Australian Society of Exploration Geophysicists
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Preview

February 1994

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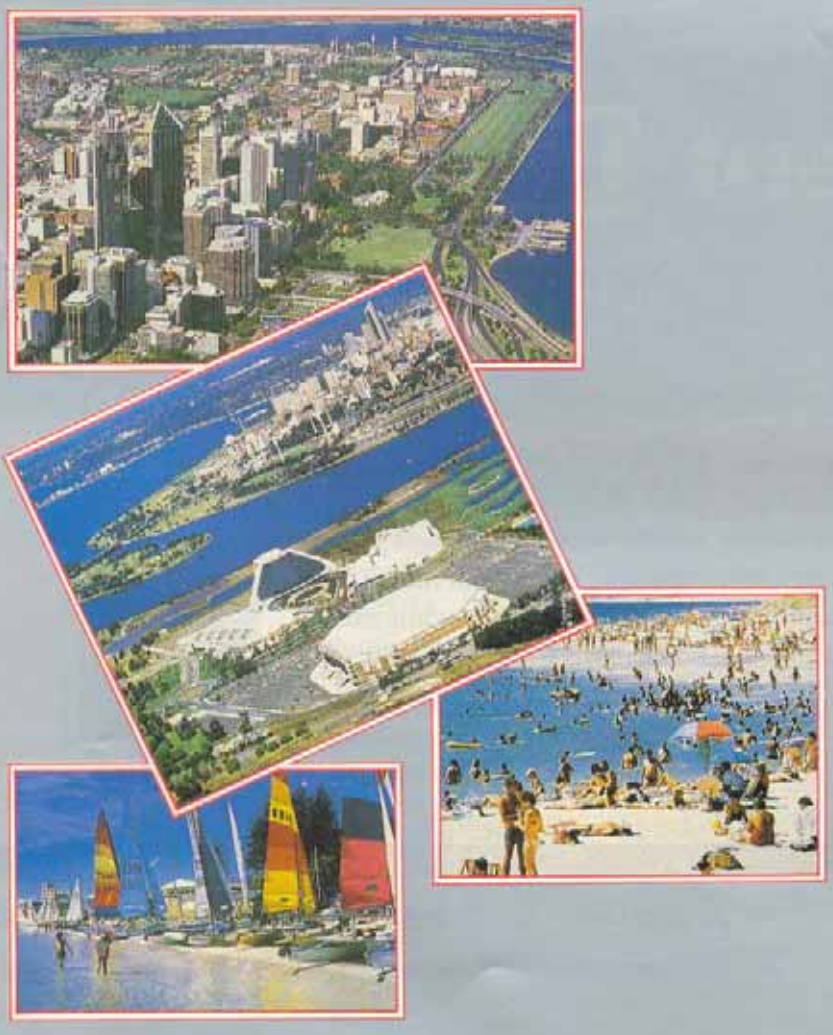
CONFERENCE EDITION

THE AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

10th GEOPHYSICAL CONFERENCE & EXHIBITION

PERTH, WESTERN AUSTRALIA
20th - 24th FEBRUARY 1994

"Increasing the Resolution: Clearing the Haze."



In this issue:

Editors Desk

Welcome to the 10th ASEG Conference and Exhibition and this special Conference handbook/abstracts volume Preview, which represents a coming of age for Preview as the Society newsletter and magazine, for this is the first issue of Preview to be associated with our regular conference. With the Conference Volumes of Exploration Geophysics it will be a permanent record of the Conference. In particular, some 35 abstracts and late extended abstracts and some additional author biographies that did not make it the Exploration Geophysics volume appear in the Conference Preview.

Now regular ASEG Preview readers who couldn't make it to Perth (over half) can have some benefit and feel of the Conference through the pages of Preview. For convenience Preview is divided into Sections as described in the contents page. Each Section has its own detailed table of contents. We hope you find the format accessible and convenient. Enjoy the Conference, in the flesh if you are reading this in Perth, or vicariously, through these pages, if you didn't make it to Perth.

ASEG Conferences are a special 'buzz' and a trip to Perth to sample the hospitality of WA, for most of us working in the eastern States, makes a Perth ASEG conference extra special. Conferences are a unique communal celebration of our professional life and give us the opportunity to catch up with colleagues, new thinking and technologies - in effect as the conference theme conveys - to increase our professional resolve and clear the haze.

Behind the scenes ASEG committees and State Branches are meeting along with the Federal Executive to report on and influence and guide ASEG activities and policy. Your input to ASEG policy is welcomed so grab the time to talk to an ASEG "official" and put your ideas to us.

Meeting at conferences also provides the chance to exchange personal ideas and views. Preview is the vehicle for you to air these ideas and viewpoints. Our regular column: Viewpoint enables members to put their ideas to the Society at large. This issue Bruce Finlayson in the hard world of consultancy, argues for greater cooperation in our professional life. If you have a viewpoint on matters geophysical, take the invitation - write to us and stir up some thinking and debate in the ASEG.

A new occasional column this issue is Mentor which profiles the thinking of major change agents in our profession. We kick off with a distinguished Australian, Dr Ken McCracken 'space turned geo' physicist and ASEG Gold Medallist. Ken has been mentored and has mentored many through his activities especially at CSIRO Mineral Physics and in space science and he talks to Preview about his formative influences and the philosophy behind his work.

Finally thankyou to a hard working team that has put this Preview together, notably Michelle Ainsworth and Don Pearce of Promaco and Janine Cross at the ASEG Secretariat but also Anita Heath, Joe and Alice Odins, Greg Turner, Mike Asten, Ken McCracken and of course numerous contributors. A special vote of thanks goes to the Perth Conference Committee and the Conference Exploration Geophysics Editors: Joe Odins and Richard Facer.

Have a great Conference.

Geoff Pettifer Editor

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Welcome to Perth

Kim Frankcombe

Norm Uren

Welcome to the Tenth Geophysical Conference and Exhibition of the Australian Society of Exploration Geophysicists. Over one hundred papers will be presented during the next four days, with an equal number from the petroleum and mining areas. Most of these will be published as refereed papers in Exploration Geophysics. The Exhibition has sixty exhibitors, evidence of a vigorous exploration industry.

This program is evidence of active geophysical exploration and research in Australia, with twenty five papers coming from overseas authors. This is pleasing to note as it is research that ensures the continued viability of our technology, and sustains our world ranking in exploration. Through technical development and corresponding changes in exploration practices we will be able to ***"increase resolution and clear the haze."***

The ASEG Research Foundation is making an impact on University research. It sponsored Natasha Hendrick's research leading to her winning a Rhodes Scholarship. Research has also been strongly supported by the Australian Government through the newly introduced Cooperative Research Centres programme bringing together industry and government. Four Professorships in Geophysics have been advertised, and in addition one has been appointed at Flinders. It is through partnerships in research between relevant parties that our science will develop. This Conference contributes greatly to the exchange of knowledge and the development of innovation within our profession.

Our Gold, Silver and Bronze Sponsors, Schlumberger, Digicon and Western Geophysical, are leading examples of this. Special mention should be made of an outstanding example of a Western Australian company involved in research and innovation, leading to a dominant position in the exploration geophysics. World Geoscience is the largest airborne contractor in the world, with fourteen aircraft and some forty geophysicists on staff and offices in major cities outside Australia. The Australian Society of Exploration Geophysicists is amassing a significant publication record through Exploration Geophysics, Preview and monographs. Its publications are now included in the Cumulative Index of the Society of Exploration Geophysicists. The previous pioneering efforts of Don Emerson have been recognised with him being awarded the Order of Australia.

You have the opportunity to make the meeting a social, intellectual and business success. Please take it.

Kim Frankcombe
Norm Uren

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President's Piece

ASEG 10th Conference & Exhibition ASEG President's Conference Address

Ladies and Gentlemen, colleagues. The Australian Society of Exploration Geophysicists is 23 years old this year. The Society was formed early in 1970 and formally incorporated on 13th August 1971 in Sydney. In many ways this coincides with the birth of geophysics as we know it in Australia today.

This is not to say that geophysics was unknown in Australia before this time, quite the contrary, but it was a turning point.

In 1929 the Imperial Geophysical Experimental Survey conducted a number of experiments around the country at places such as Chillagoe in Queensland, Gulgong in New South Wales and Gelliondale in Victoria, concluding that geophysics had a role to play in mineral exploration and geological mapping. The Bureau of Mineral Resources was established and began the mammoth task of measuring gravity on a 13km x 13km grid over the entire continent. They also began collecting airborne magnetic data on a sheet by sheet basis at a scale of 1:250,000, including radiometric data in some areas.

Exploration for petroleum was active in the 1950's and 60's in the continental areas of Australia with dynamite crews collecting many line kilometres of basic reflection data for companies such as Hunt Oil.

Then in the late 1960's the Nickel Boom hit Australia. It had already begun in Canada and a number of new developments in geophysics were being applied in the search. The Canadian and American contractors soon realised the potential market for their services and products in Australia. They were introduced through North American companies operating in Australia; they knew that some of the new techniques had been successful in the Canadian Shield and transferred the technology to Australia, in particular, Western Australia.

The Australian geophysical community was very young and we accepted the advice of the Canadian and American experts. I refer to emminent geophysicists such as Barringer, Hallof, Ward, Seigel, Brant and many others; all well known in the profession.

So we spent a few years collecting mile after mile of dipole-dipole I.P. using a 200 ft dipole size and measuring apparent resistivity in ohm.feet/2; we were informed that the Metal Factor was a diagnostic parameter; and we pondered the results of an INPUT survey from an area south of Kalgoorlie.

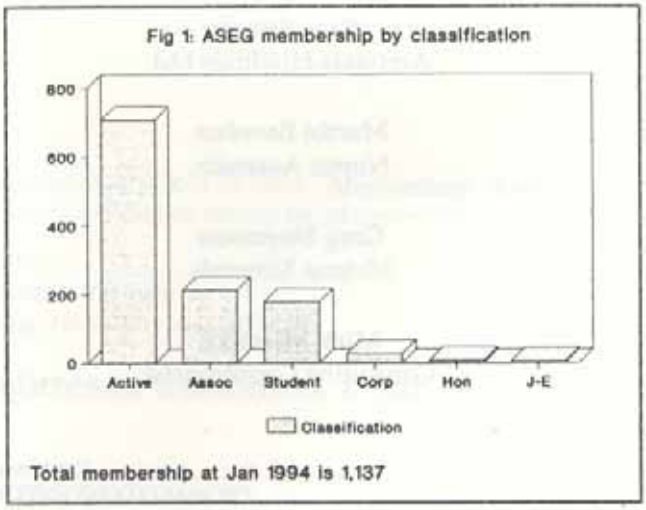
Luckily there was another boom taking place in Australian universities; geophysics was an attractive profession. The number of lecturers increased and the number of graduates increased. At last we had begun to question what we were doing. We gained the courage to point out, quietly at first, that the ground conditions in Western Australia were rather different to those in Canada, and had been for a good number of years. We had surface resistivities of less than 50Ωm, much less than the 5000Ωm attributed to the glaciated terrain of Canada. The term "skin depth" began to be talked about. We aired our doubts and misgivings of the overseas advisers and began to think for ourselves.

This was the perfect time for the ASEG to be formed; it provided a forum for discussion and a journal where ideas and results could be presented publically.

Confidence grew. Mineral Physics became a Division of the CSIRO; Chairs in geophysics were established at the Universities; Australian contracting groups were formed. We even began using a 100m dipole size and referring to the data as ohm.metres; the Metal Factor was quietly forgotten. The Sirotem was developed and eventually the software which enabled us to interpret the data was available.

By this time petroleum exploration had moved offshore and 3D seismic was becoming a reality rather than a concept. High resolution seismic was applied successfully in a number of coal fields in eastern Australia and research began into in-seam seismic and cross-hole seismic. These techniques are available on a contractual basis today.

The ASEG, which began in 1971 was very much biased in membership to NSW and Sydney; but branches in other states were soon established and regular monthly meetings were held in most states.

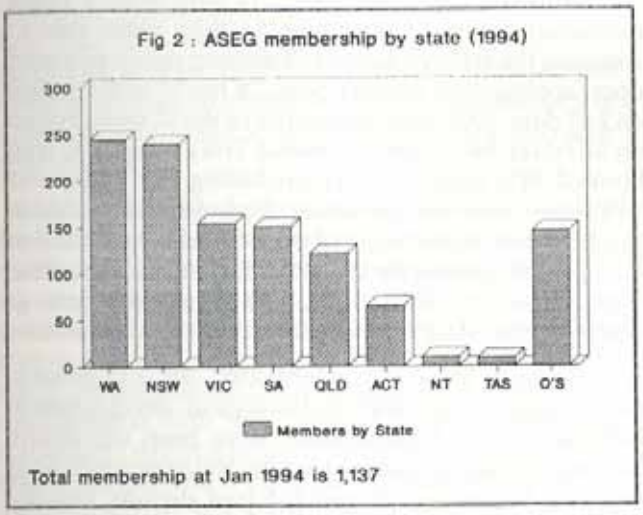


Since 1971 the society has provided the focus for the presentation of geophysical ideas, doubts, innovations, case histories, and general information about our profession.

More than 350 papers have been published in the Bulletin. There have been 8 special issues which targetted specific aspects of exploration geophysics, the first of which was the Geophysics of the Elure Orebody. And the Society has held twelve conferences.

The Federal Committee, once based in Sydney now rotates around the State capitals every 5 years or so. This may have advantages but also has some disadvantages and is a procedure which should be regularly reviewed.

Membership has grown to 1137 in January 1994, and the clear majority of these are classified as Active Members (Figure 1). Most of the members reside in Western Australia and New South Wales but a good proportion are found in Victoria, South Australia and Queensland (Figure 2). What is most encouraging is the proportion of members from overseas. It appears that at least some of our overseas colleagues are listening to us now, a reversal from the situation in 1970.



I am convinced that the ASEG membership will continue to grow, not only in Australia, but overseas, and eventually the Bulletin of Exploration Geophysics will have international status. All of us have a part to play in the Society, but in particular it is those attending this conference in Perth, those who are presenting papers, who will maintain and extend the reputation of the Society.

The technical program this week is varied and exciting. It is of worthy interest to geophysicists in Australia, and overseas. For this, I congratulate the organising committee in Perth and thank all those who are presenting papers, or workshops this week.

Hugh Rutter, President

ASEG 10th Conference & Exhibition SEG President's ConferenceAddress

Geophysics, the Exploration Risk Reducer

Michael Schoenberger

Geophysicists continue to live in turbulent times, in which resource companies are restructuring, geophysicists are facing new challenges, and technology is growing in importance. My address provides a personal perspective on the states of geophysical activity and technology and of SEG's role in furthering members' interests in those areas.

First, I discuss the state of the geophysical industry. In Nov 1993, 77% of the world's geophysical crews were operating in the CIS and China (World Geophysical News). Clearly, such a huge activity level provides a vast potential market for equipment manufacturers and software developers. Similarly, since almost all of the geophysical crews are locally sourced, Western geophysical contractors see a huge market for their services, if they can demonstrate superior performance. Furthermore, Western resource companies, which for years were excluded from operating in these countries, see the huge resource potential in this region, if favourable business conditions can be agreed upon.

Geophysical activity outside of China and the CIS is fairly uniformly distributed. The U.S. and Canada have 32%, Asia 22%, Africa/Mideast 17%, Latin America 14%, Europe 13%, and Australia 2%. Not only is the geographic distribution of geophysical activity fairly uniform, but so is the contractor distribution. No single contractor dominates. Of the 375 contractor crews operating on November 15, 1993, the single largest contractor, Geco Prakla, had 49 crews, which is only 13% of the total. Furthermore, 40% of the crews were operated by companies with five or fewer crews.

According to SEG's last survey (for 1991) of geophysical contractors, 97% of worldwide geophysical expenditures were spent in the petroleum industry, 1% each in mining and engineering and 1% for all else including environmental, geothermal, groundwater, research, and oceanographic studies. Clearly, Australia's activity has a larger minerals component, but to the rest of the world the geophysics business is the petroleum business.

For the past decade, we have been subjected to plots of worldwide seismic activity in crew-months, plots which show a continual decrease from 10 500 crew-months in 1981 to 4000 crew-months in 1991. However, crew-months are probably not the best indicator of geophysical activity, due to extremely high crew-to-crew productivity variations. A better indicator of seismic activity than crew-months is the number of line miles of seismic data acquired per year, a measure which has shown a steady increase from 1988 to 1991 (1991 SEG Activity report, Nov 93 The Leading Edge); in 1991, 1.6 million line miles of seismic data were acquired, as much as in 1981, the previous peak year of geophysical activity. An even better measure of the importance of geophysics is the amount of money companies are willing to spend on it. Between 1982 and 1987, that amount had decreased from $4 billion (U.S.) to $1.5 billion (U.S.). However, between 1987 and 1991, geophysical expenditures increased by almost 20 percent per year and reached $3 billion (U.S.) in 1991. This increase is especially impressive, since the total spending on petroleum exploration was virtually unchanged between 1987 to 1991. To quote the Sept 20, 1993 issue of the Oil and Gas Journal, "companies are using technological advances such as 3-D seismic ... to improve efficiency and reduce the number of holes needed to meet operating objectives." In a zero-sum business, petroleum company executives have decided to trade increased geophysics for decreased drilling. This decision resulted from geophysical technology advancement, the next subject of my address.

As the above quote indicated, 3-D seismic technology is clearly the most significant geophysical development of the past decade. Most if not all of the recent increase in geophysical expenditures can be attributed to that technology, which permits more accurate structural interpretations and reservoir descriptions through

(1) denser areal coverage,

(2) improved spatial resolution,

(3) superior imaging capabilities, and

(4) improved interpretation and visualization.

A 1992 Oil and Gas Journal article recounted Shell/Exxon's offshore The Netherlands experience in which two gas discoveries were followed by three dry holes. Serious consideration was given to relinquishing the block, but instead, 3-D surveys were acquired which led to a drilling program that yielded nine discoveries on the block and ony one dry hole. Their success was due primarily to superior imaging by the 3-D data of the faulted Rotliegende sandstone reservoirs beneath the Zechstein anhydrites.

A paper at the 1992 SEG Annual Meeting discussed Exxon's experience with roughly 400 3-D surveys that cost over $620 million (U.S.). These data have been used at every stage of investigation from exploration (identify prospects and assess their quality) to delineation drilling (optimize drill sites) to early development drilling (identify primary reservoir compartments) to late development drilling (identify missed reservoirs). In the early 1980s, only about 10% of the 3-D surveys were acquired for exploration. However, over time, the importance of 3-D methods in exploration has become more apparent, and now over 60% of Exxon's 3-D surveys are acquired for exploration.

Exxon has shown a dramatic increase in its success rate when using 3-D data compared to using 2-D data for its three most active areas in the world. The UK North Sea success rate was increased from 36 to 47%, the GOM from 43 to 70%, and The Netherlands from 57 to 70% - an average increase of nearly 50%. The 3-D surveys in the Gulf added 25 MOEB and permitted a savings of nearly $50 million (U.S.) - generating about $140 million (U.S.) in profit, and yielding a discounted rate of return of 22%. The economic impact in the Malay Basin was even greater, with ten 3-D surveys adding about 100 MEOB and again saving about $50 million (U.S.) - generating a $250 million (U.S.) profit with a 33% discounted rate of return.

The above economic benefits of using 3-D data extend to onshore regions as well. At the last SEG Convention, Mobil presented what was inadvertently a unique experiment. They and their partners shot a 3-D survey in South Texas, but in order to meet their drilling commitment, they also shot 2-D data with a faster turnaround time. Consequently, they were able to compare the relative success of drilling decisions based upon comparable vintage data. Of the 37 wells drilled on 2-D data, 70% were successful; of the 32 wells drilled on 3-D data, 84% were successful. The average 3-D well booked 34% more reserves (including dry holes) and 14% more reserves (excluding dry holes). The value of the 3-D wells exceeds that of the 2-D wells by $8 million (U.S.), easily paying for the $1.9 million (U.S.) cost of the 3-D survey. As a matter of fact the discounted rate of return of the 3-D wells is double that of the 2-D wells.

Although I have concentrated on 3-D seismic technology, many other technological developments, both seismic and nonseismic, have been significant. Seismic migration is an area in which almost continuous progress has occurred over the past decade. Initially, migration was limited to reflector dips of less than 15^{0}, a limit that was eventually relaxed to 30^{0}; and then, about two years ago, Chevron and Amoco simultaneously unveiled their work on turning-wave migration, in which vertical and overhung salt faces were imaged (c.f., April 1992 The Leading Edge).

Arguably one of the most important trends in geophysics is that of interactive, multidisciplinary interpretation. The importance of multidisciplinary interpretation has been recognized for many decades. The only aspect that seems to change is the set of disciplines being integrated. Several decades ago, integration of geophysics and gelogy was considered a major hurdle, but now such integration is expected as a matter of course. Currently integration of geophysics and reservoir engineering is evolving into the relatively new field of production geophysics. The modern workstation appears to be taking on a central role in integrating technologies. Subsurface models are constructed on the workstations, and geophysical responses are calculated and compared to measured data. The models are adjusted until the modelled responses match the measured data. The subsurface

model that is consistent with all measured geophysical data is the model most likely to be correct. If seismic, gravity, and magnetic responses all match recorded data, that model is more likely than one that matches only seismic data.

The final portion of my address deals with SEG - how it is faring in this turbulent environment, how it serves its members, and how it complements its Sections, such as ASEG. SEG grew rapidly during the 1970's and early 1980's, peaking at 19 559 members in 1985. Since then, membership has decreased by 26% to 14,443. However, most of that decline occurred in the 1980's and for the past four years, membership has been virtually constant. SEG members reside principally in the U.S. (67%), but a significant number (4838) live elsewhere in the world. Europe has 12%, Canada 9%, Asia 5%, Australia 3%, Africa/Mideast 3% and Latin America 2%.

Although none of us knows the actual geographic distribution of geophysicists, clearly SEG's membership does not reflect that distribution. I feel strongly that geophysicists worldwide form a community with many common interests and objectives. We need an organisation that interfaces with and serves the worldwide geophyiscal community. I would like to think that SEG as the world's largest exploration geophysics society fulfills that role to some extent. However, it cannot perform that role as well as many of us would like until it better represents non-U.S. geophysicists.

SEG membership will not, and should not, increase unless SEG can provide valued services to its new members as well as to its current members. For a very long time, SEG has provided some services directly to members and other services through its Sections. Direct services include publications (TLE, Geophysics, and books), conferences, and workshops. Services provided in cooperation with SEG Sections include continuing education, distinguished lectures, educational scholarships, and regional conferences. SEG's commitment to working with ASEG to conduct continuing education courses and distinguished lectures is stronger than it has ever been. Also, SEG and ASEG have co-sponsored conferences in the past and, hopefully will do so again in the future.

Currently, SEG Sections have a total membership of 7899, of whom 5022 are SEG members; i.e., only about one-third of SEG members obtain the full benefits of membership by affiliating with both SEG and a Sectoin. The ASEG has 1137 members, 400 of whom are also SEG members. Clearly, if Sections are to continue to act as SEG's interface with its local constituency, SEG membership in Sections must increase.

SEG currently has 21 Sections; 17 in the U.S., 2 in Canada, 1 in Australia, and a brand new one that is not geographic but one in which members share technological interests - namely, engineering, environmental, and groundwater geophysics. The Near-Surface Geophysics Section, like the other Sections, will have its own publication and conduct its own meetings, but it will also benefit from the size and strength of SEG. We are currently in the process of forming a number of Sections in other parts of the former Soviet Union. ASEG, chartered in 1970, can regard itself as a pioneer in helping SEG reach out beyond the borders of the U.S. I welcome your comments and suggestions on ways of improving services to SEG members worldwide.

I'd like to conclude by summarizing my analyses. First, the petroleum business worldwide dominates our profession. Mining has a strong presence in Australia but does not account for a large portion of the funds spent worldwide on geophysics. Environmental geophysics appears to have a great future, but even with a significant growth rate, it will take decades for it to capture a large fraction of the market.

Second, geophysical technology, especially 3-D seismic technology, is assuming ever greater importance in the exploration and production industry.

Third, we would be naive to assume that geophysics will continue to grow in importance without constant nurturing. It is essential that technological development receives continued support and that we promote those technologies that are most appropriate for our objectives. Cost analyses demonstrating the benefits of technology are extremely convincing.

Fourth, SEG is working to help its members achieve these goals, both directly and through its Sections. Encouraging participation in the international community of geophysicists is a key goal of SEG.

ASEG Corporate Sponsor Profile - Schlumberger

GOLD SPONSOR

Schlumberger

Logging in California 1930's

Schlumberger today has two service branches: OILFIELD SERVICES and MEASUREMENTS & SYSTEMS. Our 51,000 people are distributed nearly in line with revenue - two thirds in OILFIELD SERVICES, one-third in MEASUREMENTS & SYSTEMS.

The Schlumberger brothers Conrad and Marcel started the company back in the early 1900's. Conrad Schlumberger, believed that electrical measurements could help define the internal structure of the earth. After a decade of laboratory and field experiments, he left university to concentrate on his geological exploration business based on surface electrical measurements.

Schlumberger brothers Marcel (l) Conrad (r)

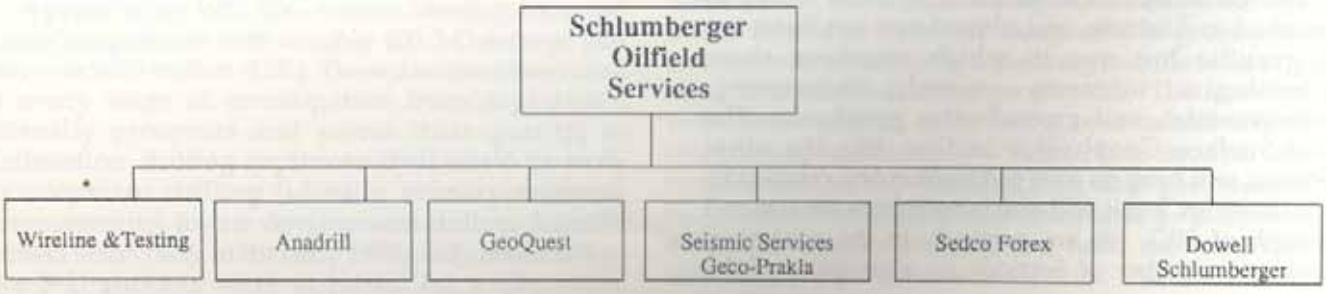
A turning point came in 1927 when the company applied the electrical prospecting techniques for the first time in a drill hole at the request of a French oil company. At the time, the only way that oil companies could identify the geological formations penetrated by the drilling bit was to watch the drilling rate, to look for bits of rock and traces of oil in the drilling mud returning from the well, and to take core samples with a coring bit. The Schlumberger crew brought a breath of science to this hit-or-miss process. With a crudely rigged logging tool, they took foot-by-foot measurements in the 1500-foot deep borehole over an arduous ten-hour day. When the data were plotted, a resistivity log emerged that would be familiar to any oil industry geologist today. It clearly showed the geological formations surrounding the well. A powerful new exploration tool was born.

The stunning success of this first log was clear to the Schlumberger people who called it "electrical coring". This was too optimistic. The early logs were valuable to the oil industry, but they could only identify formation boundaries and their depth. The ambitious dream of looking deep into the rocks surrounding a well bore and measuring all of the detailed heterogeneities such as the composition of the rocks and fluids, and the boundaries and dynamics of a reservoir would have to wait more than 60 years for the microelectronics revolution and the birth of computer processed images.

Commercialisation of this scientific data acquisition service demanded intensive research and engineering efforts in every step of the process: downhole tools which make the measurements, the cable that transmits data to the surface, the winch that raises and lowers the logging tools, the instruments that communicate with the downhole tools, recorders to capture the data graphically and finally the truck which serves as the platform and power source for all operations. Further studies were needed to understand the data and to help the customers interpret it. Research became and remains a cornerstone of Schlumberger.

Over the last seven years, Schlumberger has refocused and repositioned its product lines. There have been a significant number of acquisitions and divestitures. Major divestitures included the 1987 sale of Fairchild Semiconductor, the 1988 sale of Electricity Control & Transformers, and the 1989 sale of both the Defence Systems and Graphics businesses.

Acquisitions for OILFEILD SERVICES have concentrated on developing a seismic company. The acquisition of Geco, the Norwegian marine seismic company, took place in stages from 1987 to 1990. In 1989 Schlumberger acquired Delft Geophysical and Sonics, respectively, Dutch and Canadian seismic companies. In 1991 PRAKLA SEISMOS was acquired from the Federal Republic of Germany. Seismic acquisitions culminated with the 1992 purchase from Raytheon of Seismograph Service Ltd., a large UK seismic company. The



Geco marine Seismic vessel - GECO SAPPHIRE

acquisition of GeoQuest Systems, significantly expands our data services business.

The ultimate strength of new technology lies in integration and improvements in efficiency. Schlumberger has created synergies between the capabilities of several oilfield services to increase their value wherever the industry drills. Examples of these synergies include combining seismic and well data for better exploration success ratios through improved three-dimensional (3D) reservoir characterisation techniques and applying new drilling and completion technology to reduce the cost of production through horizontal or extended-reach wells and subsea competitions.

The main oilfield services product lines are:

Wireline & Testing	- measuring physical properties of underground formations
	- cement evaluations
	- well testing and drill stem testing
	- formation evaluation through casing
Anadrill	- measurements while drilling
	- direction drilling
	- mud logging
GeoQuest	- processing, interpretation and archiving geoscience data
	- interpretation bureau services
	- workstation software sales and support
Geco - Prakla	- Seismic data acquisition (marine and land)
	- Seismic data processing
	- Interpretation services
Sedco Forex	- Drilling services offshore and onshore
Dowell Schlumberger	- cementing, drilling fluids, stimulation and sand control
	- coil tubing services and industrial/ pipeline services

In Australia Schlumberger has been servicing the oil industry for over 30 years and has offices in Perth, Darwin, Adelaide, Moomba, Brisbane, Melbourne and Sale. All six of the above oilfield services product lines are currently operating within Australia.

MONDAY 21 FEBRUARY 1994

	SHOWROOM		
9.00	Welcome and Official Opening **Norm Uren**, Conference Co-Chairman		
9.10	Address to the Society **Hugh Rutter**, ASEG President and **Mike Schoenberger**, SEG President		
9.45	KEYNOTE ADDRESS *Investing in geophysical development -clearing the haze.* **Don Pridmore**, World Geoscience Corporation Ltd, WA		
10.30	MORNING TEA		
	STREAM A - *BALLROOM EAST*		**STREAM B - *SHOWROOM***
	AVO AND INVERSION	*Session Sponsored by Amoco Australia Petroleum*	**REGIONAL GEOPHYSICS**
	Chair: Norm Uren, Curtin University of Technology, WA		Chair: Bob Smith, CRA Exploration Pty Limited, SA
11.00	**KEYNOTE ADDRESS** *Applied seismic inversion for estimating velocity-depth models.* **Oz Yilmaz**, Schlumberger Geco-Prakla, USA		**KEYNOTE ADDRESS** *Success of government geophysical surveys - the South Australian experience.* **Ross Fardon**, Department of Mines and Energy, SA
11.30	*Characterization of lithology using crosshole methods -Part 1.* **Curtis Link**, University of Houston. USA (J McDonald, D Ebrom, H Zhou)		
12.00	*Modelling the effects of thin beds on amplitude versus offset response using the Campbell 2 well.* **Marianne Windhofer**, Simon Petroleum Technology, WA (M Stevens, P Kirk)		*Geophysical investigations of volcanic terrains: a case history from the Gawler Range volcanic province, SA.* **Shanti Rajagopalan**, University of Adelaide, SA (S Zhiqun, R Major)
12.30	LUNCH		
	PERTH BASIN		**SOUTH AUSTRALIA**
	Chair: Ernie Delfos, Ampolex Limited, WA		Chair: Dave Tucker, Preview Resources Pty Ltd, SA
1.30	*Structural and tectonic framework of the onshore northern Perth Basin, WA.* **Robert Iasky**, Geological Survey, WA (A Mory)		*The regional geophysical response of the Stuart Shelf, SA.* **Paul Gow**, Monash University, VIC (V Wall, R Valenta)
2.00	*A preliminary interpretation of deep seismic reflection and other geophysical data from the Darling Fault zone, Western Australia.* **Mike Middleton**, Curtin University of Technology, WA (S Wilde, B Evans, A Long, M Dentith)		*Crustal studies of SA based on energy spectral analysis of regional magnetic data.* **Irena Kivior**, University of Adelaide, SA (Z Shi, D Boyd, KR McClay)
2.30	*Structure of the eastern margin of the Perth Basin, WA.* **Mike Dentith**, University of WA (I Brunner, A Long, M Middleton, J Scott)		*Automag - an automatic method to estimate thickness of overburden from aeromagnetic profiles.* **Zhiqun Shi**, University of Adelaide, SA (D Boyd)
3.00	AFTERNOON TEA		
	POTENTIAL FIELD APPLICATIONS		**EASTERN GOLDFIELDS - WA AND REGIONAL**
	Chair: Peter Gunn, PJ Gunn & Associates, NSW		Chair: Richard Brescianini, BHP Minerals Pty Ltd, WA
3.30	*The western Otway Basin - a tectonic framework from new seismic, gravity and aeromagnetic data.* **Doug Finlayson**, Australian Geological Survey Organisation, ACT (B Finlayson, C Reeves, P Milligan, D Cockshell, D Johnstone, M Morse)		*Seismic reflection images of the major ore controlling structures in the eastern Goldfields Province, Western Australia.* **Barry Drummond**, Australian Geological Survey Organisation, ACT (B Goleby)
4.00	*New developments in aeromagnetic techniques for oil exploration.* **Don Pridmore**, World Geoscience Corporation Ltd, WA (C Norman, I Campbell, McKenna)		*On the gravity signature of Archean Greenstones in the Widgemooltha - Tramways area, eastern Goldfields, WA.* **Allan Trench**, WMC Ltd, WA (M House, D Miller, J Withers, B Goleby, B Drummond)
4.30	*High resolution aeromagnetics clarifies structuring in the Vlaming Sub-Basin, WA.* **David Heath**, Woodside Offshore Petroleum, WA (V Clark, A Bint)		*Use of detailed ground geophysics at the Leviathman and South Venus gold prospects, Southern Cross, WA.* **Alan Perry**, World Geoscience Corporation Ltd, WA (V Wilson)
5.00	*High resolution marine and airborne gravity by digital control.* **Don Pridmore**, World Geoscience Corporation Ltd, WA (T Lafehr, J McQueen)		*The Australian continent: a numerical model of its electrical conductivity structure and electromagnetic response.* **Ted Lilley**, Australian National University, ACT (R Corkery)
5.30	HAPPY HOUR ***Sponsored by Australian Seismic Brokers*** in the Trade Exhibition Area		
6.30	OPTIONAL RIVER CRUISE		

TUESDAY 22 FEBRUARY 1994

	STREAM A - *BALLROOM EAST*	STREAM B - *SHOWROOM*	POSTER PRESENTATIONS - *2nd FLOOR FOYER*
	BASIN ANALYSIS Chair: Larry Tilbury, Woodside Offshore Petroleum, WA	**SHALLOW HIGH RESOLUTION GEOPHYSICS - REGOLITH AND ENVIRONMENTAL MAPPING** Chair: Geoff Pettifer, Dept of Minerals and Energy, VIC	Chair: Roger Henderson, Geo Instruments Pty Ltd, NSW
9.00	**KEYNOTE ADDRESS** *Resolution.* **Eve Howell,** Hadson Energy Ltd, WA	**KEYNOTE ADDRESS** *Environmental geophysics: perspectives and challenges.* **Bob Whiteley,** Coffey Partners, NSW	*The Burkitt Hill dynamic test range: a new facility in South Australia for calibration of airborne gamma spectometers* **David Tucker,** Preview Resources Pty Ltd, SA
9.15			*Flairtem: A new airborne TEM system.* **Peter Elliot,** Elliot Geophysics Pty Ltd, SA
9.30	*Improvements in the resolution of seismic data discovered a new basin in the Gulf of Carpentaria.* **Tun Maung,** Bureau of Resource Sciences, ACT	*Geophysical surveys of leaking tailings impoundments.* **Greg Street,** World Geoscience Corporation Ltd, WA (A Perry,L Greenham)	*The use of magnetostratigraphy and magnetic susceptibility for dating and correlating oil shales in eastern Queensland.* **Zheng-Xiang Li,** University of WA
9.45			*Accurate heights for gravity surveys using global positioning system (GPS) technology.* **Richard Haines,** Haines Surveys, SA
10.00	*The contemporary stress field of the Barrow-Dampier Sub basin and its implications for horizontal drilling.* **Richard Hillis,** University of Adelaide, SA (A Williams)	*A multi-method approach to the geophysical assessment of 500km of alluvial sediments associated with the Darling River: Menindee to Brewarrina, western NSW* **Joe Odins,** Department of Water Resources, NSW (R Williams, D O'Neill, J Beckham)	*Geophysical exploration of the Ghanzi-Chobe belt, Botswana.* **Christopher Campbell,** Geological Survey, BOTSWANA (McLelian)
10.30	MORNING TEA		
	ACQUISITION Chair: Mike Sayers, WAPET	**AIRBORNE EM** Chair: Hugh Rutter, Geophysical Exploration Consultants, VIC	**STREAM C - *KESTREL ROOM*** **STRUCTURAL MAPPING** Chair: Paul Wilkes, Curtin University of Technology, WA
11.00	*3D survey design by computer.* **Michael Galbraith,** Seismic Image Software Ltd, CANADA	*Airborne electromagnetic surveys of the regolith.* **Greg Street,** World Geoscience Corporation Ltd, WA (A Anderson)	*Structural geophysics.* **Mark Jessell,** Monash University, VIC (R Valenta, G Jung, J Cull, A Geiro)
11.30	*The importance of on-board seismic processing.* **Paul Haskey,** Simon Petroleum Technology, UK	*A comparison of airborne and ground electromagnetic techniques for mapping shallow zone resistivity variations.* **Ann-Marie Anderson,** World Geoscience Corporation Ltd, WA (A Dodds, S McMahon, G Street)	*3D magnetic model inversion for structure mapping.* **John Coggon,** Mines Geophysical Services, WA (J Lai)
12.00	*Seismic reflection profiling of the Taupo Caldera, NZ.* **Bryan Davy,** Institute of Geological and Nuclear Sciences, NEW ZEALAND	*A SALTMAP case history: high resolution near surface conductivity measurements from the air.* **Andrew Duncan,** World Geoscience Corporation Ltd, WA (A Anderson, G Roberts)	*3-D analytical signal in the interpretation of total magnetic field data at low magnetic latitudes.* **Ian MacLeod,** Geosoft Inc, CANADA (K Jones, T Fan Dai)
12.30	LUNCH		
	MIGRATION Chair: Prof John Claerbout, Stanford University, USA	**SHORT PENETRATION - VERY HIGH RESOLUTION TECHNIQUES** Chair: Andrew Duncan, World Geoscience Corporation, WA	**PETROPHYSICS** Chair: Dave Clark, CSIRO Div of Exploration & Mining, NSW
1.30	*(f, x) migration - some side issues.* **Catherine Haddow,** Simon Petroleum Technology, UK	*Ground penetrating radar: will it clear the haze at your site?* **Greg Turner,** CSIRO, VIC (A Siggins, L Hunt)	*Timing and genesis of Hamersley iron ore deposits.* **Zheng-Xiang Li,** University of WA (C Powell, R Bowman)
2.00	*A practical approach to one-pass 3D depth migration.* **Peter Whiting,** Western Geophysical, WA (M Brzostowski, F Snyder, P Smith,)	*Bringing geophysics into the mine - radio attenuation imaging and mine geology.* **Scott Thomson,** Mets Pty Ltd, NSW (S Hinde)	*Drill core orientation using palaeomagnetism.* **Mark Lackie,** CSIRO, NSW (P Schmidt)
2.30	*3D salt and sub-salt imaging strategy: a case history from the Gulf of Mexico.* **Bob Godfrey,** Geco-Prakla, UK (A Pieprzak, K Berg, O Yilmaz)	*Sub-audio magnetics (SAM) - a high resolution technique for simultaneously mapping electrical and magnetic properties.* **Malcolm Cattach,** University of New England, NSW (J Stanley, S Lee, G Boyd)	*Physical property variations within Archaean Granite-Greenstone terrane of the Yilgarn Craton, Western Australia: the influence of metamorphic grade.* **Barry Bourne,** CRA Exploration, Mt Isa, QLD (A Trench, M Dentith, J Ridley)
3.00	AFTERNOON TEA		
	NUMERICAL Chair: Brian Evans, Curtin University of Technology, WA	**SATELLITE BASED TECHNIQUES** Chair: Tim Pippett, Geo Instruments Pty Ltd, NSW	**GEOTECHNICAL** Chair: Greg Street, World Geoscience Corporation, WA
3.30	*The study of diffusion effects in RIM tomographic imaging.* **Jeanne Young,** CSIRO Division of Radiophysics, NSW (G Rogers, L Brandt, J Kot)	*Increased resolution of processed satellite altimeter data: the development of a quality global gravity database.* **Andrew Long,** World Geoscience Corporation Ltd, WA (T Spurling)	*Dewatering assessment at Hilton Mine - an application of gravity methods.* **David Leaman,** Leaman Geophysics, TAS (B Mutton)
4.00	*Coherent noise attenuation methods for a low-fold seismic data.* **Guy Duncan,** University of Melbourne, VIC (G Beresford)	*The resolution of GPS.* **Wayne Jones,** Curtin University of Technology, WA	*Urban geophysics: TEM mapping in the Taipei Basin, Taiwan.* **Roger Henderson,** Geo Instruments Pty Ltd, NSW (C Chen)
4.30	*Extrapolation of vector (elastic) displacements by displacement potential field continuation.* **Jingping Zhe,** Flinders University, SA (S Greenhalgh)	*Posmag: an ad hoc GPS positioned ground magnetic surveying system.* **Marcus Flis,** Newcrest Mining Limited, WA	
5.00	*The application of robust and non-stationary analysis methods to MT Data from the West Anesi Anticline.* **Katherine Edwards,** University of QLD (L Hastie)	*GPS co-ordinate transformations and their use in gravimetry.* **Will Featherstone,** Curtin University of Technology, WA	
5.30	HAPPY HOUR *Sponsored by Guardian Seismic Data* in the Trade Exhibition Area		

Session Sponsored by Hadson Energy Limited

WEDNESDAY 23 FEBRUARY 1994

	STREAM A - *BALLROOM EAST*	STREAM B - *SHOWROOM*
	GEOPHYSICAL SIGNATURES OF WESTERN AUSTRALIAN ORE DEPOSITS Chair: Nick Sheard, MIM Exploration, QLD	**INVERSION** **KEYNOTE ADDRESS** Chair: Jan Willem de Maarg, Woodside Offshore Petroleum, WA
9.00	**KEYNOTE ADDRESS** *Australian geoscientific imperialists: discoveries at home and abroad.* **Bruce Kay,** Normandy Poseidon Ltd, WA	*The role of new technology in seismic exploration.* **Brian Russell,** Hampson-Russell Software Services Ltd, CANADA
9.30	*The relationship between magnetic anomalism and epigenetic gold mineralisation in the Victory-Defiance area, WA.* **Peter Williams,** WMC Ltd, WA	*Entropy and geophysical inverse problems.* **Peter Whiting,** Western Geophysical, WA
10.00	*The geophysical setting of banded iron formation-hosted gold deposits at Tuckabianna, WA.* **Lisa Vella,** Newcrest Mining Ltd, WA	*Evaluation of seismic trace inversion techniques.* **Natasha Hendrick,** University of Oxford, UK (S Hearn)
10.30	MORNING TEA	
	Chair: Graham Drew, CRA Exploration, WA	**AVO AND VSP** Chair: Peter Kirk, Simon Petroleum Technology, WA
11.00	*The application of geophysics over the Mount York gold deposit, WA.* **Nick Sheard,** MIM Exploration Pty Ltd, QLD (C Koning, S Robinson)	*AVO and anistropy: from logs and walkaways.* **Scott Leaney,** Schlumberger Interpretation Development, Jakarta, INDONESIA
11.30	*Geophysical investigations of the Kalgoorlie goldfield, WA.* **Paul Sauter,** KCGM Pty Ltd, WA (P McMickan, K Frankcombe)	*Reservoir prediction utilizing AVO walkaway VSP data to calibrate surface seismic gathers, a case study in Indonesia.* **Patricia Henderson,** Maxus SE Sumatra (D Hampson, S Leaney, N Smith, J Rice)
12.00	*Bounty gold deposit, Western Australia: magnetic and electromagnetic responses.* **John Coggon,** Mines Geophysical Services, WA (R Rutherford)	*Shear wave VSP in Amarume Oil Field.* **Takashi Imazumi,** Technology Research Center, Japan National Oil Corporation, JAPAN (Y Ishii)
12.30	LUNCH	
	Chair: Marcus Flis, Newcrest Mining Group, WA	**MULTIPLES** Chair: John Moore, Kufpec Australia Pty Ltd, WA
1.30	*Geophysical characteristics of the Telfer gold deposits, WA.* **Michael Sexton,** Telfer Gold Mine, WA	*Surface multiple attenuation and subsalt imaging.* **Bill Dragoset,** Western Geophysical, USA (S MacKay)
2.00	*Geophysics and iron ore exploration: examples from the Jimblebar and Shay Gap-Yarrie regions, WA.* **Tracy Kerr,** BHP Minerals Pty Ltd, WA (A O'Sullivan, D Podmore, R Turner, P Waters)	*Identifying multiples on seismic sections.* **Greg Beresford,** University of Melbourne, VIC (S Gregory, F McIntosh)
2.30	*Geophysical signature of the Kintyre uranium deposit, WA.* **Jonathon Root,** CRA Exploration, WA (W Robertson)	*Water bottom, multiple attenuation - case study.* **Nigel Fisher,** Digicon, QLD (M Taylor)
3.00	AFTERNOON TEA	
	Chair: Kim Frankcombe, Normandy Poseidon Ltd, WA	**SOUTHERN AUSTRALIA CASE HISTORIES** Chair: Doug Roberts, SAGASCO
3.30	*The geophysical response of Rocky's Reward nickel sulphide deposit, Leinster, WA.* **Andrew Mutton,** CRA Exploration Pty Ltd, WA (P Williams)	*Tertiary channeling in the Duntroon Basin, Australia - significance for hydrocarbon trap styles and plays.* **David Ormerod,** BHP Petroleum Pty Ltd, VIC
4.00	*The application of geophysics to nickel sulphide exploration in the Kambalda district, WA.* **Allan Trench,** WMC Ltd, WA (P Williams)	*Stuctural framework of the eastern Otway Basin/Torquay Basins: inversion and interaction between two major structural provinces.* **Kathy Hill,** Monash University, VIC (G Cooper, J Richardson, C Lavin)
4.30	*The role of geophysics in exploration for Mississippi Valley type lead-zinc deposits on the Lennard Shelf, WA.* **Robyn Scott,** BHP Minerals Pty Ltd, WA (T Whiting, R Turner)	*3D visualisation of transpressional structures in the eastern Otway Basin.* **Earl O'Callaghan,** BHP Petroleum Pty Ltd, VIC
5.00	*Geophysical responses over the Scuddles volcanogenic massive sulphide deposit.* **Graham Boyd,** Normandy Poseidon Exploration Ltd, SA (K Frankcombe)	*Image processing for seismic mapping saves papering the walls.* **Dave Cockshell,** Department of Mines and Energy, SA (J Allender, D Vinall)
5.30	HAPPY HOUR *Sponsored by Landmark Graphics* in the Trade Exhibition Area	

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POSTER PRESENTATIONS - *2nd FLOOR FOYER*

Chair: Terry Allen, Western Geophysical, WA

3.30	*The central Officer Basin preliminary results.* **James Leven & John Lindsay,** Australian Geological Survey, ACT
3.45	*Quantifying erosion in sedimentary basins from sonic velocities in shales and sandstones.* **Richard Hillis,** University of Adelaide, SA
4.00	*A new method for the determination of three dimensional dip and azimuthally dependent NMO.* **Brian Evans,** Curtin University of Technology, WA
4.15	*Application of geophysical methods to the exploration of coal deposits in Sarawak, Malaysia.* **Ch Grissemann,** Institute for Geosciences and Natural Resources, GERMANY (R Seitz, U Sirisena, B Zawawie)
4.30	*A review of shallow seismic and gravimetric exploration of brown coal.* **Raimund Seitz,** Institute for Geosciences and Natural Resources, GERMANY (H Gaertner, H Schubert)

5.30 HAPPY HOUR *Sponsored by Landmark Graphics* in the Trade Exhibition Area

THURSDAY 24 FEBRUARY 1994

	STREAM A - *BALLROOM EAST*	STREAM B - *SHOWROOM*
	SEISMIC PROCESSING Chair: John McDonald, Houston University, USA	**POTENTIAL FIELD METHODS** Chair: Pat Hillsdon, Exploration Computer Services, NSW
9.00	*Depth transform of seismic data by use of equi-travel time planes* **Yuzuru Ashida,** Kyoto University, JAPAN (K Sassa)	*Separation filtering applied to aeromagnetic data.* **Duncan Cowan,** Cowan Geodata Services, WA (S Cowan)
9.30	*Recycling stacking velocities for better seismic processing.* **Forbes McIntosh,** BHP Petroleum Pty Ltd, VIC (J Oden)	*Application of computerised tomography methods to the interpretation of magnetic anomaly profiles.* **Jun Zhou,** University of New England, NSW (J Stanley)
10.00	*Pre-stack and post-stack noise attenuation using the diversity tau-p transform.* **Terry Allen,** Western Geophysical, WA (R Martinez, D Cowan)	*Comparison of regional-residual separation techniques for gravity surveys.* **Michael Roach,** University of Tasmania, TAS (D Leaman, R Richardson)
10.30	MORNING TEA	
	BOREHOLE GEOPHYSICS Chair: Andrew Sutherland, Schlumberger Seaco Inc, VIC	**MINERALS CASE HISTORIES** Chair: Graham Boyd, Poseidon Exploration, SA
11.00	*Experimental techniques in VSP recording and tube wave supression as applied in the northern Mount Isa Basin.* **Michael Barlow,** Comalco Aluminium Ltd, QLD (B McConachie)	*MIP test survey over HYC deposit in McArthur River area,NT.* **Hajime Hishida,** Metal Mining Agency of JAPAN (T Tsujimoto, G Humphreys, G Linford)
11.30	*Seismic tomography for VSP field surveys in an inhomogenous and anisotropic medium.* **Peter Hatherly,** Curtin University of Technology, WA (P Zhao, B Evans, F Wenzel)	*Ulten case history of a base metal prospect Goianesia, Brazil.* **Michael Zang,** Anglo American Corporation, SOUTH AFRICA
12.00	*Characterization of lithology using crosshole methods -Part 2.* **Curtis Link,** University of Houston. USA (J McDonald, D Ebrom, H Zhou)	*An effective combination of geophysic methods for prospecting lead-zinc ore bodies located in the Cho Don Area (Vietnam).* **Lah Tang Muoi,** Geological Survey of VIETNAM (N Tai Thinh)
12.30	LUNCH	**POSTER DISPLAY - *EASTERN FOYER*** Low latitude magnetics. ***Sponsored by Aurora Gold Pty Ltd, WA***
	MODELLING AND STATICS Chair: Andy Padman, Woodside Offshore Petroleum, WA	**MINERALS CASE HISTORY AND AIRBORNE TEM** Chair: Mike Asten, BHP Minerals International, VIC
1.30	*An intelligent seismic first-break time calculation scheme for inhomogeneous models.* **Shunhua Cao,** Flinders University, SA (S Greenhalgh)	*Geological mapping capabilities of the Questem airborne electromagnetic system for mineral exploration, Mt Isa Inlier, QLD* **Helen Anderson,** World Geoscience Corporation Ltd, WA (A Duncan, S Lynch)
2.00	*The use of continuous velocity analysis and dynamic replacement for the solution of near surface problems in an offshore environment.* **Nigel Fisher,** Digicon, QLD (W Dutler)	*Exploration for Cyprus style copper deposits, Sultanate of Oman: a case history.* **Steve Webster,** Austirex International Ltd, NSW (H AlAzry, D Isles, H Al Zubaidy, W Witham)
2.30	*Improved statics corrections plus pre-stack interpretation improves the resolution of 2D seismic data.* **Milovan Urosevic,** Curtin University of Technology, WA (B Evans, P Hatherly)	*Downhole three component TEM probes.* **James Cull,** Monash University, VIC
3.00	AFTERNOON TEA	
	MODELLING Chair: Stuart Greenhalgh, Flinders University, SA	**ADVANCES IN EM** Chair: Jim MacMae, CRCAMET, NSW
3.30	*Seismic interface modelling, a physical approach to Zoeppritz theory.* **Justin Norris,** Geco-Prakla, WA (B Evans)	*Conductance-depth imaging of airborne TEM data.* **Guimin Liu,** BHP Research, VIC (M Asten)
4.00	*Spatial resolution and amplitude studies in anisotropic seismic reflection: a physical modelling study.* **Patrick Okoye,** Curtin University of Technology, WA (N Uren)	*TEMPER: a software package for the interactive interpretatim of airborne TEM data.* **Tim Monks,** BHP Research, VIC (M Asten)
4.30	*The seismic reflection process in anistropic media.* **Mohammad Norozi,** Curtin University of Technology, WA (B Evans)	*Enhancement of different types of airborne geophysical data acquired in difficult terrains.* **Martin Schneider,** Geoterrex Pty Ltd, NSW (S Dodd)
5.30	CONFERENCE FAREWELL Awards and Closing, Kim Frankcombe, Conference Co-Chairman	

Session Sponsored by Phillips Oil Company Australia

Exhibitor Catalogue

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8	Tesla 10 Pty Ltd
9	Universal Tracking Systems Pty Ltd
10-11	Department of Mines and Energy, SA
12	Century Geophysical Corporation
14-15	Earth Resource Mapping
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Exhibitors in alphabetical order

ABEM INSTRUMENT AB 27
Box 20086
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Tel: (46) 8 764 6060
Fax: (46) 8 281109
Contact Person: Bjorn Schoon

ABEM Instrument AB is a Swedish based manufacturer and world-wide supplier of geophysical instruments.
ABEM Instrument is a Nitro Consult company in the Scandinavian Dyno Group. The Dyno Group has about 7500 employees in total. The 70 year old company develops and manufactures a wide range of geophysical equipment for refraction and reflection seismic-TERRALOC, resistivity-TERRAMETER, and Very Low Frequency EM - WADI. ABEM Instrument AB also represents ABEM Geoscience for borehole logging equipment-WELLMAC, borehole radar-RAMAC and EM equipment. At the ASEG meeting in Perth ABEM Instrument will exhibit the new seismograph TERRALOC MARK 6, the multi-electrode resistivity system MULTIMAC with TERRAMETER, the logging system WELLMAC L/I and the VLF WADI.

ADVANCE GEOPHYSICAL CORPORATION 77
111 North Bridge Road
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Contact Person: Peter Chalcraft

Advance Geophysical is a developer of interactive seismic processing software and systems. Responsible for the MicroMAX field seismic processing system, Advance's latest entry into seismic processing is the workstation based ProMAX system. This is a complete 2D & 3D processing system featuring: special marine quality control tools, a comprehensive suite of imaging capabilities and complete interactive on-screen data manipulation features. In a little less than two years ProMAX has established itself with an installed user base of over 350 systems world-wide.

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION 81, 82, 83, 84
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Contact Person: Lynton Jaques

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INDONESIA
Tel: (62) 21 390 7139
Fax: (62) 21 390 7139
Contact Person: Mark Parker

ARK GEOPHYSICS is a specialist gravity and magnetic contractor, providing high quality acquisition, processing, imaging and interpretation services. ARK holds a world-wide exploration database of non-exclusive and public domain potential field data and reports. ARK is at the forefront of technical innovation in gravity and magnetic

exploration. In particular, ARK has developed advanced processing techniques for gravity and magnetic data from 3D seismic surveys, which improve resolution bY a factor of five or more. ARK's modelling software allows close integration of potential field and seismic interpretation. ARK emphasises high quality and fast turn-around, made possible by your strong team of specialists and by continuous investment in innovative software and powerful workstations.

ASHTECH/SAGEM AUSTRALASIA **94**
2/122 Euston Road
ALEXANDRIA NSW 2015
Tel: (02) 516 5399
Fax: (02) 516 5595
Contact Person: Rod MacLeod

Sagem Australasia represents Ashtech Inc GPS products in the Australasian region, providing the best of both GPS experience and technological innovation with accuracies from metres to millimetres. Ashtech GPS receivers are used in such areas as precise surveys, offshore positioning, sea, air and land navigation, airborne geophysical surveys and military applications. Some of the products on display at our stand include the new Z-12 GPS dual frequency receiver with P-code tracking, even under an Anti-spoofing environment, PNAV real time centimetre positioning system and the 3DF attitude determination receiver giving position, heading, pitch and roll.

AUSLOG PTY LTD **48, 49**
PO Box 125
DARRA QLD 4076
Tel: (07) 376 5188
Fax: (07) 376 6626
Contact Person: Bill Smith

VELSEIS 'Integrated Seismic Technologies'
Specialists in High Resolution Surveys

- Seismic reflection
- Seismic refraction
- Research and development
- Processing by specialist subsidiary **Velseis Processing Pty Ltd**
- Tape transcription services
- Broad range of expertise in exploration and development surveys for COAL, GROUNDWATER, PETROLEUM, TRANSITION ZONE work, stratiform MINERALS and GEOTECHNICAL STUDIES
- Dynamite, Mini-SOSIE and marine energy sources

Further contacts: *Mike Reveleigh*, Velseis Pty Ltd
Tel: (07) 376 5544 Fax: (07) 376 6939
Karel Driml, Velseis Processing Pty Ltd
Tel: (07) 279 0400 Fax: (07) 279 0743

AUSTRAL GEOPHYSICAL CONSULTANTS **89**
16 Ilford Avenue
BUTTABA NSW 2283
Tel: (049) 753 361
Fax: (049) 752 165
Contact Person: Dollina Renton

AUSTRAL provides QC supervision for

- marine seismic surveys, including 3D surveys implementing the latest multiple source/streamer technologies
- high resolution surveys
- positioning of drilling vessels
- post processing of navigation data
- advisory/audit services in OH&S

AUSTRAL is an independent Australian company with experience in domestic/international operations. The QSEA Company is a specialist offshore surveying/consulting company currently producing Acumen, Qbin and Quantum for the offshore industry and Quicksilver for the transport industry. The company specialises in highly technical applications dealing with precise positioning and processing for the oil and gas industry and with difficult data interfaces and translations.

AUSTRALIAN SEISMIC BROKERS **47**
Unit 8, 328 Albany Highway
VICTORIA PARK WA 6100
Tel: (09) 362 9334
Fax: (09) 362 9315
Contact Person: Steve Jeffrey

Australian Seismic Brokers (ASB) has offices in Perth and is 50% owned by Petroconsultants. The product range marketed includes open file seismic sections (paper or film), SEGY seismic tapes, unedited well completion reports, reprocessed seismic data and speculative survey data. Although most of the above data comes from Australia, an increasing amount of seismic data is now available for countries such as the PNG, NZ, Philippines, Equatorial Guinea, Eritrea. Full datatsets are available for the Australian acreage gazettals.

BPB SLIMLINE **58**
47 Felspar Street
WELSHPOOL WA 6107
Tel: (09) 356 2078
Fax: (09) 353 4025
Contact Person: Michael Lees

BPB Slimline Services is a wholly-owned subsidiary of the BPB Industries group, based in the UK, where borehole logging activities commenced in coal and minerals 30 years ago. The emergence of our Wireline Services Division as a major international oilfield service company has resulted in some remarkable spin-off's, and not surprisingly our slim oil suite (soon to include an acoustic scanning tool and 4-arm multi-button dip meter) is second to none. With most tools (including dipmeter) under 2" diameter, an unrivalled range of measurements is available to mineral explorers within the constraints of typical bore gauges. QLOG commercial software is a recent development.

CENTURY GEOPHYSICAL CORPORATION **12**
Unit 1, 4 Visor Court
HOLDEN HILL SA 5088
Tel: (08) 396 5166
Fax: (08) 396 4735
Contact Person: A Richsteiger

Century Geophysical Corporation has been a recognised leader in the Mineral Logging Business since its commencement in 1946. We pride ourselves in being technical innovators, able to work with clients to develop equipment and techniques to provide answers. Our active Engineering Department, backed by a commitment to spend 10% of gross revenue on engineering, has gained a well deserved reputation for excellence. Our entry into the international sales and rental market for geophysical equipment, has now brought a full range of field proven equipment to clients who wish to carry out their own logging.

COGNISEIS DEVELOPMENT **35**
Zheng Yi Building
#05-02 35 Jalan Pemimpin
SINGAPORE 2057
Tel: (65) 258 3414
Fax: (65) 258 3077
Contact Person: Gareth Taylor

CogniSeis provides geophysical and geological processing, interpretation and modelling systems used for oil and gas exploration. DISCO, first delivered in 1980 is the company's renowned batch 2D and 3D seismic processing software. Focus, recently released, based on UNIX, X-Windows and Motif, brings evolutionary 2D and 3D seismic processing solutions to the geoscientist with transparent batch and interactive object-oriented processing tools. Geosec, a geological modelling and interpretation system offers sophisticated cross-section construction, restoration and balancing capabilities. In addition to advanced exploration software, CogniSeis also provides total solutions in the form of hardware, networking, geophysical and geological processing, support, training and consultancy. With over 350 customers in more than 25 countries, CogniSeis is headquartered in Houston, Texas, with regional offices in London and Singapore and support centres in Canada and China and a geological division in Boulder, Colorado.

CROCKER DATA PROCESSING **67**
Unit 6, Research and Development Centre
Technology Park
BENTLEY WA 6102
Tel: (09) 470 5004
Fax: (09) 470 5003
Contact Person: Hugh Crocker

CROCKER DATA PROCESSING is a research and development software company supplying the Petroleum Exploration Industry since 1981 with Data Storage (archival and on-line), Data Management, Processing and Graphics software, either under licence or as a bureau service. The main office is in Perth, with subsidiaries in the USA, Canada, England, France, Columbia, Taiwan, Malaysia and Indonesia. The formations of the Far East are amongst the most difficult to interpret; as a consequence the CDP software has been enhanced and refined to an outstanding level. There are currently more than 90 installations world-wide in 18 countries. All common platforms, digitisers, plotters, printers, tape drives etc., and connectivity with other systems or software is actively supported.

CSIRO DIVISION OF EXPLORATION AND MINING **69**
PO Box 136
NORTH RYDE NSW 2113
Tel: (02) 887 8757
Fax: (02) 887 8921
Contact Person: Judy Thomson

The CSIRO Division of Exploration and Mining addresses the strategic research needs of the Australian mineral exploration and mining industries. It aims to improve their productivity and competitiveness by developing new concepts and techniques for selection and evaluation of prospective terrain, deposit deliniation, mine design and engineering, mining technology and equipment and the management of associated environmental issues. Geophysical techniques span this spectrum of activities. New research initiatives will focus on airborne gravity and downhole geophysics. Work on the development of an airborne electromagnetic system to detect orebodies concealed beneath deep weathered cover continues within the Cooperative Research Centre for Australian Mineral Exploration Technologies.

DEPARTMENT OF MINES & ENERGY, SOUTH AUSTRALIA **10, 11**
191 Greenhill Road
PARKSIDE SA 5063
Tel: (08) 274 7671
Fax: (08) 373 3269
Contact Person: Dave Cockshell

The Department's mission is to generate wealth and jobs for the community by supporting the development of the State's petroleum, minerals and groundwater. A major strategy to accomplish this is to promote exploration for these resources within South Australia. Considering the depth of cover prevalent over most of the State, geophysics is the major tool for future exploration. The South Australian Exploration Initiative has recognised this need for geophysics. $7 million of airborne geophysical and seismic survey data has already been acquired. Another $8 million is allocated for further surveying over the next 3 years. Data validation plus the creation and updating of geophysical databases and indexes is continuing facilitating speedy access to the extensive array of geophysical data stored within the Department.

DEPARTMENT OF MINES & ENERGY WESTERN AUSTRALIA **55**
100 Plain Street
EAST PERTH WA 6004
Tel: (09) 222 3333
Fax: (09) 222 3430
Contact Person:

1994 is the centennial year of the Western Australian Department of Minerals & Energy. Through its nine operating divisions, the Department provides a range of services to the mining and petroleum industries and the general public. Displays from the Geological Survey of Western Australia and the Surveys and Mapping Division represent facets of the Department's activities, which are directed towards the geoscientific mapping of the State, and the computer-based, graphical representation of mining tenements through the new TENEGRAPH system.

DESMOND FITZGERALD & ASSOCIATES **34**
Unit 2, 1 Male Street
BRIGHTON VIC 3186
Tel: (03) 593 1077
Fax: (03) 592 4142
Contact Person: Maggie Pinder

Desmond Fitzgerald & Associates has provided consulting and software services to the mining and geo-engineering community for seventeen years. We supply **Techbase, Datcol** and **ER Mapper** mining and geo-engineering software and develop the ***Intrepid*** geophysics package.
Intrepid is a geophysical software system that provides aircraft to final hardcopy capabilities. The advanced"Motif" interface operates under UNIX. A Windows version will be available mid 1994. The software's graphical and interactive nature ensures that users can effectively use all the product's power and capabilities.
Intrepid has evolved from the best Australian practice - it is the successor to AGSO's "ARGUS" and BHP's "PITS" systems.

DURRANT & ASSOCIATES **68**
4th Floor, 1060 Hay Street
WEST PERTH WA 6050
Tel: (09) 322 7075
Fax: (09) 321 5197
Contact Person: Jim Durrant

Petroleum exploration consultants and Australasian representative for the GeoDepth software suite which provides advanced imaging tools for exploration geophysicists, including model-based velocity estimation and depth imaging. Bureau service also available.

EARTH RESOURCE MAPPING PTY LTD **14, 15**
Level 2, 87 Colin Street
WEST PERTH WA 6005
Tel: (09) 388 2900
Fax: (09) 388 2901
Contact Person: Sharon Lezer

ER Mapper is an image processing software product developed in Perth and marketed world-wide by Earth Resource Mapping Pty Ltd. ER Mapper is used to process a variety of data including satellite, seismic magnetic, gravity, digital elevation, and digitised air photo data. ER Mapper is used in a wide range of industries including mining, oil and gas, mapping, environmental monitoring, forestry and research. Existing clients include CSIRO, BP, BHP, Western Mining, Shell and many others.
ER Mapper runs on the following platforms:-
- □ Sun SPARC/SunOS
- □ Sun/SPARC/Solaris 2.x
- □ DEC Alpha/OSF
- □ DEC MIPS/ULTRIX
- □ SGI MIPS/IRIX
- □ HP PARISC/HPUX
- □ Windows NT (available 28 April 1994)

EXPLORATION COMPUTER SERVICES **91, 92**
PO Box 160
BOWRAL NSW 2576
Tel: (048) 612 122
Fax: (048) 613 902
Contact Person: Pat Hillsdon

Exploration Computer Services Pty Ltd (ECS) was established in Australia in 1966, initially providing airborne geophysical software and processing services to the exploration arm of the mining industry. ECS developed further software in the early 1980's for mine planning and geological modelling for the coal industry. This software was developed initially to meet the needs of our consulting team, however it became apparent that there was a market for it in Australia and overseas, and accordingly, ECS diversified into software sales. With success and further projects, the software was subsequently extended to support the metals industry in the late 1980's. ECS now has an extensive record of projects in both metals and coal and over 100 software clients world-wide including such major companies as Western Mining Corporation, Shell Australia, CRA Exploration, North Flinders Exploration, Texas Utilities (the 4th largest coal producer in the USA) and Sumitomo Coal Mining, Japan. ECS business revolves around technical computing and we derive our income from three main areas, namely:
- □ Data processing of airborne geophysical and borehole data
- □ In-house consulting
- □ Direct software sales and technical support, with over 110 installations world-wide.

ECS support all of these activities with offices in Bowral (HQ), Perth and Denver, USA and agents world-wide.

ENCOM TECHNOLOGY **5, 6**
Level 1, 110 Alfred Street
MILSONS POINT NSW 2068
Tel: (02) 957 4117
Fax: (02) 922 6141
Contact Person: Peter Gidley

Encom Technology provides a wide range of services to the Minerals and Petroleum Exploration Industries. The company was incorporated in 1984 and now employs 20 staff in its Sydney and Melbourne offices.
Principal business activities include:

- Technical Software Development
- Geophysical Consulting and Bureau Processing
- Data Services
- Tape Transciption and Remedial Treatment

Software developed by Encom is marketed to exploration companies in Australia and overseas. These products are also used by our own staff to provide processing and consulting services. Recent products such as our newly released Modelvision (gravity and magnetics modelling) are being developed using methodology which allows them to take advantage of windowed interfaces on a range of platforms including MS Windows, Sun and Silicon Graphics. Encom also distributes 3rd party software including ER Mapper, Intrepid, Stratamodel and Geopak. Encom provides updated petroleum and mineral tenement data on a subscription basis. Encom also distributes data on behalf of ACRES (satellite imagery) and AUSLIG (thematic spatial data). A comprehensive range of tape services including the remedial treatment and archiving of deteriorating tape data are provided by Encom. In recognition of our success in this area, we have been chosen as one of only two companies that are authorized to process deteriorating Commonwealth petroleum exploration tapes held at the Australian Archives.

EXPLORANIUM **70**
264 Watline Avenue
Mississauga
ONTARIO CANADA
Tel: (905) 712 3100
Fax: (905) 712 3105
Contact Person: John Cox

EXPLORANIUM is the leading supplier of Gamma-Ray Spectrometers to the geophysical industry. The GR-820 Airborne Spectrometer is used by most geophysical survey companies, but is also used extensively for airborne surveillance applications. The GR-650 is a new Vehicle-Based Radiation Monitoring System featuring a powerful ruggedized computer with integrated radiation data and location data from an internal GPS system. The KT-9 susceptibility meter offers hi-sensitivity with digital output and a variety of external coils. The GR-320 is a new portable spectrometer with many features including dual detector support, GPS data input, zero dead-time etc.

GEO INSTRUMENTS PTY LTD **31, 32, 33**
348 Rocky Point Road
RAMSGATE NSW 2219
Tel: (02) 529 2355
Fax: (02) 529 9726
Contact Person: Tim Pippett

Geo Instruments Pty Limited, based in Sydney, Australia, 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 as complete a range of different geophysical equipment types as possible. Geo Instruments has moved into the manufacture of the GMS-2 Magnetic Susceptibility Meter and has the world-wide marketing rights for SIROTEM, the transient electromagnetic system. Geo Instruments also operates a helicopter geophysical contracting division for surveys in magnetics, radiometrics and electromagnetics. Its staff has a wide experience in the rugged mountains of the Pacific rim.

GEOTERREX PTY LTD **25, 26**
PO Box 386
ARTARMON NSW 2564
Tel: (02) 418 8077
Fax: (02) 418 8581
Contact Person: Peter Jackson

Geoterrex was founded in 1966 in Canada and Geoterrex Pty Ltd commenced operations in Australia 1972. Geoterrex operates throughout the world with our own and CGG's agents and representatives in 52 countries. Geoterrex Pty Ltd operates in the airborne and ground geophysics market, providing data acquisition, processing and interpretation surveys and services. These surveys have been successfully conducted in the search for coal, oil and gas, base metals, precious metals, uranium and groundwater as well as geological mapping, engineering site investigations and land management/salinity assessment. Our mission is to provide international geophysical services of the highest quality.

GEOSOFT INC. **30**
Suite 500
204 Richmond Street West
Toronto, Ontario
CANADA M5H-2G4
Tel: (416) 971 7700
Fax: (416) 971 7520
Contact Person: Tim Dobush

GEOSOFT is a developer and supplier of comprehensive geophysical software for processing, mapping and modelling of geophysical data.

GEOPHYSICAL RESEARCH INSTITUTE **60, 61**
University of New England
ARMIDALE NSW 2351
Tel: (067) 73 2617
Fax: (067) 71 1661
Contact Person: John Stanley

The Geophysical Research Institute has become the World leader in the application of high definition magnetic, GPR and electromagnetic techniques to geological mapping for mineral exploration, engineering site characterisation, industrial waste and explosive ordnance detection, salinity monitoring and archaeological site investigation. Theses techniques involve airborne, ground level and down-hole applications. Our speciality is methods for exploration in situations where traditional geophysical techniques are inadequate or deficient. GRI research staff are engaged in developing more efficient methods for high definition sub-surface mapping. We have expertise and facilities for instrumentation development, image processing, data interpretation and modelling, and general problem solving requiring geophysical methods. We build much of our own equipment and develop most of our own software.

GEO SYSTEMS PTY LTD **64, 65**
2 Mooney Place
O'CONNOR WA 6163
Tel: (09) 314 2644
Fax: (09) 314 2762
Contact Person: Stephen Tobin

Geo Systems Pty Ltd is a joint Australian/American owned Onshore Seismic Acquisition company specialising in High Resolution Land 2D/3D and Multiline Swath acquisition for both the Petroleum and Minerals exploration industries. Geo Systems has operated and currently operates both portable Dynamite and Vibroseis land crews with an emphasis on environmentally and geophysically demanding operational and technical problem solving. Data Quality Control and Crew Efficiency has been greatly enhanced with the addition of New Toyota fleets, New High Performance Field Processing, New GPS Survey Control, New Pelton Vibe Control electronics, New Heavy Weight Vibrator trucks and Mobile Caravans. Over the past 2 years Geo Systems, Perth has successfully designed and completed either itself in Australia and SE Asia or through the USA affiliated companies, GSC and SECO a total of 28 Multiline Swath and Full 3D Land Seismic Surveys using both Vibroseis and Heli-portable Dynamite sources.

GUARDIAN DATA **78**
Unit 2, 72-74 Gibbes Street
CHATSWOOD NSW 2067
Tel: (02) 417 6144
Fax: (02) 417 0297
Contact Person: Bryan Robertson

Guardian Data specialises in the pre-processing of seismic data. Its services include:-

- Recovery of data from deteriorating tapes
- Analogue to Digital conversions
- Archiving of data to high density media
- Tape copying, reformatting and pre-processing
- Data management functions such as tape validation, cleaning, retensioning etc.

With offices in Sydney and Melbourne in Australia and in association with PT Geoservices in Jakarta, Guardian Data is able to offer fast turnaround, competitive pricing and attention to your data from people with extensive geophysical experience.

HAEFELI-LYSNAR SURVEY EQUIPMENT **66**
325 Harbourne Street
OSBORNE PARK WA 6017
Tel: (09) 242 4444
Fax: (09) 242 5544
Contact Person: Peter Hugall

Haefeli-Lysnar Survey Equipment is a locally owned company which has been selling and supporting survey equipment for over ten years. We are the major supplier of survey equipment and accessories to the mining industry of Western Australia and the Northern Territory, with a reputation for fast, friendly, and efficient service. As WA agents for both GARMIN and MOTOROLA, Haefeli-Lysnar is very active in the GPS field with individual units and complete systems available for all applications. Also on display will be the new CRITERION hand held, reflectorless total station which will revolutionise tasks such as face mapping, grid pegging and asset management surveys.

HAINES SURVEYS PTY LTD **75**
PO Box 65
MODBURY NORTH SA 5092
Tel: (08) 369 0760
Fax: (08) 261 8221
Contact Person: Richard M Haines

Haines Surveys specialise in Global Positioning System (GPS) satellite surveys for the mining, mineral, oil and gas exploration industries. They have developed GPS methods which are capable of producing horizontal and vertical (height) accuracies of better than 5 centimetres over distances of 20-30 kilometres. Station occupation times are in the order of 30 to 40 seconds. Haines Surveys have over six years of GPS surveying experience and have developed an impeccable reputation for providing a professional service ingrained with technical excellence. This experience includes several projects overseas. Their most recent developments have been the integration of GPS height determination with gravity surveys. Haines Surveys have already taken over 20,000 gravity/height readings throughout Australia using this method.

HAMPSON-RUSSELL SOFTWARE SERVICES LTD **90**
510, 715-5 Avenue SW
CALGARY ALTA
CANADA T2P 2X6
Tel: (403) 266 3225
Fax: (403) 265 6651
Contact Person: Ruth Peach
Hampson-Russell is a seismic software developer based in Calgary, Canada. Products include STRATA, a 2D and 3D seismic inversion programme; AVO, a pre-stack modelling and amplitude vs. offset analysis programme; GLI3D, a programme designed to interpret first break picks from 2D and 3D seismic data and derive a near-surface geological model; and INVEST, a noise attenuation programme based on the parabolic Radon transform. The programmes run on PCs, UNIX workstations and mainframe computers.

INTERA **71, 72**
1175 Hay Street
WEST PERTH WA 6005
Tel: (09) 322 4333
Fax: (09) 322 7254
Contact Person: John Law

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

KEVRON GEOPHYSICS PTY LTD **29**
10 Compass Road
JANDAKOT AIRPORT WA 6164
Tel: (09) 417 3188
Fax: (09) 417 3558
Contact Person: David Gibson

Kevron Geophysics is a subsidiary company of the Kevron Group based in Perth, and has been actively involved in the acquisition and processing of airborne geophysical data since 1986. Three directors are David Gibson, general manage, Gary Paterson, technical engineer, and Gordon Macdonald, senior field operator. The company operates 3 Aero-Commander Shrike aircraft and employs a total of 20 staff, all of whom have wide experience in airborne geophysics. The aircraft are fitted with the latest state-of - the-art equipment including real-time magnetic compensation, and real-time GPS Satellite navigation systems. The data processing manager, Mark Baigent BSc, is in charge of in-house processing, using SUN 4-280 and SPARC STATIONS.

LAMONTAGNE GEOPHYSICS **76**
4A Whiting Street
ARTARMON NSW 2064
Tel: (02) 906 6221
Fax: (02) 906 1778
Contact Person: Andre Blaha

Lamontagne Geophysics (Aust) Pty Ltd specializes in collection and interpretation of EM data for Geophysical Exploration. Designers and manufacturers of proprietary EM system , UTEM III, we operate the system world-wide, both in surface and borehole mode. We are also developers and distributors of flexible EM modelling software, MultiLoop II. On airborne EM front, we provide Conductivity Depth Imaging, using our proprietary software.

LANDMARK GRAPHICS CORPORATION **95, 96**
15150 Memorial Drive
Houston TEXAS 77079-4304
USA
Tel: (713) 560 1371
Fax: (713) 560 1370
Contact Person : Mindy Manning

Landmark offers geophysical and geological interpretation workstations including 3D volume interpretation software, integrated exploration software, data management software, petrophysical analysis software, log analysis and mapping software, seismic processing applications, depth conversion software, and environment and software consulting services. For more information visit our stand number 95 and 96 or contact the Landmark office in Perth at Tel (619) 481 0277.

LEICA INSTRUMENTS PTY LIMITED **59**
45 Epping Road
NORTH RYDE NSW 2113
Tel: (02) 888 7122
Fax: (02) 888 7526
Contact Person: Rod Eckels

LEICA INSTRUMENTS is a new company which encompasses the survey suppliers of Wild Leitz and Kern. LEICA has been a supplier of all geodetic instrumentation including theodolites, EDM instruments, levels and Global Positioning Systems since the 1800's. LEICA introduced its first GPS Unit in 1987. This was one of the first survey GPS units on the market. The latest LEICA GPS was released in December 1991 and has been especially designed for the surveying and mapping industries. The equipment is ideal for the quick collection of field data and incorporates the latest in hardware and software algorithms to ensure maximum field productivity. Please visit the LEICA stand to discuss how LEICA can assist you in GPS data collection and positioning.

MACHA INTERNATIONAL, INC. **38**
12 Archimedes Street
DARRA QLD 4076
Tel: (07) 375 3300
Fax: (07) 375 4027
Contact Person: Ron Feenaghty

Macha International, Inc. is the leading supplier of seismic source control equipment for both land and marine exploration. Macha International's geophone and hydrophone testers lead the industry in fast and easy evaluation of sensor performance. Two new control systems were introduced in 1992. The MULTI-VESSEL RECORDING SYSTEM (MVRS) synchronizes multiple recording vessel operations via a high speed radio link. Two-way timing signals and customer data are transmitted to all locations on each shot. The GUN NETWORK (TGN) provides complete multi-gun management for single/multiple boat operation. The GUN NETWORK is a modular system available in 16 gun increments.

ODEGARRD & DANNESKIOLD **39**
1 Kroghsgade
DK - 2100
COPENHAGEN
DENMARK
Tel: (453) 526 6011
Fax: (453) 526 5018
Contact Person: Lene Jeppesen

OD-S will demonstrate RAMESSES II for onboard quality control of seismic data. RAMESSES II offers a module for quantitative monitoring of noise, gun performance and streamer sensitivity. A Near Trace Cube module which performs quality control of post-processed navigation data by merging navigation data with seismic data has been added as well as a Satellite Link module which enables data to be satellite transmitted to shore to provide a quick way for the office to assess data quality. Any trace header values can be displayed or written to ASCII file along with

any seismic attributes generated by RAMESSES II. Data can be transferred, via ethernet, to onboard navigation binning/QC systems. OD-S also markets the OSIRIS software package for modelling of land and marine seismic data and the global seismic inversion method, ISIS.

OUTER-RIM EXPLORATION SERVICES **93**
PO Box 122
Flinders Mall
TOWNSVILLE QLD 4810
Tel: (077) 253 544
Fax: (077) 254 805
Contact Person: David Lemcke

Outer-Rim Exploration Services was established in July 1993 to carry out Pulse EM surface and downhole surveys using Crone Time-domain PEM equipment throughout Australia and the Southwest Pacific. Crone Geophysics & Exploration Ltd is a Canadian company founded in 1962. Crone builds, develops, and maintains its own equipment and is responsible for several 'firsts' which set it apart from the rest. Two of the most important developments are the 3 Component Time-domain EM Borehole Logging System and the Borehole Orientation Tool. These, and the system's durability, reliability and portability, makes EM an essential and cost effective facet of your exploration programmes.

PATERSON, GRANT & WATSON LTD **62**
204 Richmond Street West
Suite 500
Toronto, Ontario
CANADA M5V 1V6
Tel: (416) 971 7343
Fax: (416) 971 7520
Contact Person: Liane Kelly

PGW specializes in the processing, interpretation and research of geophysical data for the mineral, petroleum, environmental industries. Their work has extended from ground field work, to country-wide compilations and interpretations, to continent-wide compilations. The Geological Survey of Canada continues to employ PWG for an on-going Canada-wide magnetic compilation. Country-wide interpretations and field programmes were carried out in Malaysia, Venezuela, Ivory Coast, Burkina Faso, Uganda, Algeria, Western and Southern Africa. Most recently, PWG has finished a major compilation project of the entire continent of Africa and are currently doing a similar project for South America, South East Asia and Central America. In the last two years, exploration for diamonds across Canada and parts of South America attracted several major mining concerns to utilize PWG's experience and software. Virtually all of PWG's work is accomplished using GIPSI, their in-house, commercially available software.

PETROCONSULTANTS **45, 46**
Level 4, 39 Chandos Street
ST LEONARDS NSW 2065
Tel: (02) 901 3599
Fax: (02) 901 3636
Contact Person: Daryl Eyles

Petroconsultants Australasia Pty Ltd and Petroconsultants Digimap Pty Ltd are 100% subsidiaries of Geneva-based Petroconsultants SA, part of the world-wide Petroconsultants Group of companies. Headquartered in Geneva, the Group also has offices in Sydney, Singapore, London and Houston. In Australia, the Group specialises in data services such as paper seismic-to-digital SEGY scanning (Digiscan), digital shotpoints, digital well logs, custom mapping, synthetic seismogram preparation and graphical interactive selection computer software for seismic line data, wells concessions, coastlines and fields. The Group also specialises in world-wide scouting services and consulting and multi-client reports/studies (Geology, Geophysics, Petroleum Economics).

PETROLEUM INFORMATION ENERGY SERVICES PTY LTD **50**
180 Stirling Highway
CLAREMONT WA 6010
Tel: (09) 389 8499
Fax: (09) 389 8243
Contact Person: Dave Griffin

Petroleum exploration data vendors offering a wide range of both hard copy and digital Australian services.

Hard Copy Service	Digital data/software
Seismic sections	Seismic digital shotpoint
Shotpoint base maps	database
Well logs	Well logs
Well completion reports	Well summaries
Geophysical reports	CD-ROM (well logs)
General reports	Voyager GIS
Palynological data sheets	GO Simulator
Synthetic seismograms	Stacked/migrated seis
Vulcan Basin study	Seismic Index
Carnarvon Basin pressure study	Bathymetry & coastline

With an office in Perth all data and services can be examined on the premises and in many cases copies supplied immediately. Comprehensive data catalogues and descriptive flyers available on request.

PETROSYS PTY LTD **56, 57**
Suite 11, 15 Fullarton Road
KENT TOWN SA 5069
Tel: (08) 363 0922
Fax: (08) 362 1840
Contact Person: Michael Brumby

Petrosys Pty Ltd specialises in developing and supplying geological and geophysical software to the petroleum industry. The company was founded in 1984 and since this time the Petroseis mapping product has become an industry standard amongst many petroleum companies in Australia. Petroseis is a seismic database and mapping

package that can be used to create presentation quality maps or seismic, grids, contours and cultural data. Data can be digitized or imported from interpretation systems and then manipulated using the editor, gridded and contoured or depth converted. Recently Petrosys have released DBMAP, a mapping application that has dynamic SQL links to a corporate database. Petrosys also supports PEP, a log package for log editing, digitizing and cross section displays and Platte River Associates software, which includes the popular Basin Mod package for geological and geochemical modelling.

PHM SURVEY CENTRE **80**
Unit 5, 14 Main Street
OSBORNE PARK WA 6017
Tel: (09) 444 0233
Fax: (09) 443 2598
Contact Person: Doug Lloyd

PHM Survey Centre are a leading supplier of GPS Systems to the Exploration Industry. As the Australian Distributor for Magellan System Corporation and Novatel, PHM can supply the complete range of GPS Systems from the low end Hand Held Magellan Trailblazer up to high end Real Time Sub Metre Systems offered by Novatel. On stand 80 on the 1st floor, PHM will be displaying the new Magellan Pro Mark V GPS Receiver with 8 hours onboard Carrier Phase and Code data storage. Also on display will be the Novatel Smartbase Receiver which can broadcast 10 channel Real Time output with an accuracy of 70 cms. This receiver is ideal for Griding or Drilling in Real Time. Various software packages will be on show including Geolink for Real Time Mapping in the field and Terra Vision for Intelligent Vehicle Tracking Systems.

RESOURCE INDUSTRY ASSOCIATES **73**
538 Brunswick Street
NORTH FITZROY NSW 3068
Tel: (03) 482 4945
Fax: (03) 482 4956
Contact Person: Jeff Bailey

Resource Industry Associates (RIA) has developed **TerraScan ProGPS** Version 2.0 for release at the ASEG Conference. TerraScan is a low cost image processing/GIS program that runs under Microsoft Windows 3.1 and NT. The program displays raster and vector data such as SPOT, Landsat (supplied by RIA), geophysical data, DTM, and airphoto. TerraScan now provides the ability to combine imagery, vector data and GPS on a laptop in the field. Version 2.0 has on-screen digitisation, 3D Surface generation, 3D viewing as well as GPS logging with attribute fields. The RIA stand also has the new RIA/SONY Image Writer, Magellan, Sony and Navlogger Differential GPS.
RIA - Resource Mapping Technology that won't cost you the earth.

SCINTREX PTY LTD **86, 87**
1031 Wellington Street
WEST PERTH WA 6005
Tel: (09) 321 6934
Fax: (09) 481 1201
Contact Person: Graham Linford

SCINTREX Pty Ltd provides geophysical instruments for sales, hire and contract surveys to the mining exploration industry and has operated in Australia for over 25 years, making it the most experience Australian company in its market. The geophysical methods include induced polarization, magnetic induced polarization, electromagnetic VLF, SIROTEM, and Genie, gravity, proton and cesium magnometers, radiometrics and physical properties. The exhibition features the new proton ENVIMAG, Cesium SMARTMAG, IPR-12 time domain IP receivers, CG-3 Autograv gravity meter and other instruments. Please call to discuss your instrument and survey requirements for within Australia and overseas.

SEISMIC IMAGE SOFTWARE **79**
1100, 444 -5 Avenue SW
Calgary, ALBERTA
CANADA T2P 2T8
Tel: (403) 233 2140
Fax: (403) 266 2685
Contact Person: Judi MacDonald

SEISMIC IMAGE SOFTWARE LTD
Seismic Image Software (SIS) is a 100% Canadian owned software company providing PC-based geophysical software to the petroleum, mineral and resource industries. The company currently has over 300 installations world-wide with our software and training services being used by major oil companies, seismic contractors, consultants, government institutions and universities alike. There are also 11 SIS agents/distributors in USA, England, Australia, Taiwan, India Brazil, China, Indonesia and Russia. Products include VISTA, our seismic processing and interpretation system features over 50 seismic functions. FD, our 3D seismic survey design and analysis package. FD TOOLS, considers the theoretical aspects - geological modelling and regular geometry configurations. Together with Green Mountain Geophysics, SIS will also show MESA, an advanced 3D Survey Design and Quality Control Software Package, currently drawing rave reviews around the world.
GREEN MOUNTAIN GEOPHYSICS, INC
Green Mountain Geophysics, Inc (GMG) develops and manufactures geophysical software providing high quality interactive products and product support on PC's, Mac's and workstations. The mission of GMG is to reduce the time, cost, and frustration of front-end 2D and 3D seismic processing functions by connecting the field and the office with software applications.

SEISMIC SUPPLY INTERNATIONAL PTY LTD **36, 37**
PO Box 519
DARRA QLD 4076
Tel: (07) 375 3300
Fax: (07) 375 4027
Contact Person: Ron Feenaghty

Seismic Supply has been a prominent supplier of equipment consumables and services to the petroleum exploration industry in Australia since 1959 and in South East Asia since 1969. The geophysical systems division throughout the 1980's has become a leading supplier of instruments and consumables from the world's most established and respected manufacturers in their respective fields. Our exhibit will focus on the latest in seismic data acquisition and GPS, in particular, the new real-time kinematic GPS systems from Sercel and OYO Geospace's recently released 24 bit seismic data acquisition system, the DAS-1.

SILICON GRAPHICS **51, 52, 53, 54**
446 Victoria Road
GLADESVILLE NSW 2111
Tel: (02) 879 9500
Fax: (02) 879 9585
Contact Person: Ian Lilly

Silicon Graphics (SGI) is the world's leading manufacturer and supplier of high performance graphics workstations. SGI is also the world's fastest growing UNIX workstation company. On display are a range of our current products including the newly released Indigo2 Dual Head featuring the fastest 2D and 3D graphics systems on the one workstation. Applications being displayed include seismic interpretation (Photon Systems), 3D seismic volume rendering and interpretation (Vital Images), 3D geological volume reconstruction (Midland Valley-3DMove) and interactive 3D reservoir characterisation (Stratamodel). Check your satchels for other displays of applications on SGI workstations.

SIMON PETROLEUM TECHNOLOGY AUSTRALIA PTY LTD **41, 42**
69 Outram Street
WEST PERTH WA 6005
Tel: (09) 322 2490
Fax: (09) 481 6721
Contact Person: Peter Kirk

SPT was formed in 1991 when SIMON GEOPHYSICAL SERVICES (formerly Horizon Exploration Ltd) was merged with the Robertson Group. SPT have offices in Perth and Jakarta and offer the following services and products:- 2D and 3D Land, Marine and Transition Zone Seismic Data Processing, Tape copying and transcription, Interpretive Processing - AVO modelling and analysis, seismic trace inversion, pre-stack depth migration, interpretation, integrated studies. Non-exclusive reports and seismic data. Biostratigraphy, geochemistry, core analysis, reservoir geology. Petrophysical log analysis, TIGRESS - The Integrated Geoscience and Reservoir Engineering Software System.

TESLA AIRBORNE GEOSCIENCE PTY LTD **7**
41 Kishorn Road
APPLECROSS WA 6153
Tel: (09) 364 8444
Fax: (09) 364 6575
Contact Person: Rodney Pullin

Tesla Airborne Geosience (TAG) offers magnetics with picoTesla resolution. The single-engine Cessna 210N (VH-

JBH) was chosen for its low noise characteristics, its simple automatic compensator geometry and the efficiency over-the-ground of retractable undercarriage. Scintrex Cesium vapour magnetometers are recorded along with top-of-the-line Novatel GPS positioning on 486 computers both at the base station and in the aircraft's TAG-2 data acquisition system. The radiometrics are new from Exploranium. The satellite positioning can be real-time for 50-100 metre line-spacing surveys or post-processed for coarser surveys. Accuracies within metres are achieved. Data processing is carried out by Tesla-10 at their Perth head office where data can be frequency-sliced for petroleum clients seeking the TAG low-noise characteristics. For mineral exploration clients the data lends itself to susceptibility mapping or quality imaging.

TESLA-10 PTY LTD **8**
41 Kishorn Road
APPLECROSS WA 6153
Tel: (09) 364 8444
Fax: (09) 364 6575
Contact Person: David Abbott/Craig Annison

Tesla-10, the Perth based geophysical contractors, specialise in resource data processing and ground geophysical surveys for the mineral and petroleum industries. High quality computer processing of airborne and ground datasets has always been a major part of our operations, and in recent years Tesla-10 has become a major supplier of a range of ground surveys including seismic reflection, electromagnetics, IP, Gravity and magnetics. Tesla-10 was the first Australian contractor to purchase a Sirotem Mark 3 and now owns 3 of the systems including the latest multi-channel option. Logging configurations are also undertaken. The"Geoliner" vehicle drawn magnetics and EM system is proving popular in environmental and agricultural work. With automatic sampling of several parameters simultaneously the Geoliner is able to collect large datasets rapidly and economically.

ULTRAMAG GEOPHYSICS **28**
43 Marks Parade
MARKS POINT NSW 2280
Tel: (049) 45 9472
Fax: (049) 47 7513
Contact Person: Phil McClelland

Ultramag Geophysics manufactures a range of Overhauser Effect, Proton Precession Magnetometers and VLF systems in Australia under licence to GEM Systems, Canada. Our speciality is high quality, state-of-the-art fast sampling

magnetometers and gradiometers. **Applications include:-** Mineral Exploration, Magnetic Observatories, Environmental, Un-exploded bombs and ordnance detection. **Technical Support:-** Custom instrumentation, Comprehensive data processing software for IBM PC-XT-AT, Custom software, 6 years manufacturing experience in Australia, Prompt service 24 hours - 7 days a week, 2 year warranty on all instruments. **Ground Magnetic Survey Work:-** Survey design, Low or high resolution, Image processing, Interpretation. **Rentals:-** Slow and fast sampling magnetometers-gradiometers, Hipchain trigger and accessories, Attractive rent-lease-purchase arrangements, Software.

UNIVERSAL TRACKING SYSTEMS PTY LTD 9
Valentine Road, Perth Airport
PO Box 126
BELMONT WA 6104
Tel: (09) 479 4232
Fax: (09) 479 1008
Contact Person: Neil Goody/Nino Tufilli

UTS is an Australian owned data acquisition company which offers its clients the latest in technological exploration methods in both fixed wing and helicopter data acquisition. **High Detail Magnetics:** UTS offers the world's first helicopter stinger system obtaining levels of magnetic detail comparable only to ground based surveys. The system offers airborne magnetics as low as 10m sample height, 25m line spacings and with sample intervals of 3m. **Computer Aided Navigation Systems:** GPS based aircraft navigation systems for high accuracy surveying and data processing. Real-time and post processed Differential GPS are available. **Design and Manufacture for Customised Data Acquisition Systems:** UTS has designed and developed data acquisition systems for helicopter, fixed wing and ground based surveys companies. All software and hardware is developed in-house to fully meet specific client requirements. UTS is committed to providing its clients with cost effective, technologically advanced exploration systems.

WORLD GEOSCIENCE 43, 44
65 Brockway Road (Cnr McGillivray Road)
FLOREAT WA 6014
Tel: (09) 383 7833
Fax: (09) 383 7511
Contact Person: Heather O'Rafferty

World Geoscience Corporation Limited (WGC), a subsidiary of Aerodata Holdings Limited, is a world leader in airborne geoscience providing services in the fields of mineral, oil and groundwater exploration, agricultural-environmental management and coastal bathymetry. The WGC Group is the world's largest airborne geophysical surveyor operating thirteen survey aircraft, eight based in Perth and five in North America, with offices in Sydney, Houston, New Delhi, Gaborone, Jakarta and London. Services are provided in earth resource mapping using high resolution magnetic, radiometric and electromagnetic measurements taken from low flying aircraft and helicopters. Fields of specialisation include High Resolution Aeromagnetics, QUESTEM Digital Airborne TEM, Calibrated Multichannel Radiometrics; Geophysical Equipment Development and Manufacturing; Consulting, Interpretation and Educational Courses; Airborne and Satellite Remote Sensing; Ground Geophysics; and Data and Image Processing. A recently developed new survey technique is the Airborne Laser Flourosensor (ALF Mk 3) for detecting leaked or seeped petroleum on the sea surface which originated from reservoirs beneath the sea bed.

ZEH GRAPHIC SYSTEMS 85
54A Taman Nakhoda
Villa Delle Rose
SINGAPORE 1025
Tel: (65) 473 6230
Fax: (65) 473 6305
Contact Person: Neil Varty

Zeh Graphic Systems, established in 1980, operates world-wide and specializes in monochrome and colour plotting systems. The company's highly developed productivity tools enable users from a wide range of industries to produce high quality laser raster plots. At ASEG a new CGM (+) preview/composer with many innovative features, large dynamic colour ranges and inkjet plotting links will all be demonstrated along with the very latest versions of ZPS. Zeh Graphic Systems, now well accepted within the Australian E&P software market, can offer the widest possible range of plotting solutions tailored to meet each users needs.

ZONGE ENGINEERING 20
240 Glen Osmond Road
FULLARTON SA 5063
Tel: (08) 338 1559
Fax: (08) 379 6753
Contact Person: Kelly Trembath

Zonge Engineering has operated field crews world-wide for the last 21 years, and in 1978 began selling its versatile, multi-purpose receiver systems. Zonge's reputation for first-rate data collection and reliable equipment is the result of in-house design engineers working continuously operating field crews. Today, Zonge provides field services, data processing and consulting services in all electrical geophysics, including IP, resistivity, TEM, NanoTEM, CSAMT, and AMT , as well as other less commonly used methods. Zonge's receivers and transmitters are designed too be capable of a wide variety of methods, and are expandable both in hardware and software to accommodate changing survey needs.

Preview

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Special Feature

Ken McCracken -
Satellites to Sirotem

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April '94	April 1, 1994
June '94	May 27 1994
August '94	July 29 1994
October '94	September 30, 1994
December '94	November 25, 1994

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Notice of ASEG Annual General Meeting and Election of Executive Committee

A combined Federal AGM / Victorian Branch AGM and social evening will be held on Tuesday 12 April, 1994 in Melbourne.

Date and Time: Tuesday 12th April, 1994 5.30pm for a 6.00pm start

Venue: Kelvin Club, Melbourne Place, Melb.

Federal AGM Agenda:

1. Welcome to members
2. Apologies
3. Minutes of the 1993 AGM
4. Matters arising from the minutes
5. President's report
6. Treasurer's report
7. Secretary's report
8. ASEG Sub-committee reports
9. Election of office bearers for 1994
10. Items of general business
11. Close of meeting

Refreshments will be served prior to the meeting. The Federal AGM will be followed by the Victorian branch AGM, drinks and supper.

Incumbent Officers:

President:	Hugh Rutter	Geophysical Expl. Cons.
1st V. President:	Mike Asten	BHP Minerals
2nd V. President:	Robert Singh	Schlumberger Geoquest
Treasurer:	Lindsay Thomas	Melbourne University
Secretary:	Brenton Oke	BHP Petroleum
Committee:	David Gamble	Billiton Australia
	Andrew Sutherland	Schlumberger Seaco Inc
	Koya Suto	Pacific Oil & Gas
	Greg Turner	CSIRO
	Geoff Pettifer	Geological Survey of Vic

In accordance with Item 48 of the Article of Association, all incumbent officers of the Federal Executive shall retire at the AGM.

Nominations are sought for the above positions. Nominations must be made in writing, signed by three or more members and bear the consent in writing of the nominee. Such nominations must be received by the Secretary no later than 11th April. For practical reasons, nominees should reside in Melbourne.

Brenton Oke, Secretary

Viewpoint

Fighting Bushfires

Bruce Finlayson

Over this Christmas I managed to take a breath from everyday work. I had just completed the first stage of a major seis-strat and tectonic basin analysis for a client and returned home for my daughter's 21st birthday at the end of January. I had five weeks with perhaps two of three weeks of small projects to do, plus Christmas shopping and visiting/having over my other three younger children from whom I am largely separated. So I had that unusual commodity these days, spare time. A chance to catch up with local friends, reading and well, just thinking about life.

A couple of significant things emerged. Somewhere in my reading, the impact of working as a consultant geophysicist raised its head. And the bushfires. I was obsessed for a day or two with listening to the bushfires on the radio. My obsession was partly explained by my having been involved n the Ash Wednesday fire where I was trapped in my house and watched it burn around me before making my escape to shelter in the driveway. I lost everything I had but the clothes I was wearing.

There were many firefighters who volunteered to go from South Australia to NSW. There was a need and they went. They were experienced, well trained, they worked as teams, cooperated and performed to the highest levels. They were mostly men.

In the article from Preview 46 October, 1993, Roger Henderson and Mary-Linda Adams noted that we as geophysicists tend to criticize each others efforts too readily. Well, we live in a declining industry. There are new young well trained geophysicists joining the industry, competition is strong for the few available positions. The less competent are weeded out. Natural selection, a stronger profession etc. but two points, one that Mary-Linda touched on is that ongoing rivalry and criticism diminishes our overall standing.

Around the world I still hear today from the managers who control the funds that are spent on the work we do. "Lets just drill more wells and get our costs down that way. Lets get some real data." Geophysicists are often seen as somewhat mystical isolates who can't agree on what's going on, so why bother with them? We know how expensive that is, what the success rates are. And we should know that this diminishes the use of geophysics in the short term and helps confirm the decline rather than expansion of our industry.

There is another point. Continuing competition is hell to live with. Sure the thrust and parry of the game is fun every now and then. The wins are exciting and occasionally triumphal. But the continuing competition has its drawbacks too. Less competitive players leave not because they have nothing to offer but what they offer is lost in the clamour. Those who stay and continue to fight and win enough to stay in the game also suffer. Geophysicists have other reputations. They are often seen by others as social isolates and those who do come out to play often do so in the macho world where alcohol numbs the bits that hurt.

So back to firefighters. They will go back to work which involves to some degree greater or lesser, the same competitive games. Yet they have just experienced togetherness, cooperation, brilliant thinking, successful action and for many a high point of their lives. Competition would have been less effective, less rewarding. It just wasn't appropriate.

Lets look at our industry. Lets look at creating that cooperative style. It comes from having clear shared goals, clear thinking about reality, encouragement to individual input and acceptance of mistakes without any question but to identify the new way the mistake has shown. It comes from building useful networks and teams and institutions. It comes from building useful networks and teams within and across existing boundaries - companies, people and institutions. It comes from generously and assertively communicating and always seeking to add value to our creations. To some extent we are already doing it and we can be inspired by what we have created because what we have created is already one of the most sophisticated industries on earth.

Errata

In December 1993 Preview No. 47, page 42 the two figure captions were inadvertently interchanged.

Preview - 50th Issue

June, 1994
History of Geophysics

For our 50th issue we wish to feature some articles on aspects of the history of geophysics and the ASEG in Australia.

If you can contribute an article, please contact:
Geoff Pettifer, Preview Editor
Tel: (03) 412 7840; Fax: (03) 412 7803

Preview - Next Issue

- *High Performance Computing and Visualisation Trends in Exploration*
- *Seismic Window - Sequence Stratigraphy*
- *Southern Cross Gravity Survey*
- *News From the Conference*

From Satellites to SIROTEM

Interview with Ken McCracken

MIKE: Ken, Can you describe your origins, in particular when did you become Chief of the Division of Mineral Physics. It was obviously a major career change; what made you take that step from physics into the world of geophysics?

KEN: First let me talk about the 37 years prior to that change. I had lived with changes all my life. My father was an itinerant tax collector - by the end of high school, I had been to schools in Brisbane, Melbourne, Canberra and Hobart. I had learned that changes can provide very positive advantages. Thus I was an atrocious student of languages, and was failing dismally in Canberra in the middle of my second year, but we moved to Hobart, where the syllabus ran a year behind, and I was then top of the class. I resumed my monotonic decline; squeaked through in fourth year; and dropped the lot. Again and again it has been my experience that what you know when you make a change, often gives you a great (unfair?) advantage in a new community or endeavour.

Then again, the mining industry was not unfamiliar territory. My maternal grandfather had been an underground miner in the Gympie gold mines, and my grandmother's family had been antimony miners at Tin Can Bay, near Gympie. You might well ask then - how did I end up in Physics in the first place? The early 1950's were still a time of post-war austerity - and the norm was to do your honours degree where you lived. I almost chose theoretical physics, but chose to study cosmic ray physics. It was "hands-on"; I liked electronics - there was lots of interesting travel to the Antarctic etc. In the event I took my equipment to New Guinea - I didn't object to that either.

In fact, New Guinea, and my military service, were vital parts of my real education. They taught me how to achieve things, away from all the usual support structures of a research laboratory, or professional community. In New Guinea my only assistance was from a team of "bush kanakas" given to me the day I landed. I knew no Pidgin - but learned very quickly. Then my cosmic ray laboratory was housed by the Australian Department of Civil Aviation. This opened doors for me and I flew all over Papua/New Guinea as a "super-numerary" on the bush airlines. The aeroplanes were "war disposals" DC-3's, with hard wooden benches down each side of the cabin. The space down the middle was piled high with cargo, food, tyres, cement, live pigs - etc. Then the passengers got on. They were usually indentured labour for coconut plantations, and were scared out of their wits by "big pella balus" - the aeroplane. My job was to open the door from the pilot's cabin and shout out "yu-kissim seatbelts quicktime eh. Maski buggerim up". I was the closest they got to the air hostess of today.

My cosmic ray work in Hobart (PhD project) led to an invitation to work with Bruno Rossi at MIT. It came out of the blue - and I couldn't have found a better place, time or mentor, anywhere in the world.

Space flight was then just two years old. Every flight resulted in startling discoveries. It was beyond the realms of possibility for a quiet, wet behind the ear, scientist in Australia's smallest University, to even dream of participating. Yet when my brand new wife and I arrived at MIT, we found we were deep in the middle of it. Rossi's group was building two of the first "Explorer" satellites. Being too dumb to know better, I taught myself FORTRAN by programming a very complex program for the worlds' first "numerically intensive" computer, the execution time being several times greater than the "mean-time - between failures". In the event it worked just fine, many hundreds of times - I rapidly became very well known for this work and within two years I was building the first of the seven instruments that I flew on US satellites - in my own right.

Ken McCracken
A.O., F.A.A., F.T.S.
Ph.D, DSc

Ken McCracken, sole recipient of the ASEG Gold Medal, is one of Australias best-known and highly honoured scientists, here and overseas. He gained a PhD in Physics from the University of Tasmania (1959) and joined the MIT (Boston), where he showed his flair for innovation in the early US space program.

After seven years, he returned to Australia to a Chair of Physics at the University of Adelaide. In 1970 he made a major career change into exploration geophysics, and over a period of 14 years with CSIRO generated innovative programmes of geophysical research which continue to endure today. He returned to space science as Director of the Office of Space Science and Applications for five years up to his retirement in 1989. Ken continues to inspire innovation, as a consultant to both government and industry.

In this interview, over a meal, Ken discusses his role in the genesis of geophysics in CSIRO, and its influence in Australia. Bob Smith, Mike Asten and Geoff Pettifer listened, and refilled the glasses.

Mentor - the rationale

mĕ'ntŏr *n.* Experienced and trusted adviser. [F, f. L f. Gk *Mentôr* adviser of the young Telemachus in Homer's *Odyssey* and Fénelon's *Télémaque* (root **men-* think)]

So says the Oxford Dictionary. In the Mentor series of articles we talk to prominent mentors and change agents in the field of geophysics to see what makes them tick and discuss their views on geophysics.

Prof Ken McCracken with his X-ray astronomy apparatus at Adelaide University.

In any new endeavour, such as space was then, you learn to be bold. Ignoring mean times between failures. Telling NASA they were wrong - and winning. Phoning the Chief Executive of General Electric to complain about deliveries. Being the first to fly integrated circuits in space. Recognising the significance of a single measurement of X-Rays from a point near the centre of the galaxy, and changing your whole research program overnight.

My family and I stayed in the US for seven years. I returned to a chair in physics at the University of Adelaide. I thought that space research, as I had known it, would go on for ever. I was wrong. That very year it "went over the top" in the USA. In Australia, the people running the Australian space program didn't want to know me.

MIKE: Was that because you were too big on budget?

KEN: No. The kindest explanation is that it was a combination of "minding your turf" and "not invented here". I believe that the real reason was that the senior management of the Department of Government that ran the Woomera Rocket Range, didn't want their nice tidy operation being loused up with University Scientists.

In fact, Australia paid 50% of the very considerable costs of the "joint project" that operated the rocket range. The British universities, and research community were provided with research flights using a beautiful, stable rocket called "Skylark". Six Skylarks were provided each year for Australia to use. They were flown empty (or almost so) to "calibrate" the tracking cameras.

The Australian research community tried many times to "piggy-back" experiments in those Australian Skylarks. The Vice-Chancellors of the universities had made a careful submission. The answer was always "no".

Yet when I returned to Australia, I was one of very few who had started a new form of astronomy - looking at X-Rays from the stars. No-one had looked at the stars of the southern sky. Rockets from Woomera were the ideal solution. It was the chance of a lifetime. Some real lateral thinking was necessary.

I was at a conference in London and Geoff Fenton (who had been my PhD Supervisor), and I hatched up a plan. We went to the British equivalent of NASA. In those days our Australian passports had "BRITISH PASSPORT" on their covers. I pulled out my passport - showed the cover - and said "Gentlemen - we are here not as Australians, but as holders of British Passports. We wish to propose to fly on Skylarks as British experimenters, not Australian".

The Poms almost rolled on the floor with laughter, as if to say "what else will these bloody Australians get up to?" They said "put a proposal in". We did within two days. And that is how those two well known British Universities; the Universities of Adelaide and Tasmania, became part of the British research program from Woomera. We were given "rides" on two British Skylarks, and a great deal of "in-kind" support.

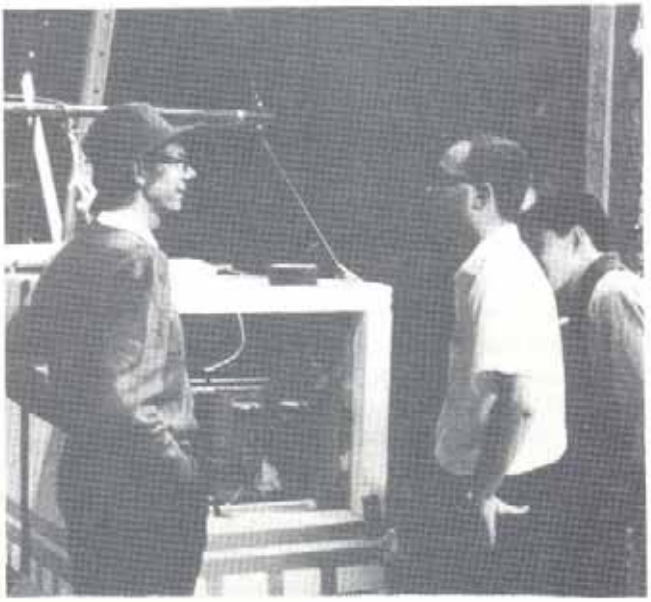
Having sneaked in the back door, we then got tremendous support, and in particular - flights on the Australian Skylarks. One of our discoveries led to great editorial excitement in the scientific journal "Nature".

Then the UK and Australia decided to terminate the "Joint Project". There were no more Skylarks. That was the end of hands-on space for me for a long time. And so I made my third career change, this time to minerals.

MIKE: But why mining? Were there not other possibilities that were closer to your space experience?

KEN: In my mind - no. I saw the mining industry of 1970 as the Australian equivalent of the US space industry of the early 1960's. It was already a key component of the national cash flow, and with great possibilities for expansion. CSIRO management was thrashing around saying "surely there is a role for us here". The existing divisions were saying - "we are too busy", and - "there is no real physics or research in that".

Enter Victor Burgmann and Ivan Newnham of CSIRO, and I suspect Prof. Eric Rudd of Adelaide University. They proposed to the Executive of CSIRO



A very Australian Ken McCracken participating in a scientific balloon launch in the US (circa late 1960's).

that they find "someone who can apply the new technologies of space to minerals exploration". I was already on my way back to a permanent "full professorship" at MIT when I was "head-hunted" by the Chairman of CSIRO of the time. It was another "opportunity of a lifetime" (I've had a few of them). I came like a shot, to be Chief of a new Division of Mineral Physics.

To me the vision was very clear. I was carrying with me a great deal of technological know how. In particular - the benefit of a systems approach - and the great virtue of digital systems. I had been building digital systems for 15 years and I knew that digital systems were an order of magnitude more accurate, and reliable, than analog systems. And lo and behold, mineral geophysics was deeply immersed in analog systems.

GEOFF: What was the stage of development of digital circuitry at the time?

KEN: The key to the accuracy, and reliability of digital systems - lie in the analog to digital converter (ADC), and the microprocessor. Nowadays you buy these as nicely packaged chips. Sixteen bit ADC's are standard.

The situation was quite different in 1970. The first, most primitive microprocessor did not appear until 1975. In 1970, we built our own ADC's from transistors and integrated circuits and thought 8 bits were heaven. It was quite an art form. We were developing geophysical instruments, methods, and interpretation for components that were three or more years off - but whose arrival was totally inevitable.

In the ten years before the start of Mineral Physics, computing speed had increased ten-fold and memory close to 1000-fold. There was no doubt whatsoever that the capability would continue to increase greatly. So there was no doubt that the infant technologies of modelling, inversion, etc would reach maturity in the lifetime of the Division. The key question was - would the Australian industry want to use those technologies. CSIRO and I, with the sage advice of Stan Ward and from some far-sighted individuals in Australia, gambled that they would. We aimed to accumulate the people, and equipment, to provide the Australian industry with an indigenous source of state-of-the-art development.

GEOFF: Would you like to comment on those early days as Chief of the Division of Mineral Physics and outline your vision in 1970 for the future?

KEN: First let me acknowledge the role of Stan Ward. He had been commissioned by the CSIRO, prior to my appointment, to provide an assessment of the national and industrial need for R & D in geophysics. Then I spent several days with him in Salt Lake City in late 1970. His knowledge, and long experience in geophysics were vital. I listened very intently, then used my understanding of physics and technology to identify the thrusts for the new Division. As I recall it, Stan and I differed somewhat on relative priorities, but not violently so.

There were five original thrusts for the Division:

EM Exploration Technology

The physicist in me told me that the contemporary EM systems were being hopelessly compromised by the Australian overburden. I was quite confident that we could change that.

Remote Sensing

Entirely new technologies that spring from older, very useful technologies, are usually worth backing. Aerial photography was important in mining, so I argued satellite remote sensing would play an important role in the future.

Rock Magnetism

At the time, magnetic surveys were the most common form of geophysics. Yet there was little information on the magnetic the properties of rocks themselves. The goal was to fill that crying need.

Nuclear Geophysics

I inherited nuclear borehole logging from an existing CSIRO Division. There was a clear need for careful studies of the disequilibria in uranium ores. Over time, new detection technologies, and a particle accelerator were added when future roles were identified.

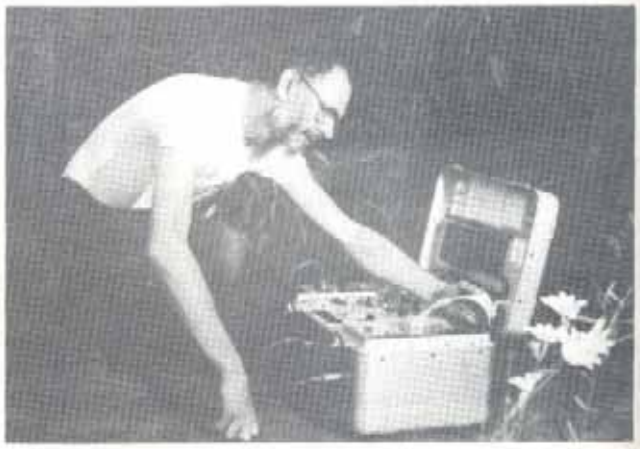
Mathematical Geology

This sought to apply the logic of mathematics to geological investigations.

Did the divisional program turn out as well as I expected? No - it turned out a great deal better. But then, if you have keen switched on people, and a whole swag of new technology just when there is a sea change in all technologies - and when the local industry begins to appreciate good R and D - you would have to be a pretty hopeless leader not to be successful.

And then there was one other major cause for our success - the Australian continent itself. The small geophysical signatures; the masking effects of the over-burden; the harsh environmental conditions; all demanded excellence. Nothing could be taken for granted. Good advice for a scientist is - "run scared". We were, and it paid off.

BOB: Very early you made a visit to many exploration offices and mines all around Australia. Did this first introduction to the industry change your ideas?



Ken McCracken operating SIROTEM in the bush. (circa 1983).

KEN: Fundamentally no. In detail - yes. And from the point of view of understanding the attitudes of the industry - immensely. But - let's be honest, I was a technology freak. I had been an integral part of the revolution in solar system geophysics and was certain the same would happen in mineral geophysics.

GEOFF: Did many of the geophysicists at that time share your vision, or embrace it?

KEN: A few. And there weren't many geophysicists in mining companies then - most were in the BMR, and the contracting firms. Many of them - for corporate reasons I think - found my thoughts - ah - a little strange and dangerous.

But one of the great strengths of CSIRO, was it's ability to understand the strategic forces that were shaping, or would shape Australia, and the world. There was a strong belief in scientific leadership - a belief that some people had something - an intangible insight - that was the key to the conduct of R & D of national importance. So there was no market study. No planning committee. Just a number of quiet discussions by the CSIRO Executive with Stan Ward, and several key people in mining management. On the basis of that they took a guy - who knew nothing about geophysics - and backed him. The attitude was very much like that of the US space industry in the 1960's; give him support, give him room to move - and if he hangs himself, tough.

Once I was installed, and visiting, exploration companies, I found what you would expect - some strong support - and various shades of other attitudes. Western Mining was particularly supportive - I particularly value the discussions I had with Roy Woodall, Tim O'Driscoll, and later, Hugh Rutter. John Nixon of CRA was also very supportive. Their encouragement, and faith, got me through the rough patches.

BOB: You backed EM which had had a poor record in Australia - Why?

KEN: Because I was convinced it would be a success - once it was "tuned" to the Australian Environment. First there was the spectacular contrast - 10^5 to 10^6 - between the properties of the target, and the country rock. And obviously - very obviously - the frequencies being used in Australia then were all very, very wrong. As a physicist, I thought "skin depth", and the skin depths for those frequencies, were only a small fraction of the thickness of the regolith. We had to go to greater skin depths - that is, lower frequencies. And that was close to impossible with the "tuned-circuit" transmitters used then. The physicist once again said - "think fourier series" - use a square wave.

Then in late 1970 I visited Western Mining in Kalgoorlie - and they were using a Russian MOPPO-1 time domain system. Right there in front of me was a clear demonstration that I was on the right track.

For it's time, the MOPPO-1 was revolutionary - but it had two fatal flaws. Firstly, the designer must have been more a mathematician, than a physicist. It was carefully designed to obey the theories regarding the reconstruction of sampled signals. In so doing, it had a quite excessively large band width for noise. Then - to measure the low frequencies of importance - it had to use DC coupled amplifiers. This was not easy using a single battery - the Russian designer chickened out and used 9 different battery packs in the one instrument. The probability of 9 batteries working simultaneously was almost zilch.

There is another reason why I was comfortable with the concept of transient EM - the mathematics were almost identical to the mathematics of the magnetic fields in the solar system. For the previous 10 years I had been writing papers about those magnetic fields - whose weird behaviour is controlled by the same diffusion equations that are central to the propagation of the B-fields in TEM. I had developed a good "feeling" for transient fields - and for my other passion in geophysics - noise. I knew both would be valuable in TEM.

GEOFF: Did any companies come on board at that stage?

KEN: No. We didn't even try to get them - it was too early and too contrary to accepted practice. We bought a very old fashioned "multi-channel signal analyser" that allowed us to stack signals in the time domain. It was not a geophysical instrument - it was designed to measure the decay of short-lived nuclear isotopes.It educated us to what the whole TEM signal looked like - the design of SIROTEM was based upon that information.

Other companies assisted in 1973 and 1974 - field trials were run near Cloncurry, and at Woodlawn. Then we put a proposal to AMIRA in 1974, and five companies supported us.

MIKE: A research program like SIROTEM has extended over 20 years and must have had some high points, and low points; excitement, and frustration. What were they?

KEN: First and foremost - seeing Elura. The AMIRA sponsors provided us with a series of 10 trial targets ranging from the trivial and obvious, through to Elura which I believe was regarded as impossible. Unknown to us the Crone PEM system - another TEM system that was loosely derived from the Newmont system - had been tried there, and had not seen anything - not a whisper! We ran our trial lines, and the Elura TEM - signal came through, loud and bloody clear. It was beautiful! The next high point was seeing the Crone team back there several days later working their butts off to find out what they had done wrong.

MIKE: I suspect that they must have done their survey with their small transmitter loop. Not enough NIA.

KEN: Exactly! Strange to relate, it was only about then that we all realised the extent to which the success of TEM in Australia was due to the large magnetic moments we were using.

Another high, and also low point, was the trial before Elura - Teutonic Bore. It had already been seen by MOPPO - and then the SIROTEM survey was awful. The response was there - but immersed in enormous noise peaks. Brian O'Neill and I hopped on the first available plane (Jock Buselli was in Russia).

By then, Teutonic Bore was a little like a pin cushion, with lots of drill collars sticking out of the ground? A lot of the noise, we found, was due to the TEM loop being too close to the collars.

But there was another source of noise - that was intermittent. We had a portable oscilloscope with us - I have a vivid memory of us huddled under sheets of black plastic in order to see the faint oscilloscope trace - and Graham Sands sitting behind us saying "gee - it's not going to work, you know". Several minutes later Brian O'Neil said " what was that" - he had seen our first sferic "in the raw". We rapidly learned how to handle sferics after that.

The other highpoint was the technology transfer. All countries find technology transfer to be difficult. Australia -in my opinion - is not better, nor worse, than most. When we let the manufacturing licence for SIROTEM in 1977 there were several very good examples how not to do it. We took note.

I believe our transfer of the SIROTEM technology was very successful. It was hard. We had many crisis points. The public "launch" of the product had a small problem - there were no electronics in the unit - just a brick. Then the manufacturer ordered the cheapest version of the micro-processor we had specified - and it was cheapest for a very good reason - they didn't work. The telephone lines from Adelaide almost melted over that one.

Yet we got there. The licensee had estimated he would make eight sales. More than 80 have now been sold. It has been a very conspicuous part of Australian exploration for 15 years. That has been very satisfying.

And yes - one other high point - a personal one - when the ASEG awarded me the Gold Medal. Leading a research team is sometimes a very lonely, discouraging business - because most of the time you are dealing with things that are not working out like you hoped. Nature can be very unco-operative. The Gold Medal was a marvellous compensation for all that. I recall I became a little emotional - which is not my style - but it probably says how important it was to me.

GEOFF: I think I can recall you talking about your cattle at the Award ceremony?

Ken "rockets" off from Mineral Physics to COSSA - CSIRO Staff cartoon about his 5th career change.

KEN: Oh - I think I commented on the great similarities between running a research laboratory and running a cow farm.

GEOFF: How does the kangaroo you are eating nowcompare to beef to eat?

KEN: Oh I don't eat beef. They're my friends.

BOB: I thought they were named after ex-colleagues and bureaucrats!

KEN: Also Ministers of Government. Certainly, some bureaucrats were very worried about who I would name the bulls after.

MIKE: Do you still have the steer called the Minister of Science?

KEN: No. He went to the great bull pen in the sky a long time ago.

MIKE: Could I ask about your mentors? Who was your greatest mentor, and why?

KEN: There were two. The first one was my mathematics teacher in the second last year of high school. Until then I was good at maths - but it was all rote learning. Gerald Rush changed the emphasis entirely - he said - don't remember the formula until you know the basic principles and assumptions. And if you have to forget anything - forget the formulae. But never the basic principles - I have applied that advice to all my science, all my life.

And the other mentor was Bruno Rossi, who I worked with at MIT. He had been Enrico Fermi's first graduate student - and the characteristics I learned from Bruno were also those of Fermi's (one of the greatest nuclear physicists of all time). That characteristic was - "keep it simple".

I guess it was both Gerald Rush and Bruno, who gave me the confidence to ask my "trade mark" question - "this is probably a dumb question, but what.....!"

There is another type of person who is usually important in a young scientist's life - the "influential advocate". The guy who backs you - and you hardly ever know about it. I have been lucky - I have had many - but most important were three - Bruno Rossi mentioned above - another American - who was Chief Scientist of NASA for many years - and Ivan Newnham of CSIRO.

GEOFF: Looking back on your five, or is it six, career changes; looking back at space, and minerals, etc - would you do it all again?

KEN: Oh yes! To put it another way, I hope my children, and the present generation of young scientists are as lucky as I have been. And if I were doing it again - in the 1990's and 2000's - I believe I might be making even more career changes - because it is they that have kept me mentally "on my toes" - while also giving me immeasurable advantages because of what I have seen elsewhere.

Next in Mentor :- Bob Sheriff.

ASEG People Profiles

Joe Odins, Assistant Editor Exploration Geophysics & Conference Guest Co-Editor

Joe lived the first 10 years on a farm, learning to feed pigs, fall off horses and developing a liking for the outdoors. Formal education was provided by Richmond High (New South Wales), within sight of the Blue Mountains. The wide open spaces offered plenty of opportunities to explore, and plenty of exercise for both the mind and the body.

Studies continued at The University of New South Wales (UNSW) leading to a B.Sc. in mathematics and physics (1965). The following year (1966) Joe completed the graduate diploma in applied science (geophysics), under the guidance of Prof. Laric Hawkins. This was the first year the course was offered, and Joe was the first student.

His interest in Exploration Geophysics was enhanced by joining the UNSW Team of The Australian Naval Frigate, HMAS 'Diamantina', involved in a two-ship survey in collaboration with the Lamont-Doherty geological observatory crew from Columbia University on 'Vema'.

Back on land, Joe started work as a geophysicist with the Department of Water Resources (NSW) Hydrogeology Unit, specialising in borehole logging and seismic refraction. It was a foregone conclusion that this work contributed to the completion of an external M.Sc. (1975), again under the supervision of Prof. Hawkins. Naturally, the topic covered the application of seismic refraction to groundwater exploration.

Projects for the Department of Water Resources have included the location and mapping of groundwater in all the major river valleys of N.S.W. Joe has completed detailed mapping of the hydrogeological basement in the Murray Basin.

His specific experience is in seismic refraction, resistivity borehole logging and electromagnetic survey techniques.

Joe has used this combination of skills to benefit the users of New South Wales' water resources in:

- mapping sub-surface structure
- quantitative evaluation of groundwater resources
- identifying and managing salinity problems
- supply of town water
- geotechnical surveys
- drill site location

He is particularly interested in sharing his experience with universities, and has participated as guest lecturer at UNSW, The University of Technology (NSW), panel member on research conducted by Macquarie University into the use of audio-magnetotelluric methods for groundwater studies. He has particupated in introductory geophysics courses run by the Australian Water Resources council and many in-house sessions.

Joe has helped review and edit technical papers submitted to the ASEG Publication "Exploration Geohysics". He is one of the Guest Editors of the 10th ASEG Conference volume.

Always on the lookout for something new Joe joined the Water Resources in time to introduce the Department to its first computer - The Digital Equipment PDP-8e, with a total memory of 4 kbytes!

His current interest is in the Application of Shuttle Imaging Radar (SIR-C) to the detection of waterlogging and soil salinity, in conjunction with the quantitative use of airborne transient electromagnetic, magnetic and radiometric data. His dream is to see Australia-wide coverage with the above method, coupled to efficient algorithms and fast machines, enabling the routine application of the data for mineral and groundwater exploration and management.

In his spare time Joe enjoys ocean sailing, photography and reads anything to do with cosmology.

He is an active member of the SEG.

Richard Facer, Assistant Editor, Exploration Geophysics & Conference Guest Co-Editor

Richard Facer has BSc and PhD degrees from the University of Sydney, studying in the Department of Geology and Geophysics. The latter degree was completed during the rather exciting, but daunting, period of setting up a full three- (and then four-) year course at the then Wollongong University College of the University of New South Wales. Because of the initial small size of the Department (three academics) Richard taught not only Geophysics but various complementary courses. While there may be difficulties with that, one important positive aspect is the opportunity to fully integrate Geophysics into the total degree program - and to emphasise the many areas of interaction between Geophysics and Geology. Close co-operation with industry was another important input.

The opportunity to spend study leaves in the University of Toronto (1975) and University of Western Ontario (first half of 1979) enabled Richard to broaden his geophysical horizons. Over that same period, and beyond, he increased his administrative role at the University of Wollongong, reaching Chairmanship of the Faculty of Science and member of the (University) Senate.

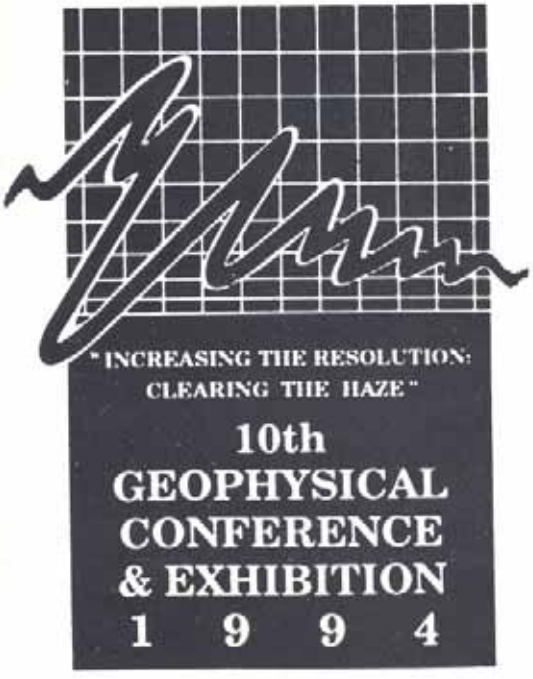
In 1981 Richard took the major step of not just working with/consulting to industry but actually

working for industry by joining Esso Australia Ltd. This provided the opportunity of learning much and greatly expanding understanding - especially of the petroleum industry, but also by working with Minerals and Coal and Synfuels Departments. Richard's involvement across the industry/research/university interaction continued at Esso.

After leaving Esso, Richard maintained and strengthened his contacts with industry, university and government across a range of sectors - and added resource economics to his practical experience (having been introduced to that study at Esso, and then with Australian Mineral Economics). this diversity of interest was recognised when Richard was asked to help with classes at the University of Sydney in 1990 - because of his industry perspective. He is still teaching there. Richard was found that students have a real thirst to learn about what is not infrequently called "the real world". While clearly there is a role for the specialist - Geophysics is just too big - Richard believes that there is also a need for some who can bridge the gaps, and who can apply diverse perspectives, frequently with considerable success.

Richard's involvement with ASEG spans the 25 years. In addition to technical contributions to the Bulletin and Exploration Geophysics he is now an Associate Editor - quite apart from conference work. Richard is also a member of the New South Wales Committee. He is of the firm opinion that the ASEG has much to offer the resources industry, and that includes the continuing education aspects of conferences, seminars and Exploration Geophysics.

EXPLORATION GEOPHYSICS
THE BULLETIN OF THE AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS



Letters

Hugh Rutter
ASEG President

5 January 1994

Dear Hugh,

In response to your column in December 1993 issue of Preview and the strategy outlined in Towards 2005, my view is that this will have limited success in achieving a solution to the "serious gaps in Australian geophysical research" ie "instrumentation research and mathematical geophysics" if the proposed solution is "to encourage the concentration of people and resources into a fewer number of locations". In my view this "encouragement" has been in place for the last five or more years where research concentrations via CRC's, centres of excellence etc have all sought to increase the "critical mass" of research groups, and has not necessarily been successful. Alternatively small groups have had significant success. More of the same may not be the best strategy! Collaboration at a distance can be very successful. Communications by telephone, e-mail and fax make co-operating at distances not difficult. At the Radio Science Laboratory, we currently have a very successful collaborations with the Antarctic CRC (Hobart) and Centre for Intelligent Robotics at Monash University. Creating new large concentrations of people in the same location is not the answer.

The Radio Science Laboratory was established in 1983 to "transfer new and innovative ideas in radio science into new products and services for industry: in particular, environmental monitoring, mining engineering, mineral exploration and geotechnical engineering". One major thrust was a VLF surface impedance meter which has been successfully employed on mine sites and exploration leases. Currently two units are on a major traverse in the Antarctic employed along side an ice radar. The application is ice depth mapping and bed-rock profiling. The laboratory has expertise in many fields including electromagnetic modelling, microprocessor and DSP systems, robotics and a host of electronics technologies in addition to access to fixed wing light aircraft for experimental purposes. Instrumentation geophysics must be fuelled by leading edge technology, and this may not be a priority in establishing larger geophysical research centres. My guess is that the strategic centralisation of geophysics as suggested by Towards 2005 would result in my laboratory turning further away from geophysics as a result of lack of support, both financial and verbal. There are other small groups around Australia who may face the same problems. This ultimate result is detrimental to Australian geophysics research.

David V. Thiel

Director,

Radio Science Laboratory

AGSO Develops New Airborne Topographic Mapping Method

The Australian Geological Survey (AGSO) has demonstrated a new method of mapping the Earth's surface, the Minister for Resources, Mr Michael Lee, announced recently.

A recently completed airborne geophysical survey of the Leinster area of Western Australia, located about 350 kilometres north of Kalgoorlie, has been used to demonstrate the new method.

This is the first time that data from the satellite positioning system in an aircraft has been combined with the radio-altimeter record to produce a high resolution elevation model over a large area. At present, no other technique is available for producing elevation models of this accuracy in such a cost effective way.

The digital elevation model of the Sir Samuel 1:250,000 Sheet area of Western Australia will be released by the Australian Geological Survey Organisation (AGSO) later this month. It is the first of a new series of products to be produced over areas where AGSO undertakes airborne geophysical surveys.

"The new model will be useful to those involved in geological mapping and mineral exploration because it provides a detailed accurate picture of the topography of a large map sheet area," Mr Lee said.

"Those interested in land use development and management who require accurate topographic models should also find these data sets to be of value."

The Sir Samuel Sheet area covers approximately 18,000 square kilometres and its surface is represented by an image containing over 3.5 million points using an 80 metre grid spacing. The image provides a detailed digital terrain model comprising elevation and position information over the whole area to better than two metres. The elevation over the sheet area ranges from 380 to 615 metres, and details of drainage patterns, ridges and other similar features are displayed on the image. This provides improved visualisation of the topography, compared with conventional contour maps.

"The data set was gathered as part of an airborne geophysical survey flown by AGSO from May to July in the Leinster area of Western Australia," Mr Lee said.

"The survey is part of the National Geoscience Mapping Accord, a joint Commonwealth/State program to obtain geoscientific information in Australia's key mineral and petroleum provinces.

"A total of 47,000 line kilometres of new high quality aeromagnetic and gamma-ray spectrometric data were acquired to assist with the geological mapping," Mr Lee said. Flying at 130 knots and at a height of 100 metres above the ground, the AGSO Aero Commander survey aircraft flew each day for about 9 hours and collected basic height data on east-west lines 400 metres apart. The satellite Global Positioning System (GPS) provided

AGSO
AUSTRALIAN GEOLOGICAL
SURVEY ORGANISATION

SIR SAMUEL 1:250 000 MAP SHEET
DIGITAL ELEVATION MODEL

Geophysical Mapping
Airborne Group

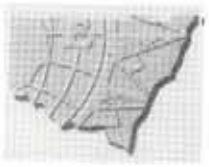
the height information, data being sampled every 335 metres.

The GPS height data were corrected for the height of the aircraft above the ground to produce raw elevation data sampled every 67 metres. These data were corrected for the geoid-ellipsoid separation and the height difference between the radio-altimeter and the GPS antennas on the aircraft to produce the final model.

Further information: Dr David Denham, AGSO, Ph: (06) 249 9267, Fax (06) 249 9986.

ASEG Branch News

New South Wales



The New South Wales Branch Christmas dinner was held at the Kirribilli RSL club on Friday December 3rd. A guest speaker was dispensed with this year, so we could concentrate on the festive process. The evening got off to an auspicious start, when the reception staff determined that anyone living within a 10 kilometre radius, who was not a member of an affiliated club, was barred from entry, which would have effectively reduced our number to about half! Fortunately Phil Woods found a toilet window open on the ground floor, and led a galant team of local non-RSL club members to the inner sanctum.

We were then ushered into a spacious dining room with magnificent views over the harbour, then onwards into a backroom where the club had managed to find some space for the ASEG between the poker machines and the dance floor.

Joining us in this secluded setting were a group of mentally handicapped people also hell-bent on enjoying the festive season. They soon showed their intellectual superiority over the ASEG members; they were a lot quicker than any of us to test out Fiona Turton's dancing skills, when the "Red Hot Bill Haley Revivalists" took to the stage to play some tunes. Some lasting friendships were forged during the course of the evening; later on Nigel Brown and Claus Kuball joined the mentally handicapped group to discuss the derivation of Zoeppritz's equations at some length.

ASEG members gave some impressive dance flor performances. Mike Smith, in particular, showed that Gus Mercurio will have some serious competition in the casting for "Strictly ballroom 2". There was a tense moment, when a small group of visiting Canadian geophysicists attempted to settle their tabs with worthless Canadian dollars. Derecke Palmer narrowly avoided an international incident by arranging for the Frostbacks to wash dishes for an hour in lieu of payment.

In conclusion, the evening was viewed by most as being extremely character forming. Police are still strying to locate Shane Wright, branch secretary, who did a "John Friedrichs - style" bunk to W.A., rather than face the "rock and roll" at Kirribilli RSL club.

NT Jones, NSW Branch Committee Member

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Obituary

John Webb 1922 - 1992

The Australian geophysical community lost a valued member when John (Jack) Webb died on November 8th, 1992, after an extended illness.

Born in 1922, John spent his early years on a Queensland dairy farm, before going to school in Brisbane. He served in the army during World War II, and then completed matriculation and went on to the University of Queensland (UQ). While an undergraduate, he worked as a technical assistant changing seismograph records, and devloped an enduring interest in seismology. John completed a Ph.D. at St Louis University, a thriving centre for earthquake seismology, and in 1954 the young Dr. J.P. Webb returned to the University of Queensland as a lecturer.

During his 30 years at UQ, his professional life seemed focussed in two main areas. Firstly, his enthusiasm for the science of seismology led to the establishment of two first-class seismograph stations. Shortly before his death, John returned to the University to present an entertaining address documenting the history of the stations, and to see the latest major upgrade to the CTA station. This upgrade, which places the station among the relatively small number of IRIS stations worldwide, was the culmination of John's efforts and international diplomacy over several decades. John Webb was undoubtedly held in high esteem in the global seismological community.

The second focus of his university career was on excellence in teaching. John Webb's lectures were always lucid and pedantically organised. Although his first love was earthquake seismology, he had a broad knowledge and interest in exploration seismics, and provided students with a well balanced diet of theoretical and practical issues. Along with his colleague Sydney Hall, John was instrumental in developing the B.Sc.App. (Geoph) at University of Queensland into one of the country's most respected applied geophysics degrees. Graduates from the course are ubiquitous throughout the geophysical industry.

For many years John was a pivotal member of the ASEG in Queensland, serving on the state executive, and acting as technical papers coordinator for the 1983 ASEG Conference. In recent years, he maintained a strong interest in the activities of the Society.

I was personally privileged to have had John Webb as teacher and supervisor. He was not a theoretician, but a practical geophysicist with a vast understanding of his discipline. He was probably the most highly literate geophysicist I have known, being widely read on diverse subjects from electronics to philosophy. Above all he was a true gentleman, and a person of seemingly endless good humour.

John is survived by Erin, and their children Anne-Marie, John and Michael, who over the years have become well known to many of John's former students and colleagues.

Steve Hearn

Company News

Dighem Joins CGG

As of December 17, 1993 Dighem Surveys & Processing Inc. incuding its I*Power custom processing division, became an integral part of the worldwide CGG geophysical group.

Dr D C Fraser and the staff of Dighem and I*Power will continue to offer their high quality helicopter borne electromagnetic surveys as divisions of CGG Canada Ltd, a wholly owned subsiduary of Comagnie Generale de Geophysique (CGG).

Geoterrex Pty Ltd based in Sydney, (Australia), has operated as the agent for Dighem and I*Power in Australia and SE Asia for many years. With Dighem becoming part of the group, Geoterrex will be able to provide an enhanced range of services to our clients through our extensive network of offices and agents around the world.

The group can now offer a complete suite of fixed wing, helicopter and ground geophysical services, data processing, interpretation, and imaging systems to the mining, petroleum and environmental industries.

Doug Fraser, President of Dighem Surveys and Processing Inc., will again be visiting Australia and attending the ASEG Conference and Exhibition in February.

First Announcement

THE JOHN S. SUMNER MEMORIAL
INTERNATIONAL WORKSHOP ON INDUCED
POLARIZATION (IP) IN MINING AND THE ENVIRONMENT

(Geological, Geochemical, and Geophysical Aspects)

SPONSORS:	LASI - Laboratory for Advanced Subsurface Imaging, The University of Arizona, Tucson. MDRU - Mineral Deposits Research Unit, The University of British Columbia, Vancouver. CRCAMET - Cooperative Research Centre for Australian Mineral Exploration Technologies, Macquarie University, Sydney, New South Wales.	
LOCATION:	Tucson, Arizona	
DATES:	October 17-19, 1994	
OBJECTIVES:	To bring together users and practitioners of linear and non-linear IP for a three-day workshop dedicated to recommending geological, geochemical, and geophysical research for IP in the 10^{-3} to 10^{4} Hz frequency range as applied to mining and environmental problems.	
REGISTRATION:	$375 prior to Sept. 15, 1994; $450 thereafter.	
VENUE:	Doubletree Hotel, Tucson, AZ, tel. 602-881-4200 or 800-528-0444; fax 602-323-5223. Rate $79, single or double occupancy (must request IP Workshop rate); a luxury resort hotel with excellent restaurants and recreational facilities at the hotel, championship golf across the street, and close to shopping; refrigerators and microwaves available to rent.	
CALL FOR PAPERS:	Submit titles as early as possible, but no later than May 1, 1994. Abstracts due July 1, 1994.	
CO-SPONSORS:	To be announced. Contact Ben Sternberg if your group is interested in co-sponsoring this workshop.	
CONTACT:	LASI U of A	Ben Sternberg - General Chairman Stan Ward - Coordinator Doug LaBrecque - Chairman, USA Tel. 602-621-6376, fax 602-621-8330
	MDRU UBC	John Thompson - Chairman, Canada Tel. 604-822-6136, fax 604-822-6088
	CRCAMET Macquarie	Andy Green - Chairman, Australia Tel. 02-805-8365, fax 02-805-8366

Abstracts

Index of Speakers Abstracts by Session

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STREAM B (Cont'd)

Additional Biographies

(See Exploration Geophysics for the majority of speaker biographies)

Pre-Stack and Post-Stack Noise Attenuation using the Diversity t-p Transform

Terry Allen, Ruben D. Martinez & Philip Cowan

Halliburton Energy Services Inc.

Abstract

A new method for attenuating seismic noise, the diversity t-p transform (DTPT), is presented and illustrated with synthetic and field data examples. This method can be used either with pre-stack or post-stack data. Furthermore, the method can also be used for trace interpolation.

In the pre-stack case, the DTPT is implemented exploiting the benefits provided by the classical t-p transform using hyperbolic velocity filtering during the transform procedure and diversity scaling applied to the data prior to the t-p transformation. This approach permits attenuation of complex noise - for example, aliased noise, non-linear noise trends, noise bursts, spikes, etc. Conventional f-k and f-x modelling techniques do not cope well with these types of noise. Most importantly, with the use of the DTPT technique, the useful signal does not suffer distortion in any part of the frequency spectrum at any offset.

In the post-stack case, the DTPT method is performed using the local slant stack concept. A discrete t-p representation of the data can be determined which minimises the presence of random noise and compresses the t-p response of linear events so that aliasing effects are much reduced. The DTPT technique used as a post-stack noise attenuator has significant benefits when compared with conventional approaches to noise attenuation. It attenuates noisy isolated traces (spikes, noise bursts, etc.) and does not demand uniform spatial sampling (as required by f-k and f-x prediction techniques).

In addition, by exploiting the DTPT characteristics mentioned above, the DTPT technique may be utilised for trace interpolation purposes - thus improving the lateral resolution of the seismic data prior to the migration process. Trace interpolation is achieved during the inverse t-p transform by outputting traces at a finer spatial sampling than the original input data. In addition, the output spatial sample interval may be uniform even though the input interval may not be.

A Comparison of Airborne and Ground Electromagnetic Techniques for Mapping Shallow Zone Resistivity Variations.

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Abstract

Both airborne and ground TEM methods have been used for many years for detection of deep conductors, especially where the prospective zone is overlain by conductive overburden. Recent concern over environmental problems has caused a refocus of this method towards shallow zone resistivity variations, particularly in areas affected by dryland salinity and groundwater pollution. To be useful, the method must be economical and combine reasonably high lateral resolution with a quantitative interpretation of resistivity variation with depth in the shallow zone (top 30 m below surface).

The National Landcare Program has funded a survey program to test the airborne TEM technique in a range of geological environments around Australia. The airborne TEM data was collected by World Geoscience Corporation's QUESTEM system. In each survey area a variety of ground surveys have already been performed, using the techniques favoured by the responsible state government authority.

In two areas studied so far (Wanilla, South Australia and Cressy-Longford, Tasmania) a comparison of airborne and ground TEM measurements demonstrated good agreement, especially with the recently developed very early QUESTEM channels. Improvements in these very early channels between the flying of Wanilla and the flying of Cressy-Longford are also evident. The comparison showed that very early channels are sampling the shallow zone of interest, without being significantly affected by conductivity at greater depth, except in areas where thin resistive layers are present at the surface. The transparency of thin resistive layers applied to both the ground and airborne TEM systems.

The airborne TEM was effective for mapping areas of salt storage and provided a qualitative picture of resistivity variations with depth. Current developments in both airborne and ground TEM are aimed at improving the effectiveness of these techniques in shallow zone investigations. Gathering of data at very early times after very rapid turn-off times and effective data inversion schemes will lead to a better interpretation of resistivity variations with depth.

Geological Mapping Capabilities of the QUESTEM Airborne Electromagnetic System for Mineral Exploration - Mt. Isa Inlier, Queensland

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Abstract

Airborne electromagnetic (AEM) surveys are now being flown to assist in geological mapping programs. In areas of varying electrical conductivity AEM data provide significant information that can be used in conjunction with aeromagnetic and ground geological data to build up a three-dimensional interpretation of the geology. Image presentations enable interpretation and mapping of the geology.

A QUESTEM airborne geophysical survey was flown over the Lady Loretta deposit in the Lawn Hill Platform, north-west Queensland, with the aim of mapping the geology, using both AEM and airborne magnetics. The survey area comprises folded and faulted Middle Proterozoic sediments unconformably overlain by Cambrian sediments in the east of the area.

High electrical conductivity contrasts between the different stratigraphic units has enabled a detailed geological interpretation to be made from the AEM data. For example, the Esperanza and Gunpowder Creek Formations are strongly

conductive relative to overlying and underlying formations allowing fold structures and faults to be mapped. The Upper Lady Loretta Formation includes strongly conductive pyritic shale that hosts the lead-zinc mineralisation. In addition broad subtle changes in conductivity enable different lithologies to be distinguished. The aeromagnetic data does not provide the detail seen in the AEM data due to the lack of magnetic susceptibility contrast within the Proterozoic sediments. Faults interpreted from the aeromagnetic data generally correlate with those evident in the AEM.

In the eastern part of the survey area conductive units can be traced below the Cambrian sandstone. These may represent areas of further exploration interest.

Keywords - AEM, Loretta, conductivity, mapping, QUESTEM.

Depth Transform of Seismic Data by Use of Equi-Travel Time Planes

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Abstract

The present paper proposes an algorithm for the three-dimensional depth transform of the surface reflection, the cross-well reflection and VSP data by use of equi-travel time planes.

The equation of equi-travel time planes of waves which travel from source to receiver through reflection point on reflector is derived. The derived equation shows an ellipsoid of which foci are source and receiver. This means that a reflection point on the reflector is located on the ellipsoid. Ellipsoids are drawn for each pair of source and receiver. Consequently, the reflector is determined by drawing a common tangent plane to these ellipsoids.

The procedure of depth transform is as follows.

1) The velocity distribution within the survey area is assumed.
2) The ellipsoids for each sample time in seismograms for each pair of source and receiver are drawn.
3) The reflector is determined as the common tangent plane to these ellipsoids.

Here, the reflector is automatically drawn as follows.

1) Survey area is divided into cubic cells of appropriate size.
2) An ellipsoid is drawn from seismogram for each pair of source and receiver by changing with one sampling interval from the designated time after travel time of first break.
3) The intersecting points of the ellipsoid with the vertical lines of cells are shifted to the nearest cell corners.
4) Amplitudes for the corresponding sample times on seismograms are stacked on these cell corners.

The amplitudes on the cell corners where the common tangent plane of ellipsoids passes are amplified by summation with in-phase. However, the amplitude on the other grid cell corners would be cancelled because of the summation with out-of-phase.

Judging from the model studies, it was clarified that this algorithm reconstructed the structure with good accuracy, the short calculation time and the small requirement for core memory.

Keywords - Depth transform, equi-travel time planes

Experimental Techniques in VSP Recording and Tube Wave Suppression as Applied in the Northern Mount Isa Basin

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Abstract

This paper reports the first implementation of a downhole airgun and tube wave baffle to VSP recording in Australia.

A downhole airgun, offset from the wells, was recently applied to the acquisition of VSPs in petroleum exploration in the northern Mount Isa Basin. Despite excellent source-to-ground coupling, good bandwidth and repeatability of shots, the recorded data were of poor quality. This is considered to be a consequence of both interference from tube wave energy and geology, rather than VSP source characteristics. In one of the wells, recording of the full VSP wavelet could not be reliably achieved for receiver depths greater than 1000 m, despite using a high powered airgun with a volume of 120 cubic inches.

Field displays showed that the data were severely contaminated by tube wave energy which, in some cases, was 60 dB above reflected signal strength. Attempts were made to reduce the tube wave in the field by lowering the mud column in the well and by attaching a tube wave baffle above the receiver. In both cases there was little improvement in relative signal strength. However, the lowered mud column did attenuate the tube wave at high frequencies.

A significant improvement in data quality was achieved by aligning, enhancing and subtracting the tube wave in processing. Unfortunately the requirement for pre-drilled pilot holes negated offsetting the source further from the well to delay and attenuate tube waves during recording. This would obviously have been a better approach to tube wave reduction so that the dynamic range of the recording system was tuned principally to signal. Extensive fracturing above targets and multiple velocity inversions within the sequence drilled also contributed to the relatively poor signal strength.

Keywords - Northern Mount Isa Basin, vertical seismic profile, tube wave, tube wave baffle, downhole airgun

Identifying Multiples on Seismic Sections

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Abstract

One of the most serious difficulties faced by geophysicists when interpreting seismic sections from areas like the Northwest Shelf of Australia is the problem of distinguishing multiples from primaries. Misinterpreting a multiple for a

primary or vice versa can easily lead to an invalid play for a mapped prospect. Current techniques for identifying multiples on migrated sections are based on periodicity or dip and tend to be speculative and ambiguous. Conflicting dips can not always be resolved by associating one event with a multiple from higher in the section. Identifying an event as part of a reverberation is difficult, especially if processes like predictive deconvolution have been applied pre-stack to suppress periodicities. Correlation with synthetics can also be used when well data are available but even then the interpreter is rarely able to identify multiples events with certainty. The root of the problem is that current seismic processing techniques for multiple suppression are not fully effective.

Keywords - event labelling, multiples, Timor Sea, case study, velocity analysis, seismic.

Physical Property Variations within Archaean Granite-Greenstone Terrain of the Yilgarn Craton, Western Australia: The Influence of Metamorphic Grade

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Abstract

Petrophysical properties (magnetic susceptibility, density) and gravity data are presented from greenstone belts of the Yilgarn Craton which have been subjected to greenschist and amphibolite facies metamorphism. The study areas were the Weebo/Wildara greenstone belt (greenschist facies) and Southern Cross greenstone belt (amphibolite facies). Comparison of similar rock types from these areas reveals systematic changes in their magnetic susceptibility and density interpreted as reflecting mineralogical changes associated with metamorphism. Bulk rock chemical analyses from each area are similar.

Increased density of ultramafic rocks from greenschist to amphibolite facies results from replacement of serpentine/talc (2.7 g/cm^3) by olivine (3.3g/cm^3). The prograde reaction of actinolite/tremolite and plagioclase to hornblende causes increased density of the mafic rocks.

Changes in magnetic susceptibility are closely related to magnetite abundance and therefore extremely sensitive to local alteration processes (e.g. talc-carbonate alteration of ultramafic rocks). In this study, an increase in magnetic susceptibility with increasing metamorphic grade is noted for both mafic and ultramafic rocks. These effects may reflect increased magnetite content of the amphibolite facies rocks of approximately 0.005 volume % and 0.5 volume %, respectively. Additionally, the average grainsize of magnetite was observed to increase with metamorphic grade, thereby further increasing the magnetic susceptibility.

Gravity modelling suggests a maximum vertical thickness of mafic greenstones of 2 km at Weebo/Wildara and Southern Cross. The absence of a thick mafic pile below the Weebo/Wildara greenstone belt is interpreted to reflect tectonic detachment at shallow depth.

Keywords - Yilgarn, Weebo/Wildara, Southern Cross, greenstone, magnetic susceptibility, density.

Geophysical Responses over the Scuddles Volcanogenic Massive-Sulphide Deposit

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Abstract

The Scuddles copper-zinc deposit was discovered in 1979. Before mining commenced in 1990, many exploration techniques were tested over the deposit. Of the geophysical techniques, aeromagnetics and gravity have proved the best regional mapping tools. For direct detection of the mineralisation, time-domain electromagnetics from both surface and drill-hole has been the most effective. Mise-a-la-masse successfully outlined the limits of the mineralisation whereas IP responded to shallow mineralisation only.

Several airborne electromagnetic surveys have been flown over the nearby Gossan Hill deposit, which has similar characteristics to Scuddles but is considerably shallower. All have failed to produce anomalies which would warrant follow up on a regional exploration survey.

Geophysical Exploration of the Ghanzi-Chobe Fold Belt

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Poster Session Abstract

A fixed-wing triaxial airborne magnetic survey is currently underlay over approximately 40,000km^2 in the Ghanzi and Chinamba areas within the Ghanzi-Chobe fold belt of northwestern Botswana. Some 188,440 line kilometres of low-level, very detailed triaxial gradient aeromagnetic data will be acquired from September 1993 through April 1993.

Both private sector companies and various government organisations have worked in this area, and significant stratiform copper mineralisation has already been proved. Several relevant papers have been presented by various workers at regional conferences. The survey area is also being studied as part of an inter-country agreement between Botswana and Germany to provide detailed geological mapping and assessment of the mineral potential so as to stimulate private sector mineral exploration activity. Mapping of eight quarter-degree map sheets in the area has been completed. The groundwater resources of the area between Ghanzi and Makunda are also being studied by the Department of Geological Survey, Botswana, as part of the Tribal Grazing Lands Project (TGLP). The Ghanzi-Makunda TGLP Groundwater project began with regional gravity surveys late in 1992, and will continue through 1994. It is anticipated that this latter project will site 15 to 20 boreholes in order to assess groundwater potential to support agriculture activities.

The present survey, a joint project of the Government of Botswana and the European Communities, therefore has the following immediate objectives:

(a) to enable systematic geological mapping of the areas,

(b) to prospect for exploitable mineral deposits,

(c) to assist in evaluation of groundwater resources.

Detailed geological mapping of the area will be accomplished by correlating the processed aeromagnetic images to geological maps and satellite imagery. Lithomagnetic units and structure may be interpreted from the aeromagnetic data, which can be correlated directly to the geology by direct measurement of the physical properties (magnetic susceptibility and remanence) of representative rocks from the area.

Regional geology of this area is comprised of Proterozoic rhyolite and basalt volcanic and minor sediments of the Kgwebe Formation lying at the base of the stratigraphic succession. These are overlain by predominantly clastic sediments of the Ghanzi Group. The rocks underwent greenschist facies metamorphism and deformation in the Damaran orogeny, resulting in a strong northeast tending fold pattern.

Upper-Palaeozoic Karoo sediments are found to the north and south of the survey area, and may also be preserved locally in small grabens. Strongly magnetic post-Karoo dolerite dykes with a predominantly west-northwest trend crosscut the stratigraphy.

The bedrock is covered by a thickness of between 0 and 100m of Cretaceous to Recent Kalahari beds consisting of fluviatile and aeolian sand, silt and gravel with duricrusts of calcrete, silcrete or ferricrete occurring locally.

Strata-bound disseminated copper-silver sulphide mineralisation occurs within the Ghanzi Group sediments. It is believed to be stratigraphically related to the deposits found at Witviei and Klein Aub in Namibia, and may be similar to the Zambia/Zaire copperbelt mineralisation of about the same age.

Copper mineralisation is located in the fine grained units of the upper Ghanzi Group immediately above the oxidise lower Ghanzi coarser clastic sediments. Distinctive geophysical markers lie in the upper Ghanzi with both Em and magnetic methods, caused by carbonaceous shales and reduced iron-rich horizons. The lower Ghanzi is generally oxidized and is generally coarser clastic sediments with no distinctive magnetic or conductive markers.

Secondly epigenetic copper mineralisation is generally concentrated in fault structures which may be surrounded by a hydrothermal alteration halo. The hydrothermal alteration destroys the magnetic characteristics of the host rock, thus detailed magnetic surveys may be used as a guide to mineralisation.

Fault structures terminate or offset the well defined stratigraphic markers in the Ghanzi group, providing precise targets for siting groundwater exploration boreholes.

For the benefit of both groundwater and mineral exploration, the most important information is the mapping of the Ghanzi stratigraphy and identifying fault structures. Results to date indicate that this will in fact be accomplished very effectively by the detailed, triaxial aeromagnetic survey now being flown.

At the conclusion of the project, final products available to both the department of Geological Survey and placed on open-file will include total magnetic intensity and measured vertical gradient contour maps based on the micro-levelled gridded data, at scales 1:50,000 and 1:125,000. The contour maps will include the base map and the flight paths with fiducials as a screened background. Total magnetic intensity and vertical gradient profile maps at a scale of 1:50,000 will also be provided.

In addition to the standard contour maps, colour maps at a scale of 1:125,000 will be delivered for the total magnetic intensity and measured vertical gradients. The magnetic field will be represented by thirty different colours overlain by isomagnetic contour lines in black. This colour scheme will be consistent across all map sheets and should give approximately equal areas of each colour.

The primary digital data will form part of the Geological Survey's data archive and will be fully available at nominal cost to interested parties. Micro-levelled total field data will be supplied as the final total field grid as part of the final archive, with other additional files to include:

- Micro-levelling
- Reduction to the Pole
- Magnetic Susceptibility
- Digital Terrain Model
- Total Gradient
- Euler Deconvolution

An Intelligent Seismic First-break Time Calculation Scheme for Inhomogeneous Models

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Abstract

Seismic first-break times can be computed by treating each node of a given model as a secondary source and applying Huygens' Principle from the source to its surrounding nodes and successively from inner nodes to outer nodes of the source. At each node, different travel times are possible from the source via different secondary sources (virtually all the other nodes) and only the least (minimum) time is kept as the first-break time for this particular node. As the number of nodes increases, the selection of the least time for each node can be a huge computational task. However, for the first-break time, only a small number of secondary sources, i.e. the immediate neighbouring nodes, need to be considered. An efficient first-break wavefront tracking algorithm is used to maintain the causality of the process.

This efficient tracking algorithm arranges the nodes of the model into a directed graph. Only neighbouring nodes are connected by edges. The weight of each edge is denoted by the travel time difference between the two connecting nodes. The local gradient of the first-break time field determines the direction of the edges. With this directed graph, a minimum travel time tree is constructed by taking the source node as its root. At any stage of this wavefront tracking, the nodes of the model can be thought of as divided into three (disjoint) categories: tree nodes in the tree constructed so far; fringe nodes which are not in the tree but adjacent to some nodes in the tree; and unseen (other) nodes. The fringe nodes roughly represent and keep track of the current first-break wavefront.

Thus the key point in the construction of the minimum travel time tree is how to evolve the first-break wavefront outward from the source. To maintain causality, the fringe node of least travel time is always selected as a secondary source to illuminate (forward) nodes along the local wave propagation direction. Once the travel times for forward neighbouring nodes are updated, the current node of least travel time is converted to a tree node and the first-break wavefront advances one node away from the source. This

updating process is repeated until all the nodes are converted into tree nodes.

An efficient sorting method, the heap sort method, is employed to find the least travel time node from the current fringe. A special data structure is adopted for the implementation of an intelligent indirect heap sort. At any stage of the wavefront tracking, only the fringe nodes are in this special data structure and thus only local sorting is required.

Keywords - seismic first-break, wavefront, nodes, travel time, heap algorithms, eikonal, ray.

Sub-Audio Magnetics (SAM) - A High Resolution Technique for Simultaneously Mapping Electrical and Magnetic Properties

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Abstract

A high definition technique has been developed for simultaneously mapping electrical and magnetic characteristics of the ground. Each of the parameters may be measured at sub- metre intervals while continuously traversing either on foot or in a vehicle. Electric current, typically in the frequency range of 5 Hz to 200 Hz is induced in the ground by either galvanic of electromagnetic means. An optically pumped total field magnetometer continuously measures the natural and synthetic field changes from DC to the highest transmitted frequency. Real-time spectral analysis of the magnetic field changes allows a suite of geophysical parameters to be derived.

The geophysical measurements so obtained include, but are not limited to: Total Field, High Definition Magnetics (HDM).

Total Field, Magnetometric Resistivity (TFMMR).

Total Field, Magnetometric Induced Polarisation (TFMMIP).

Total Field, Electromagnetics (TFEM).

Because of its inherent cost-efficiency and superior spatial resolution, the SAM technique has the potential to significantly enhance geophysical mapping for mineral exploration, archaeological investigation and environmental studies of salinity, industrial waste and chemical contamination in soils.

Keywords - Sub-Audio Magnetics, SAM, HDM, TFMMR, TFMMIP, magnetometer, high-definition, geological mapping, environmental geophysics.

Urban Geophysics: TEM Mapping in the Taipei Basin, Taiwan

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Abstract

In order to investigate the subsurface engineering geology of the Taipei Basin, Taiwan, more than 60 transient electromagnetic (TEM) soundings were made. Coincident loop configuration with square transmitting loops 50 m on a side, were used for the survey.

Qualitative interpretation of the apparent resistivity contour maps located the aquifer and geologic boundaries. Quantitative interpretation using nonlinear least-squares inversion further refined the aquifer boundaries of the Taipei Basin, and the resulting geoelectrical model adequately represented the known geology.

In an attempt to map possible faults and to remove ambiguity from the model, during the inversion process the resistivities of the layers were kept within narrow limits across the entire area. Sharp depth discontinuities clearly displayed the known fault zones, reflecting some of the tectonic events of Taipei Basin.

The TEM soundings provided information on the distribution of aquifers, sedimentary depositional environments, and the delineation of fault traces. The TEM method proved to be one of the most useful geophysical tools for urban geophysics.

Keywords - TEM, urban geophysics, Taipei Basin

Image Processing for Seismic Mapping Saves Papering the Walls

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Abstract

Correct display and interpretation of geotechnical data are critical in mineral and petroleum exploration. Subtle geophysical patterns are of particular interest in petroleum exploration where targets are becoming increasingly difficult to discern.

Contour maps traditionally have been used in the petroleum industry to present data, particularly interpreted seismic horizon mapping. Improvements in computing power have enabled digital gridded and image processed datasets to be displayed quickly and easily. Subtle features within very large or complex areas can now be displayed and recognised, as exemplified by Eromanga and Otway Basin seismic horizon datasets. Enhancement of features in a particular orientation of interest to the explorationist can be accomplished by judicious choice of sun shade imagery.

Integration of geological, geochemical and geophysical datasets is vital for successful petroleum exploration. Preparation of digital geotechnical databases is the key element for such efficient concentration of data. Integration of datasets into single image processed displays can then present complex information in a powerful way.

Keywords - seismic maps, imagery, petroleum exploration, structural contour maps, Eromanga Basin, Otway Basin, image interpretation.

3-D Magnetic model inversion for structure mapping

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Abstract

A series of three-dimensional magnetic models has been designed to represent a wide range of geological structures. The models have been incorporated into automatic inversion routines, so that their parameters may be derived quickly from magnetic anomalies. The objective in developing this modelling scheme was to devise tools for applying to aeromagnetic data that would yield quantitative structural information, complementing the qualitative interpretations usually carried out.

The models are based on simple slab components, and include single and double slabs, horizontal and plunging fold structures. The number of critical parameters for each model has been minimised to facilitate stable and rapid inversion.

The inversion modelling scheme has been tested in the area of the Kurrawang Syncline near Kalgoorlie, WA. Here a magnetic conglomerate marker horizon has been folded and subsequently faulted. The results from the inversions of aeromagnetic data show excellent agreement with the known geology. It has been found that orientations tend to be determined more reliably than do thicknesses and depths.

Other structures that have been modelled are the Mount Edwards folded ultramafic belt, near Widgiemooltha, WA, which is complicated by cross-cutting dykes; and a series of banded ironstones that host copper-gold mineralisation at Osborne, Queensland.

The modelling technique is useful for testing an initial qualitative interpretation by trying the appropriate model and finding out if it can be made to fit. If a model fits well, then valuable structural information (strikes, dips, plunge etc) can be obtained. Although the modelling procedures were developed for use in reconnaissance mapping with airborne data, they are equally applicable to prospect exploration and ground survey measurements.

Keywords - magnetic interpretation, 3-D models, aeromagnetic, folds, inversion, structural models, Kurrawang, Widgiemooltha, Osborne

Bounty Gold Deposit, Western Australia: Magnetic and Electromagnetic Responses

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Abstract

Mineralisation at the Bounty gold deposit is in a steeply plunging zone within a sheared iron-formation in the Archaean Forrestania greenstone belt. The gold was deposited together with pyrrhotite, replacing magnetite, but later dyke intrusion has converted pyrrhotite to magnetite adjacent to the dyke. Geophysical surveys have included magnetic and transient electromagnetic measurements. Magnetic data show the Bounty mineralisation is highly magnetic. The magnetic information has mainly been used to help map stratigraphy and structure, seeking favourable sites for mineralisation. An orientation transient electromagnetic survey showed that the Bounty orebody is a good conductor. More extensive surveys delineated an anomaly over the North Bounty deposit also, and discovered several other conductive zones which, so far, have been found only to be barren sulphidic shale and chert horizons.

The Turkey Creek No 2 VSP and Frequency Attenuation

Bob Cornect and Noll Moriarty

Abstract

A VSP was carried out in the Turkey Creek-2 well to look at the frequency attenuation of seismic due to shallow basalt layers with the aim of enhancing the seismic acquisition parameters in this area. It was also felt that a vibroseis sourced VSP would provide a better match to the vibroseis surface seismic than the conventional synthetic seismogram calibrated using a dynamite sourced check-shot survey. The Turkey Creek structure is a Permian gas field located at the northern end of the Denison Trough, straddling the boundaries of ATP 337P, 502P and 451P in Western Queensland.

While the high frequency content of the records generally deteriorated with depth, there was a significant drop in amplitude after about 50-60Hz even at shallow depths using a convention 10sec linear upsweep of 8-100Hz. However at 97m and 255m several test sweeps were performed in which frequencies up to 100Hz were recorded using a 15 db/oct logarithmic upsweep.

The VSP was carried out by Schlumberger using a GECO MERTZ M26 vibrator, capable of 54,000 lbs of peak force coupled with Pelton Advanced 11 electronics connected into a Schlumberger logging truck.

In addition to the downhole phone, a 12 geophone string with a 15.0m effective array length was located 140m on the opposite side of the well. These parameters were the same as those used in acquiring the surface seismic used over the well location.

The five seconds spent sweeping the 54-100Hz region in the linear sweep appears to have been insufficient time to allow data in this bandwidth to be recorded at a similar strength to the data in the 8-54Hz zone. However the 15 db/oct log sweep spent approximately 90% of its time sweeping the upper half of the spectrum and as a result recorded data over a 25-100Hz bandwidth.

Previous recording and testing in this area has limited the upper end of the swept bandwidth to 60 or 70Hz. By being able to measure the seismic signal after only half the conventional ray path, a plateau area above 50Hz, but some 25db down from the strongest signal was observed that was a possible candidate for enhancement.

It was originally hoped, prior to the VSP, that any such spectral zone could be boosted by applying a form of spectral whitening in the sense that an inversely proportional amount of time would be spent sweeping the various frequency ranges according to the relative strength of the recorded signal from a linear sweep. This was to be done discrete but continuous linear sweeps and was later coined a paralinear sweep.

This option was not however available to us on the day and a logarithmic sweep was used instead. It was felt it would test the same idea for the high side of the spectrum. An exponential sweep was used for the low end of a limited bandwidth sweep was used for intermediate data dropout zones.

The log sweep clearly boosted the high end of the spectrum which hopefully has a significant signal component to it. The small amount of time spent sweeping from 8-50Hz (about 1 sec) effectively band limited the spectrum at the low end and thereby reduced the effective number of octaves present in the recorded signal from 8-60Hz, about 3 Octaves, to 25-100Hz or 2 octaves.

Reduction in the bandwidth results in increased ringing or enhancement of the side lobes preferentially to the central peak of the sweeps autocorrelation and a subsequent loss in resolution. It was felt this could be corrected by spending more time sweeping the 8-50Hz zone, either by increasing the total sweep length or decreasing the slope of the log increase from 15 db/oct downward.

While this last aspect wasn't tested during the VSP, it was put into practice some two weeks later when a Vibroseis crew was acquiring in fill data over the Turkey Creek structure by increasing the total sweep time. In particular more time was allocated to the low frequencies than in the VSP sweep.

The encouraging increase in bandwidth observed in the VSP resulted in the decision to record a 4km portion of a seismic line twice. Once using the production 6-70Hz 10 sec linear upsweep and then a second time using a modification of the log sweep used in the VSP.

Considerable testing in which side lobe to central peak ratios of the various sweeps autocorrelations were calculated and compared to that of the linear sweeps, resulted in using a 14 second -24 db/oct log sweep which appeared to return the highest bandwidth.

Both passes of the line were recorded uncorrelated to give more flexibility in handling phase issues during the processing stage as the data is currently still being processed.

In conclusion, the Turkey Creek-2 VSP was successfully used to investigate the frequency attenuation properties of an area prone to enhanced high frequency degradation because of shallow basalt flows. The Vibroseis acquisition parameters in the area were optimised by drawing upon the VSP results.

Separation Filtering Applied to Aeromagnetic Data

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Abstract

Separation filtering of regional and residual gravity and magnetic fields has been the subject of extensive research. Wave number and spatial domain methods, variously described as matched filtering, layer filtering, depth slices etc. have been developed

Separation or layer filtering of magnetic data allows us to deconvolve the effects of causative sources occurring around a particular level. In practice, it is impossible to achieve a complete separation since the problem is non-linear. Separation filtering depends fundamentally on the concept of random distributions of sources within discrete layers and assumes that there is no statistical difference in response along each ideal layer and no correlation between the distribution in each layer.

Interpretation of the log-power spectrum provides slope and intercept parameters for filter design. It is necessary to be able to recognise distinct linear segments of the spectrum corresponding to well separated depth ensembles in the data in order to deconvolve the effects of each depth ensemble with minimum contamination from sources at different levels. Non-linear spectra cannot be interpreted. It is important to apply a finite source width correction to the raw spectrum, otherwise indicated source depths will be too deep.

Tests have been carried out on spectral matched filtering, differential upward continuation separation filtering, exponential taper filtering and a modified second vertical derivative filter. All filtering was performed in wavenumber domain. Spectral analysis of the test area suggested three depth ensembles with average depths of 1500 m, 300 m and 20 m below surface. The modified second vertical derivative technique provided the best representation of the shallow source ensemble being more stable and with a larger dynamic range than the matched filter residual filter. The spectral matched filter regional provided the best representation of the deep ensemble, although there was some contamination by shallower sources. The intermediate ensemble could not be extracted with any degree of confidence.

Separation filtering can make a useful contribution to the enhancement of magnetic data, provided the limitations in the methods are recognised. Even where spatial source separation is reasonable, the filter will not manage to perform a complete rejection of shallow sources or deeper sources and will distort intermediate sources even more. The results should be used qualitatively to assist in source discrimination rather than used as input to analytical techniques.

Downhole Three Component TEM Probes

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Abstract

A three component transient electromagnetic (TEM) probe (VECTEM) has been constructed to eliminate rotational ambiguities associated with data obtained along a single axis. Individual components are obtained sequentially using a surface adapter for multiplexing to any standard TEM recorder. The critical rotation angles are also indicated by this surface unit and are recorded in the data header. Data have been obtained for several sites and interpretations have been generated using filament inversion routines. The results agree in general with previous axial data and are consistent with geological constraints. However noise levels are higher than expected compared to single-component probes and anomalies confined to late windows may remain obscured.

Keywords - TEM probes, downhole, orthogonal sensors, filament inversion

Seismic Reflection Profiling of the Taupo Caldera, New Zealand

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Abstract

Previously published estimates of eruptive volumes suggest that the Taupo volcano, in the centre of New Zealand's North Island, is one of the most active rhyolitic volcanoes anywhere in the world. The last eruption from this volcano in about 180 AD is the most violent eruption yet documented.

The estimates of eruptive volume are based upon exposures outside of the collapse caldera presently occupied by Lake Taupo. The development of a digital seismic reflection recording system suitable for surveying from a small boat has dramatically improved seismic images obtained from Lake Taupo, enabling the identification of eruptive structures observed onshore with seismic units in the lake.

Three seismically distinctive units occur to the west of Horomatangi Reefs, the interpreted eruption vent of the 180 AD Taupo eruption. The units from lake floor downwards consist of a featureless unit 100 m to 150 m thick (unit A), a sequence of laminated reflectors up to 700 m thick (unit B) and an underlying unit characterised by mounded and discontinuous reflectors (unit C).

The structure of these units suggests they were derived from the area of the 180 AD eruption. Two alternative interpretations of the observed seismic sequence are possible. Unit A may correspond to the entire 180 AD Taupo eruption deposit within the lake or alternatively this eruption may have formed all three units. The corresponding eruption volumes implied for the 180 AD Taupo eruption beneath Lake Taupo are estimated to be 70 km^3 or 130 km^3, respectively. Both of these volumes are greater than previous estimates.

The deeper northeastern corner of Lake Taupo has a contrasting seismic reflection character and is interpreted as a collapse structure formed by the removal of underlying magma during the Taupo eruption.

Keywords - seismic reflection, small boat, Taupo, caldera, volcano

Structure of the Eastern Margin of the Perth Basin, Western Australia

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Abstract

The Darling Fault is well defined by the seismic data. At New Norcia the fault, based on the structure of its hanging wall sediments, is listric. In contrast, at Moora about 30 km further north, the fault is most likely concave downwards. The difference in structure is probably a function of the geometry of Precambrian strike-slip structures reactivated during Phanerozoic extensional and strike-slip events associated with basin formation.

Keywords - Darling Fault, gravity, Perth Basin, seismic reflection, Yilgarn Block

Surface Multiple Attenuation and Sub-Salt Imaging

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Abstract

Surface multiple attenuation (SMA) is a prestack inversion of a surface-recorded, 2-D wavefield that removes all orders of all surface multiples present within the wavefield. In addition, the process determines the average acquisition wavelet embedded in the wavefield. SMA requires no assumptions or modelling regarding the positions, shapes, or reflection coefficients of the multiple-causing reflectors. Instead, SMA relies on the internal physical consistency between primary and multiple events that must exist in any properly recorded marine data set.

A general SMA inversion equation can be derived in a simple fashion from just two assumptions: (1) the recorded wavefield is a superposition of primary events, 1st-order surface multiples, 2nd-order surface multiples . . . and Nth-order surface multiples; and (2) a recursive relationship can be found that allows Nth-order surface multiples to be predicted given the primary wavefield and the surface multiples of order N-1. A specific inversion equation is obtained depending on the nature of the wavefield and whatever relationship is used to satisfy assumption (2). Thus, for a 1-D Earth, SMA inversion is accomplished by deconvolution, while for a 2-D Earth, one can use the Kirchoff integral or the 2-D scalar wave equation in assumption (2). The Kirchoff integral approach, described in this paper, formulates SMA in the f-x domain, in which the inversion is accomplished simply by inverting a matrix.

Because SMA handles all surface multiples, it is an ideal method of removing surface multiples generated by the top and bottom of a salt-injection feature. An example line from the Gulf of Mexico has shown that multiple attentuation via SMA can greatly improve the final migrated image obtained below a salt layer.

Keywords - multiples, multiple attentuation, surface multiples, imaging, subsalt imaging, salt, Kirchoff integral.

Seismic Reflection Images of the Major Ore-Controlling Structures in the Eastern Goldfields Province, Western Australia

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Abstract

Gold mineralisation in the Eastern Goldfields Province of the Yilgarn Block, Western Australia, is associated with shear zones within the greenstone supracrustal succession. Regional shear zones are imaged in seismic reflection sections as bands of strong reflections. Although individual wavelets within the bands of reflections can only be correlated over small distances, the bands of reflections can be correlated over tens of kilometres. The Bardoc Shear, adjacent to which considerable mineralisation has been found, dips west and links with the Ida Fault, which forms the boundary between the Eastern Goldfields Province and the Southern Cross Province farther west. The Ida Fault dips east at about 40°, and can be traced from the surface to about 27 km depth. Bands of reflections within the upper and middle crust have a similar seismic signature to the Ida Fault, Bardoc Shear Zone and the basal detachment of the greenstones, and are therefore interpreted as shear zones.

Interpreted shear zones in the upper crust under the greenstones mostly dip west. Shear zones in the lower crust dip east. The upper crust east of the Ida Fault and below the

Bardoc Shear is an exception. There, east-dipping shear zones, including the Ida Fault, are interpreted to extend from the lower crust into the upper crust, thereby providing a simple plumbing system for mineralising fluids migrating from the lower crust, into the Bardoc Shear, and then to high levels in the greenstones.

Keywords - Seismic reflection, ore-controlling structures, seismic surveys in basement terranes, Eastern Goldfields, Yilgarn Block

A SALTMAP Case History - High Resolution Near-Surface Conductivity Measurements from the Air

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World Geoscience Corporation

Abstract

The first surveys using SALTMAP, a new fixed-wing airborne electromagnetic geophysical system, have been flown and processed. The results illustrate the ability of the system to supply valuable conductivity information about the regolith in a cost-effective manner. Processing of the SALTMAP data collected over the EAST Yornaning water catchment, a trial area for environmental geophysical survey technology, and other areas, has given rise to new processing philosophies for airborne electromagnetic data sets.

SALTMAP ground conductivity interpretations are enhanced because the system measures three orthogonal components of secondary fields. Data from the horizontal and vertical axis sensors are used to stabilise layered earth inversions and apparent conductivity calculations. Conductivity of the near-surface can be calculated in plan and cross-section form with the aid of routines that effectively normalise the geometry and altitude of the SALTMAP system to a constant for a given survey. In this way, any artificial anomalies due to slight geometry and altitude variations are removed. This artifact can be quite significant in conductive terrain.

As a result of the high frequency of operation, the system makes measurements particularly close to the inductive limit of the terrain over which it flies. This has ramifications for both the separation of primary and secondary fields and the calculation of conductivity. New techniques for the removal of primary fields are evolving to allow accurate conductivity calculation.

Comparison of SALTMAP interpretations with those obtained from ground-based electromagnetic surveys, both frequency and time domain, show that SALTMAP is able to resolve conductive layering within the upper 10 metres. In addition, comparisons of data from SALTMAP and QUESTEM, a lower frequency airborne electromagnetic system, over the same area show the benefits of the broader bandwidth in characterising the regolith.

After 3 years of development by World Geoscience Corporation and CSIRO, the SALTMAP system is now available to be contracted on a commercial basis for applications in groundwater monitoring and exploration, geological mapping and mineral exploration.

Coherent Noise Attenuation Methods for Low Fold Seismic Data

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Abstract

A shot interval equal to the group interval is required to satisfy the stack-array criterion for split spread seismic data. If the shot interval is larger than the group interval, much of the coherent noise energy may leak through to the stack. This is because coherent noise, although probably unaliased in the shot domain, is highly aliased in the CMP domain. Prestack velocity filtering may be used to attenuate coherent noise, but can result in signal distortion and smoothing effects.

A method of using a wavenumber-filter (k-filter) in the shot domain to attenuate coherent noise is suitable for use with modern low-fold data, i.e., data shot with small group intervals, many receivers, but a large shot interval. The k-filter operates by notching energy at wavenumbers in the shot domain that correspond to alias peaks of the CMP array response. To overcome notch shifting caused by NMO correction, a shot domain NMO correction is applied before k-filtering the data. The k-filter design is based on the Remez exchange method. This method allows for different pass band and stop band error levels. Signal distortion and smoothing are reduced by keeping the error level near k=0 small, and by minimising the equivalent area in the f-k domain that is removed by the k-filter.

A simple model was used to estimate the theoretical attenuation level of the k-filter. A level of approximately 13 dB was achieved with the model data. The k-filter was also applied to field data from the Surat Basin, Australia. The results were not as good as the model results, probably because of variations in coherent noise characteristics across CMP gathers. Coherent noise characteristics have to be uniform across the whole length of each CMP gather for the method to work well. However, the k-filter did reduce significantly the level of coherent noise energy on the stacked data.

Keywords - low fold, stack-array, wavenumber filter, notch filter, coherent noise

The Application of Robust and Non-Stationary Analysis Methods to Mt Data from the West Anesi Anticline

K. M. Edwards & L. M. Hastie

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Abstract

Magnetotelluric (MT) geophysical prospecting methods use spectral analysis of the horizontal components of time-varying electric and magnetic fields at the earth's surface to determine a frequency-dependent impedance tensor. Due to the presence of excessive noise and bias in the signal, current techniques achieve lower resolutions than are theoretically expected.

It is desirable that the methods applied to MT data to estimate the impedance values be capable of improving the signal-to-noise ratio, without introducing greater bias into the result. Robust analysis (Chave et al 1978) and non-stationary time-frequency methods (Chant and Hastie, 1992) are two of the approaches devised to deal with this problem.

When a signal is found to be non-stationary, then accurate spectral analysis cannot be accomplished using classical time-domain representations such as correlation methods or frequency domain representations based on Fourier transforms. For non-stationary signals, the concept of a

time-frequency distribution (TFD) had been developed as an extension of classical Fourier analysis, in order to provide a joint function of time and frequency that will describe the energy density of a signal. This function is sometimes called the evolutive spectrum, since it shows how the spectrum evolves with time. Those estimations can of course be combined with robust methods to improve the management of non-normal stochastic signals.

In this study, the effectiveness of these estimators has been evaluated using a data set from the West Anesi anticline in New Guinea and comparing the effects on the resulting apparent-resistivity and phase estimates. The effectiveness of the time-frequency spectral estimators has been evaluated by comparison with the short-time Fourier transform, and the improvements gained by the use of the various robust estimators have been examined.

Flairtem - A New Airborne Transient Electromagnetic Method

P. J. Elliott

Elliott Geophysics Pty Ltd

Poster Session Abstract

FLAIRTEM (Fixed Loop Airborne Transient Electro Magnetics) is a new method comprising a ground based transmitter loop and airborne receiver. (Figures 1 & 2). The method was convened by Elliott Geophysics Pty Ltd and was developed with the support of Sponsor Companies through AMIRA (Australian Minerals Industry Research Association). In 1993 it was tested at sites in Papua New Guinea and South Australia. These tests showed that the method worked well in both environments.

The FLAIRTEM method is similar to the TURAIR method used by Scintrex Pty Ltd in the 1970's, in that a ground based transmitter loop and airborne receiver are used. Here the similarity ends. TURAIR was a frequency domain method employing a limited number of selected frequencies and utilising 1970's technology. Albeit the system configuration also allows frequency domain measurements if required.

The current system configuration uses a high powered ground based transmitter (up to 25kw) with a basic time domain pulse frequency range of 1Hz to 32Hz. The transmitter loops employed can be in the order of kilometres (eg. 6km x 2km). The frequency range enables data to be collected at a

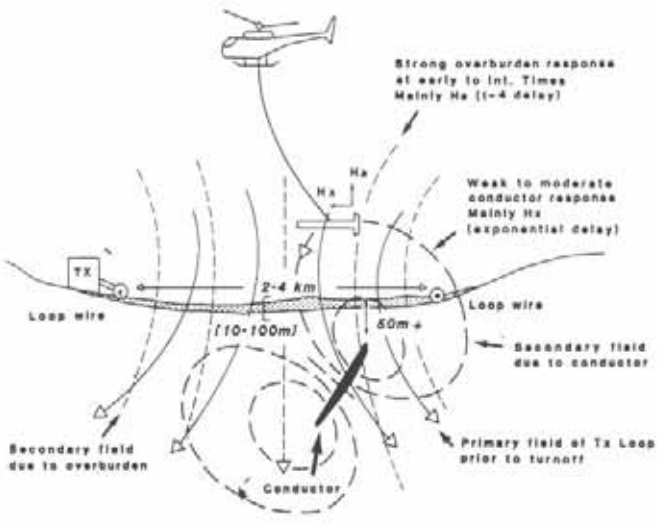

Figure 1. FLAIRTEM survey configuration in arid areas.

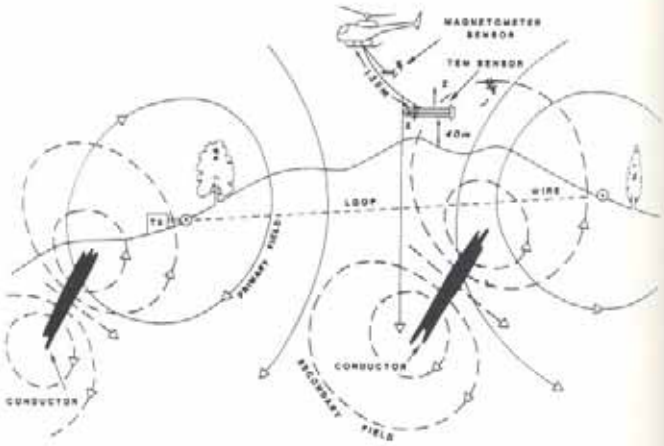

Figure 2. FLAIRTEM survey configuration in rugged terrain.

much lower bandwidth than other airborne electromagnetic systems. Plus a much larger magnetic moment is achievable using a large fixed loop (eg 3 orders of magnitude).

The receiver configuration is currently a 3 channel arrangement using independent sensors (x, y & z). All tests completed so far have only used the x and z component sensors but a third sensor is easily fitted in with the other two. The effective sensor areas are 10,000 sq m or the equivalent of a 100m x 100m loop. Data is collected using a specially designed digital receiver where data is stored on hard disk. Each independent cycle response can be stored or a selected number of cycles averaged and stored automatically. This gives a possible minimum sample interval of less than 2m on the ground and thus allows a large redundancy of data for various filtering techniques.

A helicopter with a towed bird is the currently favoured airborne platform. However other platforms can easily be adapted.

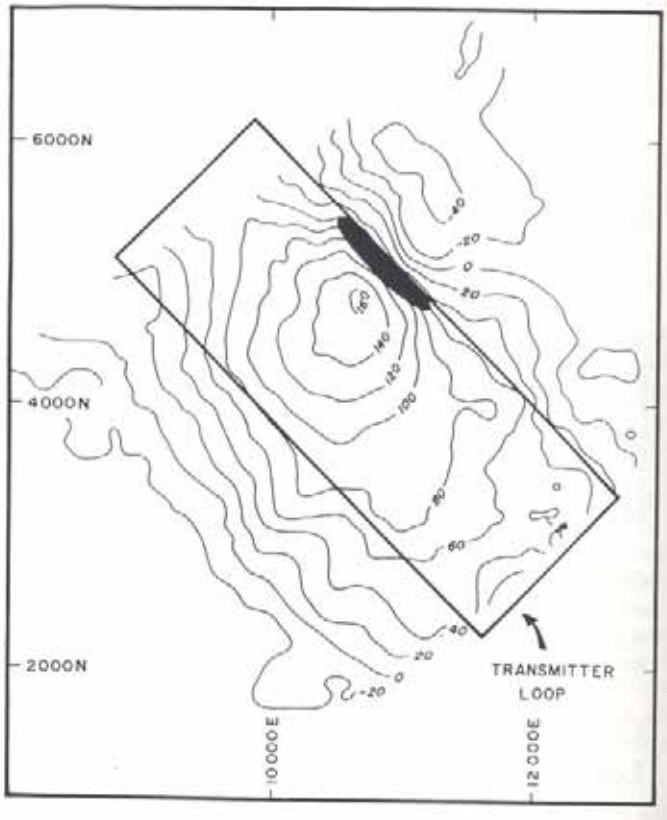

Figure 3. Hz component contours over sulphide deposit, PNG.

The preferred method of navigation is by real time differential GPS but all traditional methods can be used. (eg. visual or Syledis). All tests were carried out using a GPS system.

Special filtering methods are used to process the raw data but these are not overly rigorous. Modelling and interpretation techniques used for fixed loop ground surveys are directly applicable to this method.

An example of contoured voltage data for one time window (12ms delay) is presented for the x and z component and the peak on the x-component indicate a steeply dipping conductor at shallow depth (Figure 3). An earlier DIGHEM Survey failed to detect this conductor.

The FLAIRTEM method promises to be of great utility in surveying arid areas where conductive overburden shields conductors from higher bandwidth airborne methods. Tests have been carried out to this effect. It is also useful for locating conductors at greater depth than other airborne methods. Exploration in rugged areas such as Papua New Guinea and Eastern Australia can be greatly enhanced by the use of this method.

A New Method for Three Dimensional Dip and Azimuthally Dependent NMO

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Poster Session Abstract

Three dimensional geological dip alters the stacking velocity as the azimuth from source to receiver changes. This becomes severe in land 3-D seismic recording where the source has many azimuths with respect to the receiver lines. An innovative field technique has been devised to determine the value of the true dip and its azimuth. Implicit in the technique is the use of an algorithm which predicts what the NMO equation should be for any azimuth. The application of this NMO allows the use of consistent stacking velocities with a change in azimuth.

Performance Measures for Publicly Funded Geophysical Surveys - The South Australian Success

Dr. Ross Fardon

Department of Mines and Energy, South Australia, PO Box 151, Eastwood, SA 5063

Keynote Address Abstract

The South Australian Government's recent aggressive approach to marketing the state's mineral and petroleum potential has raised exploration activity significantly.

Blanket coverage of underexplored geological provinces with high resolution airborne geophysical surveys has been the focal point of the marketing strategy. Through the South Australian Exploration Initiative, half a million kilometres of airborne geophysical data have been acquired through state funding with an additional hundred thousand kilometres from Federal NGMA funding. The resulting magnetic and radiometric images have provided the first insight of the structure and tectonics of these areas, previously disregarded for exploration due to prevailing lack of outcrop.

Two million dollars spent on semi-regional seismic surveys over the Pitjantjatjara Lands will similarly create new petroleum targets for the Officer Basin.

The program has highlighted the value of the airborne geophysical technique for generating exploration concepts in sediment covered terrain. The threefold increase in tenement acreage shows that industry has already endorsed the exploration potential of these survey areas. The effects of such a large survey will probably go on expanding for a few years.

These surveys also rapidly expanded our client base. New clients arusing our digital databases, reports, maps, and first hand knowledge of all areas of South Australia.

The first benefit is from increased exploration expenditure in the State along with more awareness of SA being a place to do business. The main outcome of the program will be the long term employment, expenditure, taxes and royalties from the resource developments to follow.

South Australia is looking to the mining sector to play a key role in the state's economic recovery. The Exploration Initiative has provided the technical infrastructure upon which such an expansion can proceed.

GPS Coordinate Transformations and their Use in Gravimetry

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Abstract

Geodetic coordinates on Australian maps are referenced to the Australian Geodectic Datum 1984 (AGD84). Topographic elevations are referred to the Australian Height Datum (AHD). Conversely, GPS yields 3-D Cartesian coordinates and coordinate differences in the World Geodetic System 1984 (WGS84).

The difference between coordinates of the same point on the Earth's surface varies between 150 m to 200 m over continental Australia. This study presents a method of transforming between GPS (WGS84) and AGD84 latitude, longitude and AHD. This permits GPS-aided gravity data to

be integrated with other geophysical data referred to the AGD84. A new rigorous formula to simultaneously determine the latitude, free-air and slab Bouguer corrections from GPS and geoid information is derived. It is demonstrated that, if an incorrect elevation datum is used for gravimetric data reduction, a different gravity anomaly is produced.

The Western Otway Basin - a Tectonic Framework from New Seismic, Gravity and Aeromagnetic Data

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Abstract

Interpretation of new seismic, gravity and aeromagnetic data sets from the western Otway Basin has contributed signif icantly towards a better understanding of the regional tectonic framework of the basin's evolution. Geosat data from the Southern Ocean and gravity data onshore have defined what is here termed the Otway-Sorell microplate, a triangular region of extended continental crust and lithosphere bounded by the onshore northern limits of the Otway Basin, the eastern limits of the Sorell Basin, and a prominent Geosat lineament (?fault zone) extending from the offshore Crayfish Platform to southern Tasmania. The Geosat data also redefine the Spencer and Tasman Fracture Systems within the Southern Ocean lithosphere, and the existence of the previously named Gambier, St. Vincent and George V fracture zones is now doubtful.

Fragmentation of Australia's continental crust during Jurassic lithospheric extension led to the development of a series of rift segments and intervening crustal blocks in the western Otway Basin. Long wavelength aeromagnetic anomalies outline what is interpreted as the extent of Palaeozoic crustal fragments and a possible lithospheric triple junction, including the newly-named Coorrong Trough. This trough is along strike from the Scopes Range - Padthaway Gravity High extending south from the western margin of the Murray Basin, suggesting a significant onshore-offshore structural correlation near the traditional Precambrian-Phanerozoic boundary, known as the Tasman Line.

The boundaries of Palaeozoic crustal fragments can be correlated with significant changes in the character of deep seismic profiling data and a thinning of the crust south of the Tartwaup Fault Zone. The Tartwaup fault zone is interpreted as the cratonic boundary for a lower- plate margin during the episode of lithospheric extension which eventually resulted in separation of Australia from Antarctica.

Seismic mapping of the Otway Group sequences defines the early rift segments and the regional scale of later deposition. The earliest rifting developed in a series of half graben with most of the major bounding faults dipping towards the craton. These rift segments did not develop fully. However, rifting southwest of the Tartwaup fault zone did progress to the stage of continental separation. There are significant northwest and northeast structural trends which can also be identified in magnetic and gravity images. Fault reactivation occurred in Aptian, Late Albian, Late Maastrichtian, Eocene and Miocene times in response to intra-plate stress being transmitted from plate boundaries.

Keywords - Otway Basin, gravity and magnetic images, seismic profiling, early basin evolution, Otway-Sorell microplate, Coorong Trough

The Use of Continuous Velocity Analysis and Dynamic Replacement for the Solution of Near Surface Problems in an Offshore Environment

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1. Digital Exploration Ltd

2. MIM Petroleum Exploration

Abstract

Our problem concerns one of the presence of near surface and surface reefs and the consequence of implicit lateral velocity changes in the near surface which prevent good imaging of deeper seismic data. These reefs are rarely spectacular with respect to their water bottom profiles. Nevertheless, the vertical extent of these features is sufficient to cause distortions in time of up to 50 milliseconds. The existence of a near surface reflector of suitable quality enables the running of continuous velocity analysis with some confidence, thus facilitating the modelling of the above material in velocity. Replacement dynamics is then employed to create an homogenous near-surface. The method was used over a seismic grid of 5000km. Results are presented and the method discussed with relation to a survey of this size.

Water Bottom Multiple Attenuation - Case Study

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Digital Exploration Ltd

Abstract

Much of offshore Australia is characterised by hard sea-floors. This results in lack of penetration at depth and also heavy contamination of primary signal by multiple energy notably water bottom peg-legs. Such multiples cannot be removed by methods such as F-X and radon transform as these rely on a degree of separation between primary and multiple reflections which would only be the case if the sea-floor is at considerable depth. The use of post-stack predictive deconvolution to address these problems is discussed as to its unsuitability. The technique we describe is that of wave equation multiple attention, which we would recommend as a 'sine qua non' for the majority of Australia offshore seismic. Examples are presented and the question of position of this technique in the processing stream is discussed as to its optimality.

POSMAG: an Ad Hoc GPS Positioned Ground Magnetic Surveying System

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Abstract

The advent of small, cheap, and highly portable Global Positioning Systems (GPS), together with recent advances in ground magnetometer technology, has allowed the development of an economic GPS positioned ground magnetic surveying system. Like their larger sophisticated counterparts in the aeromagnetic arena, these systems facilitate the collection of magnetic data without the need for any navigation tool other than the GPS. Unlike their counterparts, however, they may be constructed at minimal cost, with minimal research and development, and with a very short lead time.

A simple marriage of off the shelf components has resulted in the creation of POSMAG, a GPS positioned ground magnetic system. POSMAG can acquire magnetic and positional information in real time. It is based on a Garmin GPS unit and a Gem GSM-19f Overhauser magnetometer. Data is collected in a "hands free" operation, at normal walking speeds, with high along line spatial resolution, and on arbitrarily placed survey lines. GPS data is corrected in a pseudo range differential fashion with post processing and combined with the magnetic data on a time basis. Positional accuracies averaging 8 m have been achieved.

The system is used in all reconnaissance applications, particularly in rugged areas where grids are prohibitively expensive to establish. High along line resolution, and speed of operation make POSMAG a cheap and effective tool. Areas previously not amenable to assessment with the ground magnetic method are now covered effectively and economically.

This paper describes the features and limitations of the equipment used in the POSMAG system. Results of tests on the accuracy of GPS positioning with rudimentary post processing are given. Finally, case studies are presented to illustrate the uses of the system in both standard grid and reconnaissance applications.

Keywords - POSMAG, ground magnetics, GPS.

3-D Survey Design by Computer

Mike Galbraith

Seismic Image Software Ltd

Abstract

Today's 3-D surveys can be large or small, laid in straight lines across deserts or tundra, or along winding roads through forest or jungle. Computer programs are essential to analyse the complexities which naturally arise.

The fundamentals of 3-D design start with the interpreter who must analyse the likely target geology and establish the desired fold (hence likely s/n ratio) and bin size (spatial resolution and maximum non-aliased frequency on dipping events). Ray paths to formations will determine minimum and maximum acceptable shot-receiver offsets.

The basic equations governing all 3-D surveys are:

$$NS = F/(NC \times B^2) \qquad SLI = 1/(2B \times NS)$$

where NC = number of recording channels, B = bin size (m), and NS is the number of shots per m^2 needed to create the fold F and SLI = shot line interval. Receiver line interval depends only on the minimum acceptable offset and is a critical part of determining the layout strategy - straight lines, bricks, zig-zags, buttons to name a few. Increasing receiver line interval can, of course, reduce clearing costs. Each strategy has advantages and disadvantages from the processor's and the field crew's perspective and must be analysed.

How will the data resulting from such a survey respond to velocity analysis, static corrections, DMO, muting, and migration. Will any noise in the data be cancelled by the stacking process (stack-array effect for linear noise, or enough offsets to attenuate multiples)? A comprehensive analysis of the fold and the offset and azimuth distribution in each CDP bin is essential.

Finally the field crew's concerns must be addressed. Equipment is expensive to place and expensive to move. Different designs can save dollars - roll-on vs. roll-off for example. The computer program must allow easy movement of shots to undershoot lakes, rivers, pipelines, buildings or to fill in "holes" created by shooting or recording along non straight lines.

Changes at each stage of the design process can be made and costed quickly leading to a successful, efficient 3-D survey.

3-D Salt and Sub-salt Imaging Strategy: A Case History from the Gulf of Mexico

Bob Godfrey, Andy Pieprzak, Kjell Berg & Oz Yilmaz

Geco-Prakla

Abstract

The purpose of this paper is to demonstrate 3-D prestack depth migration as an ultimate technique for imaging structural targets associated with salt diapirism, and compare it with other migration strategies - 2-D prestack, and 2-D/3-D poststack depth migrations. The structural problem is to image sedimentary bed terminations, bottom salt boundaries and undersalt layers around two large salt masses in the Gulf of Mexico. A large number of oil and gas reservoirs in the Gulf of Mexico is controlled by salt structures. Typical salt flank plays have been mapped quite successfully with time migration strategy. However, as exploration moves into more complicated targets around salt overhangs and subsalt traps, depth migration strategy becomes necessary.

The first task is to build a detailed 3-D velocity-depth model. To accomplish this, the following robust approach has been chosen. Using a velocity/depth model for the overburden (sedimentary section) based on edited stacking velocities, 3-D poststack depth migration was performed to verify its accuracy. Iterative 3-D poststack depth migration then followed to define the salt masses. Top salt reflectors were interpreted in 3-D and constant salt velocity was assigned to the half-space below the top-salt. Again, 3-D poststack depth migration was performed and base-salt events were interpreted. Finally, the velocity model was updated to contain complete salt bodies and 3-D poststack migration was rerun to check results. This loop of three iterations was repeated until convergence was achieved - the input model matched the result of the depth migration.

Given the velocity model, a single output line was selected and 3-D dynamic raytracing was performed to link output image points with surface shot-geophone locations. Finally, 3-D Kirchoff depth migration was run in 3-D prestack, 2-D prestack and 2-D poststack modes to produce comparison sections along the output line.

Keywords - salt, sub-salt, 3-D imaging, Gulf of Mexico, seismic

The Regional Geophysical Response of the Stuart Shelf, South Australia

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Abstract

Analysis of regional aeromagnetic and gravity data sets shows that the Stuart Shelf is host to a major volcano-plutonic complex consisting of large volumes of felsic-dominated volcanic rocks and shallow-crustal level granitic bodies. The complex is interpreted as a major eruptive centre associated with the Gawler Range volcano-plutonic event of 1600 Ma to 1580 Ma. The mid-Proterozoic basement surface in the northern and central areas of the Stuart Shelf lies beneath a thick cover of younger sediments and is interpreted as representing a section through the lower-middle levels of the volcano-plutonic complex. Volcano-plutonic elements present at this stratigraphic level include collapsed cauldrons, epizonal granites, and ring faults associated with pluton emplacement.

Some of these structures acted as fluid pathways during an extensive period of Fe-metasomatism associated with the volcano-plutonic event, and consequently are evident in the geophysical data as gravity and/or magnetic highs resulting from localised deposits of magnetite and hematite. The Stuart Shelf is a prime example of a terrane where the geophysical response is dominated by secondary alteration assemblages rather than primary lithologies. The presence of a thick cover sequence over the entire Stuart Shelf restricts direct examination of the volcano-plutonic complex. However, comparison of the geophysical data from the Stuart Shelf with data from well-exposed, well-documented terranes of a similar tectonic setting provides a useful insight into the possible structural and tectonic history of the Stuart Shelf. Such terranes include the mid-Proterozoic St. Francois Mountains of south-east Missouri and the Quaternary volcanic provinces of the mid-western United States of America.

Keywords - aeromagnetics, gravity, Stuart Shelf, Olympic Dam, volcanic

Application of Geophysical Methods to the Exploration of Coal Deposits in Sarawak, Malaysia

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Poster Session Abstract

Within the joint German-Malaysian coal exploration programme several geophysical methods including borehole measurements, DC-soundings, electromagnetics and shallow reflection seismics were applied under complicated surface and environmental conditions. The sites in Sarawak, which included the areas of Merit-Pila, Kupit-Silong, Stapang Skroh and Sintulu, are covered by secondary rainforest and show rough topography with deeply eroded valleys and steep cliffs. The exploration targets are multiple series of rather thin seams of sub-bituminous A-coal occurring within an intercalation of generally shallow dipping shales and sandstones, which discontinuously overlay a basement of folded metamorphic rock.

Early borehole logs provided the base knowledge about the physical parameters of the relevant materials. Showing high resistivity, low density and low natural gamma radiation the logs are now carried out as a routine in all exploration boreholes providing essential information about the stratigraphic details, the thickness of the coal seams and, partly, their quality.

Ground geophysical surveys started with a few HLEM lines (GENIE type) aimed to locate transversal faults inferred from coalseams. Subsequently the VLF-R ground-impedance method (Scintrex ICS-2/VLF) was tested and proved to be the most effective and economic tool to trace the subcropping seams. Generally the seams are covered over long distances by lateritic overburden and thus cannot be mapped geologically. Using the strong signal from the NWC radio station, situated approximately 2800km south of the area, the E-vector of the primary field penetrates almost perpendicular the predominantly W-E striking coalseams. MT-model calculations support the consideration that this H-polarisation is, fortunately, the best orientation to respond to resistive 2-D targets, resulting indeed in distinct apparent-resistivity peaks over the subcrops in spite of their narrow width (Fig.1.). Futhermore, changes in the resistivity background level and the pattern of geological noise indicate clearly the contacts between conductive shales and resistive sand-stones. Sometimes, the geological interpretation became more distinct when the raw data (apparent resistivity and phase) were converted into the parameters of a simplified apparent 2-layer model. Special algorithms were applied to calculate the resistivity of the substratum and either the thickness of an infinitely resistive, or conductance of a thin conductive overburden.

Intending to investigate the column of shallow dipping sediment layers towards the depth it became obvious that by means of DC-Schlumberger-soundings only a generalised sequence could be obtained. The resolution power of DC-soundings was not strong enough, to reflect important stratigraphic details, much less the coalseams.

To overcome this problem and to obtain detailed information about possible lateral discontinuities high resolution reflection seismic measurements were recently added to the spectrum of methods. The seismic equipment of the Geological Survey of Sarawak included a 24-channel EG&G Geometrics 2401 seismograph, shotgun and explosive energy radiation, with 40Hz and 100Hz geophones. The not well known thickness of the weathering layer and the structure of the expected geological target made the selection of spread and acquisition parameters difficult. The acquired data were processed with the help of the program SEISTRIX-2 and additional post-stack processing software. Main problems appeared during the estimation of static corrections which originated from the rough topography and the lack of additional refraction measurements. So the statics were calculated by refraction interpretation of the first breaks of the reflection seismograms. The interpretation was based on the drillhole information in the vicinity of seismic lines. The seismic time sections show structural details so far unknown for the coalseams in the area of investigation (Fig.2.). A discontinuous layering has been detected which coincides, however, well with the latest aereal interpretation. The coalseams are affected by several faults which were newly detected or partly confirm supposed ones.

In conclusion, the results demonstrates the useful application of geophysical methods, in particular VLF-Resistivity and High Resolution reflection seismics for

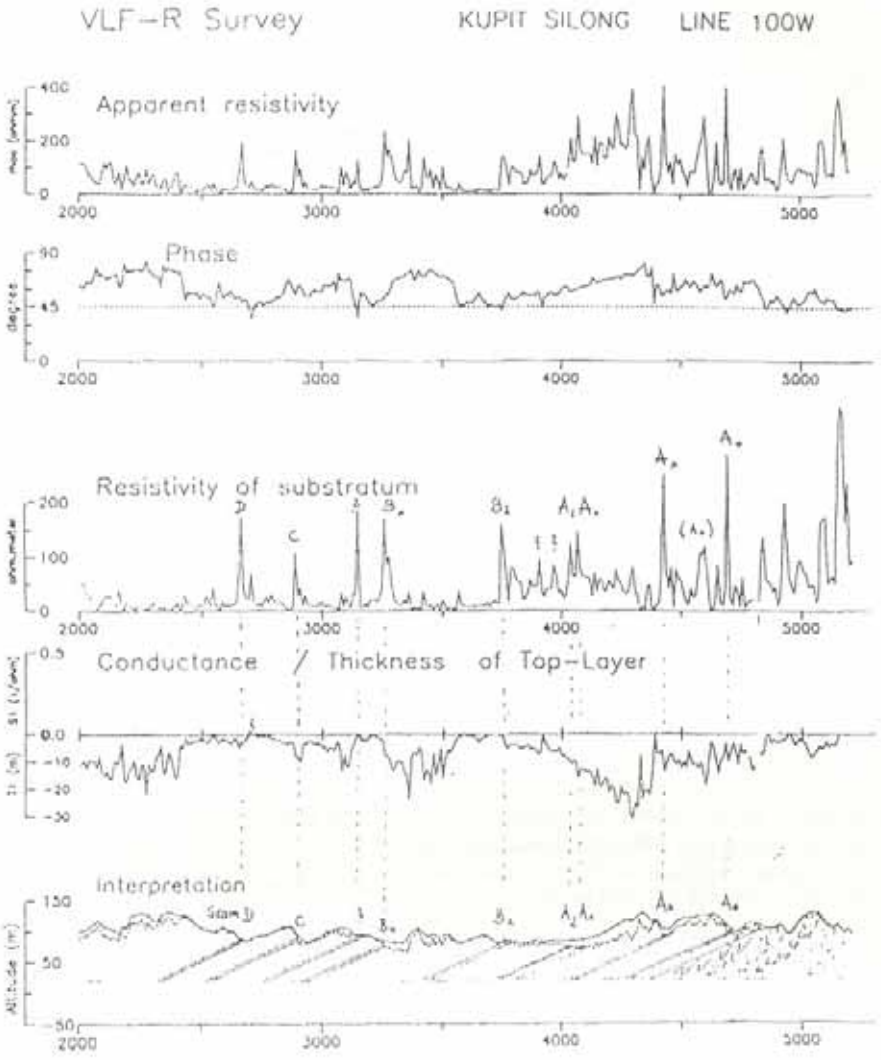

Fig.1: VLF-R profile in Kupit-Silong area. Station separation is 10m.

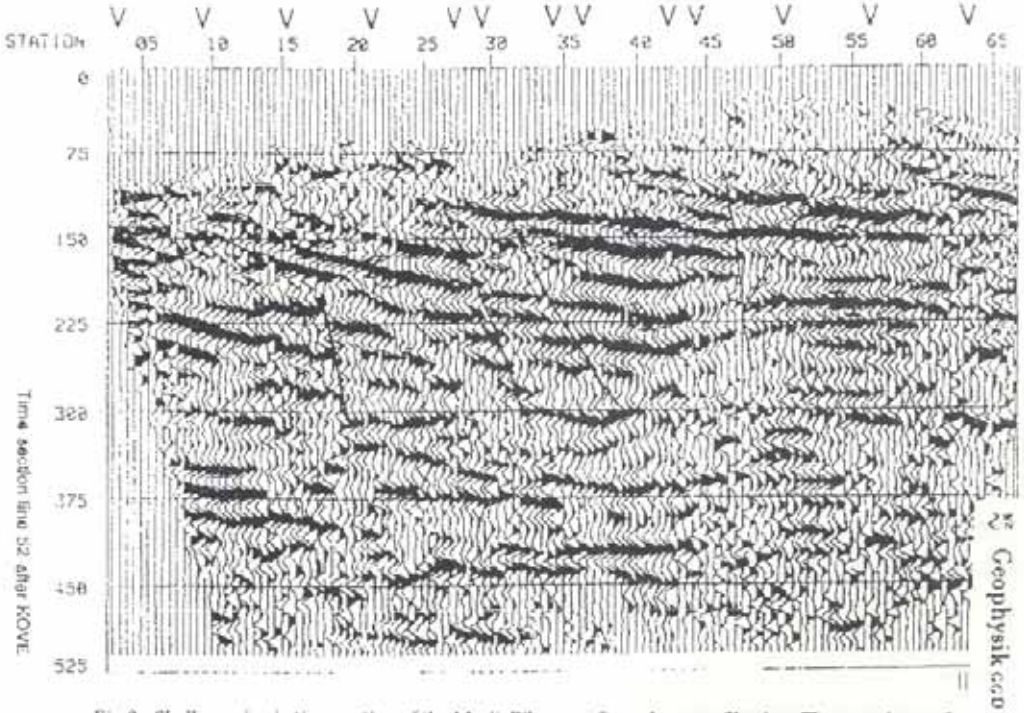

Fig.2.: Shallow seismic time section of the Merit-Pila area after coherency filtering. The trace interval is 5m, the CDP-coverage is 12 fold.

shallow coal exploration under complicated surface and environmental conditions. With geophysical information the existing knowledge of the geological structure has been improved essentially.

(f, x) Migration - Some Side Issues

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Abstract

Conventional methods of treating boundaries in finite difference (f, x) migration, namely padding in both space and time, have the disadvantage of increasing the data volume. This increase, whilst acceptable for 2-D processing, becomes uneconomical in the 3-D arena. Dipping events move up-dip during the migration process. Dips close to the sides of the data that move outside the data range can be reflected back if the boundary conditions are poorly set. This results in misleading events appearing in the migrated data. The addition of extra zero trace padding allows these events to move out of the data and so avoids these artifacts.

The alternative to padding with zero traces is to use absorbing side boundary conditions. Absorbing sides have been proposed by several authors. A method developed by Clayton and Engquist is reviewed in detail, and implementation issues are discussed. Although this method is exact for only one propagation angle, it is found to attenuate significantly the reflections of other dipping events.

Time padding is used to avoid the wraparound that causes shallow data to reappear as noise at later times in the migrated result. Wraparound is inherent in (f, x) finite difference migration, because of the cyclic nature of the fast Fourier transform. The time padding increases the run time of both the fast Fourier transform and the migration.

Clearly, it is desirable to find a technique to remove the wraparound and so avoid the need for costly time padding. Kjartansson showed a method for wraparound removal for the case when the sampling interval is equal to the migration time step or depth interval. In practice, however, a coarser time step is usually employed. A new generalised method has been developed for wraparound removal under these conditions of coarse time step. The technique is applied at each time step extrapolation. Although this obviously involves more computation, the method is more efficient than using extra time padding.

Both these techniques, the absorbing side boundaries and the wraparound removal, can be used in 2-D and one-pass 3-D implementations. Without the need for extra padding, migration run times and hence costs are reduced. The methods are demonstrated on synthetic data. The results compare well with those obtained using conventional padding, with a considerable reduction in run time.

Keywords - finite difference migration, boundary conditions, wraparound.

Accurate Heights for Gravity Surveys using Global Positioning System (GPS) Technology

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Poster Session Abstract

Gravity observations can usually be conducted to an accuracy of 0.1 mgal. This equates to an accuracy in terms of elevations of +/- 10cm. In the past, conventional spirit levelling has been the only tool readily available for providing high accuracy height determination. Levelling has usually been confined to smaller detail gravity surveys due to the expense of surveying large distances.

The Global Positioning System (GPS) has revolutionised long distance surveying. Using various techniques, distances of up to 20km can be measured within seconds and to accuracies of centimetres. These techniques are capable of providing a better than +/- 10 cm height accuracy between gravity stations. This accuracy is achieved on any gravity station interspacing.

This latest technology has already been used to height over 20,000 gravity stations throughout Australia. Specific observation procedures have been developed to conduct the gravity and GPS observations together. Successful campaigns have been completed from both vehicle and helicopter mounted systems. These surveys have proven that height determination by GPS is cost effective on both detail and regional gravity surveys.

The Importance of On-Board Processing

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Abstract

3-D marine seismic surveys acquire ever larger volumes of data, and use increasingly complex deployments of multiple streamers and source arrays to reduce costs and increase efficiency. The result of such large volumes of data presents serious problems of acquisition quality control and processing turnaround.

The rapid development of on-board processing systems has enabled these problems to be addressed directly, by providing comprehensive features for quality control, smoothing the path for final data processing, and providing access to 3-D data volumes at an early stage. Apart from the processing power provided by the modern workstation computer, the key elements in this development are the availability of real-time data links with the recording system, and the provision of similar linkages to the real-time and post-processed navigation data. These linkages enable real-time processing of a significant subset of the 3-D data in the form of a stack of the near offset traces (typically 6- or 12-fold) of all subsurface lines recorded simultaneously in multiple source and streamer acquisition. The stack traces are assigned appropriate mid-point co-ordinates and stored in the form of a 3-D volume.

The 3-D data may be viewed as in-line, cross-line or time-slice profiles at any time during the survey (and the processing), which allows the correct functioning of many key acquisition sub-systems to be verified.

The 3-D volume may be migrated on-board, or soon after completing the acquisition of the date, allowing rapid access to 3-D migrated results, and providing a basis for initial interpretation and velocity model building. The on-board processing system thus brings together all aspects of the 3-D survey - acquisition, processing and interpretation.

Keywords - real-time, 3-D processing, quality control, marine seismic.

Seismic Tomography for Field VSP Surveys in an Inhomogeneous and Anisotropic Medium

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Abstract

Direct waves generated as a result of field VSP surveys are used to obtain tomographically reconstructed images in anisotropic and inhomogeneous media.

A method is described to determine the anisotropic characteristic of velocity which assumes that velocity changes with depth and arrival angle. There is no need to assume any form of anisotropy. The form of velocity anisotropy can be determined by the results of the velocity inversion. Then a method is outlined for velocity tomography with an anisotropic correction based on the inverse theory of Newton's non- iterative solution. Instead of using 2-D or 3-D ray tracing to deal with strongly vertical inhomogeneous media, the method uses vertical changes and anisotropic velocity determined from the velocity analysis as an a priori model of reference velocity. The method circumvents image distortion caused by straight line rays and the ray divergence caused by ray tracing. The method was designed for 3-D Vertical Seismic Profiling (VSP) application and to give a 3-D volume tomographic image of velocity disturbance by displaying 2-D cross-section slices in 3-D space.

Two field VSP data sets have been analysed, one which is the result of flat layers with obvious anisotropy and the other with no obvious anisotropy but obvious horizontal velocity variation. Strata logs from the two sites confirmed the tomographic results at each well position.

The method described in this paper can be conveniently used in 2-D and 3-D VSP and cross hole seismic surveys for the petroleum and mining industry.

Keywords - anisotropy, VSP, tomography, velocity, cross hole seismic surveys

High Resolution Aeromagnetics Clarifies Structuring in the Vlaming Sub-Basin, Western Australia

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Abstract

Woodside has conducted two high resolution aeromagnetic surveys in the northern and southern extremities of the Vlaming Sub-basin. The northern survey also covered a portion of the Edwards Island Block and the southern extremity of the Abrolhos Sub-basin. The acquisition of the data highlighted the problem and characteristics of ocean swell generated magnetic noise, which had amplitudes similar to the structurally related signal.

The aeromagnetic data defined the broad basin architecture. Image processing helped to enhance many of the weaker magnetic features which correlated with intra-sedimentary structures observed on the seismic data. The aeromagnetic data showed that the structuring and the structural orientations are slightly different between the two survey areas. The northern area had a wider envelope of fault azimuths with trends of NW to NNE with the NW to NNW trends dominant. The southern area had a narrower envelope of fault azimuths with trends predominantly NNW to NNE.

In the northern area NW lineaments, parallel with the oceanic transforms, offset other lineations in a right-lateral direction. These are interpreted to be right lateral strike-slip zones related to oblique faulting during breakup. Similar NNW strike- slip features are observed in the southern survey dataset. East-west lineaments are interpreted as antithetic strike-slip faults. These are believe to be related to basement block rotations which caused localised areas of compression, observed on seismic data.

The aeromagnetic and seismic data show the Vlaming Sub-basin underwent right lateral oblique faulting during the breakup between Australia and India. Changes in fault drag on the Darling Fault, possibly related to variations in basement between the two survey areas, are proposed as the reason for the differences in fault azimuths.

Keywords - Vlaming Sub-basin, aeromagnetic, breakup, seismic data, Darling Fault, Perth Basin, ocean swell magnetic noise, Bunbury Basalt.

Reservoir Prediction Utilising AVO Walkaway VSP Data to Calibrate Surface Seismic Gathers, a Case Study in Indonesia

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2 Hampson & Russell, Calgary, Canada

3 Schlumberger, Jakarta, Indonesia

4 Schlumberger, Stavanger, Norway

Abstract

In prediction of reservoir properties using seismic data, use is frequently made of AVO techniques. However, such techniques may not always be successful. Hence a new technique has been devised - based on recording a subsurface AVO response in the well. Recording is achieved from five triaxial geophone shuttles at 15 m intervals - ideally one wavelength (of the predicted dominant source frequency) above the target. The source (two 150 cubic-inch Sleeve Guns) was deployed from the marine vessel's boom and moving in a line such that shot spacing is as close as possible to the surface seismic offsets. The line might extend 3 km to each side the well. Processing of the AVO walkaway data takes place in three steps: data orientation; separation of the down and up P-wave fields; and deconvolution (using the downgoing P-wavefield to deconvolve the upgoing P-wavefield) to remove propagation effects.

The surface seismic data (in this case a 3-D data set) are processed (gathered) and put through a rigorous 12-stage signal processing sequence. The AVO VSP and the surface gathers are then carefully tied to the zero- offset VSP. After application of the Offset Dependent Gain Function the data are solved for P-wave reflection amplitude (at angle 0o) and the gradient. Those results can then be mapped and contoured - to identify anomalous areas, at known sites (wells) and

- to identify anomalous areas, at known sites (wells) and elsewhere. Additional refinement is continuously being sought, and is welcome.

Keywords - reservoir characteristics, AVO, AVO VSP, walkaway, Offset Dependent Gain Function

Evaluation of Seismic Trace Inversion Techniques

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Abstract

The performance of three post-stack seismic inversion techniques has been evaluated using synthetic and VSP data. The application of classical recursive inversion to simple synthetic models demonstrates the importance of low frequencies in trace inversion. This is consistent with the strongly low-pass response of the inversion transfer function. Impedance profiles generated from band-limited seismic traces contain only "depth-positional" information. An accurate impedance profile can only be obtained if independent, reliable low-frequency information is incorporated following inversion. Auto-regressive (AR) spectral extension is evaluated as a representative of sparse-spike inversion techniques. Synthetic examples suggest excellent performance on sparse-spike models, but performance deteriorates as the reflectivity series becomes more dense. Poor performance on real VSP data is a further indication of the failure of the AR technique when fundamental assumptions are not satisfied.

Of the three methods investigated, model- based linear inversion is preferred in terms of accuracy, robustness and logistics. In contrast to previously published modelling algorithms, no geological interpretation is required prior to inversion. Instead, the inverted band-limited trace is used to initiate the inversion scheme. Critical low-frequency control is achieved by incorporation of RMS velocity constraints. The robustness of the model-based inversion technique when applied to VSP data suggests that it is possible to recover accurate impedance information beyond the bottom of the borehole.

Keywords - trace inversion, impedance recovery, VSP.

Structural Framework of the Eastern Otway/Torquay Basins: Inversion and Interaction Between Two Major Structural Provinces

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Abstract

Integrating reflection seismic interpretation of the onshore eastern Otway Basin and offshore Torquay Basin with thermochronological studies (both published, and currently in progress) has had an impact upon some of the recent models proposed for the Mesozoic to Recent history of the area.

Analysis of Early Cretaceous faulting with significant heaves in the Eastern Otway/Torquay offshore regions suggests that much of the faulting in the area strikes E-W, implying a major overall N-S component of extension at that time. To the east of an area centred on the Stoneyford Gravity High the strike of Early Cretaceous faults gradually changes from E-W to NNE-SSW over several tens of kilometres. There is no evidence for an abrupt discrete transfer fault, controlling the change in fault orientation.

The sedimentary section around 143°E in the Port Campbell Embayment records a near orthogonal change in fault strike

from WNW-ESE to SW-NE to the east. This change has been recognised for some time from surface data as well as published tectonic maps, and has been used as corroborative evidence for locating a major structural boundary. The WNW-ESE fault trends seen on regional maps in the Port Campbell Embayment were initiated in the Cenomanian-Santonian. Thus the orthogonal relationship of the fault trends seen around 143°E is a consequence of the juxtaposition of faults of different ages.

A large scale boundary in this general area is still supported by the significant change in Mid-Late Cretaceous subsidence patterns evident in the sedimentary record inferred from the seismic and local thermochronological interpretation. However, that boundary, at least at shallow Mesozoic levels, is not manifested as a transfer zone and may lie further east around the Stoneyford Gravity High rather than on the trend with the Woorndoo Fault zone.

Keywords - reflection seismic data, extension, inversion, Otway Basin, Torquay Embayment, Colac Trough

Quantifying Erosion in Sedimentary Basins from Sonic Velocities in Shales and Sandstones

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Poster Session Abstract

If it is assumed that sonic velocity in a sedimentary rock decreases with burial-depth according to a known velocity/depth relationship, and that velocity is not reduced by erosion from maximum burial-depth, any erosion of that rock from maximum burial-depth may be quantified using velocity data. The displacement, on the depth axis, of sonic velocity in a given unit from the normally compacted velocity/depth relationship yields apparent erosion (i.e. amount of missing section or height above maximum burial-depth).

Shales have been considered to be the only lithology to follow a sufficiently predictable velocity/depth relationship with burial- depth to be used in the estimation of erosion from sonic velocity data. However, erosion estimates based on sonic velocities in the Lower Cretaceous Allaru/Oodnadatta Mudstone of the Eromanga Basin are statistically similar to those derived from velocities in the Middle Jurassic Hutton Sandstone (an important hydrocarbon reservoir sandstone in the basin). Similarly, erosion estimates based on velocities in the Lower Triassic Bunter Sandstone (an important hydrocarbon reservoir sandstone) of the United Kingdom Southern North Sea are statistically similar to those based on velocities from the Lower Triassic Bunter Shale.

The consistency of results from the shaly and sandy units analysed suggests that overcompaction (i.e. anomalously fast

sonic velocity) of the sandstones is controlled by erosion from previously greater burial-depth, rather than by burial-depth independent sedimentological and/or diagenetic processes. The results validate the use of sandstones in maximum burial-depth studies, and perhaps more importantly suggest that, even in reservoir sandstones, burial-depth is the primary control on compaction and hence porosity.

Keywords - sonic velocity, sandstone, shale, maximum burial-depth, erosion magnitude.

The Contemporary Stress Field of the Barrow-Dampier Sub-Basin and Its Implications for Horizontal Drilling

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Abstract

The interpretation of borehole breakouts suggests that minimum horizontal stress (jh) is regionally oriented approximately N-S in the Barrow-Dampier Sub-Basin. More locally, breakout interpretation suggests that jh orientation is 005°/010° in the Wanaea/Cossack area, and 012°/022° in the Griffin/Chinook/Scindian area. Horizontal stress magnitudes in the Wanaea/Cossack area, derived from modified leak-off tests, together with vertical stress magnitudes derived from density and sonic log data, suggest that the stress (fault) regime in the Wanaea/Cossack area is on the boundary of extension (normal faulting) and strike-slip.

The contemporary stress field impacts on planning the drilling direction of deviated and horizontal wells through the issues of mechanical wellbore stability and fracture intersection. In order to maximise intersection with any open, natural fractures, and to optimise any hydraulic fracturing program, wellbores should be horizontal and parallel to j_h (minimum horizontal compressive stress) in the extensional (normal fault) and strike-slip stress regimes, and vertical in the compressional (reverse fault) regime. In order to minimise the tendency for borehole breakout, the stress anisotropy around the wellbore should be minimised - i.e. horizontal wells should be drilled in the direction of j_h in the extensional regime, and in the direction of j_H (maximum horizontal compressive stress) in the compressional regime. In the strike-slip regime, horizontal wells can be oriented such that they are not subject to any stress anisotropy by progressively changing from the jh direction towards the j_H direction.

In the Wanaea/Cossack area, wells drilled towards 005°/010° or 185°/190° will maximise the potential for intersection with open, natural fractures (should they be present), and recovery from any induced, hydraulic fracturing will be optimised. Furthermore, wells in this direction will be subject to the minimum stress anisotropy, and are thus least likely to be subject to breakout.

Keywords - crustal stress field, horizontal drilling, wellbore stability, fractures, Barrow-Dampier Sub-Basin.

MIP test survey over the HYC deposit in McArthur River area, N.T.

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1 Metal Mining Agency of Japan

2 Scintrex Pty Ltd

Abstract

A test survey using the magnetic induced polarization (MIP) method was executed over the HYC sulfide deposit in the McArthur River area of the Northern Territory, Australia in September, 1992. The survey conducted by the Metal Mining Agency of Japan (MMAJ) using Scintrex equipment and personnel, was planned to define the MIP response over the huge stratified sulphide deposit and to compare the results with other geophysical data (including conventional IP) compiled since discovery in 1955.

For current flow parallel to strike of the HYC deposit, a strong MIP anomaly was observed, providing accurate interpretation of depth and dip direction of the ore horizon and the upper pyritic shale-siltstone member. The MIP anomaly was in good agreement with the conventional electrical IP data collected with pole-dipole array.

On the other hand, current flow perpendicular to strike produced no MIP anomaly. This result is consistent with the theory of MIP, indicating that the exploration programme must take account of regional geology and structures.

Petrophysical study of drill cores showed the strongest IP source to be the ore horizon containing abundant sulphides. The upper pyritic shale-siltstone member also contains a considerable amount of sulphide and gives a significant IP effect.

The MIP test survey verified the HYC orebody as a target for both electrical and magnetic IP methods, and MIP is suggested as a viable prospecting technique for similar base-metal targets in the region.

Keywords - magnetic induced polarization, HYC deposit

Resolution

Eve Howell

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Keynote Address Abstract

There are several meanings of the word 'resolution', two of which are addressed here, namely:

Resolution - act or process of separation into component parts

Resolution - firmness of purpose; constancy

The discussion relates to petroleum exploration on the NW Shelf, and the Carnarvon Basin, in particular. The former definition of 'resolution' is the one most will associate with the conference theme of "Increasing the Resolution: Clearing the haze". The contribution of improved resolution in seismic techniques is examined in the context of its impact on discovery of petroleum reserves on the NW Shelf. Examples of the significant impact of 3-D seismic, AVO and inversion studies and workstation interpretation techniques on improved resolution and exploration/appraisal success are discussed as case histories.

The second definition of 'resolution' is developed in the context of the tenacity of explorers on the NW Shelf who after years of frustration, are seeing the rewards of their efforts resulting in the Carnarvon Basin being the prime area of success in recent years. It's contribution to the economy of Australia will be of major significance in the nineties and early twenty-first century.

Structural and Tectonic Framework of the Onshore Northern Perth Basin

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Abstract

Analyses of fault trends and aeromagnetic images, together with burial history modelling, show that the onshore northern Perth Basin has a complex tectonic history. Three major phases of tectonism are recognised.

1) Extension in a direction of 005° in the Late Permian that resulted in normal faults striking 275°, and sinistral strike- slip along the Darling Fault.

2) Extension in a direction of 355° in the Jurassic resulted in the onset of rifting which produced normal faults striking 265°, and sinistral strike-slip on transcurrent faults oriented at 310°.

3) The break-up of Greater India from Australia in the Early Cretaceous and the resultant extension direction of 255° produced normal faults striking 345°, and dextral strike-slip along transcurrent faults oriented at 300°.

Keywords - tectonic framework, structural analysis, fault trend analysis, burial history modelling, vitrinite reflectance

Shear wave VSP in Amarume Oil field

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Abstract

Japan National Oil Corporation (JNOC) acquired the following shear wave seismic data around the TRC-AMR1 (JNOC research well) in the Amarume oil field which is located in the northern part of Japan:

1) 1989 Shear wave VSP by a single, coupled source

2) 1990 Shear wave surface seismic by a single, coupled source

3) 1992 Shear wave VSP by dual coupled sources

Rotation analysis for VSP data of the first survey showed remarkable shear wave splitting. The surface seismic data of the second survey did not show this effect.

In both surveys, the motion of the shear wave source was limited to a direction perpendicular to the source-receiver line. In general, rotation analysis requires data from dual coupled sources whose motions are perpendicular to each other. The last VSP data (3) were acquired in order to investigate the conflicting results of both surveys.

Data from this survey confirmed the existence of an anisotropic layer shallower than 700 m.

The direction of anisotropy was found to be almost east-west, that is, in line with the receiver direction of the second survey. It was concluded that this was the reason why the second survey did not show shear wave splitting. The time difference between S1-wave (the faster shear wave) and S2-wave (the slower one) was over 100 ms at 700 m depth.

This survey also detected the location of a gas reservoir at around 870 m depth.

Keywords - shear wave, VSP, anisotropy, splitting, reservoir delineation

Structural Geophysics

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Abstract

This paper presents a technique for the integrated forward modelling of the structure and geophysical response of multiply deformed terranes. This technique allows information collected by field geologists and geophysicists to be reconciled by the development of a simplified structural history of the area. The modelling is based on the deformation history of the area, in terms of a succession of structural events, such as folds, shear zones and intrusions. The interaction of these events with an assumed stratigraphic model results in the prediction of feasible structures. By specifying rock properties for the units in the initial stratigraphy, predictions can also be made as to the potential field anomalies for gravity and magnetics. The accuracy of the model can be gauged by comparing the predictions with the constraints provided by the observed structural and geophysical data.

This approach points to a new methodology for the reconstruction of the geometry of structures in the Earth's crust, and has potential as a tool for both research and training.

Keywords - structure, gravity, magnetics, forward modelling

The Resolution of GPS

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Abstract

Since its inception in the early 1980's, the NAVSTAR Global Positioning System has developed from a navigation system offering only point positions to an accuracy of about 30 metres to the point where it is possible to measure distances to a precision of millimetres over several kilometres. There exists, however, a degree of confusion in the precision of measurements that GPS offers. The precision of measurements produced by GPS depends on the type of data collected, and on the methods of processing that data.

This paper will give an overview of the varying methods employed in using GPS as a positioning and measuring tool, and the resolution to be gained by those various methods. Examples of geophysical surveys carried out using the different methods will be cited to demonstrate aspects of the comparative techniques, particularly with respect to the precision and accuracy of the position. Techniques still under development will also be considered and the likely benefits to the exploration geophysicist examined.

Geophysics and Iron Ore Exploration: Examples from the Jimblebar and Shay Gap–Yarrie Regions, Western Australia

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Abstract

Aeromagnetic and downhole logging data have been acquired for iron ore deposits at Jimblebar and Shay Gap–Yarrie in the Pilbara. The Jimblebar deposits are from the Archaean-Early Proterozoic Hammersley Group and the Shay Gap–Yarrie deposits are from the Archaean Gorge Creek Megasequence.

Aeromagnetic data are used to assist in regional mapping and generation of exploration targets. In structurally complex areas, a very close line-spacing may be necessary to provide data of sufficient resolution. Careful processing is necessary to reduce the large dynamic range of the data, caused by highly magnetic banded iron-formation (BIF), so that subtle features may be seen. Deposits display both structural and stratigraphic controls which may be evident in aeromagnetic data. In addition, the iron enrichment process alters magnetite within the parent BIF to haematite, which may give rise to subdued responses in aeromagnetic data. The application of the aeromagnetic technique to exploration at Yarrie was an integral part of the discovery of the Y2 deposit.

Downhole natural gamma logging is used as an in-hole stratigraphic mapping tool. In the Jimblebar area, the stratigraphy, comprising interbedded oxide BIF and silicate iron formation (shale) macro bands, is very regular. As a result, it is generally possible for gamma ray logging to identify the strata intersected in drill holes to within a several metres, even where they are complexly deformed. Hence natural gamma logging can play an important role in resolving complex structural problems. At Shay Gap–Yarrie, gamma logging does not show the stratigraphic discrimination seen in the Jimblebar area, because the stratigraphy in the Shay Gap region is not as laterally consistent. However, gamma logging is still useful for general delineation of rock types.

Density logging is used for a variety of applications, including confirmation of ore grades, bulk density estimates for resource calculation, and geotechnical studies. At Shay Gap–Yarrie, back-scattered gamma density logging is used downhole to determine the density of iron ore, an important parameter in resource calculations. Frequent calibration of the probe with known reference samples is critical.

Crustal Studies of South Australia Based on Energy Spectral Analysis of Regional Magnetic Data

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Abstract

Energy spectral analysis applied to regional aeromagnetic data covering an area between 26°S and 35°S and 129°E and 141°E indicates an interface which lies at depths of between 5 km and 25 km. Structures indicated on the contour map of the depth of this interface are related to major features on the gravity map and to folds and faults in the Musgrave Block, the Gawler Craton and the Adelaide Fold Belt as well as to kimberlite intrusions in the Adelaide Fold Belt.

Keywords - energy spectral analysis, aeromagnetic surveys, South Australia, kimberlite, crust

Drill Core Orientation using Palaeomagnetism

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Abstract

Palaeomagnetic orientation of drill core from the Sydney-Bowen Basin is feasible. A consistent magnetisation is observed in coal measures in the basin enabling the remanence of an unoriented sample to be utilised to orient the sample. Palaeomagnetic orientation of drill core for fracture analysis has been used successfully in the Sydney- Bowen Basin.

The direction of magnetic remanence in the sediments of the southern Sydney Basin is consistent across a wide area, this direction being north and up. Similarly, the remanence direction observed in Bowen Basin coal measures is consistent from the south (Moura mine) to the north (Goonyella mine) of the basin, and this direction is also north and up. The consistency of the remanence direction is lithology dependent. Fine sandstone and siltstone/mudstone units gave the most reliable results. Coarse sandstones gave inconsistent remanence directions and should not routinely be used for drill core orientation using palaeomagnetism.

A longcore magnetometer constructed by the CSIRO Rock Magnetism Group enables measurement of the remanence of HQ drill core without the need to subsample. The measurement of the remanence of HQ drill core using a longcore magnetometer shows similar results to the remanence measured using laboratory magnetometers indicating that drilling does not alter the NRM. Thus, the non-invasive orientation of drill core by measurement of remanence using a longcore magnetometer is feasible for samples from the Permian coal measures of the Sydney-Bowen Basin. As well, storage of the drill core has no or limited effect on the remanence of the drill core. A small component is sometimes present but is easily removed by AF demagnetisation.

Weathering has a severe effect on the remanence of samples, inhibiting orientation by palaeomagnetism. Weathering can produce hematite/goethite which retains a strong chemical remanent magnetisation and thus dominates the NRM of the sample.

Keywords - drill core orientation, Sydney Basin, Bowen Basin, palaeomagnetism, longcore magnetometer.

Dewatering Assessment at Hilton Mine, Queensland - An Application of Gravity Methods

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Abstract

It was anticipated that the altered rock mass associated with Pb-Zn mineralization within Proterozoic dolomitic siltstones at Hilton, NW Queensland, would create problems during mine development. The material is variably oxidised, very porous, saturated and extensive. Semi-regional gravity data have been used to estimate the volume and extent of such material and assist mine planning and dewatering studies. Interactive, segmented, three dimensional procedures controlled by exploration drilling were used. The interpretation considers the effect of all materials and is not restricted to the high contrast alteration. The altered rock mass was found to be irregular, dip steeply west and to be etched from the ore-bearing horizons. It is up to 400 m deep. The alteration has been controlled by the steeply dipping form of the host rock footwall as well as by local faults and jointing .

The shape of the cone of depression, after dewatering for more than five years, has confirmed the interpretation within the first development block and lends confidence to the more regional implications along a strike length of at least 6 km. Analysis has also indicated that the volume and density contrast of the ore zone also varies along strike. The average bulk densities deduced for the ore and alteration zones are 3.1 gm/cm^3 and 2.1 gm/cm^3 or a contrast of about +0.4 gm/cm^3 and -0.6 gm/cm^3 with respect to the Mount Isa Group host sequence.

Keywords - Hilton Mine, gravity, dewatering, alteration, Mount Isa Group, Pb-Zn mineralization

AVO and Anisotropy from Logs and Walkaways

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Abstract

AVO (Amplitude Versus Offset) is the seismic technique used for mapping lithology, and modelling is an important step for successful AVO interpretations. Shear velocity measurements are essential, since AVO attempts to exploit the elastic (as opposed to acoustic) nature of seismic wave propagation. A property of seismic wave propagation not often considered is anisotropy. This is probable because the magnitude of the anisotropy has been difficult to measure, and its effect on AVO is not widely known.

New technology is helping to improve AVO modelling. Dipole source shear logging tools can now measure very slow shear velocities, increasing the range of applicability of AVO, and new borehole seismic techniques can measure anisotropy. When integrated, these new measurements provide more detailed information about the elastic moduli that govern wave propagation, and bring the possibility for greater reliability in AVO interpretation.

The effect of anisotropy on AVO is found to be significant and may lead to misinterpretations of AVO anomalies.

The Central Officer Basin Preliminary Results

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Poster Session Abstract

The Officer Basin is a remote intra-cratonic basin, which is poorly exposed due to widespread Pleistocene sand-dune cover. Its hydrocarbon prospectivity has been perceived t o be relatively limited and in combination with access and logistic problems, the basin has been seen as a high risk prospect.

Oil shows from a number of exploration wells in the eastern Officer Basin have demonstrated in situ oil generation from the alkaline members of the Observatory Hill Formation. The Rodda Beds have relatively low overall TOC measurements, but the volume of this unit (up to 3000m) suggests it could be a productive source. Possible reservoirs include the Relief Sandstone and the Murnaroo Formation, both of which have porosities up to 20%. The Relief Sandstone occurs predominantly in the central Officer Basin, which has had no exploration effort since 1967. Seals may include the intra-formational red beds and the evaporitic and carbonate units.

A program of 6 regional seismic lines are planned for acquisition in the central Officer Basin, which has not received any exploration attention since 1967. The AGSO seismic crew has completed acquisition on Line 1, a dip traverse of the northern portion oft basin above the conservation park. This line extends from the Musgrave Block in the north to 2.4km south of Birksgate #1 well at its southern end. Preliminary results from this line indicate a series of north dipping events (interpreted as thrusts) underlie the southern Musgrave Block. The sediments at the northern margin of the central Officer Basin display suprisingly little structure and have small dips to the south. Processing of this data is currently underway.

The Use of Magnetostratigraphy and Magnetic Susceptibility for Dating and Correlating Oil Shales in Eastern Queensland

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Poster Session Abstract

Magnetostratigraphy is a geophysical technique that is now one of the most important dating tools being used in stratigraphic studies. The technique is dependent upon recording magnetic polarity reversals, but where this can be done, gives precise results that are globally comparable. Moreover, it can be applied to sedimentary rocks that are not amenable to either biostratigraphic or radiometric methods. Examples of poorly dated sedimentary successions include numerous Tertiary oil shale deposits located along the eastern Queensland seaboard.

Magnetostratigraphy relies on the fact that the polarity of the earth's magnetic field changed frequently, but with an irregular pattern over time. This characteristic polarity pattern, particularly through the Jurassic to present, is well preserved in many rocks around the world. In particular the Tertiary is well represented and therefore highly resolved. The age of a rock sequence may, therefore, be identified by

comparing the magnetic polarity pattern with the established magnetic polarity time scale.

In a preliminary study, we have for the first time, successfully applied magnetostratigraphy to the Rundle-Stuart oil shale deposit contained within The Narrows Graben. the fluviolacustrine infill of The Narrows Graben consists predominantly of oil shale and claystone, lesser lignite and minor dolomite, and has a composite thickness in excess of 1000m. Rundle-Stuart contains an estimated 5 billion barrels of oil in situ. Although the age of the uppermost sediments is considered to be mid- to late Eocene (based on the megaspore Azolla capricornica), the succession is nevertheless imprecisely dated. No time range over which the sequence was deposited is known. Magnetostratigraphic work has thus focussed on the uppermost 400m of the lacustrine Rundle Formation where fully cored sections provide excellent stratigraphic control. Sampling was carried out at 2 to 5m intervals.

The magnetic susceptibility of each core sample was measured using a Bartington MS2 susceptibility meter. A Molspin tumbling AF demagnetizer was used for demagnetization, and a modified Digico spinner magnetometer used for remanence measurement. Data analysis was carried out by applying the principal component analysis technique in conjunction with orthogonal plots. As declinations of the core samples were not well controlled, inclination angles of the remanence were used for determining their polarities. Remanence with steep negative inclinations were treated as normal polarity and remanence with steep positive inclinations as reversed polarity. Remanence with shallow inclinations were regarded as records of polarity transitions.

Because of the clay-rich nature of the oil shale, magnetic properties have been found generally to be of a very low order. Sucseptibilities range between 5 and 26 x 10^{-5} SI units,, and remanences 0.05 x 2.4 x 10^{-6} mA/m. Nevertheless stratigraphically correlatable zones of magnetic reversal have been obtained. Individual beds can be correlated to a very fine scale within the deposit (generally less than 5m and commonly less than a metre) and this provides a high degree of confidence in these preliminary magnetostratigraphic and magnetic susceptibility results.

Timing and Genesis of Hammersley Iron-ore Deposits

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Abstract

Two types of genetic model exist for the in situ enriched ores in the Hammersley Basin: hypogene; and supergene. Although the supergene model has been adopted by a large number of geologists, conflicting geological/geophysical evidence suggests that the other model cannot be ruled out. This paper reports the results of a pilot palaeomagnetic study in and around the Tom Price mine. A negative fold test on results from the Wittenoom Dolomite demonstrates that the Tom Price region underwent an overprint event after folding in the Palaeoproterozoic. The direction of this overprint remanence is similar to that of a previously reported syn-folding remanence found in the Mount Jope Volcanics of the underlying Fortescue Group, and most of the remanence directions reported from the microplaty hematite ore bodies at Tom Price and Paraburdoo.

When these results are combined with geological observations, we are led to a tentative interpretation that the in situ enriched ores, particularly the microplaty hematite ores, could have been formed during Palaeoproterozoic extensional deformation, when the tectono/thermal fluids carried the iron to favourable structural positions, and/or leached components other than iron from those structural positions. This tentative model differs from the supergene model in that it requires orogenic/thermal fluids from the deeper sedimentary sequence rather than meteoric fluids percolating down from the weathering surface.

Keywords - Hammersley Basin, Tom Price, Paraburdoo, iron ores, banded-iron formations, palaeomagnetism, orogenic fluids, Palaeoproterozoic

The Australian Continent: a Numerical Model of its Electrical Conductivity Structure, and Electromagnetic Response

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Abstract

Electromagnetic induction, commonly associated in exploration geophysics with applied source fields, takes place on continental and global scales. At these scales it is driven by natural magnetic fluctuations which arise external to the Earth. These magnetic fluctuations, and the secondary signals which they induce within the Earth, are measured at permanent magnetic observatories, "roving" temporary magnetic observatories, and at magnetotelluric field sites. Such observed data contain information on the electrical conductivity structure of the Earth, and are a major source of geophysical information. The global induction process is of such a magnitude that it could not be generated using applied source fields.

An electrical conductivity model of the Australian continent with its surrounding oceans has been constructed numerically, for the purpose of examining its response to natural magnetic fluctuations. This paper first presents the continental response plotted as Parkinson arrows, for period 1 hour. Parkinson arrows summarize the behaviour of the three components of the Earth's fluctuating magnetic field, and for the model show particularly the coast effect. The coast effect arises most strongly at the continental edge, and penetrates far into the continent. There are also secondary effects within the continent, which arise due to electrical conductivity changes associated with geological boundaries. The present exercise models continental geological structures in a regional sense; their improved definition on a local scale, both in the field and by modelling, is an important and major exercise for the future.

The response of the continental model has also been computed in terms of magnetotelluric impedance values, which take into account the electric fields occurring at the Earth's surface. Such impedance values are presented for six particular sites, using a Mohr circle method to display their characteristics. Generally the magnetotelluric data complement the pattern shown by the Parkinson arrows. They also give extra information on the regional distortion which may be expected for data observed on the Australian continent. The character of the Mohr circles indicates that the magnetotelluric "skew" caused regionally is small at the period of 1 hour, and that generally the computed impedances are two-dimensional (2D) in character.

Such a predominantly 2D pattern for regional magnetotelluric impedances gives optimism for the interpretation of observed magnetotelluric data. Observed data for higher frequencies may be expected to be more affected by local distortion and more 3D in character; however knowledge that regional effects are 2D allows the use of decomposition techniques which are based upon local 3D effects perturbing a regional 2D pattern.

Keywords - Australia, electrical conductivity, electromagnetic induction, magnetotelluric

Characterization of Lithology using Crosshole Methods

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Abstract

A crosshole data log has been recorded in a carbonate reservoir in the Permian Basin of west Texas. This log consists of traces at 3 m depth increments recorded from horizontally propagating waves between two wells spaced 304 m apart in a carbonate reservoir. Even at this long offset the recorded data contain frequencies up to the cutoff frequency of 3000 Hz. Using first arrival times, Vp, Vs, Vp/Vs, and Ap/As calculations were made. Vp and Vs values plotted on a "Pickett diagram" indicate a limestone or dolomite lithology. A plot of Vp/Vs and porosity from the receiver well shows an inverse correlation indicating that crosshole Vp/Vs has the potential for high resolution of lithological parameters. Amplitude (Ap/As) calculations from the crosshole log show two distinct zones. The zone of higher Ap/As values has been interpreted as a fluid-filled region.

Q values have been calculated from a set of high frequency crosshole data recorded in a shallow clastic sequence in an oil field in south Texas. A piezoelectric bender and a single hydrophone receiver were used to record data over a depth interval from 152 m to 180 m in 3 m increments. Data were recorded from three in-line wells giving well offsets of 15 m and 61 m. The spectral ratio method was used to make Q calculations. Q averaged over frequency at the various depths ranges from 43 to 128. A comparison of Q with a resistivity log from the source well shows an inverse correlation. The two high Q regions have been interpreted as shaly zones and the lower Q zones as less shaly or sandy layers.

Keywords - crosshole, Vp/Vs, Q, reservoir characterization, lithology indication

Conductance-Depth Imaging of Airborne TEM Data

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Abstract

Recently a number of conductivity-depth imaging techniques have been developed for processing transient EM data. These techniques require the magnetic field data due to a step current source. However, current commercial airborne TEM systems employ a half-sine pulse source. To apply the conductivity-depth imaging techniques to airborne data, deconvolution is needed to transform the data into the required step function response. This deconvolution may be unstable with noise in the data. Furthermore, in areas of conductive overburden, the system response is mainly a function of the conductance of the overburden. The conductivity and thickness of the overburden can not be resolved uniquely. The system response may also be so high that "halfspace apparent conductivity" is undefined or the conductivity image has to be unphysically extended above the earth surface to fit the data.

To overcome the above problems, a conductance-depth imaging method is introduced. The method is based on the horizontal thin-sheet model which has a simple analytical solution. By fitting the data measured at two adjacent time channels, the conductance and the depth of a thin sheet are found using the iterative least-squares method. Transient electromagnetic profile data can then be presented as a conductance-depth section for preliminary interpretation. The technique has been tested and found to be robust on model and field data. An example of processing field data is used to demonstrate the capabilities of the conductance-depth imaging technique in minerals exploration.

Keywords - airborne, transient electromagnetic, conductance-depth imaging, conductivity-depth imaging

Increased Resolution of Processed Satellite Altimeter Data: The Development of a Quality Global Gravity Database

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Abstract

Global coverage of satellite altimeter missions have been steadily increasing with the advent of new missions. In particular, the Geosat mission has provided the greatest advance, both because of the close track spacings of the Geodetic Mission and the 68 fold redundancy of tracks from the Exact Repeat Mission.

It is this redundancy which allows "stacking" of the track data to yield a superior horizontal resolution and accuracy. Processing of the repeat tracks must involve many considerations to yield the optimum resolution, both with respect to atmospheric and altimeter orbit considerations. Recent improvements in the binning and gridding algorithms in particular have allowed the data to be gridded into 1/20° bins, using the 10 Hz data resampled to 5 Hz. Integrated gridding of all available mission data has now allowed the compilation of a global gravity grid with an accuracy of less than 1 mGal, and a cross-track resolution of the order of 19 km north of 30°S, and 14 km south of 30°S.

Further missions, both those presently acquiring data and those planned for the future will be similarly processed using the concepts developed for the Geosat data. Continuing incorporation of these data will continue to improve the resolution of the data. Furthermore, the extremely high accuracy of these new missions will help to redefine the global geoid models, allowing the improved removal of spurious factors such as dynamic topography.

A global gravity database now exists for all oceanic areas, providing a resolution and accuracy often comparable to shipborne gravity, available at a fraction of the cost.

Keywords - satellite altimeters, gravity, Geosat

3-D Analytic Signal in the Interpretation of Total Magnetic Field Data at Low Magnetic Latitudes

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Abstract

The interpretation of magnetic field data at low magnetic latitudes is difficult because the vector nature of the magnetic field increases the complexity of anomalies from magnetic rocks. The most obvious approach to this problem is to reduce the data to the magnetic pole (RTP), where the presumably vertical magnetisation vector will simplify observed anomalies. However, RTP requires special treatment of North-South features in data observed in low magnetic latitudes due to high amplitude corrections of these features. Furthermore, RTP requires the assumption of induced magnetisation with the result that anomalies from remanently and anisotropically magnetised bodies can be severely disturbed.

The amplitude of the 3-D analytic signal of the total magnetic field produces maxima over magnetic contacts regardless of the direction of magnetisation. The absence of magnetisation direction in the shape of analytic signal anomalies is a particularly attractive characteristic for the interpretation of magnetic field data near the magnetic equator. Although the amplitude of the analytic signal is dependent on magnetisation strength and the direction of geological strike with respect to the magnetisation vector, this dependency is easier to deal with in the interpretation of analytic signal amplitude than in the original total field data or pole-reduced magnetic field. It is also straightforward to determine the depth to sources from the distance between inflection points of analytic signal anomalies.

Keywords - analytic signal, magnetic interpretation, reduction to the pole, magnetic depth

Improvements in the Resolution of Seismic Data Discovered a New Basin in the Gulf of Carpentaria

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Abstract

The Gulf of Carpentaria is a sparsely explored shallow water frontier area and was covered by very poor quality seismic data up to 1973. During 1980 to 1982, five oil companies acquired 48-fold and 24-fold seismic data which established a regional grid. The quality of those data is good above the Base Mesozoic Unconformity that forms the base of the Carpentaria Basin, but poor below it. A strong seismic event, which is associated with that unconformity, masks any reflections from deeper horizons and only horizons above it can be interpreted with confidence. The major processing problem encountered was severe multiples associated with the strong seismic event from that unconformity.

A dry hole drilled in 1984 discouraged additional exploration until 1989, when Phoenix Resources acquired several km of 60-fold seismic data in the northeastern part of the Gulf. The 1989 survey used 120 groups and 3 000 m cable while the 1980 surveys had used 96 groups and 2400 m cable. The significant features in processing of 1989 data by Phoenix were velocity analysis at 1 km intervals, compared to 5 km intervals for the 1980 data, application of multiple attenuation filter before stacking and F-K filter after stacking and migration. Seven 1980 lines were reprocessed by Phoenix in 1989, with velocity analysis at 2 km intervals, application of velocity filter and F-K demult before and after velocity analysis, before stacking, and dip filter after stacking and migration.

The 1989 seismic data and the reprocessed 1980 data show reasonably good reflections from deeper events below the Base Mesozoic Unconformity. The interpretation of the deeper events on these sections indicates the presence of a thick sedimentary sequence below the unconformity, defining a new basin. This basin has been named the Bamaga Basin and is a potential petroleum province.

Keywords - Gulf of Carpentaria, Base Mesozoic Unconformity, velocity analysis, acquisition/processing parameters, Bamaga Basin, multiple attenuation

Recycling Stacking Velocities for Better Seismic Processing

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Abstract

In processing seismic data, interpretation and quality control of the primary velocity field is one of the most laborious tasks undertaken by both the processing contractor and the client. The required level of effort is even greater in areas with poor s/n ratio and a high level of multiple contamination. In order to consistently achieve optimal stack quality, a simple automated velocity conditioning technique is used to allow for the continuous recycling of a 3-D modelled stacking velocity database into subsequent processing projects. This approach reduces time spent determining the primary velocity field and improves accuracy of the results, especially in difficult seismic areas. The modelled primary velocity field is equally suited for use in both reprocessing and new infill acquisition projects.

The velocity conditioning technique creates a horizon-consistent stacking velocity database by cross-interpolation between the interpreted seismic time and raw stacking velocity databases. The top down conditioning approach commences in the shallow part of the section where velocity determination has both far less uncertainty and increased sensitivity. Stacking velocities for the initial stratigraphic interval are converted to the interval velocity domain, midpoint time- normalised to remove compaction effects, heavily smoothed using knowledge of the spatial distribution of known lithologic variations, then reconstructed back to a new lower layer stacking velocity after inverse time-normalisation. This conditioned lower layer becomes the upper layer for the next stratigraphic interval and the process is repeated.

The final three-dimensional stacking velocity model is strictly seismic-based, horizon-consistent, tied in both the

strike and dip directions, and contains only geologically plausible interval velocities.

The horizon-consistent aspect of this technique integrates geophysical interpretation with seismic processing. A preliminary horizon interpretation for all major chronostratigraphic boundaries is available to the velocity interpreter as a set of inflection points in the supplied central function velocity curve. The velocity model also provides an accurate velocity field for process testing during the early stages of seismic processing projects. The same conditioning technique can be used to spatially check the final primary velocity field prior to committing to stack and migration.

A case history from the Timor Sea demonstrates the application of this technique. This historically difficult seismic area has used two and sometimes three passes of velocity analyses. The conditioned stacking velocity database allows the processing sequence to be reduced to a single post-demultiple/post-DMO quality control velocity analysis step for both reprocessing and new infill acquisition programs - which yields a 50% reduction in the time spent picking and generating velocity analyses and eliminates the need to produce iso-velocity plots. The results show that proper conditioning of a stacking velocity database allows velocities to be recycled for improved quality and efficiency in pre-stack seismic processing, migration, and stacking velocity assisted depth conversion techniques.

Keywords - velocity analysis, database, time-normalised, seismic processing, Timor Sea case study.

A Preliminary Interpretation of Deep Seismic Reflection and other Geophysical Data from the Darling Fault Zone, Western Australia

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Abstract

Deep seismic reflection data were recorded along a 75 km long traverse that covered some 50 km within the Yilgarn Craton and 25 km within the Perth Basin, and was recorded to 12 s two-way time (TWT). Gravity was recorded at 500 m intervals and magnetics at 100 m intervals along the same traverse. The data were processed to stack stage using a conventional land seismic processing sequence. Migration proved difficult because of the poor knowledge of the subsurface velocity distribution in the Yilgarn.

Good reflections were obtained for the full 12 s TWT. The preferred interpretation of the seismic reflection data suggests that the crust beneath the western Yilgarn Craton may be divided vertically into three structural zones:

1. (0 km to 7 km) a zone of thin-skinned compressional tectonism which probably occurred between 2650 Ma and 2500 Ma;
2. (7 km to 25 km) a zone that appears to contain several minor detachments (or shear zones) and seismic events characteristic of intruded lenses of magma;
3. (25 km to 40 km) easterly dipping continuous seismic events. Reflection events between 11 s and 12 s TWT in the east of the profile may represent the top of the Moho "reflection package", but previous work suggests that it may be slightly deeper than this. The seismic reflection data also image well the fault plane of the Phanerozoic Darling Fault.

Modelling of the gravity data suggests that the Darling Fault Zone may separate the crust (43 km thick) beneath the Yilgarn Craton from the crust (27 km thick) beneath the Darling Mobile Zone and Perth Basin. This change of crustal thickness is probably coincident with the Proto-Darling Fault, and is not related to the Phanerozoic Darling Fault that is evident on the seismic reflection data. Modelling of the magnetic data indicates numerous intrusive bodies between the surface and approximately 20 km depth. Some of these bodies exhibit strong magnetic remanence.

Keywords - Darling Fault, deep seismic reflection, Yilgarn Craton

TEMPER: A Software Package for the Interactive Interpretation of Airborne Transient Electromagnetic Data

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Abstract

BHP Research has developed a software package to assist in the interpretation of AEM surveys. The package allows interactive display and manipulation of the survey data, forward and inverse modelling and the characterisation of anomalies. The software runs on Silicon Graphics work stations and is being used by geophysicists in BHP Minerals on current exploration programmes.

Keywords - transient electromagnetic surveys, TEM, AEM computer-assisted interpretation

An Effective Combination of Geophysical Methods for Prospecting Pb-Zn Ore Bodies Located Under the Gossan in Cho Don Area (Vietnam)

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Abstract

Lead-zinc ore bodies in Cho Don area (Vietnam) are located in the Pia Phuong stratum which comprises carbonate formations interfered by sericite clay layers. The ore bodies are formed in fractures or faults developed in the carbonate formation or at the sericite-carbonate contact in the form of a pseudo-layer or intersected layer.

The upper part of the ore body, due to tropical weathering is oxygenated and transformed into limonite with a thickness of tens of metres. In that case, shallow geophysical methods are of limited use.

In order to identify and assess primary lead-zinc ore bodies in this area, the authors have used combinations of

geophysical methods: Induced polarisation, transient and high precise gravity methods.

Data collected is processed and interpreted by using modern mathematical methods which permits discrimination of the limonite mineralisation zone from surrounding rock and determine whether valuable lead-zinc ore bodies are located under the gossan at the depth of tens of metres.

The Geophysical Response of the Rocky's Reward Nickel Sulphide Deposit, Leinster, Western Australia

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Abstract

The Rocky's Reward nickel sulphide deposit is located in the Agnew-Wiluna greenstone belt, about 2 km north of the Perseverance (Agnew) nickel mine. The belt lies within the northern portion of the Eastern Goldfields Province of the Archaean Yilgarn Craton, Western Australia. Ore-grade mineralisation was discovered at Rocky's Reward in 1984 as a result of drill testing a geochemically anomalous gossan.

Geophysical surveys (airborne and ground magnetics, induced polarisation/resistivity) had been carried out over or in the vicinity of the deposit well before the discovery of mineralisation. However, even though a magnetic anomaly was clearly delineated over the Rocky's Reward deposit, the target was not selected for follow up at that stage as the surface geological expression did not fit the existing conceptual geological model.

A large amount and variety of geophysical work, including airborne and surface time-domain electromagnetics, induced polarisation/resistivity, controlled source audiomagnetotellurics, gravity and downhole surveys was subsequently completed following the discovery of mineralisation at Rocky's Reward. The object of these surveys was to map and characterise the deposit geophysically, in order to assist in the delineation of the extent and geometry of the mineralisation, and to evaluate geophysical techniques applicable to further exploration in the area.

The deposit represents an excellent target for several geophysical techniques because of its shallow depth, geometry, and physical property contrasts of the ore and its host with surrounding rocks. A combination of ground magnetics and time-domain electromagnetics proved to be the most definitive and economical for detecting and mapping the deposit.

The Seismic Reflection Process in Anisotropic Media

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Abstract

A study of the seismic reflection process in anisotropic media showed a number of results which have direct consequences in an exploration context. Using laminated blocks of an anisotropic material to simulate shale-type layering, the seismic wave propagation was observed to be dependent upon the lamination orientation and, hence, on the shale layering orientation in an exploration sense.

The seismic waves were demonstrated to travel at a faster velocity in the direction parallel to the layering orientation. Stacks of conventionally recorded seismic lines parallel and across the layering resulted in a two-way travel time mis-tie at their tie-point. Time to depth conversion indicated that a severe depth mis-tie would occur. The implication for exploration is that mis-ties in 2-D land and marine data may indicate the presence of anisotropy, while 3-D land and marine data do not. 2-D recording is therefore a necessary requirement to indicate the presence of anisotropy prior to 3-D recording.

Numerical modelling of equivalent seismic data showed that commercially available numerical modelling software is inadequate for modelling the effects of anisotropy.

Keywords - anisotropic, mis-tie, modelling.

Seismic Interface Modelling: A Physical Approach to Zoeppritz Theory

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Abstract

The analysis of a seismic wave impinging on an interface and the resulting distribution of various seismic waves is intrinsically related to amplitude variations with offset (AVO). This analysis is explained numerically by Zoeppritz Theory which governs the seismic wave partitioning at an interface. The application of physical modelling to understanding the Zoeppritz equations emphasizes the acquisition and processing considerations required for optimum AVO interpretation. The extraction of the true reflection coefficient for a seismic interface is not a simple procedure, due to a variety of factors affecting amplitudes.

Physical modelling suggests that P-wave AVO studies are non- unique, since a similar signature can be obtained from different input parameters. SH-wave AVO data are consider ably more definitive due to a controlled knowledge of directivity patterns, enhancing the opinion that shear-wave data can be a more useful tool in exploration seismology than is currently perceived. Zoeppritz equations of reflected and refracted energy partitioning in a physical model are generally stable until the incident angle approaches the critical angle (28o). Beyond this point, the equations do not hold due to rapid variations in reflected and transmitted P- and S-wave amplitude data. Similarly, at far offsets where shear-wave mode conversion predominates, amplitude measurements become increasingly unreliable.

Keywords - energy partitioning, modelling, wavefield, Zoeppritz

3-D Visualisation of Transpressional Structures in the Eastern Otway Basin

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Abstract

The application of new technology and concepts to exploration in the eastern offshore area of the Otway Basin has recently resulted in two gas/condensate discoveries. Exploration for hydrocarbons in BHP Petroleum's permits VIC/P30 and VIC/P31 began in 1991. Geotechnical studies conducted by BHPP during the gazettal phase of the VIC/P31 acreage indicated the presence of a previously unrecognised compressional structural setting. A 2-D seismic grid was shot over this area which confirmed these concerns. The area displays extreme structural complexity, due to a history of reactivation closely linked to localised episodic compression and regional extension.

The "Eric The Red" anticlinal structure is a product of these forces and was drilled unsuccessfully for hydrocarbons in early 1993. Accurately resolving the complex three-dimensional structural problem in the Eric The Red area with 2-D seismic data on Landmark presented major difficulties. In the ideal case, the most structurally plausible model would be generated with a three dimensional interpretation of the 2-D seismic. Through BHP Research, state-of-the-art 3-D computer visualisation technology was employed to assist in interpretation. Visualisation of 2-D seismic data in 3-D is not known to have been previously attempted with this technology.

Mapped time surfaces and fault planes from the original Landmark/Zycor interpretation were sliced through the 3-D volume as part of the visualisation exercise. The "VoxelGeo" software utilised has the added capability of rendering the data volume transparent up to a specified amplitude threshold. This enabled detailed examination of zones and surfaces of interest.

The 3-D visualisation concept is currently at the forefront of developments in computer-based geophysical interpretation. In addition to seismic amplitude data other attributes, such as phase, instantaneous frequency and velocity, are available for the 3-D imaging of seismic data.

Keywords - Otway Basin, Eric The Red, 3-D visualisation, 2-D seismic data.

A Multi-Method Approach to the Geophysical Assessment of 500km of Alluvial Sediments Associated with the Daring River: Menindee to Brewarrina, Western New South Wales

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Abstract

Geophysical surveys were carried out during the period between 1991 and 1993 along lines crossing the Darling River. These surveys were carried out at Menindee, Wilcannia, Bellsgove, Tilpa, Louth, Yanda Crreek, Bourke and Brewarrina, western New South Wales, Australia.

Methods were: DC resistivity (Schlumberger), transient electromagnetics (TEM), fixed frequency electromagnetics (FEM), seismic refraction and borehole logging. In addition, 54 km of airborne EM flown along the Wilcannia line by Austirex International Ltd has been integrated into this study.

The preliminary interpretation of these data indicated that:

- the alluvium associated with the Darling River is generally less than 50m thick although thickness up to 160m have been detected in geological troughs.
- the groundwater associated with the alluvium along this reach of the Darling River is essentially saline often in excess of 40 000mg/L TDS; and
- a fresh waster lens centred on the Darling River Channel up to 4 km wide and 15m thick has been developed by recharge from high flow and overbank flows associated with the Darling River.

The study examines the applicability of each geophysical method, and demonstrates the multi-method approach essential for meaningful interpretation in the context of shallow, regional groundwater exploration.

Spatial Resolution and Amplitude Studies in Anisotropic Seismic Reflection: A Physical Modelling Study

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Abstract

Physical seismic modelling experiments have been conducted to analyse the effects of anisotropy on spatial resolution and amplitudes of reflectors of varying sizes using phenolite and plexiglass materials which simulate anisotropic and isotropic media respectively. Cylindrical holes of progressively increasing sizes were drilled into the bottom centres of both models. The hole sizes were varied from 0.19 to 1.33 and from 0.35 to 2.10 times the expected Fresnel-zone diameters in phenolite and plexiglass respectively. These holes, while serving as reflectors, also simulate a range of geological features, e.g. pinnacle reefs, intrusions, seals, and pipes, etc.

The spatial extents of the reflector boundaries are estimated by marking the half-amplitude points of the horizontal reflector events with respect to the amplitude at the centre of the reflectors. The degree of horizontal resolution is determined by comparing the seismically estimated reflector dimension with the true spatial dimension of the reflector.

The resolving potentials of pressure and shear body waves in anisotropic and isotropic media were compared using the collected data. Results obtained so far indicate that the presence of anisotropy would significantly affect the spatial resolving powers of body waves. Hence spatial resolution in an anisotropic medium would be quite different from that determined for the same medium if it is assumed isotropic. Consequently, the spatial resolution of seismic events from the base of thick shale sediments is most likely to be affected.

Keywords - resolution, reflector extent, Fresnel zone, anisotropy, modelling, seismic

Tertiary Channelling in the Duntroon Basin, Australia - Significance for Hydrocarbon Trap Styles and Plays

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Abstract

Consecutive major Tertiary channelling episodes localised at a major offset in the Duntroon Basin have generated large erosional structures sealed by thick transgressive marls. The controls on the trap development are the sequence of channelling events, and the nature of the channel fill as it relates to seal risk of the structures. These erosional structures, draped by sands and capping marls, offer excellent hydrocarbon trapping potential.

Keywords - Tertiary, channelling, petroleum prospectivity, Duntroon Basin, sequence stratigraphy.

The Impact of Streamer Position on 3D Data Quality

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Abstract

Considerable expense is incurred in locating the seismic vessel and the trailing equipment, particularly the streamers, during the acquisition of 3D seismic data. How important is accurate position data?

BHP Petroleum has acquired a 3D seismic survey and has independently processed the data with two separate navigation datasets, original and corrected. The two navigation datasets provided different streamer positions. At the far traces this difference was up to 95m, at the near traces the difference was about 5m. The majority of the difference was in the crossline direction.

The only difference in the processing of the two datasets was the navigation input. Velocity data was identical as the velocity analysis was performed on 2D lines before the navigation data was merged with the seismic data. The 3D binning was effectively the only variable.

The difference between the two data sets was analysed by

1. subtracting the original 3D data volume from the corrected volume and analysing the amplitude spectra of each data volume and
2. analysing the time and amplitude variations along the identical horizons interpreted in each of the two data sets.

The analysis revealed that the processing that used the corrected navigation had a higher overall amplitude than that using the original navigation data. Horizon amplitude extraction also revealed that the corrected dataset had higher amplitudes than the original dataset. Time differences were also observed at two interpreted horizons. It is not possible to determine which is the best representation of the true time field only that there is a difference.

In conclusion it can be stated that the position of the streamer has a significant effect on the data quality of the final data set. In particular the incorrect binning of the data has an effect on the amplitude of the data and on the time of the data.

Detailed Ground Radiometric and Magnetic Surveys of the Leviathan and South Venus Gold Prospects, Western Australia

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Abstract

In Western Australia, exploration for low-grade gold mineralisation is hindered by the presence of a deep mantle of weathering. Application of geophysical techniques at two prospects, South Venus and Leviathan, shows that ground magnetic surveys are useful for lithological mapping and structural interpretation, and potassium alteration associated with gold mineralisation can be mapped directly using radiometric surveys. Radiometric measurements indicate that potassium signals of up to 5%eK are associated with wallrock alteration adjacent to gold mineralisation, whereas the potassium signal from the main mineralised zone is close to 0%eK. Potassium signals associated with alteration are generally two to five times the width of the gold mineralised zone. Comparison of surface and drillhole radiometric sampling indicates that weathering does not seriously effect surface radiometric surveys except where transported soils cover the residual weathered profile.

High Resolution Marine and Airborne Gravity by Digital Control

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Abstract

The first real-time fully digital control and data acquisition system for the LaCoste and Romberg air/sea gravity meter was tested on a ship in the Gulf of Mexico in January 1992 and in the air in the fall of 1992 and the spring of 1993. During the course of marine operations, sea conditions varied from two to eight feet. The LaCoste and Romberg meter controlled by the all digital system clearly out performed the analog and partially digital systems. The average absolute (without regard for sign) error for the measurements over the salt dome and its caprock is 0.10mGal for the surface-ship observations. At this writing the airborne results are still being reduced but the indications are that the airborne error is less than 2.0 mGal over 10km, possibly as low a 1.0 mGal.

Both sea and air tests involved improved GPS positioning data, resulting in improved Eotvos and vertical acceleration corrections. This error source is significantly reduced by both differential and kinematic GPS and STARFIX positioning data. The new gravity system is considered fully digital because it digitizes directly the signals from the gravity sensor and inertial platform 200 times each second. The sampled data are processed by an Intel 386-based computer which updates the platform feedback loops 200 times a second. The computer also calculates the necessary cross-coupling monitors, filters the data appropriately and archives the data to a hard disk. The all digital system permits the parameters which control the system to be calibrated more precisely than with previous analog techniques.

A Bell Aerospace BGM-3, upgraded for airborne work, was also used in both sea and air tests, with essentially comparable results.

New Developments in Aeromagnetic Techniques for Oil Exploration

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Abstract

Aeromagnetic surveying has traditionally played an important role in reconnaissance exploration for hydrocarbons, principally as a basin mapping tool. Lately micromagnetic effects, generated at shallow depths by migrating gases or fluids above hydrocarbon accumulations have been targeted with aeromagnetic surveys.

The recent utilisation of GPS satellite navigation or similarly precise radio positioning, together with very low noise acquisition systems and recently developed image and data processing techniques, have increased the potential role played by aeromagnetics. High resolution surveys flown at line spacings of 500-2000 metres, 80-200 metes mean terrain clearance and with aircraft manoeuvre noise levels of less than 0.3nT (0.3 gammas), provide data sets that can map structures within the sedimentary section. The improved survey parameters allow basin mapping and detection of micromagnetic effects to be carried out with greater precision.

Image processing of magnetic data is an essential step for the identification and mapping of sedimentary structures, since the magnetic effects being sought are often the order of 1nT or less. Linear or curvilinear features within enhanced images of the magnetic data can be identified as structures on the basis of correlation with other data sets, in some cases seismic. The wavelengths involved in these linear or curvilinear features indicate sources within the sedimentary section.

Where detailed comparison with seismic has been carried out, structures mapped within the sedimentary section from the magnetics can be correlated with those mapped by seismic, although not every structure mapped on the seismic can be traced on the magnetics.

The magnetic expression of the structure varies both from basin to basin and within basins. In some cases it is consistent with juxtaposition by faulting of differently magnetised beds. In others the structure corresponds to a zone where magnetic minerals have have been uniformly destroyed or created, presumably by circulating fluids. A third response type, a narrow linear zone of chaotic magnetic response, has been observed to correspond with structure.

Depth slicing techniques where the magnetic response of geology from different depth intervals within the earth are isolated are showing great promise. Inherent limitations of the potential field technique severely restrict the precision and sharpness of the depth intervals that can be windowed, relative to the seismic technique. However, useful insights into rock type and structures within the basement and sedimentary section are gained by generating depth slice maps and subsequent downward continuation of the fields to sharpen subtle responses.

High resolution, low noise aeromagnetic surveys have demonstrated the capability to map structures within the sediments, enabling direct integration of seismic and magnetic interpretations. Modern aeromagnetic data complements both seismic survey planning, through knowledgeable placement of seismic lines, and seismic interpretation where the uniform and typically tight line spacing of aeromagnetic data allows structures to be interpolated between seismic lines.

These features have been observed in all sedimentary basins surveyed with high resolution, low noise, low altitude surveys over the past several years including the North Slope of Alaska, the West Permian Basin of Texas, The Papuan Basin of Papua New Guinea, The Vulcan Graben NW shelf of Australia and the eastern Celtic Sea Basin, UK.

An Interpretation of the Aeromagnetic map of South Australia

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Poster Session Abstract

Small-scale magnetic maps and images of South Australia provide the most direct in depth picture of the regional geology of the state. These maps are based on a recompilation of old data and will be updated to include data from surveys currently being flown.

From the preliminary maps a coherent picture of the regional geology has been derived. All large sedimentary basins are clearly delineated on the map. In addition major features (lineaments, faults, folds, dyke swarms) which are part of the overall tectonic framework of the state within the basement underlying the sediments have been recognised.

In the western parts of the state much of the basement rock in the Gawler Craton is obscured by a blanket of sands and recent sediments. An immense amount of geological information. e.g. variation in basement lithology, regional structures, etc., has been extracted from magnetic maps. this should prove useful in mineral exploration and in the preparation of a more complete geological map of the region.

Three different kinds of interpretation maps have been produced: a map indicating the different magnetic-geological terrains and major tectonic features, a map of near-surface sources which is equivalent to a geological map, and a map providing information about deeper crustal structures.

Geophysical Investigations of Volcanic Terrains: A Case History from the Gawler Range Volcanic Province, South Australia

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Abstract

Flat-lying magnetic cover rocks, especially when they comprise thick volcanic sequences, present a difficult interpretation problem. Magnetic maps of such regions essentially reflect the exposed volcanic rocks and sources within and beneath the volcanic rocks cannot be easily resolved. Yet such areas are often of economic interest.

The Gawler Range Volcanic Province in South Australia represents an example of one such volcanic terrain. The Volcanics are distinctly bimodal in composition: the 'older' units are mafic and the 'younger' units dominantly felsic, with few rocks of intermediate composition. The exposed Volcanics cover approximately 25 000 km^2 and drill-hole intersections

confirm their existence well beyond the present limits. Magnetite is present in both mafic and felsic volcanic rocks. The province has been identified as a target area for possible epithermal gold mineralisation and volcanogenic-hosted base metal mineralisation.

Regional gravity and aeromagnetic data are available over the whole province, while part is covered by a recent high-resolution aeromagnetic and aeroradiometric survey. The Gawler Range Volcanic Province is associated with a large gravity high caused probably by mantle underplating or the emplacement of mantle derivatives prior to the extrusion of the volcanics. This is consistent with isotope data which were previously interpreted to indicate a mantle component for the Volcanics. Two major gravity trends (NE and ESE) intersect within the study area. The ESE-striking trend has been modelled as a deep crustal fault with the southern block down- faulted. These two trends are also reflected in the high-resolution magnetic maps once the high frequencies have been removed from the data.

Initial images of the high-resolution aeroradiometric and aeromagnetic data correlated very closely with the outcrop and joint patterns. Areas of radiating fracture patterns may represent volcanic centres. The image of the K:U Ratio reflected minor variations in the otherwise homogeneous geochemistry of the Volcanics.

Through image processing and filtering, and combining the interpretation of available geophysical data, an inferred geological map for the area has been suggested. The igneous province is interpreted as extending further eastwards beneath part of the Stuart Shelf consisting of three well-defined units. The first corresponds to the main Gawler Range Volcanic Province, the second to the south-west gabbroic extension and the third to an eastward extension consisting of a felsic core circled by a mafic ring.

Keywords - Gawler Range Volcanics, aeromagnetic, aeroradiometric, magnetic cover rocks.

A Comparison of Regional/Residual Separation Techniques for Gravity Surveys

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Abstract

Tasmania lies on a triangular extension of the Australian continental crust, surrounded on two sides by deep ocean basins. Strong regional effects from these features obscure much of the short wavelength character in the observed gravity data. Interpretation of the data requires reliable separation of the residual and regional components of the gravity field.

Bouguer gravity data covering onshore and offshore Tasmania have been used to test a variety of methods of regional /residual separation, including trend surfaces, filtering, upward continuation and forward modelling.

Forward modelling was used to calculate a regional field from a three-dimensional model for Tasmania consisting of continental crust, oceanic crust, water and the mantle. The main advantage of modelling is that it enables the incorporation of geological and geophysical constraints into the regional field. Automated separation techniques are simple, fast and purely numerical but do not allow the incorporation of geological constraints. Quantitative interpretation of the resultant residual maps is difficult and uncertain. All automated methods tested produce undefined dc shifts which limit the usefulness of the residuals. Of the automated methods, trend surfaces produce residual maps which show the best correlation with known geology.

The preferred method of regional/residual separation is forward modelling, although it is both time consuming and subjective. Quantitative interpretation of residuals from modelling can be carried out with a greater degree of confidence since the regional field has a well-defined geological basis.

Geophysical Signature of the Kintyre Uranium Deposit, Western Australia

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Abstract

Kintyre is an unconformity-related, vein-style uranium deposit estimated to contain 36,000 t of U3O8. The deposit, located 70 km south of Telfer, was discovered during heli-borne follow-up of 214Bi channel anomalies detected by an airborne magnetic and radiometric survey. Ground inspection of the strongest anomaly identified outcropping secondary uranium-silicate mineralisation. Drilling beneath the mineralised outcrop intersected the Kintyre ore lens, with the best hole containing 71 m at 5.94 kg/t U3O8. Since then, six additional ore lenses have been discovered and these make up the Kintyre deposit.

A wide range of airborne, ground and borehole geophysical techniques has been applied to the evaluation of the deposit in an attempt to locate additional ore lenses and to determine a geophysical signature for use in regional exploration. Two types of geophysical signature have been determined for the deposit; that of the mineralised zones and that of the host unit.

The deposit has an anomalous ^{214}Bi channel radiometric response coupled with elevated counts in the potassium channel. Induced polarisation surveys have shown that a distinct, high apparent resistivity and high chargeability response coincides with the Kintyre mineralisation.

The ore is hosted by a lithological package which contains variable amounts of magnetite, leading to a moderate- to high-amplitude, inhomogeneous magnetic response. A density contrast detectable by gravity surveying has been noted between the host sequence and surrounding rocks. Electrical surveys have shown that the host unit is resistive relative to the rest of the host sequence and other rocks in the area.

The ore is hosted by a lithological package which contains variable amounts of magnetite, leading to a moderate- to high-amplitude, inhomogeneous magnetic response. A density contrast detectable by gravity surveying has been noted between the host sequence and surrounding rocks. Electrical surveys have shown that the host unit is resistive relative to the rest of the host sequence and other rocks in the area.

The Role of New Technology in Seismic Exploration

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Keynote Address Abstract

There have been two major technological revolutions in the geophysical business. The first one occurred from the late 1950s to early 1960s and involved moving from analog to digital recording and processing, from single-fold to multi-fold recording, and from field analysis to large dedicated processing centres. The second revolution is occurring right now, and is seeing us more from 2-D to 3-D data, from acoustic to elastic earth assumptions, and from mainframe to individual workstation technology. This last step has opened up the possibility of fully interactive processing and interpretation.

This talk will focus on the new hardware and software that is changing our approach to seismic exploration so dramatically, and how we can use this software in a productive way.

First of all, consider the objectives of seismic exploration. In a broad sense, the main objective has always been to determine the geology of the earth's near surface from seismic measurements. However, this is too general a definition and can be further subdivided into the determination of:

(1) earth structure;

(2) earth stratigraphy;

(3) large scale rock properties; and

(4) detailed rock properties.

The above list tracks the evolution of the seismic business. That is, pre-1960 seismic exploration involved determining only earth structure. In the 1970s, seismic stratigraphy was developed, and techniques such as bright-spot analysis were introduced. In the 1980s, methods such as post-stack inversion were developed to determine large scale seismic lithologic properties. We are now attempting to determine detailed rock properties from seismic measurements, using techniques such as AVO, multi-component analysis, and so on.

In the light of these new techniques, the geophysicist's task has become even more complex. Harnessing the new technology will involve the following steps:

1) providing each explorationist with adequate access to the necessary hardware;

2) developing an effective database management system which integrates such diverse datasets as 3-D seismic data, well logs, topographic maps, etc.;

3) determining which software packages are best suited to a particular area, and making sure that these software packages communicate with each other; and

4) educating each explorationist on the key aspects of the hardware and software technology, allowing predictions based on a synthesis of the data using the above analysis techniques.

While all of these points seem straightforward, there are a number of pitfalls that can occur. For example, it is almost as damaging to buy too much hardware and software too quickly, as it is not to purchase enough. A more sensible approach is to build up gradually with a long-range goal in mind.

It is also easy to fall into the trap of thinking that buying the technology is enough. The most important resource in any company is still the personnel running the hardware and software. A progressive training schedule is essential allowing each individual to utilize the new technology in a productive way.

Finally, it is important to be able to walk the tightrope between too much belief in the new technology and total rejection of it. That is, we must develop a healthy skepticism about our results, but still be able to trust them within their limits.

There is no doubt that we are at the threshold of a new area of sophistication in seismic exploration. It is important that we take full advantage of this opportunity, and learn to control the new technology, rather than let it control us.

Geophysical Investigations of The Kalgoorlie Goldfield, Western Australia

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Abstract

Leases held by Kalgoorlie Consolidated Gold Mines Pty Ltd over the Kalgoorlie Goldfield have an approximate area of 25 by 10 km, with the main production areas of Fimiston, Mount Charlotte and Mount Percy within the central portion of this tenement block. Due to the proximity of the leases to residential areas, significant portions of land are inaccessible for exploration. Near-surface contamination, as a result of historical mining and prospecting, also presents problems, as do the deep weathering profile and associated conductive overburden, which covers most of the Kalgoorlie Goldfield.

Due to the relatively small size of the lease holdings and the constraints detailed above, the currently employed geophysical techniques mainly involve detailed ground surveys and include petrophysical studies of the three principal styles of mineralisation and the surrounding host rocks. The aims of the surveys are improved definition of geological features, and indirect detection of the three principal styles of mineralisation recognised at Fimiston (Golden Mile), Mount Charlotte and Mount Percy.

The petrophysical data indicate that gravity, magnetics and induced polarisation can be used for the delineation of rock types whereas induced polarisation has potential to identify mineralisation. The combination of gravity and ground magnetic surveys at a prospect scale permits considerable refinement of the structural and lithological features in areas of poor outcrop. Studies are ongoing evaluating the potential use of downhole induced polarization for detection of Mount Charlotte-style stock work mineralisation, and the use of ground penetrating radar to detect voids for underground mining.

A Review of Shallow Seismic and Gravimetric Exploration of Brown Coal

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Poster Session Abstract

Brown coal was the main resource of primary energy in East Germany for many years. The production of more than 300 million tonnes a year implemented besides the geological exploration a great volume of geophysical activities. Within these exploration activities shallow seismic and gravimetric surveys play a major roll.

Starting 20 years ago the following problems have been solved:

- outlining of seam boundaries,
- imaging of several seams and of hard rock basement below,
- mapping of Pleistocene erosion channels,
- tracing of faults in the seam and in the hard rock basement.

The drastic decline of brown coal production during the last years required the change of shallow seismic activities to operation in the immediate pre-production sphere covering depths between 5 and 200m. Partly the surveys are carried out on several stripping planes within the open pit.

These results are requested in a very short time after finishing field work in order to be interpreted together with drilling results and data of other geophyiscal measurements executed in the forefield of the open pit. The involvement of these results in the production planning facilitates a more economical and safe mining.

Depending on the actual tasks and seismogeological conditions several shallow seismic techniques were developed which will be presented in this paper together with gravimetric results.

Enhancement of Different Types of Airborne Geophysical Data Acquired in Difficult Terrains

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Abstract

Airborne Geophysical surveys are routinely employed for exploration in a wide range of geologic and geographical environments. Not all areas are ideally suited to airborne geophysical surveying due to a variety of factors related to the nature of the survey area and the methodology employed. One factor that is inherent in any airborne geophysical survey is the effect of variations in survey terrain clearance. This is important, because such variations can introduce significant distortions into the geophysical data and, in fact, these effects are observed in many airborne geophysical datasets. Although airborne geophysical surveying is often more difficult in areas characterised by significant or rugged topography, airborne methods are commonly used for exploration of such areas due to the difficulties (and therefore high cost) of covering rugged areas with ground-borne techniques. This accentuates the need for techniques designed to reduce any degradation introduced by rugged topography and variations in the aircraft/sensor terrain clearance.

Although certain assumptions need to be made, terrain correction procedures can be successfully performed on airborne magnetic, radiometric and electromagnetic data. Examples taken from recent helicopter magnetic/radiometric surveys, fixed wing magnetic/radiometric surveys and GEOTEM electromagnetic surveys, demonstrate the utility of such procedures, as well as highlighting some of the areas of concern. The procedures involved have been expedited to a large degree by the recording of accurate GPS information, including the absolute altitude of the aircraft. This alleviates the dependence on the recorded barometric altitude, which is less accurate and prone to drift. The use of barometric altitude data also necessitated rigorous instrument calibration procedures during the survey and a certain amount of data processing before the data could be properly used.

The end result of procedures such as corrections for aircraft terrain clearance and terrain correction algorithms is a cleaner picture of the true geophysical response. The reduced correlation between the geophysical data and the terrain is particularly evident when the data is further enhanced or analysed in detail using image processing techniques.

Role of Geophysics in Exploration for MVT Lead-zinc Deposits on the Lennard Shelf, Western Australia

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Abstract

The exploration strategy in the search for Mississippi Valley-type mineralisation on the Lennard Shelf has been modelled on the approach commonly used in exploration for similar mineralisation in North America. Regional areas of interest are defined using a combination of geology, geochemistry and geophysics, then systematically grid drilled. Several Mississippi Valley-type lead-zinc deposits have been discovered on the Lennard Shelf through the application of this strategy.

Mississippi Valley-type lead-zinc deposits are difficult geophysical targets. Their geophysical characteristics have been studied on the Lennard Shelf to provide a guide for more cost-effective exploration both on the Lennard Shelf and elsewhere. On a regional scale, gravity and aeromagnetic surveys, used in conjunction with geochemistry, effectively focus exploration into favourable structural and lithological settings. Detailed gravity and seismic surveys delineate areas of the host carbonates in regions of shallow cover.

Several known Mississippi Valley-type deposits and prospects on the Lennard Shelf are associated with extensive marcasite haloes and associated induced polarisation anomalies. In areas of shallow cover, the induced polarisation method can be used to cost effectively define prospective areas by mapping mineralised systems on a semi-regional scale. These areas can then be tested using grid drilling.

Geophysical Characteristics of the Telfer Gold Deposits, Western Australia

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Abstract

The Telfer gold deposits are hosted by Middle Proterozoic marine sedimentary rocks of the northeastern Paterson Orogen. They occur within two en echelon, asymmetric, doubly plunging anticlines, with ore being extracted from reefs and stockworks.

Regional magnetic and gravity surveys have been undertaken to assist in mapping stratigraphy, intrusions and structures in the Telfer district. These surveys indicate the presence of intrusions close to the Telfer gold deposits, which is regarded as supporting a genetic relationship between granitoids and mineralisation. The Telfer mineralisation itself has no gravity or magnetic signature.

The narrowness of the reefs, deep oxidation and the presence of shallow, thin, electrically resistive beds make the Telfer gold deposits a difficult geophysical target. Direct current resistivity techniques were used to assist mapping of the quartz reefs. Surface and downhole electromagnetic pulse surveys undertaken at Main Dome after overburden stripping detected subtle responses coincident with the Middle Vale Reef.

The Application of Geophysics over the Mount York Gold Deposit, Western Australia

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2. M.I.M. Exploration Pty Ltd, 140 Colin Street, West Perth, W.A. 6005

Abstract

A resource of about 1 Mt of gold at 2.7 g/t has been delineated at Mount York, 120 km SSE of Port Hedland in the Pilbara Region of Western Australia. The deposit is contained within a banded iron-formation.

In order to supplement ongoing geological investigations to define the resource, a geophysical programme was undertaken to assist mapping and also delineate primary sulphide zones which could have associated gold mineralisation. Aeromagnetic, spectral induced polarisation, surface and downhole electromagnetic surveys, and downhole density logging were undertaken.

The magnetic data clearly outlined the lateral extent of the banded iron-formation but were unable to delineate subtle structure which was thought to control primary mineralisation. Induced polarisation and electromagnetic surveying provided numerous targets in both the primary and oxidised zones. Drill testing of these primary-zone targets intersected sulphide mineralisation but, unfortunately, no gold mineralisation of economic width and grade. Downhole density logging of the secondary oxide zone allowed the density of the mineralisation to be better defined and hence provided a sound base for resource calculations.

Re-examining Resolution for Reservoir Studies

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University of Houston, USA

Keynote Address Abstract

Resolution, "the ability to separate two features which are very close together", is often confused with detectability, the ability to know that more than one feature is present. The ability to detect features depends on factors such as the magnitude and character of the background noise and subjective aspects. Details of features which otherwise go unrecognised may be found if we know what to look for, that is, if we have a model. With an appropriate model and good signal/noise we can distinguish features beyond conventional resolution limits.

Resolution discussions usually seek vertical or horizontal limits. The vertical resolution limit is often stated as a quarter-wavelength ($\lambda/4$) thickness, beds with less thickness being "thin-beds" and those with greater thicknesses "thick-beds". The thickness of reservoirs spans both cases. A number of authors have interpreted reliably will below the $\lambda/4$ criterion where the interpretation model was appropriate, in some instances reaching the sampling limit. The sampling theorem is also involved in horizontal resolution, as in the ability to detect channel reservoirs on horizon slices.

Deconvolution to remove wavelet spreading along the time axis and migration to remove spreading effects in horizontal directions improves resolution. Since both vertical and horizontal resolution depend on the seismic wavelength, they are related, but horizontal resolution is also a function of depth. Migration largely replaces the direct depth dependence by one on migration aperture. The minimum horizontally resolvable distance exceeds the minimum vertically resolvable distance by the inverse of the sine of the migration aperture. A practical limit for a 30° aperture angle makes the horizontal resolution half the vertical resolution.

AUTOMAG - An Automatic Method to Estimate Thickness of Overburden from Aeromagnetic Profiles

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Abstract

AUTOMAG is a computer program developed from the Naudy technique to provide an estimation of the depth to magnetic basement below superficial cover; it uses high quality low level aeromagnetic profiles which are now widely available in Australia. The data can be processed using a Sun Sparc work-station and a VAX computer. In this study the method provided depth information in areas where the thickness of overburden was 100 m or less. The technique is equally applicable to much greater depths.

The depths to the basement estimated using AUTOMAG show good correlation with depths established by drilling.

Keywords - automatic depth estimation, aeromagnetic surveys, mineral exploration, overburden, South Australia airborne electromagnetics

Airborne Electromagnetic Surveys of the Regolith

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Abstract

Secondary salinity of once productive agricultural land is a widespread problem throughout the southern agricultural areas of Australia. Previous studies in Western Australia have shown that airborne electromagnetic surveys can assist in defining the location of high salt storage within the regolith by measurement of conductance of the near surface layers. A survey from the Eyre Peninsula in South Australia shows that this concept can be extended to other areas prone to salinity. Elevation data acquired in this area demonstrates that topography reveals the drainage pattern which has the overriding control on the salt storage. The geology, as indicated by aeromagnetics, shows structures within the geological basement that influence the salt storage pattern. It is believed that this relationship is similar to that seen in previous surveys in Western Australia, where the weathering of dolerites to a clay formed barriers of lower hydraulic conductivity within the regolith.

Keywords - airborne EM, salinity, regolith, magnetics.

Geophysical surveys of Leaking Tailings Impoundments

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Abstract

Alcoa of Australia's bauxite treatment plant at Kwinana discharges alkaline liquor to impoundments constructed on Quaternary formations of the Perth Basin. Contaminated groundwater has been detected outside some of these impoundments. The impoundments are constructed with an impermeable basal clay layer overlain by a permeable, thin sand blanket. Wet tailings slurry is poured in, the fine residue fraction is dried and stacked higher than the dyke walls allowing access of tracked vehicles and geophysical equipment to the impoundments. Leakage is initially detected from monitoring bores placed outside the impoundments. Approximate leak locations can then be detected from water level lows in piezometers placed within the semi-confined aquifer of the sand blanket.

The mise-a-la-masse technique uses current electrodes placed within the impoundment and within conductive, leaking water at some distance away. A current pathway is provided between the impoundment and the conductive groundwater via the leakage zone and this can be mapped as voltage highs using potential electrodes within piezometer holes near the base of the impoundment. In some cases the detection of these leakage points is complicated, but not impossible, by multiple leaks, PVC liners placed above the basal clay layer and the strongly varying conductivity within the impoundment. The mise-a-la-masse anomalies only give leak location with differences in intensity between anomalies not being diagnostic of leak properties.

Keywords - groundwater pollution, mise-a-la-masse, tailing impoundments

Bringing Geophysics into the Mine: Radio Attenuation Imaging and Mine Geology

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Abstract

Recent work using radio wave frequencies to define ore shape between boreholes shows promise for changing the way mine geologists evaluate a deposit.

Traditionally, orebody evaluation at an advanced exploration site or a mine involves three distinct tiers of information, exploration drilling (200 m borehole separation), follow-up drilling (40 m to 100 m separation), and in-fill drilling (20 m). The inexact nature of ore definition at the follow-up and in-fill stages inevitably results in poor mine design or dilution. This has been shown to have a significant cost to any operation. The clear incentive is to improve evaluation techniques by using high resolution sensing methods between physical intersections.

A new geophysical technique using comparative radio wave attentuation values from cross-borehole measurements and advanced tomographic imaging procedures has been applied at a number of mine sites in Australia. Radio wave attentuation is a function of the host medium conductivity. Conductive ore will attenuate the signal more than resistive host rock. These variations in signal attenuation may be expressed in the form of a tomographic image for analysis.

This paper evaluates results from controlled experimentation at the Broken Hill and Osborne deposits and reviews the likely future role for radio imaging at metalliferous mine sites.

It is suggested that the clear role for radio scanning is particularly in the follow-up stage of drilling (40 m to 100 m). The integration of the images into mine planning packages, as an input to geostatistics and as a visualisation aid for mine planners and geologists is likely to improve the accuracy of ore definition and overall metal recovery at individual mine sites.

Keywords - Radio Imaging Method; RIM; orebody delineation; mine geology

On the Gravity Signature of Archaean Greenstones in the Widgiemooltha-Tramways Area, Eastern Goldfields, Western Australia

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4 Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601

Abstract

A detailed gravity traverse is described along the Western Mining Corporation - Australian Geological Survey Organisation (WMC-AGSO) Widgiemooltha-Tramways crustal seismic profile. Positive Bouguer anomalies of up to 20 mGal over the greenstone sequence imply that up to 3.5 km of mafic stratigraphy occur along the profile. Comparisons to the seismic data imply the presence of a felsic stratigraphic unit forming the base of the supracrustal greenstone succession. The 3-D structure of local successor basins (Black Flags and Merougil Beds) above the mafic stratigraphy are also con

strained by the gravity data to a maximum vertical thickness in the order of 3 km. The Widgiemooltha granodiorite is modelled by the seismic and gravity data as a steep-sided intrusion underlain at depth (5 3 km) by felsic greenstone stratigraphy.

The geological history of the Norseman-Wiluna belt inferred from the Widgiemooltha-Tramways seismic and gravity data analysis indicates that:

2.9 Ga: Intracratonic basin of predominantly felsic composition (Penneshaw Formation and lateral equivalents) forms over pre-existing continental basement.

2.7 Ga: Main Kambalda mafic-felsic stratigraphy develops above antecedent felsic basin.

2.7 Ga to 2.65 Ga: Polyphase basin inversion produces the presently observed upper crustal section.

Keywords - Archaean greenstones, Widgiemooltha-Tramways, Eastern Goldfields, gravity, seismic.

The Application of Geophysics to Nickel Sulphide Exploration in the Kambalda District, Western Australia

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2. Exploration Division, WMC Ltd, 68 Daly Street, Belmont, W.A. 6104

Abstract

The limited geological outcrop within the Kambalda district, when coupled with the favourable physical properties of nickel sulphides, make geophysical methods an important tool in the exploration for Archaean nickel deposits in this area. Present exploration strategy uses detailed airborne and surface magnetics in the targeting of favourable ore environments, structures, and prospective ultramafic-mafic contacts. Surface and downhole electrical and electromagnetic techniques are then applied to optimise prospect drilling and directly detect nickel sulphides. Thick, conductive overburden, magnetic "noise" originating in near-surface laterites, "false" anomalies due to conductive sedimentary units, and the extensive blanket of lake sediments in certain areas continue to present challenges to successful exploration.

The Burkitt Hill Dynamic Test Range: A New Facility in South Australia for Calibration of Airborne Gamma Spectrometers

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1. Preview Resources Pty Ltd, Adelaide, SA

2. Department of Mines and Energy, SA

Poster Session Abstract

This paper describes the characteristics of the Burkitt Hill Dynamic Test Range and the ground calibration pads at Whyalla airport in South Australia and recommends procedures for their use for calibration of airborne gamma spectrometer surveys.

These new facilities are available to geophysical contractors and exploration companies.

The test range and in ground pads were established by the Department of Mines and Energy, South Australia; in order to bring uniformity to the gamma spectrometer results from the 1992/1993 South Australian Exploration Initiative airborne surveys. Three airborne contractors and four different aircraft were used. A particular requirement of these surveys was that the DME required the count rate results of the surveys be converted to equivalent Potassium percent, Uranium ppm and Thorium ppm, in order to bring more credible geological meaning to the results.

The four 'Whyalla Airport Calibration Pads' are located on the edge of the tarmac at Whyalla Airport, buried flush with the tarmac surface. Aircraft can be readily taxied and positioned over the pads. The pads were constructed by CSIRO to ASEG specifications.

Burkitt Hill, at the centre of the Burkitt Hill Dynamic Test Range (DTR), is located 70 kilometres northwest of Whyalla airport, and 13km west northwest of Iron Knob, over one of South Australis's rare outcrops of hot granite - the Burkitt Granite.

The full range used by the SAEI surveys extends 12km north-south and 5km east-west, and includes an area of Burkitt Granite in the south and some Gawler Range Volcanics in the north. The window of Burkitt Granite is surrounded by transported sediments. The southwest corner is at AMG 687000E/6375000N and northeast corner at 692000E/6387000N.

A centrally located north-south test line, has been pegged and flagged for 5km along constant AMG eastings. The ends, and a run in, are marked with multicoloured fuel drums and flat markers for easy recognition from the air.

Averages of chemical analyses of 81 surface samples along the centrally located test line are:

Potassium	4.40%	SD 0.5%
Uranium	9.83ppm	SD 7.2
Thorium	50.53ppm	SD 23.2

The use of the range by the SAEI surveys required flying background tests over the waters of Spencer Gulf, then flying the full range as a 'small survey' along defined north-south lines 100 metres apart, the lines being on constant AMG eastings. Height attenuation flights were also made along a key central line. Sensitivity coefficients were calculated from regressions of aircraft counts against ground chemistry.

The DTR has allowed objective comparison of the survey results produced by the SAEI contractors.

This paper is published with the approval of Ross Fardon, the Director General, Department of Mines and Energy, South Australia.

(see figures 1-5 on P41-45)

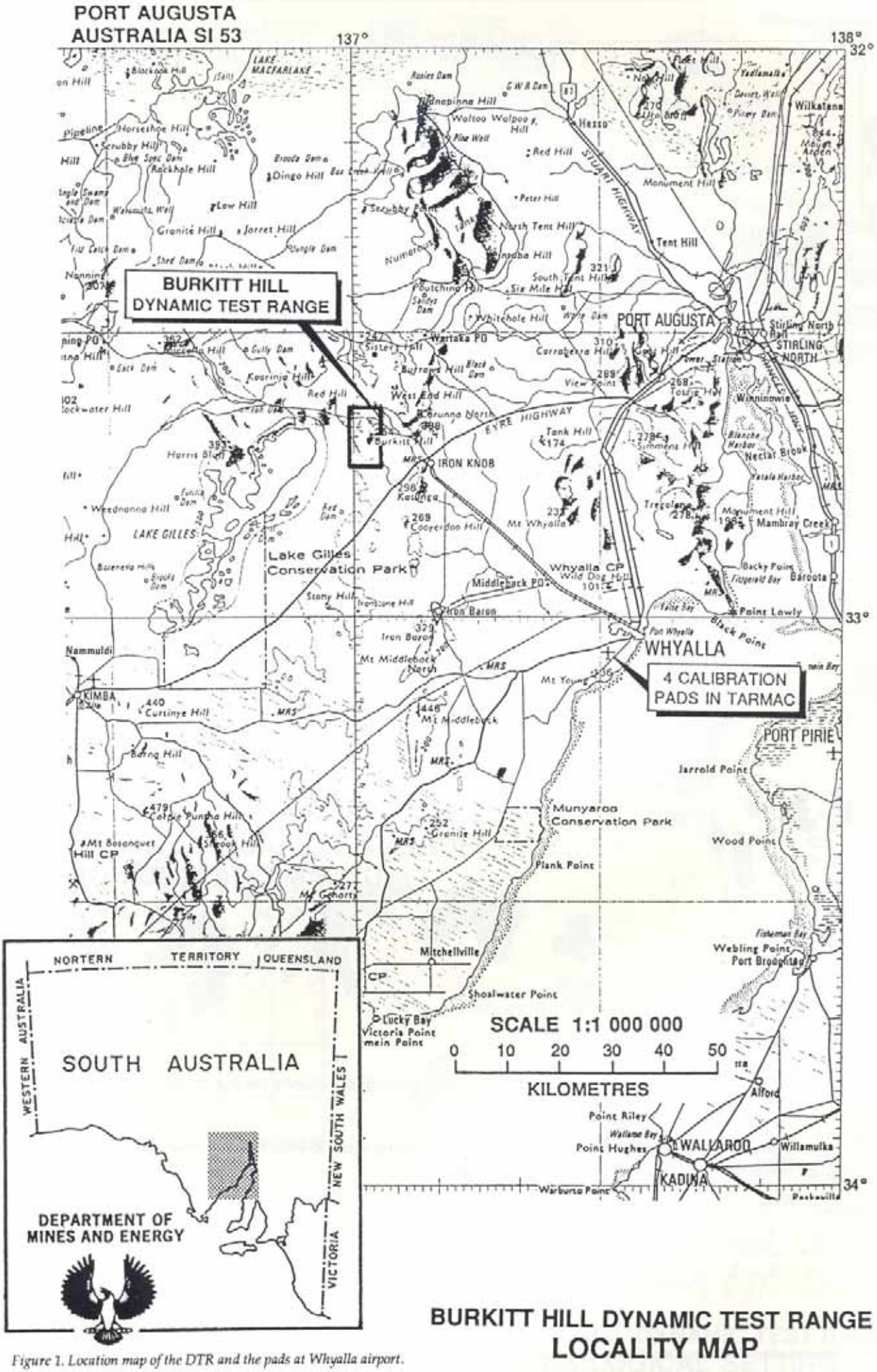
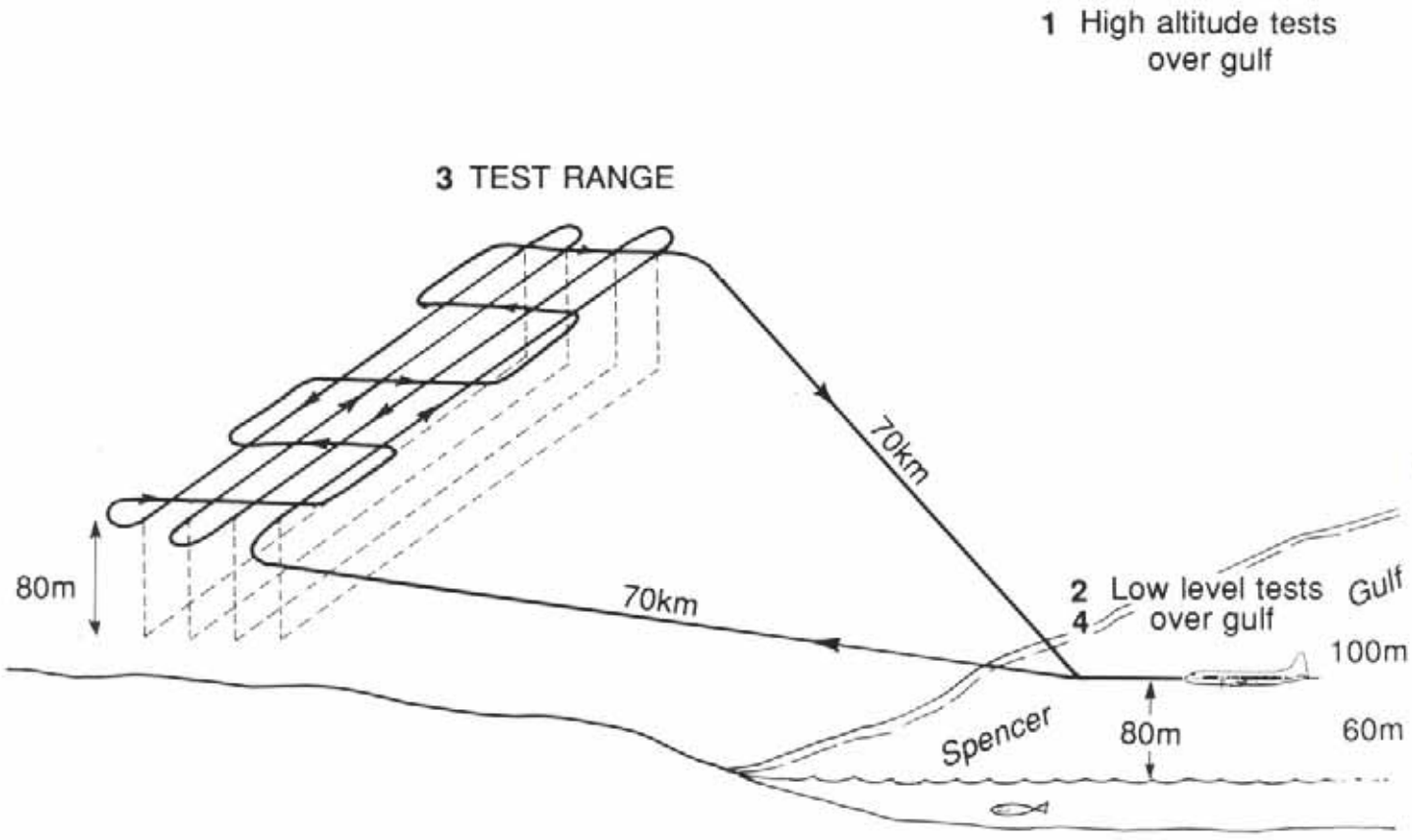


Figure 1. Location map of the DTR and the pads at Whyalla airport.

BURKITT HILL DYNAMIC TEST RANGE
LOCALITY MAP



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SCHEMATIC DIAGRAM BURKITT HILL DYNAMIC TEST RANGE

Notes:

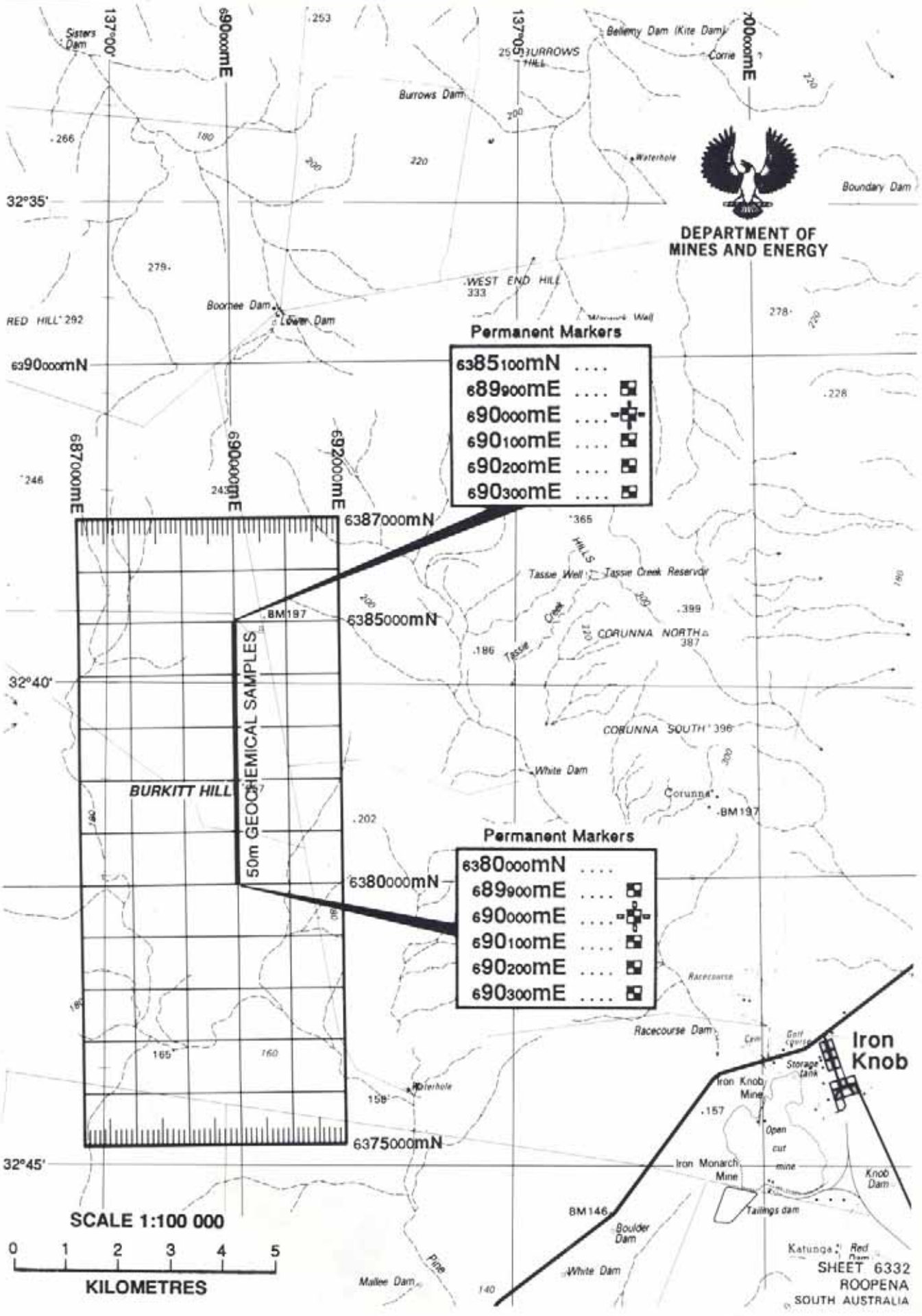
1. High altitude tests will be undertaken under optimal conditions far out to sea (2000 to 10 000 feet at 1000 feet intervals).

3. Test range includes height attenuation tests along line 689000mE at ground clearance of 150 to 600 feet at 50 foot intervals).

Figure 2. Schematic diagram for use of the DTR and calibration pads.

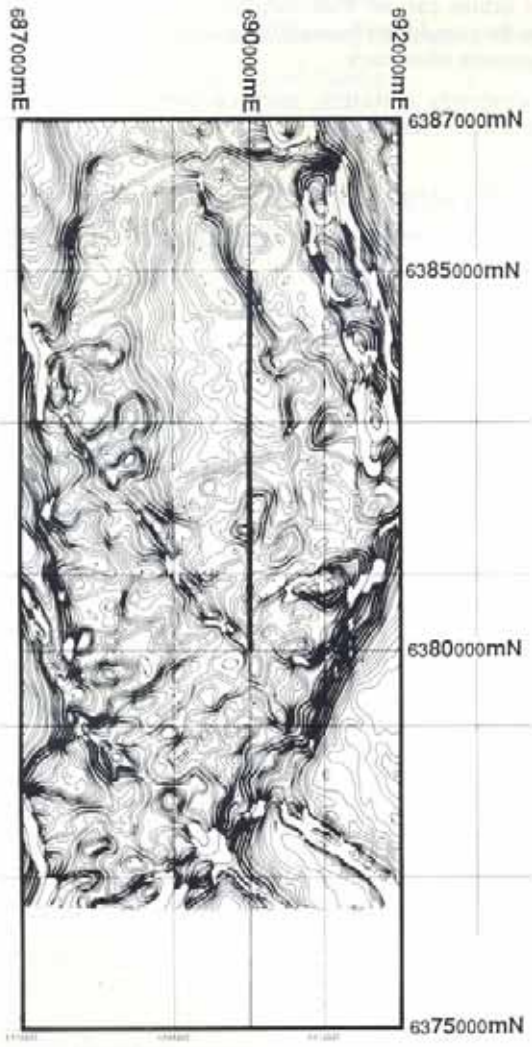
BURKITT HILL DYNAMIC TEST RANGE
GEOLOGICAL SETTING

Figure 3. Geology of the Burkitt Hill DTR.

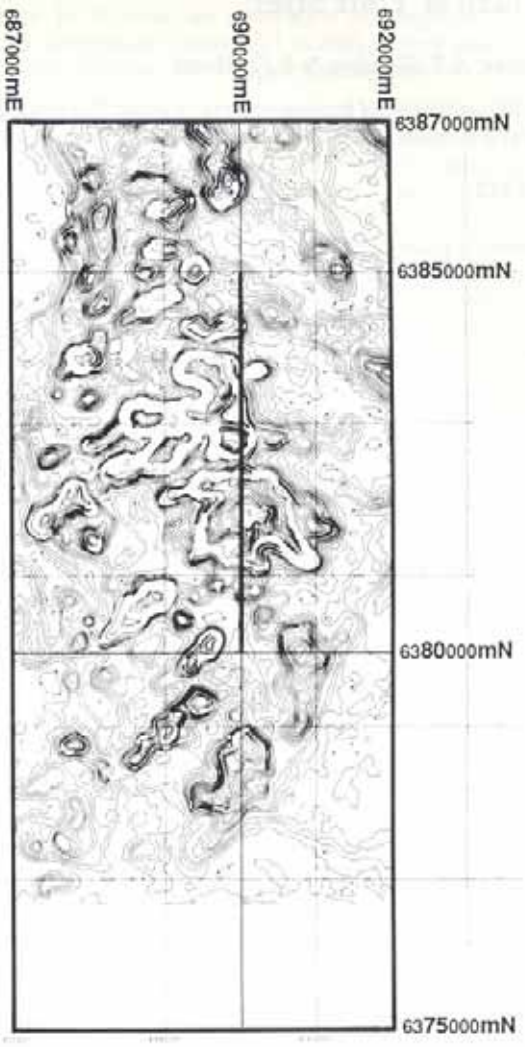


BURKITT HILL DYNAMIC TEST RANGE
FLIGHT PATH DETAILS

Figure 4. Topography contours and location of key traverse and markers.



TOTAL MAGNETIC
INTENSITY CONTOURS



GAMMA TOTAL COUNT
CONTOURS

SCALE 1:100 000

0 1 2 3 4 5

KILOMETRES

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BURKITT HILL DYNAMIC TEST RANGE
MAGNETIC AND GAMMA TOTAL COUNT

Figure 5. Total Magnetic Intensity and Total Count characteristics of the Burkitt Hill DTR.

Ground Penetrating Radar - Will it Clear the Haze at Your Site?

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Abstract

Ground penetrating radar (GPR), of all the commonly practiced geophysical techniques, has the greatest ability to provide clear high resolution images of shallow sub-surface structure. To date, however, the perceived unpredictability of its performance at different sites has limited its use.

Factors which control the performance of GPR can be summarised by the radar range equation. The site dependence of GPR is a result of the wide variation between the wave attenuation rates of different geological materials and the variation in the reflectivities of the different targets. The attenuation rate of a material depends on its conductivity and dielectric constant while the reflectivity depends on the contrast of these properties between the target and host materials. Unfortunately, since conductivity varies with frequency, conductivities obtained by resistivity and other low frequency electromagnetic geophysical measurements are different to those at GPR frequencies.

One way to obtain these properties is to make measurements of the radio-frequency electrical properties of rock samples from prospective GPR sites. For this purpose the open-ended coaxial line technique has been found to be the most practical method. Above 100 MHz measurements can be made on small samples with a single flat surface. Below 100 MHz the accuracy of this technique deteriorates and the capacitance bridge technique, which requires small disk-shaped samples, is more suitable.

In homogeneous media, nomograms can be used to convert the attenuation rates determined from the sample measurements, to a maximum depth that can be imaged by a GPR system. The maximum depth in layered media can be determined by a simple graphical method involving summing the attenuation and spreading in each layer. Case histories from 4 different sites show that despite the uncertainties involved in making any measurement on samples which have been removed from their in-situ conditions, ranges calculated in this way provide a valuable guide as to how well GPR will perform at a particular site.

Keywords - ground penetrating radar, RF sample testing, void detection, dielectric probe, radar range.

Improved Static Corrections Plus Pre-stack Interpretation Improves the Resolution of 2-D Seismic Data

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Abstract

In the quest for improved resolution, the application of good statics routines is often ignored. Using coalfield seismic data, a model independent statics routine which uses the refraction events to align reflections is discussed with examples of its application. Good statics allows improved imaging of 2-D seismic reflection data, which then allows a novel work station method to produce pseudo 3-D volumes from 2-D pre-stack data. Hence subtle features, such as low throw faults, can be well defined in the pre-stack domain, where they could not be readily observed on the conventional 2-D sections after stack.

Keywords - statics, surface consistent, pre-stack, interpretation, resolution.

Geophysical Setting of the BIF-hosted Gold Deposit at Tuckabianna, Western Australia

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Abstract

Tuckabianna Gold Mine is located about 25 km east of Cue, on the Mount Magnet-Meekatharra Shear Zone. The mine sequence consists largely of basalt, dolerite to gabbro, mafic schists, banded iron-formation (BIF), and intrusive quartz-feldspar porphyry dykes and sills. Gold mineralisation is hosted by the northeast-striking, east-dipping BIFs with shears localising the ore zones. Laterite derived from the weathering of these BIFs may contain a significant gold resource.

Downhole logging has shown that the BIFs typically have lower relative gamma activity and higher densities, resistivities and susceptibilities compared with the mafic units and porphyry.

Petrophysical measurements of magnetic susceptibility, anisotropy of magnetic susceptibility and natural remanent magnetisation have characterised two BIF types, although no relationship between gold mineralisation and the BIF types has been conclusively demonstrated.

Tuckabianna's regional geophysical dataset consists of Bureau of Mineral Resources (BMR) aeromagnetic and gravity data and high-resolution aeromagnetic and radiometric data. Of these, the most useful have been the high-resolution aeromagnetic data, because they clearly define the BIFs and structures which can localise gold mineralisation. Such lithological and structural detail cannot be recognised in either the BMR regional magnetic and gravity datasets or the high-resolution radiometric dataset.

The Geoscan remote sensing system has been flown over Tuckabianna. However, the laterite cover (1-21 m thick) has blanketed much of the geology and only some rock types and major lineaments can be identified from the data.

Ground geophysical surveys have been dominated by the magnetic method, which has been extremely useful in delineating the BIFs and structural features, as has the gravity method. Electrical surveys, including magnetometric resistivity, induced polarisation (frequency and time-domain) and electromagnetic methods have also been used. These electrical techniques have not been completely successful in the direct detection of mineralised zones. However, the resistive nature of the BIF is such that these methods may be successfully used to locate the BIF and porphyry, in addition to delineating some structures.

Exploration for Cyprus Style Copper Deposits, Sultanate of Oman: A Case History

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2 Austirex International Limited, Sydney

3 World Geoscience Corporation, Perth

Abstract

Copper mining has occurred in the Sultanate of Oman since the 3rd millennium BC in sporadic episodes. Current mining has resulted from recent (post 1970) recognition of ancient mining centres and the economy of modern concentrator and smelting processes.

Cyprus style copper/gold deposits are inherently low grade and small tonnage in nature, however, they occur in clusters along predictable structural zones. Observations, from submersible vehicles, on such deposits in mid-oceanic ridge environments have given insight to their origin and form that can be used in exploration.

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 a known deposit, were chosen for exploration using transient electromagnetic and induced polarisation techniques and orientation surveys were also undertaken in areas of deep cover.

Several TEM anomalies, of relatively moderate conductivity, were delineated by the surveys and tested by drilling. The programme produced two new copper/gold zones of higher than usual grade (greater than 2% copper and 1 g/t gold) but each less than 500 000 tonnes.

The results confirmed that use of theoretical models in conjunction with modern airborne and ground geophysics could locate new zones of mineralisation.

Keywords - airborne magnetic surveys, transient electromagnetic, induced polarisation, Samail Ophiolite, Cyprus style, copper mining

Environmental Geophysics: Challenges and Perspectives

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Keynote Address Abstract

Modern civilizations are now at risk from both natural geophysical events and from industrial pollution and accumulated wastes which release toxic substances into the environment. There is little doubt that environmental hazards are increasingly man-made, increasingly voluntary and more diffuse in their impact. Environmental geophysics, in its widest sense, is concerned with the quantification and monitoring of subsurface hazards, irrespective of their origin.

A review of current activities has identified two major challenges for environmental geophysicists i.e. to understand socio-economic and environmental factors and to develop improved methods and practices.

Recent field examples from a range of environmental geophysical studies provide perspectives on these challenges. A dryland salinity study in eastern Australia demonstrates the need to express electromagnetic responses of soils in agronomic terms. In South Australia, a new method of radiowave electromagnetic profiling which appears to overcome some of the limitations of conventional electromagnetic methods is used to locate diesel oil pollution plumes. In Victoria, an innovative underground-to-surface seismic technique screens old buried sewers and examines ground conditions around ageing structures.

It is concluded that environmental geophysics has a bright future provided geophysicists are willing to meet these major challenges. If not, other non-specialists will increasingly enter the field as has been the case in North America.

Entropy and Geophysical Inverse Problems

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Abstract

Geophysical surveys often result in the inference of Earth properties based on the data collected from organised experiments. Such problems are known as inverse problems. The mathematical theory relating the data and the Earth properties is generally non-linear which, combined with ill-posed and underdetermined attributes, leads to ambiguous solutions. A single solution needs to be chosen for the geophysical experiment to be of benefit. Of the range of possible solutions it appears that some are better than others - simply by imposing common sense.

The entropy principle consists of selecting the solution that has the maximum entropy value. Such a solution will be consistent with all experimental data and maximally non-committal with regard to unavailable data. This solution contains structure only if it is needed to satisfy the given data. The entropy function is a simple convex function of logarithmic form. The convex nature of the function is enough to provide most of the benefits associated with maximum entropy solutions. However, a simple demonstrative example shows that the logarithmic form is essential to ensure that the solution is maximally non-committal to unavailable data.

The entropy principle also provides a natural mechanism for using prior information. Prior information is that obtained from experiences prior to the execution of the geophysical experiment. Such information is generally not of the form of a hard constraint and is frequently difficult to use. The entropy values can be measured relative to a prior estimate of the model parameters. This allows prior information to be used as default values and as a guide without restricting the inversion. The addition of useful prior information models can be beneficial to the outcomes of geophysical inversions.

A synthetic cross-hole tomography example shows the benefits of maximum entropy solutions when compared to the results of the popular SIRT inversion algorithm. The most obvious of these are the lack of spurious background structure and increased resolution of the anomalies.

Keywords - entropy, inversion, tomography

A Practical Approach to One-Pass 3-D Depth Migration

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1 Halliburton Australia Pty. Limited

2 Halliburton Energy Services Inc.

Abstract

Accurate processing of 3-D seismic data sets is essential to meet the objectives of today's explorationist. Migration is a process that is particularly important in 3-D seismic processing. Originally, 3-D migration was performed in two separate 2-D passes but this suffered from the inaccuracies of a constant velocity assumption. The splitting algorithm is now a popular one-pass approach to 3-D migration. One-pass migration algorithms avoid the assumption of constant velocities and more correctly position the seismic energy. A more flexible approach to one-pass 3-D migration is known as Ky partitioning. This algorithm allows for a choice of currently available 2-D migrations to be used to perform an accurate one-pass 3-D migration. The Ky partitioning approach is also more efficient.

When lateral variations in velocity become significant, a depth migration algorithm will more accurately image the data than the standard time migration algorithm. The splitting algorithm is converted into a depth migration by including the thin lens term. For the Ky partitioning algorithm this is achieved by the use of dilation. Dilation consists of small dynamic time shifts applied to the 3-D data before migration to compensate for the existence of lateral velocity variations.

Application of both splitting and Ky-dilation one-pass 3-D migration algorithms to a synthetic data set show that the proposed dilation factors can produce sharp migrated images in the presence of lateral velocity variations. In this case the Ky-dilation results exhibit superior clarity compared with the image obtained from the splitting approach. The extra flexibility of the Ky-dilation approach allowed the use of a high-dip time migration algorithm which avoided the frequency dispersion effects that degrade the image of the finite- difference splitting migration. An improved image has been obtained for less computational effort.

Keywords - 3-D migration, Ky partitioning, splitting algorithm, one-pass migration, dilation, reflection seismic

Relationship Between Magnetic Anomalism and Epigenetic Gold Mineralisation in the Victory-defiance Area, Western Australia

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Abstract

The relationship between gold mineralisation, genetically related mineral assemblages, magnetic susceptibility and features observable in ground and airborne magnetic surveying is established at three gold mines in the Victory-Defiance gold camp at Kambalda, Western Australia. The gold mines are Orion, North Orchin and Revenge. There are significant magnetite-stable alteration haloes enveloping the gold lodes comprising these deposits.

The magnetite-stable alteration is peripheral to gold lodes in differentiated dolerites, metabasalts and meta-sedimentary rocks which have undergone lower to mid-greenschist facies metamorphism. The magnetite alteration is partly coincident with the well-documented chlorite and biotite alteration zones.

The magnetic susceptibilities of the magnetite-stable alteration assemblages range to 100×10^{-3} SI units. It is noted that the magnetic properties of the Kapai Slate vary considerably on a regional scale but appear to be consistently high (up to 400×10^{-3} SI units) within the Victory-Defiance gold camp.

Magnetic maxima are coincident with all three gold deposits. The amplitude of the maxima observed in low-level aeromagnetic surveys are 30, 300 and 400 nT for Orion, North Orchin and Revenge, respectively.

Modelling the Effects of Thin Beds on Amplitude Versus Offset Response Using the Campbell-2 Well

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Abstract

Studies of Amplitude Variations with Offset (AVO) have been used in Australia and worldwide to evaluate possible hydrocarbon prospects. This study concentrates on modelling the effects of thin beds (carbonates, shales) above and within sandstones on AVO behaviour.

Forward modelling of synthetic gathers from the Campbell-2 well has confirmed that the strongly anomalous AVO response observable over the gas and oil field is due to the hydrocarbon column in the Flag Sandstone of the Barrow Group. Modelling presented here shows that a 5 m thick shale with its top 15 m below the top of the reservoir modified the AVO response of the top of the reservoir, but this response is still strongly anomalous. However, modelling a reservoir with two 5 m thick shale beds located 5 m and 15 m below the top of the reservoir modified the AVO response of the top of the reservoir to the extent that the AVO response is not significantly anomalous.

Keywords - AVO, thin beds, Campbell-2, Flag Sandstone, Carnarvon Basin.

Applied Seismic Inversion for Estimating Velocity-Depth Models

Oz Yilmaz

Schlumberger

Keynote Address Abstract

Processing and inversion of seismic data differ in one fundamental respect -- the output from *processing* often is displayed in *time*, and the output from *Inversion* is intended to be displayed in *depth*. The main goal in inversion is to estimate a geologically plausible subsurface velocity-depth model, which comprises two sets of parameters -- *layer velocities* and *reflector geometries*. To resolve the well-known velocity-depth ambiguity in inversion, these parameters need to be estimated, *independently*.

Estimation of velocity-depth models requires a set of integrated methods of inversion and utilities built around a workstation. Specifically, post- and prestack depth migration, prestack traveltime inversion and amplitude inversion can be used in some combination to estimate velocity-depth models for structural and stratigraphic targets.

For a structural problem, the subsurface model can be divided into two parts -- the *overburden* in which ray theory is applicable, and the *substratum* in which depth migration is imperative. Typical structural targets are associated with salt and over thrust tectonics. In case of salt tectonics, the top-salt

constitutes the boundary between the overburden and the substratum. It also is the boundary where the most *severe ray* bending takes place.

Consider a 2-D seismic line along the dominant dip direction with minimal sideswipe energy present in the recorded data. The following package is then offered to estimate the velocity-depth model:

	Overburden	**Substratum**
Layer Velocities	*layer-by-layer prestack traveltime inversion*	*iterative prestack depth migration, and analysis of image gathers and image-gather stacks*
Reflector-Geometries	*layer-by-layer post-stack depth migration*	*image-gather stacks*

This scheme can be extended to estimate a 3-D velocity-depth model for structural targets as follows:

	Overburden	**Substratum**
Layer Velocities	*layer-by-layer 3-D prestack traveltime inversion*	*iterative 3-D poststack depth migration*
Reflector-Geometries	*layer-by-layer poststack depth migration*	*iterative 3-D poststack depth migration followed by 3-D prestack depth migration along selected traverses*

For a stratigraphic problem, the subsurface velocity-depth model can be divided into two parts -- the *macro-model* that represents the trend in velocity variations, and the *micro-model* that represents the details in velocity variations. Since stratigraphic targets are generally associated with low-relief structures and structure-independent velocity variations, the following package is equally applicable to both 2-D and 3-D cases.

	Macro-model	**Micro-model**
Layer Velocities	*prestack traveltime inversion*	*amplitude inversion*
Reflector Geometries	*poststack depth migration*	*not applicable*

Aside from inversion methods -- depth migration, traveltime and amplitude inversion, an inversion project also requires a set of utilities available on an *Inversion workstation*:

(1a) Interpretation of time horizons from 3-D stack volume of data.

(1b) Interpretation of depth horizons from 3-D depth-migrated volume of data.

(2) 3-D model representation of surfaces and solids.

(3) 3-D model visualisation.

(4) Editing of layer velocities and reflector geometries.

It is important to note that inversion is not intended to replace processing, rather to complement it. Conventional processing indeed is included in the data analyses described in this proposal. For instance, optimum DMO stack is used in conjunction with depth migration to facilitate accurate and efficient imaging of the overburden. Optimum DMO stack provides picked time horizon information for prestack traveltime inversion so as to avoid picking of reflection times on CMP gathers, and, following time migration, it is the principle input to poststack amplitude inversion

The Study of Diffusion Effects in RIM Tomographic Imaging

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Abstract

To date, the standard method of producing images from medium-frequency RIM measurements is to use a straight-ray tomographic reconstruction algorithm. In contrast, conventional inversion methods for low-frequency EM measurements are commonly described in terms of secondary fields, produced by eddy currents in a conductive body, and are often carried out by a combination of forward modelling and regularized inversion. These two approaches differ considerably, which brings rise to many questions on the validity of applying straight-ray tomography to RIM data. In the past, this has been justified by the success of the empirical results but work is ongoing to provide a firm theoretical basis for the RIM method and to produce more accurate transmission tomography algorithms which go beyond the straight-ray approximation.

Using numerical modelling results, this paper examines the validity of applying a straight-ray tomographic reconstruction algorithm to medium-frequency EM data. Rock conductivities are varied in the examples. The paper also looks at one of the approaches being studied which will hopefully lead to a more accurate transmission tomography algorithm.

Keywords - Radio Imaging Method, RIM, tomographic imaging

UTEM Case History of a Base Metal Prospect Goianesia, Brazil

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Abstract

The ground UTEM electromagnetic system was used to discover a large extention to the known massive sulphides at the Cafelandia Prospect in Goias state, Brazil. Large in-loop surveys were used to delineate a blind mineralized horizon with a 3.5 km strike length, shallow dip and high conductivity. Subsequent drilling has shown that the conductive horizon consists of bands of massive sulphides within an large layer of disseminated sulphides. The capacity of the UTEM time domain electromagnetic system in separating multiple conductors at depth, and the quantitative interpretation possible from the data collected make this transient EM system a highly effective tool in searching for deep massive sulphides in the Cafelandia Project area.

Extrapolation of Vector (Elastic) Displacements by Displacement Potential Field Continuation

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Abstract

Extrapolating recorded elastic displacement data from the surface downwards is the first step of a two-step elastic migration scheme. The second step is the image formation condition. Although an elastic (vector) reverse time migration can extrapolate elastic displacement data downwards, the subsurface reflections and the loss of energy due to the use of the two-way wave equations are unavoidable. The elastic Kirchoff-Helmholtz type integrals can not be used to extrapolate elastic displacement data downwards in media in which the velocity changes in both the x-direction and the z-direction. The present method attempts to first obtain the P- and S-wave displacement potentials near the surface. Then the P- and S-wave displacement potentials are each extrapolated (in a scalar fashion) with the split-step Fourier method, subject to modest velocity gradients. Finally, the elastic displacement fields within the subsurface can be obtained from the extrapolated potential fields.

In order to obtain the P- and S-wave displacement potentials near the surface, the finite difference elastic reverse time migration method is used to extrapolate the recorded elastic surface displacement data downwards only a few depth intervals, assuming a constant velocity over this small depth region, so that the P- and S-displacement potentials can be computed from the calculated elastic displacement fields. Therefore the method can be used to extrapolate recorded elastic displacement fields from the surface downwards with almost no velocity limitation except near the surface (only a few depth intervals). It was tested on the numerical model data produced by a fourth order finite difference elastic forward modelling program with good results. The finite difference elastic reverse time migration method was used because a finite difference elastic forward modelling program had already been developed and could be run inverse. In addition, the use of the Kirchoff-Helmholtz type integrals is preferable for t

Keywords - seismic reflection, displacement potentials, Kirchoff-Helmholtz integral, potential field, continuation, RTM, downward extrapolation

Application of Computerised Tomography Methods to the Interpretation of Magnetic Anomaly Profiles

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Abstract

The interpretation of a magnetic anomaly profile is achieved by solving a Fredholm integral equation of the first kind. Numerical solutions to such a problem require the conversion from the original form to a system of linear equations. The commonly used mid-point quadratic scheme for converting the integral equation into a system of linear equations is impractical because the obtained system is highly ill-conditioned and a poor approximation to the integral equation. In contrast, a strip integral quadrature method can give a very good approximation; further it enables the application of techniques of Computerised Tomography (CT) to potential field inverse problems. The new method significantly improves the accuracy and stability of the solution without any a priori knowledge and is very likely to have applications beyond the interpretation of magnetic field data.

Keywords - magnetic anomaly profile, freidholm integral of the first kind, ill-conditioning, computerised tomography.

Additional Speaker Biographies

Terry Allan, an Area Geophysicist with Halliburton Australia Pty Ltd received an Honours BSc in Mathematical Science from the University of Edinburgh in 1968. He joined Halliburton (formerly GSI) in England as a seismic data processing geophysicist. He became an area geophysicist in 1975 and moved to Australia in 1978. He has been involved in both land and marine data acquisition and processing.

Dr Yuzuru Ashida is Associate Professor at Kyoto University in Japan. Prior to his appointment in 1986, he was with the Japan Petroleum Exploration Co Ltd. Dr Ashida was awarded the Best Paper Award in the SEGJ Journal 1980 and also 1990. His main area of interest is in Reflection Sesimology.

Andrew Duncan is a geophysicist with World Geoscience Corporation. Since 1989 he has been responsible for the development of airborne electromagnetic data acquisition and processing technology for the group. The QUESTEM and SALTMAP fixed-wing airborne electromagnetic systems have been developed during this period and now operate commercially.

Katherine Edwards is currently studying for a Ph.D. 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, with particular emphasis on non-stationary analysis of magnetotelluric data.

Brian J. Evans received an M.Sc in Geophysics from Curtin University in 1985. he worked in seismic data acquisition for GSI from 1971 to 1974, after which he worked for Aquatronics and as a consultant in the North Sea for two years. In 1976, he established his own Perth based consultancy in exploration geophysics, until 1983 when he joined Curtin as a full time student. From 1985 onwards, he helped establish five research labs at Curtin, where he is also Co-Director of the Seismology Unit and Senior Lecturer in Geophysics. His present research interests are in 3-D and three component seismic. He is a member of the ASEG, SEG, GSA and PESA. He is also current WA President of the ASEG.

Ross Fardon, a Queenslander, was educated at University of Queensland and Harvard University. He has worked in Australia, North America and South East Asia. Ross is familiar with all mineral commodities, specialising in lead-zinc, nickel and gold. He has founded small, listed companies, and consulted in gold, base metals and company management. Among other things, Ross has been interested in new technology in geophysics, metallurgy, air conditioning, electronics, paints, instruments and engines. He has manufactured air conditioners in Melbourne, and marketed products in England, China, Japan and USA. Ross has been employed by BMR, Western Mining, Jedodex and BHP where he was in charge of mineral exploration.

Mike Galbraith During the period 1963-1967 Mike Galbraith attended the University of Edinburgh, graduating with a B.Sc. (Hons.) in Mathematical Physics. His career resume is as follows:
1987 - Present: President, Seismic Image Software
1984 - 1987: President, Veritas Seismic Ltd.
1975 - 1984: Programming Manager, Veritas Software Ltd.
1971 - 1975: Programming Manager, R.B. Cruz and Associates Ltd.
1968 - 1970: Research Assistant, British Gas Council

In 1988 **Richard Haines** graduated from S.A. Institute of Technology with a Bachelor of Surveying with Distinction. He has been involved with Global Positioning System (GPS) technology for surveying since 1987. After graduation he was employed by the S.A. Department of Lands to research and develop the Kinematic GPS technique for geodetic and topographic surveying applications. During this time he conducted several major GPS projects including a geodetic survey of Cyprus in the Middle East.

In late 1991 Richard formed a surveying company specialising in GPS technology. The company Haines Surveys operates both internationally and Australia wide providing specialist surveying services to the mining, mineral exploration and oil and gas industries. The company's main fields of expertise are seismic surveys and accurate height determination for gravity surveys. Haines Surveys have used the technology on gravity surveys to complete over 20,000 stations throughout Australia.

Kathy Hill graduated with a B.Sc. in Geology from the University of Alberta in 1979 and worked until 1983 with Esso Resources Canada primarily as a seismic interpreter in the Alberta and Frontiers groups. After leaving Esso to obtain a M.Sc. in Geophysics from Oxford University, Kathy joined BP in London, working in the European and Basin Studies groups and was seconded to Melbourne in 1985. In 1989 she joined Monash University and is currently VIEPS lecturer in Petroleum Geology and Reflection Seismic Interpretation. She is a member of PESA, the ASEG and the GSA.

Eve Howell graduated from King's College (University of London) with B.Sc. (Hons.) degree in Geology and Mathematics. She started her career in London where she worked for the British Geological Survey, Amoco Europe Inc. and Exploration Consultants Ltd (ECL). After fourteen years in London, she was transferred to Australia where she was Technical Manager and then Director of ECL Australia Pty Ltd. In 1984 she joined Australian Occidental which was shortly afterwards sold to Bond Petroleum. Eve joined Bond Petroleum as Chief Geophysicist and in 1987 became Exploration Manager. Following the sale of the Harriet and associated fields to a Hadson-led consortium, she joined Hadson Energy Ltd early in 1990 where she currently holds the position of Manager of Exploration. Eve is a fellow of the Geological Society of London and an active member of the AAPG, EAEG, ASEG and PESA. She is a past president of the ASEG.

Wayne Jones began his career in surveying in the '70s qualifying at Technical College level and becoming involved in cadastral, engineering and geodetic surveying.
In 1988 he resumed studies at Curtin University in Perth and graduated with an honours degree in 1991. He then continued to study at Masters level, undertaking research in the field of Global Positioning Systems applications in Geophysical Exploration, which included work on several projects in conjunction with the Department of Exploration Geophysics at Curtin.
His current work is in the area of GPS geodesy.

Mike Middleton completed a Ph.D. at Sydney University in 1978. He has worked for Amoco Minerals, Melbourne University, CSIRO, ECL Australia and the Geological Survey of Western Australia. From 1990 to mid-1993, he consulted and was also Adjunct Associate Professor at Curtin University of Technology. He is currently the Nordic Professor of Petrophysics at Chalmers University of Technology, Gothenburg, Sweden.

Justin Norris was born in Perth, Western Australia in 1971, and educated at Curtin University majoring in geophysics. He received an award presented by the Australian Institute of Physics in 1991 and he graduated from Curtin in 1992 with First Class Honours. He currently resides in Perth and has worked for GECO-PRAKLA since the beginning of 1993. He is an active member of the ASEG and his interests incude basketball and golf.

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, elecrical, 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.

Richard Parrott received his B.Sc. (Hons., 1973) degree in Geology and Geophysics from Carlton University, Ottawa, Canada, and his M.Sc. (1976) degree in Geology from Dalhousie University, Halifax, Canada. Upon graduation he joined Esso Resources Canada Ltd (Imperial Oil Ltd) where he was involved in Western Canada, Beaufort Sea and East Coast exploration. Between 1982 and 1988 he was employed by Oil Company of Australia NL in the Surat, Eromanga and Canning Basins and ultimately became the Chief Geophysicist. Since 1988 he has been with BHP Petroleum Pty Ltd as a Senior Petroleum Geophysicist in the Timor Sea and Carnarvon Basin.

Don Pridmore has a PhD from the University of Utah and a BSc Hons from Adelaide University. Prior to PhD and post-graduate studies into electromagnetic techniques, he spent two years as an exploration geologist with Western Mining Corporation (WMC). He then returned to WMC in 1979 as senior research geophysicist based in Kalgoorlie. IN 1986 he joined World Geoscience Corporation (WGC) as chief geophysicist responsible for research, marketing and interpretation aspects of airborne geophysics. In 1990 he established a new airborne division of WGC in Houston and has since been instrumental in developing and expanding airborne magnetic applications in the hydrocarbon industry. Don is currently Director/Chief Geophysicist with WGC in Perth and maintains responsibility for research projects and marketing.

Brian Russell holds a B.Sc. in Geophysics from the University of Saskatchewan, Canada, and an M.Sc. in Geophysics from the University of Durham, England. He started his career in 1976 at Chevron in Calgary as an exploration geophysicist. He then worked for Teknica as a senior explorationist, Veritas Seismic as a research and training geophysicist, and Veritas Software as vice-president of marketing and training. In 1987, Brian co-founded Hampson-Russell Software Services Ltd. along with Dan Hampson, and is currently vice-president of that company, co-ordinating their worldwide marketing efforts and participating in new software development and training. Brian also presents courses on new geophysical technology throughout the world for IHRDC and the SEG. He is active in the SEG, and is currently Chairman of *The Leading Edge* editorial board. He is also a past-president of the Canadian SEG, and is registered as professional geophysicist in the province of Alberta.

Martin Schneider completed a BSc (Hons) in geophysics at the University of Sydney, 1980 and a MSc (Hons), Macquarie University, 1985. He has worked at Geoterrex Pty Ltd, Sydney since 1981 in various aspects of ground and airborne geophysics, specialising in the processing of airborne geophysical data, particularly in relation to mineral exploration. Martin is currently responsible for the hardware and software systems at Geoterrex.

Bob Whiteley is principal geophysicist and Manager, Coffey Geophysics. He holds honours and masters degrees in geology and geophysics from the University of Sydney and a PhD in applied geophysics from the University of NSW. Dr Whiteley commenced his career at the Bureau of Mineral Resources, and has worked in the mineral industry as a general manager and senior geophysicist. He is a former associate professor at the Asian Institute of Technology, a senior lecturer at the University of NSW and a consulting geophysicist specialising in the geotechnical area. He has over 25 years experience in applied geophysics and more than 55 published scientific articles and one book. Dr Whiteley has worked on projects in India, Thailand, Solomon Islands, New Caledonia, The Netherlands, Papua New Guinea and Singapore.

Oz Yilmaz, author of the SEG best seller "Seismic Data Processing", holds a B.S., M.S. and PhD (Stanford) in geophysics with research in rock physics and exploration seismology. Oz is currently Director of Data Analysis Product Development Group of Geco-Prakla Division of Schlumberger. Oz's 20 years of experience includes research and geophysical software development, seismic data organisation, processing, teaching and interpretation and gravity and magnetic processing and interpretation. He has worked in senior research and management capacities with the Turkish Petroleum Company and Western Geophysical. He received the SEG Virgil Kauffman Gold Medal (1991) and is an EAEG Conrad Schlumberger Award winner and is currently Vice President of the SEG and an associate editor of EAEG Geophysical Prospecting and First Break.

Dr Jeanne Young received a BASc (1983) Engineering Science, University of Toronto and a PhD (1991) Geophysics, Macquarie University. From 1983-84 she was employed by Digicon Geophysical Corporation as a geophysical programmer. In 1987 she worked in West Germany with the Geophysical Institute of the West German coal research organisation WBK. She is presently a research scientist at the CSIRO.