revamped mining legislation and state of the art information system (GEDIS) and its greater customer focus is providing a positive environment for the industry to ensure the State's mineral wealth is fully utilised.

EXPLORANIUM GS LIMITED **BOOTH 79**
264 Watline Avenue
MISSISSAUGA ONTARIO L4Z 1P4
CANADA
Tel: +(905) 712 3100
Fax: +(905) 712 3105
Contact: Robin Viau

Exploranium designs and manufactures radiation detection systems for geophysical, environmental and industrial applications. The GR-820 Airborne Gamma-Ray Spectrometer is internationally recognised as the state of the art spectrometer for geophysical and environmental surveying. The company's geophysical product line also includes portable and vehicle mounted spectrometers, scintillometers and magnetic susceptibility meters. Exploranium's latest product, the GR-320 Spectrometer, designed for portable, land vehicle and small fixed and rotary wing aircraft applications, is one of the instruments being demonstrated at the company's booth.

FAIRFIELD IMAGING – VOLUMETRIX **BOOTH 74**
Ashdown Court
The Square
FOREST ROW EAST SUSSEX RH18 5EZ UK
Tel: +44 134 282 5543
Fax: +44 134 282 5591
Contact: Chris Dinsdale

FI-VoluMetrix will demonstrate GeoTracker V3.2, the industry leading software for 3-D visualisation and interpretation. GeoTracker gives true interactive 3-D voxel visualisation of seismic data, interpretations, surfaces and well data. Volume Tracker and WellMaker provide the tools for volume connectivity studies. With 1-D, 2-D and 3-D image processing for feature enhancement, GeoTracker provides the best methods to analyse structural and stratigraphic relationships. With easy links to other interpretation systems GeoTracker provides a software solution to run on your existing workstation investment.

FUGRO STARFIX PTY LTD **BOOTH 55**
18 Prowse Street
WEST PERTH WA 6005
Tel: (09) 322 5295
Fax: (09) 322 4164
Contact: Diane Studman

Perth-based Fugro Survey Pty Ltd is now one of the largest, most advanced survey organisations in Australia, and is part of a worldwide organisation of 100 offices in 30 countries around the world. Fugro Survey is a leading multi-skilled survey company that applies science and measurement techniques to collect, analyse and present dimensional, geographical and environmental data about the earth and structures for clients engaged in research, exploration, development, production and maintenance projects. Fugro Starfix Pty Ltd is a new division of Fugro Survey, opened one year ago by Premier Richard Court in recognition of Australia's first national Differential Global Positioning Satellite System. This unique service known as "STARFIX II", available from the Perth-based Network Control Centre, can offer subscribers sub meter accuracy anywhere in Australasia. By providing this service, users can save considerable costs of setting up and maintaining their own base stations. STARFIX II operates a network of nine south-east Asian, nine Australian and two New Zealand base stations, providing satellite coverage throughout these areas. We look forward to meeting you at this year's exhibition.

GEO INSTRUMENTS PTY LTD **BOOTH 88**
348 Rocky Point Road
RAMSGATE NSW 2219
Tel: (02) 529 2355
Fax: (02) 529 9726
Contact: Roger Henderson

Geo Instruments is a leader in the Australian, South East Asian and Pacific regions in the sales, rental and servicing of geophysical and marine equipment and software. A large number of overseas manufacturers are represented, in order to provide a wide range of different geophysical equipment. Geo Instruments manufactures the GMS-2 Magnetic Susceptibility Meter and has the worldwide marketing rights for SIROTEM, the transient electromagnetic system. Geo Instruments also operates a helicopter geophysical division for surveys in magnetics and radiometrics.

GEO SPACE CORPORATION **BOOTH 72**
PO Box 519
RICHLANDS QLD 4077
Tel: (07) 375 3300
Fax: (07) 375 4027
Contact: Ron Feenaghty, c/– Seismic Supply International Pty Ltd

Geo Space Corporation, a world leader in seismic sensors, has designed, manufactured and sold geophones, hydrophones, geophone strings and accessories for nearly 40 years. Geo Space also manufactures high quality leader wire and waterproof land and marsh cases for vertical, horizontal, two component and three component arrays. New products developed and sold include the MP-25 Pressure Sensor Detector with an operational depth of up to 200 metres and the GS-PV-1 Dual Sensor which combines pressure and velocity sensing to minimise the Ghosting problem in water bottom applications.

GEOIMAGE PTY LTD **BOOTH 6**
13/180 Moggill Road
TARINGA QLD 4068
Tel: (07) 871 0088
Fax: (07) 871 0042
Contact: Sylvia Michael

Geoimage Pty Ltd is an independent image processing consultancy, specialising in the sales and processing of satellite imagery and the processing of geophysical data. We are distributors of ER Mapper through Earth Resource Mapping, worldwide Landsat and ERS1 data through ACRES, and worldwide SPOT data through Spot Imaging Services. We have extensive experience in the geocoding and mosaicing of satellite imagery and the mosaicing of geophysical data, and have produced a number of large area Landsat mosaics around the world.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA **BOOTH 59**
100 Plain Street
EAST PERTH WA 6004
Tel: 09 222 3176
Fax: 09 222 3633
Contact: Andrew Svalbe

The Geological Survey of Western Australia, a division of the Department of Minerals and Energy, is dedicated to providing appropriate geoscientific information and services to support a continuing high level of petroleum and mineral exploration. The Petroleum Exploration Initiatives Program commenced in 1994/95 with the acquisition of new aeromagnetic, gravity, geochemical and stratigraphic data in onshore WA sedimentary basins. Work on technical publications, aimed at releasing both the new and existing data in basic and interpretative forms, has already commenced. Examples of recently acquired aeromagnetic, gravity and other exploration data will be on display in the GSWA booth at the conference.

GEONICS LIMITED **BOOTH 92**
8–1745 Meyerside Drive
MISSISSAUGA ONTARIO L5T 1C6 CANADA
Tel: +1 (905) 670 9580
Fax: +1 (905) 670 9204
Contact: Miro Bosnar

In addition to their normal line of electromagnetic instruments, Geonics Limited is exhibiting their three-component time domain electromagnetic (TDEM) sensor. This sensor with state-of-the-art noise levels measures three components simultaneously and,when used with the PROTEM digital three-component receiver, provides unsurpassed measuring speed and accuracy.

GEOPHYSICAL RESEARCH INSTITUTE (GRI) **BOOTH 42**
University of New England
ARMIDALE NSW 2351
Tel: (067) 732 617
Fax: (067) 711 661
Contact: Andrew Davis

The Geophysical Research Institute of the University of New England specialises in the application of high definition geophysics to mineral exploration, engineering site investigation, industrial contamination and explosive ordnance detection, and archaeological site investigation. It provides exploration services to industry based on its TM-4 magnetometer, GRI-Helimag and Sub-Audio Magnetics systems, as well as undertaking contract R&D. Established in 1978, GRI provides services to public and private sector clients around the world, and has 20 professional and technical staff.

GEOSAT INTERNATIONAL – PITT RESEARCH **BOOTH 80**
Pitt Research Pty Ltd
Geophysical data processing, mapping and interpretation services
45 Hackney Road, HACKNEY SA 5096
PO Box 110, KENT TOWN SA 5067
Tel: (08) 223 6655
Fax: (08) 223 6650
Contact: Mark Deuter

Geosat International Pty Ltd
Geophysical surveys
3 Baron Way
JANDAKOT WA 6164
Tel: (09) 414 1122
Fax: (09) 414 1130
Contact: Ross Roberts

Geosat International Pty Ltd is a Perth-based geophysical survey company. Its aircraft are fully equipped for aeromagnetic and 256-ch spectrometer surveys and the company recently conducted a major survey as part of the SAEI. Geosat has a strong commitment to R&D.

Pitt Research Pty Ltd is an independent geophysical data processing company specialising in high-quality aeromagnetic and radiometric data processing, image processing, mapping and interpretation services. Pitt Research is a key facilitator of the current SA mineral exploration boom.

GEOSCIENCE ASSOCIATES (AUST) PTY LTD **BOOTH 85**
PO Box 697
MT BARKER SA 5251
Tel: (08) 391 2865
Fax: (08) 398 2411
Mobile: 01 08 8 3657
Contact: Dennis Stevens

Geoscience Associates Australia Pty Ltd is a major Australian designer, manufacturer and service contractor of slimhole digital logging systems for the oil/gas, coal and minerals industries. Geoscience operates Australia-wide with a fleet of self contained 4WD Logging Units. Staffed by fully trained field technicians, with 24 hour/day backup, using the latest in borehole technology. So – when you are **'Probing the Depths' call us.**

GEOTERREX PTY LTD **BOOTH 91**
7–9 George Place
ARTARMON NSW 2064
Tel: (02) 418 8077
Fax: (02) 418 8581
Contact: Peter Jackson

Unit 3, 9 Sheen Place
BAYSWATER WA 6053
Tel: (09) 279 3166
Fax: (09) 377 2737

Geoterrex Pty Ltd is an Australian-based world leader in airborne and ground geophysics providing a fast and cost effective service from data acquisition and processing through to sophisticated image processing and interpretation. The group is proud of its reputation for providing geophysical services of the highest quality to the minerals, coal, petroleum, groundwater/salinity, environmental and engineering industries for over 20 years. Our services include both fixed wing and helicopter aeromagnetics/radiometrics, the GEOTEM III Multi-component EM/magnetics system (the only commercially available system worldwide), the DIGHEM heli-EM/magnetics system plus a wide range of ground services including GPS positioned Gravity, EM, IP and downhole surveys.

GUARDIAN DATA **BOOTH 30**
Unit 2
72–74 Gibbes Street
CHATSWOOD NSW 2067
Contact: Bryan Robertson
Tel: (02) 417 6144
Fax: (02) 417 0297

Guardian Data Seismic, established in 1984 and with offices throughout southeast Asia, is a specialised data transcription company capable of reading, reformatting and archiving all media types used in exploration data collection and processing. Guardian Data Seismic, in joint venture with IKODA Pty Ltd, is now offering full data loading and workstation support for both Landmark and Geoquest systems with procedures written to comply with ISO 9001 standards.

HAMPSON-RUSSELL SOFTWARE **BOOTH 46**
Suite 510
715 – 5 Avenue SW
CALGARY ALBERTA T2P 2X6
CANADA
Tel: +1 (403) 266 3225
Fax: +1 (403) 265 6651
Contact: Ruth Peach

Hampson-Russell Software is based in Calgary, Canada, with technical support offices in Hong Kong, London, Houston and Calgary. Products include: "AVO" for amplitude vs offset analysis and modelling; "STRATA", a 3-D seismic inversion program; "GEOSTAT" for geostatistical analysis and mapping; "GLI3D" for 2-D and 3-D refraction analysis; and "INVEST II" for multiple and noise elimination. All programs run on UNIX workstations. GEOSTAT also runs on PCs.

HIGH-SENSE GEOPHYSICS LIMITED **BOOTH 39**
47 Jefferson Avenue
TORONTO ON M6K 1Y3
CANADA
Tel: + 416 588 7075
Fax: + 416 588 9789
Contact: Blair Walker

High-Sense Geophysics Limited is an airborne geophysical contractor offering unique, high definition, GPS guided surveys to a variety of international clients. Survey systems include total field and vertical gradient magnetics, radiometrics, HEM and VLF-EM. Data is routinely processed and plotted in-field, providing next day results with a resolution comparable to ground based surveys. Custom software systems for a variety of geophysical data collection/compilation/processing applications are marketed commercially by our software division – Geopak Systems.

IES GmbH **BOOTH 28**
C-4-2, 202DC
202 Jalan Ampang
KUALA LUMPUR
MALAYSIA
Tel/Fax: (+60–3) 264 2893
Contact: Michael Slee

PetroMod is the industry's leading software suite integrating the industry's first sequence and seismic stratigraphy software, SeisStrat, with full petroleum modelling through time, PetroGen/PetroFlow. SeisStrat offers complete two-way integration with Landmark Open Works and Schlumberger Geoquest interpretation products, including full sequence analysis, quick-look depth conversion, interactive chronostratigraphy and integrated mapping. SeisStrat is a stand-alone interpretation product and an integrated front-end to petroleum modelling for accurate petroleum generation, expulsion and migration prediction, including the industry's first three-phase gas diffusion simulator.

INTERA INFORMATION TECHNOLOGIES PTY LTD **BOOTH 77**
1175 Hay Street
WEST PERTH WA 6005
Tel: (09) 322 4333
Fax: (09) 322 7254
Contact: John Law

Intera Information Technologies Corporation provides spatial information solutions to resource industries and governments worldwide. The Australian company primarily supports the exploration and petroleum production divisions' activities in offering a range of software, geophysical and geological consulting services to the oil and gas industry.

JASON GEOSYSTEMS BV **BOOTH 24**
PO Box 596
(Zuiderstraat 48)
DELFT THE NETHERLANDS
Tel: (+31) 15 14 72 41
Fax: (+31) 15 12 19 19
Contact: Paul Vrolijk

Jason Geosystems from Delft in The Netherlands are suppliers of software and services for Reservoir Characterisation solutions to the oil and gas industry for E&P. With the "Jason Seismic Lithology Workbench", the answer to how to make better decisions and increase productivity, is provided for today's asset teams. JSLW provides a flexible software environment, with data links to all market leading interpretation products. This enables geoscientists to make use of a variety of toolkits, allowing them to use and integrate all available information in producing superior interpretations and the best reservoir parameters. JSLW's success has made it a major cornerstone in today's E&P workflow of several of the largest international oil and gas companies.

KEVRON GEOPHYSICS PTY LTD **BOOTH 56**
10 Compass Road
Jandakot Airport
JANDAKOT WA 6164
Tel: (09) 417 3188
Fax: (09) 417 3558
Contact: Denis Macneall

Kevron Geophysics acquired and processed quality data for around three quarters of a million line kilometres in the 1994/95 financial year. We continue to strive for excellence in our field. Our goal is to maintain the reputation of providing clients with the best quality data in the industry, in a timely and economical manner. This year we introduced the latest real time GPS equipment into all our aircraft thus providing superior navigational accuracy without the need for ground based equipment.

LANDMARK GRAPHICS INTERNATIONAL INC
BOOTH 20
57 Havelock Street
WEST PERTH WA 6005
Tel: (09) 451 0277
Fax: (09) 481 1580
Contact: Kylie Prosser or Gary Klomfass

Landmark Graphics Corporation (NASDAQ-LMRK) is a leading supplier of geoscience and engineering software, systems and services used worldwide to find, produce and manage oil and gas reservoirs more effectively. The company's leading-edge software applications, along with an array of third-party software products, operate in an open, integrated and industry-standard environment to create detailed computer models of the earth's subsurface. Landmark is headquartered in Houston, with 41 offices worldwide and has installed systems in more than 75 countries.

MAGELLAN – NOVATEL GPS SYSTEMS **BOOTH 66**
PO Box 262
MT HAWTHORN WA 6915
Tel: (09) 444 0233
Fax: (09) 443 2598
Contact: Doug Lloyd

Magellan-Novatel GPS Systems will display the latest GPS technology from both Magellan and Novatel. From Novatel we will exhibit our real time kinematic (RTK) back pack system, giving sub 20 cms accuracy over many kilometres. The RTK system can be interfaced to any remote sensing device such as magnetometres, echo sounders or cameras, and navigation software can be customised to the user's requirement. From Magellan will be the Promark X 10 channel handheld receiver with on board memory and feature coding providing sub 50 cms accuracy.

MINCOM PTY LTD **BOOTH 41**
PO Box 72
STONES CORNER QLD 4120
Tel: (07) 3364 9999
Fax: (07) 3394 2844
Contact: Nicole Williams

Mincom Petroleum Technology provides consulting services and develops software products for exploration and production. Software and related services include:

- **GEOLOG** – well database, petrophysics, geophysics, geology, cross sections, maps
- **GEOBLOCK** – geological and attribute modeling and upscaling for simulation block models
- **RESNET** – fully networked multiple reservoir simulation using tanks, polygonal or cartesian block models
- **GASPLAN** – optimised networks of reservoirs and production facilities for development and market deliverability studies

Mincom is committed to excellence of product and service with offices worldwide.

NSW DEPARTMENT OF MINERAL RESOURCES
BOOTH 75
29–57 Christie Street
(PO Box 536)
ST LEONARDS NSW 2065
Tel: (02) 901 8342
Fax: (02) 901 8256
Contact: David Robson

The NSW Department of Mineral Resources is now in Year 2 of the six year $40 million exploration initiative called Discovery 2000. During Year 1, over 620,000 kilometres of air-magnetics/air-radiometrics and 10,000 gravity stations were collected over six areas – Northern Parkes, Bourke, Brewarrina, Bancannia Trough/Koonenberry, Darling and Surat Basins. The interline spacing for the airborne surveys varied between 250/400 metres and gravity measurements were infilled to 4km. Results are available at 1 cent/kilometre for the airborne data and 50 cents/gravity station.

ODEGAARD AND DANNESKIOLD-SAMSOE (OD-S) **BOOTH 53**
1 Kroghsgade
2100 COPENHAGEN
DENMARK
Tel: (+45) 3526 6011
Fax: (+45) 3526 5018
Contact: Jorgen Andersen

The Danish company Odegaard and Danneskiold-Samsoe (OD-S) specialises in seismic inversion, seismic modelling, satellite data transfer and marine QC and processing. The OD-S a/s group markets ISIS, OSIRIS, RAMSAT and RAMESSES II from offices in Copenhagen and UK. ISIS is a new seismic inversion technique that needs no prior model to be implemented. Many international companies have bought this unique seismic inversion technique as a bureau service since 1994. An ISIS 2D software package is now available offering log calibration, wavelet estimation and seismic inversion functionality. In October this year a full 3D software package will be released.

OUTER-RIM EXPLORATION SERVICES BOOTH 19

PO Box 7891
GARBUTT QLD 4814
Tel: (077) 25 3544
Fax: (077) 25 4805
Contact: David Lemcke

Outer-Rim Exploration Services was founded in 1993 to conduct Pulse EM surface and downhole surveys using the Crone time-domain system. The reliability, portability and repeatability of the Crone system is now well established. This, combined with ORE's dedicated personnel and professional approach to data collection, has led to the company's rapid growth and reputation. Crone's 3-component downhole EM system has revolutionised borehole surveying and now, with the new longer time-base and faster ramp, the system is adapted for all Australian environments and applications.

OYO INSTRUMENTS INC BOOTH 70

PO Box 519
RICHLANDS QLD 4077
Tel: (07) 375 3300
Fax: (07) 375 4027
Contact: Ron Feenaghty, Seismic Supply International Pty Ltd

Oyo Instruments Inc., a Texas corporation, designs, manufactures and markets worldwide from its Houston facilities, instruments and systems that are used in the acquisition, processing and presentation of geophysical seismic data. Systems include the GS 624-2, GS 636-2 and GS 644-2 Second Generation of Wide Format Thermal Plotters with hysteresis control and Greensheet capability; GS-608P and GS-612P Portable Thermal Plotters that operate from either 12VDC or 115/230VAC (Autoswitch); DAS-1 and DAS-2 Seismic Data Acquisition Systems (48/240 Data Channels) with the 24-bit Delta-Sigma A/D converter; DFM-480-P Digital Field Monitor with a Pentium based CPU; PCD-3480 Portable Cartridge Drive that is IBM 3480 compatible.

PETROCONSULTANTS BOOTH 71

Level 4
39 Chandos Street
ST LEONARDS NSW 2065
Tel: (02) 901 3599
Fax: (02) 901 3636
Contact: Dave Kirkham

The Petroconsultants Group is the world's largest supplier of international information to the oil and gas exploration industry. In Australia, Petroconsultants Australasia is involved in geophysical and economic consulting projects including acreage valuation reports, and publishes many non-exclusive reports, together with ongoing economic services. Petroconsultants Digimap offers computer services to the exploration industry. It is the only company to supply an Australia-wide digital shotpoint location database, and has developed two GIS products, SeiSearch and PetroWorld, to provide explorationists instant data access.

PETROLEUM GEO-SERVICES AS BOOTH 25

271 Bukit Timah Road #03–13
Balmoral Plaza
SINGAPORE 1025
Tel: +(65) 735 6411
Fax: +(65) 735 6413
Contact: Charles Ramsden

Petroleum Geo-Services AS (PGS) is a holding company offering a range of marine oilfield services through its subsidiaries. The group was established in 1991. Core expertise within the group is based around developing and operating high-tech vessels, onboard and insea electronics, data transmission and processing, sensor technology, commercial geoscience operations, reservoir evaluation and petroleum data management. Its largest service segments are the acquisition and processing of contract seismic surveys and the planning, completion and marketing of multi-client seismic surveys. The group operates a fleet of 13 advanced seismic vessels. Onshore data processing centres are located in USA, Europe, Middle East, South America and Asia. PGS employs approximately 900 people in 15 locations around the world.

PETROSYS PTY LTD BOOTH 36

11/15 Fullarton Road
KENT TOWN SA 5067
Tel: (08) 363 0922
Fax: (09) 362 1840
Contact: Volker Hirsinger

Petrosys is an established supplier of computing systems for the petroleum industry. Petrosys' major products are:

Petroseis	a database and mapping system specifically designed for seismic survey and interpretation data
PGC/3	gridding, contouring and surface manipulation software
dbMap	an industry standard petrotechnical database system with a mapping front end
Pep	a multi-well log database and display package

Petrosys operates from Adelaide, South Australia, and provides European support from a subsidiary in Ayr, Scotland. A number of strategic relationships with software vendors and industry groups have allowed Petrosys to be an active member of the petroleum computing community.

PROTOCOL GROUP BOOTH 60

Suite 3
209 Toorak Road
SOUTH YARRA VIC 3141
Tel: (03) 9826 6149
Fax: (03) 9824 0792
Contact: Andrew Pearcy

The Protocol Group is a well-established Australian company specialising in marketing and support of advanced 3D imaging and analysis software in Australasia, South Africa and southeast Asia. Software relevant to the resources industry includes Dynamic Graphics' earthVision®, a geospatial analysis and modelling package, Vital Images' VoxelGeo® for 3D seismic interpretation and Cogniseis' GeoSec 3D for geological modelling. An Australian VAR for Silicon Graphics and a SAR for SUN Microsystems, Protocol endeavours to supply turnkey solutions of hardware, software and training.

QSEA INNOVATIONS PTY LTD **BOOTH 57**

22 Bournemouth Parade
TRIGG WA 6029
Tel: (+61 9) 245 1150
Fax: (+61 9) 245 1148
E-mail: eccles@iinet.com.au
Contact: Roger Loweth

QSEA Innovations is part of the Energy Innovations Group and overall we have more than 350 years of combined experience in the industry. Our Houston and London offices have ISDN links.

- Software – CENSUS, MESA, SEISCOPE, GEOLAB, PROMAX, SEISUP, OPUS4X, OPUS, PRODRAK, 3D AIMS, SEISPACT
- Access to all personnel via Internet
- Seismic Survey Quality Control
- Seismic Survey Design and Management
- Rig Move and Site Survey Services
- Education Services
- Special Services – Data Compression, AVO Modelling, 3D Interpretation

RESOURCE INDUSTRY ASSOCIATES (RIA) **BOOTH 40**

538 Brunswick Street
FITZROY NORTH VIC 3068
Tel: (03) 9482 4945
Fax: (03) 9482 4956
Contact: Jeff Bailey

MapPad™ and TerraScan™ ProGPS provide 'State of the Art' data-capture and image processing tools for portable computing. MapPad™ enables field data to be collected digitally in any customised format including AGSO standard fieldbook format and then easily downloaded to your GIS for analysis. TerraScan™ offers high functionality in image processing at low cost with smart links to MapInfo® and GPS. Both products were developed in Australia and are distributed exclusively by Resource Industry Associates.

SAGEM AUSTRALASIA PTY LTD **BOOTH 83**

Unit 2
122 Euston Road
ALEXANDRIA NSW 2015
Tel: (02) 516 5399
Fax: (02) 516 5595
Contact: Rod MacLeod

SAGEM Australasia represents Ashtech GPS Products in the Australian and Pacific regions. Ashtech GPS provides high accuracy positioning in various equipment configurations, and is widely used throughout the surveying and geophysical industries. New products have recently been released to provide specific application packages. This includes real time positioning to a centimetre using the new RTZ system and add on packages for Land Seismic and mining operations. Other DGPS systems are also available.

SATTLEGGER GMBH **BOOTH 68**

PO Box 1639
MEPPEN 49706
GERMANY
Tel: (05931) 18069
Fax: (05931) 13923
Contact: Wilma Sattlegger

Sattlegger GmbH was established in December 1989 and has assumed all tasks and responsibilities related to the Interpretive Seismic Processing system ISP003 developed by Sattlegger Ingenieurboro For Angewandte Geophysik since 1973. ISP003 is a comprehensive software system including a database system for gathering, processing, migration, modelling and mapping of seismic interpretation results and related data. It is in use in more than 30 locations worldwide and available on a variety of computer systems and workstations.

SCINTREX PTY LTD **BOOTH 22**
1031 Wellington Street
WEST PERTH WA 6005
Tel: (09) 321 6934
Fax: (09) 481 1201
Contact: Graham Linford

Scintrex Pty Ltd provides geophysical instruments for sales, hire and contract surveys to the mining exploration industry, having operated in Australia for over 25 years. The geophysical methods include induced polarization, magnetic induced polarization, VLF, SIROTEM, GENIE, gravity, proton and Cesium magnometers, radiometrics and physical properties. The exhibition features the new proton ENVIMAG, Cesium SMARTMAG, IPR-12 time domain IP receiver, CG-3 Autograv and other instruments. Please call to discuss your instrument and survey requirements for both within Australia and overseas.

SEISMIC IMAGE SOFTWARE LTD **BOOTH 44**
1100, 444 – 5th Avenue SW
CALGARY ALBERTA T2P 2T8
CANADA
Tel: +1 (403) 233 2140
Fax: +1 (403) 266 2685
Contact: Judi MacDonald

The ingredients came together in July 1987. Mike Galbraith and Randy Kolesar took two products – *VISTA*, a PC based seismic processing system, and *FD*, a 3D design software package (destined to become the world standard!) – and started a company. Seismic Image Software Ltd today is recognised worldwide as the leading developer of 3D survey design products and front end software. SIS employs 12 staff and distributes their software products through 14 agents to over 300 customers in 37 countries around the world. ***SIS products:*** *VISTA* is a PC based seismic processing system; *CAM120* attaches to the I/O System 2 and provides field monitor records; *MESA* is a suite of programs designed by SIS in 1992 to replace FD; *SIGMA* provides seismic interpretation through the use of travel time inversion.

SEISMIC SUPPLY INTERNATIONAL PTY LTD **BOOTH 73**
12 Archimedes Street
DARRA QLD 4076
Tel: (07) 375 3300
Fax: (07) 375 4027
Contact: Ron Feenaghty

Seismic Supply International's 11th participation features two of its main principals, OYO Instruments Inc and Geo Space Corporation, in adjoining booths (details under respective headings). Seisply's exhibit focuses on the latest in multiple air gun control by Macha International, along with other Seismic source control equipment, geophone and cable testing instruments, etc. Also featured are the latest additions to Sercel's SN388 series seismic data acquisition system, and their differential GPS systems range. Also introducing the Racal "Landstar" DGPS service covering Australia via the Optus satellite system.

SIGNAL ESTIMATION TECHNOLOGY INC **BOOTH 76**
2020, 633 – 6th Avenue SW
CALGARY ALBERTA T2P 2Y5
CANADA
Tel: +1 (403) 262 6260
Fax: +1 (403) 262 8153
Contact: Manfred Baum

Signal Estimation Technology Inc. provides interpretive seismic processing services for hydrocarbon reservoir imaging and characterisation. SET uses its proprietary software to perform such services. We will exhibit and demonstrate several unique techniques for reservoir imaging including noise attenuation, wavelet processing, wavelet estimation, matching bore hole and seismic data, and seismic trace inversion. Moreover, SET shall exhibit its reservoir characterisation tools including spectral imaging, waveform analysis, neural networks and pattern recognition.

SILICON GRAPHICS INC **BOOTH 61**
446 Victoria Road
GLADESVILLE NSW 2111
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Contact: Ian Lilly

Silicon Graphics Inc (SGI) is the world's leading manufacturer of 3D graphics workstations, servers and project supercomputers. All SGI systems use 64 bit RISC CPUs designed by MIPS Technologies Inc, a division of SGI. SGI's graphics workstations use the Indigo Magic user environment, an intuitive "drag and drop" interface that simplifies program execution, file and system management. SGI provides its developers with a rich suite of tools to build the leading applications in most market segments. Our world's best graphics subsystem and industry standard OpenGL graphics language provide the highest performing and most productive systems in the marketplace.

SIMON PETROLEUM TECHNOLOGY AUSTRALIA PTY LTD **BOOTH 13**
69 Outram Street
WEST PERTH WA 6005
Tel: (09) 322 2490
Fax: (09) 481 6721
Contact: Steve Smith

Simon Petroleum Technology (SPT) is a joint venture company between the Robertson Group and Simon-Horizon. It provides integrated services worldwide to companies in the private sector, financial institutions and government agencies and specialises in petroleum exploration, development and exploitation. SPT Australia's services include: 2D and 3D land, marine and transition zone processing, interpretive processing, AVO modelling and analysis, inversion and petrophysical log analysis, non-exclusive seismic data reprocessing and full 2D pre-stack depth migration. Additional services offered by SPT's Jakarta office include: interpretation, integrated studies, non-exclusive reports, biostratigraphy and geochemistry.

SOLO GEOPHYSICS LEICA **BOOTH 78**
3A McInnes Street
RIDLEYTON SA 5008
Tel: (08) 346 8277
Fax: (08) 346 0924
Contact: Graham Rau

SOLO GEOPHYSICS specialises in regional and detailed ground surveys using Electromagnetics, Gravity GPS, IP Magnetics techniques.

Instrumentation: Sirotem MK 3 systems, Lacoste and Romberg gravity meters, Huntec MK 4 IP, Eda Omni magnetometers, Leica system 200 GPS (Geodedic).

R&D: Solo ESP high power TEM transmitters.

LEICA INSTRUMENTS is a supplier of high accuracy measurement equipment for the Survey Industry. Products include GPS, Total Stations and Levels. GPS capabilities include: post-processing, real time, on the fly. Accuracies to the 3–5cm level (X,Y&Z) can be achieved.

SYSTEM DEVELOPMENT INC **BOOTH 29**
10500 Westoffice Drive #100
HOUSTON TX 77042
USA
Tel: +1 (713) 266 5667
Fax: +1 (713) 974 4911
Contact: Noel Daly

System Development (SDI) provides a wide range of interactive and hard copy graphics solutions for both UNIX and DOS environments. Products include CGM, CGM+ and CGM*PIP application development libraries; X-Windows/Motif previewing and montaging software; graphics format translators and complete local or network plot servers. Plot servers provide both batch and interactive plot submission, queue management and direct or spooled output to a wide range of desktop and large format plotting devices including thermal, inkjet, laser and electrostatic plotters.

TESLA-10 PTY LTD/TESLA AIRBORNE GEOSCIENCE PTY LTD **BOOTH 34**
41 Kishorn Road
APPLECROSS WA 6153
Tel: (09) 364 8444
Fax: (09) 364 6575
Contact: Freda Dicè

Tesla-10 is the core company of the Tesla Geographical Service Group. It commenced operations in 1983 as a GEOPHYSICAL PROCESSING house devoted to Quality, Service and Innovation. Acquisition was later added, firstly with the GROUND SURVEY and RENTAL division in 1988 and more recently with the establishment in 1993 of TESLA AIRBORNE GEOSCIENCE whose three Cessna aeroplanes have already flown 600,000 line kilometres. DATABASE sales and LAND CARE INITIATIVES complete our current activities.

THOMAS NELSON AUSTRALIA **BOOTH 98**
102 Dodds Street
SOUTH MELBOURNE VIC 3205
Tel: (03) 9685 4111
Fax: (03) 9685 4163
Contact: Michele Roberts

Thomas Nelson Australia, publishers and distributors of professional and reference titles, distribute for Chapman & Hall in Australia and New Zealand. Chapman & Hall have over 600 new titles to offer across the fields of science, technology, medicine and business in 1995. The Atlas of Deep Water Environments, the flagship book which we hope you will take the opportunity to inspect this week, is a unique source of detailed images and field data. Also worthy of inspection is Surface Geochemistry in Petroleum Exploration written by the successful oil finder, S A Tedesco.

ULTRAMAG GEOPHYSICS **BOOTH 81**
43 Marks Parade
MARKS POINT NSW 2280
Tel: (049) 459 472
Fax: (049) 477 513
Contact: Phil McClelland

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PO Box 126
BELMONT WA 6104
Tel: (09) 479 4232
Fax: (09) 479 1008
Contact: Neil Goodey

UTS Geophysics is an airborne geophysical exploration company specialising in helicopter-borne surveys both in Australia and overseas. UTS provides advanced technologies to the mineral exploration industry to maximise the effectiveness of their geophysical program. UTS offers both data acquisition and data processing services. UTS's primary exploration service is ultra-high detail helicopter magnetics. UTS has pioneered the development of the world's first 'stinger' mounted helicopter system. UTS is committed to providing its clients with cost-effective, technologically advanced geophysical exploration methods.

VELSEIS GROUP **BOOTHS 8**
PO Box 118
SUMNER PARK QLD 4074
Tel: (07) 376 5544
Fax: (07) 376 6939
Contact: Brent Haines

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ZONGE ENGINEERING AND RESEARCH ORGANIZATION **BOOTH 31**
3322 E Fort Lowell Road
TUCSON ARIZONA
USA
Tel: +1 (520) 327 5501
Fax: +1 (520) 325 1558
Contact: Kelly Trembath

Since 1983, Zonge Engineering has been providing the mining community with high quality geophysical field services and equipment – specialising in ground techniques like IP, CR, CSAMT and TEM. Zonge has recently added NANOTEM and Natural Source AMT and MT to its equipment offering and field services. With these newly added techniques we are able to provide exploration services for targets that are near surface as well as those that are too deep for standard electrical techniques. Please stop at our booth and see what's new.

Preview

SECTION THREE

Special Features

- Geophysics as a Career
- Advanced Seismic Reservoir Characterisation
- 3D Aeromagnetics

Contents

Preview Features

Also in this Issue

Special Features

Regular Features

Executive Brief

Welcome to the Conference Edition of Preview. This issue will be an important record of the proceedings of the ASEG 11th Geophysical Conference.

The Federal Executive is busily planning the next Conference in Sydney during March 1997. Steve Mudge has been appointed Head, Conference Advisory Committee, Roger Henderson, elected Chairman, Sydney Conference Organising Committee with the Sydney based Conference Action acting as Conference organisers. Furthermore planning is under-way for the ASEG 13th Geophysical Conference during September 1998. Letters have been sent to all State branches requesting expressions of interest for organising this event. The Federal Executive will leave Melbourne shortly after the Sydney Conference as part of the 5 year rotational cycle. Expressions of interest are also being solicited for hosting the Federal Executive. Due to the excessive workload the conferences should be held outside the state where the Federal Executive resides.

The ASEG has joined World Wide Web thanks to the WA branch, who have organised a workpage devoted to ASEG material including office bearers, contacts, meetings and a list of articles in the current Exploration Geophysics. For those having trouble surfing the Internet give Jim Frazer at WAPET a call on (09) 263 6566.

The ASEG, along with AIG, AusIMM, AEG, AGS, IAG, AGIA and GSA are member societies of the Australian Geoscience Council (AGC). Currently the registration of geoscientists is one of the top priority tasks for the AGC. Registration is currently handled by two AGC member organisations (AIC and AusIMM). These bodies are currently in the process of setting up accreditation mechanisms. As a registration process may have direct impact on ASEG members, the Executive has written to the AIG and AGC requesting Preview articles in which they can outline the functions of their respective organisations and in particular the registration mechanisms and requirements.

Greg Blackburn
Federal Secretary

ASEG People Profile

John Denham
Conference Editor & Editor
Exploration Geophysics

John Denham graduated in Geology from Sydney at the end of 1961, and started work in 1962 with Austral Geo Prospectors Pty Ltd, a seismic contractor. This company merged with United Geophysical Corporation in 1968 when AGP was bought by Bendix, who already owned United.

John worked in the field, as party chief after 1965, in Qld, NT and Papua New Guinea, until 1971, when he left United and joined BHP as a Senior Geophysicist.

With BHP he worked on most areas of the company's interests in Australia and New Zealand before becoming Chief Geophysicist from 1982 to 1991. In this period he was involved in the company's geophysical activities worldwide. With a reorganisation of BHP Petroleum in 1991 he became Division Geophysicist for the Australia Division, leaving BHP Petroleum in November 1993.

While working for BHP Petroleum he was the company's principal authority on geophysics, especially processing of seismic data, overseeing and reviewing the majority of the company's seismic processing in Australia and processing problems from other areas. Most recently he instigated the introduction of interactive processing (PROMAX) after a detailed evaluation of competing systems. In 1993 he encouraged the use in BHPP of the leading edge of processing technology, 3D pre-stack depth migration.

He was responsible for the first use in BHPP of computer assistance for seismic interpretation in 1973, and the introduction of the Landmark interactive interpretation system to BHP Petroleum in 1983, bringing BHPP to the forefront of geophysical technology worldwide, as the first system was Landmark's first commercial delivery.

Since leaving BHP Petroleum he has been a part time geophysical consultant.

His particular geophysical interests include depth conversion of seismic interpretations, computer applications to interpretation, and the integration of acquisition, processing and interpretation. He has written a number of papers, mostly on these subjects, published in APEA, ASEG and AusIMM and SEG journals and is a member of SEG, ASEG, EAEG and AIG.

Other interests include geophysical research and teaching, being involved in the formation of VIEPS, and is currently a member of the ASEG Research Foundation Committee. He became a member of the AGSO advisory committee in 1992 being nominated to that position by the ASEG. He was joint technical chairman for the 1989 ASEG Conference in Melbourne and is currently the editor of the ASEG journal Exploration Geophysics.

John has a number of interests outside of geophysics, and moved in 1994 from Melbourne to a 2000 acre farm near Dubbo NSW, which he has owned since 1980. Here he is building a solar powered house, located 6km from the nearest road. The house building has been slow as the running of the farm has to take priority.

In 1989 John married Jane, acquiring two stepsons; one has recently graduated with honours from Latrobe, and the other is still studying at RMIT. Jane is an accountant, now retired and sharing the farm life with John.

He has owned an eleven metre yacht since 1979. It is now in Brisbane, he and his wife having sailed it there from Melbourne in April 1995. He has been sailing since 1965, and has extensive offshore experience in Bass Strait and the east coast as far as North Queensland.

He has held a private pilot's licence since 1967 and has flown well over 1000 hours including over 200 hours in Papua New Guinea.

Preview Deadlines

Issue	Deadline
October 1995	September 29, 1995
December 1995	November 24, 1995

Preview - Next Issue

- *Queensland Exploration Initiatives*
- *Ethics of Off-Title Airborne Geophysics Flying*
- *ASEG 1995 Membership List*
- *IP, Complex Resistivity & FFT*

AMIRA Geophysical R&D Initiatives

AMIRA's mission is to help its members improve their technology through the provision of high quality development and management of jointly funded research projects. The association works exclusively in the area of collaborative research where its members share costs, risk and outcomes. To achieve its mission, AMIRA has been actively involved in a number of Cooperative Research Centres. Recently we have been working closely with the CRC for Australian Mineral Exploration Technologies (CRCAMET) to develop a number of initiatives. One of the CRCAMET's primary roles is to develop new, non-invasive geophysical technologies that will assist the Australian mineral exploration industry find ore deposits. The aim of this note is to briefly describe two new initiatives that AMIRA and the CRCAMET are in the process of developing with industry. Anyone interested in further details should contact me at AMIRA.

(1) Geophysical Unmanned Aerial Vehicle Acquisition (gUAVa) to collect magnetic data.

The CRCAMET is particularly focussed on developing more cost effective airborne technologies. Thanks to availability of imaging technology and hardware improvements, spiced with lower prices, airborne magnetics is by far the most utilised geophysical technique. However, there is a new aircraft technology waiting in the wings which may lower costs of acquisition even further. This technology is a new generation of Unmanned Air Vehicles (UAV's) for which the CRCAMET has negotiated exclusive access.

Costs for airborne magnetics vary depending on the size and nature of the survey, but are typically at the lower end of the $8-15 per kilometre range (costs are much higher if helicopters are required). Normally radiometrics is included in the price. However, with UAV's costs of magnetic acquisition could conceivably come down below $1 per kilometre. Use of UAV's will not only lower costs, they could also decrease survey times because of their ability to fly continuously without the statutory down time required for manned aircraft. Furthermore, safety issues associated with flying in rugged terrain clearly are not going to be a problem with UVA's. These new generation UAV's are lightweight, have sophisticated computer controlled on-board avionics, communications and sensors. They are relatively inexpensive (~ $25,000 once in full production), can be programmed to fly a set course, can be easily launched and do not require trained engineers to operate. An important attribute is that the UAV's do not require CAA certification. The gUAVa would allow collection of high resolution data at altitudes as low as 10m or 20m with 24 hour operation for efficiency.

AMIRA and the CRCAMET are currently developing a proposal (293/EM/JC) for a feasibility study to determine the cost as well as the technical and regulatory requirements to attach and fly a sensitive magnetometer to the UAV. The study will both identify the modifications that may be needed to make geophysical measurements, and determine the requirements to develop and field test a prototype in the second stage of the research. The feasibility study should take about nine months. The project will be supervised by Prof. J. Macnae and Dr. A. Green.

(2) Capacitive Electrodes and IP Arrays

In discussions with representatives of the exploration industry, a number of problems have been identified relating to receiver electrodes, optimum survey layouts and noise rejection techniques.

The CRCAMET has been conducting research into capacitive receiver electrodes with the ultimate aim of determining the feasibility of airborne IP measurements. While these efforts have shown some encouragement, they have not been completely successful in airborne operation. It appears, however, that there is interest in capacitive receiver electrodes for use in IP and resistivity surveys in very arid and sandy areas, where it may be virtually impossible for conventional electrodes to achieve the necessary contact resistance for reliable data to be obtained. Furthermore there is a severe problem with making electrical contact in the logging of dry or plastic cased holes for IP/resistivity.

Most arrays in common use for profiling, such as the pole-dipole, gradient and dipole-dipole arrays, have been in use for decades. Developments in data acquisition systems have recently been achieved that allow simultaneous collection of multiple channels of data. There is clearly a need for a re-evaluation of actual array layouts that can be used with these newer systems. This is particularly justified since modelling shows that resistors and conductors have responses that are different functions of background current direction. The common arrays are optimum for the detection of thin resistive zones in the strike direction rather than conductive zones.

AMIRA is currently developing a proposal P460 that will address the issues in a 2.5 year project. The project will be supervised by Prof. J. Macnae and will have the following specific objectives:

- Redesign existing CRC capacitive electrodes to determine their application and limitations in ungrounded surface and borehole electrodes.
- Determine and field test survey layouts designed to optimise the response of polarisable targets, particularly polarisable conductive targets.
- Investigate noise rejection techniques through remote referencing.

For further information contact:
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Email: joe@amira.com.au

ASEG Geophysics Promotion - Geophysics as a Career

Welcome to Geophysics

Koya Suto
Boral Energy Ltd

Let's look around ourselves. In your room, you see furniture with steel frames, plastic and vinyl boxes, containers, pens and ink, lead pencils, bright coloured posters on nicely painted walls. They are all final products of minerals and petroleum. Even your shirt's fabric contains polyester which is made from oil. Outside, you see cars made of metal which came from iron ore, running by burning petroleum fuel. When cooking in the kitchen, we use metal utensils, pots and pans over a gas stove. Your appliances work with electricity generated by coal, carried through copper wire insulated with petroleum derived plastic, held by ceramic cups on steel poles. Coal, copper, steel and ceramics all owe their origin to mining. Without mineral and energy resources none of them can work or even exist.

Australia is fortunate enough to be rich in these resources. In fact coal and mineral ores account for the largest proportion of Australia's export earnings. Our oil is close to self-sufficiency but its reserves are declining. A lot of effort is being made in the search for more mineral and energy resources all over our continent and offshore territory. It is no exaggeration to state that the resource industry is the lifeline of Australia's economy. It tries to secure well-being of not only the people in Australia but all the nations of the world.

Minerals and fossil fuels are unreplaceable resources. Only a small part of the mineral products can be recycled for the next generation's use. On the other hand, those easy-to-find near-surface resources have already been found, and only those hidden underground or below the ocean remain to be discovered. With the advanced technology, we can now look for mineral deposits hundreds of metres under the ground, or search for oil and gas several thousand metres under the sea. This advanced technology is called exploration geophysics.

In order to search for such resources, we need to understand the earth better. For that purpose, geophysicists use leading edge technology, most advanced precision instruments and a lot of computer power. Research to improve the accuracy and techniques is continuing. Vast computerised databases are growing world-wide to help understand our planet.

Geoscientists share a love for our planet, which has led them into this area of study in the first place. Awareness of environmental sensitivities goes hand in hand with sensible development. Many geophysical techniques are developed and deployed for detection of environmental probelems, an ever continuing research frontier.

The Australian Society of Exploration Geophysicists (ASEG) is presenting its efforts in new developments to you, Australia's future generation, so that you may know what geophysics is, what geophysicists do and how you can participate in our future prosperity through exploration geophysics. Australia still has a relatively unexplored frontier; one of the few places left in the world, offering excellent opportunities to geophysics and geophysicists.

I sincerely welcome you to this Student Session in the ASEG's 11th Conference and Exhibition, and look forward to working together towards our future.

Koya Suto graduated from Akita University, Japan's only mining college, and further studied at the University of Adelaide. He has worked for Esso Australia in Sydney, CRA Exploration in Melbourne and is currently consulting to Boral Energy in Adelaide. Since 1992 Koya has been a member of Federal Executive Committee of ASEG and chairman of its Promotions Subcommittee.

Geophysics - Discovering Australia's Mineral and Energy Wealth

Kim Forward
Wesley College, Melbourne

Our human senses of sight, hearing smell and touch are useful for identifying features of the world around us but cannot be relied on when the things we wish to see or find are shielded from us by height, distance, depth or time. The science of geophysics is about sensing the composition of the earth by utilising physical properties of rocks such as density, magnetism,electrical conductivity, radioactivity and acoustic or elastic properties.

All over Australia, geophysicists are carrying out surveys from the air, land and sea, in drillholes, and from satellites using advanced instruments and powerful computers to enable them to "see" beneath the surface. Their purposes vary widely: some are trying to understand the structure and history of the earth; some trying to develop methods of predicting earthquakes; some searching for oil and gas, some exploring for precious and base metals, uranium and diamonds; some looking for environmental contaminants; and others developing techniques, instruments and software for all these purposes.

There are various geophysical methods to "see" different physical properties. The targets of resource exploration have different physical properties from the surrounding rocks. Iron ore has stronger magnetic properties than other rocks; most metal minerals have a greater density than rock-forming minerals and they are more electrically conductive; uranium ore emits more gamma-rays than other rocks; and elastic waves travel faster through sandstone (which may be an oil reservoir), than through shale. Collectively, these differences are called "geophysical anomalies". Geophysicists, through analysing geophysical data, look for these anomalies which may lead to a greater understanding of the earth and sometimes the discovery of economic mineral and energy resources.

Gravity - Newton's law of gravitational attraction is an important topic in high school physics. In a local sense, a heavy material under the ground causes a strong gravitational force in its vicinity. If you are standing over an iron ore deposit, you actually weigh more than your normal everyday weight. A gravity meter, used to measure the force, comprises a spring suspending a small constant mass. It is extremely sensitive; sensitive enough to detect the difference in the gravity between the floor and top of the table, which is about three millionth of the earth's gravity field. From a series of measurements with such an instrument, geophysicists can map and model underground density distribution. Typical rocks have density around 2.5 g/cm^3, while that of coal is about 1.3 and iron ore 5, copper 5.6 and lead ore 7.5. It is from these principles that gravity surveys detect ore deposits.

Magnetics - As you know, a magnet attracts rocks (or any objects) that contain iron. While all minerals can be magnetised to some extent, some minerals have significantly high magnetic susceptibility. They are magnetised naturally in the earth's magnetic field. Some of those minerals are magnetite (Fe_3O_4), pyrrhotite (Fe_mS_nO) and ilmenite ($FeTiO_3$). Unlike gravity measurement, magnetic measurement is not affected by movement and the survey is often carried out from the air in an airborne magnetic or aeromagnetic survey. The advantage of the airborne survey is easy access to an area and coverage over a large area quickly and cost-effectively. This method of survey is deployed in the early part of an exploration program.

This helicopter magnetic system measures the earth's magnetic field in a specially designed magnetometer "bird" below the helicopter.

An airborne electromagnetic system with the large transmitter coil. The rear tail "stinger" contains the magnetometer.

Radiometrics - An aeromagnetic survey aircraft often carries a gamma-ray spectrometer and measures the Earth's radioactivity at the same time. This survey detects near-surface concentration of radioactive materials. Some radioactive isotopes emit gamma-rays with a characteristic spectrum. Three common spectra, ^{40}K, ^{232}Th and ^{235}U, are measured. The information collected is useful not only for uranium exploration but also for mapping soil and its depositional environment.

Electrical Methods - Metal is a good conductor of electricity while dry soil is a resister. Electric resistivity survey involves placing electrodes into the ground, forcing a small electric current between them and measuring the voltage. This method is also used for undergroung water surveys: water itself is not a good conductor but it carries ions that enhance its conductive properties. In petroleum exploration electrical survey are carried out down a well. As oil is more resistive than water, this data can indicate the presence of oil in a rock formation.

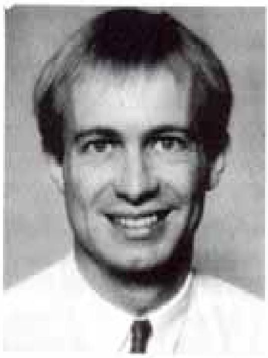
Electromagnetic Methods - Rather than actively forcing electric current through electrodes into the ground, electromagnetic surveys induce electric currents in the ground. A large coil (the transmitter) is placed on the ground and produces a magnetic field. When the current in the coil is turned off, the secondary field is induced and then diminishes but not instantaneously. The time the secondary magnetic field takes to decay is a function of the underground resistivity structure. The electromagnetic survey measures this decay pattern using another coil (the receiver). This survey is also carried out in the airborne

Land seismic vibrator truck for generating seismic waves.

mode with coils around the tips of wings, tail and front of a light aircraft.

Seismic Method - Seismic waves travel through different rock types at different speeds, and reflect back at interfaces between different rock layers. The reflection seismic survey transmits a seismic signal, and measures the return time to estimate the depth of the reflective interface. The signals are generated by causing a minute "earthquake". Explosives were once commonly used, but nowadays, on land, truck-mounted vibration devices are used to generate seismic signals. At sea, surveys use airguns to generate signals. The offshore seismic survey is particularly efficient, involving a seismic boat dragging several streamers full of sensors (hydrophones), and collecting data as it cruises. On land, geophones are "planted" manually along seismic lines before signals are generated.

In addition to airborne, marine and ground-surface surveys, geophysics is used extensively underground in mines and drillholes. At another extreme, increasing precision of satellite scanning enables effective exploration from space. These methods represents only some of geophysical techniques being used today or still being developed. Researchers are continuing to develop the theory and technology for devising and improving instruments, increasing the efficiency of survey techniques and increasing capability of software for analysing and interpreting data.



Kim Forward graduated with Honours in Geophysics from the University of Adelaide. After working for BHP as an exploration geophysicist, he completed post-graduate studies in education and commenced teaching secondary school science and physics, during which he studied for a Masters Degree from Monash University. He is currently Curriculum Coordinator for Mathematics and Science at Wesley College Melbourne.

Life as a Geophysicist

Katherine McKenna
Austirex International Ltd

An enjoyment of science and love of the outdoors were two assets that I believe lead me to a career in Geophysics. Being unsure of what path to follow after finishing school, I started a science degree at Macquarie University with no particular major. However the day we had a field trip to a mine and were given a hard-hat and hammer, my direction was clear.

On discovering the field of earth sciences one finds that the range of avenues within this field are wide and varying. On graduating, with a major in geophysics/geology in the late 1980s, job prospects were limited but at the same time there were not many graduates. I was hired as a junior Geophysicist for a Sydney-based company called Lachlan Resources and discovered that the learning process had to start all over again.

My job involved collecting, processing and presenting ground magnetics for the company's exploration licences along with geological and geochemical activities including drilling, mapping and surveying. This is how my job description went, however, I discovered there was much, much, much more. Working on their leases throughout NSW and New Zealand, I gained many extra assets such as how to change tyres, how to de-bog cars, trucks and drill rigs, how to drive a 4WD correctly, the importance of keeping receipts, the importance of being able to work with a team, that a good magnetics diurnal base station is never a good spot for lunch, and how to live out of a suitcase.

The numerous directions in geophysics (Maralinga airport, SA).

My next job was with a company Austirex, which is a subsidiary of World Geoscience, where I have been working for the past five years. I have been involved in quality control, processing, presentation, and more recently interpretation, of airborne magnetics and radiometrics. This has been a most exciting job as development and discovery of the use of magnetics has been a daily experience. Travel has also been a major part of this position, not only within Australia but to any part of the world that an airborne magnetic survey can be achieved. This has included numerous parts of the United Kingdom, South Australia, Western Australia, Queensland and India.

Many diverse, assets and personal qualities, after obtaining a degree, are an advantage. Flexibility, being a team member, a sound knowledge of the working of a car, passport, a strong growing suitcase, a good sense of humour, an understanding partner, a love of travel, and a sense of adventure just to name a few. In return, a career in geophysics rewards you with a feeling of discovery with every new project.

Katharine McKenna is a graduate of Macquarie University. Since graduation, she has worked with Lachlan Resources and is currently a geophysicist with Austirex International Ltd. Her main interest is airborne magnetic surveys, which has taken her to many areas in Australia and overseas.

What Are Geoscientists Doing for the Environment?

John Mignone

Mines and Energy South Australia

Earth scientists were among the first to become aware of the processes of climatic changes through time, the greenhouse effect, sea level changes, the moderating role of the oceans in the earth's carbon cycle and the dynamics of our ozone layer.

In addition their work has taken them to challenges like, dry land salinity, ground water supplies, engineering geology problems as well as providing for a growing want for natural resources to maintain the comforts and well-being of our society.

Why do these people spend time, money and effort doing this?

The answer is obvious. Everything we need to sustain life must come from this planet, ranging from the toothpaste and talcum powder we use in the bathroom to the cars we drive and the very air we breath.

The well-being of the earth must be the highest priority, and this can be achieved through understanding its history, its processes, their interactions and tolerances.

Some snapshots of their work includes:

Isostasy:

This is the study of changing coastlines through shifting sea level, or the rising and sinking of the continents. Natural causes, such as off-loading of continents through erosion and/or ice sheet melting and freezing have operated through earth's history to drive this slow motion "Bobbing". The volume of water in the oceans has accompanied ice cap fluctuations. In more recent times human industrial processes and land management practices in agriculture and pastoral industries have added new factors to the situation. Earth Scientists including Oceanographers, Meteorologists, Glaciologists, Geologists and Geophysicists, have been studying the situation to see the extent, whether it is containable by natural factors, what humans can do, etc.

Earthquakes:

Seismologists design, install and monitor earthquake surveillance sensors with the object of improving our understanding of how, why, where and when these destructive spasms of the earth will next hit. Together with engineering geophysicists they work toward designing and locating safety structures like office blocks, bridges, hospitals and utilities we take for granted in our day to day affairs about town!

Non-Invasive Mineral Exploration:

Resource exploration geophysics is about "**Finding Out as Much as One Can about What Is Underground with Sensing Devices without Disturbing the Ground**". This defines prospective ground from barren areas bett er and faster, as it does the size, shape and depth of the resource. Returns on the investment improve as a result. The "wild cat sampling" is a thing of the past.

Methods used include:

- **Satellite remote sensing** which can tell vegetation types, minerals and rock types and subsequent geological formations such as faults, folds lineaments, etc.

- **Airborne sensing** with:

Magnetometers detect changes in the earth's magnetic field caused by magnetic minerals often rich in useful ore minerals. Fracture zones and ancient volcanic vents responsible for introducing mineral rich fluids can also be defined helping to build a more complete picture of what is below the shifting dunes and extensive limstone cover of South Australia.

Radiation sensing Spectrometers which calibrated to known sources of radio elements can be used as a high speed chemical analyser of the earth to a depth of 30 cm as the aircraft flies at 200km/hr. This serves to show where minerals are transported from their mother lode by wind and water by the tell-tale radioactive characteristics they carry, such as Potassium, Uranium and Thorium. This is similar to the sensors used in medicine to study body processes in patients.

Electromagnetic sensors, which can induce conductive materials such as metal rich minerals, graphite and salt to produce a magnetic signal when stimulated by a current carrying coil surrounding the aircraft, can be found hidden underground. This mineral exploration tool has been used to successfully study salt build-ups in agricultural areas known to have destroyed previous civilisations through crop destruction.

Thermal Infrared Video records the ground temperatures controlled by the evaporation of waterlogged ground and from vegetation. Bare soils and dry salt- affected areas are hotter, showing up a different colour on the images. These methods combined, tell of blocking subsurface rock structures and ground water movements causing surfacing of salinity, and crop health.

GPS navigation by position fixing satellites giving updates on position each second along with video tracking of the ground complete the map making capabilities of the airborne sensing methods when linked into computers.

- **Ground Surveys**, accessed along existing tracks and then on foot, use geophysical sensors including gravity meters to fill in details. This combined with geological mapping and geochemical sampling, enables areas of high mineralisation potential to be identified for drilling and this is done with 10 to 15 cm drilling bits on mobile rigs usually on existing tracks and roads, followed by rehabilitation of the disturbed ground. The drill hole data is later given to Government Mines Departments., for storing and making available to other companies if needed, so avoiding unnecessary duplication.

Petroleum Exploration Advances:

Airborne magnetics can show the depth to the crystalline basement rocks underlying the sediment layers potentially containing oil and gas. A thickness of 2 to 3000 metres is needed for the right conditions to form the petroleum. Over the ocean, hydrocarbon sniffing sensors onboard the aircraft can be used to detect seepages.

Once the sedimentary basin is defined, likely reservoir traps are sought using seismic shock waves transmitted into the grond and observing their eventual return to the surface. After intensive data processing, an "X-Ray" style image of the sedimentary layer return to the surface. After intensive data processing, patterns is revealed showing the most likely places to drill. Seismic lines on land are placed away from Aboriginal sacred sites approved by community chosen scouts.

Methods promoting more rapid and complete environmental recovery are constantly being developed. These include surveying seismic lines around trees, using vibroseis trucks with low load tyres, tracked vehicles in dune country, rollers in gibber deserts and narrow hydra-axe cutters in heavily vegetated areas, which allow revegetaion off the root stock.

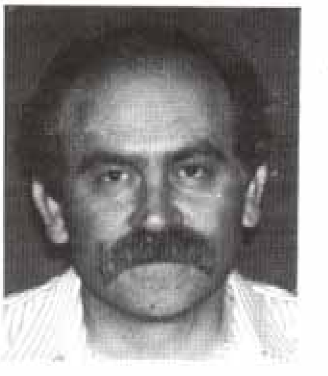
Drilling Technology has developed ways of drilling vertically down, sideways, horizontally or even upwards. They use advanced liners, aquifer sealing cements and muds and many other techniques. Drillhole information is collected with electric logging tools, down-hole video cameras, and porosity and permeability testers. Technology aids in increasing information gained and safety for the environment.

It all comes down to the quote: " Listen to the Earth and it will Speak to You ".

Rehabilitation:

There are Regulations set out under the Government mining and petroleum Acts which require exploration and mining groups to have plans, funds and programmes to deal with studies of the environment and its maintenance during the projects and subsequent rehabilitation.

This is monitored by the government through officers of the State Mines Department.



John Mignone graduated from Flinders University's school of Earth Sciences taking Geochemistry and Geophysics as his main areas of interest in his B Sc. He then completed his Diploma of Education taking him into a 20 year secondary school teaching career and is currently Education and Community Consultation Coordinator with Mines & Energy South Australia

Companies Offering Work Experience in Geophysics

The industry recognises the benefit of work experience and offers high school students of opportunities in various areas of exploration including geophysics. The following is a list of some of the companies that may offer such opportunities. Please note that most companies would require at least 4 weeks' notification for a work experience placement so that a program of a useful nature can be organised.

Aberfoyle Resources Ltd:
37 Fullarton Road, Kent Town, SA, 5069
Contact :Greg Walker -Senior Geophysicist
Ph: 08 270 6666
or Level 31, 525 Collins St, Melbourne, Vic, 3000

Amona Mining and Exploration NL:
82 Fullarton Road, Norwood, SA, 5067
Contact:John Simnovic -Company Director,
Ph: 08 276 5271

Ampolex Ltd:
580 George St, Sydney, NSW, 2000
or 250 St Georges Terrace, Perth, WA, 6000
Contact: Greg Thomas or Rita Saunders,
Ph: 02 364 4999, Fax: 02 364 4992
2 months notice needed

BHP Minerals Ltd:
3rd Floor, 3 Plain St, East Perth, WA, 6004.
Ph: 09 220 5222
or 152 Wharf St, Brisbane, Qld, 4000.
Contact: Lidica Alingford, Ph: 07 834 7500

Boral Energy Ltd:
60 Hindmarsh Square, Adelaide, SA, 5000
Contact: Charlotte Malcolm,
Ph: 08 235 3737, Fax: 08 223 1851

BP Exploration:
360 Elizabeth St, Melbourne, Vic, 3000
Contact: Geoff Hill, Ph: 03 268 411, Fax: 03 268 3003
1 month notice & minimum 1 month duration

Capital NL:
Level 14, 191 St Georges Terrace, Perth, WA, 6000
Contact: John Begg, Ph: 09 322 3011, Fax: 09 32 2190
2 weeks notice & 2 weeks duration

Cobb M A:
PO Box 756, South Perth, WA, 6151
Contact: David Clarke, Ph: 09 321 25 60

Command Petroleum Ltd:
191 New South Head Rd, Edgecliff, NSW, 2027
Contact: Bruce McCarthy -Gen Manager -Technical,
Ph: 02 362 4233, Fax:02 362 4248

Commercial Minerals Ltd:
PO Box 74, Rosewater East, SA, 5013
Contact: Lew Barnes -Chief Geologist,
Ph: 08 475 977, Fax: 08 341 0305
Prefer students with Year 12 Geology experience minimum

CRA Exploration Pty Ltd:
Box 254, Kent Town, SA, 5067
Contact: Dave Jackson,
Ph: 08 362 8871, Fax 08 363 1795

Cultus Petroleum NL:
Level 4, 828 Pacific Highway, Gordon, NSW, 2072
Contact: Valerie Parry, Ph: 02 418 1522, Fax 02 418 1504

Cyprus Australian Coal Co:
PO Box 406, Collie, WA, 6225
Contact: Sam Reich, Ph: 097 342 7000

East Australian Pipelines Ltd:
115 Canberra Avenue, Griffin, ACT, 2603
Contact: Brian Wyndham,
Ph: 06 295 5222, Fax 06 295 1677

Engineering Computer Services:
500 Mossvale Rd, Bowral, NSW, 2576
Contact: Pat Hillsdon, Ph: 048 612 122, Fax: 048 613 902
2 months notice needed

Euro Exploration:
63 King William St, Kent Town, SA, 5067
Contact: Chris Anderson -District Manager,
Ph: 08 363 1414

Mines and Energy SA:
191 Greenhill Rd, Parkside, SA, 5063
Contact: John Mignone,
Ph: 08 274 7709, Fax 08 274 1239
6 weeks notice needed

Parker and Parsely Australasia Ltd:
Level 9, 255 Elizabeth St, Sydney, NSW, 2000
Contact: Wes Jamieson,
Ph: 02 263 6080, Fax 02 261 8481
3 months notice needed

Petrosys Pty Ltd:
11 - 15 Fullarton Rd, Kent Town, SA, 5067
Contact: V Hirsinger, Ph: 08 363 0922, Fax 08 362 1840

Petroz NL:
Level 23, 300 Queen St, Brisbane, Qld, 4000
Contact: Wal Muir, Ph: 07 231 0213, Fax: 07 231 0222

PHM Survey Ltd:
PO Box 262, Mt Hawthorn, WA, 6016
Contact: Doug Lloyd, Ph: 09 444 0233, Fax: 09 443 2598
Perth Office - All aspects of GPS satellite based systems
1 month notice needed

Preview Resources Pty Ltd:
PO Box305, Eastwood, SA, 5063
Contact: Dr David Tucker, Ph: 0418847175 (mobile),
Fax: 08 338 2865

Santos Ltd:
101Grenfell St, Adelaide, SA, 5001
Contact: Ashley Haren, Ph: 08 218 5111
5 weeks notice required

Acknowledgements

The ASEG would like to thank the following organisations for their generous support to the Students' Day and in the creation of this information booklet: World Geoscience, the major sponsor; BHP Minerals; Boral Energy; BP Developments; CRA Exploration; Cultus Petroleum; Engineering and Computing Services; Geoinstruments; Geosystems; GFE Resources; Leica Instruments; Noble Resources; Petrosys; PHM Survey; Santos Ltd; Australian Institute of Petroleum; National Centre for Petroleum Geology and Geophysics of The University of Adelaide; Seismological Research Institute of Royal Melbourne Institute of Technology; and Department of Mines and Energy of South Australia.

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New Developments in Advanced Reservoir Characterisation

Paul D. Vrolijk and Peter R.Mesdag
Jason Geosystems BV,
Delft, The Netherlands

Introduction

This article will deal with the topic of true data integration for reservoir characterisation purposes. It will describe a software solution recently developed to enable reservoir data integration and reservoir characterisation on a computer workstation.

Different disciplines like geophysics, geology and engineering, rely on quite different data types. These data types include well logs, seismic, geological information and engineering data. To be truly successful in understanding oil and gas reservoirs, one has to harmonise the contribution from all disciplines and data sources.

In the area of reservoir characterisation (bridging structural interpretation, reservoir simulation and drilling), many new seismic lithology techniques have been developed for this purpose. A key observation from the practical application of seismic lithology methods is that the detail and resolution of seismic derived lithology improves as more non-seismic information such as well log control and geology is utilised.

Improved lithologic detail therefore, requires increased interpreter involvement. Economics of prospect evaluation and reservoir development vary widely, as does the availability of seismic, well, and geologic information.

Jason Geosystems from Delft, the Netherlands, is offering the industry the Jason Seismic Lithology Workbench. This Unix workstation based software supports a full range of seismic lithology modelling and inversion methods. Depending on available information and economics, a judicious management choice can be made as to which seismic lithology approach to apply.

Trends in the Industry

To truly appreciate the impact of this new technology, the following trends in the industry have to be examined more closely.

- Easy prospects are gone;
- A shift from structural to stratigraphic analysis;
- Full use of 3D seismic;
- True integration of data and disciplines. Synergy of technologies;
- Less people, more data, more complexities.

This list is by no means complete, but it helps to understand some of the basic trends which influence the interest in advanced geoscience technology.

For true explorationists the first trend mentioned above is quite an understatement, when one considers how many "elephants" were discovered during the last 10 years.

More and more, people "explore" for oil and gas in, or close by, existing fields and facilities.

This implies a shift from examining easy structural interpretations, to complex structural and stratigraphic analysis. To be successful in this new world, "picking horizons" is not good enough to find additional oil and gas reserves.

The quality and applicability of 3D seismic has gone through incredible improvements over the last 10 years.

Better understanding of 3D acquisition and processing, have made it possible to use 3D seismic more cost effectively for development and production purposes, mainly because much more information can be extracted from the seismic data.

Many times it is impossible to point to one piece of technology to explain a particular exploration and production success. It is often a combination of factors which lies behind a success story.

A very powerful combination of technology is the following one:

State-of-the-art 3D seismic, horizontal drilling technology and advanced analytical tools that combine different information like seismic, well and geological information.

Workflows

The way geoscientists are doing their job, has also changed dramatically over the last ten to fifteen years.

The computer revolution has changed the geosciences forever. In the last couple of years the industry has made incredible progress in it's journey to go from 100% paper, to 100% digital.

Besides this technical revolution, also the economic environment in which geoscientists are working also changed as dramatically. To put it simply: Less people (after all the restructuring in the eighties and nineties) have to analyse more data, related to more complex prospects, in less time.

Both the technical revolution and the economic realities, have changed oil companies organisations beyond recognition.

Ten years ago, all geophysicists would be working in the Exploration Department (and staying there for the rest of their lives). Most of the geologists, petrophysicists and engineers would spend their entire careers in the Production Department.

Now, people are employed in "asset-teams", organisations have flattened and life-long employment does not exist anymore.

All this had quite an impact on the way people do their work:

- Specialists from different disciplines have to work together;
- Data from different sources has to be combined into one reservoir model;
- Sequential, one-way, geoscience work ("throw the results over the fence and never bother"), has changed (or is changing) into iterative, multi-disciplinary teamwork;
- "Luxuries" like large research departments and special project groups have been cut back in size considerably. This means that more advanced technical work is being out-sourced to speciality companies, or, is integrated into the daily workflows, or, is not done at all;
- Computer technology, and other scientific developments, have cut down processing and interpretation time, enabling oil companies to bring fields into production much quicker. This often leaves less time for lengthy, in-depth, analysis;
- "High-tech" computer and software technology is now available for every oil company.

These developments had an impact an all aspects of the oil industry.

This article will focus on how these developments have changed reservoir characterisation.

Figure 1 gives an overview of a number of tasks which can be performed in the reservoir characterisation stage.

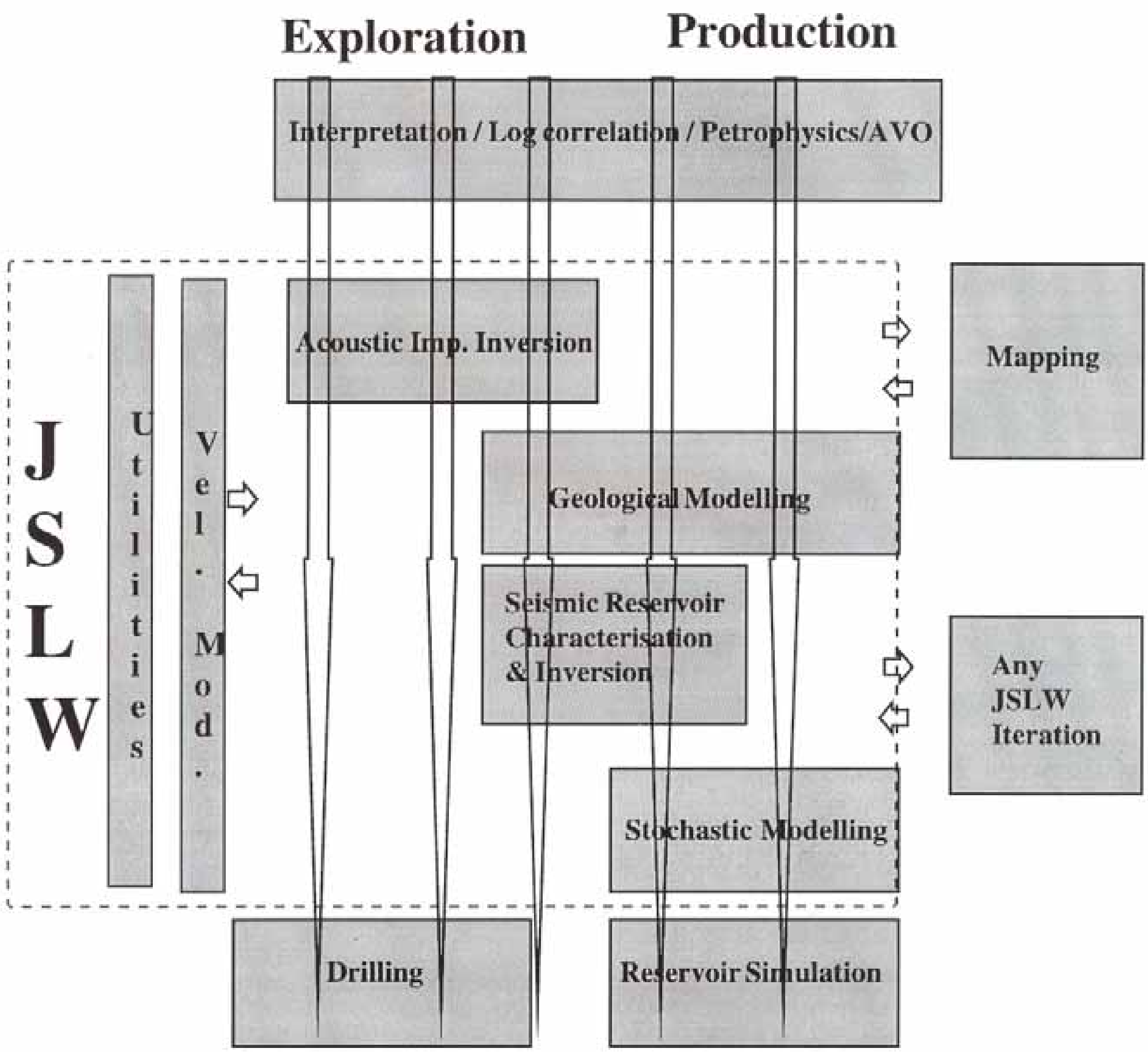


Figure 1. JSLW in exploration and production.

This figure shows five main workflows which all combine seismic, well and geological information at different stages between exploration and production.

Workflow 1 can be used in "pure" exploration. Limited well information is available and the analysis relies mainly on seismic data and stacking velocity information. One well can be used to define a trend curve.

Workflow 2 can be used in an exploration/ development setting, where more well data is available. A low-frequency model is generated using all the wells, which is merged with the band limited models coming from the seismic inversions.

Workflow 3 will be used in a production setting where a lot of well data is available, enabling the geoscientist to generate a reservoir model which goes beyond the seismic resolution by using all well, seismic and geological information. Note that the technology used in this Workflow ensures a proper match of all the logs with the seismic data. This is quite unique!

Workflow 4 combines Workflow 3 with Stochastic Modelling, such that seismic inversion results are harmonised with geostatistical calculations.

Finally, Workflow 5 allows the geoscientist to analyse all this data in a pure geostatistical way (leaving out the seismic).

All these workflows are can be used iteratively, which allows for the following mode of operation: When a drilling location has been selected based on one of the workflows, the well will be drilled, guided by the results generated. As soon as the well data come in, results are analysed, the geological model can be easily updated, and the inversion or modelling can be performed within a couple of days, enabling the geoscientists to have an impact on the next well location.

Oil companies are focusing on optimising these workflows. It is the objective of the Jason Seismic Lithology Workbench to provide the industry with a complete range of Reservoir Characterisation

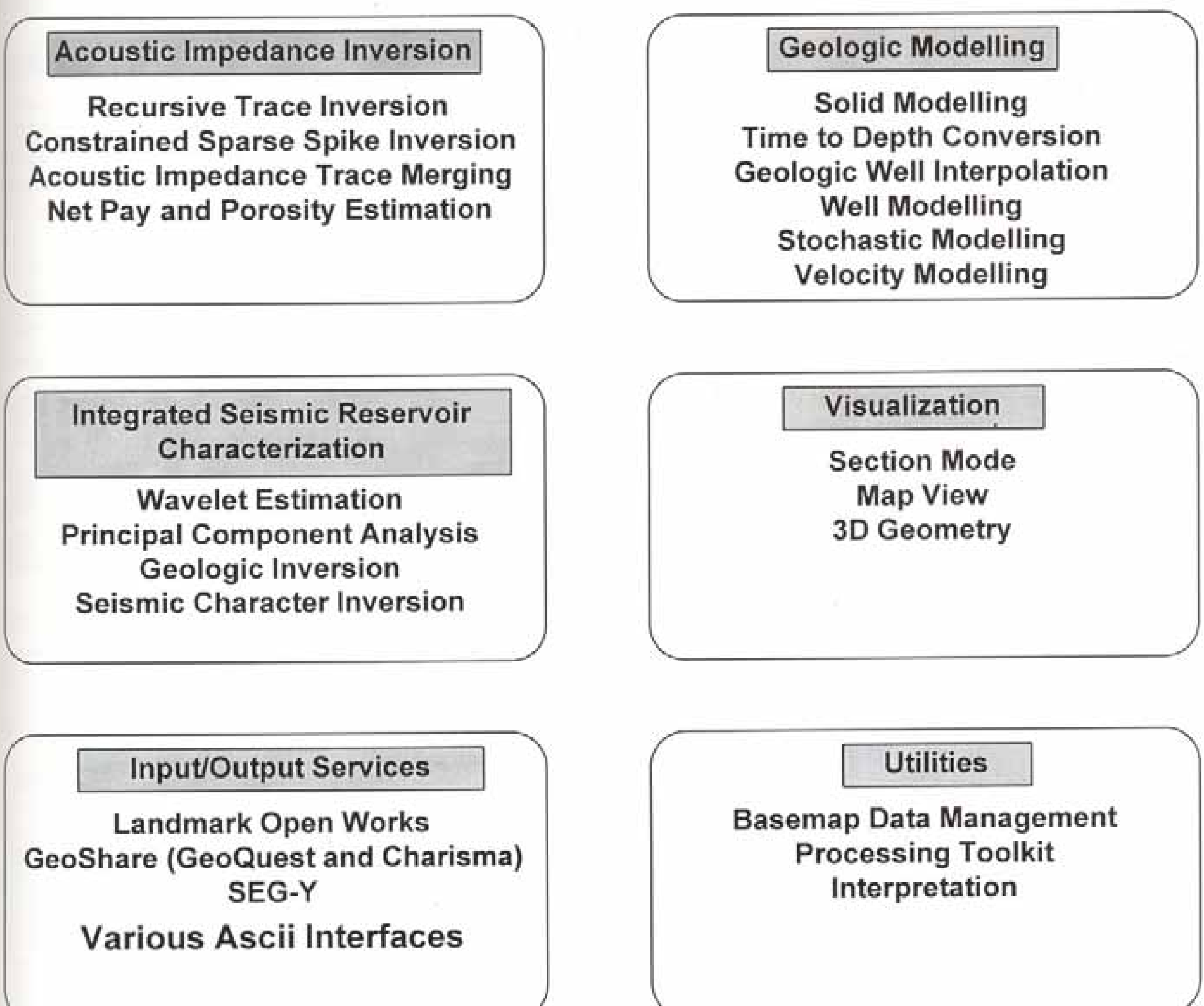


Figure 2. Seismic Lithology Workbench functions.

Workflows, which can be used in Exploration, Development and Production.

The software is designed in such a way that getting in to the system is straightforward, and that updating the reservoir model is easy when new data becomes available, for example a new well.

The Jason Seismic Lithology Workbench

The Jason Seismic Lithology Workbench (JSLW) provides the user with a rich, integrated set of software tools spanning the range of seismic lithology applications; from reconnaissance acoustic impedance inversion for exploration, through detailed seismic lithology/rock property prediction for production. These tools function together smoothly and seamlessly, and are also tightly integrated with the most popular seismic interpretation systems in use today.

The integration of information from various disciplines is the cornerstone of the JSLW philosophy. Seismic data provide sufficient areal coverage, but poor resolution.

Well logs provide excellent resolution, but are valid only in a small area around the well. By combining the strength of both, detailed lithology volumes are generated. The lithology data are used to obtain superior interpretations and robust estimates of key reservoir parameters such as net pay and porosity.

Figure 2 summarises the basic components of the JSLW software. The software contains three toolkits: the Acoustic Impedance Inversion Toolkit, the Geologic Modelling Toolkit and the Integrated Seismic Reservoir Characterisation Toolkit. Each of the toolkits in turn consists of several modules. The toolkits and their modules functionality and underlying principles are discussed in some detail below.

Table 1 gives the software and hardware platform specifications for the JSLW.

The JSLW Acoustic Impedance Inversion Toolkit

The Acoustic Impedance Inversion Toolkit is a key component of the Jason Seismic Lithology Workbench software and consists of the modules: Recursive Trace Inversion, Constrained Sparse Spike Inversion, Acoustic Impedance Trace Merging and Net Pay and Porosity Estimation. A typical work flow through this toolkit is shown in Figure 3.

Acoustic Impedance **(AI)** sections and volumes, when properly generated, are a valuable asset for exploration, appraisal and development, having several applications:

- **AI** data can often serve as a direct hydrocarbon indicator;
- **AI** data can be interpreted more easily and more accurately than seismic data;
- **AI** based estimates of key reservoir parameters such as net pay and average porosity are much more robust and accurate than those obtained from methods using seismic amplitudes.

The key to getting reliable **AI** results is recovery of the low frequency information missing from the seismic data. Recovering the missing high frequencies is of interest for thin bed detection. The **AI** Toolkit addresses both issues, but particularly emphasises the accurate recovery of the missing low frequencies.

Constrained Sparse Spike Inversion

This module is based on an L-1 norm spiking algorithm, constrained by a low frequency trend. The acoustic impedance trend is interactively specified from interpreted horizons and well control. The constraints are specified around the trend, providing further geologic control, and ensuring robustness of the results.

By their nature, spiking algorithms generate broadband results. The unique feature of the **AI** Toolkit algorithm is the level of interpretative control which can be applied, providing the means to obtain the required robust estimates of the low frequency component.

Table 1. JSLW Software and Hardware Specifications

Software	*: Jason Seismic Lithology Workbench*
Hardware	*: Sun Sparc, IBM RS6000, SGI (on request)*
Licensing	*: Fully modular, Flexible Network Licensing*
First release	*: January 1994*
Current Version	*: 3.2*
GUI	*: OSF Motif*
Programming language	*: C++*
Seismic handling	*: 2D, 3D and mixed*
Modules	*: Exploration, Development, Production*
Data Links	*: Landmark, GeoQuest, Charisma and others*
Broad data model	*: Works various data, in time and depth*
Plotting	*: CGM+, Postscript*

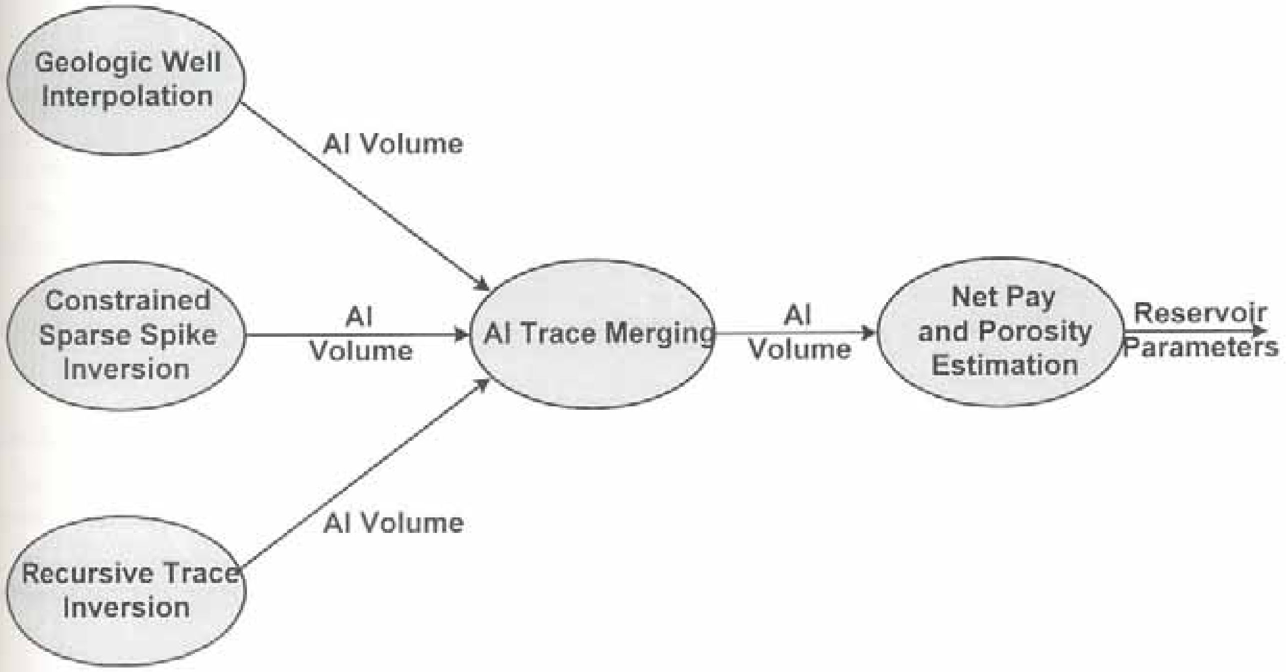


Figure 3. Acoustic Impedance Inversion data flow.

Geological Interpolation from Wells

In appraisal, and in particular during development, information from multiple wells is available. Using the tools provided in the JSLW Geologic Modelling Tookit, the well information can be interpolated in the layers defined by the interpreted horizons. The interpolation within each layer is according to the layer geology, e.g. conformable, truncation, onlap etc. The **AI** sections of volumes created by geological interpolation from wells can be used in the **AI** Toolkit to provide an alternative source for the missing low frequencies.

Recursive Trace Inversion

This module encompasses the standard recursive trace inversion algorithm to generate **AI** data within the seismic bandwidth.

Acoustic Impedance Trace Merging

In this module the interactive tools are provided to define how frequency bands of different input **AI** data sets are combined. For example, results of the geological interpolation from wells can be combined with constrained sparse spike inversion results and/or with results from recursive trace inversion.

Net Pay and Porosity Estimation

The acoustic impedance techniques provided in the AI toolkit culminate in this module. Robust estimates of net pay and average porosity are generated from calibration curves linking **AI** to pay and porosity. To fine tune the calculation and for sensitivity analysis the user can interactively define a depth dependent threshold function. **AI** values below this threshold contribute to the calculation, those above are rejected. The calculated net pay and average porosity can be displayed in map form.

The JSLW Geologic Modelling Toolkit

The Geologic Modelling Toolkit (GMT) is a unique, powerful software system for 'smart' geologic interpolation of well logs. GMT combines seismic interpretation, geologic, and well log information to efficiently generate detailed 3D depth and time subsurface models consisting of spatially distributed log properties. The models are generated by interpolating well control, guided by the structural information, derived from the seismic interpretation, according to the geologic deposition type in the model layers.

GMT is finding extensive application in reservoir characterisation and in seismic modelling and inversion by providing an efficient way to build accurate models.

GMT features are:

- Both time and depth models may be generated. They are linked through the GMT time to depth conversion facilities;
- Input interpretation horizons are almost always incomplete, having gaps and/or crossing events. GMT incorporates a solid modelling algorithm to repair input horizons and to build fully defined model layers;
- Deviated wells are accurately handled;
- Any log type can be interpolated, with preservation of the fine scaling of the well log measurements;
- Both 2D and 3D input line grids are (jointly) handled. In case of 2D input line grids from 2D seismic interpretations or well log section correlations, 3D models may still be generated;

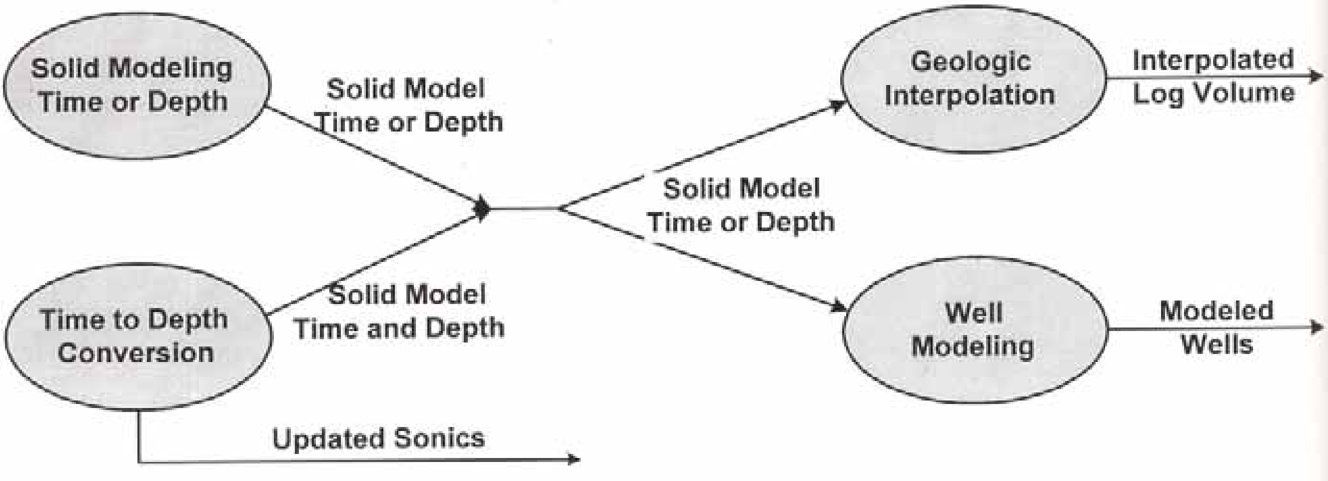


Figure 4. Geologic Modelling data flow.

- Complicated geometries are properly handled including reverse faulting, overhangs, channels and reefs;
- High performance. Extensive 3D models on 100,000 point grids can be generated on a Sparc 10 in 2-3 hours;
- When time sonic and/or density models are generated, seismic synthetics and residuals for modelling QC can be simultaneously generated.

The Geologic Modelling Toolkit can operate as a stand alone application or operate seamlessly with all other JSLW inversion and lithology tools for enhanced seismic reservoir characterisation. A further benefit is that the tight input/output JSLW links with Landmark, GeoQuest and Charisma are available. ASCII links are also available, for example to link in with reservoir simulators.

GMT has four core modules: Solid Modelling, Time to Depth Conversion, Geologic Modelling and Well Modelling. The data flow in Figure 4 identifies only the key data. Two more modules are under development: Stochastic Modelling and Velocity Modelling. These will not be discussed further here.

Solid Modelling

In solid modelling the following steps are taken:

- The user selects the wells, logs and horizons for model definition.
- The user interactively builds up the 'Stratigraphic Framework' to define the layer units in the model and their stratigraphic deposition mode (conformable, fault, truncation, onlap, offlap, reef and channel). At any point model sections can be interactively generated and inspected to QC the build up of the stratigraphic framework.
- The system takes over and automatically:

  1. Maps the deviated wells to vertical. For improved accuracy vertical mapping is done separately in each layer at the average well track location for that layer, and log samples are mapped according to the depositional mode;

  2. Interpolates and extrapolates horizons and faults to fill in any gaps;

  3. Properly forms closed layers by truncation crossings events according to the information provided in the stratigraphy table.

  The end product Solid Modelling is a solid model in which closed layers are defined, i.e. a model in which there are no gaps and no crossing events.

The following output is generated:

- Repaired input horizons;
- A horizon set describing layer boundaries; (Layer boundaries may be a subset of input horizons, or a merged set);
- Layer thickness information in time or depth for mapping.

Particularly attractive about the layer thickness information is that it accurately incorporates overhangs, overthrusts etc., without any additional effort on the part of the user.

Time to Depth Conversion

The solid modeller works in either time or depth. However, GMT also includes a solid modeller which incorporates time to depth conversion. In this version of the solid modeller the basic input information is:

- Horizons interpreted in time;
- Well trajectories, tops and logs defined in depth.

Optionally, a datum horizon defined in time and depth. If not available, this module can generate a datum by depth converting a user selected time horizon and fitting it to the corresponding well tops in depth.

The time horizons are converted to depth by constrained optimisation of the well log sonics such that the depth converted horizons fit through the corresponding well tops. This optimisation is carried out simultaneously for all input horizons and wells so that the available information is optimally utilised.

The result of Time to Depth Conversion module is an internally consistent set of time and depth horizons, corresponding well log tops and sonics consistent with the time and the depth horizons.

The following output information is generated in addition to the standard solid modelling output:

- Horizon sets and layer thicknesses both in time and depth;
- Optimised sonics.

Geologic Modelling

In the Geologic Modelling module cubes of log properties are generated by:

- Stratigraphically interpolating the logs away from well control;
- Combining the logs by inversely weighting according to the distance from wells.

To give the user additional control over the interpolation, the contributing weights for the wells may be modified by:

- Assigning a weighting factor for each well;
- Spatially modifying weights of each of the model layers by editing them in map view mode.

The latter mechanism allows the user to build in trend information.

In case of time modelling, an additional option is provided to generate seismic synthetics. These synthetics can be scaled to the seismic data, thus also supporting the generation of residuals. The synthetics and residuals provide a powerful means of assessing the quality of the model against seismic data.

Well Modelling

Besides modelling data volumes, a module is also provided to model well logs.

In this module log properties are stratigraphically interpolated to well tracks specified by the user, generating synthetic log curves. This provides a unique tool to assist the user in planning new wells.

The Well Modelling module is part of the next upgrade release of GMT.

GMT Applications

GMT has a broad application range in reservoir characterisation studies and in seismic interpretation. Important GMT applications include the generation of:

- Depth models providing a detailed spatial description of porosity, lithology fraction, permeability and water saturation distributions, for use in well planning and reservoir simulation. By utilising seismic horizons, these models incorporate structural and dip information unavailable from well control only;
- Accurate information on layer thicknesses in time and/or depth, also in cases of complex structure. This information is automatically generated through solid modelling, and is obtained much more efficiently and more accurately than through conventional mapping.
- Sets of consistent horizons in which gaps and holes are repaired and crossing events are properly truncated. These horizons can be re-exported to seismic workstations.
- Acoustic impedance time models to serve as the stabilising low frequency component in seismic acoustic impedance inversion. The output model can be directly used for this purpose in the JSLW Acoustic Impedance Inversion Toolkit;
- Depth models to serve as the initial model for detailed seismic inverse modelling, as implemented in the JSLW Integrated Seismic Reservoir Characterisation Toolkit;
- Cubes of seismic synthetics and residuals to aid in seismic interpretation.

The JSLW Integrated Seismic Reservoir Characterisation Toolkit

Modern Exploration and production computing environments are designed to facilitate easy data transfer between applications. This provides a first step in creating an environment supporting team work, in which information is cross utilised between the different disciplines to improve accuracy and reliability. The Jason Seismic Lithology Workbench (JSLW), and in particular the Geologic Modelling Toolkit and Integrated Seismic Reservoir Characterisation Toolkit, are designed to accomplish the next step: true information integration. Seismic, geologic and well log data are combined to generate an accurate, quantitative description of reservoirs.

The Integrated Seismic Reservoir Characterisation Toolkit (ISRC) works in conjunction with JSLW's Geologic Modelling Toolkit (GMT). ISRC takes the 2D or 3D geological model constructed with GMT as a basis, and combines this with well log and seismic data to generate a detailed reservoir model. Dependent on the set-up, this model may be represented by a series of 2D cross sections or as a full 3D cube. The ISRC reservoir model optimally fits the well data, geological information and the seismic information. The resulting reservoir model is defined in density, velocity, porosity, or any other lithology parameter available in the well logs.

ISRC is particularly useful for the characterisation of reservoirs in field development, where a number of appraisal wells are already available, and in the production stage, where many wells are available. In situation of such well control, ISRC overcomes the drawbacks of conventional seismic inversion schemes.

Conventional inversion schemes result in models that have less detail than models derived by interpolation of wells without using any seismic. ISRC honours and accurately extrapolates the information from wells utilising the geologic and seismic trace amplitude information. The result is a geologic model, with small scale lateral and vertical heterogeneities derived by combining the seismic, well log and geologic information.

ISRC is one of the toolkits in the Jason Seismic Lithology Workbench (JSLW). This means it can operate as a stand alone application or operate seamlessly with all other JSLW modelling and lithology tools for enhanced reservoir characterisation. A further benefit is that the tight input/output JSLW links with Landmark, GeoQuest and Charisma are available. ASCII links are also available, for example to utilise ISRC results for reservoir simulation.

As depicted in the Figure 2, and as described below, ISRC has four core modules: Wavelet Estimation, Principal Component Analysis, Geologic Inversion and Seismic Character Inversion. The data flow in the Figure 5 identifies only the key data.

Wavelet Estimation

When ISRC is run in the Geologic Inversion mode, the seismic data is modelled through the convolutional model. This requires a wavelet, which in the inversion may be laterally varying.

With the Wavelet Estimation module, wavelets are derived on basis of seismic traces (2D or 3D) around the Wells, sonic and density logs in depth, well tracks and information tops. Key features of the Wavelet Estimation Algorithm are:

- The wavelet estimation algorithm is multi-trace, and is driven by a multi-trace model derived from well control and interpretative information around the well;
- To reduce bias in the wavelet estimates, the well logs and model around the well are optimised as part of the process;
- Consistency between the sonic log and time-to-depth conversion curve is maintained throughout the process;
- To further enhance robustness, one wavelet may be estimated by simultaneously using multiple wells;
- Deviated wells are properly handled.

The result of applying Wavelet Estimation is:

- Wavelets that optimally tie the seismic data to the well information;
- Calibrated density and sonic logs;
- Quality Control (QC) information, such as synthetics at and around the wells to judge the well-to-seismic tie.

The Wavelet Estimation module is not only a tool to be used for deriving a wavelet for ISRC Model Estimation, but is a powerful tool in its own right. It provides an attractive alternative and improvement upon state-of-the art wavelet estimation technology.

Principal Component Analysis

The ISRC inversion algorithms are driven by a model description of the reservoir. To describe the reservoir, a series of log segments are created for each layer by segmenting the input logs at the layer boundaries, as defined by the formation tops. The variability of lithology in the model is subsequently described by linearly combining these well log segments.

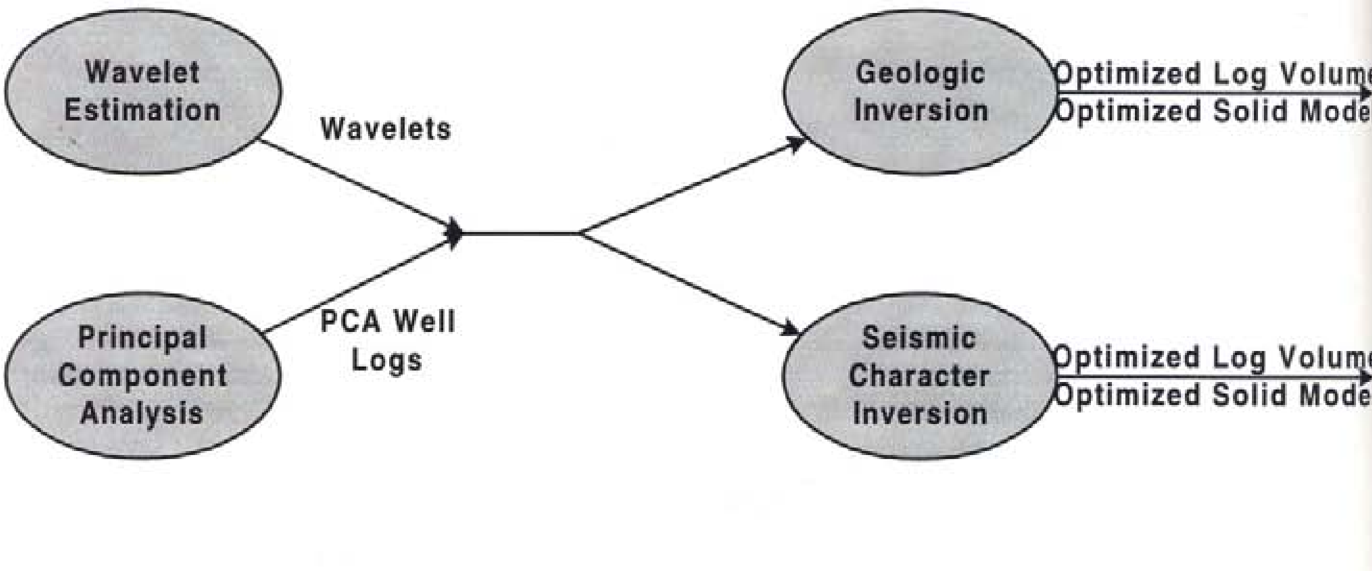


Figure 5. Integrated Seismic Reservoir Characterisation data flow.

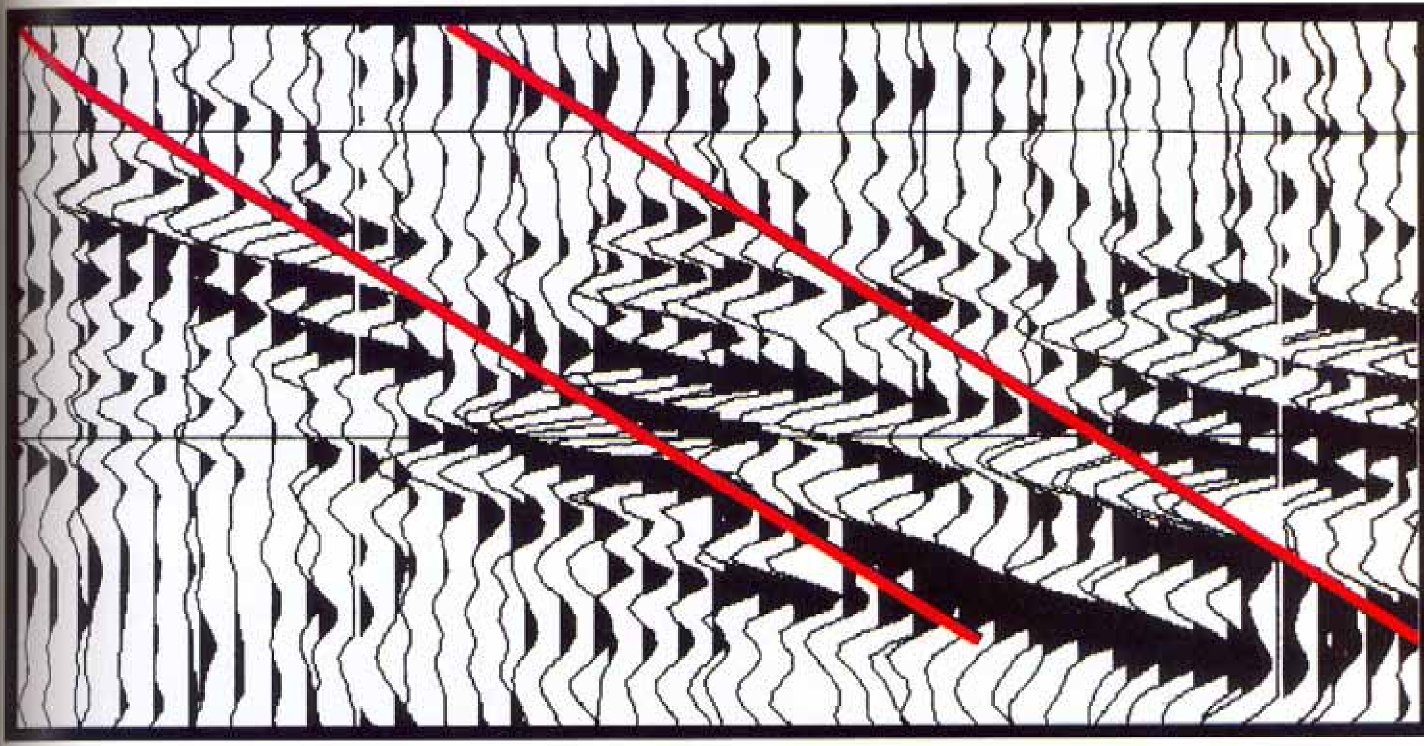


Figure 6a. In this Gulf of Mexico example, the company was planning to drill two extended reach wells to penetrate this amplitude anomaly. Each of these wells would have cost several million dollars to drill.

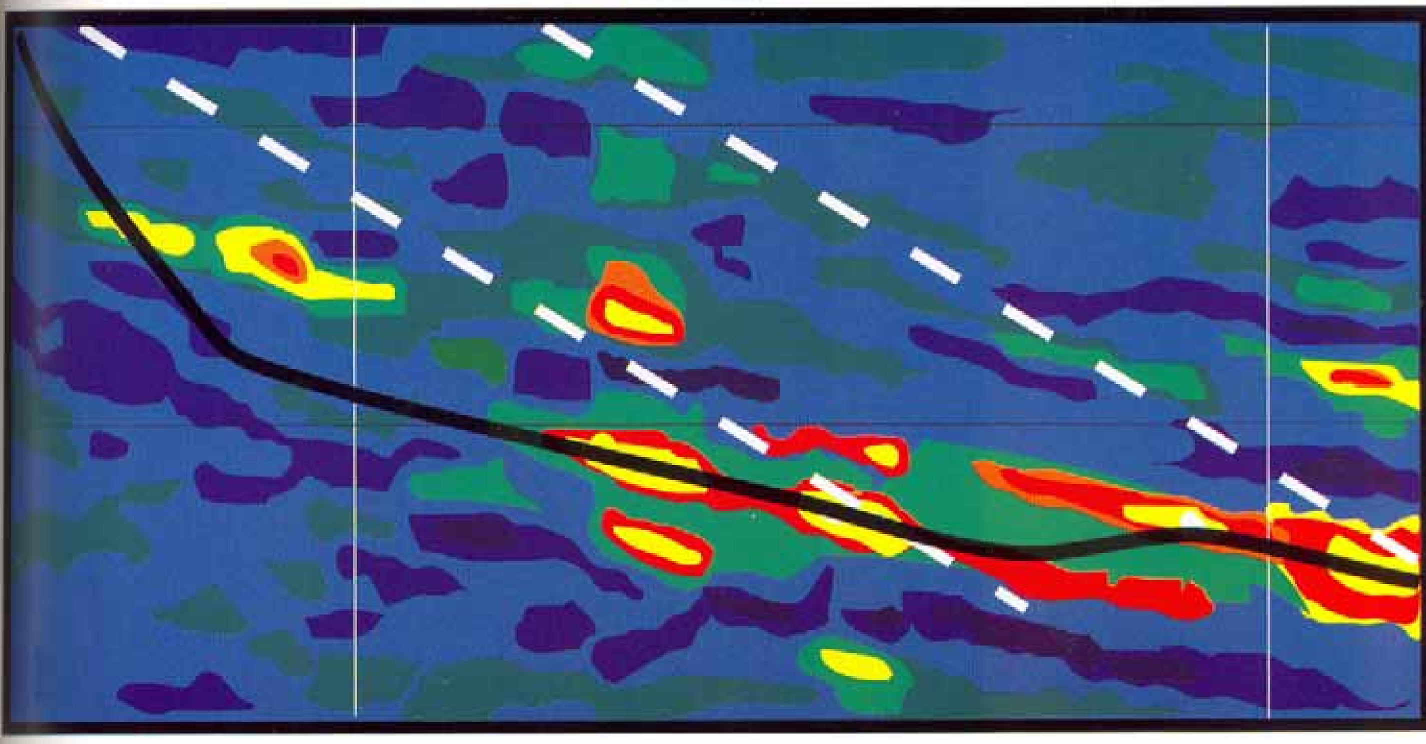


Figure 6b. After using Seismic Lithology tools to determine the most porous areas of the reservoir, the drilling plan was revised. The new plan called for a single horizontal well, which cost no more than one of the extended reach wells and actually yields higher production than the two previously planned wells combined.

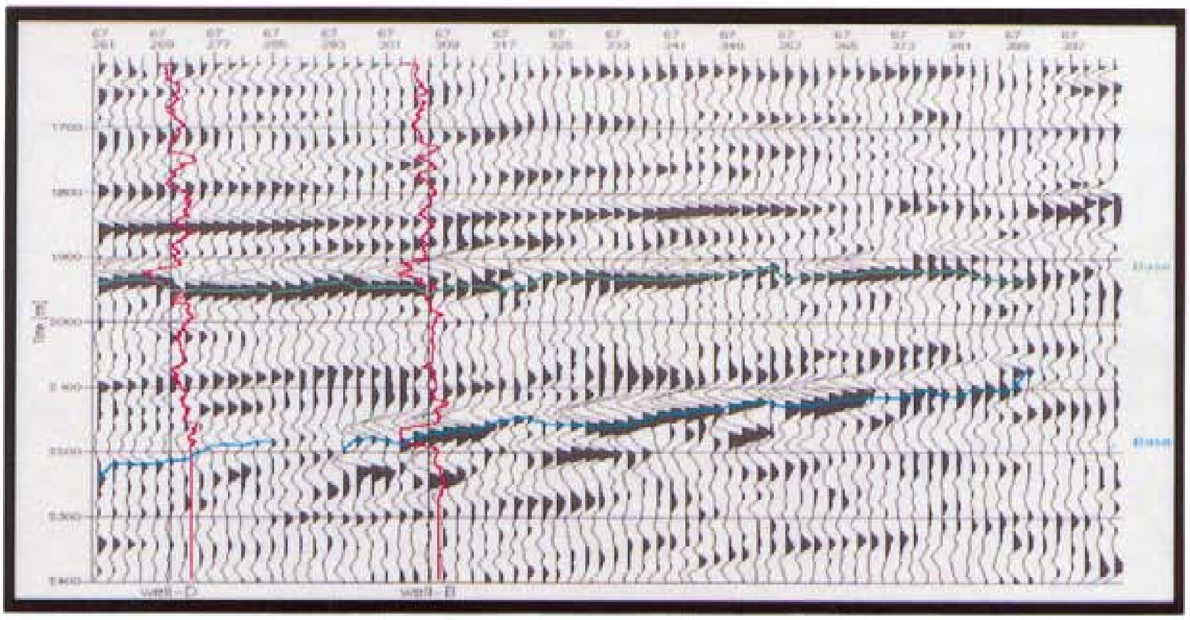


Figure 7a. Seismic section in time with horizons and wells.

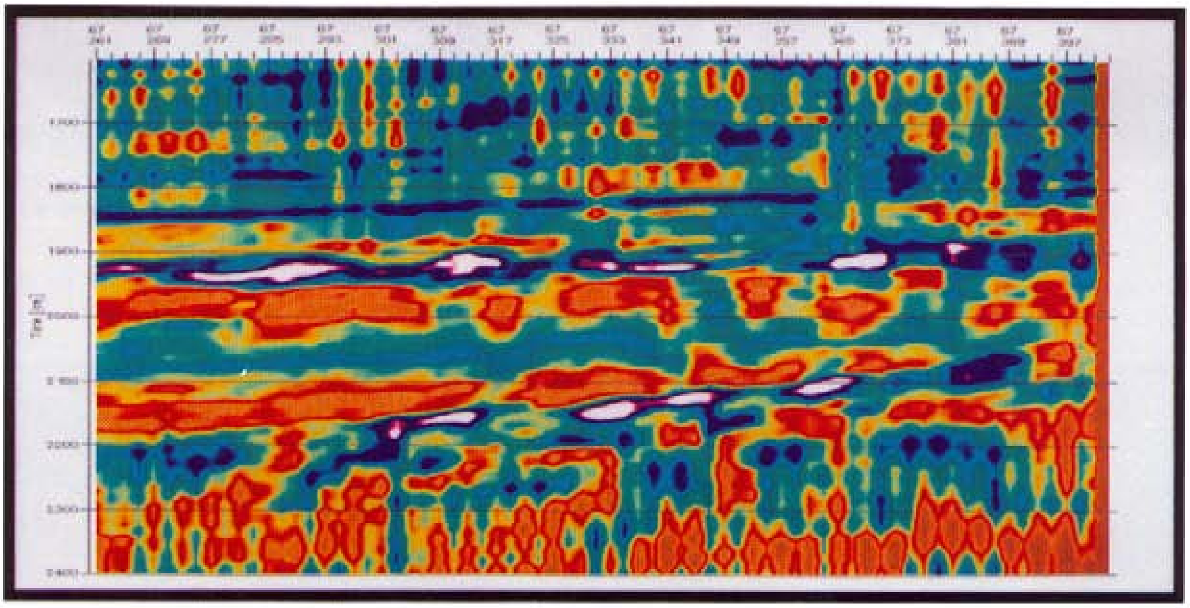


Figure 7b. Seismic section after Constrained Sparse Spike Inversion.

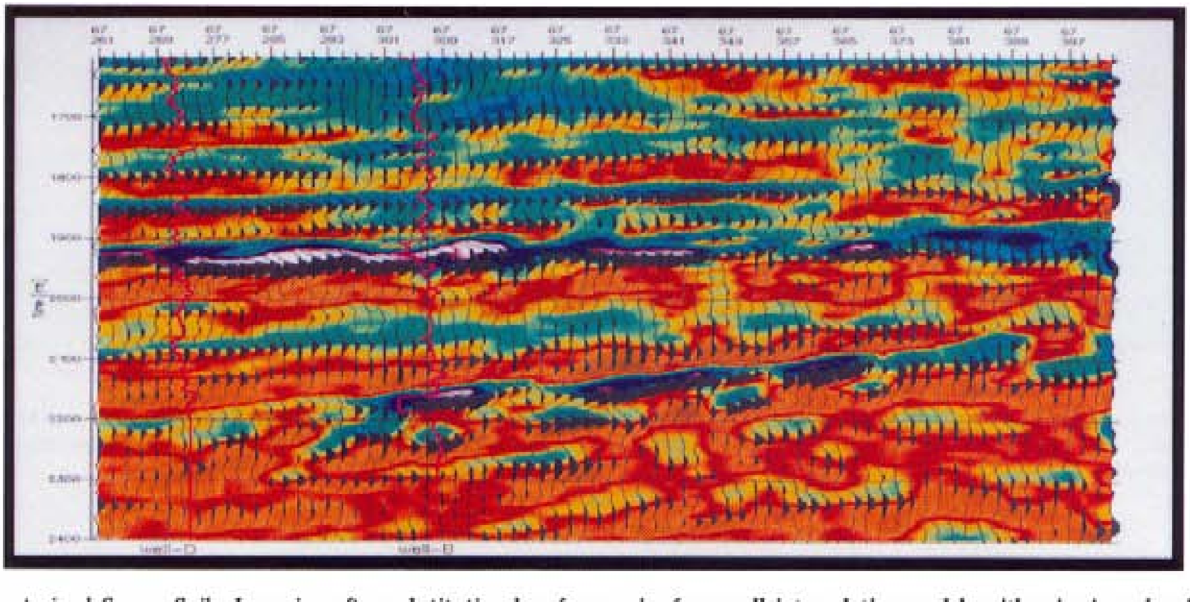


Figure 7c. Constrained Sparse Spike Inversion after substituting low frequencies from well interpolation model, with seismic and wells in overla

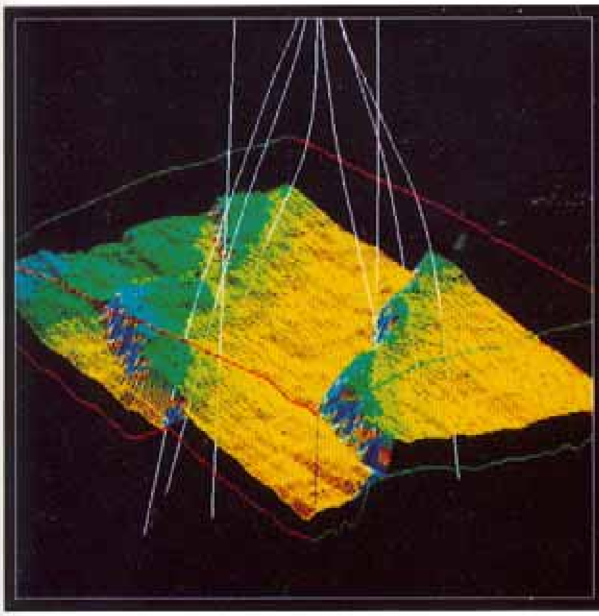
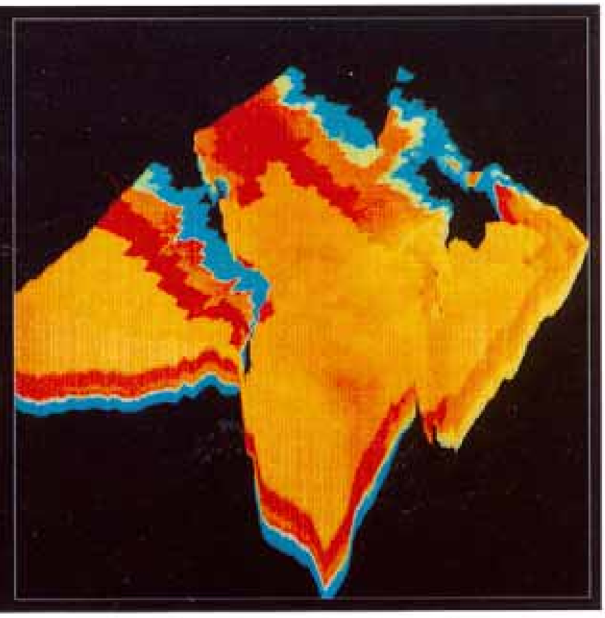


Figure 8a. Closed surface for Top Reservoir.



Interpolated 3D reservoir sonic model.

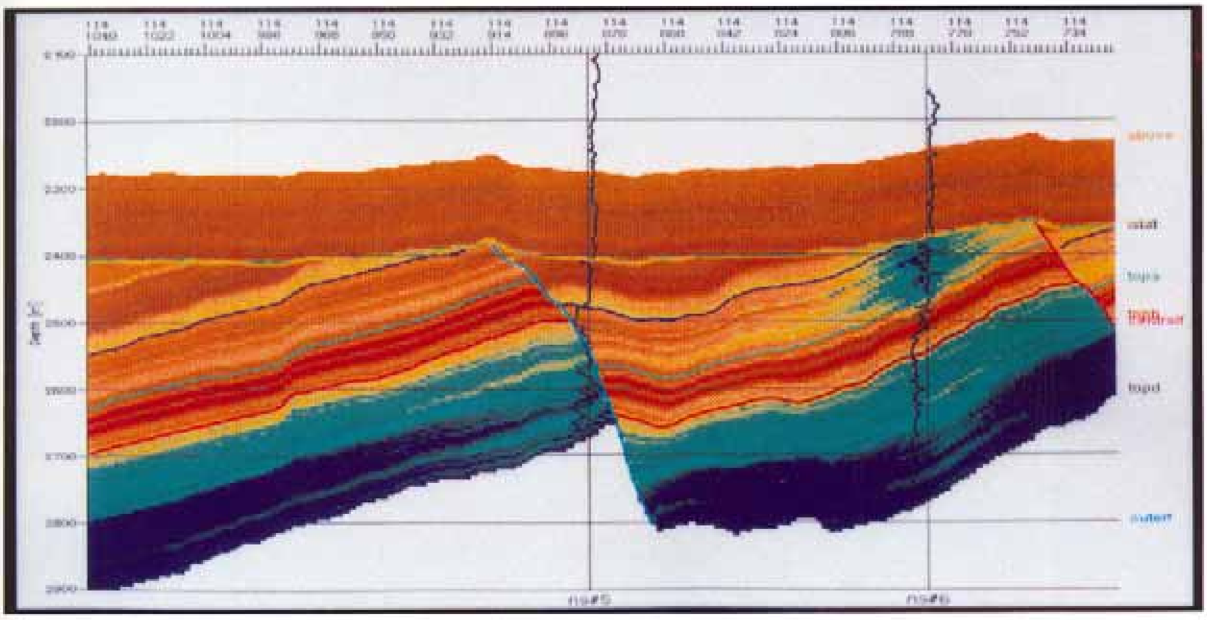


Figure 8b. Cross section of interpolated sonic model in depth after time to depth conversion.

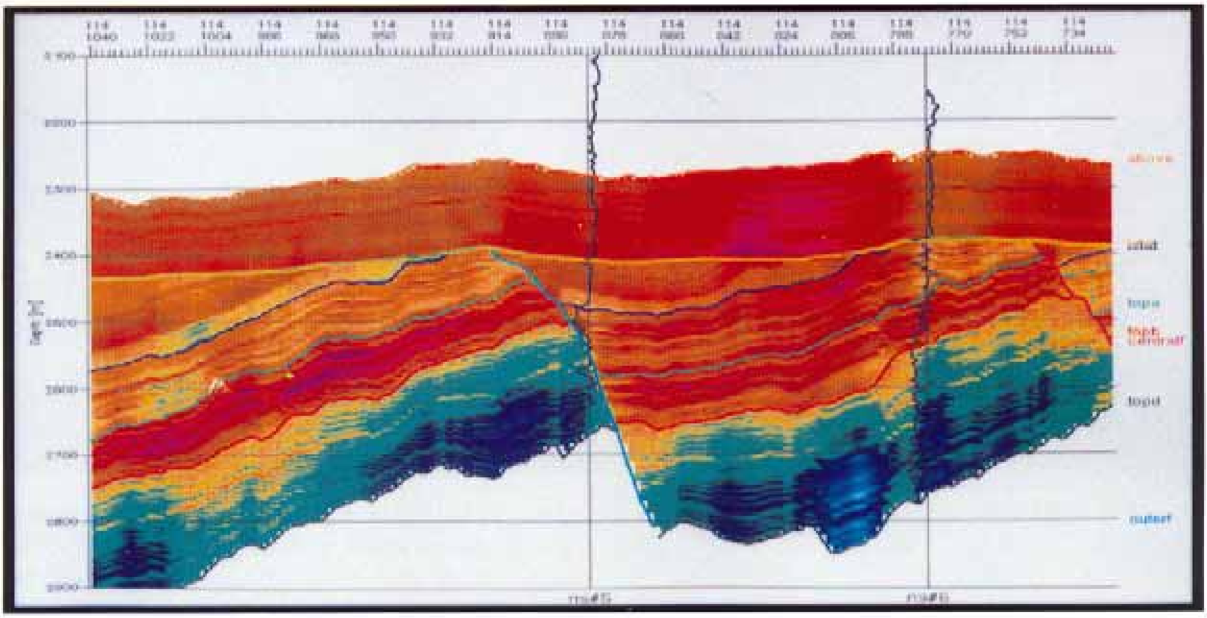


Figure 8c. Cross section of sonic model in depth after model driven inversion.

If there are many wells in a project, it is unlikely that each well contributes independent information. The information contribution from the input set of wells is analysed through the Principal Component Analysis procedure. Utilising Singular Value Decomposition, this procedure quantifies the level of independent information. It also allows the user to generate a reservoir description based on principal components. In cases where a lot of wells are available, this may result in a significant reduction in the number of variables to be handles in subsequent optimisation. This leads to improved inversion efficiency and stability.

Geologic Inversion

Through GMT a detailed reservoir model is generated, where at each trace location a model trace is generated by a weighted linear addition of well log segments. In GMT the weights are determined as a function of distance to the wells, modified by user editing. The principle of the Geologic Inversion is simple: Update the weights at each trace location such that an optimal match to the seismic is obtained. In this process the convolutional model is used to describe the relationship between the log data and the seismic data. The inversion process is enhanced by the following features:

- The sonic is simultaneously optimised, so that any stretching and squeezing required to improve the match of the synthetic seismic to the input seismic data, is also incorporated;
- The optimising works in accordance with the geologic rules specified in the GMT stratigraphic framework table, so properly handling truncations, faulting, etc.;
- The rate of lateral variation in the model is controlled;
- The optimisation takes into account laterally varying wavelets by wavelet interpolation from wavelet estimation control points;
- Once optimal weights have been estimated from the seismic data, any other log property can be reconstructed.

A key benefit of the Geologic Inversion approach is that the resolution of the logs can be maintained, as the inversion works with the full log segments. This implies that detailed features, which are lost in conventional seismic inversion approaches, such as transitions zones and thin layers, are preserved by virtue of the detail in the input logs.

As part of the process residuals are generated. These provide a particularly powerful tool to assess results. Unacceptably high residuals signify that the input log data set cannot describe the seismic data, indicating that the input logs do not provide an adequate subsurface description.

Another useful inspection tool is provided by a map view of the weights. Weights may show trends and can be used as an indicator of the areal distribution of log types and, therefore, as a hydrocarbon indicator.

Seismic Character Inversion

There are many cases in which the convolutional model used in the Geologic Inversion module does not adequately describe the relationship between the log data and the seismic data. In such cases the Seismic Character Inversion module offers an attractive alternative. At each well, segments are cut out of the seismic data corresponding to the well log segments. This establishes a relationship between the well log segments and the character of the corresponding seismic trace segments.

The inversion problem to now solve is to update the weights at each trace location such that the weighted addition of the corresponding seismic segments results in an optimal match to the seismic. The following features of the Geologic Inversion module are retained:

- The optimisation works in accordance with the geologic rules specified in the GMT stratigraphic framework table;
- The rate of lateral variation in the model is controlled;
- Once optimal weights have been estimated from the seismic data, any other log property can be reconstructed.

Replacing the convolutional model allows the Seismic Character Inversion process to be applied more widely:

- Any kind of seismic input data is handled, e.g. seismic cubes with near, mid and far offset data;
- Multiple input seismic data sets, e.g. near, mid and far offset data, may be simultaneously inverted for.

As in Geologic Inversion, the resolution of the logs is maintained. Residuals are also generated as a key tool to QC results, as well as weights in a form suitable for image display.

Case Studies and Examples

The data shown in this article comes from clastic reservoirs in the North Sea and in the Gulf of Mexico.

The example from Figure 6 is from the Gulf of Mexico. Here you see how, by utilizing the seismic lithology tools, one can dramatically reduce drilling costs.

Figures 7 and 8 show an example from a North Sea field which has a reservoir consisting of fluvial sand stones deposited in the Late Triassic to Early Jurassic. Due to the complexities of the fluvial systems and thereby the difficulties in mapping the channel belt sand stones, it is important to investigate different methods for the mapping of the lateral extent of these sand bodies for reservoir management purposes.

Figures 7 and 8 show various panels depicting some views of the same 3D seismic data set.

In Figure 7a a cross section from the input data for the modelling and inversion is shown. Figure 7b depicts the same cross section after CSSI. Note the rapid trace-to-trace variations in the acoustic impedances due to the instability of the low frequency model. Figure 7c shows the same model after merging with the more stable low frequencies from the geologic model.

In Figure 8 some steps in the ISRC are shown. Figure 8b is the input model for the inversion, while Figure 8c shows the high resolution inverted model.

The North Sea data has been analysed together with Saga Petroleum and it's partners. This case study has been presented on a number of international conferences including Kristiansand, 1994 and Bahrain Geo'94 (Zijlstra et at., 1994, Zijlstra and Debeije, 1994).

The reservoir characterisation technology described in this article has been used in many different geological settings, both in clastic and carbonate environments. These projects have ranged from frontier exploration to mature production cases. Up to date information is available from Jason Geosystems.

Conclusions

The advances in computer technology, 3D seismic, horizontal drilling, and in data integration technology had a substantial impact on exploration and exploitation success during the last decade.

Much can be gained in understanding todays oil and gas reservoirs, by further integrating the contribution from different disciplines of: geophysics, geology, petrophysics and reservoir engineering.

Advanced seismic lithology methods can play an important role in that process.

Besides the developments in the technology, economic developments in the industry, have forever changed the way geoscientists do their work. Less people, have to analyse more data, in more complex areas, in less time.

Technical innovations therefore, have to blend into practical "workflows" which enable people to make full use of these technical developments in a practical way.

References and Further Reading

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Zijlstra, D.M. and Debeije, H., 1994. Integrated reservoir characterization using 3-D seismic. *Proceedings Geo'94, Bahrain, 1994.*

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Guderjahn, C. and Johnson, E., 1993. Teamwork worked on Gulf project. *Explorer, American Association of Petroleum Geologists, October,1993 8-9*

Debeije, H., 1993. Inverse reservoir modelling using 3D seismic. *American Association of Petroleum Geologists International Conference and Exhibition, The Hague, 1993*

Debeije, H., 1993. Inverse reservoir modelling using 3D seismic. Seismology: Integrated Comprehension of Large Data Volumes. *SEG Summer Research Workshop, California; Technical Program and Abstracts, 1993*

For further details on the JSLW Software please contact

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Jason Geosystems Company Profile

Jason Geosystems, founded in 1986, is based in Delft, The Netherlands.

Since the first days of the company, all focus has been directed to developing practical seismic inversion methods to increase drilling and exploitation success.

Jason expertise in this area, has grown considerably over the years. Currently Jason's flagship software the "Jason Seismic Lithology Workbench" fills the gap between conventional structural interpretation, and reservoir simulation.

The Workbench forms a complete solution for Reservoir Characterisation using all available data.

With the growing importance of full data integration, and the increased use of seismic for stratigraphic purposes, Jason's technology has gained prominence in the workflows of many national and international oil companies.

The Jason Seismic Lithology Workbench consists of a multitude of modules which can help with integration of all seismic, well and geological information, in different stages of the development of a field.

Besides marketing the Jason software, Jason offers a wide range of consultancy and project services.

Over the years, Jason's software and consultancy has been used by companies around the world.

Currently the company is strongly expanding in the Middle and Far East, and will open offices in Jakarta and Singapore in 1995

ASEG Standing Committee Reports

Corporate Affairs

There has been no activity to report on since the last Conference in February 1994.

Lindsay Ingall, Chairman

Honours and Awards

The last series of Honours and Awards were presented at the 10th ASEG Conference in Perth in February 1994.

Honorary Membership

For distinguished contributions to the profession of exploration geophysics was awarded to Roger Henderson of Geo Instruments.

Grahame Sands Award

For innovation in applied geoscience was awarded to Stuart Nixon, Richard Kurzeja and David Hayward of Earth Resource Mapping.

Laric Hawkins Award

For the most innovative use of a geophysical technique was awarded to Marcus Flis of Newcrest Mining.

The 11th ASEG Conference will be held in Adelaide in September 1995 when the next series of Honours and Awards will be presented.

Lindsay Ingall, Chairman

Geophysical Activity

Annual Report 1995

The Activity Committee continued its task of obtaining the seismic activity statistics for the previous year and having them published in Preview as usual.

There continues to be a reluctance from contractors to provide any other statistics such as airborne geophysical activity, although it is widely known that this activity has increased tremendously in the last year, thanks to the impetus provided by the State Geological Surveys with their various attempts to promote exploration in their State. At least the state survey flying statistics are publicly known and for the year ending June 1995 are as follows, in kilometres:

WA: 175,000; SA: 213,055; NT: 64,550; VIC: 228,000; NSW: 620,000; QLD: 143,000 for a total 1.44 million.

All is fixed-wing at generally 400m line spacing except for 98,000 of Victoria's being helicopter at 200m spacing. At least 15 aircraft were involved altogether. Most states are forecasting approximately the same amount for the next year.

The very low charges for airborne magnetics and radiometrics would seem to continue to preclude other foreign contractors from entering the maket.

The NSW Geological Survey also contracted 10,000 gravity stations in the year ending June 1995.

Roger Henderson, Chairman

ASEG Research Foundation

The ASEG Research Foundation formally commenced to function in September 1989. The objective of the ASEG RF is to support research into applied exploration geophysics, via approved research projects at B. Sc. (Hons) and M. Sc. level in Australian Tertiary Institutions.

Since 1990, ASEG RF has supported several projects each year. In 1994, the projects were:

1. **Complex Resistivity Signatures for Mineral Exploration.**
   Student: David Boothroyd
   Supervisor: Jim Cull, Monash University
   Support: $4188.00
2. **Joint Inversion of Gravity and Magnetic Data**
   Students: Tom Ridsdell-Smith and Kate Crossing
   Supervisor: Dr. M. Dentith, University of WA
   Support: $2020.00
3. **The Removal of EM Coupling Effects from Frequency Domain IP Data**
   Student: Gerard McNeill
   Supervisor: Peter Brooker, University of Adelaide
   Support: $5000.00
4. **An Analysis of Velocities within the Lake Hope 3-D Seismic Survey Area**
   Student: Ralph Weiss
   Supervisor: Andy Mitchell, University of Adelaide
   Support: $4940.00
5. **Seismic Shear Wave Anisotropy Experiment**
   Student: Shane Squire
   Supervisor: Richard Hillis, University of Adelaide
   Support: $5000.00
6. **Depth Conversion of Seismic Travel Times in Inverted Basins**
   Student: Troy Macklin
   Supervisor: Richard Hillis, University of Adelaide
   Support: $3500.00
7. **Validity of the Randam Reflectivity Assumption in Australian Sedimentary Basins**
   Student: Paul Pythian
   Supervisor: Steve Hearn, University of Queensland.

Four projects are being supported in 1995, they are:

1. **Fracture Analysis in the Australian Coal Environment using Shear Wave Splitting**
   Student: Belinda Suthers
   Supervisor: Steve Hearn, University of Queensland
   Support: $4800.00
2. **Review of Alternative AVO Approaches**
   Student: James Mennie
   Supervisor: James Applegate, NCPGG

Support: $4950.00

3. **Geophysical Exploration Using Power Lines**
Student: Justin Ward
Supervisor: Jim Cull, Monash University
Support: 5600.00

4. **Structure of the Longford Basin, Northern Tasmania**
Student: Nicholas Direen
Supervisors: M Roach and David Leaman, University of Tasmania
Support: $4790.00

The performance of all projects will be reviewed in a committee meeting, to be held during the ASEG Conference in Adelaide in September.

The current members of the committee are:

Prof. D. Boyd	*The University of Adelaide*
Mr. J. Cucuzza	*AMIRA*
Mr. J. Denham	*Consultant*
Dr. B.J.J. Embleton	*CSIRO (COSSA)*
Prof. D.W. Emerson	*Systems Exploration Pty Ltd*
Mr. N.J. Fisher	*Digital Exploration Ltd.*
Dr. S. Hearn	*The University of Queensland*
Mr. N. Hungerford	*Consultant*
Mr. W. Jamieson	*Bridge Oil Limited*
Dr. D. King	*Consultant*
Mr. S. Mudge	*RGC Exploration Pty. Limited*
Mr. P.W. Priest	*Chartered Accountant*
Mr. D.C. Roberts	*SAGASCO Resources*
Mr. M.J. Sayers	*West Australian Petroleum Pty. Ltd*
Mr. N. Sheard	*MIM Exploration Pty. Ltd.*
Mr. R.J. Smith	*CRA Exploration Pty. Limited*
Mr. N. Uren	*Dept of Exploration Geophysics, Curtin Uni*
Mr. P. Williams	*Western Mining Limited*

The ASEG RF relies on donations from members, their companies and the ASEG executive for funds. All funds are used for research support, no overheads or operating expenses are deducted. All committee members act in an honorary capacity and all operating expenses are absorbed by the committee members, or their employers.

A treasurers report is availble from the ASEG office, including a statement of payments and receipts for the year ended December 31, 1994, and details of transactions from 1/1/94 to 30/6/95. The ASEG RF is in reasonable financial shape ($45,372.47 in bank) and could maintain operations for some time without further donations. Donations are still requested however, to build up sufficient funds so that operations can be sustained from interest on investments.

The ASEG RF committee members give their time freely to support these activities, in support of exploration geophysics research, and in an effort to underpin the future of our profession.

ASEG RESEARCH FOUNDATION

Post to: Treasurer, ASEG Research Foundation
Peter Priest, 39 Ningana Ave. KINGS PARK, SA 5034

NAME: ....

....

COMPANY: ....

....

ADDRESS: (for receipt purposes)

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AMOUNT OF DONATION: $ ....

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ASEG RESEARCH FOUNDATION

Receipt of donation

Received from ....

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The Sum of ....

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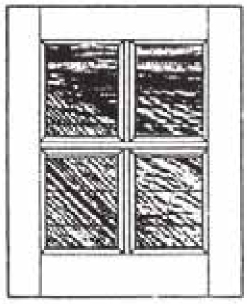
In accordance with Income Tax Assessment Act S73A, this donation to the ASEG Research Foundation is tax deductible.

Signed: ....

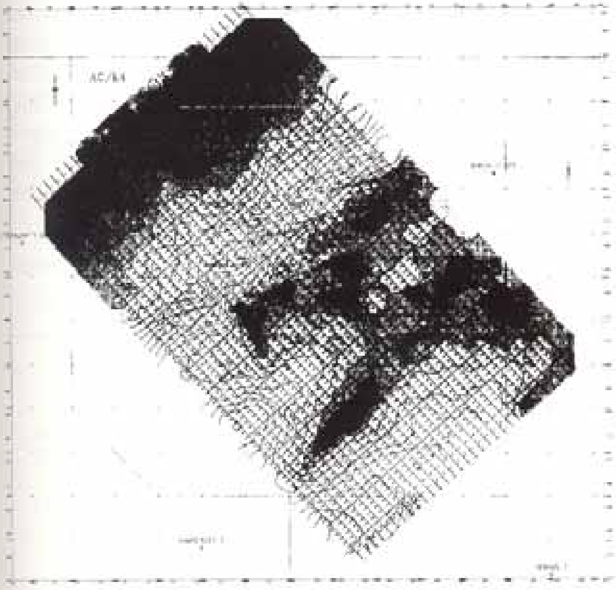
(This form should be retained for tax purposes)

Seismic Window

With



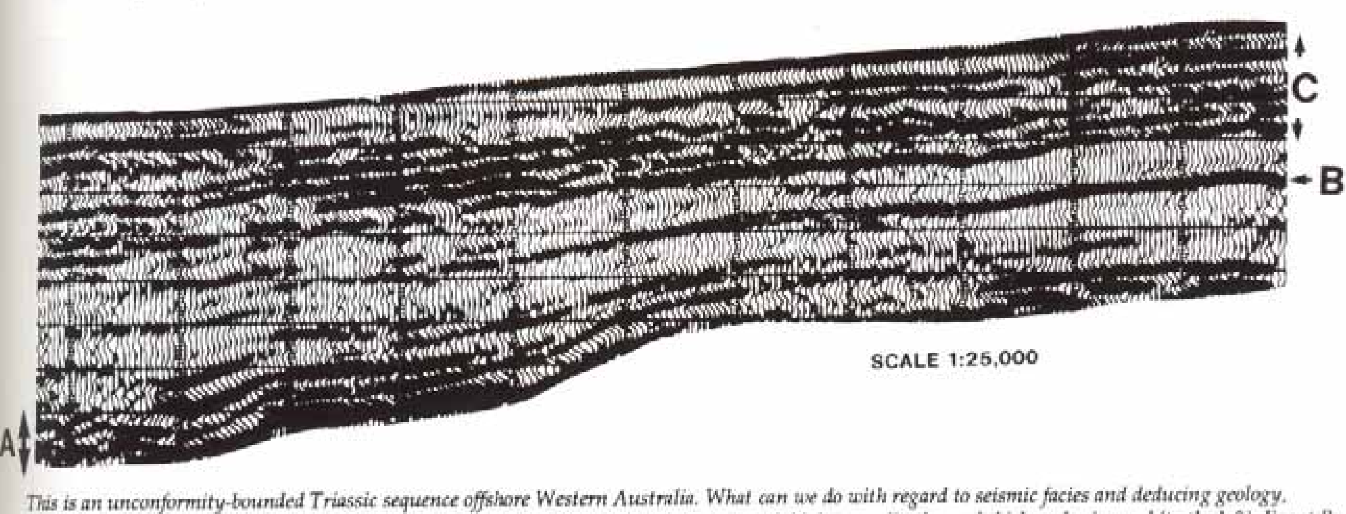
Rob Kirk
BHP Petroleum



TOP PALEOCENE TIME STRUCTURE

TOP PALEOCENE IMAGE WITH SUN ILLUMINATION

It's amazing what a difference an image processor can make! Both images are using the same input data set - a series of two way travel times from a 3D seismic survey. The contour map is the standard way of looking at a surface while the sun illumination image is from an image processor. The additional detail is striking. Many is the time that new subtle fault trends are observed on the image processed map. (Data courtesy of BHPP and AC/L4 partners).



SCALE 1:25,000

This is an unconformity-bounded Triassic sequence offshore Western Australia. What can we do with regard to seismic facies and deducing geology, given that we have no well data? (Isn't that always the case!) Facies A is continuous with higher amplitudes and thickens basinward (to the left). Event B is continuous but diminishes basinward. A low amplitude and continuity facies brackets B. Facies C has a higher amplitude and continuity character which may be channelled, just right of centre. Do the amplitudes climb "up-and-out" to the left? In the absence of well data we need to map geometries and amplitude/continuity changes and then employ a reasonable model, such as Vail's sequence model (Vail, 1987). We might end up with an interpretation which would call facies A a lowstand unit (it dies out against a syndepositionally active fault to the right). Event B may be a flooding surface (breakover from transgression to highstand). Facies C may represent highstand deltas. Such an interpretation uses calibrated analogies such as discussed in Kirk, (1985).

References:

Kirk, R.B., (1985). 'A seismic stratigraphic case history in the Eastern Barrow Subbasin, Northwest Shelf, Australia.' In: Berg, O.R. And Woolverton D.G., Eds. Seismic Stratigraphy II, Am. Association Petr. Geol. Memoir, 39, 183-207.

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Clean and Green

With

Derecke Palmer

University of New South Wales

This issue Roger Henderson brings news of SAGEEP '95, the 8th symposium of the EEGS, an annual event which is approaching ASEG Conference size and is the premier environmental and engineering geophysics conference. Roger is the Australian representative for EEGS (details of which can be found in Preview No 46, October 1993, p46).

SAGEEP '95

The Symposium on the Application of Engineering and Environmental Geophysics was held in Orlando, Florida. This year is the eighth in an annual series of such symposia. It has been getting bigger each year and now is of the order of the size of our ASEG Conferences and Exhibitions, with about 400 delegates and 30 exhibitors. This year, for the first time, the papers ran in two parallel sessions for the three days and I see this as an unfortunate expansionist trend, as it meant that there were many times when one was interested in both papers, that were on concurrently. Even the fact that there were two rooms for the sessions was disappointing for some of the delegates who enjoyed the atmosphere previously of all attendees being in the one session together.

In all, 76 oral and 28 poster papers were presented and the conference proceedings constituted a thick volume of 983 pages. Speakers from Russia, Japan, Denmark and South Africa provided an international flavour to the delegation.

The exhibition included most of the companies that manufacture near surface geophysical technology such as radar with GSSI, Sensors and Software. Electromagnetic methods were represented by Geonics, Scintrex, Phoenix Geophysics and good old Geo Instruments with SIROTEM. Two airborne EM companies were represented in Aerodat and Dighem. Shallow electrical methods were represented by Bison, IRIS Instruments (as part of the big Oyo booth) and AGI with their Swift multi-electrode resistivity system. Geometrics had their new caesium magnetometer and seismographs. Software companies included Geosoft and Interpex and well-logging from Mount Sopris and Auslog.

If you're not familiar with the background of the formation of the Society behind SAGEEP, which is EEGS for Environmental and Engineering Geophysical Society, this was formed by a group who were frustrated with the lack of support given by SEG for near surface techniques when they were becoming very popular in the clean up of America's waste problems. The Engineering Geophysics Section of SEG were very upset at this breakaway group and this resulted in the formation of the SEG's Near Surface Geophysics Section. Their publications were part of Geophysics which granted them special issues of Geophysics. EEGS on the other hand are now producing their own journal. A European section of EEGS has now also formed and they are to hold their first international meeting in Torino, Italy in September of this year.

One innovation that SAGEEP has always promoted is that they allocate sessions for outdoor demonstrations of equipment by the exhibitors. This has become a very formal affair now with a marquee set up on the lawn with microphones, loudspeakers etc. The highlight of these particular demonstrations was with a TEM system which has a separate transmitter and receiver. Unfortunatately for them, the transmitter was outside the marquee adjacent to their loop and the operator inside the marquee had believed that the transmitter was on and was apologising for the very noisy data, until it was brought to his attention that the transmitter operator had not switched on. The catch cry of the conference from there on was his exclamation, "Turn the f'ing transmitter on, Frank".

Roger Henderson

Contributions:

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Excitations

by

Stephen Mudge
RGC Exploration Pty Ltd

Increasing the Resource, Reducing the Risk: Geophysical Modelling and Drill Targeting.

Most geophysical drill targets are defined by modelling geophysical data. If an anomalous geological feature is defined by the model then a drill target can often be specified to test the ground for the occurrence of ore. In the search for ore the interpreter must be clear as to the objective of specifying a drill target: is it to test the model or to test the observed anomaly?

Introduction

There are two main purposes to modelling geophysical data, firstly to construct a physical property model of the ground to understand the structures that produce the observed geophysical responses and secondly, to model a anomalous response to specify a drill target. Both situations have completely different purposes and call upon the interpreter to produce two different types of models having quite different degrees of precision. Models comprising simple geometrical shapes are used and often several of these are assembled to simulate complex 3D structures.

In the first case the accuracy of the model is often not high but this is usually quite acceptable in most situations. Modelling to specify drill targets on the other hand requires precision: an expensive drill hole is being designed by the interpreter to discover ore. A missed target will increase the cost of discovery and unnecessarily delay the progress of the exploration program.

Once the interpreter is satisfied with his analysis of the observed data a drill target can be specified. But how should a drillhole be specified to maximise the probability of successfully intersecting the source of the anomaly? Also, at what part of the model should the drill be targeted and what can be done to specify error limits for the drill target?

The Modelling Process

Often drillholes are targeted to test the attributes of the model structure and sometimes the results can be very disappointing as evidenced by the complete lack of any rock or mineralisation that could explain the anomaly. Often an intersection of mineralisation is made that does not reflect the dimensions of the model. A drilling miss is declared, but could this have been avoided: were all attempts taken to minimise the risk of missing the source of the anomaly?

For ore discovery our aim is to drill test an observed geophysical response. The model is just a geometrical shape that the interpreter uses as a mathematical vehicle to compute a response to match the observed anomaly. This does not necessarily imply that the selected model is the actual source of the anomaly. In geophysics we have to learn to live with a thing called non-uniqueness; many types of buried structures can produce the same anomaly. Herein lies one of the fundamental sources of

Drilling on the Plutonic/Marymia Greenstone Belt Gold Prospect (Source Resolute Resources, Annual Report 1991).

error in modelling observed anomalies: selection of the appropriate source geometry to simulate the observed response. But the definition of the source geometry is often taken as the basis for modelling the anomaly in order to specify a drill target.

Errors in fitting the model response can be determined by systematically adjusting the model parameters, such as depth, dip, width etc. and estimating the degree of overall fit between the two responses. The skill and experience of the interpreter is required here. It is essential that an attempt be made to determine error bounds for each parameter of the model for this is the basis for specifying an accurate drill target.

This error analysis is fine as far as the chosen model is concerned, but the interpreter must first be satisfied that the model geometry is appropriate for the purposes of specifying a drill target. The deeper the source, and to that extent the greater the depth extent of a particular structure, the lower the resolution a surface geophysical survey will provide for these deeper parts and greater will be the error for this part of the model.

.... We should drill to test the anomaly, not to test the model ....

Anomalies or Models

Recall what it is that the explorer is trying to achieve from the geophysical survey; definition of anomalous responses that indicate the presence of ore that can in turn be tested by drilling. This says nothing of testing the model. The interpreter uses a model to compute a model response to explain the observed anomaly, but variations in the chosen model and different models can produce the same response. It is wise and instructive to repeat the modelling using a different model geometry. For example an initial prism might be replaced with a sphere (geological constraints not withstanding) and possibly with the addition of a deeper structure to account for longer wave lengths in the observed anomaly.

Other models, particularly those having multiple close-spaced bodies, ought to be considered. The intersection of these various models for the range of body parameters being considered, i.e. the volume of the ground common to all the model geometries - the common ground if you like, is clearly a certain location for the source of the observed anomaly. The definition of source geometry is a minor issue, it's the location of the anomaly source that is important for ore discovery. We should drill to test the anomaly, not to test the model.

This has some interesting ramifications for designing modelling procedures. In particular the possible development of computer based methods for locating anomaly source as apposed to fitting a particular (erroneous!) model to the observed anomaly to resolve source geometry.

So we must use caution in defining the drill target, we don't want to test the model geometry to check how good (lucky) we were in selecting all the right parameters to get the 'right' model, but we want to get the drillhole to intersect that part of the ground that has the greatest likelihood of causing the anomaly. We can only test the geometry of the model by drilling a pattern of holes, and we can't do this until we successfully target the discovery drillhole.

Drill Targets

The 'common ground' forms the drill target which in turn must be specified in terms of its location in the volume, i.e. Easting, Northing and depth from the ground surface taking into account the height of the geophysical sensor. It ought to show no significant bias towards any one particular model geometry. Again I say, geological constraints not withstanding, but interpretation of surface geological information can sometimes provide misleading perceptions of the sub-surface geology.

The interpreted dip of the anomaly source can be accounted for in the drill target by next specifying the most appropriate direction and inclination for the drill hole designed to pass through the target point. Remember, the important thing for ore discovery is to intersect the source of the anomaly, we can investigate the geometry of the source later with further drillholes. You won't get to do that unless you successfully target the initial discovery hole, and if you can achieve that, you'll be forgiven for predicting the wrong model geometry. Don't forget to account for the natural rise (flattening of hole inclination) of deep drillholes when you specify the inclination and collar position of the hole.

Petrophysical information can be acquired from the material intersected in the (first) discovery drillhole. Along with the width of the intersection, this information can be used to refine the geophysical model and to specify further drillholes to investigate the actual shape of the anomaly source. But the trick is to intersect the source of the anomaly with the initial drillhole.

Increasing the resource, reducing the risk: ultimately it's all about specifying drillholes to properly test anomalies for the occurrence of ore when we first drill.

Happy Excitations.

Contributions:

Please send contributions to Excitations column to:

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Three Dimensional Aeromagnetics

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Summary

Significant improvements in magnetic mapping are achieved by measuring three orthogonal components of the field using a triaxial aeromagnetic gradiometer system.

Incorporation of the measured horizontal gradient into the gridding algorithm in part compensates for the sample bias inherent in any line-based survey. The continuity of linear magnetic features is improved by using gradient-enhanced gridding. Short strike length (*e.g.* cylindrical) anomalies such as those caused by kimberlite diatremes can be recognised between the flight lines.

Primarily due to improvements in instrumentation, measured gradients are now considered superior to calculated derivatives. Processes which utilise calculated derivatives such as Euler deconvolution and analytic signal can be more precisely calculated.

Introduction

Poseidon Geophysics, and their sister company Geodass, have developed a commercially viable high precision airborne magnetometer system which measures three orthogonal gradients of the magnetic field. The triaxial gradiometer system overcomes some of the limitations of conventional single sensor aeromagnetic surveys and the derived map products are much improved, which will greatly assist the interpreter.

Single sensor aeromagnetic surveys are limited by the sampling bias inherent in all surveys where data are measured at closer intervals along traverse lines compared to the distance between the lines. This bias can in part be overcome in gridding algorithms by making the assumption that the underlying geology is primarily 2-dimensional. Anomalies which appear on adjacent lines are assumed to be continuous in between. This assumption is definitely not valid for small cylindrical bodies such as kimberlite intrusives.

Instruments

The triaxial gradiometer system is installed in a Cessna Titan 404 aircraft, with Scintrex H8 caesium vapour magnetometer sensors mounted on each wingtip and on the top and bottom of the tail (Plate 1). The wingtip sensors are separated by 16.28 m and measure the transverse horizontal gradient (ΔH_x), the tail sensors are separated by 1.83 m and measure the vertical gradient (ΔH_z). The in-line horizontal gradient (ΔH_y), is calculated by subtracting the average of the two wingtip sensors from the bottom tail sensor which are separated by 8.682 m.

The aircraft has been extensively modified to reduce the magnetic noise from the aircraft. Ferrous metal components have been replaced with non-magnetic stainless steel and aluminium. Components which could not be replaced are degaussed to eliminate any acquired remnant magnetism.

There are two recent developments in instrumentation that have remarkably improved the noise levels in aeromagnetic surveys: active compensation and aircraft positioning.

In high precision aeromagnetic surveys, it is necessary to compensate for aircraft manoeuvre, magnetic perturbations caused by eddy currents in the aircraft, and heading-dependant errors. The residual magnetic effect of the aircraft is compensated in flight using an RMS Airborne Aeromagnetic Dynamic Compensator (AADC), which uses a 27-term software compensation derived from the output of a 3-component fluxgate magnetometer. The AADC has achieved exceptionally low noise, with a compensation Figure of Merit (GSC, 1991) typically less than 1 nT and noise levels in the measured gradients are less than 5 pT in normal turbulence conditions (McMullan and McLellan, 1994).

1. Location map, Lekgodu and Ghanzi-Chobe areas, Botswana

There are several types of aircraft positioning systems used to record the flight path of the aircraft. Ground-based radio navigation systems using microwave frequencies (*e.g.* Motorola MiniRanger) typically have a measurement accuracy of 1 to 3 m. GPS satellite positioning systems are becoming more popular. Airborne navigation systems can achieve 3.5 to 7 m absolute accuracy relative to the WGS-84 ellipsoid by post processing (McMullan and McLellan, *op. cit.*), and less than 0.5 m in real time using a radio link between the aircraft and a reference station.

Aliasing

The sample bias is defined as the ratio between the spacing of magnetic readings along the flight lines and the flight line spacing. In a typical detailed aeromagnetic survey, readings are taken at 5 Hz (approximately 14 m along track distance) on flight lines spaced at 200 m. Most line-based gridding algorithms use a polynomial spline interpolation technique which is limited to approximately 5:1 sample bias ratio, which necessitates desampling of the line data. Utilising the measured transverse horizontal gradient in the polynomial equation to predict the magnetic field, larger sample bias ratios can be tolerated.

The consequence of a strong sample bias in line-based geophysical surveys is a spatial aliasing of the data in the direction across the survey (flight) lines. The most important gradient to consider in compensation for this aliasing is the transverse horizontal gradient (ΔH_x). Poseidon have developed proprietary gridding algorithms incorporating the horizontal transverse gradient whereby the term in the polynomial spline used to interpolate between the flight lines are replaced by the measured H_x values.

The relations between magnetic gradients has been derived by several authors (Nabighian, 1984; Nelson, 1986; Pederson, 1989). By making assumptions about the source body geometry, the knowledge of one gradient enables calculation of the others, such that the total field at a point satisfies Laplace's equation. Comparison of the calculated derivatives to the measured gradients illustrates that the derived relationships are not valid in a true 3-dimensional earth, the flaw being the fundamental assumptions made about the source body geometry.

It is possible to reduce the flight line spacing without noticeable increase in the spatial aliasing effects if the magnetic gradients are measured, and the gradients are included in the gridding algorithm (Pedersen & Rasmussen, 1990). This is especially true where linear structures are sought. However, the improvement in the continuity of linear features sub-parallel to the flight lines, and the identification of three-dimensional structures such as kimberlites advocates measuring the gradients on flight lines at conventional spacing (Reid, 1980).

Measured Versus Calculated Gradients

Derivatives calculated from the total field magnetic measurements, especially the first vertical derivative, are a commonly used interpretive tool. Vertical derivative maps emphasise near surface features relative to deeper sources, and improve the resolution of closely spaced anomalies (Hood and Teskey, 1989).

Measured gradients have the advantage of inherent suppression of the regional and diurnal variations of the Earth's magnetic field. Calculated derivatives often suffer in quality because of poor diurnal corrections.

If assumptions about the source body geometry are made (*i.e.* 2-dimensional), it has been demonstrated that calculated derivatives closely approximate the exact gradient response (Paine, 1989), but noise in the input data may be amplified by the calculations and yield unacceptable results. Generally, however, the calculated derivatives compare favourably to the exact responses within the noise levels of conventional aeromagnetic instrumentation.

However, using the measured gradients there are no *a priori* assumptions made about the source body geometry and the calculated derivatives such as Euler deconvolution and analytic signal are more precise and are not biased by any fundamental geometric assumptions.

Case Histories

Lekgodu Area, south-western Botswana

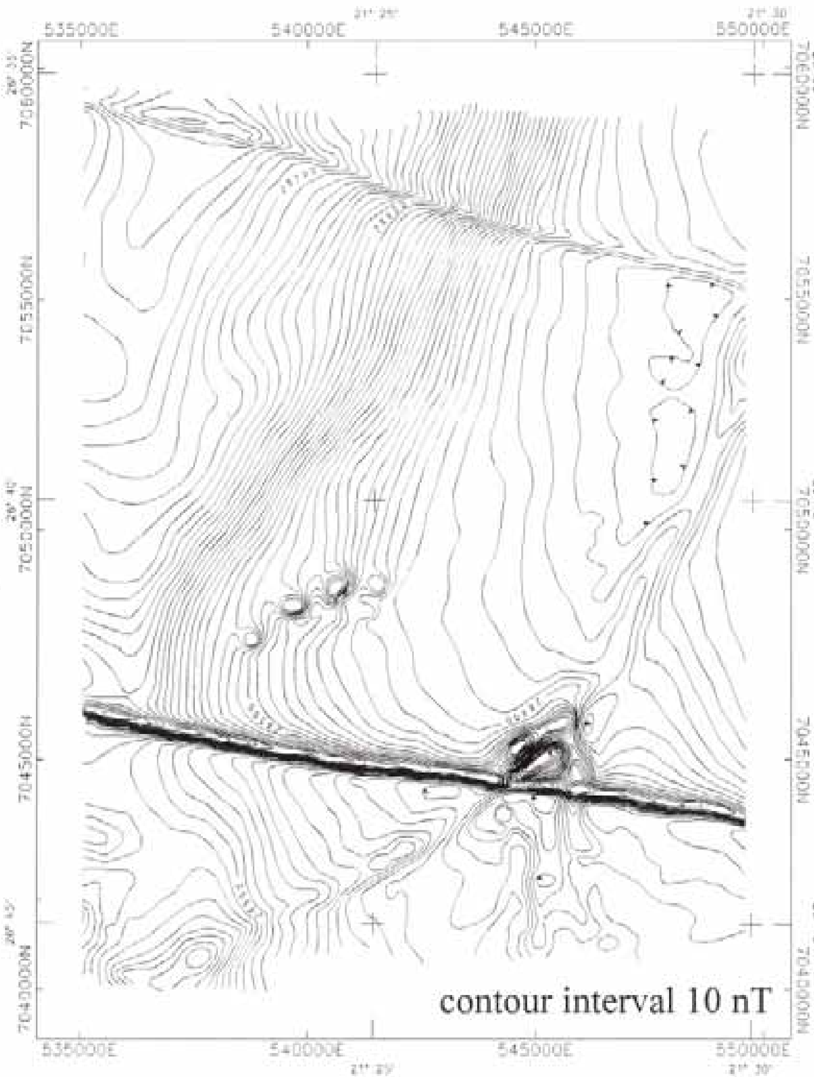
The Lekgodu area (Figure 1) is underlain by Eburnian metasediments, part of the Kheis Orogenic Belt which is accreted to the Archaean Kaapvaal Craton. Unconformably overlying the basement rocks are shales and mudstones of the Karoo Supergroup. Intruding the basement and Karoo rocks are mid- to late-Karoo age dolerite sills and dykes. The entire sequence is covered by approximately 30 m of Kalahari beds which are comprised primarily of sand and associated duricrusts.

Kimberlites were first discovered by De Beers Prospecting Botswana (Pty) Limited in 1978 primarily by following the dispersion trains of kimberlite indicator minerals (De Beers, 1979). Because the kimberlites in this area are strongly magnetic compared to the host rocks, ground magnetic surveys were quite effective in outlining some of the diatremes in the Lekgodu field. Seven kimberlite bodies were drill proven in the Lekgodu area, none of which subsequently proved to be of economic diamond grade.

A test survey of the triaxial gradiometer system was undertaken in 1994. Flight lines were oriented north-south at 250 m intervals. Control lines orthogonal to the flight lines were spaced at 1250 m. The mean terrain clearance of the aircraft was 80 m.

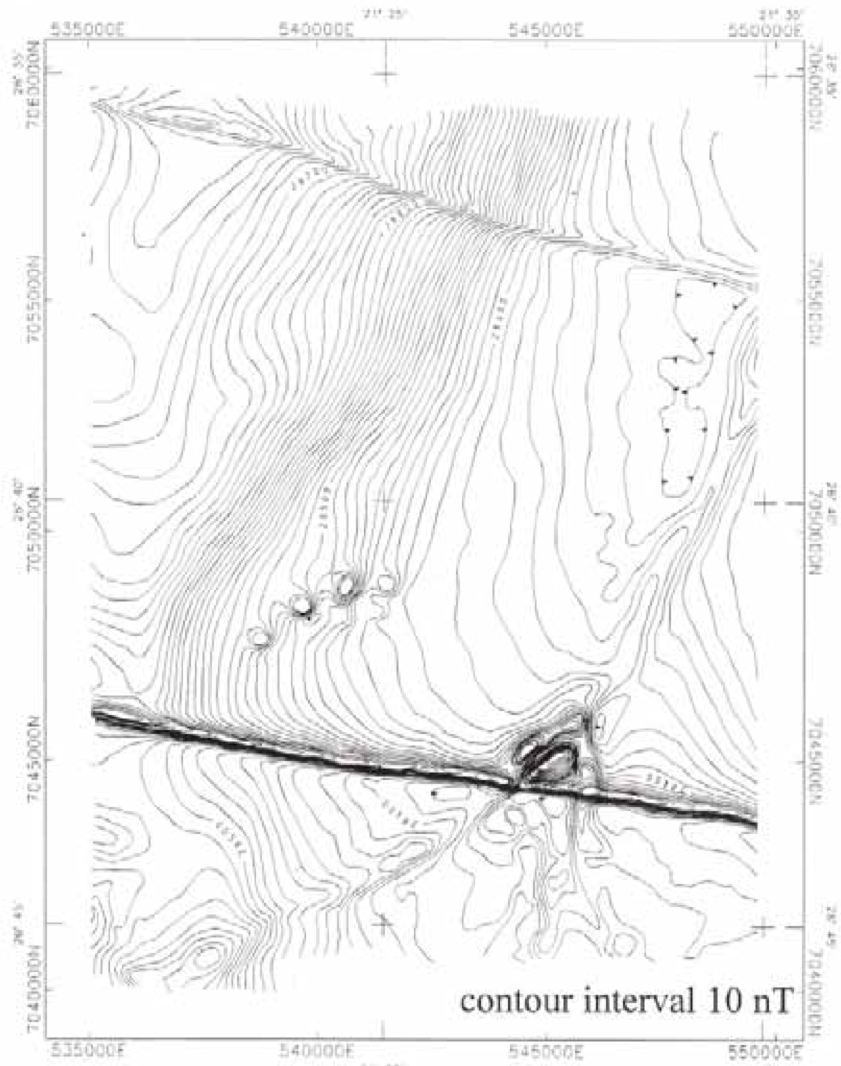
The magnetic field from each of the four sensors was recorded 5 Hz, equivalent to 14.4 m along the ground.

Lekgodu Kimberlite Field
Botswana



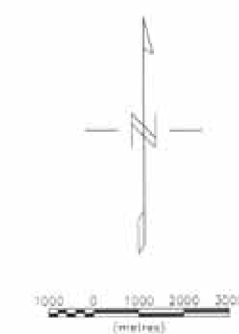
250 m flight lines
conventional minimum curvature gridding

Figure 2a. Lekgodu area, 250m flight lines, conventional gridding.

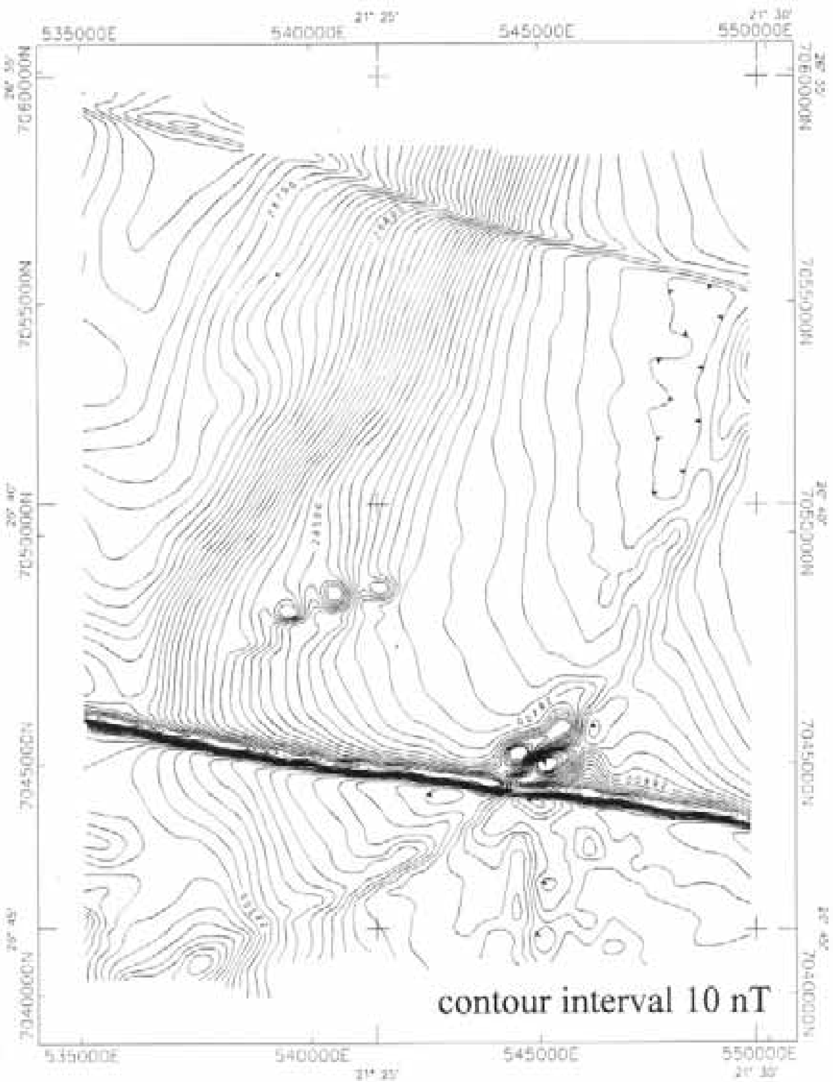


250 m flight lines
horizontal gradient enhanced gridding

Figure 2b. Lekgodu area, 250m flight lines, HGE gridding.

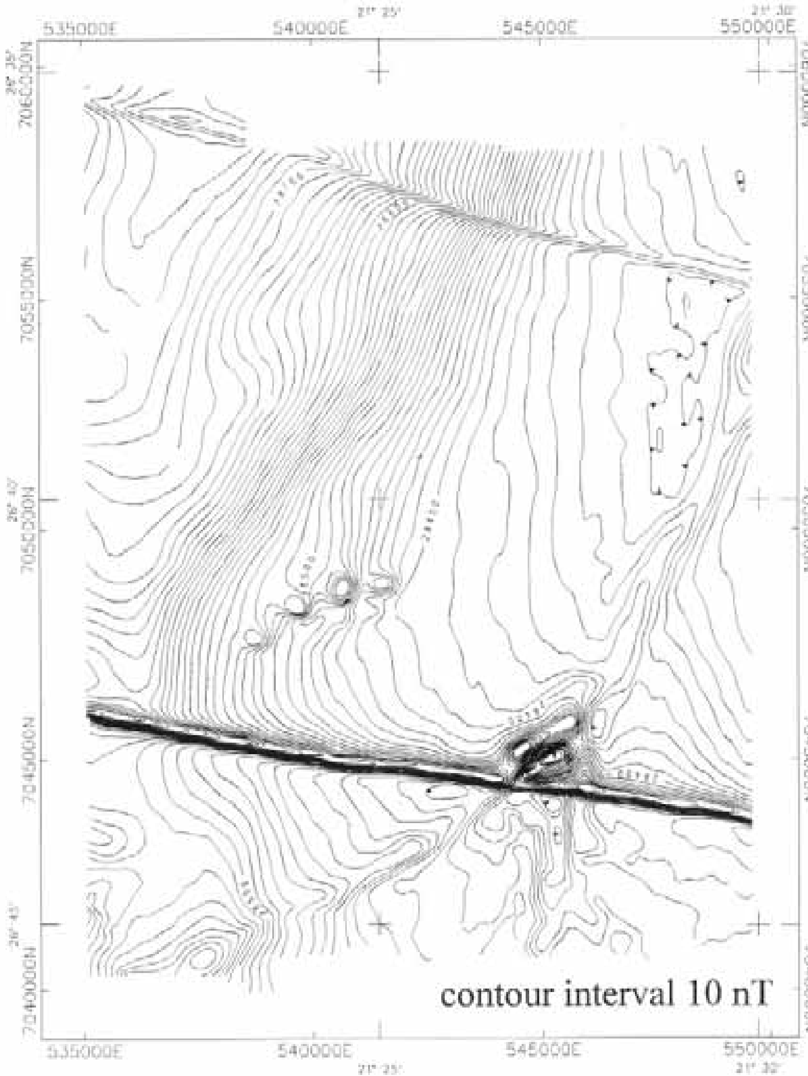


Lekgodu Kimberlite Field
Botswana



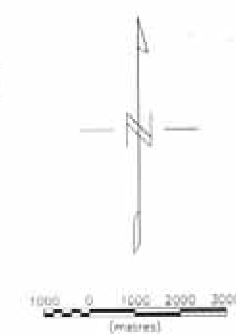
500 m flight lines
conventional minimum curvature gridding

Figure 3a. Lekgodu area, 500m flight lines, conventional gridding.

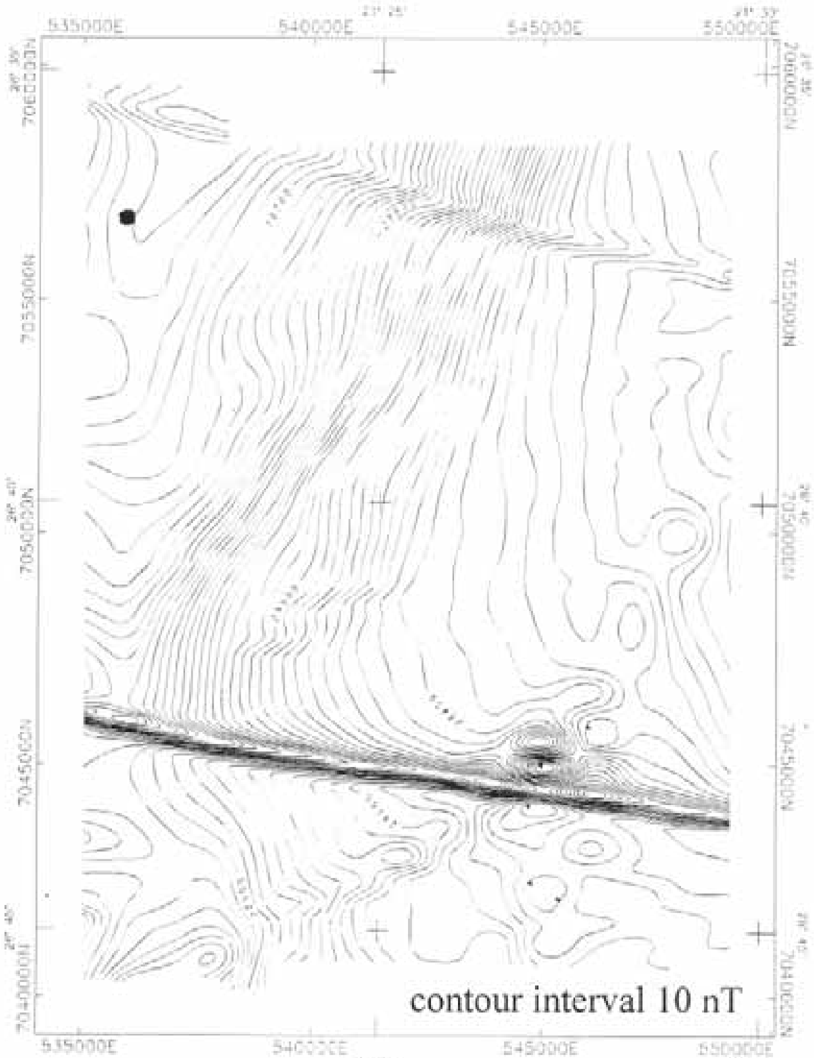


500 m flight lines
horizontal gradient enhanced gridding

Figure 3b. Lekgodu area, 500m flight lines, HGE gridding.

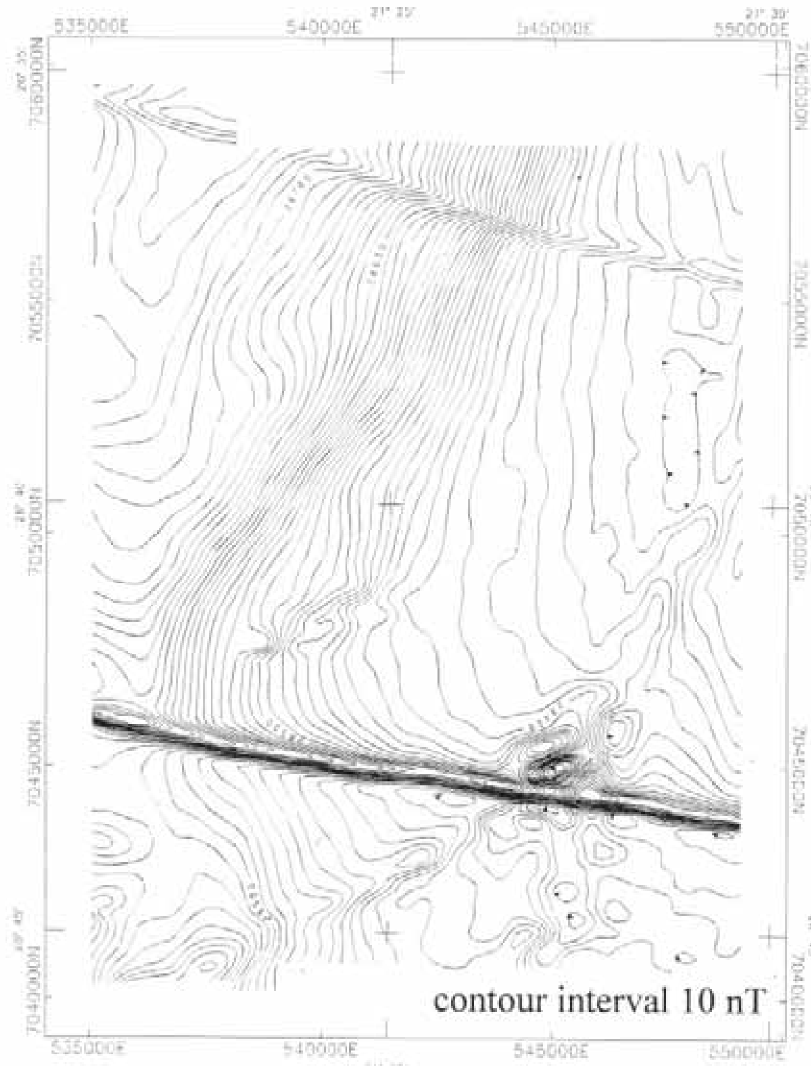


Lekgodu Kimberlite Field
Botswana



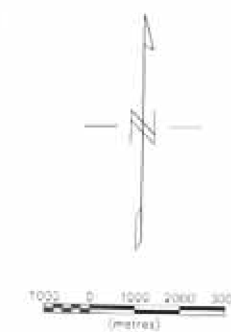
1000 m flight lines
conventional minimum curvature gridding

Figure 4a. Lekgodu area, 1000m flight lines, conventional gridding.



1000 m flight lines
horizontal gradient enhanced gridding

Figure 4b. Lekgodu area, 1000m flight lines, HGE gridding.



There are two features of note in the total field magnetic contours. There is a cluster of four known kimberlite pipes located at approximately $26^0$42'S/ $21^0$24'E which are equally well resolved with a 250 m flight line spacing with the total field using conventional gridding, and the horizontal gradient enhanced (HGE) gridding methods (Figures 2a,b). As the line spacing is successively increased to 500 and even to 1000 m, the benefit of the HGE gridding is demonstrated (Figures 3a,b and 4a,b). The isolated sub-circular responses in the 1000 m flight line HGE grid may still have been identified as priority targets for follow-up.

Perhaps a more important benefit to geological mapping is demonstrated by the improvement in the continuity of linear features which trend sub-parallel to the flight lines. The NNE trending strong magnetic linear on the east side of the area is caused by a dolerite dyke. As the line spacing is increased, the effect of spatial aliasing causes the contours to break up into isolated circular anomalies. Again using the HGE gridding method, the response of the dyke even in the extreme case of 1000 m flight lines remains as a linear feature which is truly indicative of the underlying geology.

Ghanzi-Chobe Fold Belt, northwestern Botswana

Poseidon Geophysics in association with Compagnie Générale de Géophysique and Aerial Surveys Botswana completed a high resolution aeromagnetic survey over part of the Ghanzi-Chobe Fold Belt in northwestern Botswana (Figure 1). The survey was sponsored by the European Community as an incentive to private sector mineral exploration.

The Ghanzi-Chobe area is underlain by Proterozoic metasediments of the Ghanzi-Chobe (Damara) Fold Belt. Significant stratiform copper-silver (± gold) mineralization is known to occur along the length of the fold belt. Mineralization occurs in fine grained carbonaceous metasediments in the Ghanzi Group, which directly overlie the basement. The area is also prospective for kimberlite exploration.

The Ghanzi-Chobe survey was flown at 80 m mean terrain clearance on 250 m flight lines oriented at 305^0 azimuth with orthogonal tie lines at 2.5 km intervals. The magnetic field from each of the four sensors was recorded 5/second, equivalent to approximately 14.4 m along the ground. The aircraft flight path was recorded using post-processed differential GPS.

The total field magnetics (Plate 2a) show broad magnetic trends indicative of the weakly magnetic metasedimentary basement rocks. The analytic signal calculated from the measured gradients (Plate 2b) clearly shows the strong folding. The extremely low noise levels in the measured gradients enable contouring of these data at 5 pT intervals.

To demonstrate the merit of measured gradients, compare Plate 3a - the analytic signal calculated from the total field, with Plate 3b - the total gradient from the measured gradients. The total gradient shows noticeably more detail and continuity of linear features. Also note that the signal levels in the total gradient are less than 10 pT, which illustrates the low noise of the system. The total gradient has also highlighted several sub-circular anomalies, for example at approximately $220^0$0'S/$21^0$48'E, which may be due to kimberlite diatremes.

Acknowledgements

The authors wish to thank the management of Poseidon Geophysics (Pty) Limited and Geodass (Pty) Limited for permission to publish this paper.

Data presented from the Republic of Botswana are copyright Government of Botswana and are used with permission of the Ministry of Mineral Resources and Water Affairs, represented by The Director of the Geological Survey Department. Data from the Lekgodu test area are used with permission of MPH Consulting Ltd on behalf of Southern Africa Minerals Corporation.

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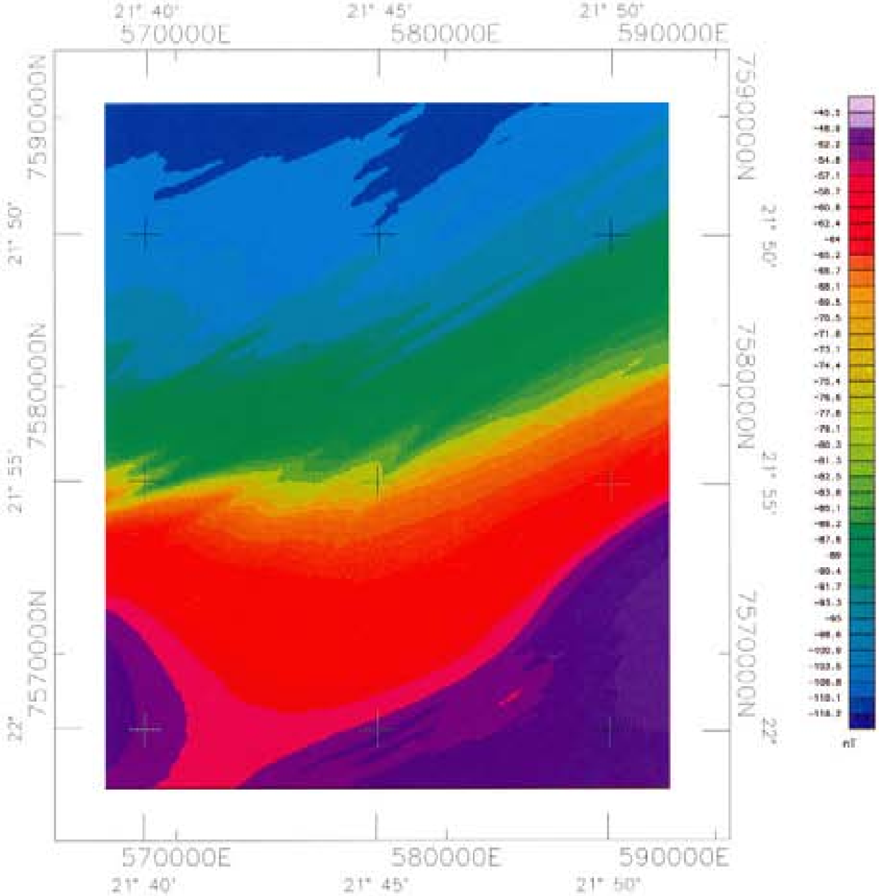
Plate 1. Triaxial gradiometer aircraft ZS-LUI



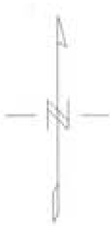


Plate 2a. Ghanzi-Chobe area, Total magnetic field, IGRF removed

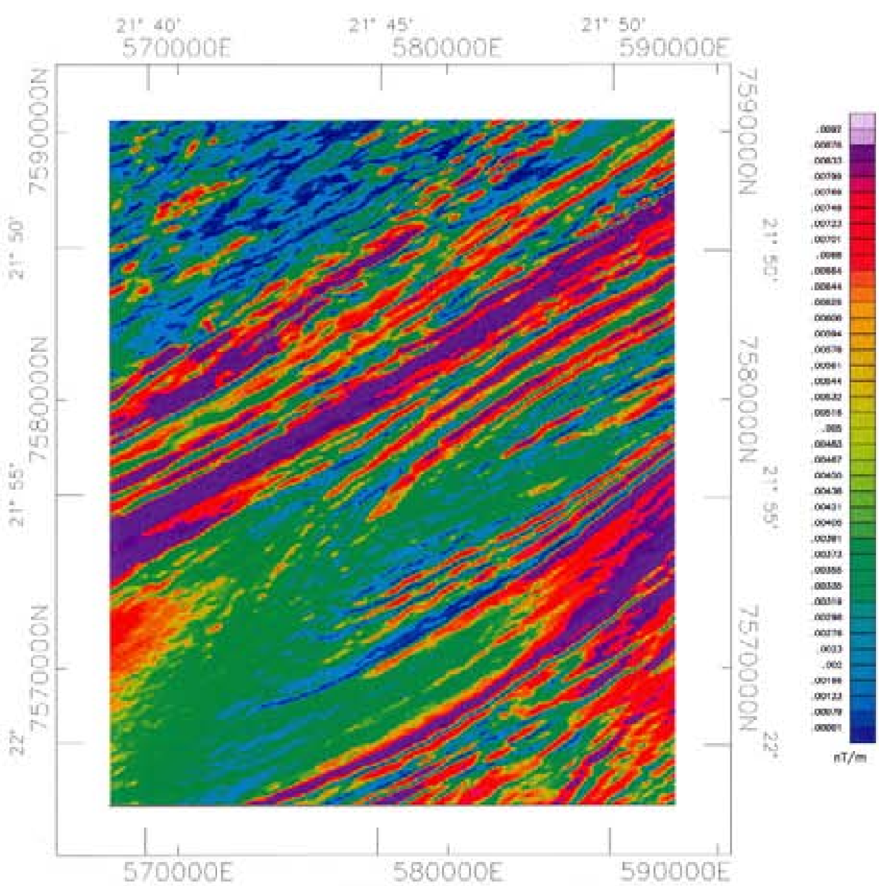


Plate 2b. Ghanzi-Chobe area, total gradient from measured gradients

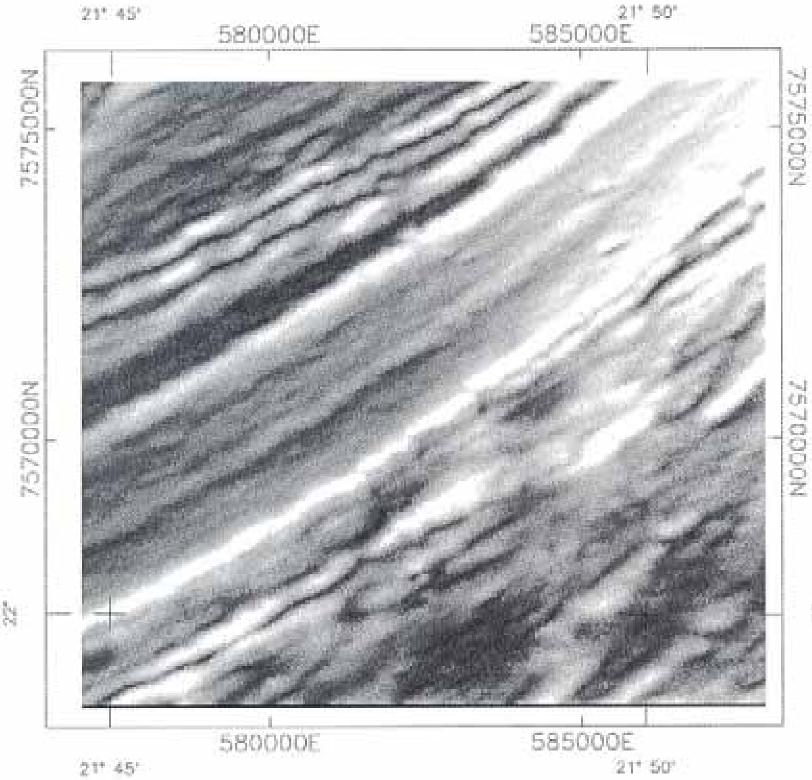
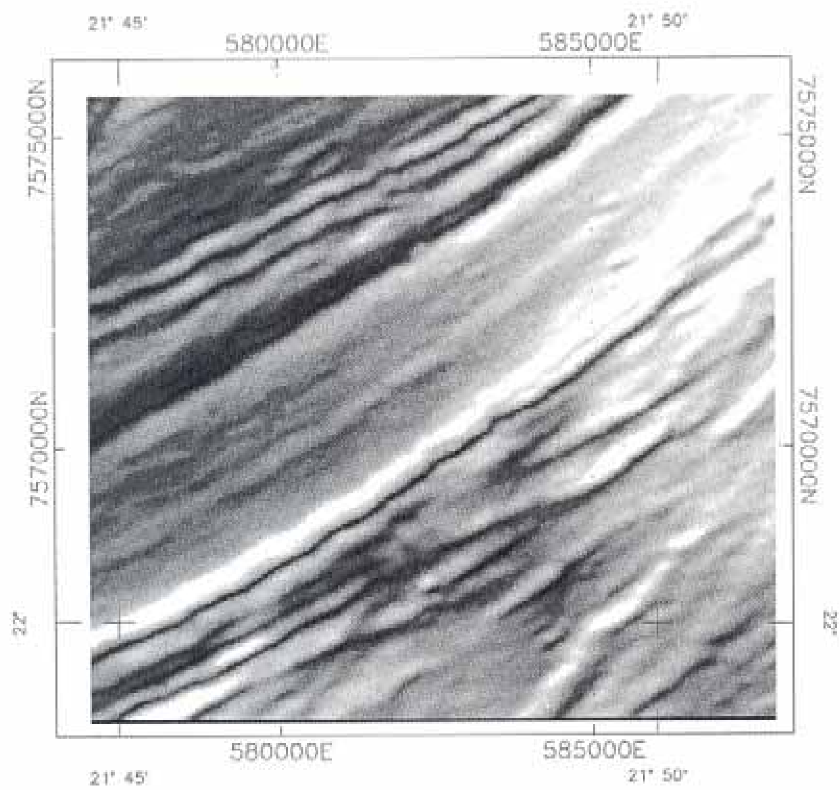


Plate 3a. Ghanzi-Chobe area, analytic signal calculated from total field



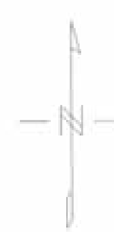


Plate 3b. Ghanzi-Chobe area, total gradient from measured gradients

Book Review: Geophysical Signatures of Western Australian Mineral Deposits

Edited by M.C. Denith, K.F. Francombe, S.E. Ho, J.M. Shepherd, D.I. Groves, and A. Trench, ISBN 0909704-84-8. Geology and Geophysics Department (Key Centre) and UWA Extension, The University of Western Australia Publication No. 26 (ASEG Special Publication No. 7), 1994. 399 p.

During the great nickel boom of the late 1960s, attempts were made to transplant Canadian geophysical techniques into Western Australia on a grand scale. The result of this phase of mineral exploration history was, in hindsight, predictable. The ancient, deeply weathered landscape and highly conductive regolith and transported cover proved disastrous to the early development of exploration geophysics in Australia.

During the ensuing years, the struggle to effectively apply geophysical methods to exploration in Western Australia, and to recover lost credibility from those early setbacks, at first progressed slowly. Since then progress has gathered pace with experimentation during the late 1970s and early 1980s using new transient electromagnetic (e.g., Sirotem) and induced polarization systems (Huntec Mk IV, Zonge GDP-16) and, more recently, with the innovative application of high resolution aeromagnetics and electromagnetics to geologic mapping applications. In short, the initial barriers to application of geophysical methods in Western Australia have become a catalyst for innovation and progress in modern geophysics around the world.

This volume is a tribute to much of the progress accomplished over the last 30 years and is, in itself, a milestone in documenting our understanding of the application of exploration geophysics in deeply weathered and covered terrain. It is a comprehensive compilation of 32 papers covering geophysical case history material of some 57 deposits all over Western Australia. Publication coincided with a special session on the same theme at the 10th ASEG Conference and Exhibition in 1994. The volume's purpose is to provide a reference for use by geologists and geophysicists involved in mineral exploration in Western Australia and similar terrain worldwide. Included are papers on all the important commodities and styles of mineralization known in the state, including base metals, gold, iron ore, uranium, diamonds, and titanium. Their content deals with identifying the geologic setting of the large variety of ore deposit types encountered, as well as methods applicable to the direct detection of mineralization.

The aim of the first three papers has been described well in the preface: "The first paper briefly describes the geology and mineralization of Western Australia and is intended as an introduction for those not familiar with the terrains of the state. The second paper reviews geophysical signatures of different types of mineral deposits in Western Australia with particular emphasis on deposits now described in the following case-study papers. The final overview paper describes aspects of airborne geophysical surveying in Western Australia."

These are excellent summaries which bring together the available information and comprehensive references on each topic. The description of the geology and mineralization of Western Australia is arranged according to craton, which is different from but synergistic with the commodity emphasis of the main part of the text. The overview concerning geophysical signatures is particularly extensive and ensures discussion of any significant deposit not covered by a case history. The paper on airborne methods is a review of state-of-the-art application of these techniques (many recent advances have been pioneered within Australia). Its only deficiency derives from its focus on application of only one of several airborne electromagnetic systems currently available.

The case histories are organized into nine chapters, generally by commodity. Papers are grouped, within these chapters, by deposit age and therefore, to a lesser degree, by deposit style. The first chapter is concerned with copper-lead-zinc deposits. These include Paleozoic Mississippi Valley type deposits of the Lennard Shelf, the Proterorzoic sedi mentary exhalative Abra deposit located in the Bangemall Basin, and the most significant volcanogenic massive sulphide deposits of the Yilgarn and Pilbara cratons. All papers in this chapter cover airborne, ground, and borehole methods. Not surprisingly, there is an emphasis on early application of aeromagnetics and later application of ground electrical techniques. Extensive application of IP to mapping the buried geology and extensive marcasite haloes of the Lennard Shelf is possibly unique in scope. Both the Abra Sedex and Scuddles VMS deposits do not outcrop and were first detected from airborne magnetic surveys.

The next chapter deals with nickel deposits, including the Proterozoic Sally Malay deposit of the Halls Creek Mobile Belt and the world class Archaean volcanic-hosted deposits of the Yilgarn Craton. The style of these papers is very similar, discussion of the favorable physical properties of nickel sulphides and the wide variety of applicable and available geophysical tools. The main variation comes from the different geologic setting of the deposits. The Yilgarn deposits are komatiite-hosted and located near pyritic or graphitic metasediments and below a complex regolith. Sally Malay is hosted in a layered igneous complex. All three nickel papers are excellent, concise presentations of airborne, ground, and borehole data and include the complexities of exploration for a good geophysical target in a difficult geologic settling.

The greatest number of papers, by far, cover Western Australia's world class gold deposits. These include the

Proterozoic Telfer deposit and the extensive Archaean lode-gold deposits of the Yilgarn Craton. A lot of invaluable geophysical rock property data, particularly on the magnetic properties of ore and host rocks, is presented. All papers emphasize the use of aeromagnetics to map lithological and structural setting of these structurally controlled deposits. There are, in addition to the strong reliance on geologic mapping applications, surprising insights into direct detection of alteration resulting from gold mineralizing events. Discussion of airborne, ground, and borehole methods is again extensive.

The final five chapters contain fewer case histories than the first four. This does not reflect the relative economic importance of the deposits discussed nor the applicability of the geophysical methods for their exploration. They include the enormous iron ore deposits of the Hammersley Basin andYilgarn Craton, the Argyle diamond mine, and the young heavy-mineral sand deposits of the southwestern coast. These resources place the state among the world's premier producers of iron ore, titanium, and diamonds. Other papers in the final chapters deal with the Kintyre uranium deposit, the Balla Balla titaniferous magnetite deposit, and the applicability of airborne multispectral scanners to exploration for diamond and gold deposits.

The volume is exceptionally easy to read and its construction makes it convenient to locate relevant information. This also makes it an excellent reference, achieving the aim of the editors. There are few typographical errors, although my copy had a binding and author superscript problem in the chapters concerning diamonds and placers. The majority of diagrams are well presented and easy to read. The extensive use of color in many papers shows much of the data to best advantage. The volume includes a complete bibliography of publications on WA ore deposits which is, in itself, a useful resource. This would have been of greater value had it been sorted by subject rather than author. One only has to peruse the list of authors to realize the quality of papers and diagrams reflected significant cooperation of Australian exploration and mining companies and their personnel. The consequence of this collaboration is an excellent publication which brings together a wealth of historical and modern data about the geophysical signatures of Western Australian mineral deposits and the application of geophysics to their discovery and delineation.

ASEG intends to produce further volumes of this kind, describing data from other states and territories. With exploration moving increasingly to the search for blind deposits and an associated reliance on both conceptual geologic thinking and innovative use of geophysical methods, such volumes will be invaluable references. This volume is a must for geoscientists involved in exploration for the deposit types discussed or in similar environments. It is well constructed, reasonably priced, and provides excellent references on the state-of-the-art and application of exploration geophysics.

(The book can be ordered from ASEG;
411 Tooronga Road, East Hawthorn, Vic 3123 Australia, fax 61 3 822 1711; cost AUD$100 plus AUD$8.00 postage Australia; AUD$20 Surface overseas postage & AUD$45 Air overseas poastage.)

Tom H. Whiting
BHP Minerals International USA

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Geophysical Data Releases

Medusa Banks And Port Keats 1:250 000 Sheet Areas

- Digital Elevation Model Maps and Digital Data
- Gamma-ray Spectrometric Digital Data and Maps

AGSO has flown an airborne geophysical survey of the Medusa Banks, WA and western two-thirds of the Port Keats, NT standard 1:250 000 map sheet areas, west flight lines spaced 500 metres apart, at a flying height of 100 metres, above ground level and sea level.

Digital elevation model maps at 1:250 000 scale and digital data of the area The prices of the 1:250 000 scale maps are $40 for dyelines and $120 for transparencies. The digital data for the complete area is $1000 (point located and gridded).

In addition to the DEM data gamma-ray spectrometric digital data and maps of the area are available.

Lissadell 1:250 000 Sheet Area, WA

- Gamma-ray Spectrometric Digital Data and Maps

Airborne gamma-ray spectrometric maps and digital data for the Lissadell 1:250 000 Sheet area in the east Kimberley region of WA were released by AGSO on 29 June, 1995. Digital elevation model maps, an image and digital data were released on 28 September 1994. Total magnetic intensity maps and digital data were released on 28 February 1995.

The Australian Geological Survey Organisation conducted the airborne magnetic and gamma-ray spectrometric survey of the Lissadell 1:250 000 Sheet area, as part of the National Geoscience Mapping Accord (NGMA) from May to July 1994. This survey was flown with east-west flight lines 400 m apart at a nominal ground clearance of 100 metres

Ebagoola 1:250 000 Sheet Area, Qld

- Gamma-ray Spectrometric Digital Data and Maps

A composite Potassium, Thorium, Uranium (Red, Green, Blue) colour pixel image map for the 1:250 000 Ebagoola Sheet area, Queensland, was released on 29 June, 1995. The basic data were acquired by Geoterrex Pty. Ltd. for AGSO in 1990 on east-west flight lines flown 100 metres above ground level and spaced 400 metres apart. The processed profile data for the three gamma-ray spectrometric bands of Potassium, Thorium and Uranium were gridded to a cell size of 3.0 seconds of arc using minimum curvature. The image was then compiled by combining the three grids into a single three-band Red, Green, Blue (RCB) composite image. The final grid was then reprojected to AMG Zone54, with a cell size of 90 metres.

The price of the image at 1:250 000 scale is $300

Murloocoppie And Wintinna 1:250 000 Sheet Areas, SA

- Total Magnetic Intensity (reduced to the pole), and
- Vertical Derivative Gradient Enhanced Pixel Maps

Colour and grey-scale pixel image maps were released for the National Geoscience Mapping Accord 1:250 000 Sheet areas of Murloocoppie and Wintinna in South Australia on 26 April, 1995.

Data for these maps were acquired by AGSO in 1991 and 1992. The survey was flown along N-S flight lines flown 100 m above ground level in the eastern one third of the Murloocoppie sheet and 80 m above ground level in the remainder of the Murloocoppie sheet and the Wintinna sheet. The line spacing was 400 m. Navigation was by the satellite Global Positioning System.

These TMI images were compiled from processed total-field aeromagnetic data from which the International Geomagnetic Reference Field has been removed. The profile data were gridded to a cell size of 90 m using minimum curvature. The grid data was then processed in the spectral domain to remove asymmetries introduced by the inclination of the Earth's magnetic field (ie. reduced to the pole). Gradient enhancement of the colour image was achieved by modulating colour intensity and saturation, using information derived from a sun-angle routine applied to the first vertical derivative of the initial grid. Pixel colours were chosen from the natural palette (magenta high, blue low) using histogram equalisation. The grey-scale image represents the first vertical derivative of the reduced to the pole total magnetic intensity grid data. Price (per sheet) for TMI colour image is $300 and $250 for grey-scale image. Both colour and greyscale images are $500

Eastern Goldfields Of Western Australia

- 1:1m Bouguer Anomaly Image

The Australian Geological Survey Organisation (AGSO) released a preliminary Bouguer gravity anomaly colour pixel image map of the Eastern Goldfields area of Western Australia on 29 June, 1995. The map is available as Transverse Mercator or Lambert Conformal projection. The image is based on a gridded data set of Bouguer gravity anomalies, calculated at a density of 2.67 tonnes per cubic metre, which has a mesh size of 1.5 minute of arc (approximately 2.5 km) over areas of regional coverage (11 km station spacing) and 0.75 minute (1.2 km) over areas of semi-detailed coverage (approximately 4 km station spacing). The 1.5 minute grid and 0.75 minute grid have been interpolated down to 0.25 minute (400 metres) to achieve a smoother image.

This image is a preliminary version, based on work completed up to 1994, and a more accurate image will be released, after proposed fieldwork has been completed, in 1997. The 1:250,000 scale mapsheets included in this 1:1,000,000 scale image release are as follows:

Wiluna, Kingston, Sir Samuel Duketon, Leonora, Laverton, Menzies, Edjudina, Kalgoorlie, Kurnalpi, Boorabbin, Widgiemooltha, Lake Johnston, and Norseman

The map may be obtained in colour ink jet format for $300.

The following maps and data sets will be released by AGSO in mid July.

Laverton And Leonora 1:250 000 Sheet Areas, WA

- Digital Magnetic and Gamma-ray Spectrometer Data
- Total Magnetic Intensity (reduced to the pole) Pixel Maps
- Vertical Derivative Gradient Enhanced Pixel Maps

Ashton 1:250 000 Sheet Area

- Magnetic and Gamma-ray Spectrometer Digital Data and Maps

Broken Hill And Taltingan 1:100 000 Sheet Areas

- Gamma-ray Spectrometer Digital Data and Maps

Bendigo 1:250 000 Map Sheet Area

- Magnetic and Gamma-ray Spectrometer Pixel Maps

Abstracts

SECTION FOUR

Contents of Speakers Abstracts by Session

Name of presenter only

Monday 4 September 1995

Tuesday 5 September 1995

Wednesday 6 September 1995

Opening Keynote Address

Ross Adler

Managing Director, Santos Ltd, Adelaide

Abstract

The Australian resources industry is currently facing turbulent times, with low commodity prices, volatile currencies, an overall decrease in prospectivity and pressures generated by increasing competition and stringent overseas fiscal regimes. These continue to generate significant challenges to our business. Clearly these forces are outside the control of the industry, however it is important to be aware of these issues, and their impact on the business. It is vital for a company to have a clear strategic direction, which is long ranging enough to provide a consistent focus, while maintaining flexibility to react to changes in the influences outside of the companies control. It is therefore necessary to focus on the issues that our industries have some control over, and this ultimately is the NPV of the discovery cost for the commodities that you, as explorationists, are seeking and the consequential competitiveness of your companies.

My address will focus on one of the many key issues associated with the Oil and Gas industry and the creation and maintenance of shareholder wealth, ie that of technology, its provision, justification and implementation. I believe that many of the seminal points in this address, while specific to the Oil and Gas industry, are relevant to all sectors of the resource industries.

The Oil and Gas industry presents many unique challenges for its participants, as we are trying to increase shareholder wealth against a background of declining oil prices (in real terms) and uncertainty in gas prices following the deregulation of the market place. It is unlikely that the current trend in world oil prices will change in the near future. There has been much discussion about the impending increase in energy requirements because of improvements in the global economy, particularly in the less developed areas of the world. However, this view must be offset against an increase in environmental awareness and the increasing trend towards energy efficient technologies. The application of energy taxes would also have both a dampening effect on the demand for hydrocarbons and would diminish the returns to the industry.

Central to the issue of wealth creation in the Oil and Gas industry is the recognition of the high risk and capital intensive nature of the business. The result is a highly leveraged ability for wealth creation, or conversely, wealth destruction. Critical to the positive leverage is the identification of technology as a primary enabling factor in the value adding chain of exploration for, and the development of, any resource. Technological leverage increases through the process chain from data acquisition, through interpretation, integration and synthesis. The latter stage affords maximum leverage. Clearly this leverage critically depends upon more than a sound application of technology. Rather it requires a complementary fit of technology, organisational structure/learning and management process. Without this fit a slide down the industry's "performance spectrum" is inevitable.

In short, it is imperative to have the right people, processes and technology to improve, or at least maintain, the position along the "performance spectrum".

As a generalised case history I will discuss how Santos is striving to improve its position on the "performance spectrum". This is due, in part, to the efficient and effective use of suitable technologies and an appropriate direction and vision for the company. This has enabled the company to focus on the critical issue of cost containment, by increasing efficiencies throughout the company and by better understanding the challenges and risks involved. Santos has embraced technology, and will continue to do so, but it is critical that the technologies are applied judiciously as these technologies are often expensive. This has resulted in the application of "Fit for Purpose Technology", the current favoured buzz-words, which basically means the use of the right tools for the right job.

Santos as Operator has been involved in many instances where this utilisation of technology has lead to considerable cost savings, through increased productivity or improved data quality. Currently seismic data are acquired in the Cooper/Eromanga Basins at costs that have not increased in real terms in the last ten years. This is a direct result of the prudent use of better technology, such as bigger, more controllable vibrators and state-of-the-art recording systems. Not only have the data acquisition costs remained static and the data quality improved, but the environmental impact of the current seismic practices are negligible, resulting in a better environmental outcome and a substantial reduction in restoration costs.

3D seismic has been successful in exploring for Birkhead Formation reservoir channel sands in the Eromanga Basin, and the identification of these has resulted in savings in optimising drilling locations. 3D has also been cost effective when compared against conventional 2D seismic. As an example the recent Jackson 3D survey was acquired at a comparable cost to a conventional 2D seismic survey of 500m line spacing, but the 3D survey has superior data content.

Santos was the first company to drill a horizontal well in mainland Australia at the Meranji Oil Field and the use of the technology resulted in increased recoveries from the Namur Sandstone target horizon. Currently Santos is reviewing other possible horizontal drilling candidates in the Cooper/Eromanga Basins at Big Lake and Keleary. Enhanced Oil Recovery (EOR) has been a focus of development of the Tirrawarra Oil Field, and the technologies implemented have meant that oil is now also economically producible from the otherwise economically marginal Tirrawarra Sandstone of the Merrimelia Field. In an effort to continue to contain the drilling costs within the Cooper/Eromanga Basins a study has been commenced to determine the feasibility of slim-hole drilling, to optimise drilling expenditure against the current drilling targets.

In the past five years there has been a dramatic increase in the available computer power available to geoscientists and engineers at Santos. The implementation of this technology has meant that more time is spent "working the data" and generating ideas. An example of this is the innovative and accurate depth conversion of the 3D seismic survey over the Stag Field, leading to the discovery and successful appraisal of a very subtle, stratigraphically trapped oil accumulation. Clearly this implementation of technology has lead to an increase in the quality of geoscientific endeavour, which has contributed to a maintenance of low finding costs,

offset against increasingly limited opportunities.

Santos has also been involved in Joint Ventures that have seen considerable savings delivered with the use of new technologies. The use of floating production storage and offloading (FPSO) facilities at Jabiru/Challis has meant that a marginally economic reserve with conventional platform technology has resulted in an economically successful venture.

These have all meant that Santos has maintained its competitive edge within the industry.

At the same time there has been a concerted move towards the integration of data from historically disparate databases, which will ultimately result in geoscientists having simple and time efficient access to the data required for their interpretations. Any time saving that will result in a company bringing production forward will have a positive impact on shareholder wealth.

It has also been shown that it is vital for the industry to learn from their mistakes, and this continuous learning process is another characteristic of the successful companies. One of the many areas on which Santos is focussing is that of adequate recognition and consistent evaluation of risk associated with exploration prospects. We now have a more rigorous and uniform approach with which to integrate historical data readily into exploration evaluations. This readily quantifies the risks in a systematic way, enables the necessary economic evaluation of potential targets to be assessed and results in a better prediction of the potential outcomes of the exploration programmes.

Technology has now enabled us to develop a custom-built prospect evaluation and inventory system which provides us, in real time, with a worldwide ranking of Santos' exploration prospects. This ultimately will increase shareholder wealth by enhancing the economic decision making process.

It is initiatives such as these that will enable Santos to improve, or at least maintain, its position on the "performance spectrum", against the setting of declining commodity prices. Such initiatives will provide the framework for the company to continue to grow and help Santos to continue to both increase its resource base while reducing the associated risks.

Swath-mapping the Australian Continental Margin: Results from Offshore Tasmania

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Abstract

Considerable areas of Australia's offshore region were mapped recently using modern multibeam seafloor swath-mapping systems such as Simrad EM12D and Sea Beam 2000. The new and advanced technology built into these systems has led to the acquisition of a vast quantity of new bathymetric data and acoustic backscatter imagery. The detailed structural information available in these data sets and their extensive coverage form the basis for renewed and enlightened examination of the tectonic evolution of parts of the Australian margin. The new data have important implications for petroleum exploration, the assessment and management of fisheries and deep-sea mineral resources, as well as 'Law of the Sea territorial claims.

Almost 200,000 km² of seafloor were mapped to the west and south of Tasmania in February to March 1994. The survey was conducted by AGSO in co-operation with French scientists using IFREMERs research vessel LAtalante. The ship is equipped with the Norwegian Simrad EM12D multibeam echosounder. This 162-beam, 13 kHz system mapped bathymetry and seafloor acoustic backscatter ('reflectivity) across a swath up to 20 km wide at a speed of 10 knots (19 km/hr). A total of 13,600 km of underway geophysical data (6-channel seismic, gravity and magnetic) were also collected during this survey.

The images of the new survey data over the Tasmanian transform margin and South Tasman Rise are both detailed and spectacular, and provide the first unequivocal insight into the structural development of this region. This development occurred during Late Jurassic to Cretaceous Australia/Antarctica continental extension through both rift and wrench movements, and subsequent post mid-Cretaceous opening of the Southern Ocean. The bathymetric images clearly show the seafloor spreading fabric, over 2 km of relief at the Tasman Fracture Zone, and rotated continental fault blocks rising up to 2.5 km above the abyssal plain west of Tasmania. An extensive system of canyons and a large field of ?Tertiary volcanoes were mapped for the first time on the continental slope. Deep, narrow transtensional basins on the western flank of the South Tasman Rise contain greater than 2.0 s two-way time of sedimentary section.

Key words – swath-mapping, multibeam echosounder, acoustic imagery, offshore Tasmania, South Tasman Rise, continental margin, seafloor spreading, plate tectonics

Evolution and Structuring of the Joseph Bonaparte Gulf as delineated by Aeromagnetic Data

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Abstract

A large portion of the southern Joseph Bonaparte Gulf area, northwestern Australia, was originally underlain by extensive contiguous Proterozoic sills and volcanic rocks. Subsequent extension and basin formation in this area during the Palaeozoic fractured this horizontal basic magnetic sheet. Evidence of this fracture pattern and the extensional movements are obvious in images of the magnetic field over the basin. A series of transfer fault accommodation zones trending at 035 degrees and an associated series of perpendicular normal faults have been mapped. Onshore geology, gravity and seismic data support the transfer fault model. An underexplored graben, 75 kilometres long and 50 kilometres wide, which formed as a result of the extension process, has been mapped on the western edge of the Joseph Bonaparte

Gulf adjacent to the Proterozoic Kimberley Basin.

The Central Officer Basin, South Australia: Geophysical Results from the NGMA Officer Basin Project

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Australian Geological Survey Organisation, Canberra

Abstract

In 1993 as part of the NGMA Officer Basin project, AGSO recorded a network of 5 regional seismic lines (totalling 550 km) to investigate the basin structure and stratigraphy of the poorly understood central Officer Basin.

Interpretation of the seismic and potential field data suggests the central Officer Basin is separated from the eastern Officer Basin by a NNE trending shear zone. West of this shear zone, the central Officer Basin can be divided into two regions:

1. the northern margin region where south-directed thrusting of the Musgrave Block has formed a triangle zone and folded the northern edge of the Officer Basin succession into a homoclinal structure,
2. a platform region in which the basin succession gradually thins southward with very little post-depositional disturbance.

Seismic Line 93AGS01

This line traverses from the Musgrave Block, across the northern thrusted margin of the basin, to provide a tie to Birksgate #1 well in the south. It shows the major crustal thrusts north of the basin margin which have controlled the sedimentary upturning and the development of this northern margin. This thrusting is due to reactivation of some of a series of north dipping structures which pervade the upper crust. These structures are interpreted to have formed pre-Willouran, as most are truncated by the basal erosional surface of the basin. This line also shows back-thrusting of an upper sedimentary succession over a triangle zone, and the development of thrust-related kinks in the lower succession.

Seismic Line 93AGS03

This line provides a tie from Munta #1 well to the seismic network south of the Unnamed Conservation Park, and shows a remarkably constant thickness of section (between 1100 and 1300 ms twt) over its 170 km length. It crosses a disturbed zone between stations 3800 and 4100. This corresponds to the point of oblique intersection of a significant NNE trending lineation in the TMI data. Analysis of the TMI image suggests that this is a major strike-slip fault with about 30 km of sinistral movement. East of the fault, the seismic network (including previous seismic lines in the eastern Officer Basin) shows complicated thrusting and diapiric piercement structures with associated collapse-faulting. In contrast, west of this strike-slip fault, 93AGS03 indicates little post-depositional disturbance of the Officer Basin succession.

Seismic Lines 93AGS04, 93AGS05 & 93AGS06

These lines investigate the structure of the central Officer Basin south of the Unnamed Conservation Park. 93AGS04 crosses the southern end of a potential field anomaly in the TMI and gravity data known as the Nurrai Ridge, but the seismic data shows no evidence of any structure within the sedimentary succession corresponding to this feature. Dip lines 93AGS05 and 93AGS06 show the basin shallowing gradually southwards from around 1300 to 1000 ms twt (approx. 2600 to 2000 m). Minor structural disruption on these lines correlates well with anomalies evident in the aeromagnetic data.

High Resolution Aeromagnetic Surveying for Petroleum in the Western Otway Basin

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Abstract

In 1993 the South Australian Department of Mines and Energy (MESA) commissioned a high resolution aeromagnetic survey over part of the Western Otway Basin, the economic potential of which is demonstrated by recent gas discoveries. The survey area is situated in the southeast of S.A. and consists of a section along the S.A./Vic. border, approximately 25 km. wide, from north of Penola to offshore south of Mt. Gambier (–37° 15 S to –38° 10 S and 140° 40 E to 141° E). This survey was a test case to determine whether a high resolution survey (400m. line spacing and 60m. altitude) would permit the detection of weakly magnetic, intrasedimentary horizons and allow the mapping of magnetic lineations corresponding to faults and shear zones, thus assisting in the detection of structural traps that may contain significant reservoirs of hydrocarbons.

The Otway Basin formed as a result of the separation of Australia and Antarctica with rifting commencing in the late Jurassic. The Penola Trough was one of the initial depositional centres and is bounded to the northeast by the Kanawinka Fault Zone, while its southwest margin is the Kalangadoo High. In the late Cretaceous and Tertiary a thick offshore sequence of sediments was deposited. Volcanism occurred during the initial rifting stage, during the Cretaceous and early Tertiary, and during the Pleistocene/Holocene (Mts. Gambier and Schank and the Mt. Burr volcanic complex).

The major features of the magnetic map are listed below along with depths obtained from spectral analysis, Euler deconvolution, modelling and seismic evidence;

1. The large elliptical-shaped magnetic high (400 nT amplitude) to the northeast of Mt. Gambier that is associated with the underlying magma chamber, which is approximately 7-8 km. deep.
2. The broad magnetic high on the western side of the study area which is associated with the Mt. Burr volcanic complex (approximately 4–5 km deep).
3. The magnetic high in the northeast corner associated with the Kanawinka Fault Zone.
4. Elliptical anomalies resulting from the Mt. Gambier and Mt. Schank volcanic cones as well as an anomaly near Hungerford believed to be a blind basaltic plug (300-400m deep).

5. Two elliptical anomalies in the Penola/Sawpit area; one associated with the Sawpit basement high while the northeastern anomaly is an intersedimentary source between 700m and 1 km. deep.

6. Linear anomalies striking northwest/southeast between Penola and the Victorian border, which are the result of magnetic sources within the early Cretaceous Eumeralla Formation (400-500m.), and which are possibly magnetised fault planes (amplitudes between 1 nT and 3 nT).

In addition, there are a large number of short wavelength, isolated anomalies which are associated with 'cultural' features such as buildings, railways, pipelines and, especially, powerlines. Power lines are the most significant source of cultural anomalies in the area and produce lineations on images and contour maps which can be mistaken for lineations associated with faults. The large power line anomalies can have amplitudes of up to 200 nT.

Theoretical studies in part of the Penola Trough based on models developed from seismic evidence, have shown the degree of vertical offset and susceptibility contrast required before a fault structure can be detected. From these studies, it was found that only faults or horizons within the late Cretaceous Sherbrook Group and, especially, the Eumeralla Formation are likely to produce detectable anomalies at this flight height given the susceptibility measurements available or average susceptibilities for these types of sediments. The linear anomalies east of Penola have been modelled in a similar manner and give a reasonable fit for either offset magnetic horizons or magnetised fault planes. Image enhancement of the offshore data has revealed a series of cross-cutting lineations (NW/SE and NE/SW) which may be faults in the Tertiary or late Cretaceous section.

Analogue 3D Modelling of the Extensional Fault Systems – Examples from the North West Shelf, Western Australia

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Abstract

Analogue modelling has proven particularly useful to simulate progressive deformation in the extensional terranes and can imitate style of structures imaged by seismic reflections. Mapping fault patterns in the North West Shelf of Western Australia has shown that faults may have an edge or side ramp where extension occurs in previously faulted regions. A series of models have been produced where the nature and orientation of side ramps have been varied to understand the depositional patterns and fault patterns in the North West Shelf.

The Mermaid Fault on the eastern side of the Dampier Sub-basin is a complex normal detachment fault. Depth conversion on the entire Mermaid Fault has allowed construction of scaled models incorporating this complex detachment which changes character along strike from ramp-flat-ramp to simple listric. Experiments were run over this detachment incorporating scaled thicknesses of the formations in the area with extension equivalent to that measured on seismic sections. Sectioning after stabilisation of the model shows good agreement with the hangingwall geometries seen on seismic.

Considerable compression is created above ramp-flat-ramp even though the whole model is obviously under extension. Compression results from the reversal of block rotation as the hangingwall sediments react to change in detachment curvature. Seismic interpretation and analogue modelling results confirm the existence of a compressive region where the hangingwall movement is controlled by ramp-flat-ramp detachment. Compression of this nature is likely to influence fluid migration, moving fluids from zones of compression to zones of extension. This compressive zone diminishes towards north where the detachment is simple listric.

Arabella-1 was drilled in an area where extension occurred above ramp-flat-ramp detachment, that caused compression during all the stages of extension. This study provides evidence that the well may not have been drilled in a suitable location, as the most favourable area exists to the NE where the detachment is simple listric.

Computerised Tomography (CT scanning) now has been used to determine compaction and porosity variation in the hangingwall of a 3D model. These data give information on fluid migration pathways through sediment packages during extensional deformation.

Detailed Elastic Modelling to Characterise Noise Contributions to Seismic Data from the Gippsland Basin

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Abstract

Strong noise contributions currently prevent adequate definition of deep exploration targets in marine seismic data from the Gippsland Basin. We computed an elastic synthetic seismogram (Kennett, 1979, 1980) from a highly detailed depth model to match the raw field records with considerable accuracy. As part of a sensitivity analysis, we computed additional synthetics to gauge the effects of poorly known parts of the depth model upon the elastic synthetic. These synthetics also helped us to identify noise events in the field records. Subsequent processing of the synthetics led to the identification of persistent noise contributions to stacked data from the Gippsland Basin.

Noise contributions in the target zone consist of "shear reflections" resulting from strong mode conversion occurring at the Miocene channels and the Latrobe Group coal/shale sequence. These formations then reconvert the S-waves to P-waves so that they are recorded by the hydrophones. The timing and curvature of the shear reflections is such that they strongly interfere with primary reflections in the target zone stack response. At greater depths, the stack response is dominated by long-period multiples associated with the coal sequence, the Miocene channels, the hard sea floor and the sea surface. Lateral variation of these noise interferences is due to structural variation in the Miocene channels and the lower part of the coal sequence. Strong interbed multiples (including mode converted peglegs) are generated in the coal sequence and constitute a second

type of noise interference by preventing direct interpretation of the target zone primary reflections.

Our elastic synthetics also characterised shear refractions in the field data using a compactional trend to derive the shallow depth model. The modelled shear refractions were highly sensitive to the shallow shear velocity profile and this makes them an important elastic modelling constraint. Further variation of the shear velocity model also revealed the insensitivity of stacked elastic synthetics to our 'artificial VS log' based on approximate formation s values. The amplitude and timing of prominent reflections barely changed as we adjusted their formation s values.

Hammer-Induced Seismic Investigations in an Area of Observed Anisotropy

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Abstract

A seismic experiment was undertaken in order to investigate the effect of an observed (outcropping) fracture set on shear-wave propagation, and more specifically whether the observed fracture set induced shear-wave birefringence. The source for the experiment was a hammer swung to impact horizontally on a source block coupled to the ground by two large metal pins. Eight three-component geophones recorded arrivals up to 40m offset from the hammer source. Impacts of opposite polarity in the in-line and cross-line direction were differenced in order to maximise S-wave, and minimise P-wave energy. After vector gain, filtering and rotation of the recorded data into in-line and cross-line directions, Alford rotation was undertaken on selected windowed events in order to detect shear-wave birefringence. In-line and cross-line energy is maximised by a co-ordinate rotation to the north – south direction, parallel to the observed fracture direction, suggesting that the observed fracture direction results in an anisotropy that induces shear-wave birefringence.

Key words – Shear-wave birefringence, fracture direction, hammer source experiment

Variation of Stacking Velocity in Transversely Isotropic Media

Patrick Okoye

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Abstract

Numerical studies have been conducted to analyse how the elastic parameter influences the shapes of the squared travel time-offset curvesfor surface seismic data and the subsequent effects on stacking velocities using reasonably large offsets typical of reflection seismology. The velocity functions of Green River shale and Mesaverde clayshale (Thomsen, 1986) used in this study represent opposite properties of P-wave propagation. As such they have been chosen to explain fully the role of in this analysis.

A one-layer transversely isotropic solid overlying a plane reflector represents the model geometry used in the numerical studies. The axis of symmetry is vertical and both horizontal and dipping reflector cases were considered. Travel times were computed for common mid-point gathers above the reflector. The stacking velocities were computed at different offsets by fitting a tangent line to the plot at each, making it possible to generate graphs of stacking velocity versus offset using Green River shale and Mesaverde clayshale as representative examples.

The numerical modelling results indicate that the stacking velocities not only vary significantly with offset but also differ from the vertical ray velocity depending on the sign of the anisotropic parameter. Hence, P-wave surface-seismic data cannot accurately predict depths to horizontal reflectors in the presence of anisotropy. This study further emphasises that interpretation of travel time graphs must consider the presence of anisotropy. The variation of the stacking velocity, with offset is expected to give rise to non-hyperbolic travel time curves, which if not taken into consideration may lead to deterioration of stacking itself.

Results of the physical modelling obtained using phenolite material which simulates a transversely isotropic medium, indicate that, if anisotropy is present, the stacking velocity used in aligning the primary reflection changes with offset and may not be representative of either the vertical or horizontal velocity.

Key words – anisotropy, normal moveout velocity, elastic parameter .

Spectral Characterisation of Reflectivity Sequences in the Amadeus, Surat and Bowen Basins, Australia

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Abstract

A fundamental assumption in seismic reflection processing is that the spikes comprising the earth's reflectivity series are randomly distributed in time, and hence exhibit a white (flat) power spectrum. The validity of this assumption is examined via spectral analysis of log data from the Amadeus, Surat and Bowen Basins, Australia. Reflectivity spectra generated over entire wells from each of these basins are distinctly non-white, supporting observations from previous overseas studies. Typically such whole-well spectral slopes range from 0.5 in the Bowen Basin, up to 1.5 in the Surat Basin, a somewhat broader range than observed in previous investigations.

A more detailed analysis of spectra within individual geological formations has also been undertaken. It has previously been suggested that non-repetitive, randomly-bedded sedimentary rocks might be expected to possess whiter reflectivity spectra than more cyclic sedimentary deposits. In the Amadeus and Surat Basins, spectral slopes are typically moderate to high in sandstone formations, while smaller slopes are found in formations comprising finer-grained materials. In the Bowen Basin,

formation spectra exhibit a greater range of slopes as a consequence of coal seams occurring in a variety of stratigraphic relationships with other lithologies. For example, thick composite seams comprising interbedded coals and shales can generate very steep spectra. Conversely, thin isolated coal seams have a strong whitening influence on spectra. Whilst such coal-seam related influences may be obvious in log data, not all controls on formation spectra are evident in the time domain. For example, relatively low amplitude reflectivities can also generate strongly non-white spectra. This is because it is the distribution of spikes in time which influences the degree of non-randomness.

Fine-tuning of deconvolution to account for non-random behaviour may be feasible in regions where spectral character is constant over significant depth ranges. However, stratigraphic controls on spectral character are quite subtle, and true formation-based deconvolution will be non-trivial.

Shear-Wave Splitting Analysis Using a Single-Source, Dynamite VSP in the Otway Basin

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Abstract

. A shear-wave splitting analysis has been carried out on a 3-component dynamite VSP from the Namgib-1 well in the Otway Basin, southeastern Australia. The commonly-used dual-source analysis techniques are not applicable, and hence a number of single-source approaches have been investigated. Energy Maximisation and Aspect Ratio techniques are considered the most robust and efficient. Complex Component and Hodogram approaches provide visual insight, but require more manual effort. Inter-Level and Inter-Component Correlation approaches are uncompetitive in practice.

Meaningful estimates of fast shear-wave polarisation azimuth have been obtained for the Otway Basin well. Overall, these suggest that maximum horizontal compressive stress is oriented in the SE-NW quadrants. This result is consistent with independent evidence relating to present-day regional stress regimes. Localised variations in the fast shear-wave azimuth occur within sections of the borehole, and these may relate to inter-formational differences. Over the entire well, a relative time delay of 0.09s is accumulated between the fast and slow shear waves. This implies a shear-wave velocity differential averaging 6%, a value at the upper end of observations reported elsewhere.

The successful shear-wave splitting determination reported here has implications for enhanced exploitation of the existing 3-component VSP archive.

Tube Wave Suppression in High Frequency Mine Seismic Data by Singular Value Decomposition

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Abstract

Crosswell and VSP seismic survey data are frequently contaminated by coherent noise trains in the form of direct tube waves and tube-wave-to-body-wave conversions. The problem was especially acute in a recent high resolution underground seismic experiment that was conducted in a hard rock environment. Conventional processing, such as f-k filtering, was ineffective in suppressing such noise events.

A procedure, based on singular value decomposition (SVD) of a seismic section, was employed for cancelling coherent tube-wave related noise. An eigen analysis splits the section into linearly independent eigenimages. Each eigenimage is a characteristic content of the seismic record. Its energy contribution to the total energy of the seismic section is represented by the magnitude of its corresponding eigenvalue. The leading eigenimages, obtained after windowing and flattening, represent high amplitude and correlatable energies such as tube wave noise. The trailing eigenimages represent low amplitude and least correlatable energy such as random background noise. Useful records can be extracted by subtracting those eigenimages dominated by the noise from the total seismic gather.

The optimal removal of the tube waves requires the amplitude balancing of traces and the precise alignment of the tube wave event across the traces before eigen analysis. The procedure is illustrated through application to reversed VSP data acquired in a metalliferous mine. Superior results are obtained in comparison to that of a conventional f-k filter.

Huygens Principle Versus Exploding Reflector – Theoretical and Numerical Aspects

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Abstract

Huygens principle asserts that the wave motion can be described by exploding secondary sources along the wavefront. The envelope of the resulting spheres constitute successive wavefront which progress in time. This fundamental concept illucidates the nature of wave motion for virtually any field such as electromagnetism, optics, acoustics and elastic waves.

We have slightly deviated from Huygens principle, advocating that the explosions take place not along the wavefronts but rather on the reflectors of the medium

where the wave propagates. The magnitude of such explosion is directly proportional to the reflection coefficient of that reflector. Each explosion point emits particles with motion along straight lines and the weighted summation of the particles at each equally discretized reflector point of the receivers yield the wavefields.

If the reflection coefficient vanishes no explosion occurs at this point of time and space, whereas the original explosion at the source continues to have its effect of straight trajectories propagation. Using this concept two and three dimensional wave propagation can be described by multitude of straight trajectiles propagation.

The validity of this exploding reflection straight trajectory modelling by a simple two layer acoustic case is demonstrated. Comparison of the seismogram wave front arrival with that obtained by ray theory shows a good agreement. It is shown for such a simple case that the new modelling technique also yields correct amplitudes.

Suppression of Dipping Noise and Multiples using 3D Pre-stack Time Migration

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Abstract

Conventional imaging of seismic data includes an approximate NMO and DMO prior to velocity analysis. The NMO and DMO imaging steps are approximate only in the sense that an approximate (simple) velocity field is used; the algorithms themselves are accurate. After velocity analysis, NMO is re-applied with the more detailed velocity field derived from the analyses. In the constant velocity case, DMO is almost independent of velocity and the iterative procedure described above plus post-stack migration yields an accurate image. The derived velocities may also be used for multiple suppression. Also, DMO itself may change the stacking velocities of dipping noise in such a way as to suppress the noise.

An improved approach to velocity estimation and imaging is to apply the conventional approximate NMO and DMO and then also to apply an approximate zero-offset time migration to each common offset dataset prior to velocity analysis (3D MOVES). After velocity analysis, the NMO is re-applied and the data stacked. Post stack, either a residual migration or full diffraction plus full time or depth migration is applied. The pre-stack migration is either a constant velocity or single function (v(z) algorithm. This is consistent with the NMO, DMO approach of accurate algorithms in an approximate velocity field. The algorithms are fast and can be inverted post stack to allow depth migration.

The technique has been extensively used in 2D and 3D for imaging primaries and yielding accurate velocities. However, as with DMO, the derived velocity field may also be used for multiple suppression and the migration process may itself attenuate noise and multiples. For example, multiple diffractions may be focused and then attenuated in the stack process or with standard de-multiple methods. Alternatively, dipping noise and multiples may be migrated up dip and be located above the NMO mute pattern at middle and far offsets; the subsequent NMO, mute and stack remove the multiples from the data. In these applications, the migration process should be viewed as a transformation rather than an imaging tool, and the velocity used for migration need not be geologically correct, i.e. the velocity is a transformation parameter which is tuned to obtain the optimum noise suppression. Optimal imaging is obtained with residual, post-stack migration.

A Partial DMO Operator for use with the Stacking Velocity Function

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Abstract

Dip moveout (DMO) processing is frequently used to enhance stacked seismic sections. All DMO methods strictly require that the input data have been normal moveout (NMO) corrected using the true medium velocity rather than the stacking (or RMS) velocity function. Unfortunately this is rarely the case in that most data which are input to DMO have been NMO-corrected according to the stacking velocity, in order to maximise semblance on a CMP gather. Such data are incompatible with the basic DMO assumption. Under such circumstances only a partial DMO process, which produces a parabolic impulse response, should be used rather than a full DMO algorithm, such as that of Hale, which entails an elliptical impulse response. The partial DMO operator accounts for the inaccuracy of the velocity information used in the NMO correction, and leads to superior results.

Key words – Dip moveout, stacking velocity, parabolic impulse response

Computer Representation of Complex 3D Velocity Models

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Abstract

We present a geologic modelling system that can accept the large, irregular surface and volume data typical of exploration studies. The modelling system is based on topological data structures that are used in other areas of computer-aided geometric design. The explicit representation of the model's topology in the data structures is crucial for carrying out the construction and manipulation of the model.

The modelling system provides import functions to build 3D velocity fields from isolated velocity points and to build 3D surfaces from a collection of points on the surface. It also provides model visualisation and editing functions to merge multiple horizons and velocity definitions into a single model. We demonstrate the system capabilities with a complex salt body embedded in layered sediments and with a model of intersecting horizons and faults.

Key words – velocity, model, tesselation, depth migration, ray tracing

Laterally Varying Velocity Estimation

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Abstract

Lateral velocity variations in the subsurface are a departure from the simple horizontally layered model on which the extraction of NMO velocities and interval velocities are based. Significant differences between stacking velocity and interval velocity may result in complex geological areas when the estimation is based on this horizontally layered media assumption. In this paper methods are presented of velocity estimation that are both quick and accurate in the presence of lateral velocity variations.

The method developed here solves an analytic expression by fitting an unknown smooth velocity function, and also determines the reflector depth using only two simple assumptions: (1) that the ray in the laterally varying medium travels along the same path as in the homogeneous medium; and (2) that the subsurface velocity can be approximated by a smoothly varying lateral velocity function. Assumption (1) is shown to introduce only higher order correction terms to the travel time for a given source-receiver pair. It is demonstrated by assumption (2) how the use of a stable, smooth and continuous velocity function across the section results in a better migration velocity than a velocity analysis performed at an isolated CDP location.

By estimating the degree of lateral velocity variation across the seismic section at an early stage in the processing sequence, a decision on whether to use pre- or post-stack migration can be made with reliable velocity information. This method has the advantage of using an analytic expression for the travel time instead of complicated ray tracing by solving differential equations. This makes it useable in an interactive velocity analysis mode. An example using field data from the North West Shelf of Australia shows how the new travel time equation can improve the velocity analysis over a fault zone.

Key words – lateral velocity, pre-stack migration, velocity analysis, North West Shelf.

Velocity Modelling for Depth Migration using Exact-time Migration

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Abstract

Velocity modelling is often done with pre-stack time migration, at least for weak lateral velocity variations. Iterating through the combination of common-offset DMO, zero-offset migration and velocity interpretation can yield a more accurate velocity model for depth migration. However, especially when lateral velocity variations increase, this method is compromised by errors incurred through the use of DMO and, in particular, constant velocity DMO. Consideration of these errors leads to the exact-time migration algorithm which is based on ray tracing through a velocity-depth model. In order to update the velocity-depth model based upon the residual errors after exact-time migration, a theoretical relationship between time migration stacking velocities and velocity-depth functions along image rays has been established.

The velocity building process with exact-time migration consists of taking the exact-time migrated gathers and interpreting stacking velocities. A generalised linear inversion scheme then inverts these velocities and updates the velocity-depth model. This procedure is iterated as required. At any stage the velocity-depth model can be used to create a pre-stack depth migrated image which can be used for interpretation and detailed updating of the model, or as the final image. The updates made by the inversion scheme are smooth and details from interpretation of depth images can be helpful.

Application of the exact-time migration approach to an Australian field data example resulted in obvious and significant velocity model improvements in each of two iterations. The effect of these improvements on pre-stack depth migrated images verify the ability of the exact-time migration algorithm as a velocity modelling option by improving the seismic image below a high velocity buried channel.

Magnetic Mineralogy of the Black Hill Norite and its Aeromagnetic and Palaeomagnetic Implications

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Abstract

The Black Hill Norite is a mafic intrusion which formed around 487 Ma ago. It intruded sediments of the Kanmantoo Group and Adelaide Supergroup which were deformed and metamorphosed during the Delamerian Orogeny. The unusual aeromagnetic anomaly caused by the norite gave the first indication of the presence of natural remanent magnetisation (NRM) totally different

from the present field direction.

The Black Hill Norite exhibits a strong remanent magnetisation (declination = 221.2 degrees, inclination =7.6 degrees, and intensity = 4.9 A/m) indicating that it was intruded at equatorial latitudes. The remanence is probably thermal in origin. The known amount of coarse-grained multi-domain magnetite present is sufficient to explain the high magnetic susceptibility. The stable and intense remanence is carried by fine-grained single-domain pure magnetite.

Demagnetisation and hysteresis studies suggests the presence of two populations of single-domain magnetite with nearly parallel but consistently different remanent directions. Preliminary electron probe work has confirmed the presence of randomly oriented fine-grained magnetite in the rock matrix as well as magnetite exsolved out of pyroxenes and feldspars. The bimodal NRM direction can be explained as due to secular variation associated with slightly different times of NRM acquisition or due to a shape anisotropy (caused by the orientations of the exsolved single-domain grains being confined to particular crystallographic directions within the host silicates, which in turn, show a preferential orientation, possibly indicating magma flow directions).

The 3D analytic signal map and the reduced to the pole map, both made from calculations on the total magnetic intensity data, are similar, thus demonstrating the dual application of the analytic signal in the interpretation of low latitude surveys and the interpretation of magnetic sources suspected of carrying a strong, but unknown, remanent component.

The Black Hill Norite is an excellent palaeomagnetic recorder. It provides evidence for the Early Ordovician palaeomagnetic pole position for Australia (interpreted as being near the African Bight in a standard Gondwana reconstruction) which was previously in doubt because of the absence of reliable data. The success of this study illustrates how aeromagnetic maps, by indicating the presence of remanently magnetised rock units, can be constructively used to select sampling sites for NRM studies.

Textural Filtering of Aeromagnetic Data

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Abstract

The qualitative interpretation of aeromagnetic data relies on amplitude and textural variations within the data to map different geological units. An interpretation is commonly based on a suite of images where the data have been subjected to various filtering operations designed to highlight different characteristics. Most of these filtering operations respond primarily to amplitude variations within the data. An alternative approach is to use filters that respond to variations in the texture, that is spatial variation of amplitude. There are a number of different methods of filtering in this manner including simple statistical transforms, methods based on grey-level co-occurrence matrices, methods using fractal measures and a method based on the textural spectrum. These methods have mainly been developed for use in the medical and cartographic fields. Preliminary trials suggest such filters can extract additional structural and stratigraphic information from aeromagnetic data which complements that derived from the standard amplitude-based filtering operations.

Geophysics of the Orlando Au-Cu-Bi Mine Area

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Abstract

The Orlando Au-Cu-Bi deposit(s) occurs within the Lower Proterozoic Warramunga Group turbiditic siltstones, shales and greywackes, which are host to the majority of ironstone related Au-Cu-Bi mineral deposits in the Tennant Creek Goldfield.

The Au-Cu-Bi mineralisation is associated with the Orlando Shear and magnetite-haematite ironstone bodies within an envelope of chloritic sediments.

The presence of sulphides (chalcopyrite & pyrite) and magnetite lends the prospect to the application of geophysical exploration techniques, in particular Induced Polarisation (IP) and ground Magnetics. Both these methods were successful in mapping mineralisation and structure at Orlando.

The Orlando prospect area was also the focus of a technical feasibility trial of the SAM (Sub-Audio Magnetic) method. The method yields high resolution Magnetics and Total Field Magnetometric Resistivity (TFMMR). The TFMMR data also successfully mapped mineralisation and structure evident in the conventional electrical data. Furthermore, the TFMMR data resolved finer detail which correlates with other geological information not evident in the IP data.

Interpreting Aeromagnetic Data in Areas of Limited Outcrop: An Example from the Arunta Block, Northern Territory

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Abstract

Aeromagnetic data from the highly structured and metamorphosed geology of the Highland Rocks 1:250 000 map sheet of the Arunta Block of the Northern Territory is virtually impossible to interpret in its original form by virtue of complexity due to the inclination of the Earth's magnetic field, interference between anomalies, regional effects and an extreme range of anomaly amplitudes. Only by employing a comprehensive suite of enhancement techniques is it possible to produce an interpreted geological map of the area. Although virtually no geological control exists for the area it has been possible delineate lithologic units and a complex system of faults in which thrusting appears to predominate.

Key words – magnetic interpretation, Arunta Block, Highland Rocks.

Interpretation and Field Investigation of Some Aeromagnetic Anomalies from the Abminga Area, South Australia

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Abstract

Aeromagnetic surveying carried out in the Abminga area by Mines and Energy South Australia (MESA) and published in 1993 identified several groups of isolated magnetic anomalies which have a strong prima facie resemblance to kimberlite or lamproite diatreme fields. Aeromagnetic anomalies produced by diatremes are characterised as being generally of low amplitude, isolated, compact, di-polar, of short strike length and indicative of a shallow source.

This paper compares data flown for diamond explorer Caldera Resources NL at 100 metre line spacing with the published 400 metre line spaced data. Modelling of several of the anomalies using an inversion algorithm gives very good fits to shallow pipe-like bodies with appreciable depth extent. Conventional field exploration techniques such as loaming have not been successful but floaters of ultramafic rocks collected at 3 anomaly sites have been petrographically identified as extremely weathered kimberlites. Chromite grains recovered from these carry up to 59% Cr_2O_3. Diamonds have not yet been recovered but active exploration is in progress.

It is concluded that while most of the magnetic anomalies were successfully identified from the 400 metre line spaced data, useful modelling can only be done using more detailed data. Although positive identification of the source of these magnetic anomalies is still awaited they constitute some very intriguing exploration targets.

Key words – Aeromagnetic anomalies, diamond exploration, magnetic modelling, kimberlite rocks

Three dimensional structural mapping applications of In-loop TEM at the Maroochydore Copper Deposit, WA

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Abstract

The sediment hosted Maroochydore copper deposit is located in the Rudall River area of Western Australia. Discovered by Esso in 1984, a number of companies including Barrack Mines and more recently M.I.M., have explored the area in an attempt to identify an economic resource. The deposit is hosted in a carbonaceous siltstone within the Broadhurst Formation, which is overlain by 50 to 100m of Permian sediments. The mineralised zone is associated with fine-grained bedded pyrite and a hanging wall sulphide zone containing coarse-grained pyrite and pyrrhotite veins lies some 50m above it. The mineralised zone appears to be layer parallel and dips at a shallow angle to the east. This part of the Broadhurst Formation has been subject to folding and faulting, and has been intruded by gabbroic sills.

Exploration approaches have incorporated a number of geophysical techniques including airborne and ground magnetics and detailed gravity. During the 1992 and 93 field seasons, M.I.M. Exploration conducted a program of In-loop Sirotem measurements. As an alternative to profile analysis, these data were displayed as apparent depth versus conductivity sections using the "Spiker" algorithm described by Smith and Buselli (1991). To aid in the interpretation of the TEM, magnetic susceptibility and conductivity measurements were taken on core from a number of holes and down-hole TEM surveys were also undertaken.

In the absence of outcrop in this sand covered region, these sections achieved remarkable agreement with the drilling results and core physical property measurements. They were also able to resolve the mineralised zone, and hangingwall sulphide zone as separate conductive horizons. There was good agreement between depths estimated from the one-dimensional "Spiker" inversion, parametric inversion using the GRENDL algorithm, and actual drilling results. Gabbroic sills could be recognised as resistive zones and it was possible to interpret significant subsurface folds and faults and to provide additional drill targets.

In this particular geological environment comprising conductive and resistive layers with shallow dips, the one dimensional inversion procedure provided a simple method of portraying TEM data in a form which could be more easily assimilated. The data presented in this form was nevertheless sufficiently quantitative to be used directly as an aid in visualising the subsurface geology.

Deep DHEM Exploration at the Isa Mine – The Anhydrite Prospect

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Abstract

The drillhole electromagnetic (DHEM) technique is routinely used to help explore for new orebodies within the Mt Isa-Hilton corridor. The targets are often deep, sometimes in excess of 2000m below the surface and are hosted by conductive carbonaceous shales. The target zones also contain several conductive faults and usually one or more bands of massive pyrite. The Anhydrite Prospect is an example of such a target.

A zone of anhydrite-dolomite-barite carrying primary copper and lead mineralisation was intersected by underground drilling to the north west of the Isa Mines zinc/lead orebodies. Further underground and surface drilling was undertaken to assess the zones prospectivity. The main drilling program consisted of a number of deep wedges (to 2641m) from a parent hole. DHEM logging of this hole using UTEM recorded two responses where amplitudes were still increasing to the latest times. The source of these responses were interpreted to be off-hole, lying above the drillhole with conductances in the order

of 3000 S. Analysis of the decays indicated that the deeper anomaly was the more conductive. A further wedge was drilled and this successfully intersected the two interpreted conductors. The shallower conductor was shown to be due to fine grained pyrite with minor pyrrhotite and the lower to be sphalerite+galena+pyrite mineralisation including one interval of 15.2m @ 212 g/t Ag, 10.9% Pb and 11% Zn (downhole width). Logging of this second hole with the Crone system confirmed the locations of the responses but much lower conductances were used in the interpretation.

Physical property measurements have indicated that the fine grained pyrite is more conductive than the base metal intersection. However the latter has a greater thickness, which gives it a larger conductance.

A Magnetotelluric Traverse Across the Adelaide Geosyncline

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Abstract

This paper reports on the results of the first detailed magnetotelluric experiments across the Adelaide Geosyncline. The eastern end of the traverse is located on the Stuart Shelf, from where it then traverses the Adelaide Geosyncline and ends on the western side of the Murray Basin. The five components of electromagnetic time variation data at 15 sites were collected by the EMI MT-1 system. Regional strike direction (south – north) was first determined and found to be consistent with the strike of geological trends. The dimensionality indices indicated that in this specific coordinate system the MT data could be described as two-dimensional. We analyse, model, and interpret the data using several modern processing and inversion techniques (i.e. Occam2D inversion, 2D rapid relaxation inversion and 2D finite element modelling). Thus an electrical conductivity structure model across the Adelaide Geosyncline has been determined. The model shows: (1) that a conductive sequence of 10–200 ohm-m which has depths from a few hundred metres to about 20 km in the Adelaide Geosyncline may represent the sediments, (2) an resistive body with with a resistivity of >1000 ohm-m found in the Stuart Shelf at depths from 100 meters to 10 km may be interpreted as volcanic rock, (3) the old basement underlying the sediments was modelled to have a resistivity of 600 ohm-m , (4) There are two extremely conductive structures (1 ohm-m) within the interpreted sediments. One is located near the Torrens Hinge Zone with a maximum depth of 5 km. This vertical structure appears to intersect the easterly dipping sediments, and to be along a direct continuation of the Spencer Gulf graben structure. The second one is located within the thick pile of sediments of the Adelaide Geosyncline. This extremely conductive zone appears to extend to the lower crust.

Key words – Adelaide Geosyncline, magnetotelluric, dimensionality, 2D inversion and modelling.

A Comparison of Airborne and Ground Electromagnetic Responses

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Abstract

In this paper, we perform a two step analysis of electromagnetic data obtained by different EM systems used in mineral exploration and shallow sounding. First we investigate the parameter resolution of each system with synthetic data. Second we compared inverted conductivity structures using field data collected along coincident profiles. Systems used on the ground were PROTEM 47, SIROTEM III and UTEM III, supplemented by a DC-resistivity profile. Airborne data were collected with the fixed-wing towed-bird SALTMAP and the helicopter rigid-boom DIGHEM V system. These EM systems are quite distinct, having different measuring domains, a variety of transmitter waveforms, basefrequencies, measured responses, loop sizes and geometries.

Before interpreting the collected data, the sensitivity of each of the systems to the parameters of a typical regolith conductivity scenario was calculated. For this purpose synthetic data were inverted using a singular value decomposition (SVD) algorithm. The by-products of a SVD inversion, namely the eigenvector matrix and eigenvalues of the inverted parameters were used to calculate the uncertainty region in parameter space corresponding to a data uncertainty (i.e. noise) in data space. The calculation of uncertainty volumes not only allows us to evaluate the relative sensitivity of an instrument to a set of conductivity scenarios but also allows a direct comparison of sensitivities between different EM systems.

Next, geoelectric sections were derived from collected data using layered earth inversions. In addition to the 1D inversions the results of a number of alternative algorithms are presented. Because of the differing response of the applied EM systems to IP effects, current channelling and geometry, and due to their different depth penetrations, derived geoelectric sections of different EM systems, particularly in 2D or 3D terrain, may be expected to differ.

SALTMAP, DIGHEM, PROTEM and DC-resistivity profiles have been collected across a shear zone and the geoelectric sections derived from all four systems show overall agreement in the modelled conductivity structure. Differences are interpreted to be mainly due to their different geometries. SALTMAP, SIROTEM, UTEM and PROTEM data were collected across an anomaly indicating deep seated conductors. The presence of deep conductors is indicated by all EM systems and by all data interpretation algorithms applied in this study.

An Application of the GEOTEM Airborne Electromagnetic Method to the Study of a Salinity Affected Area in Eastern NSW.

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Abstract

This study, undertaken in a farming district in eastern NSW, is aimed at evaluating the feasibility of using airborne geophysical methods to study and define the vertical and lateral variations of soils affected by waterlogging and salinity. The study was further aimed at testing the resolution of the airborne EM system in an area of known salinity and comparing the airborne and ground derived conductivity measurements. This study is unique in the innovative use of airborne electromagnetic data to generate and display images of conductivity at precise depths beneath the surface profile. A Conductivity Depth Transform (CDT) has been implemented for display of both vertical and horizontal conductivity colour images. The horizontal conductivity images represent 'depth slices' which provide a unique view of the lateral variations of groundwater conductivity at progressive depths beneath the surface. The vertical conductivity images represent conductivity-depth cross-sections which can be related directly to the depth slices.

The results of the study show excellent correlation between airborne and ground measured conductivities. The CDT depth slices also indicate the presence of previously unknown conductive (saline) groundwater at depth and show preferred groundwater directions in three dimensions, which represent a potentially serious agricultural problem if the prevailing groundwater level continues to rise. The method used for airborne EM surveying has proved to offer a cost effective predictive tool for the identification of emerging salinity problems.

This paper also addresses the issues that are being faced by land management groups seriously addressing the problems and treatment of dryland salinity in the 1990s. It is now clear that airborne and ground geophysical technology can offer a valuable monitoring and management mechanism for land use planners and administrators.

The Use of Dighem in Conductive Environments

Stephen Kilty

Geoterrex Pty Ltd.

Abstract

The Dighem V system became the standard operating variant of the Dighem HEM system in 1994. The system contains 2 vertical coaxial coil pairs operating at 900 hz and 5500 hz and three horizontal coplanar coil pairs operating at 450 hz, 7200 hz and 56,000 hz. A Dighem system in this configuration has been based in Australia since May 1994 where it has been utilised for both mineral exploration and for groundwater mapping.

The system is used both for direct detection of conductive targets (ie kimberlite pipes, massive sulphides, porphyry copper, alteration zones...) and for geological mapping (contacts,fault zones, magnetite content, lithology...). The Dighem system is always flown in conjunction with a caesium magnetometer and can also be operated with either a four channel or a multi channel spectrometer.

Specific examples of the Dighem system are a combined Dighem/Magnetic/Radiometric survey for structural mapping in Africa, conductivity depth sections over a porphyry copper deposit in South West United States, and the Dighem system response to the Seppelt kimberlite pipe located in Western Australia.

An Algorithm for Reduction to the Pole that works at all Magnetic Latitudes

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Abstract

Classical fast Fourier transformation methods for reduction to the pole cease to produce realistic results at low magnetic inclinations because the factor by which the frequency domain field representation must be multiplied becomes infinitely large due to the denominator of this term approaching zero. The problems of the Fourier transformation method however can be avoided by performing the transformation in the space domain by convolving the field with a set of filter coefficients which perform the desired transformation. Such filter coefficients may be calculated using the Wiener design principle which produces filter coefficients for transformations such that a known input is transformed to a desired output in a manner that the mean square error between an actual output and a desired output is minimised.

De-Warping the Composite Aeromagnetic Anomaly Map of Australia using Control Traverses and Base Stations

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Abstract

The composite aeromagnetic anomaly map of Australia, like similar maps of other continent-size regions, contains spurious trends, warps, and baselevel shifts. These arise from the arbitrary nature of aeromagnetic data processing methods and edge matching of disparate surveys. Corrections have been

applied to the Australian map based on long aeromagnetic control traverses flown around the country in January and February 1990. The control traverses were timed to coincide with a continent-wide magnetometer array study, thus enabling accurate corrections to be made for transient (diurnal) variations of the geomagnetic field. Magnetic observatory data spanning several months each side of the traverse interval were used to correct for long-term displacement of the total field from its normal value. The transient contribution to total field was modelled as a set of one-minute time slices over the whole country, and then used to reduced the control-traverse data to normal values. Absolute anomaly values were generated along traverses by subtraction of IGRF 1990, then compared with corresponding anomalies given by the uncorrected composite map. The resulting anomaly difference values were interpolated and extrapolated over the whole country and used to relevel the composite magnetic anomaly map. The corrections applied range typically between -200 and +200 nT, with a maximum of about +400 nT in the far western region and a minimum of about -450 nT in South Australia. These corrections are smaller than expected, but are still large compared with the amplitude of long-wavelength magnetic anomalies.

A Global Perspective on Developments in Electromagnetic Prospecting and Research

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Abstract

Electromagnetic prospecting is one of the basic methods of geophysical exploration. It is based on the study of the electromagnetic field propagation in the earth and determining the electromagnetic parameters of the earth, containing unique information about petrophysical properties, lithological characteristic, thermodynamic and phase status of the rocks in the earth's interior. During the twentieth century electrical prospecting methods grew from simple resistivity methods to complicated modern technologies based on a complex array of electromagnetic soundings with natural and controlled sources. Not only the methods and equipment have changed, but our ideas about the models of geoelectrical cross sections used for interpretation have modified tremendously. For many years the basic model for interpretation was the one dimensional model of layered earth. However, in recent years, geophysicists have more and more often used two dimensional and even three dimensional models for interpretation. This required developing corresponding mathematical methods of interpretation, based on the modern achievements of electromagnetic theory and numerical modelling and inversion. Using natural and artificial sources, the electromagnetic methods in geophysics have been proven to be one of the major tools for surveying underground structures. From electromagnetic measurements conducted on the earth's surface, in the air, or in wells, we are in principle able to map the earth from surface units to the mantle. Thus electromagnetic methods have found and will continue to find wide use in geological mapping, mineral and oil prospecting, tectonic studies, earthquake studies, and environmental assessment and monitoring. The further perspective in electromagnetic prospecting methods lies in the development of multitransmitter and multireceiver methods with the array of observation system analogous to the seismic data acquisition system. The electromagnetic investigations will be conducted on the surface of the land and in the wells, in the air and on the sea bottom. The main efforts in the development of electromagnetic data interpretation in the future will be concentrated in the following three directions: 1) fast and accurate multidimensional modelling; 2) rapid imaging; and 3) full scale multidimensional inversion. The development of electromagnetic methods in each of these directions will require significant efforts by researchers so fortunately a lot of work and many discoveries lie ahead.

Estimation of Limestone Reservoir Porosity by Seismic Attribute and Avo Analysis

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Abstract

Parigi Formation is a group of sedimentary rocks deposited during the Neogen time transgression in Northwest Java Basin. Its lithology comprises mostly limestone biostrome with 10–50m thick, bioherm of 300-500 m thick. It was deposited in the shallow marine environment during the Late Miocene. Parigi Formation is one of the most important gas reservoirs in Northwest Java Basin.

In the limestone reservoir, the hydrocarbons were trapped within vughs of the formation. The vughy or porosity in the Parigi Formation is studied by seismic attribute and AVO analysis. In this formation the top of porous zone could be first identified by the reflection strength and instantaneous frequency from the seismic attribute analysis. After the spatial location of this top has been identified, the value of porosity is estimated by using AVO analysis. In Shueys AVO equation, the reflection coefficient as a function of angle of incidence depends on P-wave velocity, density and Poissons ratio. The Marquardt iterative algorithm was used to find the Poissons ratio which is directly related to the S-wave velocity.

For carbonate reservoir, an empirical relationship exist between the porosity and the Young modulus. Since the Young modulus is related to the density, the P-wave velocity, the S-wave velocity and the Poissons ratio, then the porosity of the reservoir can be computed.

The application of these two method to one structure in the Parigi Formation shows a zone of high reflection strength and low instantaneous frequency in the reef limestone reservoir. Porosity calculation in that zone by AVO analysis give a value of porosity of 36.6% with a Poissons ratio 0.266. These results compared favourable with borehole data in the location (20–38% porosity). The method has given a satisfactory result in estimating the porosity and delineating its lateral direction.

Key words – seismic attribute, AVO, limestone reservoir, porosity, Northwest Java Basin

Using Variations in Amplitude with Offset and Midpoint to Constrain Tomographic Inversion

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Abstract

Seismic amplitudes are shown to provide useful information about rapid lateral velocity changes. Inversion of seismic amplitude data is used to constrain conventional traveltime tomographic inversion, producing an improved velocity field. Amplitude measurements recorded over a time gate, and normalised for each offset, can be assumed to be influenced solely by absorption in the overlying rocks. A normalised image of seismic velocity can be produced by using this simplification to invert seismic amplitudes. Lateral velocity gradients calculated from the amplitude inversion are used as a filter to constrain the traveltime solution. This approach results in sharper resolution of lateral velocity variations. This technique is applied to a model of a surface reef from the Northwest Shelf of Australia.

Key words – amplitude inversion, traveltime inversion, tomography, lateral velocity variations, seismic velocity

Evolution and Structuring of the Offshore Otway Basin, Victoria as Delineated by Aeromagnetic Data

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Abstract

A large portion of the western offshore Victorian portion of the Otway Basin appears to have originally been underlain by an extensive horizontal basic magnetic sheet emplaced during the initial stages of basin formation. Subsequent basin extension along transfer faults trending at 210 degrees has fractured this sheet, and evidence of the transfer fault fracture system is given by the present day outlines of the magnetic anomalies arising from the fragments of the sheet. The transfer fault system is further indicated by linear magnetic anomalies within the sedimentary section due to magnetic material accumulated in the fault planes. Gravity and seismic data support the transfer fault model which can be used to explain features of the depositional history and structural development of the area.

3D Seismic Surveying in the Otway Basin

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Abstract

The Tilbooroo seismic survey, recorded in early 1993, is the first 3D survey acquired in the Otway Basin. It was preceded by an extensive study to optimise acquisition parameters in a cost-effective manner. This survey followed-up the minor oil recovery from fractured basement intersected by the exploration well Sawpit-1 and forms part of an integrated geological and geophysical analysis of the structural history of the Sawpit area. Evaluation of this fracture play requires accurate prediction of the orientation and intensity of the basement fault and fracture pattern.

The 3D data, sampled at a spacing of 15m inline by 30 m crossline, are acquired over a 44 km^2 area. Land use is mainly pasture land, but also extends into the Coonawarra vineyards. There were numerous obstacles – swamps, fences, buildings, no-access areas, vineyards – that challenged ingenuity in the planning, acquisition and processing stages of the survey. The 3D seismic data are acquired at less than one quarter of the fold and twice the group interval of 2D data, yet have a vastly superior signal-to-noise ratio. Confident interpretation of the basement fault pattern, combined with structural analysis of fault attributes and knowledge of the present day stress field, indicates the basement fracture play would be best evaluated by a deviated well with a southwest azimuth.

AVO as an Exploration Tool in the Penola Trough

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Abstract

Amplitude-versus-offset (AVO) analysis, in conjunction with seismic inversion, has established itself as an exploration tool for the detection and mapping of gas reservoirs in the Penola Trough in the onshore Otway Basin.

The Penola Trough is a Late Jurassic to Early Cretaceous half graben filled mainly with synrift sediments of the Crayfish Group. In 1988, Katnook 1 discovered gas in the overlying basal Eumeralla Formation but all subsequent commercial discoveries have been within the Crayfish Group. AVO performed on single gather records correctly predicted the discovery of gas within the Crayfish Group in the Pretty Hill Sandstone in the Katnook 2 well. It also predicted the discovery of gas in the Ladbroke Grove 1 well, although the column height was much less than prognosed and the gas contained 54% carbon dioxide.

Seismic recorded since 1990 has used much longer spread lengths with more geophone groups, resulting in better quality data which are more suitable for AVO analysis. Two lines were recorded in 1993 over the Katnook Field to help mature an appraisal well location. These lines tied the three Katnook wells, but on several interfaces only a small AVO effect was predicted from modelling using the well data, probably due to the poor quality well logs. The seismic AVO analysis, however, using all gather records, produced clear anomalies at both reservoir levels which approximately matched the predicted extent of the gas in the field from structural mapping. The subsequent Katnook 4 appraisal well confirmed the presence of gas at these levels, but unfortunately the reservoir was too tight at one level and too thin at the other to be commercial.

AVO and inversion were also run on three lines over the Haselgrove Gas Field prior to its discovery in 1994. AVO anomalies are seen at both Katnook reservoir levels, but the strong basal Eumeralla Formation anomaly is too widespread and consistent to indicate gas and is interpreted to be due to a clean water saturated sand. The anomalies at the top Pretty Hill Sandstone level are more consistent with structure although they extend below mapped closure. Subsequent reprocessing using pre-stack migration prior to AVO analysis produced anomalies closely matching the actual gas column height, and also within the zone of strong seismic amplitudes at this level. One of these lines extended over Wynn 1 and shows a very strong AVO anomaly in a stratigraphically deeper sandstone sequence which tested both gas and oil.

AVO anomalies in the area appear to be caused by both clean water filled sands and the presence of hydrocarbons. Seismic inversion can help the prediction of sand quality variations, and the mapped extent of structural closure can be used to identify those AVO anomalies more likely to be related to hydrocarbons. Pre-stack time migration prior to AVO processing is essential in most cases. Unfortunately, AVO anomalies also occur in reservoirs with low gas saturations or low reservoir permeability. Despite these drawbacks AVO with inversion has proven to be a valuable exploration tool in the Penola Trough. No gas discoveries have yet been made which are not associated with an AVO anomaly.

Key words – AVO, inversion, Penola Trough, Katnook, Haselgrove, Wynn, Otway Basin.

Lake Hope 3D – A Case Study

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Abstract

In 1992, a 138 km^2 3D seismic survey was recorded over the central eastern section of the Lake Hope Block within the South Australian PELs 5 and 6. The 3D data provided a marked increase in data quality and interpretability over the previously recorded 2D seismic data. The survey was recorded over the Sturt/Sturt East, Tantanna, Taloola and Malgoona Fields, and had specific exploration and development objectives.

The production history of the Cretaceous and Jurassic reservoirs of the Tantanna Field indicated that the recovery factors for some wells were anomalously high. Potential was recognised both in the Tantanna and Taloola Fields for pool extensions and unswept reserves behind some form of permeability barriers. The 3D data has allowed a complex fault pattern to be mapped over these fields. In the Sturt/Sturt East Fields, the objectives were to better define the stratigraphic edges of the Jurassic Poolowanna and Birkhead Formation reservoirs. In the Malgoona Field, the 3D data has more clearly defined the trapping geometry, which is a three way dip closure against a basement fault. The highly sampled amplitude data from the 3D may help describe the porosity distribution of the reservoir, a thin sand within the Late Carboniferous Merrimelia Formation. After drilling Hollows 1, an anticline, the remaining exploration potential within the 3D is now confined to stratigraphic, and lowside fault plays. The 3D data will allow these plays to be explored with reasonable risk.

The 3D seismic dataset has provided a clearer understanding of the structural style in both the Cretaceous and pre Jurassic sections. This will lead to direct economic benefit through the better definition of reservoir geometries. The depth conversion has been greatly improved through delineation of the high velocity calcite cemented sandstones in the Jurassic section, and the increased stability of the 3D velocity model.

The Lake Hope 3D seismic project has demonstrated that land 3D seismic data can be used to revitalise the exploration and development potential of a mature oil province.

Key words – Eromanga Basin, Cooper Basin, Lake Hope Block, 3D Seismic, Depth Conversion, Calcite, Tantanna, Taloola, Sturt, Malgoona.

The Integrated Use of 3D Seismic Data, Well Information and Seismic Forward Modelling – Lake Hope Field Area

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Abstract

The Lake Hope 3D survey was acquired in 1992 and covers five producing fields in the Lake Hope Block of the South Australian sector of the Cooper/Eromanga Basins. A total of 38 wells have been drilled within the survey limits, of which 24 are currently producing from eight different reservoir levels. The bulk of the production comes from the Early Cretaceous/Namur Sandstone and Jurassic Birkhead Formation, Hutton Sandstone and Poolowanna Formation. The reservoirs occur between 1.2 and 1.5 seconds two way time (1300–1800 m below MSL).

The excellent quality of the Lake Hope 3D seismic data and the large number of wells in the area allowed extensive use of seismic forward modelling. The object was to better understand the quality and distribution of the various reservoirs in the area.

Integration of well data, seismic amplitude information and production history made it possible to define the presence and extent of producing Birkhead Formation sands. Two dimensional forward modelling was utilised to interactively alter well-logs and observe the corresponding change in seismic response. By using these procedures and horizon slices from the 3D seismic

volume it was possible to prognose additional areas where similar sands are likely to be present.

The Hutton Sandstone reservoir contains over one quarter of the oil within the Lake Hope Fields and is also a very productive reservoir elsewhere in the Eromanga Basin. The Birkhead Formation is the top seal to this unit and the Birkhead/Hutton Interface marks the change from the high energy braided stream environment of the Hutton Sandstone to the lacustrine/low energy fluvial environment of the Birkhead Formation. This interface varies from an abrupt change to a transitional change over a 10 metre interval. Reservoir quality and pay thickness are heavily dependent on the nature of this transition. Well information was correlated with observed seismic response to establish the character of the Birkhead/Hutton Interface within the area of the 3D seismic survey.

The above studies demonstrate the importance of integrating geological information, well production history and observed variations in seismic response to fully utilise 3D seismic data.

Key words – Eromanga Basin, Lake Hope Block, Birkhead Formation, Hutton Sandstone, 3D seismic, seismic forward modelling.

Regional Depth-conversion of Mapped Seismic Two-way-times in the Cooper-Eromanga Basins

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Abstract

Mapped seismic two-way-times to the top of the Cadna-owie and Toolachee Formations in part of Petroleum Exploration Licences 5 and 6 of the Cooper-Eromanga Basins were depth-converted using the interval velocity and velocity anomaly methods. Two types of input velocity data were used for each depth-conversion method: (i) based on mapped seismic isochrons combined with thicknesses at well locations, and (ii) based on drift-corrected checkshot/sonic log data and thicknesses at well locations.

The sequence was split into three layers for the depth conversion: surface to top of the Mackunda Formation (layer 1), top of the Mackunda Formation to top of the Cadna-owie Formation (layer 2) and top of the Cadna-owie Formation to top of the Toolachee Formation (layer 3). The interval velocity method used constant layer interval velocities as predicted by interval velocity maps. In the velocity anomaly method, regional velocity/depth functions were fitted to the input layer velocities. Anomalies with respect to these regional functions were then mapped and used in conjunction with the regional functions in order to undertake the depth-conversion.

The accuracy of the depth-conversions was assessed with reference to test wells not used in the determination of the input velocity models. The 95.5% confidence limits of the error in depth-conversion for the velocity anomaly method are 7-16% closer to zero than for the interval velocity method at the top of the Cadna-owie Formation, and 21-41% closer to zero at the top of the Toolachee Formation. Hence velocity anomaly can be more accurately mapped and predicted away from the input wells than 'raw' interval velocity. There is no significant difference between the errors in depth-conversion based on seismic isochron and checkshot/sonic log input velocities. Given that the former are more widely available, and more easily determined than the latter, their use is preferred.

Topography Imaging for Structural Mapping of Basins – Otway Basin Case History

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Abstract

Topography and bathymetry, the shape of the earth's geological surface, is the simplest measurable geophysical property of the earth. In hydrocarbon exploration, much effort is expended in mapping the two-way travel-time structural relief and relationships of subsurface unconformities. The earth's surface, which is the current day unconformity, is commonly ignored, buried in the seismic mute zone or lost above the seismic datum. Small scale structural relief on the present day unconformity surface, is often related to deeper structure, either directly or by reactivation or by differential settlement.

Sources of digital elevation data for gridding, detailed mapping and imaging of topography and bathymetry, include topographic contour data, benchmarks, boreholes, cultural surveys, gravity stations, seismic traverses and digital terrain derived from airborne geophysics. In a sedimentary basin the surface unconformity can often have the greatest data coverage. Further, surface relief can be measured with much greater precision and lower cost than can be achieved with subsurface seismic mapping of unconformities.

The Otway Basin is structurally complex, with seismic data quality problems in many areas that inhibit subsurface mapping of structure. Structure of the basin is related to Palaeozoic basement structure, rifting in the Early Cretaceous, continental breakup and drifting in the Late Cretaceous and Tertiary, and various periods of uplift, compression and inversion which reactivated older structures and also created new structural trends.

Image processing and digital terrain modelling of gravity, magnetics, seismic horizon and all available surface topography data for the entire onshore and parts of the offshore Otway Basin and surrounding basement, shows that many structural phases and controls are often reflected in the surface topography of the basin and surrounding basement. Structures not mapped by other geophysical methods can be seen in the subtle detail revealed by modern imaging and visualisation.

The Otway Basin case history discusses the effect of previously unmapped major Palaeozoic structures on the early Cretaceous rifting architecture of the basin and illustrates the advantages and limitations of use of imaging of surface topography, in conjunction with seismic subsurface mapping gravity and magnetics, as a routine hydrocarbon exploration technique for regional and prospect structural mapping in sedimentary basins.

Tectonic Development of the Eastern Officer Basin, Central Australia

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Abstract:

Interactive interpretation of some 3000km of seismic section, combined with the integration of well, potential field, subcrop and surface geological data with satellite imagery have shown that the structure of this prospective basin is controlled by compressive tectonics.

Four stages of basin development between the late Proterozic and Carboniferous can be identified on calibrated seismic sections from the eastern Officer Basin.

Recent work suggests that the Officer Basin was originally part of an extensional Centralian Superbasin which included the present Amadeus, Ngalia, Savory and Georgina Basins. Justification for this hypothesis comes from the broadly similar stratigraphy in each of these basins. A model is proposed which explains the deformation of the Centralian Superbasin into those basins recognised today, separated by basement uplifted to shallow depth and exposure by compression. The main deformation is believed to have commenced at or around the Proterozoic-Cambrian boundary, with a substantial pulse at the end of the Cambrian. As a result, the original broad platform depositional system was deformed into a series of foreland-style basins. Stacked thrust sheets of late Proterozic to Cambrian sediments, containing the best known source rocks in the basin, illustrate the intensity of the compressive deformation. Interbedded reservoir units have been folded to form traps suitable for hydrocarbon retention.

This model will enhance the probability of prospect generation and the search for commercial hydrocarbons.

Key words – Officer Basin, Petermann Ranges Orogeny, Delamerian Orogeny, Alice Springs Orogeny, compressive tectonism. Tectonic development of the eastern Officer Basin, central Australia

NABRE (North Australian Basins Resource Evaluation) Phase 1

NABRE Project Team

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Abstract

The North Australian Basins Resource Evaluation project (NABRE) is a major new National Geosciences Mapping Accord cooperative venture between the Commonwealth Government (AGSO), the Northern Territory and Queensland governments (NTGS and GSQ), and collaborating resource companies and universities. The project consists of 3 concurrent phases of investigation: (1) identification of principal basement blocks and bounding structures and establishment of a tectonostratigraphic framework for the basement to the North Australian Mesoproterozoic sedimentary basins; (2) development and critical evaluation of the structural and stratigraphic framework of the Mesoproterozoic basins, using modern sequence stratigraphic principles; and (3) consideration of the timing of fluid migration and fluid pathway evolution at the 'play' scale.

Phase 1 of NABRE has focussed on determining: (1) the size, shape and distribution of basement blocks and bounding structures; (2) the nature, kinematics and evolution of tectonic elements in the basement; (3) the relative and absolute timing of tectonic events recorded in the basement; and (4) the influence of basement architecture on basin evolution. This has largely involved the compilation of numerous regional data sets (such as gravity, airborne magnetics, MSS and other satellite data), the development of a series of data bases (such as inter/intraplate tectonic events, isotopic dates, province/terrane characteristics) and their integrated interpretation.

Regional potential field data sets are essential for understanding large-scale structural architecture and its development, both within basement and in overlying basins, and associated resource accumulations. The interpretation of gravity and airborne magnetics imagery (in hard copy or interactively), when correlated with mapped geology, allows extraction of critical geometrical and kinematic data and an understanding of regional geodynamic evolution. When this typically hard-rock, mineral industry approach to geological analysis and exploration is combined with petroleum industry basin analysis methods, sophisticated basin models can be generated which lead to a vastly improved predictive framework for resource exploration.

3D Reflector Imaging of In-mine High Frequency Crosshole Seismic Data

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Abstract

A combined crosswell and VSP seismic reflection experiment was carried out in a metalliferous mine in an attempt to image in three-dimensions the stope tunnels and residual ore. The experiment provided initial field testing of a newly designed hardware – software system for high resolution in-mine seismic work.

High frequency (1–3 kHz) seismic signals were recorded on both hydrophones and triaxial geophones from detonator explosions. The major form of noise contamination was tube-waves. The data were migrated in 3D by forming a partially coherent sum of the cross-products (semblance) between the components of the particle motion vector and the components of the wave vector, over all receivers and all sources, for every grid point in the investigated volume. Migration maps with the PP mode using the crosshole data were the most successful. The images correlated remarkably well with the known geology and mineworkings.

Key words – Crosshole seismic, reflector imaging, in-mine.

Two Step Inversion (Tomography & Pre-stack Migration) for High Resolution Seismic Imaging in Crosshole or VSP Surveys

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Abstract

In the petroleum and the mining industries, more detail about underground structures is often needed than can be determined from surface seismic surveys. Crosshole surveys and vertical seismic profiles are commonly used techniques for determining the velocity distribution between two wells by traveltime tomography. Seismic migration is also a powerful tool for imaging the structures between wells, but it requires velocity information. Neither seismic tomography nor migration alone can achieve an ideal underground image in both velocity and structure.

To get a high resolution image both in velocity and structure, we propose a two step inversion which is implemented by tomography and then pre-stack migration. The strategy uses the first arrival times to recover the low spatial frequency velocity components of the medium by tomography, then this velocity model is applied as a migration velocity to pre-stack migration to recover the higher spatial frequency components. As the result, high resolution images both of velocity and structure are obtained by this two step inversion process.

For the pre-stack migration, a general Kirchhoff integral is used, based on Huygens' principle, which applies a Green's function by traveltime and amplitude mapping, using the finite difference method. This method handles an arbitrary velocity model (including high velocity contrasts and shadow zones) represented by a grid of velocities. For the tomographic technique, either a constant velocity or a gradient velocity background can be used, depending on the particular case. This two step inversion offers a very useful tool for the petroleum and the mining industry for getting a high quality seismic image. A numerical example which uses a strongly contrasting velocity model for imaging a low velocity anomaly from crosshole survey data is given here using this two step approach.

Key words – tomography, pre-stack migration, VSP, crosshole, inversion.

Using Seismic Data and Cross-hole Analysis to Image Fractures

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Abstract

Two stratigraphic bore-holes 335 m apart, drilled to the Bulli coal seam at a mine site in the Southern Sydney Basin, showed an average velocity discrepancy of 10 per cent throughout the entire lithological section. Subsequently, a comprehensive seismic experiment was performed by BHP Steel (AIS) Pty. Ltd. Collieries Division which included the surface seismic reflection, walk-away vertical seismic profile (VSP) and cross-hole recording over the area connecting the two bore-holes.

The surface seismic data indicated possible seam disturbances between the bore-holes. The VSP data were of variable quality, while cross-hole data were of the best quality. Strong transverse isotropy was measured through the sandstone unit. The top 100m of the Bulgo sandstone showed weak P-wave anisotropy. However, shear wave splitting in the Bulgo sandstone suggested fracture induced anisotropy. Methane accumulations were inferred from the reflection and VSP data and Poisson's ratio computed at the receiver borehole.

Analysis of these data revealed a high complexity of the zone between and away from the boreholes. The poor quality of reflection and VSP data resulted from the presence of faults, associated fractures and several methane accumulations in the Bulgo sandstone. The overall velocity difference between the boreholes is related to a change in stress field. The results of the experiment showed that where reflection seismic data was poor, the application of three component VSP and cross-hole seismic data can be used to define a structurally complex area which may contain faulting/fracturing and methane. In such areas special care has to be taken in data processing, analysis and time to depth conversion.

High-resolution Seismic Tomographic Delineation of Ore Deposits

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Abstract

A crosswell tomography (CWT) experiment in a hard-rock environment was carried out to image the subsurface between two 240m wells separated by 28m. Detonators were used as downhole sources and a 24-channel hydrophone streamer provided the downhole receivers. The receiver spacing in the streamer is 2m. An effective 1m receiver spacing was achieved by two deployments of the streamer with a shift of 1m. High quality seismicdata were recorded at a sampling interval of 0.1 ms.

Seismic first-break times from the experiment were used to construct the velocity tomogram between the two wells by a least squares algorithm. Large source statics were identified in many receiver gathers. These statics can have strong adverse effects on the tomographic imaging. The statics can, however, be mostly recovered and compensated for in the analysis. In a tomographic inversion, they are treated as part of the model parameters and are reconstructed simultaneously with the velocity distribution.

Tomographic images agree well with the known geological structure obtained from the two imaging wells and a third one between them. They also agree with other independent geophysical survey results (e.g. Applied Potential and TEM). The difference between the CWT and the other geophysical methods is that the CWT can provide a high-resolution 3D image between the wells rather than simple detection and localisation of the anomaly using the other geophysical techniques. CWT can offer vital information for further exploration and may have great economic potential.

High Resolution Survey for Coal Exploration Using a Newly Developed Integrated Seismic System

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Abstract

Since 1992, the New Energy and Industrial Technology Development Organization (NEDO) of Japan, with the cooperation of the Queensland Department of Minerals and Energy (DME), has been conducting a research project: "Joint Research on the Development of Coal Resources New Exploration Technologies". One of the aims of the project is the development of a new high-resolution integrated seismic survey system for shallow coal formations.

In Japan, geophysical exploration techniques for coal, mainly the reflection seismic method, have been used since the 1980s. Due to the low dominant frequency (50–80 Hz) of reflection events from coal, it has been difficult to resolve closely spaced multiple formations and to detect small faults with throws of a few metres. As a result, the geophysical data could not have been incorporated in designing mines.

Production from coal mines is inevitably moving underground. Designing of underground mines requires precise subsurface information with a higher resolution than the conventional geological interpretation can provide.

The new system presented here is an answer to this requirement. The goal is the development of a seismic system with the capability of surveying with a dominant frequency of around 150 Hz to achieve a resolution up to a few metres in target coal formations 300–400 metres deep.

The project includes the development and improvement of all aspects of the seismic data acquisition system: source, receiver and recorder. The new high-frequency electromagnetic vibrator is capable of controlling sweeps up to 1000 Hz, far superior to the conventional explosive sources. The natural frequency of the receiver has been improved to 150 Hz, and its sensitivity has been increased by a factor of three. A new computer control has enabled the use of a modified sercel SN358 system to sample 120 channels at 0.5 millisecond sampling rate. It is also capable of correlation and shot control.

The present paper introduces the elements of the new seismic system both developed and improved, then demonstrates improvements in resolution by comparing the records from new and old systems. The test survey was carried out in the Taraborah test site to the west of Emerald, Queensland in 1994.

Combined Seismic Technology for Mine Planning – A User's Perspective

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Abstract

Combined seismic techniques have been used to provide complementary information to exploration drilling for underground coal mine planning and development. These techniques include two and three dimensional surface reflection seismic, in-seam seismic, cross-hole tomography, vertical seismic profiling (VSP), exploration VSP and guided wave VSP.

The purpose of the surveys is to verify that the coal seam is free of significant geological disturbances, such as faults, dykes and highly jointed zones. In the relatively shallow Australian coal deposit environment, a combined use of surface and borehole related seismic surveys offers a cost-effective means of delineating seam structures.

The field procedures of these surveys are straight forward and, with dedicated portable data acquisition systems and processing software, the turn around time is quick. These techniques have now been accepted and integrated as routine mine planning practices.

Key words – Coal, mine planning, surface seismic, in-seam, cross-hole, VSP, guided wave

A Resistivity Tomography Test Survey in the Toyoha Mine, Hokkaido, Japan

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Abstract

Resistivity tomography was intensively developed from the mid 1980's to early 1990's. The technical development department of the Metal Mining Agency of Japan(MMAJ) had conducted research on the application of resistivity tomography to mineral exploration until the end of 1993.

The MMAJ has adopted the McOHM-21 system as the data acquisition system for resistivity tomography. The McOHM-21 is a DC transmitter and receiver combined unit manufactured by OYO Corporation, and can be programmed to simultaneously measure three potentials as well as injected current wave forms.

Using the McOHM-21, the MMAJ executed a resistivity tomography test survey in the Toyoha Mine, Hokkaido, Japan, in August 1993, in order to delineate the location and shape of the known lead-zinc sulfide vein as a low resistivity anomaly.

Electrodes were set up with 5m separation along three sides (90m-110m-60m) of the mine development

encircling the inclined vein whose maximum width was 2m. Two sets of data obtained by pole-pole and dipole-dipole configurations were analysed by the alpha centers method and a combination of the finite element method and nonlinear least-squares method respectively. The reconstructed resistivity images show the vein as a low resistivity zone, though there are some differences in the location and width between the expected vein and the reconstructed image. The resistivity image, corrected for the high temperature (95 degrees centigrade) of the rock in the survey area, coincides with the resistivity values (20 degrees centigrade) of rock and ore samples taken from the walls of the mine development.

Such resistivity data is a great support in solving the exploration problems in mines, where information on the target (e.g. veins) is only partly exposed in the mine development.

Key words – Resistivity tomography, McOHM-21 system, Toyoha Mine, Pole-pole configuration, Dipole-dipole configuration, Alpha centers method, Finite element method, Nonlinear least-squares method

Interpretation of Rim Surveys in Underground Potash Mines

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Abstract

RIM surveys in underground potash mines in Saskatchewan, Canada, have been undertaken for several years with generally positive results. The methodology is similar to surveys carried out in underground coal mines in the U.S. and Australia, where TEM-mode magnetic-field amplitudes are measured and subsequently processed to produce absorption-coefficient images of the seam being exploited. The primary differences between the coal and potash situations are the great transmission range possible in potash, which exceeds 3000 m, and the nature of the target anomaly, which for potash is always the anomalous presence of brine.

The RIM method responds to zones of anomalous conductivity in a manner that does not well match the commonly-applied ray assumption. There is a difference between how two rays respond to the same anomaly where one of the rays has both end points outside the anomaly and the other has either the beginning or end of the ray within the anomaly. In each case grossly different measurements are made of essentially similar volumes of earth which, if unrecognised, can lead to serious interpretational pitfalls. These effects have been recognised in field data and turned to advantage: if both ray "modes" traverse the same anomaly the thickness and conductivity of the anomalous material can be derived by a curve-matching method.

A Staged Genetic Algorithm for Tomographic Inversion of Seismic Refraction Data

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Abstract

A genetic algorithm has been developed to tomographically construct the sub-surface velocity distribution using first-arrival seismic refraction data. The performance of the genetic algorithm is improved by the inclusion of a ÒzoomingÓ technique able to perform a staged subspace search in the higher dimensional solution space. This allows the complexity of the model defining the solution to be progressively increased during the inversion and results in an increase in the speed and accuracy with which a solution can be obtained.

The procedure has been tested with both synthetic and model data. The method proved able to correctly recover the geometry and velocity structure of a non-planar refractor and the overlying lower velocity layer without the need of any 'a priori' information.

Spectral Acoustic Techniques for Joints and Fracture Characterisation

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Abstract

An ultrasonic pulse transmission method was used on a large block of gabbro (18x18x30cm), at low normal stresses (0.01-15 MPa) and low frequencies (0.02–1Mhz) in order to determine the transmission coefficient of a simulated fracture. The contact stiffness was measured directly and spectral ratios of the received signals calculated for comparison with predictions from the displacement discontinuity model. The agreement between the measured and derived spectral ratios was significantly better for the rough surface, indicating that the model provides a better approximation for natural fractures than for smooth interfaces. The model predictions also improved at lower frequencies, suggesting that spectral analysis of seismic data might yield useful information about the presence and stress state of fractures in the field.

Petrophysical Characteristics of BIF-hosted Gold Deposits and the Application of Downhole EM to their exploration, with Examples from Hill 50 Gold Mine, Mt Magnet, Western Australia

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Abstract

Hill 50 Gold Mine is located at Mt Magnet, 560 km NNE of Perth, in the Murchison Province of the Yilgarn Craton. The Mt Magnet greenstone belt consists of a sequence of mafic, ultramafic and felsic volcanic rocks, with interbedded volcanogenic sediments, predominantly banded iron formations (BIFs). The belt has been deformed into a principal structure, known as the Boogardie Synform. Major NNE – NE striking faults, superimposed on the synform, are referred to as Boogardie Breaks and exhibit important control over many of the ore deposits. Historically, most of the gold production in the Mt Magnet district has come from BIF – hosted deposits (e.g. Hill 50 and Boomer – styles).

Hill 50 – style deposits are hosted by BIF "bars" of the Sirdar Formation, having a width generally greater than 20 m, and being structurally controlled by the Boogardie Breaks. Gold mineralisation is closely associated with pyrrhotite and to a lesser degree, pyrite. Hillcrest South and Brown Hill West prospects are currently being explored using a Hill 50 model. Petrophysical measurements carried out on samples from these areas demonstrate that pyrrhotite – rich BIFs are characterised by lower magnetic susceptibilities and higher Koenigsberger Ratios, conductivities and densities. Use of downhole EM in locating the pyrrhotite – rich BIF has been extremely successful.

Boomer – style deposits are hosted by multiple NW – trending BIF units, and breccias, and are distinguished by the close association of gold mineralisation with pyrite. Petrophysical testing on samples from the Boomer pit showed that the pyrite – rich rocks are characterised by higher densities and magnetic susceptibilities than their pyrite – poor counterparts. Although the conductivities are also slightly higher, Boomer – style deposits are not detectable using downhole EM.

The differing conductivities observed in unmineralised BIFs and BIFs with significant pyrite and/or pyrrhotite can be explained by varying textural and mineralogical characteristics of the metallic lustre minerals involved.

CSAMT and MT Investigations of an Active Gold Depositing Environment in the Osorezan Geothermal Area, Japan

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Abstract

The Osorezan geothermal area is located in the centre of the Shimokita Peninsula, the northernmost tip of the island of Honshu, Japan. Osorezan is a long-lived composite volcano having a caldera lake. There are many active geothermal manifestations at the north shore of the lake. High-grade gold mineralisation is found in the hot-spring sediments at concentrations as high as 400 g/t (6,500 g/t max.).

Controlled-source audiofrequency magnetotelluric (CSAMT) surveys were carried out at 374 sites to investigate the detailed resistivity structure of the active gold depositing zone. The apparent resistivity contour maps show that resistivity anomalies correspond to the geothermal manifestations. Two-dimensional models analysed along west-east profiles indicate that most of the sites are underlain by a conductive layer. An extremely low-resistivity anomaly in the central part of the area is probably due to high-salinity hot water and intense argillic alteration. A high-resistivity anomaly in the western part of the area is interpreted as a silicified zone or a vapour-dominated zone.

In order to investigate deep resistivity structure, magnetotelluric (MT) surveys were carried out at 46 sites in and around the Osorezan geothermal area. A two-dimensional model analysed along a west-northwest-east-southeast profile indicates that the area basically has a two-layer structure; an upper conductive layer and a lower resistive layer. The lower resistive layer correlates well with the basement interpreted from gravity, which reflects pre-Tertiary basement rocks or intrusive rocks. However, the basement beneath the Osorezan geothermal area itself is relatively conductive. This may be due to fractures containing hot water and associated hydrothermal alteration. It seems likely that fracture systems forming circulation paths of deep geothermal fluids are developed in the basement beneath this area.

Source Component Display and Potential Field Interpretation

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Abstract

2D or 3D gravity and magnetic modelling procedures usually involves comparison of the response from a few, or simple, sources with with an observed profile. Common software may also allow complex source distributions typical of a complete geological section.

When several sources are involved the observed profile may be the result of complex interference and individual contributions may not be obvious. Gradients may be transformed by such interference. Much trial and error may be required to resolve or understand the source and effect interactions. This is not a simple process if only the resultant calculated from all sources is compared with the reference profile.

A source component profile represents the response due to a specific source within a model.

Assessment of critical geometry or contrast changes, crucial source segments and curve fitting parameters – and hence model revision, can be greatly accelerated if the actual responses from each part of the model are viewed in addition to the resultant of their effects. Review of the source contributions in a model leads to more satisfactory interpretations since it reveals how the

observed profile may, or may not, be composed. Component profiles also demonstrate how observed and resultant gradients may be modified by interference and thus provide some salutory cautions about the use and reliability of simple procedures.

Software should be modified to allow this more complex display and a declaration of how the resultant and observed curves were fitted. Most currently available modelling software either generates, stores or requests the required information.

The paper includes examples from the Mount Isa Inlier of NW Queensland to illustrate the use of source components.

The L-curve method for the selection of a good regularization parameter and its application to CT for potential field data interpretation

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Abstract

The interpretation of potential field data is described with respect to solving a Fredholm integral equation of the first kind which is mathematically a typical ill-posed problem. The properties of ill-posed problem and difficulties for solving it and its discrete form known as an ill-conditioned linear system are illustrated. In terms of Singular Value Decomposition (SVD), the mechanism of regularization methods are introduced with emphasis on the role of selecting a regularization parameter in the application of any regularization method. The advantage of the L-curve method in the selection of an optimal regularization parameter for a given ill-conditioned problem is also shown.

A simple numerical example shows the possible applicability of Computerized Tomography techniques to the interpretation of magnetic field data. The projections used for the reconstruction of an unknown image function are obtained by solving a sequence of ill-conditioned systems resulting from discretizing a Fredholm integral equation of the first kind. The result also shows the influence of inappropriate regularization parameter.

Application of Euler Deconvolution and a Neural Network System as Interpretation Aids for Three Component Downhole TEM Data

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Abstract

The relationship between the secondary field due to a TEM source and a dipolar potential field has been documented (Dyck and West, 1984; Grant and West, 1965). In light of this relationship it is possible to utilise potential field interpretation aids when dealing with TEM data. Where only the axial component of the anomalous field is available, in the case of downhole TEM data, the implementation of these techniques is very restricted and may yield ambiguous model parameters, hence alternative techniques must be considered.

Euler deconvolution may be used to obtain the approximate coordinates of the source even in the presence of an overburden response. A neural network system has been trained to output the dip and strike direction of a plate model using scaled field data as input. Utilising both the neural network and Euler deconvolution techniques, approximate model parameters may be computed directly from the field data.

Synthetic examples are presented, showing that these techniques are applicable even in the presence of noise and conductive overburden. A field example from the Flying Doctor prospect is also presented. The computed model parameters were found to be consistent with previously published data (Cull, 1993).

Resistivity Imaging by Time Domain Electromagnetic Migration (TDEMM)

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Abstract

One of the most challenging problems of electrical geophysical methods is the interpretation of time domain electromagnetic (TDEM) sounding data in the areas with the horizontally inhomogeneous geoelectrical structures. This problem is of utmost importance in mining exploration and environmental study, in particular, in the case of sounding conducted in the transmitter offset or slingram mode. The conventional 1D EM inversion technique cannot solve this problem, because the observed data are strongly distorted by horizontal conductivity inhomogeneties. The multidimensional EM inversion techniques existing today can handle only simple models, require repetitive forward modelling solutions, and therefore are very time consuming.

We developed a new approach to the interpretation of TDEM data over inhomogeneous structures based on downward extrapolation of the observed electromagnetic field in reverse time (the time domain electromagnetic migration). Numerical solution of this problem is provided by an electromagnetic analog of the Rayleigh integral. TDEM migration transforms EM data, observed on the surface of the Earth, into immediate geoelectrical images of geological cross sections. This transformation is very fast (requiring only a few seconds of CPU time on PC) and stable to the random noise in the data.

The numerical results of rapid inversion based on the time domain electromagnetic migration illustrate the property of migration described above. This method has also been applied to waste site characterisation. We have analysed the data obtained as a result of high density TDEM profiling survey with the Geonics EM47 along the set of profiles, intersecting Cold Test Pit waste site within the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory (INEL). Time domain electromagnetic migration and resistivity imaging made it possible to outline the conductive sections of the pit filled with the waste.

Higher Order Spectra in the Processing of Magnetotelluric Data

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Abstract

Magnetotelluric (MT) impedances are estimated from electric and magnetic field data using a higher order spectral (HOS) method. This technique rejects Gaussian noise contaminating the MT signal because of the insensitivity of the third order cumulant to Gaussian signals. The non-Gaussian characteristics of a representative set of MT signals are demonstrated.

Artificial non-Gaussian datasets contaminated with varying levels of coherent and incoherent Gaussian noise are analysed using this method and three existing methods: the robust remote reference (RRRMT) method, the time-frequency (TF) method and a variant of the conventional (CONV) method. The resistivity and phase estimates obtained by the HOS method and CONV method are more consistent than those of the TF and the RRRMT methods, and in general the resistivity and phase estimates from the HOS method are subject to the least bias.

Case History of Geological Mapping – Ghanzi-Chobe Fold Belt Aeromagnetic Survey

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Botswana Geological Survey

Abstract

A summary is given of the geologic background, geophysical methodology and final results of an airborne magnetic survey recently completed over a large area in northwestern Botswana, southern Africa. The survey is of particular interest and utility, successfully resulting in geological mapping in an area almost entirely obscured by variably consolidated sediments of the Kalahari Group. Detailed aeromagnetics is shown to be one of the few cost-effective tools available for resolving the basic uncertainties in mapping between complex geology and sporadic outcrops in this remote region. Data and results have been used for both mineral exploration and hydrogeological investigations. Significant stratiform copper-silver (+/–gold) mineralization, in what may yet prove to be commercially exploitable quantities, is found to lie almost directly below a consistent magnetic marker horizon. Detailed, high-resolution magnetics have also proved invaluable in assisting the delineation of faults and major shear zones in recrystallized basement aquifer rocks otherwise having little primary porosity. The airborne geophysical project has justified a considerable investment by the Government of Botswana and the European Community, and should bring real benefits to a region in need of both private and public sector development.

Key words – aeromagnetics, triaxial gradiometer, magnetics, Ghanzi-Chobe (fold) belt, Damaran Belt

Aeromagnetic Gradiometers – A Perspective

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Abstract

Measurements of horizontal or vertical gradients of the magnetic field intensity can add a new dimension to high resolution aeromagnetic surveys of shallow basement areas. Although a number of vertical, horizontal and triaxial aeromagnetic gradiometers are in operation throughout the world, very little has been documented on the relative merits of horizontal and vertical gradiometer measurements or of measured versus calculated gradients. Our results demonstrate that there are differences in spatial resolution and bandwidth between measured and calculated gradients and that horizontal and vertical gradients provide complementary information. Finally our results indicate that better georeferencing of horizontal gradiometer data is needed before we can derive reliable vertical gradient data from the measured longitudinal and transverse gradients

Development of short-baseline aeromagnetic gradiometers began in 1975 with construction of the Geological Survey of Canada vertical gradiometer. The success of current short-baseline gradiometers depends on the use of high sensitivity optical pumping magnetometers, usually cesium vapour sensors and effective compensation for aircraft manoeuvre noise.

Practical advantages of measured gradients include elimination of the diurnal problem and improved spatial resolution of small shallow sources. Transient signals have the same effect on all the magnetometer sensors so the effects are cancelled out in the gradients and diurnal-free total magnetic intensity can then be reconstructed by integrating the gradient data. The gradient data effectively remove the main field of the earth and enhance smaller scale, shallow anomalies while attenuating longer wavelength, deeper seated anomalies. In addition, measurement of the transverse horizontal gradient provides extra information between flight lines, leading to a reduction in flight line dependency of magnetic anomalies and a reduction in aliasing effects. The vertical gradient can also be derived from the longitudinal and transverse horizontal gradients with less line dependence and probably lower noise levels than the measured vertical gradient.

Data from a conventional Canadian vertical gradiometer system, an Australian horizontal gradiometer system and a Southern African triaxial gradiometer system are evaluated. The measured vertical gradient data appear to provide better resolution of shallow sources than the vertical gradient calculated from the total field. The horizontal gradient data allow us to derive the vertical gradient from the horizontal gradients and provide much improved enhanced total magnetic intensity grids.

The choice of a vertical or horizontal gradiometer system depends on survey objectives and both systems have their advantages. The vertical gradient appears to be marginally easier to measure and simpler to interpret. A

triaxial gradiometer system provides the advantages of both at the cost of an additional sensor and retractable boom installation, compared to a horizontal gradiometer. Unfortunately, in Australia, CAA certification of a retractable tail boom may prove difficult. The viability of deriving the vertical gradient profiles from measured horizontal gradients needs more research, but if this can be done routinely, we think this would tilt the balance towards the horizontal gradiometer system. The improvement in total magnetic intensity grids using the transverse gradient information can be quite dramatic in many cases and there is always some improvement in the data. The combination of transverse gradient enhanced total magnetic intensity data and high spatial resolution 'texture' filters provides excellent definition of lower amplitude anomalies. In contrast, the calculated vertical magnetic gradient is often very similar to the measured data and the benefits of the measured vertical gradient may be small in many cases.

Gradiometer performance deteriorates rapidly as the source becomes deeper and existing gradiometers are probably close to the noise level at 500m depth. Rugged topography also causes fixed wing gradiometer performance to deteriorate.

Aeromagnetic Gradiometry in 1995

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Abstract

Aeromagnetic gradiometry offers certain advantages over total field surveying in terms of providing more information per line kilometre flown. However, although these advantages have been discussed for over a decade, because instrumentation for gradiometers is considerably more complex than for total field measurement and the measurement techniques are more demanding, operators have been slow to develop such systems. To date, there are less than ten gradiometer systems being flown for production surveys. This paper discusses gradiometry techniques and presents results. Some design criteria for airborne gradiometers are briefly noted and specifications for gradiometer surveys are discussed.

The following horizontal gradiometry applications, in the fixed-wing context, are outlined and are illustrated with examples:

- Levelling of total field surveys without the use of tie lines.
- The use of measured lateral gradient in the total field gridding process to achieve higher resolution of anomalies or alternatively, to enable increased line spacing without loss of resolution.
- The identification of 2-D linear structures and their strike angles, on the basis of a single flight line and from these identifications, the formation of accurate estimates of vertical gradient leading in turn to accurate depth estimates using Werner deconvolution. This technique can be useful in the redesign or reorientation of a survey with very little flown data.
- The use of directly measured longitudinal gradient to estimate diurnal variations of the total field during the time interval in which a survey line is flown. To date, this has been unsuccessful and the difficulties associated with the technique are illustrated.

Vertical gradiometry in helicopters and fixed-wing aircraft is compared. Differences between directly measured vertical gradient and vertical gradient calculated from gridded total field are discussed.

Key words – aeromagnetic gradiometry, lateral, vertical, horizontal, configurations, levelling, compensation

Recent Developments in Sub-Audio Magnetics (SAM)

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Abstract

Sub-Audio Magnetics (SAM) is a high definition technique which has been developed for simultaneously mapping electrical and magnetic characteristics of the ground (Cattach et al., 1991; Cattach et al., 1993). Electric current, typically in the frequency range of 5 to 200Hz is induced in the ground by either galvanic or electromagnetic means. An optically-pumped total field magnetometer continuously measures the natural and synthetic field changes from DC to the highest transmitted frequency. Spectral analysis of the magnetic field changes allows a suite of geophysical parameters to be derived. Each of the parameters may be measured at sub-metre intervals while continuously traversing, either on foot or in a vehicle. A series of feasibility studies were conducted in a range of geological situations using a rapid sampling TM-4 Caesium Vapour magnetometer as a prototype SAM receiver. On the basis of those studies, deficiencies in the prototype equipment were recognized, enabling those specifications unique to a SAM receiver to be defined. The enhancements were implemented as hardware modifications to the TM-4 in the form of a plug-in option card (the SAMCard). Features of the card include:

- Larmor frequency demodulation circuitry
- Real-time mains power filters
- High Bandwidth measurements
- Constant sample interval
- GPS based synchronization with the transmitter.

Software enhancements include the ability to record either the entire or stacked SAM waveform for post-processing purposes. Real-time digital filtering of the total magnetic field data permits high definition magnetics to be recorded simultaneously with the electrical parameters.

The development of the SAMCard is a major advance towards the commercial viability of the SAM technique. The equipment now available provides a valuable platform for further investigation into the SAM technique and its potential applications, particularly the acquisition of parameters related to the Induced Polarisation phenomenon.

Key words – Sub-Audio Magnetics, SAM, SAMCard, HDM, TFMMR, TFMMIP, magnetometer, high resolution, geological mapping, environmental geophysics.

Analytical Solutions for the Total Field Magnetometric Resistivity (TFMMR) Technique

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Abstract

The analytical solutions for the TFMMR parameter of the Sub-Audio Magnetics technique are important as a tool in indirect interpretation of the field data, in assessing which subsurface structures will produce measurable signals, and for designing optimal field survey configurations.

In this paper, we investigate the theoretical TFMMR anomalies that would be observed over simple model structures such as an homogeneous isotropic and anisotropic earth, vertical contacts or faults, inclined contacts, thick dikes and outcropping hemispherical-depression models. For each model, comparisons are made with the MMR method.

In general, the magnitude and shape of the TFMMR signal varies with changes in the geomagnetic field. For 3D structures, in particular, such as faults and dikes, the TFMMR and MMR methods produce signals of similar quality. In cases where subsurface conductive bodies are striking parallel to the line joining the electrodes, our results show that the MMR method produces relatively small signals whereas the SAM signal is still quite measurable. We have also shown that the TFMMR type responses is sensitive to the geomagnetic field rather than geological strike directions as MMR is.

TFMMR measurements have higher resolution, higher data acquisition rate, lower field costs and higher amplitudes for certain subsurface geometries than MMR.

Key words – Sub-Audio Magnetics, SAM, HDM, TFMMR, TFMMIP, MMR, MIP, Magnetometric resistivity.

A Regional Scale Gravity Survey of the Southern Cross Greenstone Belt, Western Australia

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Abstract

A case study is presented from the Southern Cross Greenstone Belt, Western Australia, where regional scale gravity data have been collected in order to study the belt and associated granitoid bodies. Differential Global Positioning System (GPS) satellite surveying techniques have been used to coordinate the gravity observations, and automated processing techniques, such as terrain corrections based on digital elevation models (DEMs), have been used as part of the study. These approaches greatly reduce the manual effort and time needed to collect and process the gravity data.

While the use of GPS methods introduces further considerations in data reduction, such as the geoid-spheroid separation, it can provide up to a 250% increase in efficiency in the field while collecting survey data. The computer based terrain correction calculation using a DEM provides a considerable saving in the time expended on data reduction. With the introduction of such field practices and reduction methods, gravity as a semi-regional scale exploration tool is becoming more attractive.

The present study has shown that station spacings of 1 km should be considered a maximum when working on the semi-regional scale (50–60 km square areas), with closer station spacings (500m maximum) more appropriate close to expected geological contacts.

Regional Geophysics of the Alberton-Mangana Goldfield, Northeast Tasmania

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Abstract

Reconnaissance gravity and high-resolution aeromagnetic data, acquired in 1993 as part of the Tasmanian Government NETGOLD project, were used to investigate the regional structural setting of the area and the distribution of gold mineralisation. Gold mineralisation in northeast Tasmania occurs both close to, and remote from, outcropping granitoids. The total recorded gold production is in excess of 50 tonnes. In the Alberton – Mangana Goldfield the distribution of mineralised sites defines a prominent NNW trending regional lineament which passes through the corridor of Mathinna Group rocks separating the Scottsdale and Blue Tier Batholiths. Mineralisation occurs primarily within discrete quartz-sulphide veins hosted by the metasediments.

The Mathinna Group rocks are variably magnetic and the majority of the granitoids are effectively non-magnetic. NE-trending magnetic lineaments mark faults which truncate subtle NNW-trending anomalies attributed to lithological variations in the Mathinna Group. There is no consistent relationship between NE-trending faults and mineralised sites but dextral movement on these structures may have been important in dilation and mineralisation of pre-existing ENE-trending fractures. Broad ovoid magnetic anomalies in areas of Mathinna Group outcrop result from large scale alteration systems probably related to underlying granodioritic intrusives. The economic potential of these systems has not been tested.

The residual Bouguer gravity field is characterised by strongly negative anomalies in areas of granite outcrop. Modelling suggests that the entire Alberton-Mangana

area is underlain by low density granite with the thickness of Mathinna Group rocks increasing from less than 1 km at Alberton in the north to in excess of 3 km in the south near Mangana.

The Use of Log Residuals and LSFit Algorithms on Daedalus 1268 Airborne Scanner Data Using ER Mapper Image Analysis System – Kanmantoo, South Australia

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Abstract

Log Residuals and LSFit are image processing algorithms developed by CSIRO, Division of Exploration and Mining, North Ryde for the processing of hyper-dimensional remote sensing data sets such as Geoscan, JPL's Airborne Imaging Spectrometer (AIS) and MDA's Multi-spectral Electro-optical Imaging Scanner -II (MEIS-II). The Australian Geological Survey Office has adapted the utilisation of the algorithms for processing Landsat Thematic Mapper data demonstrating that, compared to single band and band ratios images, superior discrimination was provided over the Musgrave Block SA (Glikson, 1994).

Esso commissioned the National Safety Council in Victoria to fly seven north south runs over the Kanmantoo Trough on the eastern edge of the Adelaide Hills using the Daedalus 1268 scanner in 1985. Daedalus records 11 channels across the visible to thermal infrared wavelength range with the Daedalus bands partially emulating the Landsat TM channels. This data resides on open file with the Dept. Mines and Energy SA.

Interest in the Kanmantoo centres on assisting the exploration effort in targeting prospective mineralisation. As a possible contribution to the exploration model the Daedalus data has been retrieved from archive. Unfortunately not all of the data was recoverable, due to deterioration of the media tapes during their nine years of storage. For this reason runs 1 and 2 were selected for this investigation as they represented the most complete data sets. Band 11 (Landsat TM band 6 equivalent) has not been included due to band to band registration problems in run 1.

A tan theta correction was applied to the runs to rectify the cross-track variance using the following formula:

I1 – (x * ((cell X ( ) – cp) * d) / a)

where I1 = input band spectral value
- x = tan theta correction coefficient (ttcc) which modifies the amount of correction applied
- cell X ( ) = position of the current pixel in the line being processed
- cp = central pixel position in the run
- d = pixel dimension
- a = altitude of aircraft

Tan theta is an additive correction whose value depends on the pixel position across the run of imagery. All the bands had to be evaluated separately to determine the tan theta correction coefficient (ttcc). The cross track variance is interpreted as being related to atmospheric backscatter and is therefore wavelength dependent in magnitude. Hence the need to modify each band separately. Suitable ttcc's were selected by displaying individual bands and varying the coefficient in the formula until no visible variation in variance could be identified across the runs. A further check was conducted using false colour band combinations which highlighted any remaining systematic variance.

Log Residuals requires a three step process. Firstly dark pixel determination for bands 1 to 8 in the visible wavelength region to compensate for atmospheric haze. Second, preparation of log bands, and finally generation of log residuals to reduce backscattering, albedo effects and normalise between bands on the same pixel, and pixels within one band. Subsequent ratioing of the Log Residual bands enhanced geological features in the imagery. However vegetation effects remained.

Of major concern to geologists attempting an interpretation of the final data is the effect of the extensive vegetation cover. The LSFit algorithm has been designed to assist with the suppression of specific spectral features in an image, leading to enhancement of desirable information. Application of this algorithm showed significant reduction in the vegetation effects for individual bands of runs 1 and 2.

References: Glikson, A. Y., 1994. AGSO Record 1994/17

An Integrated Geophysical and Geological Interpretation of the High Resolution Aeromagnetic Survey Surrounding the Vaalputs National Radioactive Waste Disposal Site, Bushmanland, South Africa.

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Abstract

The generation of nuclear power produces waste products from the various steps in the nuclear fuel cycle which must be disposed of in such a manner as to limit the impact on the natural environment. In South Africa, nuclear waste originates from the Koeberg Nuclear Power Station, as well as the Safari Research Reactor at Pelindaba. Low and intermediate level wastes are being disposed of in a Tertiary clay formation at the Vaalputs National Radioactive Waste Disposal Site and the spent fuel elements are being stored at Koeberg in a pool environment at the reactors. After a period of approximately 5 years, or more, the spent fuel elements will be transferred to "dry storage" in castors which will be transferred to Vaalputs and stored above ground for a further 40 years. From this interim storage the fuel elements will be disposed in a deep geological repository which is currently being sought in the Vaalputs area.

The hazard of radiation can be effectively eliminated by the shielding of a few metres of rock. A deep geological repository (± 500 metres), in crystalline rock, is preferred

in South Africa. Pollution of the environment is most vulnerable through migration of pollutants in groundwater along faults or fracture zones which then reach the terrestrial or aquatic food chain. The safety measures within the repository are based on multiple barrier engineered systems. Multiple barriers help isolate the waste from the groundwater and prevent, or in the worst case, delay the dispersal of radionuclides. Should leakage occur, these contaminants will be contained by the geological barriers.

A multidisciplinary programme was initiated in 1978 with the aim of locating a safe radioactive waste disposal site for the South African nuclear industry. This programme is managed by the Earth and Environmental Technology Department of the Atomic Energy Corporation of South Africa Ltd (AEC). The criteria for the selection of a suitable site were based on numerous safety requirements as outlined by the International Atomic Energy Agency and yet to be ratified by the South African Council of Nuclear Safety. A 100km2 area was selected in the Northwest Province of South Africa in which a low and intermediate level waste site was developed. Vaalputs is situated within the Namaqua Metamorphic Complex, which comprises a series of tectono-stratigraphic and tectono-metamorphic domains separated from one another by transcurrent shear zones. The low and intermediate level site lies within the Tertiary Vaalputs Formation (a sandy gritty clay) which overlies the granite gneisses of the Namaqua Metamorphic Complex. The highly impermeable clayey nature of the Vaalputs formation renders it suitable for the safe disposal of low and intermediate level waste. This study is directed at locating a suitable deep geological repository for spent fuel elements in the underlying granitic gneiss.

On a regional scale, a distinct domain can be recognised from the aeromagnetic data (the Proterozoic Vaalputs sub-terrane). The regional gravity is equivocal. Because of the success of the aeromagnetic data in helping to select the low level waste site under the sand cover, a high-resolution triaxial gradiometer aeromagnetic survey was undertaken over the contiguous area, east of Vaalputs, Annex Vaalputs. The target sought is an unfractured, homogenous block of granite gneiss underneath the sand cover. The magnetic data are processed, imaged and integrated with other geophysical and geoscientific data for lithological and structural mapping.

On the Use of GPS in Geophysical Surveys

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Abstract

The Global Positioning System (GPS) is a satellite-based positioning and navigation system which offers 24-hour, world-wide, three-dimensional positioning. Single point GPS positioning yields coordinates accurate to +/–100m, which is adequate for regional scale, low-accuracy applications and field reconnaissance. In order to achieve more accurate positioning, differential GPS (D.GPS) is employed, which uses two or more GPS receivers simultaneously. This can either be in the form of code-based D.GPS, which offers +/–1–5m relative positioning, or carrier-phase-based D.GPS, which offers 1–10cm relative positioning. The vertical and horizontal gradients of geophysical observables dictate that most exploration methods must be positioned using D.GPS, especially those that require subsequent data reduction. The GPS methods currently available, their accuracy, operation and suitability for positioning during geophysical surveys are summarised. Finally, in order to integrate GPS-positioned data with existing data, coordinate transformations are necessary.

Key words – GPS, positioning, coordinates, geophysical surveys.

Esoteric and Mundane Geophysics for Diamondiferous Pipe Exploration

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Abstract

Geophysical techniques have been shown to be effective in diamond exploration. Airborne magnetics and EM can in most cases accurately detect and map most kimberlite and lamproite pipes. The variations in observed response are large and controlled by both geological and physical factors. The controls on EM for example are multiple and include geological facies: whether diatreme or crater; degree of brecciation and porosity, depth of weathering and groundwater salinity.

There is strong evidence that the source of unweathered kimberlite and lamproite magnetic anomalies is predominantly remanent. Viscous magnetisation may become important in weathered rocks. Observed local anomalies may thus be of normal or reversed polarity compared to a non-magnetic background.

There are many sources of confined geophysical anomalies with lateral extent around the nominal 300m minimum diameter of economic diamondiferous pipes These include amphibolites, collapse breccia pipes, massive sulphides, skarns, inhomogeneous regolith, culture, alkaline diatremes, confined mafic and ultramafic bodies, local sediment patches and magnetite concentrations in granite. Some simple geophysical tests can help discriminate these possible sources in many cases.

Diamond grades within economic pipes are known to be strongly zoned, grade also varies greatly between separate intrusions within one pipe. Detailed ground geophysics can usually map out the surface extent of many diatreme and crater facies kimberlites or lamproites, and at times clearly identify separate intrusions within one kimberlite or lamproite. Such detailed geophysics is likely to be far more cost-effective than the alternatives such as grid drilling or pitting.

Recent Geophysical and Geological Mapping Progress and Implications for Exploration

Alan Willocks

Abstract

The Victorian Government through the Department of Agriculture, Energy and Minerals is undertaking a 3-year, $16.5 million Victorian Initiative for Minerals and Petroleum (VIMP) to support the state's mineral and petroleum exploration industry. Projects being undertaken as part of the initiative include the acquisition of airborne magnetic and radiometric, gravity and regional seismic data, stratigraphic drilling and geophysical interpretation and geological mapping products. Major airborne surveys are being carried out in the north west of the State, the Eastern Highlands and the Otway Basin.

Geological mapping of the highly prospective Lachlan Fold Belt in Eastern Victoria has been hampered by difficult mountainous terrain. High level regional magnetic surveys contribute little to the detailed geological understanding. As part of VIMP, the Victorian Government has undertaking systematic helicopter geophysical helicopter surveys with a line spacing of 200m over an area of 30 000 km^2 in the Eastern Highlands of Victoria to assist the detailed geological mapping required for mineral exploration.

A case study from the Orbost area of the Eastern Highlands illustrates the advances available in geological mapping with the timely collection of detailed airborne geophysics and the implications this has for future exploration in Eastern Victoria. The Orbost magnetic and radiometric data are of a high quality and detailed interpretation enables the production of accurate lithological and structural maps in an area which has significant potential for gold and base metals.

The magnetic data differentiate between various types of volcanics in the Buchan Rift, indicate multiple intrusions, show bedding and faults in many areas within the Palaeozoic sediments, and reveal a previously unknown pervasive west-northwest to northwest fault direction. The radiometric data show compositional differences between the outcropping granites, correlate well with the magnetic data in identifying different types of volcanics in the Buchan Rift, and provide a number of lithological boundaries in areas with little magnetic contrast between the rock types.

Interpretation of High Quality Aeromagnetic Data over the Polda Trough

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Abstract

The Polda Trough is a major geological feature on the southern Gawler Craton in South Australia. The structure has such meagre surface expression that its full extent was not recognised until the late sixties. These surveys showed that the Polda Trough is a narrow rift, extending for more than 400 km westward from the centre of Eyre Peninsula towards the edge of the continental margin in the Great Australian Bight and that its widest and deepest part lay offshore. The onshore part of the Polda Trough which is the eastern end of the larger structure and a small section offshore is the subject of this paper..

Interpretation of the new aeromagnetic data incorporates previous geophysical surveys. At the coast in the wider part of the rift, spectral analysis of TMI, confirmed by forward modelling, shows two troughs of sediments separated by a relay ramp structure; there is no evidence of cross faults. The rift structure on land is of Mesozoic and Tertiary age. The northern boundary is a major fault; in the south the syn-rift sediments onlap the basement.

On-shore the central section of the rift is less than 5 km wide. The thin Permian sediments are restricted to the narrow graben only. Relay ramp structures are present in the central section also and faults are identified which determine the limits of the Lock Coalfield. The eastern end is a half graben which develops a NW trend; its boundary faults strike both E-W and NW. Where it is possible to determine the dip of the faults, they are nearly vertical.

Investigation of the crust of the south-western Gawler Craton to depths of about 30 km using spectral analysis of TMI and analysis of the long wavelength magnetic anomalies shows that there is a major change in the deeper crust coincident with the Uno Fault, that is on the southern margin of the Gawler Range Volcanics, and a second change in the deeper crust which also strikes E-W and coincides with the location of the Polda rift. The imprint of Polda rift in the deeper crust appears to cut the Kalinjala Mylonite Zone and stops at the Torrens Hinge Zone. A statistical correlation is established between the regional component of the TMI and the depth of a magnetic interface obtained from spectral analysis which corresponds to the thickness of the upper layer of the crust in the south-western Gawler Craton and the Adelaide Geosyncline. The upper layer of the crust under the Polda rift, indicated by the long wave length TMI anomaly and the correlation established, appears to be thicker than under the adjacent parts of the Gawler Craton.

Conductivity-Depth Transform of GEOTEM Data

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Abstract

A conductivity-depth transform (CDT) of airborne transient electromagnetic (EM) data generates approximate sections and maps of the subsurface electrical conductivity variations. The resulting products have instrumentation parameters such as the transmitter waveform removed and can be directly integrated with other information from the survey area. Although approximate, the conductivity depth transform has a number of advantages over an exact inversion method. These are illustrated with two examples: a groundwater salinity study in Australia and a survey over the Bushman mineral deposit in Botswana.

Key words – conductivity, airborne, GEOTEM, groundwater salinity, Bushman deposit, Botswana

Airborne Electromagnetic 3D Modelling and Inversion

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Abstract

Numerical EM 3D modelling and inversion are computationally challenging problems that can be solved by traditional methods only for models with a rather limited number of parameters. This severely restricts their application to realistic geophysical problems. In an effort to ease this restriction a number of levels of approximate forward modelling have been implemented including the 1D approximation, the 3D Born approximation, the finite element method, and the direct hybrid solution. A comparison of these modelling methods for the simulation of airborne EM data over a 3D conductivity earth model shows that the 1D approximation is very fast and gives a reasonable qualitative response, the Born approximation is moderately rapid but gives an inaccurate response, and the finite element and direct hybrid methods give similar responses with the finite element method requiring significantly less computer resources. The corresponding inverse problem is more challenging than the forward problem because each method of solution for the forward problem may require a different optimisation method for the inverse problem. This occurs because of the trade-off between the CPU time and accuracy of the forward modelling and the CPU time and number of forward modellings required by the optimisation method. Inversion tests based on the same airborne EM simulation show that for moderately large models the preferred optimisation method is quasi-Newton however for smaller models or when the finite element or hybrid modelling methods are used then the preferred method is Gauss-Newton.

Key words – 3D electromagnetic modelling, 3D inversion, airborne electromagnetic, conjugate gradients, quasi-Newton, Gauss-Newton, optimisation, Born approximation, finite elements, hybrid method Airborne Electromagnetic 3D Modelling and Inversion.

Is Full 3D Inversion Necessary for Interpreting EM Data?

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Abstract

The Process of converting a set of airborne and ground EM data into valid geoelectrical sections remains a difficult problem. Although significant advances have been made in 3-D inversion technology, coupled with remarkable increase in desktop computing power, it will be some time before full 3-D inversion becomes a practical tool for routine EM interpretation.

One of the first approaches was to approximate 3-D inversion as a series of 1-D layered Earth inversions, but a number of papers in the literature have demonstrated the deficiencies of this method. More recently, several approximate 3-D conductivity depth section methods have come into use. These include Spiker, Conductivity Depth Imaging, and various filament inversion schemes. Their use has been justified on the fact time domain EM is a low resolution diffusive process and that they are fast and easy to use.

How valid are they ? In this paper we generate a number of simple 3-D models including simple blocks, interacting dykes, and heterogeneous targets overlain by irregular overburden. This can be done for both ground and airborne surveys. We apply the various imaging algorithms to each of these and examine how close the image was to the original conductivity section model as a function of model parameters.

We use this information to answer the question posed by the title: How necessary is full 3-D EM inversion for useful EM interpretation?

Key words – Ground EM, Airborne EM, 3-D inversion, 3-D Models, Spiker, Conductivity Depth Imaging, Approximate Methods

Reducing Risk Through Technological Innovation: Challenges for R&D in the Service Sector

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Abstract

Exploration, development, and production projects in the oil industry are increasingly demanding of technology. The challenges for seismic data acquisition and processing involve smaller plays requiring higher resolution, difficult physical environments, complex geology, demand for reduced turnaround, and seismic for reservoir monitoring and delineation. Meeting these demands requires innovative and exacting science to deliver high quality data at good value. And yet, these demands for technology come at a point of historically low oil prices, industrial downsizing and outsourcing and so the resources for R&D are scarce.

Common themes for achieving technological objectives in the current environment are emerging. Strategic alliances that allow co-operative efforts between oil companies and service contractors, vendors, universities, and government research entities are forming to pool resources and expertise. Focused in-house R&D in the service sector has increase in response to reduced efforts in the major oil companies. Technologies such as depth imaging, multiple removal, velocity and geological modelling systems, advanced interpretation systems, and time lapse or 4D seismic now are being either jointly developed between the majors and contractors or produced solely within the service sector. Finally, a key element in improving quality and efficiency is the continuing effort to fully integrate seismic acquisition, processing, and interpretation and carry the results through to reservoir simulation.

This talk focuses on several examples of recent advances in these key technologies. The first example

features recent advances in prestack 3D depth migration and velocity modelling. The second topic examines the relationship between acquisition geometry, subsurface illumination, and imaging algorithms. By unifying these two technologies, imaging and acquisition, we can ensure that subsurface reflectors have been illuminated properly so that they may be correctly imaged.

Attempting to define a subtle trap by seismic attribute mapping of thin sands – a Timor Sea example.

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Abstract

The Pituri Prospect was a combined stratigraphic/structural trap on the Puffin Horst in the Vulcan Graben area of the Timor Sea.

This paper describes a case study where the problem to be solved was one of mapping the lateral extent of a thin sand defined by well control. The sand is a 7m thick unit within the uppermost Puffin Formation claystones of Maastrichtian age. The interpreted environment of deposition is submarine which is biostratigraphically calibrated on a basin wide scale with water depths interpreted as Upper Bathyal to Outer Neritic. The fan units have been regionally mapped seismically to define the major feeder systems. The resulting regional sand distribution maps do not however provide a simple explanation for the thin sands which are seen in the Puffin-2, Grebe-1 and Prion-1 wells. Two models were proposed, a submarine fan unit at the very distal end of the Late Maastrichtian lowstand fan system or a shingled turbidite of the Highstand Systems Tract of the Prudhoe deltaics.

The sand distribution had to be defined by the seismic data with the calibration of the nearby Puffin and Pascal wells providing the possible northern limits of the sand unit. An innovative approach is called for when using seismic amplitude/attributes to try and describe facies distributions particularly when the units are at the limit of seismic resolution. The amplitude anomalies were analysed for tuning effects, inverted for acoustic impedance and mapped on timeslices datumed on the regional flooding surface at the base of the Palaeocene above the Puffin-2 sand. Modelling for seismic amplitude response was undertaken using nearby well data. The analyses carried out generated a model for the Puffin-2 sand where that unit is a crevasse splay/levee overbank unit which was associated with a major submarine channel system to the south of the well location. The channel system ended at a broad lobate feature which was interpreted to be a submarine fan lobe which was targeted by Pituri-1.

The well found no sand in the section interpreted to have the sand unit however what was present was a 15 metre thick low density, low velocity claystone which is interpreted to be the thickening into the palaeo-low of a minor flooding surface seen at the Puffin-1 and Puffin-2 wells. This then highlights the difficulty in predicting sand distribution from seismic attributes alone. However the ability to predict reservoir distribution from seismic data is of critical importance in future exploration and further work which integrates all seismic attributes and geological/rock physics datasets could provide the means to better reservoir prediction.

An Improvement in Lithology Interpretation from Well Logs in the Patchawarra Formation, Toolachee Field, Cooper Basin, South Australia

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Abstract

Conventional lithology interpretation from well log data becomes unreliable when the target bed is thinner than the vertical resolution limit of the logging tools. The thin bed log analysis method of Bateman (1990), using the concept of binary lithology and a filtering technique applied to conventional logging suites, is able to detect beds as thin as 15 cm. This paper will focus on the use of the Bateman method to improve log-derived lithology estimates in the Permian Patchawarra Formation sandstone gas reservoirs in the Toolachee Field of the southern Cooper Basin in South Australia. In three representative wells, conventional log analysis overlooks most of the thin sandstone beds and underestimates the gross sandstone by up to 36% when compared with core data. In contrast, the thin bed algorithm identifies the thin sandstone beds and gives a gross sandstone thickness which agrees with the core value to within about 5%. It therefore provides a more correct picture of reservoir rock distribution, and reveals more potential pay than conventional log analysis. The method also makes core to log depth matching easier and more accurate. Log character and flow test results imply the presence of relatively permeable gas-bearing zones within some of the thin sandstone beds, suggesting that overlooking thin bed reservoirs may significantly lower reserve estimates. Since the method does not require the use of any high resolution logging device, it is possible to re-evaluate old log data for which conventional log analysis is subject to such underestimation.

Key words – well log, thin bed, lithology, reservoir, Cooper Basin

Wide-angle Reflection Profiling – Applications for Petroleum Exploration and Crustal Studies

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Abstract

Wide-angle reflection profiling (WARP) is a seismic mapping tool that is gaining wider acceptance in petroleum exploration where, previously, it has been focussed on crustal and earthquake studies. It has the potential to solve problems in areas where conventional normal-incidence seismic reflection data is either

ineffective or prohibitively expensive:

- low cost reconnaissance exploration of frontier areas (onshore, offshore or transition zone) providing basin geometries and sediment thicknesses,
- mapping of deep basin structures beneath vólcanic or salt/evaporitic sequences,
- definition of upper crustal structure in relation to the basin's structure and tectonic development, and
- high resolution velocity data providing a depth model, and possible keys to lithologies.

The wide-angle reflection profiling technique takes advantage of the concept that by increasing the offset distance between the source and the receiver, the percentage of energy reflected from a seismic interface increases compared to the energy transmitted through the interface. At the critical distance, the energy is totally reflected. Conventional recording systems cannot normally be operated at these distances. Stand-alone, three-component, analogue and digital recording stations have been developed for both onshore and offshore operations that record continuously for several days. Profiles are generally 50–200 km long for adequate penetration to the target depths. For offshore profiles, the Ocean-Bottom-Seismometer (OBS) units are spaced at 2–5 km intervals and shots with a large air-gun array are at 100–200m. For onshore profiles, the reverse configuration of closely-spaced recording units (land observation stations – LOBS) and wider spaced shots is used.

The data are modelled by kinematic ray tracing of a velocity-depth model, initially estimated by tau-P inversion of records from selected recording stations, using software developed from the published work of Cerveny and Psencik (1981). The modelling is done progressively layer by layer from the surface, and can incorporate any data from wells, conventional seismic data, outcrop geology and structural models. The arrival times of the model are compared to the recorded data, and synthetic shots are generated utilising a full elastic forward modelling algorithm to compare reflection amplitudes in the P and S domains.

The types of areas that could benefit from the use of WARP data are where conventional methods do not provide adequate penetration to identify the resource potential and hence, additional data is required to better assess the exploration risk, as follows:

- frontier basins with little geological control to identify sediment thicknesses,
- poor seismic data quality areas to identify the basement profile and the structure of the basin,
- compressional terrains or over-thrust areas where WARP data will penetrate high-velocity basement wedges and image the sub-thrust plays,
- basins covered, or heavily intruded, by volcanics to identify the base of the sedimentary section and intra-sedimentary structuring, and
- additionally, mineral provinces and regional crustal studies can be investigated with WARP data.

The paper will present examples of data from Europe (Greece; Baltic Sea), the Americas (Guyana; Oregon, U.S.A.) and other areas. Model sections of examples from the Australian region will be presented to illustrate its application to local problems. The potential development of 3D-style surveys with this technique will be reviewed.

Note: A written paper, technical details of the Wide-angle Reflection recording system and examples of modelled results from different areas and geological settings will be available from the Conference Secretariat Office during the Conference or can be requested from Brian Rumph in Sydney by fax on 02-419 4414 (international -61-2-419 4414).

Pre-stack Processing Techniques for Multi-source and Multi-cable Data Acquisition

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Abstract

3D marine acquisition techniques which use multi-source, multi-cable methods have well known sampling and data processing problems. Lowfold acquisition and aliasing can be caused by the undersampling inshot, i.e. too large a shot interval. The use of multi-cable recording can result in irregular offset and azimuth distributions. In this paper we describe possible methods for handling some of these problems by use of pre-stack interpolation techniques.

A North-south Crustal Transect Through Central Australia Based on Deep Seismic Reflection Profiling

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Abstract

A model for the crustal geometry of central Australia presented here is based on deep seismic reflection profiling that was conducted by the Australian Geological Survey Organisation (AGSO) in two major surveys in 1985 and 1993. North-south oriented seismic traverses crossed parts of the Arunta Block, Amadeus Basin, Musgrave Block and Officer Basin. In the region of the central Australian transect, the crust is dominated by major north-dipping structures, interpreted as thick-skinned thrust faults. Many of these thrusts cut deep into the crust. At least one thrust, the Redbank Thrust Zone within the Arunta Block (seismic line BMR85.1A), appears to cut the crust-mantle boundary, displacing it vertically by about 25 km, and horizontally by at least 40 km. By contrast, in the southern Amadeus Basin and northern Musgrave Block, where deep seismic reflection data are lacking, teleseismic data suggest that the major crustal structures are south-dipping.

The crustal structure below the southern Officer Basin (seismic line 93AGS06) consists of a series of planar parallel structures that we interpret as north-dipping thrust faults, similar to those seen in the northern part of the Arunta Block (seismic line BMR85.1A). With one exception, the thrusts do not cut or deform the overlying Officer Basin succession, implying that the crustal structure in this area was set in place by the end of the

Mesoproterozoic; there has been virtually no later reactivation of the thrusts.

At the northern margin of the Amadeus Basin (seismic line BMR85.1B), the monoclinal upturn of the basin is interpreted to result from the rotation and limited backthrusting of the sediments in front of a south-directed, imbricate basement thrust wedge which formed a triangle zone beneath the basin margin. Reactivation of Mesoproterozoic thrusts took place during the Middle Palaeozoic Alice Springs Orogeny, because Late Devonian rocks occur in the monocline. For the northern margin of the Officer Basin (seismic line 93AGS01) a very similar triangle zone, due to thrust wedging in the basement, produced the upturned Officer Basin succession above a steeply south-dipping backthrust. Because Cambrian rocks occur in the monocline, we infer that this deformation was also due to the reactivation of Mesoproterozoic thrusts during the Palaeozoic. Farther east, in the eastern Officer Basin, foreland basin sediments of Devonian age indicate that movements on this thrust system occurred during the Alice Springs Orogeny.

In contrast to the thick-skinned deformation that dominates the region, in the central to southern Amadeus Basin, deformation during the Alice Springs Orogeny is essentially thin-skinned, and confined to north-directed thrusting within the sedimentary succession. A planar south-dipping structure, that occurs at the southern end of seismic line BMR85.1E, does not appear to cut the Amadeus Basin sediments and is interpreted as a Mesoproterozoic thrust fault.

Geophysical Basement Elements Map of Australia: Implications for Crustal Tectonism in Central and Southern Australia

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Australian Geological Survey Organisation

Abstract

AGSO is producing new geophysical basement tectonic elements map of Australia. The coherence between magnetic and gravity anomalies allows us to delineate major tectonic domains. Two main boundary types are recognised. The first type shows a change in trend or pattern indicating a structural domain boundary. The second type shows a gross change in field magnitude indicative of a change in upper crustal material, as well as structure. Most exposed geological boundaries correlate well with these boundaries of the basement elements. Various criteria imply relatives age of magnetisation and 'cratonization' of crustal elements. Known geology was used to differentiate between first and second order boundaries and to constrain the interpretation. The map shows magnetic boundaries, gravity boundaries and interpreted tectonic boundaries at the basement surface.

The map allows us to track geological provinces underneath sedimentary cover and to begin to recognise different types of crust with different relative age.

The poster will focus on the implications of the map for crustal tectonism in central and southern Australia. It will include a new regional interpretation of the geophysical domains in these regions.

Results of Recent Seismic Acquisition Trials and Near Surface Correction Comparisons in the Cooper and Eromanga Basins

J.R. Hughes and N.A. Fitzgerald

Santos Ltd

Abstract

The economic constraints brought about by low oil prices make it necessary to maximise the structural and stratigraphic resolution of our seismic data while still being subject to these economic constraints. Thus, whenever any new technology or procedures become available, the cost impact of any parameter changes must be carefully considered against the potential technical benefits achieved.

This paper reviews some of the acquisition trials carried out during 1989–1994 and discusses the impact of those trials on the current acquisition parameters utilised in the Cooper and Eromanga Basins. The modification to parameters and procedures brought about by these trials has seen the productivity of seismic crews increase from 1.36 km/chg hr in 1988 to over 1.85 km/chg hr during 1992–1994. Thus, average monthly production in excess of 400 km/crew month in 1988 has increased to 550–600 km during the last few years, with the remarkable totals of 651 km and 665 km achieved in July 1993 and March 1995 respectively.

The main acquisition parameters analysed include group interval/receiver array length and source effort. The opportunity to use 60,000 lb vibrators is considered to have given a 10–15 Hz increase in bandwidth at the high frequency end. This means that the previously perceived 65 Hz ceiling, which was considered to be caused by high transmission losses in the shallow section (Q = 25), is no longer restricting the bandwidth.

Further investigations into static control techniques have demonstrated that the refraction method has been unable to match the results gained from upholes, whereas subsequent upholes drilled to check residual static profiles generally add confidence to the use of residual statics tied to upholes.

Keywords – Cooper/Eromanga; shorter group intervals; increased bandwidth; heavy vibrators; refraction statics; seismic recording productivity.

Can Linear Inversion Achieve Detailed Refraction Statics?

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Abstract

In recent years, generalised linear inversion or GLI, has been used to process seismic refraction data in order to determine the long wavelength statics correction not adequately addressed by residual statics routines. With GLI, a model of the subsurface is refined after comparing

the traveltimes of the model with the field data. This approach of constructing a model which agrees with the data is known as Backus-Gilbert construction. Unfortunately, it does not produce a unique solution. Furthermore, the forward modelling aspect using ray tracing is of questionable efficacy because of incomplete knowledge of the surface layer velocities as a function of depth and direction, the widespread occurrence of diffractions with irregular refractors, and inadequate spatial sampling. Furthermore, the accuracy of the inversion can be poor with complex weathering problems.

An alternative approach is the formation of linear combinations of the data to generate unique averages of the model. This is known as Backus-Gilbert appraisal, and includes the GRM. However, the spatial sampling employed with most CMP acquisition programs precludes the use of any detailed refraction method, such as a fully optimised GRM approach. Instead a migration distance of a single station separation is used to compensate for the effect of the extended receiver array, to produce an effective CRM model.

The CRM linear averages, also known as time-depths, are converted to a weathering replacement correction, using a ratio which is a function of the ratio of the weathering and sub-weathering seismic velocities. These CRM corrections are within a few milliseconds of the values computed with a fully optimised GRM approach.

Interactive Attenuation of Seismic Multiples in the Radial Domain

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Abstract

In marine seismic surveys, reverberations in the water layer known as multiples obscure primary reflections from deeper geological boundaries. This is especially a problem in areas of the North West Shelf of Western Australia, where the geology of the area can produce very strong multiple events, often with similar NMO velocity to primary events. Because of this lack of velocity discrimination, conventional multiple attenuation methods often fail.

An effective method of multiple attenuation using 1D Feedback Autoconvolution in the Radial Domain has been devised. This does not rely on a velocity discrimination between primary and multiple events, and can be applied interactively via a Motif X11 Graphical User Interface, and with minimal user input.

A radial transform has been written that converts either CMP or shot record data, to make both simple water bottom and pegleg multiples from a horizontal sea floor, periodic on each trace, and is suitable for the application of autoconvolution.

The extension of the radial transform to a dipping sea floor has been modelled using the mathematical modelling package MAPLE, and an approximate solution has been devised.

The technique of successive autoconvolution on each seismic trace in a feedback loop, predicts surface related multiple events, at the correct time, reverse polarity, and theoretically correct amplitudes. In practice a scaling algorithm has been incorporated to match the predicted multiples to the original data.

A program module to apply 1D Feedback autoconvolution on radial transformed data for both horizontal layer and dipping water bottom models has been developed, and applied successfully to both simple water bottom multiples and water bottom peg-legs.

Key words – multiple attenuation, radial transform, dip extended radial transform, autoconvolution, seismic .

A Method for the Removal of Long Period Surface Related Multiples

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Abstract

Traditional seismic processing methods such as CMP stacking and predictive deconvolution often fail in the attenuation of long period multiples. Stacking often fails due to the lack of velocity differentiation between the multiple and surrounding events and because of the amplitude of the multiple reflections. Predictive deconvolution and Event Prediction (DePledge and Uren, 1992) fail because of the non-periodic nature of the multiples and to a lesser extent because of the variation of the wavelet with angle of incidence.

A four step procedure to precondition and attenuate surface related long period multiples has been devised. The first two steps of this procedure solve both the periodicity problem and the variation of wavelet with angle of incidence. The third step, therefore, is the attenuation of the surface related multiples using the standard techniques mentioned above. The remaining step is to reverse the transforms applied in the first two steps.

An example is given to demonstrate the performance of this method on field data. The procedure is simple, fast to apply and gives results superior to other existing techniques.

Keywords – Multiples, Multiple Moveout, Radial Trace Transform, Event Prediction and Predictive Deconvolution.

High Resolution Digital Elevation Models – A New Data Source

Peter W. Holyland

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Abstract

High resolution digital elevation models (DEMs) can now be produced for large areas of Australia. This paper will describe the method of producing DEMs and some of the applications.

The change in technology which has made possible routine generation of height data for large areas, is soft photogrammetry. In the past, the method of determining height was by matching points on two airphoto stereopairs. This was accomplished manually which made for a tedious and time consuming process. The advent of computer software that can match features on stereopairs has meant that DEMs can be created much more quickly.

The procedure is to scan the diapositives of the air photographs with a geometrically accurate scanner at high resolution (15-30 microns). This will give a pixel size of 1.5 metres for a 1:50,000 scale photo. Internal and external distortion is then removed from the scanned images by internal, relative and absolute orientation procedures. The images are then resampled as epipolar pairs. The final procedure is to automatically match common features on both of the stereopairs. Changes in the X parallax give the height or Z value.

The DEMs are accurate to within +/- 1 pixel i.e. 1.5 metres for standard 1:50,000 scale photography or 25 cm for 1:10,000 photography. This high resolution allows for a number of novel applications, including:–

- identify topographic anomalies associated with mineralisation (e.g. kimberlite lows, silicified highs)
- georectify photographs to produce orthophotos
- 3D visualisation, 3D Photomaps#, and terrain draping
- structural analysis using shaded relief images
- landform analysis including palaeo surface reconstruction
- slope vector maps for soil sampling and geochemical dispersion
- drainage maps and drainage divides for stream sampling programs
- height corrections for high resolution gravity surveys

Images for these applications will be shown for the Laverton 1:50,000 sheet area in Western Australia.

Key words – Digital elevation models, orthophoto, landform analysis, mapping and sampling base maps.

Use of Magnetics for the Location of Environmental Contamination

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Abstract

ADI Services, in conjunction with the Geophysical Research Institute of the University of New England, have been utilising the TM-4 Imaging Alkali-Vapour Magnetometer to locate and validate the presence of buried ferrous items in contaminated areas. Unlike many conventional systems, the TM-4 enables many conventional systems, the TM-4 enables the rapid collection of high resolution magnetic data. The data can be displayed as colour images and interpreted semi-automatically and/or manually. Flexibility within the TM-4 system enables irregular blocks to be surveyed without requiring the user to know the exact beginning and end coordinates of the survey lines.

Two case studies are presented which demonstrate the effectiveness of high resolution magnetic surveys for contaminated site assessment. The first case study shows how the TM-4 system has been used for the detection of unexploded ordnance, associated ammunition components and fragmentation. The objective for the second case study was to locate one edge of a former waste burial pit which was known to contain significant quantities of ferrous waste. The contrast in the total magnetic field between the burial pit and the surrounding bedrock was easily recognised.

Key words – high resolution, magnetics, buried waste, environmental contamination.

The GRI-Helimag System – a Multisensor, Airborne Array for High Definition Magnetic Mapping

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Abstract

Research and development of magnetometer technologies that meet the standards of unexploded ordnance detection has resulted in new strategies that will redefine the practices presently used in airborne geophysics. Exposure to potential litigation if geophysical methods are not properly applied is an unfamiliar threat to the resource exploration geophysicist. It is a real threat when geophysical methods are applied to the detection of hazardous materials such as unexploded ordnance and industrial waste.

A poorly conducted exploration survey may miss a target or provide uninterpretable data. Such incompetence is rarely recognised. Through a combination of ignorance and short term economic expediency, the acquisition practices of most mineral exploration surveys could be deemed negligent for ignoring available information if the explorationist was ever made accountable.

When all available information is to be measured, economic issues dictate that this be acquired most efficiently. It is possible to determine the elevation at which the signal-to-noise ratio (signal from the exploration target and noise from geological and instrumentation sources) is a maximum. The optimum survey elevation then determines the most efficient sample interval and survey line spacing. The computation of this elevation requires knowledge of the instrument system noise, the assumed depth of weathering or target cover, and the simple geometry of the target (contact, pipe or horizontal sheet). It also requires a representative measurement to be made at a known elevation above ground of the magnetic noise due to sources near the surface. The optimum elevation and relative degradation either side of the peak can be surprising.

For example, in geological mapping the target is a pattern of contacts. Assume that the depth of cover is 20m, the instrument noise is 1 nT and the ground noise at 1m elevation is 5 nT. The optimum sensor elevation is 2.5m. If however, the instrument noise is reduced to

0.1 nT then the optimum elevation is 5m and the S/N ratio has improved eight times

A helicopter mounted, transverse magnetometer array which embodies the design features for optimum data quality at minimum acquisition cost has been built. A patented digital compensation system has reduced the system noise to below 1 nT. With this system it has become routine to fly the sensors at the optimum ground clearance and line spacing, vegetation and buildings permitting. Comparing the data quality of a GRI-Helimag survey with that from an industry standard fixed wing survey highlights the virtues of measuring all available information. While the explorationist may never become accountable for targets not detected, the economic advantages of interpreting the best available data will become self-evident.

Key words – Airborne magnetic survey, explosive ordnance detection, industrial waste, mineral exploration, multi-sensor, survey specifications.

Native Title Horizons

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Abstract

The movement among Australian Aboriginal and Torres Strait Islander groups throughout the nation for Land Rights is developing apace since its formative co-ordination in the 1970's. Momentum gathered slowly at first, yet gradual recognition for and establishment of Land Rights has evolved since that time. An increasingly concerted approach legitimately involving both the legal and political processes is assurance to the Australian Community of sustained persistence in Land Rights claims.

Many setbacks were inevitably experienced by those advocating increased Land Rights, as our young and conservative structures of government grappled with unfamiliar and usually distant issues. Milestones important to the movement and to the nation as a whole were achieved, however, notable among which are the Northern Territory Land Rights Act, Aboriginal Lands trusts and both State and Commonwealth indigenous heritage protection legislation. Developments in the Criminal Justice systems have increased sensitivities to indigenes, and the High Court's now famous Mabo decision precipitated the Commonwealth Native Title Act ('NTA'), which provides statutory recognition and protection to native title where its continued existence can be ascertained.

The existence of native title in Australia was legally recognised by the High Court in its historic Mabo No. 2 judgment of 3 June 1992. 'Native title' is a shorthand expression used to describe those activities pursued by native peoples in connection with their traditional lands, in accordance with traditional law and custom. It could be extinguished in many ways, and once extinguished cannot be revived. The Commonwealth enacted the NTA after an intense public debate waged in the press throughout 1993, and for most purposes, it commenced on 1 January 1994. The NTA recognises and protects native title, enabling its future extinguishment in only limited cases.

Land Rights obtained by establishing claims to native title under the NTA are regarded as relatively tenuous. Non-indigenous Australians continue to be perplexed and suspicious about native title. Many perceive native title alone as a new threat to the stability of established land uses, rather than the broader horizon of Land Rights claims which has been and will continue to be the core activity. By contrast, Land Rights advocates view native title as merely one more advance along the road to indigenous autonomy. That autonomy includes separate economic, legal and political divisions for indigenous people. Consequently, there are many other theories and analyses waiting to be expounded in the courts which those advocates hope will succeed in increasing the scope for legal recognition of Land Rights. Well resourced efforts to achieve those goals are at advanced stages of preparation for Court hearings, pressure on politicians for more legislation and internationally in the United Nations. All of these have the capacity to expand native title concepts well beyond the law as it is presently understood from Mabo and the NTA. Australia is only at the beginning of the evolution of legal recognition of native Land Rights.

Consultation, exploration and some practical implications

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Abstract

In looking at various evidence of the year and a half just gone, some commentators have suggested that the arena of Native Title disputation does not offer much hope for Aboriginal and non-Aboriginal reconciliation. "Responses to the Native Title legislation have generally been marked by confusion, acrimony and a messy relationship that exists between the States and the Commonwealth in relation to land-use management".[1]

Access to land for mineral exploration and mining is a key issue for the mining industry and all Australians. Nearly all exploration and mining occurs on someone else's land regardless of the type of title operating over that land. On these areas the industry is guided by established procedures. Native Title introduces an additional layer of land tenure and a set of procedures that have yet to be fully established or easily understood.[2]

The additional uncertainty created as a consequence of the future grants process means that new processes of communication and consultation with Aboriginal and Torres Strait Islanders must be considered in determining the impact of mineral title on Native Title in areas where Native Title has not yet been determined.

What it all means to the average Australian is more than likely a vexed issue. However, what it means to the mining industry and in this case exploration, is critical. Survival at both the macro and micro economic levels both off and in the mining industry poses a real question. Guidelines to assist the mining industry in dealing with these vexing circumstances have now been developed by different organisations around the country. The results of such development, their refinement and implementation has yet to be seen. Similarly, enlightened Aboriginal and Torres Strait Islander organisations and leadership will

look to the mineral industry for recognition of key factors. The need to create and construct relationships between the mineral industry and the Aboriginal and Torres Strait Islander community is here to stay. The broadening of horizons and the consultation processes undertaken, directly influence the impact that Native Title will have on our industry.

1. Robert Champion de Crespigny, January 1995 paper – Role of Native Title and the Mining Industry
2. Simon Williamson, May 1995 paper – Practical Implications of Native Title

The Geophysics of the Ernest Henry Cu-Au Deposit (N.W.) Qld

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Abstract

The Ernest Henry copper-gold deposit is located approximately 30 km NNE of Cloncurry in northwest Queensland. It contains an indicated resource of 122 Mt at 1.14% copper and 0.55 g/t gold. The deposit is hosted in Proterozoic rocks of the Mt Isa Inlier. The Proterozoic geology is overlain by 40 to 50m of flat lying Phanerozic sediments.

The discovery of the deposit was the result of a geophysically and geologically driven exploration program that was guided by a simple empirical model for the deposit type. Magnetic methods were used to initially focus exploration. Transient electromagnetic (TEM) techniques were used to filter the magnetic target areas. The first drill hole into the deposit intersected economic copper and gold grades.

After the discovery, downhole TEM surveys demonstrated that the initial surface TEM target was due to a supergene layer of mineralisation that in part included a section rich in native copper. It also demonstrated that the bulk of the primary mineralisation did not produce a TEM anomaly. The primary mineralisation is intimately associated with the matrix of a felsic to intermediate volcanic breccia. The matrix to the breccia is rich in magnetite and disseminated sulphide mineralisation. Ground magnetic, gravity and Induced Polarisation methods were used to help guide the delineation drilling of the deposit.

Key words – Ernest Henry, copper, gold, Mt Isa Inlier, magnetics, gravity, transient electromagnetic, induced polarisation.

The Magnetic Signature of Komatiitic Peridotite-hosted Nickel Sulphide Deposits in the Widgiemooltha Area, Western Australia

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Abstract

Wannaway, Mariners and Mt. Edwards are three of many type 1A komatiitic peridotite-hosted nickel sulphide deposits clustered in the Widgiemooltha area, approximately 560 km east of Perth.

Magnetic susceptibility measurements show that the susceptibility of the ore is generally high but is extremely variable, from 4.5 x 10-3 SI units to 269 x 10-3 SI units in serpentinised environments, and 14.9 x 10-3 SI units in talc-carbonate altered environments. Hangingwall ultramafic rocks have a generally high but variable susceptibility depending on the style of alteration. Serpentinised ultramafic rocks have a high susceptibility of 70 x 10-3 SI units, while talc-carbonate altered ultramafic rocks have a low susceptibility of 4.4 x 10-3 SI units due to the respective formation or destruction of magnetite. Footwall basaltic rocks have a consistently low susceptibility average of 0.8 x 10-3 SI units.

Susceptibility-temperature data indicate that ores with a high susceptibility contain monoclinic pyrrhotite and magnetite, and ores with a low susceptibility contain only small amounts of monoclinic pyrrhotite, minor magnetite and abundant, non-magnetic, hexagonal pyrrhotite. Components of remanent magnetisation in the ores and hangingwall ultramafic rocks lie in two dominant orientations. Remanent magnetisations held by pyrrhotite and magnetite at Wannaway and by pyrrhotite at Mt. Edwards are upwardly inclined toward the northwest. Vectors held by pyrrhotite at Mariners and magnetite at Wannaway are upwardly inclined toward the southeast.

Two dimensional magnetic modelling of the Wannaway ore environment indicates that the anomaly over the Wannaway deposit is caused predominantly by the hangingwall ultramafic unit, with a small contribution from the near-surface hangingwall ore. Contact ore makes only a minor contribution to the anomaly due to the depth of the ore below the surface. Although the ore is significantly magnetic, it is difficult to directly detect on magnetic data due to the highly magnetic nature of the surrounding ore environment.

Key words – Komatiitic peridotite-hosted nickel sulphides, magnetic susceptibility, monoclinic pyrrhotite, magnetite, remanent magnetisation, Wannaway, magnetic modelling, direct detection.

Geophysical Surveys for Strata-bound Outokumpu-type Cu-Co-Zn Deposits at Kylylahti, Eastern Finland

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Abstract

Economically the Outokumpu region in eastern Finland ranks among Finland's most important metallogenic provinces. Exploration for Outokumpu-type Cu-Co-Zn-deposits has been carried out in the region for more than 80 years. To date several such deposits have been discovered in a zone covering an area about 4500 km². Three of the deposits were in production and all of them are now mined out. The last mine, Outokumpu, was closed down in 1989.

A later stage of exploration, started in 1979, led to the discovery of the Kylylahti deposit in 1984. This triggered the latest phase of exploration in 1991. The present paper describes geophysics used in this discovery and later studies of the surrounding area.

The relatively small Kylylahti deposit was successfully detected although at this depth of about 500 m. The most successful methods for locating conductive deposit near surface were Mise-a-la-masse, HLEM and Gefinex 400S (Sampo), an EM frequency sounding system developed by companies in the Outokumpu Group. Even though the Kylylahti deposit is sandwiched between thick, conductive layers of black schists it was eventually intersected with some drill holes guided by the above mentioned geophysical surveys, lithogeochemistry and geological reasoning.

Key words – Outokumpu association, copper-cobalt-zinc-deposit, gravity, mise-a-la-masse, EM Gefinex 400s, Finland.

Exploration for Copper-gold Deposits, Sultanate of Oman: A Case History

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Abstract

Copper mining has occurred in the Sultanate of Oman since the 3rd millennium BC in sporadic episodes. Current mining operations and exploration have resulted from recent (post 1970) recognition of ancient mining centres and gossans plus the economic benefits of modern concentrator and smelting processes.

Copper-gold deposits in Oman are inherently low grade and small tonnage in nature (eg. Hayl As Safil 4.3mt @ 1.2% Cu), however, they occur in clusters along predictable structural zones at or near to specific volcanic horizons. The accumulated tonnages, from numerous deposits in close proximity, impacts on mining economics and is one of the reasons why initial exploration was focused near known mineralised zones.

Airborne magnetic (and radiometric) surveys were contracted to map the geology and structure of prospective terrains in Oman and to recommend anomalous zones for follow-up. Magnetic anomalies, close to the Hayl-As-Safil deposit, were chosen for exploration using transient electromagnetic (TEM) and induced polarisation (IP) techniques, plus reconnaissance TEM surveys were undertaken elsewhere in areas of deep cover. Some trial TEM surveys were conducted over the Rakah deposit (3.7mt @ 0.9% Cu and 1g/t Au) to calibrate the methods and determine typical response parameters.

Near Hayl-As-Safil several reconnaissance TEM anomalies, of relatively low – moderate conductivity, beneath 20 metres of unconsolidated cover were delineated by fixed-loop TEM surveys and IP traverses prior to interpretation of drill-hole recommendations.

The drilling programme produced three new copper/gold deposits (totalling 3.8mt) of higher than usual grade (averaging 1.6% copper and 1.02g/t gold) which almost doubled the exploitable ore reserves in the vicinity.

The results vindicated the exploration efforts of the Ministry of Petroleum and Minerals and confirmed the application of modern airborne and ground geophysics to locate new zones of mineralisation.

Key words – airborne magnetic surveys, transient electromagnetic, induced polarisation, Samail Ophiolite, copper-gold mining

The Geology, Geophysics and Mineralisation of Graingers Old Mine and Kohinoor Mine, Kangaroo Island, South Australia

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Abstract

Kangaroo Island is approximately 120 kilometres south west of Adelaide and extends 145 kilometres east west and 55 kilometres north south. Graingers Old Mine and Kohinoor Mine areas lie within the Kanmantoo Group, a regionally metamorphosed and deformed sequence of metasediments of Early to Middle Cambrian age. The sequences strike west-north-westerly to east-south-easterly and dip moderate to steeply to the south. Pb-Zn-Ag-Cu mineralisation is distributed throughout the length of the Kanmantoo Trough with known mineralisation confined to the Carrickalinga Head Formation, Talisker Calc-siltstone and Tapanappa Formation.

The major structural element of Kangaroo Island is the east-west striking Snelling and Cygnet Fault system, which separates thick Kanmantoo Trough metasediments from buried Gawler Craton with Cambrian Kangaroo Island Group cover. The Cygnet and Snelling Faults are approximately coincident with the southern margin of the Gawler Craton and a number of abandoned gold or base metal mines and prospects are scattered along, or close to, these faults. The mineralisation along the Cygnet and Snelling Fault zone is hosted by Tapanappa Formation type sandstone and metasiltstone.

Gravity and Ground Magnetic surveys were carried out over each of Graingers Old Mine and Kohinoor Mine areas. All field equipment and processing software were supplied by Mines and Energy, South Australia. Grid and line traverses were set up at 25 metre intervals over cleared ground, along tracks and through the dense scrub. To calculate elevation measurements for the Graingers Old Mine and Kohinoor Mine areas two different methods were used, barometers and EDM (Electronic Distance Measurement) respectively. A plot of each Gravity survey was produced using Petroseis on a Unix based system. The gravity data was processed by calculating the observed gravity values, and merging them with the elevation and coordinate values. It was found that an increase in elevation of 0.3 metres represents a decrease in the Bouguer value of approx. 0.06 mGal. The Magnetic surveys of Graingers Old Mine and Kohinoor Mine areas were carried out using two Overhauser Magnetometers. The data was corrected for drift by collating the base and field data together on a spreadsheet. Manual contouring of the drift corrected

data for each area was carried out.

From interpretation of the gravity data over Graingers Old Mine area it appears that there is nothing of any significance over the grid area, however it appears that the barometric elevations have effected the data with troughs over areas of lower elevation. The only significant trend appears to be a north-west to south-easterly one and is likely to represent the trend of bedding as well as that of the Cygnet and Snelling Faults in this vicinity. A significant low in the vicinity of the New Shaft in the Kohinoor Mine area may represent the tonnage taken out of the shaft in the vicinity, but also appears to reflect the trend of most quartz veins in the region. A higher zone to the south-west appears to represent the silicified fracture zone seen in the No. 1 Level of Prime's Tunnel.

An interpretation of the magnetics over Graingers Old Mine area shows that most trends appear to be in a north-west to south-easterly direction which represents the trend of both the bedding and the Cygnet and Snelling Faults. Mineralisation reflected in the Magnetic Contours at the Graingers Old Mine area appears parallel to bedding trends and quartz veins and this supports the idea that the mineralisation is syngenetic. Secondary mineralisation of fractures suggests that mineralisation was syntectonic with faulting, with the faults trending in the same direction as bedding. There does not appear to be anything magnetically anomalous in the Kohinoor Mine area.

The Kangaroo Island Aeromagnetic Survey was conducted in May this year by Carnegie Minerals NL. The Graingers – Kohinoor Total Magnetic Intesity Image comprises an area of the K.I TMI Image encompassing both the Graingers Old Mine area and the Kohinoor Mine area. The Graingers – Kohinoor TMI image was processed using ER Mapper and is the compilation of two images, pseudocolour and intensity. From an interpretation of the Graingers – Kohinoor TMI Image, it appears that the Cygnet and Snelling Faults join together in the vicinity of the Graingers Old Mine area and therefore may well be a good representation of the southern margin of the Gawler Craton.

A Geophysical Study of the Koolka Section of the Curnamona Craton, South Australia.

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Abstract

In the Curnamona 1:250,000 Sheet, geological information for the Willyama Supergroup (WSG) rocks which host the Broken Hill mineralisation comes from limited outcrop, drill hole data and geophysics. Five lithological suites have been broadly correlated between the Broken Hill Block and the Olary Block for these rocks. In succession they consist of the Quartzofeldpathic gneiss and migmatite suite (QF&M), the Quartzofeldpathic suite (QFS), the Calcsilicate suite (CS), the Bimba suite (BS) and the Pelite(PS) suite. CS has been previously reported as a magnetic marker unit which underlies the target, economic, non-magnetic, sulphidic BS. The possibility of mapping the boundary between these two suites using the known geology and aeromagnetic data has been investigated for the Koolka South sheet. An objective was to trace the boundary to the unexposed areas of WSG rocks. A further aim was to delineate structural features from the magnetic information.

Susceptibilities of all representative WSG rock suites were measured during an excursion to the Olary Block in March, 1995. Although showing considerable variation between and within measurement sites, the most magnetic unit was always QFS, at least one order of magnitude greater than the CS. Thus the previous definition of CS as the magnetic marker unit has been called into question.

Comparison of the detailed geological map with both the total magnetic intensity map and the vertical gradient map for the region also confirms this observation that the QFS is the strongest magnetic unit. Where the mapped QFS grades into the mapped CS the magnetic signature is scarcely altered. Comparison also showed that both the mapped QFS and CS appear as one curvilinear magnetic anomaly in several places where they were mapped east of the Mt. Howden Mine area. A similar example may be observed in the central part of the recently published Kalabilty North sheet. It is proposed that the QFS is the dominant magnetic unit in the WSG rocks and allows the magnetic map to be used to trace the suite to unexposed areas.

Modelling of linear anomalies in the Mt Howden area arising from QFS required an average susceptibility of similar order as the measurements taken in the field. Differences can be related to the use of a constant susceptibility value whose estimate was based on limited and variable field measurements, possible remanence which has not been measured or variation in model parameters. The results showed the QFS to have variable thickness of between 15m to 440m with an average of 75m. The position of BS may be deduced from this magnetic marker horizon.

Structural features such as faults and shears, folds and intrusions have now been mapped on the basis of the magnetic map. Six curvilinear magnetic anomalies showing folding and refolding of the magnetic marker horizon (QFS) were interpreted and mapped as two antiforms and three synforms in the vicinity of the Mt. Howden Mine. The older fold axes trend NE-SW with a younger one being superimposed on them in the E-W direction. The NE-SW and E-W fold axes are related to D2 and D3 deformation in the WSG rocks respectively. Modelling results using averaged measured susceptibilities over some of the outcrops of these folds indicated a general NW dip.This is interpreted as a domain of overturned folds. A WNW-ESE fault continuing through the Kalabity South sheet disrupted the continuation of the magnetic marker horizon in the northeastern part of the Koolka South sheet. Similar but less continuous faults were also mapped where the QFS was displaced.

The pattern of folded curvilinear anomalies of the magnetic marker horizon has been disrupted by migmatite and intrusion to the south and southwest of the Mt Howden Mine. The migmatite corresponds with the mapped QF&M in the Triangle Hill area. A few susceptibility measurements over the Triangle Hill granitoid showed an average value of 0.0072 SI units. This is higher than the average susceptibility of 0.0024 SI units measured over the Tonga Hill granitoid in the southwest. The outcrop of the granitoid at Tonga Hill is

limited but the magnetic map in the area shows two large semicircular features with similar magnetic character. The eastern part corresponds with the outcrop whilst the western part is laterally displaced by the MacDonald fault.

In summary, a better geological map is able to be produced for the Koolka South area using known geology and aeromagnetic data. This uses QFS as the magnetic marker horizon in the WSG rocks. The horizon is able to be traced to the unexposed areas of WSG rocks. Faults and shear zones, folds and intrusions which are the prospective areas in the WSG rocks are clearly mapped.

A Geophysical Study of the Malbooma Anorthosite Complex, Gawler Craton, South Australia

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Abstract

The Northwestern Gawler Craton is largely unexplored because the paucity of outcrop and complex geology hinders exploration. An anorthosite complex was discovered in 1991 after drillholes, drilled as part of a regional bedrock drilling programme, intersected large amounts of anorthosite at shallow depths. This complex, informally named the "Malbooma Anorthosite Complex", and located 65 km NNW of Tarcoola, contains anorthosite, gabbro, syenite and granodiorites. The absence of outcrop and the availability of high-resolution aeromagnetic data prompted a geophysical study focussed on the main part of this igneous complex.

The results of the aeromagnetic and aeroradiometric interpretation were integrated with studies of petrology and magnetic mineralogy carried out on drillhole samples to produce an inferred subsurface geology map. The main magnetic sources include gabbros, granites and magnetite skarns, most of which are near-surface. An unnamed major fault, extending along the NE-SW direction for several hundreds of kilometres, bifurcates the study area and appears to have controlled the emplacement of the igneous rocks. Initial interpretation indicates dextral strike-slip movement and dip-slip movement with the southeastern side being downthrown.

The Malbooma Anorthosite Complex is interpreted to be a massif-type Mid-Proterozoic complex. It consists of a central gabbro surrounded by less magnetic gabbro to the northwest, with granites to the south, and large volumes of anorthosite in the south and southeast. The central gabbro is highly magnetic and its effective susceptibility ranges from 0.09 to 0.14 SI units. Both magnetic and non-magnetic granites are found and some clearly represent multiphase intrusions. Several faults have been mapped which may have controlled granite intrusion. The anorthosite is in general weakly magnetic and its subsurface limits have been inferred mainly from drillhole data.

The presence of minor amounts of Gawler Range Volcanics implies that the possibility that some of the granites may be part of the contemporaneous Hiltaba Suite cannot be ignored. In addition, a magnetite skarn, formed by alteration of the country rocks by an unroofed non-magnetic granite, is suspected to lie northeast of the main gabbro.

Anorthosite complexes host major mineral deposits world-wide. The existence of anomalous Cu-Zn values together with old gold workings (found in the anorthosite along the major fault described above) makes the Malbooma Anorthosite Complex highly prospective. Several targets have been identified for drilling and a gravity survey has been proposed.

The ubiquitous cover, while not necessarily thick, has hampered previous geological investigations of the Gawler Craton. This particular interpretation is another example of the successful application of aeromagnetic surveys to geological mapping.

The Geophysical Signature of the Batman Gold Deposit Mt Todd Project, NT

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Abstract

The Batman gold deposit at the Mt Todd Project is situated within Early Proterozoic metasediments of the Pine Creek Geosyncline, Northern Territory. It was discovered by the Mt Todd Joint Venture (Billiton Australia and Zapopan) in 1988, following regional geochemical reconnaissance surveys.

The gold mineralisation is contained in a sheeted and stockwork quartz-sulphide vein system hosted by massive greywackes and siltstones of the Burrell Creek Formation.

Although the sulphides (mainly pyrite and pyrrhotite) are less than 5% in volume, the network of quartz-sulphide veins means that the deposit is an excellent conductor and this results in very strong EM and IP responses against a resistive background.

The total volume of pyrrhotite also leads to a moderate (140nT) aeromagnetic anomaly which is distinctive and isolated against a generally low regional magnetic field.

Although any substantial amount of known gold mineralisation in the area has a geophysical response, it also appears that some anomalies (such as to the north of the Batman deposit) reflect sulphide mineralisation which has little or no associated gold. Thus geophysics proves to be a useful, but not totally conclusive, tool for detecting gold mineralisation in this part of the Pine Creek Geosyncline.

Key words – Gold, pyrrhotite, EM, IP, magnetics, Pine Creek Geosyncline

Application of Geophysics to the White Devil Gold Deposit, NT

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Abstract

The White Devil gold deposit is developed within a steeply-dipping altered shear zone (predominantly chlorite schists containing stringers of magnetite) which is hosted by interbedded turbiditic greywackes and siltstones of the Proterozoic Warramunga Group.

Ground magnetic, gravity, and triaxial drillhole magnetic surveys have been undertaken at the deposit to assist in the mapping of the size and extent of magnetite accumulations, ranging from magnetite stringers (2-5% magnetite) to massive magnetite ironstones (>60% magnetite), which occur within the steeply-dipping shear zone.

The extensive database of three component magnetic data (based on triaxial drillhole magnetometer readings from over 200 drillholes) has enabled a three dimensional view of the magnetic field within a complex, highly magnetic ironstone system.

Key words – White Devil, Cu-Au, Tennant Creek, gravity, magnetics, petrophysics, triaxial drillhole magnetometer, 3-component magnetics

The Mt Leyshon Magnetic Anomaly

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Abstract

The Mt Leyshon magnetic anomaly is an intense magnetic low located to the south of the Mt Leyshon Gold Mine. Recent investigations including deep drilling, detailed core logging, petrophysical measurements and magnetic modelling indicate the source of the anomaly to be biotite-magnetite alteration. Geological relationships suggest that this alteration is an early hydrothermal phase of the breccia complex whereas the gold mineralisation is interpreted as post dating emplacement of the breccia complex.

Geophysical Exploration for Gold in Deeply Weathered Terrains, Two Tropical Cases

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Abstract

Basic geophysical techniques were used to characterise two gold deposits that lie within tropical-to-subtropical climates. These two deposits are the Posse deposit, which lies within the Mara Rosa Greenstone Belt of central Brazil and the Syama Mine which lies within the Bago, Greenstone Belt of southeastern Mali. Both deposits were discovered by geochemical techniques but subsequent magnetic and induced polarisation (IP) surveys were used to identify rock types and basic structures and contacts while VLF-EM was used to define more detailed structures associated with both ore deposits. The radiometric method was used at Syama to map the surface expression of sericitic alteration. The success of geophysics in both areas led to an extension of those surveys along strike. The results were used to assist in the ranking of geochemical anomalies.

The desire for additional oxide reserves at Syama and the success of the ground geophysical surveys led to an airborne magnetic and radiometric survey over the mine. The results confirmed the usefulness of the two methods for mapping geology and structure in greenstone belts of West Africa. Additionally, the results were used to identify and rank prospective oxide reserve targets. Initial follow-up soil auguring was successful in identifying significant gold reserves but the success rate declined as the lesser-ranked targets were tested. Potassium concentrations unrelated to the subsurface geology in areas of transported laterite limited the success of the venture.

Although both deposits are covered by a thick mantle of laterite, in neither case did this impede the ability of basic geophysical techniques to provide very useful information relating to lithologies, structure and alteration.

Key words – gold exploration, weathered terrain, laterite, magnetic method, airborne magnetic and radiometric method, VLF-EM, induced polarisation

Geophysical Exploration for Epithermal Gold Deposits: Case Studies from the Hishikari Gold Mine, Kagoshima, Japan

Kazuya Okada

Sumitomo Metal Mining Co. Ltd., Mineral Resources Division, 5-11-3 Shimbashi Minato-ku, Tokyo, 105, Japan

Abstract

Various geophysical techniques were applied experimentally to exploration for epithermal gold deposits. The Hishikari gold-silver deposit, located in northeastern Kagoshima, Kyushu, Japan, was selected for this study. This paper presents the results from these case studies and discusses the applicability of each method in several stages of the exploration; the reconnaissance stage, the detailed follow-up stage and the final stage where the surveys are directed at detecting veins. The results are summarised as follows;

1. A high-gravity anomaly was interpreted as the swollen basement. This subsurface structure was considered to be local doming of basement associated with volcanic activity. Local gravity highs are worthy of notice because the doming of basement might cause fractures;
2. A resistivity cross-section was characterised by three layers; an uppermost layer with high resistivity (100–1000m) corresponding to unaltered volcanic rocks, an intermediate layer with low resistivity (3–8m) corresponding to altered volcanic

rocks and a bottom layer with relatively high resistivity (80–200m) corresponding to the basement. Resistivity mapping and sounding are useful to identify lithologies and structures that may control gold mineralisation;

3. IP anomalies (high chargeability) within the area of low resistivity are the most important indicators of vein zones. For this reason, in the detailed follow-up stage and the final stage of exploration, IP surveys play the most important role.

Key words – Hishikari Gold Mine; epithermal gold deposits; gravity; resistivity; MT; CSAMT; Time domain IP; TEM.

Hydrogeological Evaluation of the Keep River Plains using Airborne Electromagnetic Mapping

Gary Humphreys, Steven Tickell, Desmond YinFoo and Peter Jolly

Water Resources Division of the Power and Water Authority of N.T.

Abstract

The application of airborne methods with follow-up "ground truthing" is a very efficient technique for groundwater studies. Geophysical mapping to differentiate and investigate hydrogeological environments is very different from the more traditional "shapes-of-anomalies" approach, and the geophysical programme must be planned to cover all possible environments. To maximise results, time and money must be allowed for an iterative interpretation process, so the geophysical maps may be related to geology and landforms. On this project, a multi-disciplinary team – geophysicist, hydrogeologist and groundwater modeller – enabled maximum value to be derived from all datasets.

The governments of the Northern Territory and Western Australia are evaluating the feasibility of extending the Ord River Irrigation Area eastward across the Weaber Plains and the Keep River Plains towards the sea. To assist in planning optimum locations for irrigation plots, channels and drains, a joint hydrogeological mapping programme was developed. This included airborne and ground geophysics, drilling, test-pumping and groundwater quality analysis.

After a preliminary geomorphic study using satellite imagery and air-photographs, an airborne electromagnetic and magnetic survey was flown. The EM was effective in mapping water quality and solid-rock geology. Detailed geological mapping around the Sorby Hills base-metal deposit provided a calibration area to evaluate the mapping ability of the EM. Strong conductors mapped exactly the Milligans Formation black shale. The contact between the electrically conductive shale and the more resistive Border Creek Formation sandstone/conglomerate was defined precisely. Using the EM, geology was extrapolated for over ten kilometres beneath black soil cover, in spite of limited geological indication. Subsequent drilling confirmed the shale at several sites. Groundwater located within the conductive shale zones was generally poor quality and electrically conductive. Areas of sandstone outcrop and shallow subcrop were more resistive and groundwater was less conductive. The relationship between lithology and water quality is primarily due to the relative hydraulic conductivities of the weathered layers and the basement rocks.

Near the mouth of the Keep River, high electrical conductivity was attributable to saline groundwater beneath a cover of a few metres of black soil. Historical records of water bores show highly saline water, and the areal extent of the highly conductive zone matched the known tidal limits of the river.

At thirteen sites within the investigation area, joint Sirotem/DC soundings were performed to estimate search depth of the EM. These sites were drilled where possible, and logged with an inductive-conductivity tool. Inversion of the soundings was initially uncontrolled, and then refined using drilling, water quality and soil conductivity (EC 1:5) data. Drilling confirmed that the airborne EM conductance map reflected both geology and groundwater electrical conductivity.

In summary the airborne EM survey proved a very useful mapping technique for defining hydrogeological environments. Using the EM to extrapolate geology between necessarily sparse drillholes enabled confident evaluation of the hydrological properties of the proposed irrigation area. The soundings were a necessary part of the interpretation, since they provided a control on layering.

Supplementary Ground Geophysics for Airborne Electromagnetic Survey over Jemalong-Wyldes Plains Area

Joe Odins

Water Resources Department of NSW

Abstract

Airborne transient electromagnetic (TEM) methods initially developed for the detection of deep conductive targets are continuously being upgraded to improve near-surface resolution of both vertical and lateral conductivity distributions suitable for salinity mapping. However, since it is a combination of location, proximity to the surface, as well as the mobility of saline groundwater that constitutes the problem, it is important to the hydrogeologist to map the complete subsurface structure responsible for the aquifer framework.

A QUESTEM survey was flown over the Jemalong-Wyldes Plains area, New South Wales, by World Geoscience Corporation with the help of funding by the National Soil Conservation Program. The data have been re-evaluated with respect to ground TEM, DC resistivity, GEONICS EM 34-3, shallow drill hole sampling and a comprehensive hydrogeological investigation. Apparent conductance maps were used to guide the location of specific ground surveys, and conductivity-depth sections calculated from the airborne data were used for semi-quantitative comparison with the ground methods.

Comparison with TEM and DC resistivity results showed correlation with true conductivity trends down to ~140m. Comparison with GEONICS EM 34-3 data and electrical conductivity (EC) measurements on drill cutting samples to a depth of 10m also showed good correlation with the near-surface features of the airborne TEM conductivity-depth section.

The significant correlation with both shallow and deep conductivity trends observed in ground surveys suggests that the presentation of complete conductivity-depth sections calculated from airborne TEM, should become routine procedure in hydrogeological investigation.

Radiometric Calibration Facilities and Procedures Established for the South Australian Exploration Initiative (SAEI) Airborne Surveys from 1992 to 1995.

Grant R Koch

Mines and Energy South Australia

Abstract

The Burkitt Hill Dynamic Test Range (DTR) and pad calibration facilities at Whyalla Airport were established as part of the airborne geophysical component of the South Australian Exploration Initiative (SAEI). These facilities assist with the conversion of airborne radiometric counts to equivalent ground chemistry. They provide the means to calibrate different aircraft and acquisition systems, thus enabling different surveys to be integrated and processed. This paper outlines the methodology MESA used to establish the (DTR) and calibration pads. A description of the characteristics of these facilities is provided. The results of the ground gamma spectra recorded over the DTR, calibration pads and the DTR rock sample analysis are discussed. It is acknowledged that problems exist with the current configuration of the calibration pads. MESA is investigating these problems and intends to provide corrections to background measurements in order to improve stripping ratio calculations.

Airborne Radiometric Calibration: An Australian Perspective

Robert Groves

Abstract

Airborne radiometric systems must be calibrated to present data devoid of artifacts peculiar to their acquisition. The IAEA (1991) model of the components of airborne radiation is outlined. This features: aircraft background radiation; cosmic-effect (related to survey altitude); Stripping Ratios which account for the spectral overlap of radiation from different radioelement sources; and height attenuation coefficients, which quantify the effect of Compton Scattering of gamma rays passing through the air. Resources of calibration pads and radiometric test range sites are listed. The facets of calibration procedure are discussed according to their application to the IAEA model. The resulting calibration parameters are used in a process to generate airborne radiometric system sensitivities by comparison of airborne and ground spectrometer data. This method can avoid errors in system sensitivity caused by environmental factors.

Continued Developments in Rapid, Multi-modal Electromagnetic Scattering Algorithms

Ross W. Groom, Peter W. Walker

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Abstract

A major impediment that geophysicists have when trying to understand electromagnetic data is the difficulty of finding suitable numerical modelling algorithms. Leaving aside the issues of user interfaces and seamless interfacing with the data, the geophysicist is still left with several profound problems: Is the modelling algorithm accessible – or is it only usable by specialists working on expensive mainframe computers? Does the modelling algorithm adequately represent the physical nature of electromagnetic scattering – or will some important mode either be underestimated or neglected? Is the model used to simulate the geology applicable to the case at hand – or is it so simplistic that any semblance to the actual geology is purely fictitious?

These three questions are fundamentally important if numerical modelling techniques are to be successfully used by the practising geophysicist. We have developed a number of algorithms which are based on new approximations which address these issues in the sub-propagation regime. These algorithms successfully model the inductive, current channelling and static magnetic polarization modes of the response, as well as their interactions, thus mitigating the worry that the modelling software is representing the physical nature of the response correctly. Furthermore, the resulting algorithms are both rapid and simple enough to run on a personal computer, while allowing structures and sources to be modelled which approach the complexity encountered in the field.

To practising geophysicists, such modelling algorithms allow new possibilities not only for interpreting their data, but also for designing highly focussed survey and follow-up work based on existing data. As modellers, we view these developments as the first step towards fully representing scattering in the sub-propagation regime, and a fundamental step to our understanding of scattering at the megahertz range and beyond.

Simple Geological Models for 3D Magnetotelluric Data

F.E.M.(Ted) Lilley

Research School of Earth Sciences, Australian National University, Canberra, ACT 0200

Abstract

If a one-dimensional (1D) geological structure, in which electrical conductivity varies with depth only, is subjected to a shearing which also affects the electrical conductivity, then the structure will appear two-dimensional (2D) to magnetotelluric measurements made at the surface. A simple interpretation of 2D data is then in terms of a sheared 1D structure.

If the electaric fields at the surface of a 2D structure are rotated or "twisted" by local geological effects, then the structure will appear three-dimensional (3D) to magnetotelluric measurements made at the surface, A simple interpretation of 3D data is then in terms of a 2D structure, above which the electric fields in the ground have been locally distorted.

Putting these two phenomena together shows that 3D data can be reduced to 2D data by a suitable counter rotation or "detwisting" of the measured electric fields, and that the 2D data can in turn then be reduced to 1D data by invoking a suitable counter shearing of the structure.

For the process to apply to observed magnetotelluric data, the above effects should be frequency independent, and the same shearing and electric field rotations should be evident in both the real (in-phase) and the quadrature (out-of-phase) parts of an MT impedance tensor.

The use of Mohr circles to portray observed MT data allows a visual description of the above analysis.

The Standardisation of Airborne Gamma-Ray Surveys in Australia

R.L. Grasty and B.R.S. Minty

Abstract

In the last few years, the use of airborne gamma-ray spectrometry for geological mapping and mineral exploration has shown considerable growth. With this growth there has developed an increasing need to standardise the airborne measurements so that they will be independent of survey parameters. This paper describes the various calibration and processing procedures that have to be followed to achieve this goal through the conversion of the airborne measurements to ground concentrations of potassium, uranium and thorium. One of the most critical steps in this process is in the use of airborne calibration ranges whose potassium, uranium and thorium content must be measured at the time of the calibration flights. Two calibration ranges have been set up in South Australia and Queensland. However, these ranges are radioactively inhomogeneous which has made this calibration task more complicated than it otherwise would have been.

Optimum Channel Combinations for Multichannel Airborne Gamma-ray Spectrometry

B.R.S. Minty and B.L.N. Kennett

Abstract

A new method for determining the optimum channel combinations for reducing the number of channels of data for multichannel airborne gamma(ray spectrometry is developed. The concept of 'generalised' channels, which are the summation of one or more 12 keV data channels that are not necessarily contiguous in the spectrum is introduced. The method uses a simulated annealing minimisation technique to find the best generalised channels such that the sum of the fractional errors for each of the 3 radioelements is minimised. All methods of summing channels lead to an increase in the fractional errors of the radioelements. But the new method is an improvement on existing methods, with the greatest improvement occurring as the number of generalised channels is decreased. A simple method of determining optimum window boundaries for conventional 3(channel airborne gamma(ray spectrometry is also demonstrated. Equivalent thorium fractional concentration errors can be reduced by broadening the conventional ^{208}Tl window.

Short-period Geomagnetic Variations Recorded Concurrently with an Aeromagnetic Survey across the Bendigo Area, Victoria

Peter R. Milligan

Australian Geological Survey Organisation, G.P.O. Box 378, Canberra City, ACT 2601

Abstract

A high-resolution aeromagnetic survey was undertaken by the Australian Geological Survey Organisation (AGSO) across the Bendigo 1:250 000 map sheet area during February to April 1994. For part of this period, high-resolution ground magnetometers were also deployed to test for the way that short-period variations of the geomagnetic field (including micropulsations) affect data recorded by the aircraft.

These ground instruments consisted of the newly developed Helium base-station for AGSO aeromagnetic surveys, and two ring-core fluxgate magnetometers developed by the School of Earth Sciences at The Flinders University of South Australia. The Helium instrument was deployed at the Bendigo airport, in the south-west corner of the area, and the ring-core instruments were buried in the north-west and north-east corners of the area.

Preliminary results indicate that while the phases of continuous Pc3 micropulsations of about 20 s period change little across the map sheet area, the amplitudes can vary significantly. For longer period geomagnetic variations (60 s to 600 s), there are significant differences in the amplitudes and phases of the total-field values measured at different sites. Induction vectors indicate a shallow zone of higher conductivity between the east and west measurement sites.

Data from a single base-station magnetometer subtracted from airborne survey data will not adequately remove the short-period geomagnetic variations of the total field recorded during this survey period — they are an additional noise source in the survey data.

Key words – micropulsations; geomagnetic variations; magnetometer; aeromagnetic; induction vectors.

Geomagnetic Micropulsations: Implications For High Resolution Aeromagnetic Surveys

J.A. Wanliss, and L.A.G. Antoine

Abstract

The noise budget of an aeromagnetic survey is inherently high, having contributions from several

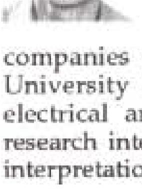
components, for example, instrumentation, the platform, aircraft motion, navigation errors and effects of the temporal variations of the geomagnetic field. Variations in the geomagnetic time series are studied in terms of their contribution to the noise budget of high-sensitivity, high-spatial resolution aeromagnetic surveys. We quantify the electromagnetic and magnetic induction effect and show, from first order approximations, that these are insignificant. An experiment was undertaken to test the spatial coherence of the time varying component of the geomagnetic field. Over a baseline of 17km, and during quiet magnetic conditions, the temporal variations are incoherent within the micropulsation band. This latter result suggests that the limiting factor in resolving the temporal constituent of the noise budget of an aeromagnetic survey is the spatial coherence of micropulsations.

Speakers' Biographies

SECTION FIVE

Ross Adler is Managing Director of Santos Ltd, Australia's leading independent oil and gas company, with extensive exploration and production interests in Australia, Asia, the USA and the UK. Ross is also a director of the Commonwealth Bank of Australia and of QCT Resources Ltd. He is Chairman of the Art Gallery of South Australia, Deputy Chairman of the Australian Formula One Grand Prix Board and a member of the board of the MFP Development Corporation and the MFP International Advisory Board.

Luc Antoine graduated from the University of Cape Town. He received an MSc in exploration geophysics from the University of Rhodesia (Zimbabwe) and a PhD from the University of the Witwatersrand. He has worked many years in mineral exploration for various mining companies in southern Africa and later joined the University of the Witwatersrand where he teaches electrical and electromagnetic methods. His current research interests are in the acquisition, processing and interpretation of high-resolution aeromagnetic data.

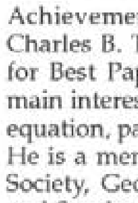


Eiichi Arai received his B.Sc.(1991) in geophysics (DC resistivity method) and his M.Sc.(1993) in geophysics (MT method) from Kyoto University. In 1993 he joined Metal Mining Agency of Japan (MMAJ) and has been engaged in development of mineral exploration technique.

Yuzuru Ashida received a B.Sc. in Geophysics in 1967 from Kyoto University and joined JAPEX (Japan Petroleum Exploration Co., Ltd.) as geophysicist from 1967–86. Since 1986 he has been teaching seismic interpretation and data processing as Associate Professor at Kyoto University. He received a Doctor of Engineer from Tokyo University.

Mark Baigent graduated from Sydney University in 1986 with B.Sc (Hons) after earlier studying Engineering. Mark is currently Data Processing Manager and Chief Geophysicist with Kevron Geophysics since 1987. From 1981–84 he worked for EG&G Geometrics both here in Australia and in the USA, processing airborne magnetic and radiometric data. Mark is involved with Geometrics horizontal gradiometer project and the processing of the nationwide Curie point survey of Japan.

Craig J. Beasley received his B.S. degree in mathematics in 1974 from the University of Houston and completed an M.S. at Emory University in 1977. After receiving his Ph.D. in mathematics from North Texas State University in 1981, he joined Western Geophysical in Houston and served in several capacities in both the Computer Sciences and Geophysical Research and Development departments. He is currently General Manager of Geophysical R&D. In 1985 he was awarded the Litton Advanced Technology Achievement Award and in 1993 received Litton's Charles B. Thornton award. He received the SEG award for Best Paper presented at the 1989 SEG meeting. His main interests lie in geophysical applications of the wave equation, particularly in the areas of migration and DMO. He is a member of SEG, EAEG, American Mathematical Society, Geophysical Society of Houston, ASEG, SIAM, and Southeast Asia Petroleum Exploration Society.



Fabio Boschetti graduated with a B.Sc in Geology from the University of Genoa (Italy). Afterwards he worked for four years in association with the Dept. of Physics, University of Genoa in the field of environmental science, specialising in alternative energy assessment, atmospheric pollutant diffusion and climatology. He currently holds an Overseas Postgraduate Research Scholarship and he is a PhD student in Mathematical Geophysics at Dept. of Geology and Geophysics and Dept. of Mathematics at The University of Western Australia. His Ph.D project is on the inversion of geophysical data using genetic algorithms.

David Boyd carried out and interpreted geophysical surveys in forty eight countries while employed as senior geologist/geophysicist with John Taylor and Sons Mining Engineers, chief geophysicist of Hunting Geology and Geophysics and professor of geophysics at the University of Adelaide. He runs courses in geophysics for geologists for the Australian Mineral Foundation in Australia and overseas. He was the president of the Geological Society of Australia from 1986 to 1988.

Noel Bridge received a BBus (Accounting) in 1987 from the Edith Cowan University (WA) and a diploma from the Institute of Company Directors in 1994. Noel worked for Nelson Parkhill BDO and the Aboriginal Torres Strait Islander – Commercial Development Corporation before joining the Normandy Mining Group in April of this year. Since joining the Normandy Mining Group, Noel has held the position of consultant to the corporate and exploration areas of the Group, particularly dealing in land access issues and Aboriginal matters. His current responsibilities include advising the Group in relation to Native Title, Aboriginal heritage protection, Aboriginal employment and assisting in the matters of the Council for Aboriginal Reconciliation. Noel is also a member of the Institute of Company Directors.

Christopher Campbell obtained his B.Sc. in geophysics and geology from the University of British Columbia in 1972, and subsequently a M.B.A. from the University of Denver in 1986. Campbell has worked as an exploration geophysicist in Canada, Lesotho, the United States, Australia and Botswana. At present, Campbell is attached to the Botswana Geological Survey on a Canadian International Development Agency-sponsored localization project.

Shunhua Cao earned a BSc from the China University of Mining and Technology in 1985 and a PhD from the Australian National University in 1991. He is currently a Research Fellow at School of Earth Sciences, Flinders University of South Australia. His research interests include the study of crustal structure, seismic wave propagation, DC resistivity, geophysical imaging, geophysical data processing and mine geophysics. He is a member of AGU and ASEG.

F.H. Chamalaun graduated from the University of Leiden (Holland) in 1959 with a B.Sc. in physics and geology. He then undertook a Ph.D. study in palaeomagnetism in England and obtained his doctorate from the university of Durham in 1963. Subsequently he continued his palaeomagnetic research as a Research Fellow at the ANU in Canberra. In 1969 he joined Flinders University as senior lecturer in geophysics where he developed research projects in geomagnetic induction studies. They currently have a large array of magnetometers for MV array studies, but are also actively developing a strong MT capability.

David Cole is an environmental planner and lawyer. He holds a Masters Degree in Environmental Studies from the University of Adelaide. David has provided legal advice and consulted to the petroleum industry since 1980. The majority of David's work now involves the provision of advice to the petroleum and mining sectors on compliance with environmental laws. Much of the legal advice provided relates directly to the conduct of field exploration activities in various Australian States and the Northern Territory.

Steven Carroll graduated with BSc(Hons) in Physics from the University of Melbourne in 1990. He is currently undertaking a PhD in Geophysics at the University of Melbourne, and his research interests include travel time inversion, prestack migration and seismic modelling. He is a current member of the SEG and ASEG.

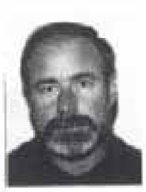
Malcolm Cattach obtained a B.Sc. in 1980 and an M.Sc. in 1986 from the University of New England. His research interests included a study of the Induced Polarisation method with an appraisal of digital IP receivers. Since 1985, Malcolm has been working as Senior Research Associate with the Geophysical Research Institute, UNE, where he has been involved in the design and development of high definition magnetometer systems for mineral exploration and environmental purposes. Malcolm is currently the principal research worker involved in the development of the Sub-Audio Magnetics (SAM) technique which is also the subject of his Ph.D. project. He is a member of ASEG and SEG.

Mike Dentith is senior lecturer in geophysics in the Department of Geology and Geophysics, The University of Western Australia. His main research interests are the structural interpretation of geophysical data and the geophysical signatures of mineral deposits. He has undertaken research of this type on a variety of mineral deposits in Western Australia including the Mississippi Valley-type base metals deposits in the Kimberley, gold and nickel deposits in Archaean greenstone belts and the iron ore deposits of the Pilbara. He was also senior editor of the ASEG Special Publication 7, 'Geophysical Signatures of Western Australian Mineral Deposits'. His current research is on the geophysical signatures of South Australian mineral deposits, in association with MESA.

Sue Downie completed a BSc in Physics from the University of Western Australia in 1981, a Grad.Dip App.Phys (Geophys.) from the Western Australian Institute of Technology (now Curtin University) in 1984, and a Grad.Dip.Computing from Curtin University (part-completed at Melbourne University) in 1991. She is currently completing a MSc (Geophysics) and a Post-Grad.Dip.Comp.Sci. from Curtin University. She has worked for Seiscom Delta United, CSIRO (Division of Mineral and Process Engineering), the Centre for Water Research (UWA) and the Department of Exploration Geophysics (Curtin). She is currently working for Western Geophysical (Research and Development).

Jarrod Dunne completed his B.Sc. (Hons.) in geophysics at Melbourne University in 1992. He is currently continuing his Honours study as a Ph.D. and is sponsored by ESSO and BHPP. The research aim is to characterise and then suppress the strong noise below the Latrobe Group coal sequence in seismic data throughout the Gippsland Basin. He has also worked with magnetic datasets during vacation employment with CRA Exploration. His interests include seismic modelling, inversion and their practical applications in seismic exploration.

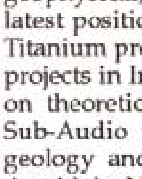
Katherine Edwards is currently studying for a PhD at the University of Queensland, having completed a B.Sc. (Hons) degree in physics in 1992. Her current interests are in linear systems and signal processing, particularly in the area of magnetotelluric data analysis.



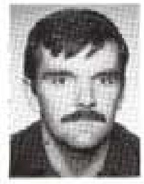
Peter Elliott graduated with a Bachelor of Science (Hons) in Geology and Geophysics from The University of Melbourne. The last two years of study were completed under a cadetship with the Department of Mines (Victoria). He worked as a geologist and geophysicist with the Department of Mines. He then joined the Shell Company (Australia) Ltd where he worked as a regional geophysicist with the Metals Division. Peter was awarded an M.Sc. from The University of Melbourne in 1983. He left Shell in 1987 to join Search Exploration Services Ltd as managing director. In 1991 he started his own company, Elliott Geophysics Pty Ltd, which currently services the minerals industry in Australia, Papua New Guinea and South-East Asia. He is also completing a Ph.D. through Macquarie University in conjunction with the CRC-AMET. Peter Elliott was president of the WA Branch of the ASEG; secretary and business manager of the ASEG Federal Executive; and first vice-president ASEG Executive. Following education at Hutchins School in Hobart, Ted Lilley was awarded a cadetship in geophysics by the Australian Atomic Energy Commission, and graduated B.Sc (Hons) from the University of Sydney. 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 in 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 on measurements of natural electromagnetic induction in the Earth.

Robert G Ellis received a BSc (Hons, 1976) and PhD (1981) in physics from the University of Melbourne, Australia. He has worked as a research associate at the University of British Columbia, Canada (1981–1982, 1987–present) and at the University of Melbourne (1983–1985). His current interests focus on the electromagnetic forward and inverse problems.

Nader Fathianpour has a B.Sc and M.Sc from Tehran Univ., Iran, in Mining Exploration Engineering in 1987 and 1990 respectively. Following graduation, Fathianpour worked as the mining exploration expert in the ministry of mines and metals of Iran particularly in the exploration of Lead, Zinc and Titanium deposits using all geophysical, geochemical and geological techniques. His latest position was as the deputy project manager in the Titanium project, one of the ministry of mines and metals projects in Iran. Currently he is completing a PhD course on theoretical modelling (analytical and numerical) of Sub-Audio magnetic Technique in the department of geology and geophysics, University of New England, Armidale, NSW.



Will Featherstone graduated with an Honours degree in Geophysics and Planetary Physics from the University of Newcastle upon Tyne then undertook a D.Phil in Geophysical Geodesy at Oxford University. In 1992, he moved to Australia and is currently Senior Lecturer in Geodesy in the School of Surveying and Land Information at Curtin University of Technology. Will's research interests are primarily in physical geodesy, gravimetric geoid determination and the Global Positioning System (GPS). He has used GPS for a wide variety of applications, such as monitoring crustal deformation in Greece, and providing elevation control during regional gravity surveys.



Andrew Michael Foley completed his BSc in Geophysics at Macquarie University in 1986 and a BSc Honours in 1988 (part-time). He commenced employment as a Geophysicist with Surtec Geosurveys in Sydney in 1988. He has worked extensively in Queensland, New South Wales and the Northern Territory, as well as Tasmania and Papua New Guinea. In 1991 Foley joined Poseidon Exploration (now Normandy Exploration) Adelaide as a geophysicist. Andrew is involved in software development and research and development of new geophysical equipment being developed by Normandy Exploration. He moved to Perth early this year as a senior geophysicist. His current work areas include Western Australia, Laos, New Zealand, Turkey and Greece. He is currently treasurer of the Western Australian branch of ASEG.

Ross Groom completed a PhD at the University of Toronto in 1988 where he developed a novel decomposition for the magnetotelluric impedance tensor that now enjoys wide application. Following this, he held a number of research positions in industrial, governmental and university institutions. He co-founded PetRos EiKon Incorporated in 1993, and since that time has been actively involved in developing electromagnetic simulation software under a number of projects co-funded by industrial and governmental sponsors.

P. Robert Groves graduated from the University of Western Australia in 1983 with a B.Sc. in Physics and joined Aerodata in August 1984. His role has long been associated with the science of navigation and proceeded from programming microcontrollers for navigation interfaces, to software for airborne navigation using UHF radio beacons... and onward to the development and maintenance of a Differential GPS navigation package. For several years, he performed as Aerodata's Systems Programmer for all airborne data acquisition and navigation systems and undertook research and development as the opportunity arose. His involvement with radiometrics began in 1991, and was renewed in mid-1994. Robert is a member of ASEG, ION & IEEE Computer Society.

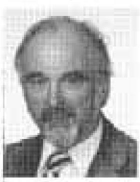
Bob Grasty received his Bsc in Physics from Imperial College, London University in 1961. He completed his PhD in geophysics from London and Cambridge University in palaeomagnetism and the geological dating of volcanic rocks. In 1968 he joined the Geological Survey of Canada and became head of the airborne geophysics section in 1978. His major interest has been in the development of the theory of airborne gamma-ray spectrometry, particularly on the calibration side.

Peter Gunn studied at the Universities of Melbourne, Manitoba (Canada) and Durham (U.K.). He has undergraduate majors in physics, mathematics, geology and geophysics, MSc and PhD degrees in geophysics and recently completed a Graduate Diploma in Applied Finance. He worked worldwide for 17 years with the Elf Aquitaine Group reaching Chief Geophysicist level in both their mineral and petroleum activities. He has also worked Geoterrex in Ottawa, Canada, where he was in charge of their processing centre, BHP Minerals and West

Australian Petroleum. Peter is currently Head of the Geophysical Mapping Section of the Australian Geological Survey Organisation.

Mohammad R. Haidarian received BSc in geology from Tehran University, Iran, in 1972 and MSc in geophysics from Bowling Green State University, Ohio, USA in 1976. Worked with Prakla Seismos for airborne radiometric and magnetic surveys in Uriran, Iran from 1976 to 1978. From 1978 to 1993 Haidarian taught geophysics as a lecturer in Mashhad University, Iran . Since 1993 has been on study leave as a PhD student in the Department of Geology and Geophysics at the University.of Adelaide.

Michael Hallett received a B.Sc. with Honours from The University of Sydney in 1988 and is currently completing a Master of Science part-time whilst working full-time for Geoterrex Pty Ltd as an interpretation geophysicist. Since beginning work at Geoterrex Pty Ltd, Michael has worked on airborne geophysical surveys, travelling to Canada and South America and has been actively involved in the study of groundwater salinity in Australia through airborne geophysics coupled with other related fields. He has published articles for various magazines on the subject and is currently working on a cooperative project with CaLM (The Department of Conservation and Land Management) on a landmark salinity site study in eastern NSW.



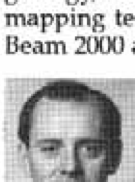
Douglas Hardwick is Manager of Airborne Science at the Flight Research Laboratory, Institute for Aerospace Research, of the National Research Council of Canada. His Geophysical Projects include development of the world's first three-axis aeromagnetic gradiometer, development of advanced aeromagnetic compensation methods and the application of strap-down magnetometers to geophysical exploration. Current projects include development of ultra-precise differential GPS for airborne gravity. He graduated from the Royal Military College of Canada in 1955 as a navy pilot and obtained a BASc in Electrical Engineering from the University of Toronto. He worked on the design of advanced flight control systems in Canada, the US and Germany before joining the National Research Council in 1971.

Aimo Hattula graduated from the Helsinki University of Technology with an M.Sc.(Tech.) degree in 1970. His thesis, entitled "On regional interpretation of geophysical anomalies" dealt with software development for modelling and its use in systematic profile interpretation. He worked as a geophysicist for the Geological Survey Of Finland between 1971 and 1974, for Rautaruukki Oy Exploration 1974–1984 and for Rautaruukki Oy Instruments 1984–1986, and joined Outokumpu in 1986. He is currently Exploration Manager - Geophysics at Outokumpu Metals & Resources Oy. His professional activities have been in both applied and mining geophysics. He is a member of the EAEG, and the Nordic and national geo-societies.

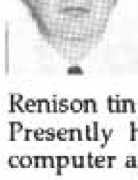
Steve Hearn holds Applied Science (Hons 1) and Ph.D. degrees in geophysics from the University of Queensland, and has 15 years experience in the seismic industry. Since 1990 he has been a consultant with Wavebaud Associates, specialising in borehole geophysics. He holds a fractional appointment at the University of Queensland, and is Software Development Geophysicist with Digicon Geophysical Limited.

Natasha Hendrick graduated from the University of Queensland in 1993 with First Class Honours in Applied Science (Geophysics). She was awarded an Australia-at-large Rhodes Scholarship and spent time as a research student in the Department of Engineering Science at the University of Oxford. Natasha has undertaken vacation employment with MIM Exploration and BHP Petroleum, and is currently working in the special projects group of Digicon Geophysical Limited, Brisbane.

Peter J. Hill is a research scientist in the Marine, Petroleum and Sedimentary Resources Division, Australian Geological Survey Organisation (AGSO) in Canberra. He graduated from the Australian National University (ANU) in 1967 with a B.Sc., and subsequently completed a B.Appl.Sc. (geology) at the University of Canberra and M.Sc. at the ANU. In 1970, he joined AGSO (then BMR) as engineering geophysicist. On secondment to ANARE, he was in charge of Australia's geophysical observatories at Macquarie Island (1973) and Mawson (1975). During 1979-82, he was Senior Geophysicist with the Geological Survey of Papua New Guinea. He joined AGSOs marine geoscience group in 1983, and has since worked on projects of the Continental Margins Program using AGSOs research vessel 'Rig Seismic. He has also had considerable involvement in SW Pacific geomarine research and has participated in a number of international research cruises in this region – investigating seafloor mineral resources, tectonics and other aspects of marine geology, using geophysical, seafloor sampling and swath-mapping techniques such as SeaMARC II, GLORIA, Sea Beam 2000 and Simrad EM12D.



Richard Hillis graduated BSc (Hons) from the Royal School of Mines, University of London in 1985, and PhD from the University of Edinburgh in 1989. After research positions at Flinders University, Adelaide, and at the British Geological Survey, Edinburgh, Richard was appointed Lecturer in Exploration Geophysics at the University of Adelaide in 1992. His main research interests are in contemporary stresses and sedimentary basin dynamics. Richard is a member of ASEG, EAEG, SEG, GSA, PESA, AAPG, AGU and GSL.



Peter Holyland graduated from Trinity College Dublin in 1970. Spent a number of years as an exploration geologist with RGC in Australia. In 1984-87 he undertook a PhD at Queensland University, comparing quantitative observations of fluid flow, deformation, heat and mass transfer at the Renison tin mine, Tasmania, with computer simulations. Presently he directs two companies concerned with computer applications for mineral exploration. Products include Stress Mapping Technology, and Digital Elevation Models.

David Hoskins received an H.N.C. in Electronic Engineering from Portsmouth University and a B.Sc in Geology from The University of Adelaide. He has over twenty years experience in seismic acquisition and processing. He has worked with Delta Exploration in Europe and S.E.Asia, IOSC in France, SONATRACH in Algeria, Petty-Ray in Australia and N. Africa, as Area Manager for both regions and most recently with MESA as a senior geophysicist. He is currently a PhD candidate at the NCPGG carrying out an integrated geophysical study of the Officer Basin. David is a past Chairman of the IAGC (Austral and Cairo Chapters), a member of PESA and SEG.

John Hughes graduated from UCW Aberystwyth, UK, in 1969 with a Bsc (Hons) degree in geology. From 1969 to 1981 he worked with GSI, based in the UK but travelling and working extensively in Europe, Africa and the Middle East. His responsibilities included land and marine processing, interpretive processing, interpretation, computer mapping and synthetic seismogram processing. In 1981 he transferred to Australia as GSI's Land Data Processing Manager and in 1983 joined Delhi Petroleum Pty Ltd as Senior Processing Geophysicist. He transferred to Santos Ltd in 1987 where he is currently responsible for the Operations Geophysics Department. He is an active member of the Australian Society of Exploration Geophysicists, the Society of Exploration Geophysicists and the Petroleum Exploration Society of Australia.

Gary Humphreys has an Engineering degree from University of Western Australia and a Graduate Diploma in Applied Geophysics from W.A. Institute of Technology (now Curtin Uni). He worked with Scintrex as a contractor/consultant for 14 years in Australia and Asia (including China, Japan, Malaysia, Laos and Pakistan), specialising in mineral exploration, groundwater studies and technical training. He joined Water Resources Division in 1993, and leads a team in the application of geophysical techniques to groundwater exploration and evaluation. Current interests include sounding methods and geophysical approaches to estimating groundwater quality and quantity. He is a member of ASEG, SEG, EAEG and IAH.

Nigel Hungerford is the director of Hungerford Geophysical Consultants. From 1980 to 1995 he was the Chief Geophysicist of Billiton Australia (Shell Metals), responsible for the application of geophysics to the company's exploration for base metals, gold and diamonds. Prior to that he worked with BHP's Oil and Gas Division as a seismologist, and in a similar capacity with B.P. in London and Dublin from 1974 to 1977. He obtained his M.Sc. in Exploration Geophysics from Birmingham University in 1974, following employment as a mining geophysicist with Anglo-American in Southern Africa from 1970 to 1973, and as a seismologist with G.S.I. in Saudi Arabia from 1968 to 1970. He received a B.Sc. (Hons) in Physics from St Andrews University in 1968.

Eiji Ishii received a M.E. in Mining Geology from Akita University in 1980. He has worked at Suncoh Consultants Co., Ltd, as a geophysicist. He is a member of SEGJ and ASEG.

John Jackson graduated from the University of Tasmania with an Honours degree in Geology/Geophysics in 1985. He was employed as a geologist undertaking regional mapping as part of the Mt Read Volcanics Project by the Tasmanian Department of Mines. Since joining MIM Exploration Pty Ltd in mid-1987 he has worked as a geophysicist/geologist in north Queensland and the Mt Isa area in both regional and mine scale gold/base metal exploration.

George Jung completed his B.Sc in Geophysics at Monash University, followed by an Honours year in 1991. In 1992, he worked for the Victorian Institute of Earth and Planetary Sciences, developing algorithms for 2D and 3D structural magnetic and gravity interpretation. Currently, he is enrolled as a Ph.D. student at Monash University, investigating seismic properties of fractures. George is a student member of the ASEG.

Abbas Khaksar graduated in Mining Engineering (Exploration) in 1990 from the University of Tehran, Iran 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 PhD student at the National Centre for Petroleum Geology and Geophysics at the University of Adelaide. His PhD research is concerned with the petrophysical evaluation of well logs with particular interest in the influence of reservoir pressure on sonic log response. He is a member of ASEG and PESA.

Stephen Kilty is a graduate of the University Of Western Ontario (Honours B.Sc., Geophysics). He has been involved in the acquisition, processing and interpretation of airborne frequency and time domain electromagnetic surveying since 1975. Steve has been involved in Dighem, and Input/Geotem surveys in Australia, North and South America, Europe, the Middle East and Africa. He was transferred to the Sydney office of Geoterrex when Dighem Surveys & Processing Inc. was acquired by the Geoterrex group in 1994. He is presently Director of Technical Services at Geoterrex Pty Limited in Sydney.

In 1976 **Irena Kivior** obtained her M.Sc. Eng. degree from the Academy of Mines and Metallurgy, Department of Exploration Geology and Geophysics in Krakow. Between 1976–1980 she worked as a mathematician at the Technical College in Walbrzych. Migrating to Australia in 1980, she worked as a geologist with Rockdale Hill and with AFMECO in rare elements and uranium exploration. From 1982 to 1990 whilst with ETSA, Coal Resources Department she was involved in coal exploration, and discovered the Lochiel Lignite Deposit. Additional research undertaken was in the geophysical and chemical properties of coal. Since 1990 she has been a PhD research student at the University of Adelaide holding an Australian Postgraduate Research Award. Her current research integrates geological and geophysical studies of the Polda Trough of the Eyre Peninsula SA as well as studies on the regional crustal structure based on the analysis of potential field data for the entire South Australian region.

Russell Korsch obtained B.Sc.(Hons) and Ph.D. degrees in structural geology and tectonics from the University of New England and then lectured at the Armidale College of Advanced Education and Victoria University of Wellington in New Zealand. He joined the Bureau of Mineral Resources (now Australian Geological Survey Organisation) in 1985 and initially worked on the Amadeus Basin. He has been involved in the geological interpretation of several of AGSO's onshore deep seismic reflection surveys, and is currently Project Leader of the National Geoscience Mapping Accord (NGMA) project 'Sedimentary Basins of Eastern Australia' project within the Marine, Petroleum & Sedimentary Resources Division.

David Leaman graduated with 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 a visiting lecturer in geophysics and structure at the University of Tasmania. He is a member of ASEG, SEG, EAEG and GSA.

Jim Leven graduated from the University of Queensland with a B.App.Sc.(Geophys) Hons in 1975 and with B.Sc. in 1976. After completing a PhD in theoretical seismology at ANU in 1980, he was employed on an AMIRA sponsored project at the University of Queensland until he joined BMR in 1983. In 1984 he was awarded a postgraduate Fullbright Fellowship. During his employment at AGSO (formerly BMR) he has worked on seismic acquisition, processing and interpretation in the Eromanga Basin, the Lachlan Fold Belt, and the Officer Basin. He is currently employed as a Senior Research Scientist working in the North Australian Basins Resource Evaluation project. He is member of ASEG, SEG, PESA, GSA and AGU.

Rod Lovibond has a BSc (Physics,Mathematics) from the University of Sydney and a Graduate Diploma in Applied Geophysics from the University of New South Wales. He joined GSI in 1972 and worked in Australia, the USA and Singapore, mainly as a seismic interpreter, before joining Shell in Perth in 1981. He was transferred by Shell to Holland in 1983, and in 1985 joined Hudbay (BP/Lasmo)in Jakarta, initially as a Senior Staff Geophysicist. In 1991, Rod returned to Australia, joining SAGASCO Resources as the Otway Basin Team Leader. His current position is Manager, Regional Exploration (East), responsible for SAGASCO's exploration activity in eastern Australia. He is a member of PESA and ASEG.

Judith MacDonald is a corporate marketing advisor, Seismic Image Software, Calgary, Alberta, Canada. She entered the oil and gas industry in 1976 and was responsible for marketing and market co-ordination for various major international geophysical acquisition and processing companies. Judith has been recognised by the Canadian Society of Exploration Geophysicists (CSEG) with a Meritorious Service Award and has been heavily involved with their promotional material and with writing for their monthly magazine. She is a member of the SEG and CSEG.

James Macnae is a Professorial Fellow at Macquarie University, and is responsible for the EM interpretation program of the Cooperative Research Centre for Australian Mineral Exploration Technologies. He has wide research interests in exploration geophysics, with most experience in Africa, Canada and Australia.

Tariq Mahmood received his BSc (Applied Geology) in 1988 and an MSc (Structure 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 an MSc in Petroleum Geology and Geophysics has been supported by an AIDAB scholarship with extension of his work towards a PhD supported by the APCRC. Tariq is a member of PESA, ASEG and AAPG.

David Maidment obtained his B.Sc.(Hons) degree in geology from the University of New South Wales in 1991. He then worked for UNSW as a research assistant performing geochronological work as part of AGSOs collaborative Phanerozoic Timescales project. In 1994, he joined AGSO and is currently involved in the Broken Hill Exploration Initiative.

John Main is the group geologist for CRA Exploration. John commenced his career in New Zealand as a geologist in a small silver mine. Following this he worked in South Africa for four years as an exploration geologist. John moved to Australia in 1979 and worked for the Peko Group in Tennant Creek prior to joining CRA Exploration at Broken Hill in 1980.

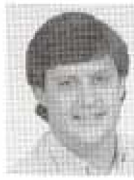
Dylan Mair completed his B.Sc. (hons) in geophysics at the University of Melbourne in 1990. He is currently completing his final year as a Ph.D. student, in a project sponsored by BP Petroleum. The goal of his research is to find methods of improving seismic imaging and velocity analysis beneath irregular seafloor topography, particularly surface reefs and canyons. His interests include statics, dip moveout and prestack migration.

Jannis Makris was born in Greece and originally studied geophysics in Clausthal, Germany. He obtained his Ph.D. in 1971 and was elected professor of geophysics, director of the Institute for Geophysics and chair at the University of Hamburg in 1978. Jannis is a member of various committees on European research programmes. He specialises in marine geophysics with particular emphasis on the development of the WARP seismic survey technique.

Steven Markham worked at Telecom Australia prior to commencing university studies. Commenced Bachelor of Science (B. Sc.) at the Flinders University of S.A. in 1990. Completed Bachelor of Science (B. Sc.) degree majoring in Geophysics in 1992. Completed Bachelor of Science (Hons) degree in Geophysics in 1993 also at Flinders University. Currently undertaking a Master of Science (M. Sc.) degree in Geophysics at the University of Adelaide.

Alan Mauger graduated with honours in geology from the University of Western Australia in 1978. He subsequently worked for Australian Consolidated Minerals using digital classification of Landsat MSS for mineral exploration. From there he worked with CSIRO Division of Mineral Physics in North Ryde, Sydney for four years researching the geological structure of the Sydney Basin. At this time he undertook his masters in remote sensing at the University of New South Wales. In 1984-85 he served the United Nations in Bangkok as a consultant preparing a database on the remote sensing community in the Asia-Pacific region and from there took up a one year foreign expert appointment to the Wuhan Technical University of Surveying and Mapping in China. Alan returned to Australia in 1987 as a geological consultant in WA before accepting a position with the South Australian Centre for Remote Sensing (SACRS) in Adelaide, South Australia. Upon the closure of SACRS in 1993 Alan was redeployed to Mines and Energy, South Australia where he is currently involved promoting the utilisation of remote sensing and spectral analysis throughout the department.

Louisa McCall has completed a four year Bachelor of Science Degree with first class honours (1991–1994), majoring in Geology at the University of Western Australia. Her degree had a geophysical emphasis, including a geophysical-based honours project. She was employed as a geophysical assistant over the summer vacations of 1992-93 and 1993-94 with Western Mining Corporation's Kambalda Nickel Mines/St Ives Gold Mines, where she subsequently undertook an honours project on the magnetic signature of nickel sulphide deposits. She is currently employed by Central Norseman Gold Corporation Ltd. as an Exploration Geophysicist.



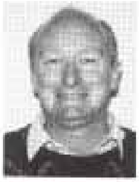
John McGaughey currently works at the Noranda Technology Centre in Pointe Claire, Quebec, Canada. His principal interests are in the development and application of geophysical technology to rock mechanics, ore delineation, and mineral exploration. He graduated with a Ph.D. in geophysics from Queen's University in 1990. Former employers include a mineral-exploration consultant, Chevron Canada, Shell Canada, and Schlumberger.

Peter Milligan graduated from The Flinders University of South Australia in 1975 with a B.Sc. (Hons.) in Geophysics and Geology, and a Dip.Ed. in Education. He subsequently studied for a Ph.D. degree in Geophysics at Flinders University. Since 1974 he has also 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 Geophysical Observatories and Mapping Division, where he is now a Senior Geophysicist. Research interests are in the fields of Geomagnetism and in image processing of potential field data. He is an ACT committee member of ASEG.

Brian Minty received a B.Sc (1976) in mathematics and physics from Rhodes University, a B.Sc (Hons) (1977) in geophysics from the University of the Witwatersrand, and an M.Sc (1982) in exploration geophysics from the University of Pretoria, South Africa. He currently works as a research scientist for the Australian Geological Survey Organisation whilst studying part-time towards a PhD with the Research School of Earth Sciences, Australian National University, Canberra. His research interests relate mainly to the acquisition, processing and presentation of airborne magnetic and gamma-ray spectrometric data.

Noll Moriarty graduated B.Sc.(Hons) in geophysics from Adelaide University in 1974 and via external study M.Sc. (Hons) from Macquarie University in 1989. During 1974-81 he taught at secondary schools in South Australia. Between 1982 and 1990 Noll worked as a project geophysicist in the Cooper-Eromanga Basins for Delhi Petroleum Pty. Ltd. Currently he is employed by Oil Company of Australia Limited as an exploration supervisor for permits in the Otway and Eromanga Basins. Noll is a member of ASEG, SEG, EAEG, AAPG and PESA.

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 of the development project of the high resolution seismic survey for coal resource and is a member of SEGJ and ASEG.



Andrew Newland Senior Geologist, BHP Engineering Geosensing Group Andrew graduated from Macquarie University, Sydney, with a BA(Earth Sci) and from the University of Wollongong with a MSc(Hon) by research on seismic techniques for coal exploration. He worked for Kembla Coal and Coke as a mine geologist from 1974 to 1987. Since 1987, he has been working for BHP Engineering Geosensing Group, offering seismic and other geosensing services for mine planning and geotechnical engineering.

Joe Odins graduated from the University of NSW with a B.Sc. degree in physics and mathematics, a Grad. Dip. App. Sc. (Geophysics), and an M.Sc. on the application of seismic refraction to groundwater exploration. Currently working with the Water Resources Department of NSW, he heads a small group dedicated to the geophysical mapping and evaluation of the groundwater resources of the State. His main interests are shallow seismic, electrical, electromagnetic and borehole logging techniques. He is currently working on the application of airborne transient electromagnetic sounding and shuttle based radar to groundwater salinity mapping. He is a member of the ASEG.

Kazuya Okada received his B.Sc. in geophysics (seismology) in 1983 from the Kyoto University, Japan. Okada joined Sumitomo Metal Mining Co., Ltd. as an exploration geophysicist in 1983. His main field is mineral exploration and remote sensing. He is a member of ASEG, ASPRS, EAEG, SEG, SEGJ and The Remote Sensing Society of Japan.

Patrick Okoye received his B.Sc. degree (1984) in physics and Astronomy, and his M.Sc. (applied geophysics 1989) from the University of Nigeria. He then moved to Australia and gained his PhD in exploration geophysics from Curtin University of Technology, Perth, in 1995. From 1986 to 1988 he was employed by the Department of Physics, University of Nigeria, as a graduate assistant. Between 1988 and 1991 he lectured at the Federal polytechnic, Oko, in the Department of Sciences. Currently, he is a Senior Research Fellow with Curtin University and is presently conducting a pilot project for the Australian petroleum Co-operative Research Centre (APCRC). His main research interest is in the area of lateral or spatial resolution in anisotropic media. He is a member of the SEG and ASEG.

Andrew Oldham graduated from the University of Wales with a Bsc (Joint Hons) in Oceanography and Marine Biology in 1980. After spending six years on seismic acquisition field crews in North Africa and Australia, he joined Santos Limited as an interpreting geophysicist. He is currently working on the Lake Hope and Gidgealpa 3Ds from the South Australian sector of the Cooper Basin.

Anna Oranskaia graduated with a BSc in geology and exploration geophysics from Moscow State University in 1988. From 1988 to 1992, she worked as a geophysicist with Marine Oil and Gas Geophysical Prospecting Company on Sakhalin Island, Russia. Her duties included data processing and interpretation of marine gravity and magnetic data. Anna migrated to Australia in 1993 and studied at the University of Adelaide where she graduated with a Bsc (Hons.) degree in geophysics in 1994. Currently she is employed as a geophysicist with the Department of Energy and Minerals of Victoria. She is involved in the interpretation of aeromagnetic and aeroradiometric data for mineral exploration.

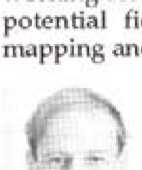
David Ormerod, Seismic Stratigrapher, Graduated from Melbourne University with Honours in Geophysics. 1988 to 1991 Geophysicist with Petrofina Australia working on the FINA operated VIC/P20 block in the Gippsland Basin and subsequently on New Ventures in the Beagle and Bonaparte Basins. 1991 to present Exploration Geophysicist with BHPP Australia Division working in the Duntroon Basin and subsequently in the Timor Sea. Specialist skills in seismic stratigraphic interpretation using a sequence stratigraphic approach to generate structural and stratigraphic leads/prospects. Detailed analysis of reservoir seismic characteristics using geostatistics, outcrop and modelling. AVO and Inversion analysis for reservoir prediction.

Derecke Palmer is a senior lecturer in geophysics at The University of New South Wales. He graduated from The University of Sydney with a BSc with first class honours in geophysics in 1967. He was then employed at the Geological Survey of New South Wales as a senior geophysicist, where he developed the generalized reciprocal method for interpreting seismic refraction data, and later, high resolution seismic reflection methods. In 1976, he obtained a MSc from Sydney University for his development of the GRM, which was subsequently published as an SEG monograph in 1980. He completed a more comprehensive book on exploration refraction seismology in 1986, at the invitation of Geophysical Press. In 1992, he was presented with the Grahame Sands Award for Innovation in Applied Geoscience by the ASEG for his work on the GRM. His current interests includes seismic refraction and reflection methods, and anisotropy.

Geoff Pettifer obtained his BSc in Physics and Geophysics from the University of Melbourne in 1968 and a Graduate Diploma in Applied Geophysics from the University of NSW in 1969. He worked in BMR initially in regional geophysics and then in engineering and groundwater geophysics. In 1977, he continued this work in the Geological Survey of Papua New Guinea. He joined the Geological Survey of Victoria in 1980 and is currently employed as a Senior Geophysicist in the Victorian Department of Agriculture, Energy and Minerals. His present interests include basin studies geophysics, information systems, image processing and environmental geophysics. He is a member of the ASEG, SEG, PESA, and IAH and is Editor of ASEG Preview.

Timothy Pippett, Manager Sub Surface Imaging, ADI Services, NSW, Australia. Timothy has a diverse background in Geophysics in such areas as consulting, contracting, instrument sales and instrument manufacture. His field of competence relate mainly to environmental contamination, GPR, frequency and time domain EM, seismic refraction and reflection, and radiometrics.

Shanti Rajagopalan graduated in geophysics from Osmania University, India, in 1984. She worked on the interpretation of the Kanmantoo Trough from aeromagnetic data for her PhD from the University of Adelaide. Shanti went on to work with the Airborne Geophysics Group at the National Geophysical Research Institute (the Indian equivalent of AGSO). She returned to Australia in 1991, and worked briefly with AGSO, before going on to teach exploration geophysics at the University of Adelaide. She is currently working for CRA Exploration. Her major interests are in potential field theory and application to geological mapping and mineral exploration.



Timo Rekola received a M.Sc degree in 1972 at the Helsinki University of Technology. He worked as a geophysicists for Finnprospecting Ky between 1972 and 1974. In 1975 he joined Outokumpu Exploration where is now responsible for volcanic massive sulphide exploration in Finland. His main exploration interests are in methods for detection of high grade massive sulphide ore, drillhole geophysics, petrophysics, structural modelling and integrating geodata in geology and geophysics.

Michael Roach received his B.Sc. (Hons.) in 1987 from the University of Newcastle and Ph.D. in geophysics from the University of Tasmania in 1994. He joined BHP Research as a trainee in 1979 and transferred to BHP Collieries in 1981 were he worked on coal exploration in the Hunter Valley including surface geophysical and in-seam seismic surveys. Michael is currently a research fellow at the University of Tasmania. His main research interests are in the processing and interpretation of potential field data and in petrophysical measurements.

Suzanne Roberts completed a Bachelor of Applied Science in Applied Geology in 1992 at the University of South Australia. She worked with Mines and Energy, South Australia, SAGASCO Limited and the Engineering and Water Supply Department during University vacations. During 1993 and early 1994 she worked on short term contract with Mines and Energy, South Australia before returning to the University of South Australia in 1994 to undertake a Bachelor of Applied Science (Honours) in Applied Geology (& Geophysics). Suzanne has worked for Western Geophysical Australia in their Adelaide office since December 1994.

James Robertson received a BSE in civil and geological engineering from Princeton University in 1970 and a PhD in geophysics from the University of Wisconsin in 1975. He joined ARCO in 1975 and has held technical and management positions in both ARCO's US and international E&P divisions. He is currently exploration vice president for Asia and Latin America. James has been active in the Society of Exploration Geophysicists for more than 20 years. He received SEG's Best Paper in Geophysics Award in 1985, served as SEG Distinguished Lecturer in 1988 and was technical program chairman of the 1989 SEG Annual Meeting in Dallas. He is the 1994–95 President of the Society of Exploration Geophysicists.

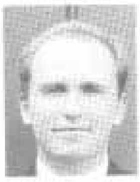
Stuart Robinson obtained an Honours Degree from Macquarie University in 1973 majoring in geophysics, subsequently he received a Master of Science Degree in geology from James Cook University. He has spent over 20 years working for major Australian and International resource companies both in Australia and overseas. Most recently he was Regional Manager WA and SA for the MIM group. After leaving MIM he became Exploration Director of Caldera Resources N.L. He is actively involved with a number of other companies.

David Rout graduated from the University of Auckland in 1992 with a B.Sc and M.Sc (Hons) in Geology. During his study at Auckland he obtained experience in the collection and use of geophysics, particularly gravimetric and aeromagnetic data, in conjunction with geochemical studies to investigate volcanic systems. He is currently enrolled as a Ph.D. student at the University of Western Australia investigating the use of geophysics to resolve the three-dimensional structure of Archaean greenstone belts.

Djoko Santoso received his first degree (Sarjana Teknik, 1976) in Geology/Geophysics from Bandung Institute of Technology (ITB-Indonesia), the Post. Grad. Dipl. in Seismology from International Institute of Seismology and Earthquake Engineering Tokyo-Japan (1979), M.Sc in Geotechnical Engineering from Asian Institute of Technology Bangkok-Thailand (1982). He completed his Doctor of Technology (1990) in Geology from ITB. He has wide range of experience in geological and geophysical exploration activities in Indonesian region. He currently holds the position of Associate Professor in applied geophysics and Head of the

Geophysical Program at the Department of Geology, Bandung Institute of Technology. He also has an appointment as Adjunct Professor at the Department of Geology and Geophysics, Texas A & M University, USA. He is a member of SEG(active member), EEGS, AAPG, IAEG, and AGID.

Daniel Sattel received his Vordiplom from Universitaet Karlsruhe, Germany in 1986, and an 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 went to Argentina for an internship in groundwater exploration. Currently he is enrolled in a PhD program at Macquarie University, Sydney working in electromagnetic data processing and interpretation.



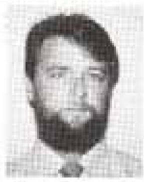
Konrad Schmidt received a B.Sc. in Physics and Geophysics from Monash University. He then completed his Honours year in 1991 at the University of Queensland. His thesis investigations into synthetically focussed resistivity were applied in practice when he developed the Electric Array Logging tool with Auslog. After working with Digicon and Encom Technology he returned to Monash University to work towards an M.Sc. His reaserch topic is investigating possible interpretation tools for three component TEM data. His interests include development of potential field interpretation aids and technology transfer between geophysics and other disciplines.

Michael A Sexton is a graduate of the West Australian Institute of Technology (now Curtin University of Technology). Since 1980 he has worked for Anaconda Australia Inc, P & V Geophysical Services, the Northern Territory Power and Water Authority and Newcrest Mining Ltd (formerly Newmont Australia Ltd). He is currently employed by the Normandy Mining Group based in Townsville.

Russell Shaw, an AGSO (formerly BMR) geologist since 1964, is a principal research scientist with a wide experience in geological mapping. He has a M.Sc. degree in Structural geology and Rock Mechanics (Imperial College, University of London) and a Ph.D. in Geodynamics (RSES, ANU). He is a member of ASEG, AGU and AAPG. His current research interests are in crustal structure, particularly the dynamics of major crustal boundaries, basin development and modelling of potential field data. From his home base in the Division of Regional Geology and Mapping, where he currently provides structural and geophysical support to the Kimberley-Arunta NGMA project, as well as being involved in the structural studies in the Canning Basin and production of the 1:5 000 000 Basement Tectonic Map of Australia based on potential field data.

Cvetan Sinadinovski received his BSc in physics (1981) and MSc in geophysics, both from Zagreb University, Croatia. He was a Visiting Fellow to Fermi National Accelerator Laboratory in Chicago, Illinois (1980), and University of Southern California, Los Angeles (1983/84), while he was employed as a Research Scientist at the Institute of Earthquake Engineering Seismology in Skopje Macedonia. From 1988 to 1990 he worked at Dala General, Australian and at the S.A. Department of Mines and Energy as a software specialist. In 1995 he was awarded a PhD for his studies in geophysical imaging and tomography at Flinders University. Dr Sinadinovski joined the Australian Geological Survey Organisation in Canberra in 1994, where he works as a Professional Officer in the Nuclear Monitoring Section of the Australian Seismological Centre.

Hege R. Smith is of Norwegian nationality and has a Master's degree in geophysics from the Norwegian Institute of Technology (NTH) in Trondheim, Norway. She has worked as a geophysicist with Statoil, Stavanger for 9 years, mainly involved in the interpretation of 3D seismic data from the North Sea and South East Asia. She joined Santos in 1993 and has since worked in the South Australian and Queensland Cooper/Eromanga onshore basins.



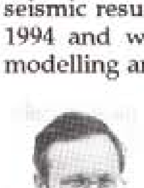
Peter Smith graduated in 1988 from the University of Sydney. From 1988 to 1990 he was employed by Pan Australian Mining based in Brisbane. After the successful take over of Pan Australian Mining by Poseidon Ltd in late 1989 he was transferred to Poseidon Exploration in Perth. In 1992, he was transferred to Darwin where he was employed as the Regional Geophysicist for the Northern Territory. In late 1994 Peter joined Pasminco Exploration where he is currently the Senior Geophysicist servicing regional and overseas projects.

Shane G. Squire graduated from the University of Adelaide in 1994 with a B.Sc.(Ma&Comp) in the faculty of Mathematical and Computer sciences, majoring in Applied Mathematics, Statistics, Geology and Geophysics. In 1995 Shane graduated with a First Class Honours degree in Geophysics, during which he won the award for best paper at the annual ASEG Students night and the Normandy Poseidon Prize for best Honours thesis in Geophysics at the University of Adelaide. He is currently working for Santos Ltd., based in Adelaide, and is a member of ASEG, PESA and SEG.

John M Stanley. Ph.D., University of New England (UNE) Australia, 1975. Director of the Geophysical Research Institute at the UNE, Managing Director of Geophysical Technology Pty Ltd. Lecturer in exploration geophysics, 1978 until 1983. Member of the University Council 1984 until 1987. Ph.D. was awarded for the development of the optically pumped caesium vapour magnetometer. Co-inventor of the Sub Audio Magnetic (SAM) exploration method by which the magnetic and a range of electromagnetic properties of the ground are simultaneously mapped with a total field magnetometer. Winner of the ASEG award for innovation in 1988. Winner of the best paper at the ASEG conference, 1994 for the definitive description of the SAM method.

Ned Stolz graduated from the University of Adelaide in 1985 with an honours degree in geophysics. For the following five years he was employed by CRA Exploration and worked on projects in Western Australia, Northwest Queensland and the Northern Territory. In 1991 he left CRA and began a PhD at the Cooperative research centre for Australian mineral exploration technologies, Macquarie University. His research topic is automatic interpretation of EM data. Ned is an active member of the ASEG and SEG.

Shinichi Takakura received his B.Sc. in geophysics in 1984 from Kyoto University. In 1985 he joined the Geological Survey of Japan (GSJ) where he worked on the interpretation of electromagnetic (EM) and gravity data for the geothermal and mineral exploration. From 1992 to 1994 he was employed by the Japan National Oil Corporation where he worked on the integration of non-seismic data with seismic results for oil exploration. He returned to GSJ in 1994 and works as a senior geophysicist on EM data modelling and interpretation.



Chris Tarlowski received his MSc in physics from Moscow State University in 1971 and his Ph.D. in computational geophysics in 1978 from the Institute of Geophysics, Polish Academy of Sciences. He joined the Division of Mineral Physics, CSIRO, Australia in 1981 and worked for three years on electromagnetics in exploration geophysics. He joined the Australian Geological Survey Organisation in 1985 where he currently hold the position of Research Scientist. His present scientific interests are mainly focused on potential fields theory but also include imaging of geophysical datasets and compilation of aeromagnetic maps.

Edward Tyne has gained extensive experience over 25 years in the application of geophysics to regional mapping and exploration mainly for base metals and precious metals. He is currently Manager of the Data Processing and Interpretation group in Geoterrex Pty Ltd., Sydney Australia and is in charge of the data processing and interpretation operations for Geoterrex airborne magnetic, radiometric and electromagnetic (GEOTEM and DIGHEM) surveys throughout Australasia. In the past few years he has supervised the compilation and interpretation of surveys in southern Africa, South America, North America and Australia. Prior to 1993, he was Principal Geophysicist in charge of the regional geophysical and specialist geophysical research program at the Geological Survey of NSW in the Department of Mineral Resources. He was responsible for overseeing the application of modern high resolution airborne geophysical surveying to geological mapping. He developed a computerised borehole IP logging and spectral IP system and has published on surface and borehole electrical methods for Australian exploration conditions. He continues to give short courses on IP and EM to universities and company exploration groups.

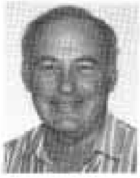
Milovan Urosevic graduated from the University of Belgrade, Yugoslavia with a B.Sc. in exploration geophysics (1980). He received an M.Sc. in geophysics from the University of Houston in 1985. He has worked for the oil industry since 1980, in the areas of seismic data processing and interpretation. He joined Curtin's research group in 1991. His research interests include the use of high resolution seismic data to detect subtle structural and stratigraphic changes. His particular research interest is in the detection of anisotropy by using multi-component seismic data analysis. He is a member of SEG, ASEG and PESA.

Lisa Vella graduated from the University of Sydney in 1991 with a B.Sc (Hons.) in Geophysics. Upon graduating, she worked with Newcrest Mining Limited on a variety of exploration projects, with the majority of her work being for Telfer and Tuckabianna gold mines. In 1994 she joined Western Mining Corporation Ltd. where she currently works as a Geophysicist for Hill 50 Gold Mine NL.

Ewan Vickery is a barrister and solicitor, and partner of Minter Ellison Baker O'Loughlin, the Adelaide office of the Minter Ellison Legal Group, for which he heads the mining, oil and gas division. Admitted to legal practice in 1971, he has held a number of professional positions including National President of the Australian Mining and Petroleum Law Association in 1993. He is presently the SA convenor of the Law Council of Australia's Resources Law Committee and a member of the SA Chamber of Mines Legislation Committee. Principal areas of Ewan's legal practice are mining and petroleum law, company law, business transactions and foreign investment. He has also had careers in the army and in stockbroking, and holds qualifications in electronics and aviation.

Peter Walker completed a PhD at the University of Toronto in 1988 where he developed a robust integral equation solution for a thin plate in conductive media. Following this, he held a number of research positions in industrial, governmental and university institutions. He co-founded PetRos EiKon Incorporated in 1993, and since that time has been actively involved in developing electromagnetic simulation software under a number of projects co-funded by industrial and governmental sponsors.

Michael Webb graduated from Macquarie University in 1979. From 1979 until 1986 he worked with the Minerals Division of ESSO in Eastern Australia and Papua New Guinea. In 1986 he helped set up a contracting and consulting company called Terra Search. He joined Western Mining Corporation in 1988 and is currently working in the Eastern Goldfields of Western Australia.



Steve Webster is a geology (B.Sc.) and geophysics (M.Sc.) graduate from the University of Sydney with in excess of 30 years experience in minerals exploration. He has worked for several mining companies in diverse Australian environments and for the NSW Geological Survey as Principal Geophysicist during the 1980s. He is a member of SEG and ASEG. Since 1988, Steve has been employed in the World Geoscience Corporation group of companies as General Manager of Austirex International Ltd. with duties extending through Eastern Australia, New Zealand, PNG, Malaysia and Japan. Since 1991, he has also been involved with WGCs activities in the Sultanate of Oman.

Peter Whiting received a B.Sc. from the University of Sydney in 1983, a M.Sc. (Geophysics) from Macquarie University in 1989 and a Ph.D (Applied Mathematics) from the University of Sydney in 1994. He has worked for GSI/HGS from 1984 to 1993 as an Area Geophysicist in both Sydney and Perth. He has been with Digicon Geophysical Limited in Brisbane since early 1994 and is currently the Data Processing and Technology Manager for that centre. He is a member of the ASEG and SEG. His main interests are seismic data processing, imaging and inversion.

Gareth Williams graduated from Southampton University with a B.Sc. in Physics (1975), an M.Sc. in Theoretical Physics (1976) and a Ph.D. in Atmospheric Physics (1979). He studied at the University of Colorado as a Fulbright-Hays scholar from 1977–78 and he spent a year at Imperial College, London as a post-doctoral research fellow. He has worked for Digicon Geophysical Ltd since 1981 as a Research Geophysicist and as Research Manager for the Far East division of Digicon. He is a member of the SEG and EAEG. He is currently Research and Marketing Manager for the EAME division of Digicon.

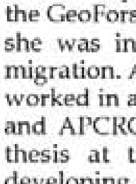
Robbert Willink is a graduate of the University of Tasmania and the Australian National University. He gained experience as a petroleum geologist in Australia, the Sultanate of Oman, and Turkey for nine years and accepted an academic position at the University of Adelaide as Senior Lecturer in Petroleum Geology for one year. In October 1988, Robbert joined SAGASCO Resources as Exploration Manager, and following that company's acquisition by Boral was appointed General Manager, Oil & Gas Exploration of Boral Energy Limited in May 1995.

Alan Willocks graduated from LaTrobe University with a B Sc (Honours) in Geology in 1975 (the first year of geology graduates from La Trobe). After four years of teaching secondary school physics, he joined the Geological Survey of Victoria in 1981. Initially he worked as a geophysicist for five years on groundwater and engineering problems and later magnetic interpretation. He worked as a geologist with the Basin Studies group for two years. He has a keen interest in GIS and information management and joined the Department's GEDIS project in 1989 undertaking the early system design and data modelling. He became Manager of the Geophysics Section in 1991 where he has been instrumental in the implementation of advanced computing techniques within the Geological Survey, the integration airborne techniques and gravity into the geological mapping programme and the acquisition of detailed airborne data to encourage mineral exploration. He is now co-ordinating the geophysical component of the Victorian Initiative for Minerals and Petroleum.

Ken E Witherly graduated from the University of British Colombia, Vancouver, Canada with a BSc in Geophysics (1971). Since then he has worked as a minerals geophysicist, first with Utah Construction and Mining, later Utah International and since 1984, with BHP Minerals. His work experience has covered the exploration for essentially all ferrous and non-ferrous minerals including diamonds on all continents excluding Antarctica. His professional interests include the application of new technology into mainstream exploration and computer methodologies for the display and interpretation of exploration data in four dimensions.

Peter Wolfgram holds degrees in geophysics from the University of Munich and the University of Toronto. Following his postdoctoral work on seafloor MMR he had a brief encounter with geophysical contracting, and then joined the University of Cologne where he was involved in applying LOTEM to hydrocarbon exploration in China and India. He joined Geoterrex Pty Ltd in Sydney as a senior research geophysicist in 1992 and has since been active in airborne EM research and development. Dr. Wolfgram is a member of SEG, ASEG, EAEG, AGU, DGG, and BDG.

Richard Wombell was born in London, England in 1962. He received his BSc and PhD in Physics from the University of London, King's College. During 1989–1990 he was a post-doctoral fellow in the Department of Mathematical and Computer Sciences at the Colorado School of Mines and 1991–1992 in the Department of Mathematics and Computer Science at the University of Dundee. Since 1993 he has been a research geophysicist with Digicon Geophysical, based in East Grinstead, England.



Ping Zhao obtained her BSc in seismic exploration at the department of geophysics in Chengdu Institute of Geology in 1982. After graduation, she worked as an engineer in the State Seismic Bureau in China. She received an MSc in geophysics at Macquarie University, Sydney. In 1993 she started her PhD in the department of exploration geophysics at Curtin on VSP and crosshole seismic exploration. In 1994 she worked as a scientist in the GeoForschungsZentrum at Potsdam, Germany where she was involved in 3D seismic data processing and migration. At the same year she came back to Curtin and worked in a joint project between CSIRO Mining in QLD and APCRC at Curtin. She expects to submit her PhD thesis at the end of 1995. Her main interests are developing new techniques for achieving high resolution seismic images for the purposes of mineral and oil exploration. She is a scholarship holder of SEG and

Michael S. Zhdanov, Professor of Geophysics, Department of Geology and Geophysics, University of Utah, USA. Doctor of Sciences, Ph.D. 1978 – 1990, Head of the Department of Deep Electromagnetic Study, Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN), USSR Academy of Sciences. 1990 – 1992, Head of the Troitsk Branch, Institute of the Physics of the Earth, Russian Academy of Sciences. 1992 – 1993, Visiting Professor, Colorado School of Mines, Colorado. Full Member of Russian Academy of Natural Sciences. Honourary Gauss Professor, Gottingen Academy of Sciences, Germany. Member of Society of Exploration Geophysicists, USA, and of American Geophysical Union. Author of the more than 200 papers, including 10 monographs. The recent monograph is: Zhdanov, M.S. & Keller, G., 1994, The Geoelectrical Methods in Geophysical Exploration, Elsevier, Amsterdam, 873 p.p.

Binzhong Zhou received his BSc (1983) and MSc (1986) degrees in geophysics from Chengdu Institute of Technology, PRC. He received his PhD in geophysics at Flinders University of South Australia in 1993. From 1986 to 1989 he was a Lecturer in Geophysics at Chengdu Institute of Technology. Between 1991 and 1993 he was a Computer Program Designer for Wiltshire Geological Services in Australia. In 1993, he joined Lincoln College at Oxford University as a Research Fellow in Geophysics and Elf Research Centre in London as a Consulting Geophysicist. He is to take up appointment as Research Scientist with CSIRO Division of Mining and Exploration in late 1995. Dr Zhou's research interests are in seismic theory and data processing. He is currently working on seismic modelling, multiple suppression and migration. He is a member of 'SEG and ASEG'.

Jun Zhou received his B.Sc in physics in 1980 and M.Sc in geophysics in 1987 from the University of Science and Technology of China. From 1980 to 1985 he was an engineer with the Aeronautic Research Institute in China and was engaged in researching into optical signal processing and related instrumentation. From 1987 to 1990 he worked with the computer center of the Bureau of Marine Geological Survey in Shanghai, in the area of seismic data processing. Having completed his Ph.D on applying Computerized Tomography techniques to the interpretation of potential field data, he is now working with Geophysical Research Institute (GRI) at University of New England. His major interests of research are in geophysical inverse problems both in seismic and potential field data, application of wavelet techniques and tomographic methods.