Australian
Society of
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Preview

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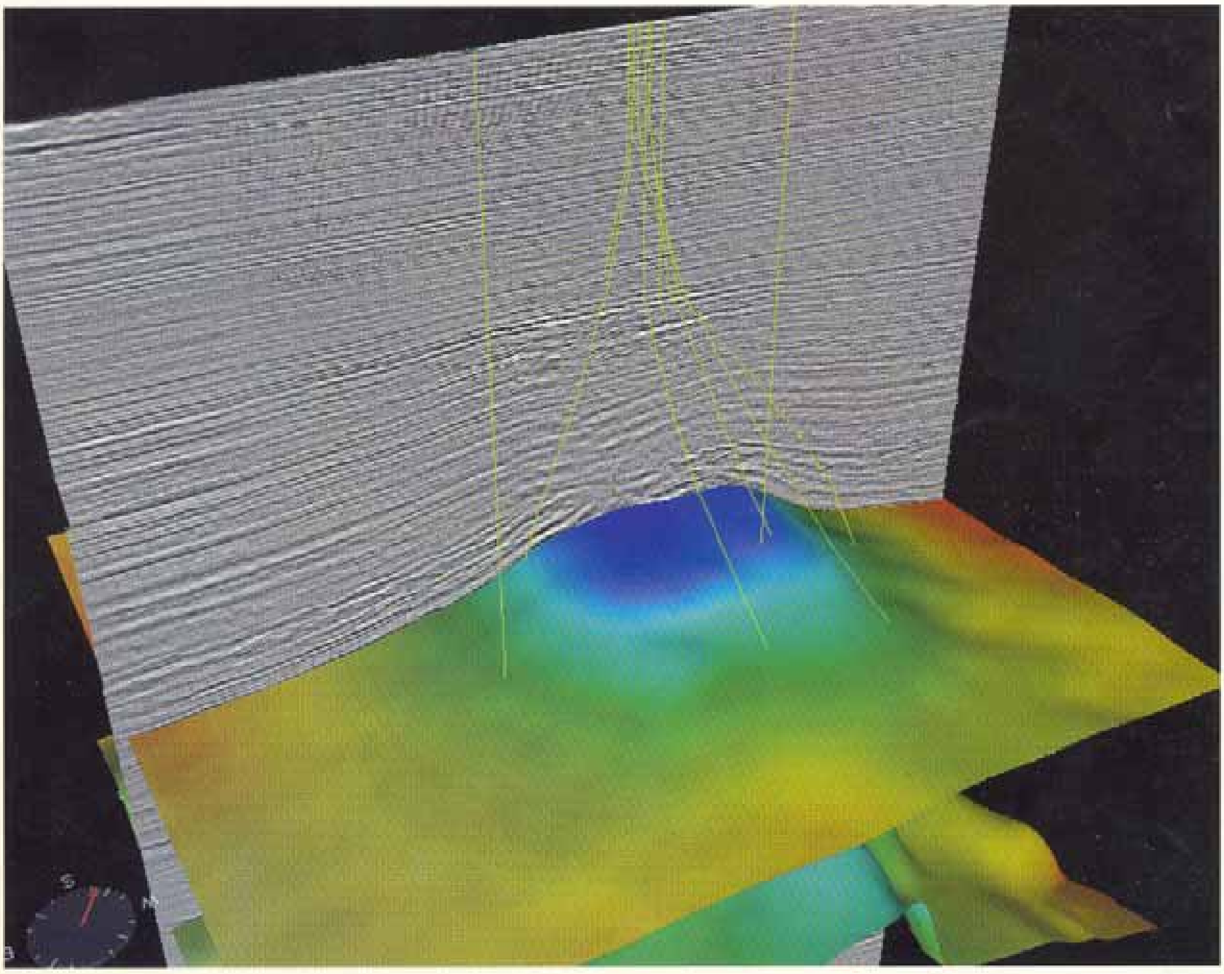
Special Feature:



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Editor's Desk

Firstly an apology for the lateness of the last *Preview*. It turned out that the members handbook was a lot more of a handful than expected and held up the distribution of *Preview*.

In the process of putting the last couple of issues together, I learned a considerable amount about file formats and what's available for people to communicate electronically with each other. 'Don't worry I've got it in digital format' is an expression that needs to be taken with an aspirin.

There is virtually no restriction to formats that are suitable for *Preview* but I have a couple of suggestions to contributors. If all you have are words, then you may as well send them as plain text. They are reformatted into Quark at the printers and any original formatting is lost. Having said that, if your document contains embedded graphics, tables or equations it's a good idea to send hardcopy as well. I have noticed that different page margins, printers and font libraries can cause distortions.

Have you noticed what's on people's computer monitors nowadays? As often as not geoscientists will be looking at spreadsheets, word processing documents or some sort of presentation document. Geoscientists are beginning to know more about Microsoft than they do about Landmark or Geoquest.

We have received further encouraging feedback from our library subscribers who have been receiving *Preview*. The AMF is now on the lookout for a full set of *Preview* to catalogue the technical papers. The ASEG has only one 'master' copy that is held with the secretariat. Anyone that can help should contact Andrew Mutton or myself.

Regards
Henk van Paridon, Editor

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President's Piece

As the ASEG President for 1998/99 – from an election, I note, where there wasn't anyone else clamouring to nominate – I'd like to declare my main objective. This is to ensure the Society continues to grow, such that all members see a strong relevance to their professional geophysical development. The vision is a Society that has a long-term plan for where it's going, where those people in the silent majority with something to offer actually feel emboldened to contribute.

How close do you think the Society is to this version of Nirvana?

Stop for a moment and consider this: what proportion of members do you think are actively interested in the Society - what it can do for them and what they can do for it? Nearest correct guess can nominate for the next President!

I'd like to explore this in the coming months. To kick start this process, all State branches have been contacted regarding these issues. The underlying theme revolves around what the Society can do so that it continues to grow and be relevant to its members – in essence, how can we increase members' participation and regard for the Society? Over the years, it appears the ASEG Executive initiates and determines most/all of the direction of the Society – while the valuable skills and experience of people resident in other States are not sought out. It seems that too much is asked of too few – how can we share the load more evenly?

Let's throw some topics on the table for discussion:

Membership

Should we have a long-term plan for the Society's growth?

What is the Society – ie you not just the Executive - actively doing to gain additional members : Active, Corporate, and Student?

Publications

Are *Exploration Geophysics* and *Preview* relevant and interesting to you?

Should *Preview* be self funding (ie treat it like PESA News)?

Finances

Should the Executive and State Branches produce yearly budgets?

What long-term financial planning should the Society have to ensure its viability?

Research Foundation

What is the Foundation's place in the Society?

Is its current profile appropriate?

Conferences

Should we review the frequency of the conferences?

Should there be a permanent Secretariat?

Publicity/Representation

What public profile should the Society have?

How should the Society manage the myriad of calls for funding support from educational and other institutions?

How should the Society determine what line to take on bodies such as the Australian Geoscience Council?

Standing Committees

What should be the functions of the Standing Committees?

Are they providing a useful service?

The above are a lot - too many - topics and may scare off those with something to say. We can't expect instant critical analysis and answers, can we?

Could I suggest the main issues for discussion are membership and publications. To avoid a deafly silence on these issues, the following procedure is suggested to get a debate going.

It is recommended that each State nominate a person who will be the contact to co-ordinate discussion on a given issue. Ideally a number of people in each State will nominate for different topics, thus sharing the load. Views would be put to the informal Australia wide subcommittee. The benefits of this approach are that it will increase the decision-making participation of the Society and maintain continuity as the Executive moves from State to State.

Please contact your State branch to express your interest in these informal subcommittees. Alternatively, write a letter to *Preview*.

Please take this opportunity to make the Society stronger. Are there other matters that should be addressed by the Society? Feel free to be candid and criticize the areas where you think the Society needs improvement. Suggest initiatives to add value to the membership as a whole.

In closing, I note the ASEG Executive is beginning its third (and we expect final!) year in Brisbane. It has been an exciting and interesting time, capably directed last year by President Nick Sheard (and Henk van Paridon in the previous year). Both they and the rest of the Executive are thanked for their unstinting dedication and wisdom. I trust this year's Executive will continue at the same high standard.

Noll Moriarty
President

Executive Brief

You have a new look Federal Executive for what we envisage (hope?) is the final year for the executive in Brisbane. The AGM was held at the Spring Hill Hotel on 7 April and the new Executive team was elected unopposed!! Actually, we had an excellent turnout to the combined Federal and Queensland Branch AGM's with an entertaining talk given by Lindsay Horn from OCA on innovative exploration over a salt lake in South Australia.

Noll Moriaty has eagerly taken on the job as President and the outgoing President, Nick Sheard will remain on the Executive as a committee member. We have some new blood on the team namely the Treasurer, Grant Asser and two new committee members, Doug Price and Margot Whittall. The office bearers and committee members for this year are as follows:

President - Noll Moriarty
First Vice President - Andrew Mutton
Second Vice President - Wayne Stasinowsky
Hon Treasurer - Grant Asser
Hon Secretary - Robyn Scott
Preview Editor - Henk van Paridon
Committee - Nick Sheard, Koya Suto, Steve Hearn, Margot Whittall, Doug Price

Thanks must go to Nick for his contribution and enthusiasm and to Peter Fullagar for his commitment and tireless work keeping the accounts in order.

Noll is keen to spend this year consolidating and reviewing the work done by the Brisbane Executive over the past two years. To this end and to facilitate the change-over to a new executive, we are forming several sub-committees which will comprise not only members of the current Federal Executive, but include other interested members in the Society. In addition to reviewing current issues we hope to address some long term strategies such as membership growth plans, publicity and the profile of the society. More on this from Noll.

The Profit & Loss estimate for 1997, for the period 1/1/97–3/12/97 was presented at the AGM. The informal (un-audited) Federal income from all sources exceeded outlays by about $24,000. It should be noted that the profits from the Sydney conference are included in these figures. The Federal Budget provides an insight into the major income sources and burdens of the society and was published in the previous issue of Preview for those members interested.

Financial Status:

At 20 March 1998:

Cheque Account (0080 0044) balance =	$50,768
Cash management account (0079 1483) balance =	$81,115
Term deposit (CBA commercial bill) =	$158,000
Cash management account (00791475) balance =	$10,584
Term deposit (5008 4219) balance =	$40,000
Net cash:	~$340,737

Robyn Scott
Hon. Secretary

Personality Profiles

MARGOT WHITTALL
FEDERAL EXECUTIVE MEMBER

Margot Whittall is a geophysicist with BHP Exploration in Brisbane. She is a recent graduate from the University of WA where she completed a B.Sc. Hons in 1996. Prior to accepting a job with BHP in 1997 Margot did some vacation work with BHP (Perth) and Pasminco (Broken Hill). At BHP her work domain is the NW Queensland area.

A born and bred sandgroper she is finding the local football code a little strange. Apart from following the AFL her interests include netball, tennis and swimming.

Margot's willingness to be involved in ASEG matters is welcomed by us all.

DOUG PRICE
FEDERAL EXECUTIVE MEMBER

Doug graduated from the University of Adelaide in 1970, B.Sc(Hons) at the time of the great nickel crash and into a difficult job market. However he rates the current downturn as the worst he has experienced.

He began his career in 1971 with BHP in Melbourne. Since then he has explored for a variety of commodities including porphyry copper, coal, fluorite, gold, tin, molybdenum, diamonds and base metals. As well as stints as a geologist, Doug worked for a three year period as grade control officer and as an ore reserves officer in a mine environment.

For the last 15 years he has been actively involved in the application of EM techniques and, more recently, concentrating on airborne EM. His current roles centre on research and application of geophysical techniques and the management of computing environments.

Within the FE Doug will be acting as liaison officer with kindred societies including the AGE, a role that he will fashion himself.

Preview Deadlines – 1998

August	**July 15**
October	**September 15**
December	**November 15**

Calendar Clips

1998

August 30 - September 2
West Australian Basins Symposium, Perth.

September 13-18
SEG Conference, New Orleans.

October 15-16
Cooper Basin Symposium, Adelaide.

October 28-30
Gas Habitats of SE Asia &Australasia, Jakarta.

November 8-12
Australian Society of Exploration Geophysicists 13th International Conference and Exhibition. Hobart, Tasmania, Australia.

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

1999

April 21-23
Murray Basin Conference, Mildura

Details and more events on Page 36.

Society Briefs

Membership Directory

The revamped ASEG Members Directory was enclosed with the previous edition of *Preview*. Some important changes have been made to the new directory, including geographical as well as alphabetical listings, a section for special group interest listings, and an expanded advertising section to allow all members wishing to advertise their business the opportunity to include from business card up to full-page advertisements.

We hope that the new directory will be an even more valuable source of information and contact reference than its predecessor, which was one of the Society's most used publications. The ASEG would welcome any feedback on the new format and suggestions for improvement in future years.

If you notice any errors in the handbook please advise the secretariat. In particular many of the email addresses look suspicious.

As part of the publication of the Members Directory, it is worthwhile noting some interesting trends in the Society's membership since 1995. The overall membership has increased in this period by about 15% (total number now just under 1,400). Please note that the total membership number indicated in the booklet is incorrect due to a typographical error.

The increase in Australia has been 10% (to about 1,150 total), with Western Australia again having the greatest improvement of 22% (now 340 members). Other states with increasing membership are Queensland (13%), ACT (12%) and Victoria (10%). Membership has remained fairly static in the other states.

The major proportional change in ASEG membership has been from overseas, where an increase of 46% since 1995 has been recorded (total now about 230). Canada (77%) and USA (66%) have provided the bulk of these new members, with total membership from North America now about 100. The biggest increases in membership (albeit based on a small starting number) were in Chile and Indonesia, where membership has doubled since 1995.

The increasing awareness of the ASEG and its activities and publications, and the reputation of Australian geophysics generally, are no doubt contributing to this encouraging level of interest from overseas.

There is a good proportion of student members (12% of total membership) within the Society, reflecting the potential of the profession to meet future needs.

There is still much potential for continued growth of the ASEG and its membership, as evidenced by the number of non-members who regularly attend the ASEG conferences. This continuing growth in membership is the sign of a healthy Society and a healthy geophysics industry.

Andrew Mutton

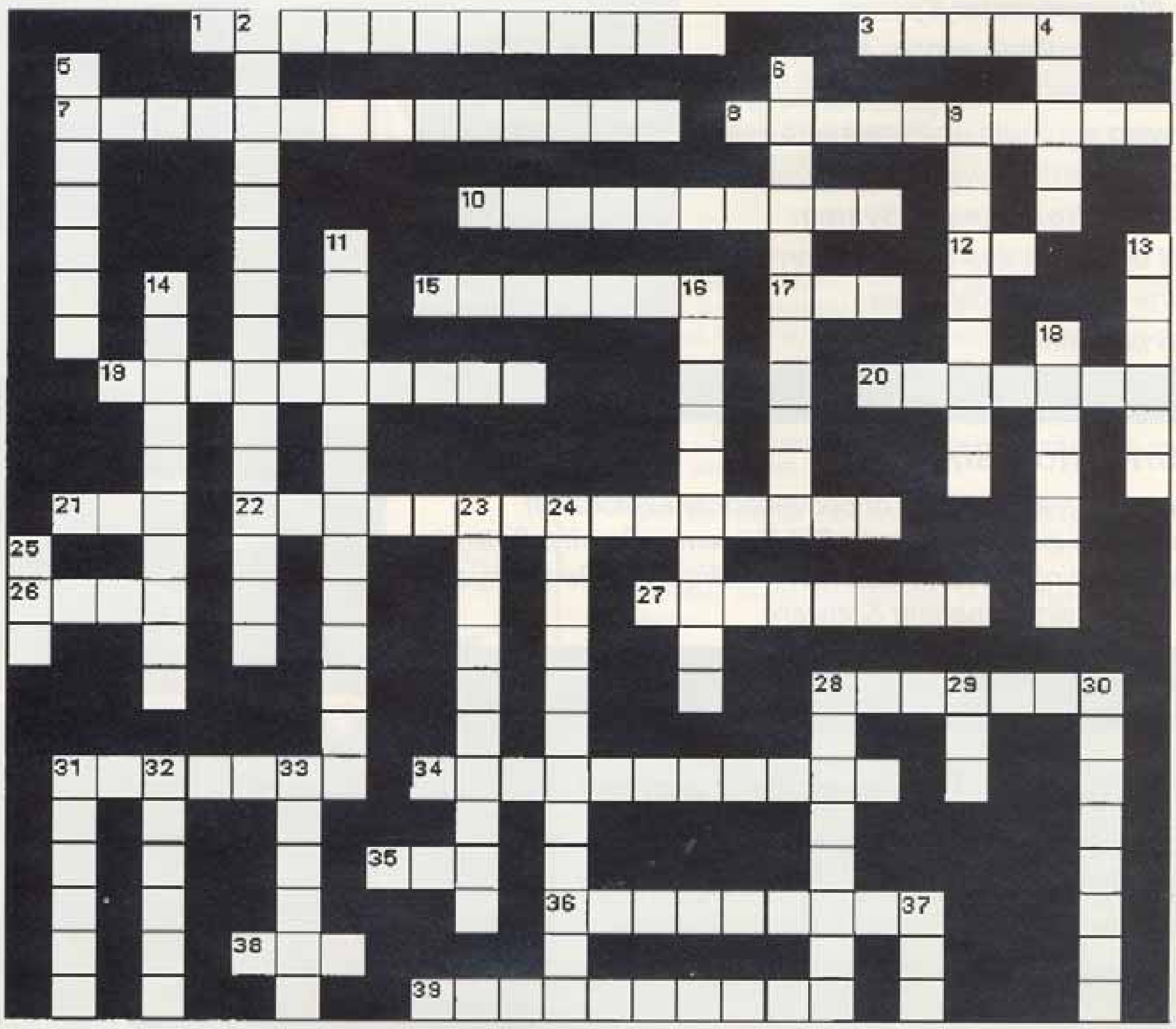
Doodlebug Doodling

ACROSS

1 Instrument for measuring magnetic field strength (12)
3 Hot melt (5)
7 Device for detecting scintillations (14)
8 Change in direction of seismic ray (10)
10 Temperature at which material loses its ability to retain magnetism (10)
12 Decibel (2)
15 Measuring physical properties around a borehole (7)
17 Seismic transform (3)
19 Monochromatic light has but one of these (10)
20 The electrode at which electrons are taken up (7)
21 Unit of electrical resistance (3)
22 Rate of temperature increase with depth (7,8)
26 Detonation of seismic energy (4)
27 Pore volume per unit gross volume (8)
28 Offshore seismic source (7)
31 A ground position at which a geophysical instrument is set up for an observation (7)
34 Portion of a plane mainly responsible for generating reflector (7,4)
35 Seismic method now common (3)
36 Body becomes magnetised by placing it in a magnetic field (9)
38 Method preferred by transients. (3)
39 Hollywood, making the earth move. (10)

DOWN

2 Correlation of a waveform with itself (15)
4 Frequency ambiguity resulting from the sampling process (5)
5 Tidal wave (7)
6 Dipping zone containing earthquake hypocentres (7,4)
9 A body within which electrical current can flow (9)
11 Multiple reflection in a layer (13)
13 Arrangement of geophone groups in relation to source point (6)
14 Instrument for measuring variations in gravitational attraction (10)
16 Whatever happened to this ? (10)
18 A high-level computer language (7)
23 Variation of a physical property depending on the direction in which it is measured (10)
24 One who studies the physical properties of the Earth (11)
25 You can walkaway from this (3)
28 Fold in stratified rocks in which rocks dip toward central depression (8)
29 Erasable memory (3)
30 Part of acquisition system which senses the information signal (8)
31 Supertidal to semiarid environment, often characterised by evaporite-salt, and tidal-flood deposits (6)
32 A seismic source which injects a bubble (3,3)
33 Amplitude varies with this (6)
37 Moveout that's not dipping (3)



ASEG Branch News

Queensland

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The Queensland Branch AGM was held on April 7th 1998. The following committee was elected:

President: Andrew Davids
Vice President: Troy Peters
Secretary: Kathlene Oliver
Treasurer: Grant Asser
Committee: Gary Fallon, Natasha Hendrick, Damian Kelly, Rick Smith, Wendy Watkins

In addition to the AGM proceedings, Lindsay Horn from Oil Company of Australia gave an interesting presentation on seismic surveying using hovercraft.

The new committee met on the 21st April, to plan the year ahead. An exciting year is planned, with eight technical meetings, the Golf Day on Wednesday 15th July, the SEG Distinguished Instructor Short Course on July 10th, a student BBQ, and a Short Course on a Mineral Exploration related topic.

The next technical meeting is scheduled for Wednesday the 3rd of June. There will be two speakers. Nick Sheard, MIM, will present "The effectiveness of Technology in Exploration - a Base Metal Perspective". The second speaker, Grant Roberts of Groundsearch, will present "Applications of Radio Imaging and Ground Radar to Mine Development". This meeting will be held at the Spring Hill Hotel.

Andrew Davids
Branch President

New South Wales

Contact details:

President: Timothy Pippett
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The NSW Branch continues to have regular meetings on the third Wednesday of each month with the speaker at the last meetings being Dr. Bob Whiteley on 'Reducing Geotechnical Risk with Site Characterisation Geophysics'.

The June meeting, to be held on 17 June, will be on 'Acquiring and Processing Regional Gravity Data'. There will be two speakers, Reg Court of Surtec Geosurveys on the GPS component of gravity surveys and John Peacock on road and airborne collection of gravity data.

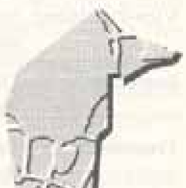
The July meeting (15 July) will be on 'Recent Experiences with Helicopter EM' from Geoterrex Dighem and Geo Instruments (on the Hummingbird).

The NSW Branch has also been involved in the discussions regarding a National Network for Earth Science and Engineering Learning. The aim of this network is to give teachers skills in the earth sciences to pass onto students, therefore encourage them in the earth science field. The network would also be involved in training students through interactive 'learning laboratory' education opportunities. The ASEG has been asked to support this concept both financially and with other assistance, if anybody is interested, please give Timothy Pippett a call.

Please remember, if you are in Sydney on the third Wednesday of a month, there will be an ASEG meeting held at the Rugby Club, Rugby Place (down near Circular Quay).

Timothy Pippett
NSW Branch President

ACT



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Treasurer: Bob Groves (08) 9370 1273/Fax: (08) 9370 1273

South Australia

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Fax: (03) 9421 1099
Email: (new address)

Secretary: Dave Boothroyd
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Treasurer:	**David Gamble** dga@acacia.com.au	**Acacia**	03 9684 4925 03 9696 9977
Committee:	**Henry Cao** hcao@melbourne.wireline.slb.com	**Schlumberger**	03 9697 1247 03 9690 0309
	Geoff Dunn Geoff Dunn <gippyboy@rocketmail.com>	**Schlumberger**	03 9478 3415
	Jarrod Dunne Jarrod.C.Dunne@shell.com.au	**Shell**	03 9666 8103 03 9667 2099
	Alan Hogan Hogans@bigpond.com		03 9499 8839
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	Neil Hughes hughesn@pasminco.com.au	**Pasminco**	03 9439 6521
	Roger Hurren r.hurren@ugrad.unimelb.edu.au	**(Student)**	
	Geoff Pettifer g.pettifer@geo-eng.com.au	**Geo-Eng**	03 5133 9511 03 5133 9579

ASEG RF – Donations

ASEG RESEARCH FOUNDATION

Post to: Treasurer, ASEG Research Foundation
Peter Priest, Ste 3, 17 Hackney Rd,
Hackney SA 5069

NAME: ....

....

COMPANY: ....

....

ADDRESS: (for receipt purposes)

....

....

....

AMOUNT OF DONATION: $ ....

Do not detach – To be completed by ASEG Research Foundation

ASEG RESEARCH FOUNDATION

Receipt of donation

Received from ....

....

The Sum of ....

....

dollars being a donation to the ASEG RESEARCH FOUNDATION

$ ....

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

Signed: ....

(This form should be retained for tax purposes)

ASEG Research Foundation

The idea of forming a research foundation to address the decline in student enrolments in exploration geophysics took root in early 1988. With the help of a number of people and in particular Bob Smith the ASEG Research Foundation (ASEG RF) become a reality in September 1989, with the first projects supported in 1990. Bob Smith was the inaugural Chairman of the ASEG RF. The overall aim of the ASEG RF is to attract high caliber students into our profession and thus ensure a future supply of talented, highly skilled, geophysicists for industry.

The ASEG RF achieves its aim by promoting research in geophysics specifically by providing research grants at the B.Sc.(Hons.) and M.Sc level and Ph.D. projects. The grants are paid directly to the relevant University departments to cover field or laboratory expenses associated with the project. Grants are not provided as student scholarships in order to preserve the tax deductibility status of donations.

In the past companies have made annual contributions of up to $5,000 to the Research Foundation. The ASEG RF has recently negotiated a more formal funding mechanism with the ASEG. The ASEG will donate $40,000 per annum, as well as a proportion of the annual corporate membership fees. Direct donations from companies will continue to be encouraged and sought, however, particularly from those who are not members of the ASEG. These arrangements will assist in developing a more sustainable financial base for the RF.

ASEG members from mining and petroleum as well as from academia serve on an honorary basis on the ASEG RF Committee. No ASEG RF funds are used for operating expenses, all administrative costs are borne by the committee members. The office bearers and the currently active committee members are as follows:

Office Bearers

Chairman: Mr. Joe Cucuzza, Australian Mineral Industries Research Association Limited

Vice-Chairman: Mr. Nigel Hungerford, Consultant

Secretary: Mr. Doug Roberts, Boral Energy Resources Limited

Treasurer: Mr. Peter Priest, Chartered Accountant

Immediate past-Chairman: Mr. Bob Smith, Riotinto Exploration

Committee members: Mr Bob Smith, Riotinto exploration; Prof. David Boyd, The University of Adelaide; Mr. John Denham, Consultant; Dr. Mike Dentith, The University of W.A.; Prof. Don W. Emerson, Systems Exploration Pty Ltd; Dr Steven Hearn, Digicon, U of Q; Mr Nigel J Fisher, Consultant; Mr. Wes Jamieson, Consultant; Dr. David King, Lowell Petroleum; Mr Gert Landerweerd, Woodside Offshore Petroleum Pty Ltd; Mr. Steve Mudge, RGC Exploration; Mr. Mike J. Sayers, West Australian Petroleum Pty. Limited (WAPET); Mr. Nick Sheard, M.I.M. Exploration Pty Ltd.; Dr. Norm Uren, Curtin University of Technology; Mr. Peter K Williams, Resolute Limited

Mining Sub-Committee: Mr. Nigel Hungerford; Mr. Steve Mudge; Mr. Peter K Williams; Mr. Nick Sheard; Mr. Dick Irvine; Dr. Mike Dentith

Petroleum Sub-Committee: Mr. John Denham; Mr. Wes Jamieson; Dr. David King; Mr. Doug C. Roberts; Mr. Gert Landeweerd; Mr. Mike J. Sayers

Applications for grants are invited from Institutions around September of each year. Second round applications are also sought in February. The person responsible to supervise the student submits a two to three page summary of the project. The application must detail the aims of the project, degree level, and the nature of the expenditure. It is not necessary when submitting an application for a student to be identified. However, successful Institutions will need to submit the student's CV and approved by the ASEG RF before the grant is paid. Project selection is made by sub-committee of specialists on the basis of the project's quality, relevance to either mineral or petroleum exploration or potential to impact on exploration technology or know-how. In this way we support quality research projects in exploration geophysics of interest to a wide cross-section of the mineral and petroleum industry.

For each project, a liaison officer is appointed, who is a member of ASEG (but not necessarily of the ASEG RF Committee), and who monitors the progress of the project and report to the Committee. On the completion of the project, a copy of the thesis is forwarded to the ASEG RF. Theses are stored at the Australian Mineral Foundation library in Adelaide and are accessible through the library. Furthermore, the ASEG RF requires that an abstract is published in "Preview" and any publication as a paper is first submitted to "Exploration Geophysics" at the completion of the project. The supervisor is normally expected to co-author the publication and is responsible for submission.

The project supervisor is also responsible for drawing the grant funds as required and for managing the expenditure. The supervisor ensures that a research report and financial reconciliation is provided to the ASEG RF on completion (or cessation) of the project. Grant funds must be accounted for and, if not used, returned to the ASEG RF.

The following summarises the status of current projects as well as those offered in the 1st and 2nd rounds for 1998.

For 1998 - 1st round

Univ Tas – Dr M Roach – Hons – 1 Year.
Geophysical mapping for gold exploration in NE Tasmania

Univ WA – Dr A Endres – PhD – 3 Year.
Geophysical Characterization of Aquifer Heterogeneity & Hydraulic Properties

Univ Melb – Dr L Thomas – Hons – 1 Year.
Detailed magnetization properties of recent basalts

2nd Round offers currently being made - 1998

Curtin Univ – Dr Brian Evans – Hons – 1 Year.
The effects of stress on seismic imaging of geology

Univ WA – Dr R List – PhD – 3 Year.
Joint Inversion of 3D IP & MT data incorporating EM coupling effect

Macquarie U – Dr K Gohl – Hons – 1 Year.
High resolution seismic imaging of prospective mineralisation zones
Curtin Univ – Dr P Okoye/ N Uren – PhD – 1 Year.
Determination of velocity field and anisotropic elastic parameters in layered transversely isotropic media

A number of policy changes are foreshadowed that will streamline not only the administration of the ASEG RF but will also make it easier for supervisors in applying for grants. These changes will include eligible expenditure, procedures for making applications, the frequency of applications. The ASEG RF Committee will be formulating these and other policies at the ASDEG Conference in November. The aim is to raise the profile of the ASEG RF.

Joe Cucuzza
Chairman - ASEG Research Foundation

Book Review

Time-Lapse Seismic in Reservoir Management

Ian Jack
(1998 Distinguished Instructor Short Course)

This volume represents course notes for a short course presented by the author on the subject of time lapse seismic. The course, which is sponsored by the SEG, will be given in Australia in July .

The volume comprises two sections - course notes and case histories. The course notes commence with a discussion of the reasons for using time lapse seismic monitoring and a summary of existing methods of monitoring fluid flow. This is followed by a section explaining the things that can change with time, including reservoir properties such as pore pressure and pore fluids, and seismic observables such as time, amplitude, velocity, frequency and phase. A chapter on rock physics explains the seismic changes which might be observed as a result of changes in reservoir properties, with examples for different rock types. The repeatability requirements of seismic data are emphasised, with examples illustrating the impact of relatively small differences in processing and acquisition parameters, and timing and positioning discrepancies. The notes conclude with a short discussion on processing for time-lapse seismic, and some pointers on how to achieve a successful time-lapse survey.

The style of the course notes is concise, with points being demonstrated by comprehensive figures rather than wordy explanation. The figures are clear and well–presented, being colour reproductions of the course visuals. No attempt is made at in-depth treatment of any of the subject material in the notes, though there is presumably scope to expand on issues during the course. References are also provided.

The second and somewhat larger section of the volume consists of 12 case histories. These case histories, which are drawn from a variety of sources, include:

- An ARCO report on the successful seismic monitoring of an in-situ combustion EOR process at the Holt Sand Unit in Texas
- Papers (previously published in TLE and Preview) on seismic monitoring of the Duri steamflood in Indonesia
- An Imperial Oil/Exxon paper on the successful use of 3D seismic monitoring to discriminate heated reservoir from unheated reservoir at Cold Lake
- A report on time-lapse seismic analysis of the North Sea Fulmar Field, where the effects of water influx and pressure decline were clearly shown by impedance differences on seismic data shot before and after 10 years of production
- A Colorado School of Mines report on a time-lapse multicomponent (4-D, 3-C) seismic survey undertaken to monitor CO2 injection at the Vacuum Field, New Mexico
- A BP paper on the use of seismic time-lapse analysis to aid reservoir management at the Magnus Field

The case histories, as always, provide valuable insights into the methodology employed and results achieved for time-lapse seismic projects conducted by others in the industry. They illustrate many of the points made in the course, and form a very useful addition to the reference material.

In summary these course notes, while not an in-depth treatment of the subject, provide a useful overview of time-lapse seismic, highlighting key issues and presenting options. It is recommended for anyone considering the application of time-lapse seismic to his or her reservoir problem.

The book will be available from the SEG bookshop for $US49 in September. Ian Jack was interviewd in the March 1998 edition of First Break as a lead up to the presentation of his course at the EAGE conference.

Jenny Bauer
Boral Energy

Sneak Preview

- *Radiometrics Workshop Roundup*
- *3D Imaging using vertical Cable Technology*
- *Conference Edition*
- *Guest editors to decide!!*

New Exploration Initiative

Northern Territory Minister for Resource Development

Mining sector production figures show an increasing trend. 1996/97 saw an 11% surge in the value of production. Key players and significant contributors to this increase are the world class deposits at Nabalco (bauxite), Gemco (manganese), Ranger (uranium) and Mcarthur River (lead-zinc-silver).

The key to the future of the mining sector lies in boosting exploration.

Despite the impact of Native Title uncertainty on the issue of exploration licenses on leasehold land since the Wik decision in December 1996, exploration for minerals has exceeded $90M in the Territory for each of the last two years. A little less than 50% of this represented exploration for new mineral deposits.

In the 1997/98 budget a new exploration initiative was announced involving an additional $1m in the financial year and a further $1m next year to fund airborne geophysical surveys for release to the mining exploration industry.

Airborne geophysical surveys are an essential tool in understanding the sub-surface geology of large areas. The information is used by mineral explorers to determine sites which are prospective for mineral deposits and which therefore are the best targets for further exploration programs.

The magnetic and radiometric information is gathered from 60 metres above the ground, along lines 400 metres apart. The data is then processed and made available to industry in hard-copy and digital formats.

In technical terms, digital data will be available in line and gridded formats for magnetics, radiometrics, and ground elevation. Contour maps for radiometrics and magnetics, as well as stacked profiles for magnetics will be available in hard copy. Vector and plot files will also be available.

The 1997/98 airborne work covered about thirty-four 1:100,000 scale map sheets over the Alcoota–Alice Springs, the Napperby–Hermannsburg, and the Birrindudu–Tanami 1:250,000 map sheets' areas. Data acquisition has been completed and results will be released to industry this month. The 1998/99 flying will commence mid year.

The Northern Territory Government recognizes, as one of the prerequisites of company exploration programs, the necessity to provide regional geophysical data in key areas to attract exploration in a highly competitive world market.

Australian mining companies are now placing around 40% of their exploration efforts overseas and several other Australian states have developed exploration initiatives to attract exploration by the collection and release of modern geophysical data. The Northern Territory needs to match and better such initiatives or we will face a decline in exploration investment.

There is no doubt that the Territory has high potential for mineral commodities but their discovery is directly dependent on the level of exploration. Explorers can be attracted to the Territory principally by the availability of quality geological data and effective promotion.

The programs of the Department of Mines and Energy are directed at attracting mineral exploration. These have been reviewed and as a result, the Department will be:

- Developing new programs that strengthen geophysical data collection and data presentation;
- Developing new promotional programs for Territory mining and petroleum exploration; and
- Further development of its information databases using advanced technology systems.

Experience elsewhere shows that increasing Geological Survey initiatives leads to more mineral and petroleum exploration, enhancing the rate of new discoveries. New discoveries provide the basis for new mines. New sources of energy enhance security and competition.

Claire Bell
NT Dept Mines & Energy

Major improvement in 3D seismic imaging expanding North Sea opportunities

Workstation interpretive depth imaging solves gas cloud problem

Thad Dunbar, Amoco (U.K.) Exploration Company, London, England
Mark Lance, Landmark Graphics Corporation, Denver, Colorado

The global industry today continues to push E&P activities into areas of increasing complexity. Not only must asset teams make more complex inferences about subsurface geology; they must also support more complex business processes. The rising cost and demand for seismic vessels and drilling rigs has created an urgent need to compress cycle times at every stage of exploration and exploitation. With projections that equipment and personnel shortages will continue, oil and gas companies are more focused than ever on the economic value of making the right technical and business decisions, *fast!*

Inspiring new play concepts and fueling ongoing exploitation projects in areas of great geologic complexity demand that geoscientists employ the most advanced geophysical technology.

For years, resolving subsurface interpretations in subsalt, deepwater and other difficult areas has been possible using sophisticated 3D seismic velocity modeling and prestack depth imaging technologies. However, business constraints often prohibited more routine use of these tools. Geoscientists were faced with the formidable task of balancing the accuracy of the seismic image and resulting earth model with the actual time and cost required to create them.

3-D velocity

Today, advances in integrated exploration software, visualization, and computing technology are enabling oil companies to realize the practical value of 3D velocity modeling and depth imaging, when they are used in appropriate integrated workflows.

Some years ago, Amoco (UK) brought onstream a development project in a stratigraphically and structurally complex part of the UK sector of the North Sea. As reservoir pressure declines over time, additional infill drilling is required in the near term to maintain production rates, meet sales contract obligations, and capture incremental reserves. In addition to the planned drilling, other exploration targets have been identified below the producing formation. These deeper targets could be drilled at the same time and if successful, might reduce the number of infill wells.

The current producing field consists of deep marine Paleocene turbidites. Mid-Miocene salt intrusion uplifted the sands, creating four-way closure and the field trap. The deeper targets have much greater structural and stratigraphic complexity, translating to greater risk than the infill wells. One target is the Upper Jurassic sand.

These shallow marine sands were deposited into structural lows (rifts) created by a period of Jurassic extension. The rifts were also zones of weakness resulting in preferential zones of salt uplift. Later mid-Miocene salt movement inverted the structure, creating the trap for this target. A second potential target is the fractured Cretaceous chalk. The same late salt movement also uplifted and flexed the relatively brittle overlying chalk, creating fracture porosity with four-way closure.

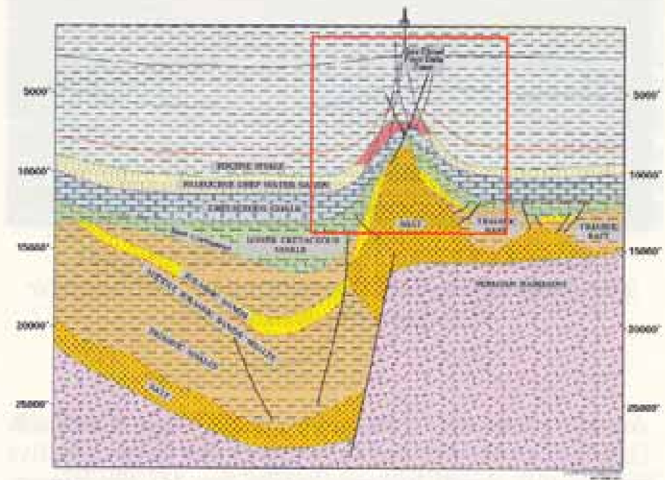

Figure 1. Schematic cross section of the regional geology and the project area outined in red.

Gas-charged zones

A gas-charged zone that developed over parts of the salt structure is largely responsible for the 3D seismic imaging problem. The velocity contrast of the gas cloud hinders imaging of both the producing horizon and deeper potential. Imaging the 3D seismic data within and below the gas cloud presents a challenge that must be overcome before recommending the infill-drilling plan to meet production obligations.

To solve the imaging problem Amoco considered two key technologies, prestack depth migration and four-component (4C) ocean bottom cable (OBC) seismic acquisition. Both technologies have been successfully used to improve the image of seismic reflectors within a gas cloud.

The time and cost of acquiring OBC data, plus additional processing and interpretation cycle time, posed a risk to meeting Amoco's business milestones. Due to the lead time required for contracting OBC vessels, Amoco had to make a decision quickly.

Given the complexity of the geology and the relative newness of OBC technology, Amoco geoscientists believed prestack depth migration offered a better chance of imaging target reflectors within the available time.

Figure 2. The gas-charged zone (center of diagram) that developed over the salt structure is largely responsible for the poor 3D seismic imaging.

Amoco partnered with geoscientists from Landmark Graphics to design and implement the most effective interpretive depth imaging workflows for the project. The objective was to improve the seismic image within and beneath the gas cloud while meeting timelines dictated by Amoco's business situation.

Integrated Workflow Solutions

For prestack depth imaging to be successful, the project team needed to develop an accurate velocity model for the key geologic intervals and particularly the troublesome gas-charged zone. Amoco had already launched a major 3D prestack depth migration project covering 500 square kilometers to support ongoing exploration in the license area. But velocity modeling consumes a large percentage of overall cycle time, so this depth migration project was scaled down. A target-oriented volume, focused only on the area of the gas cloud and two deeper targets, was selected.

The Amoco/Landmark team then designed a practical workflow that would optimize the attributes of integrated software and a networked workstation environment. Key attributes of the integrated solution included:

- flexible workflows that matched appropriate technology to geologic complexity
- integrated data access among interpretation, modeling, and processing domains
- 3D visualization and animated analysis graphics
- symmetric multi-processor computing architecture and network communication.

The well database, interpretation system and the velocity modeling tools were run on a dual-headed SGI Octane with R10000 CPU and SI/SSI graphics. 3D prestack depth imaging was executed on an eight-node SGI Power Challenge with two gigabytes of shared memory. The two systems were connected by a switched 10BaseT network, allowing rapid data transfer between team members.

Building the Velocity Model

To keep the velocity modeling project on schedule, appropriate technologies were applied to each interval depending on geologic/velocity complexity. In a three-phase approach, less rigorous and more rapid modeling techniques were used in the shallow, simpler portion of the model. More sophisticated and time-consuming technologies were used only in intervals requiring greater accuracy.

- **Phase One: Vertical Depth Stretch.** The initial interval velocity field was created by converting stacking velocities to depth interval velocities using a horizon-constrained Dix conversion. The original poststack time-migrated data and interpreted horizons were vertically stretched to depth. The accuracy of the depth conversion was evaluated in two ways.

Forward ray tracing provided a qualitative validation. In 3D views of the depth-converted seismic data and velocity field, image rays were vertical from the surface of the model to the top of the current producing horizon. Below this horizon and around the gas cloud, image rays were noticeably bending. Vertical depth conversion was not valid due to geologic complexity.

The model was further validated quantitatively. A comparison of well tops with depth-converted seismic revealed depth errors averaging nine percent at the top of the producing formation. Both validation methods indicated the initial velocity model was unacceptable and more accurate modeling techniques would be required.

- **Phase Two: Coherency Inversion and Map Migration.** To improve the accuracy of both the interval velocity and the structural position of reflectors in the depth model, two additional technologies were brought into the workflow. 3D common-midpoint (CMP) coherency inversion analysis measured lateral velocity changes between the sparse well control. The result was a gridded velocity map for each interval. Then the interpreted time horizon for each interval was

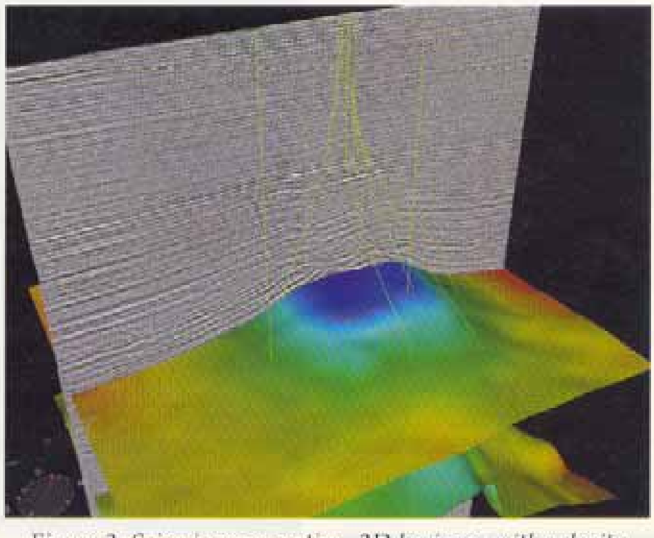

Figure 3. Seismic cross section, 3D horizons with velocity overlay derived from ray traced based methods, and wellbore paths to the producing horizon.

converted to depth using map migration, a more accurate technique than simple vertical stretching.

Validating the model at known well locations showed that the previous nine percent depth error had been reduced to approximately three percent. Below the chalk, however, coherency inversion produced velocities that were inconsistent with the interpreter's experience. The rapid velocity contrast in the gas-charged zone was apparently responsible. To derive velocities below the top of chalk, a more rigorous method was necessary.

- **Phase Three: Global Tomographic Inversion.** Properly imaging target horizons below the chalk required even more sophisticated technology. The team needed to analyze the scope of the velocity problem and determine if tomographic inversion and prestack depth migration could indeed image the key horizons before committing time and resources to 3D prestack depth migration on the full target volume. To save time, the team targeted a single line from the 3D survey, then performed global tomographic inversion and prestack depth migration on it. Global tomographic inversion was perfectly suited to resolve the combined adverse effects of the gas cloud, the chalk layer, and the salt.

The resulting depth image was a clear improvement over the original time migration. The team proceeded to complete the full 3D velocity model. In a target-oriented fashion, the velocity field below the chalk was updated using tomographic inversion along key lines then interpolated along structure to create the 3D model. Next, phase two results for the upper section were merged with phase three updates for the deeper, more complex portion of the data.

Rapid improvements in the accuracy of the velocity model were due, in part, to the integrated interpretation and analysis environment. Direct access to shared data by the interpretation system, well database and modeling tools significantly reduced cycle time by eliminating data reformatting and intermediate tape storage or transfer. Already, collaboration between interpreter and processor was paying off. The interpretive approach ensured that results from each phase were aligned with current knowledge of the regional geology and play concept.

Prestack Depth Migration

Expanding the target-oriented approach which had proven so effective, the team 3D prestack depth migrated every 20th line of the survey using the updated velocity model. They quickly verified that coherency inversion had produced an accurate velocity solution down to the chalk, and that tomographic inversion had accurately resolved velocities in the deeper section. Both within and beneath the gas cloud, structures were better imaged. These results gave the team confidence to proceed with 3D prestack depth migration of the full target volume.

Interpretation of the prestack depth migration is currently underway. With the improved imaging, the infill wells can be better located, reserves can be more effectively exploited and the need for the 4C OBC data will probably be eliminated. The deeper exploration targets can also be evaluated better with the new depth data. If successful, these targets will not only provide new reserves but may reduce the number of infill wells.

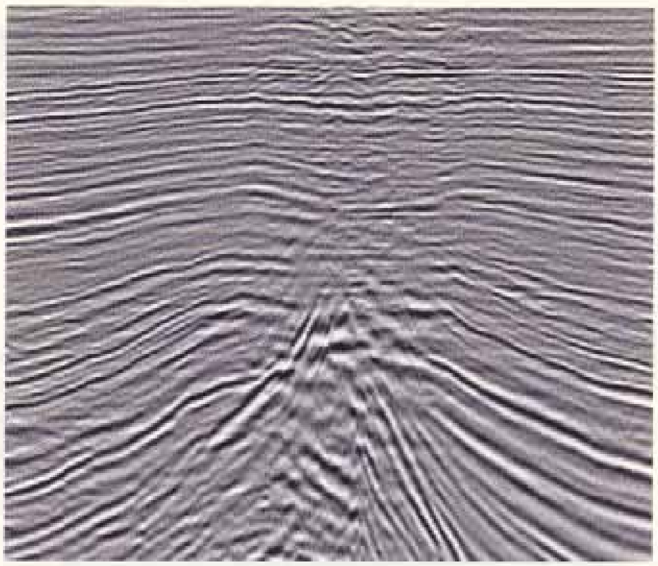

Figure 4. 3D prestack depth imaging has improved the resolution of events through the gas cloud and around the salt intrusion.

Conclusion

Historically interpretation, modeling, and seismic imaging have taken place in isolation, stretching out cycle times. In this complex North Sea setting, an interpretive, target-oriented approach resulted in more accurate depth imaging in far less time. The integrated environment supported a collective effort that crossed traditional disciplines. Integrated applications enabled flexible workflows in which velocity data, interpreted horizons, and seismic data could be shared between team members without data reformatting or intermediate data storage.

3D prestack depth migration is becoming a critical tool for evaluating exploration and exploitation opportunities. Its greatest value is in areas of complex structure and rapidly varying velocities. Advances in computing power and software integration are making depth imaging more accessible to asset teams than ever before. Oil and gas companies that take advantage of these sophisticated technologies will achieve better technical solutions and make better business decisions, even under today's challenging conditions.

Acknowledgements

We would like to thank Amoco (U.K.) Exploration Company, Amerada Hess Ltd, and BG plc for allowing us to publish the results of this project. Special thanks also to Buzz Davis and Gregg Hofland of Landmark for their modeling and depth imaging expertise, and their technical contributions to this article.

Free Software in Education: A case study of CWP/SU: Seismic Un*x

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A silent revolution has been altering the way universities work with computer technology. This is the revolution of free software, a sweeping movement that has been accelerated by the ease of communication provided by the Internet. I am fortunate to be a participant in one small part of this revolution that relates to seismic processing and education in geophysics.

In this article I will tell you about a free software package that is dedicated to seismic research and processing tasks. It is called CWP/SU: Seismic Un*x or simply SU and was developed at the Center for Wave Phenomena at the Colorado School of Mines. In addition to being a poor man's seismic processing package, SU is a valuable educational tool that is seeing increased use in universi-ties, filling many important niches in geophysics graduate and under-graduate education.

What is Seismic Un*x?

The short answer is that SU is a package that gives the user of any computer with a UNIX-like (UNIX is a trade name of AT&T) operating system an instant seismic research, educational, and processing environment.

The package is distributed as full source code under a free software license, permitting people to use the package in any way they choose, as long as they don't directly resell it or try to deny access to the package to others in any way. The availability of the source code gives users the power to alter and extend its capabilities and to use parts of the code in the development of their own applications, including commercial ones. These attributes make SU unique among seismic processing packages.

SU has been in public release since September 1992 and has more than 900 known installations in at least 37 countries. Since that time, the package has doubled in size, and has been altered and expanded almost beyond recognition from its first public release (Figure 1).

Geophysicists, earthquake seismologists, environmental engineers, software developers, government researchers, and even nongeophysicists working on wave-related problems use SU.

History of SU

By examining the history of Seismic Unix, we can see that the development of a successful free software package is an evolutionary process. While SU is known as a CSM product, the actual beginning of the package was at John Claerbout's Stanford Exploration Project (SEP), circa 1981.

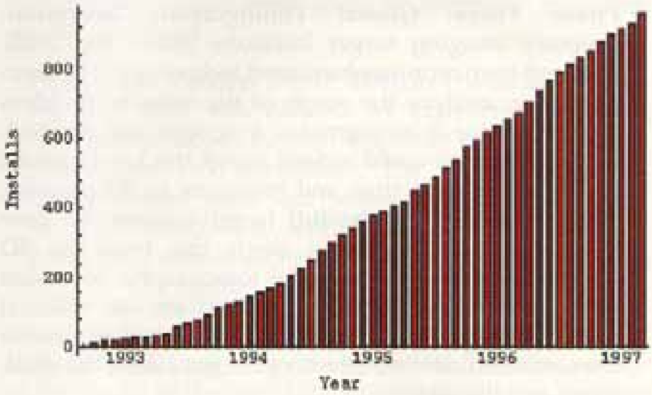

Figure 1. Cumulative installations of SU.

Two of Claerbout's students, Einar Kjartansson, now with the Orkustofnun (National Energ y Authority) in Reykjavik, Iceland, and Shuki Ronen, now with Geco-Prakla, wrote the first draft of a package called SY, when they were graduate students at SEP. Ronen brought this work to CSM's Center for Wave Phenomena (CWP) when he began a two-year stay in 1983. The original package was a collection of library routines, written in C, that would give the user access to the data and header fields of a SEG-Y dataset.

Jack Cohen of CWP, working with Ronen, renamed the package SU and began transforming it into a supportable, expandable, and exportable product. Christopher Liner, now a professor at the University of Tulsa, and an Assistant Editor of GEOPHYSICS, was an early contributor to SU while a graduate student at CWP.

Liner's broad knowledge of exploration seismology and seismic data processing continues to influence the SU coding philosophy to the p resent day. Originally, SU was intended to be a rough and ready research code development and processing environment for the computer-literate geophysicist, but it still was not sufficiently user-friendly for distribution to the public at large.

The major groundwork for the modern form of the package was laid by Dave Hale, now of Landmark Graphics. Hale wrote several of the "heavy duty" processing codes as well as the majority of the core scientific and graphics libraries. His greatest contribution was the adoption of ANSI (American National Standards Institute) C as the language standard for the package. Hale's commitment to well-researched and carefully documented C-coding helped make our package a valuable example of software management and coding style for computer scientists – one of the many hats that geophysicists wear these days. Prior to 1992, SU was still

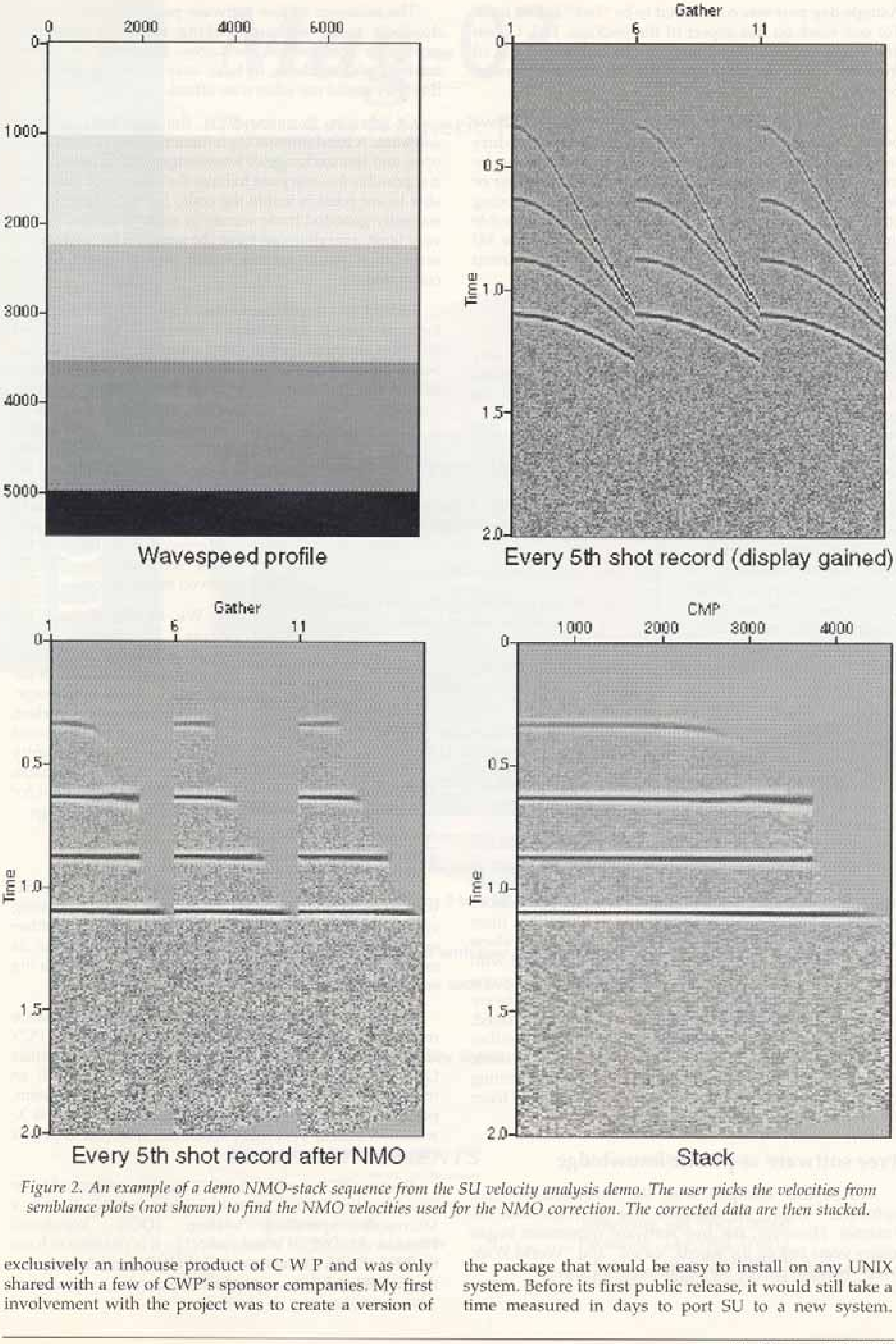

Figure 2. An example of a demo NMO-stack sequence from the SU velocity analysis demo. The user picks the velocities from semblance plots (not shown) to find the NMO velocities used for the NMO correction. The corrected data are then stacked.

exclusively an inhouse product of C W P and was only shared with a few of CWP's sponsor companies. My first involvement with the project was to create a version of the package that would be easy to install on any UNIX system. Before its first public release, it would still take a time measured in days to port SU to a new system.

Asingle day port was considered to be "fast" at that time. For our work on this aspect of the package, Jack Cohen and I received the 1994 University to Industry Aw a rd from the Colorado Chapter of the Technology Transfer Society.

Since its first public release, the contents of SU have been streamlined and the installation procedure simplified to the point that the entire package can be installed (code compilation time included) in an hour or less on most systems, with the majority of the time being consumed by compilation. This has been made possible in large part by the suggestions of the worldwide SU users community. Figure 2 is an example of SU's current capability.

Why free?

Anyone who was in academia prior to 1980 probably experienced the perishability of software. Graduate students have been producing computer codes for geophysical applications since the 1960s. By the 1970s, most students produced some form of software as part of their thesis work. Yet, how many of these monumental creations, some of which took months or even years of a student's life to complete, survive to this day? Few of these codes would survive more than a couple of years beyond the time of a student's graduation. Commercial packages are a different story. Many commercial packages began as student thesis p rojects, but have survived much longer, owing to their marketablity. The impact of such software packages on academia is neither as gre a t nor as uniform as might be thought. The cost of commercial codes is prohibitive, making it impractical for a university to purchase more than a few licenses. For some of the more expensive commercial packages, it is unlikely that most academics can p u rchase even a single license, let alone outfit a research group or classroom environment with the package. This is not the rule, as there are some generous software developers who do donate software licenses to universities. Whether donated or purchased, commercial codes are distributed as executables, rather than as source code. This means that there is little possibility of a student being able to modify the existing code to implement new ideas (or to fix bugs), or to learn by examining the code's inner workings.

Web pointers of interest

CWP's Seismic Un*x package (SU): http://www.cwp.mines.edu/cwpcodes/

Samizdat Press: http://landau.Mines.EDU/~samizdat/

Edo Nyland's Geophysics 428 Web Page: http://uglab.phys.ualberta.ca/web/Geophysics 428/webPage.html

Jerry Barker's wavefield animations made with SU: http://www.geol.binghamton.edu/~barker/animations.html

The LINUX Documentation Project: http://sunsite. unc.edu/LDP/

The GNU Software Project: http://www.gnu.org/

Free software as public knowledge

All of this changed with the invention of "free software." Today, we associate free software with the Internet. However, the free software movement began many years before the words "email" and "World Wide Web" became part of the public consciousness.

The existence of free software permits researchers to do their work without seeking funds to purchase expensive commercial packages. Likewise, it allows teachers and students to have easy access to packages that they could not otherwise afford.

Of greater importance is the openness of free software. A fundamental ingredient to good science is the open and free exchange of knowledge. With free software it is possible for everyone to have the same code and to be able to see what is inside the code, because there are no jealously guarded trade secrets in such packages. At the very least, everyone can have the same set of software to serve as a datum against which new software can be compared.

Indeed, it is important to view f ree software as being a form of "public knowledge," similar to textbooks and technical journals. Traditionally, computer source code has been "private knowledge", written in various styles, with or without documentation. With the decision to make software public comes a responsibility by the authors of the code to follow the same rules of presentation as are seen with journals and books. Source code must be clearly presented, documented, and referenced, if the needs of the user community are to be served to the fullest.

We at the Center for Wave Phenomena have made an effort to enforce such coding standards in the Seismic Unix package. However, no code is perfect, and the input of the world SU users community continues to be a valuable and necessary ingredient for the success of the package.

The LINUX revolution

One of the g reat stumbling blocks to the use of SU was the fact that it depends on the UNIX operating system. Prior to 1994, putting UNIX on a PC was either out of the question, or a proposition that was as expensive as buying another PC. UNIX was largely a big workstation and mainframe operating system.

However, this has changed thanks to the free software revolution. Afree UNIX-like operating system for PC's called "LINUX", was developed by Finnish programmer Linus Torvalds, who started the project while still an undergraduate. LINUX is a serious operating system, permitting a person to have the equivalent of a fast X-windows based, UNIX-like workstation for the cost of a PC and a few hours of work.

Because PC's running LINUX can be configured to be "dual booting" – i.e., bootable either in LINUX or in a Microsoft operating system (DOS, Windows, Windows95, OS2, or Windows NT) – it is possible to have the best of both the Microsoft and UNIX worlds at a price that is affordable to any school, research group, and to many students, as well. Machines of such configurations are so popular that there are now companies that sell reasonably priced LINUX PC systems, preconfigured to order.

The GNU project

The LINUX project was not the work of Torvalds, alone, however. Without the cooperation of a worldwide community of f ree software developers, the LINUX project would still only be an idea. An integral part of the movement is the GNU Free Software Foundation at MIT.

The GNU project writes everything to build a UNIX-like environment, and much more, including free C, C++, and Fortran compilers and a host of other packages. Their packages are easy to install owing to an autoconfigure script that comes with every package. Because of the high quality and universal availability of GNU software, many GNU codes have become "instant standards."

GNU is also working on their own free UNIX-like system called HURD, which may eventually replace LINUX as the preeminent free UNIX-like operating system.

SU in education

I have set the stage by showing that free software exists in abundance and is easily accessible to the average user. I will now tell you how the SU package may be used to enhance the academic environment by giving examples of its actual use in this capacity.

SU as a processing environment

The primary reason for the existence of SU is to process seismic data.

I have received email testimonials from a broad spectrum of users, ranging from those who use SU as their primary processing environment, to those who prototype processing sequences in SU and then use a commercial package for the heavy lifting of production - level processing.

In education, Seismic Un*x enables students to do industrial style processing in an environment that they can afford and understand. It is possible for instructors at colleges with small earth science departments to give realistic seismic data processing assignments to their students.

With the availability of LINUX, the impact of SU goes beyond the classroom. Students can now have the equivalent of a seismic processing workstation of their own. Indeed, many of our graduate students have purchased LINUX-based PCs so they can do the seismic processing and software development required for their thesis work at home.

SU as a model software environment

The SU package is the home working environment of CWP. The fact that we periodically bundle up our home working environment and share it with the world forces us to keep a fairly clean house. The package, itself, is an excellent example of how to maintain and manage a moderate to large size software environment.

Codes created by CWP students are held to high standards, both in performance and in source code o rganization and appearance. Students are required to document the source code, include references, and acknowledgments of the work of others when parts of the code are based on other sources, and to p rovide at least one demo of the code. The unified software environment permits students (even students who have never coded in C) to develop code quickly, through the many available examples and preexisting coding structures present in the package. Our interaction with the worldwide user community has resulted in many code extensions, bug fixes, and new software additions not developed at CWP to be included in the package. SU has continued to i m p rove and grow as a direct result of this interaction with the world user community.

SU in the classroom

As might be expected, the SU package has been used as part of classroom exercises at CSM for several years now.

This began when John Scales of C W Pw rote a textbook called *The Theory of Seismic Imaging* (Springer Verlag, 1995) which has many SU-based homework problems. Although Scales' book (which is available online via Samizdat Press at no cost) was initially intended for a graduate level course, it soon became apparent that the text would be useful for portions of underg raduate courses, as well. In fact, Ken Larner uses portions of this text in his senior-level seismic prospecting class at CSM.

This book has inspired other professors to use the SU package as an adjunct to both their graduate level and undergraduate seismic education programs. Most notable is Edo Nyland of the University of Alberta, who has designed the seismic portion of an undergraduate geophysics course around SU and has made it available on his Web site.

Jeno Gazdag of the Geotechnology Research Institute (GTRI), at the Houston Advanced Research Center (HARC), reports that the modular nature of SU permits students to have a a "quick look" at their processing results, without the overhead associated with some commercial packages. Wayne Pennington of Michigan Technological University, has also used SU in this capacity. Each of these professors plans to make more detailed use of the package in the near future. But while they all have commercial seismic packages available, as well as SU, Lorraine Wolf of Auburn University relates that the SU package is the only seismic processing package that her group has available, as it is the only one they can afford. Her group has used it for graduate student thesis work for a couple of years now and finds that the package suits their needs. She plans to use SU in Auburn's advanced geophysics course in the fall.

The code need not be used solely for hard - core seismic applications, however. Jerry Barker of the Department of Geological Science and Environmental Studies at the State University of New York at Binghamton, has used the finite difference modeling program SUFD-MOD2 to produce movies of propagating acoustic waves. He reports that these simple movies are well received in the classroom – far better than the chalkboard sketches that he used to draw.

Other academic uses of SU

The Seismic Un*x package has had other impacts in academia, as well.

Michelle Miller, a student at the California State University at Chico, has used a Bison 5000 seismograph to perform a shallow reflection survey at a high school whose property adjoins her campus. The purpose of the survey was to map the lateral extent of shallow aquifers underlying the site of an old fuel-oil tank, as a prelude to a cleanup operation at the site. Her frustration with a commercial package purchased for this survey led her to use SU as her data processing environment.

Alexander Koek of the DELPHI group at Delft University in The Netherlands reports that SU has had a great impact on how his group works and that their software is heavily based on it. The fact that the package is distributed as full source code has permitted his group to make many additions to it that has helped them create a flexible research environment for faculty and students.

The future of free software and of SU

Given the trend toward standardization of hardware, and the ease of communication provided by the Internet, it is easy to see that free software is here to stay. Such packages are no threat to the dominance of commercial software in industry, because commercial packages are industrial-strength codes expressly designed for production level tasks. However, free packages do fill an important niche that can never be filled by commercial software.

I have only drawn a rough sketch of the impact of free software in the academic environment. All of this is very new and will likely evolve in unexpected ways. I am confident that free software will continue to perform an important role in academia, and in industry, as well. However, this will only happen if industry recognizes the importance of the contributions of the free software movement and enthusiastically supports such important projects.

Getting SU

The SU package may be obtained via the World Wide Web at:

http: / / www.cwp.mines.edu / cwpcodes /

or by anonymous ftp from the address:
ftp.cwp.mines.edu in the directory path:
pub / cwpcodes.

If you do not have Internet access, the package may be obtained on floppies (UN*X tar format) from:

Center for Wave Phenomena
Colorado School of Mines
Golden, CO 80401

There is a handling fee of $20 (U.S.). Please make the check or money order (we cannot accept credit card orders) payable to the Colorado School of Mines.

Corresponding author:
John Stockwell, 303- 273-3049

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*The author John Stockwell, john@dix.mines.edu, reports that the number of installations for SU is now over 1400. In the July TLE there is also a memorial to Jack K. Cohen. Jack Cohen died in 1996 at the age of 56. With Shuki Ronen, Jack created the Seismic Un*x package from a handful of codes created by the Stanford Exploration Project. He was a founding member of the Centre for Wave Phenomena at the Colorado School of Mines.*

Exploration Geophysics Abstract

The following paper has been accepted for publication in Exploration Geophysics.
For more information visit the ASEG website under publications.

Porosity form Sonic Log in Gas-Bearing Shaly Sandstones: Field Data versus Empirical Equations

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The effect of clay content on elastic wave velocity is an important factor which should be considered in porosity estimation from sonic log data. Over the past ten years several investigators have reported experimental results of ultrasonic P-wave velocity measurements in clastic rocks and a number of empirical relationships have been proposed for velocity as a function of porosity and clay content for sandstones. These studies provide a better understanding of the complex nature of elastic wave velocities in reservoir rocks. However the practical aspects of applying the empirical equations derived from these studies have not been examined. This paper briefly reviews some of the most often-cited empirical velocity/porosity equations and compares them with commonly used sonic porosity methods for a series of gas-bearing shaly sandstones from the Cooper Basin in South Australia. None of these empirical equations present a globally acceptable method for porosity estimation from the sonic log. The shortcomings of these equations are more noticeable when they are used for gas-bearing reservoirs in shaly sandstones with low to moderate porosities. The application of some of these equations to field data in the Cooper Basin implies that their reliability when used on other datasets should be considered suspect until a good calibration can be achieved.

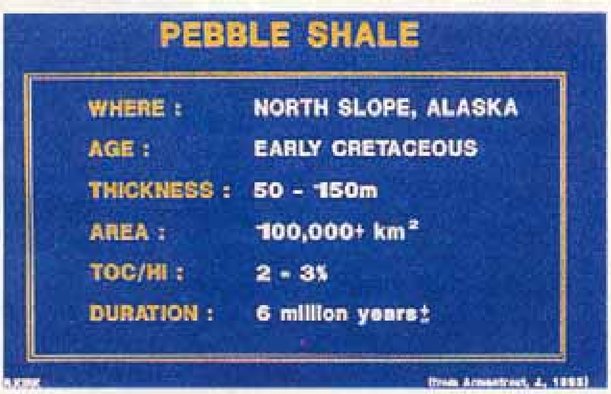
Keywords: velocity, sonic log, porosity, clay, shaly sandstone, Cooper Basin

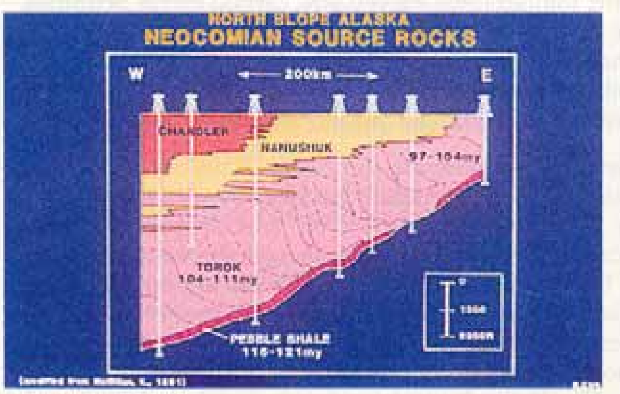
Seismic Window

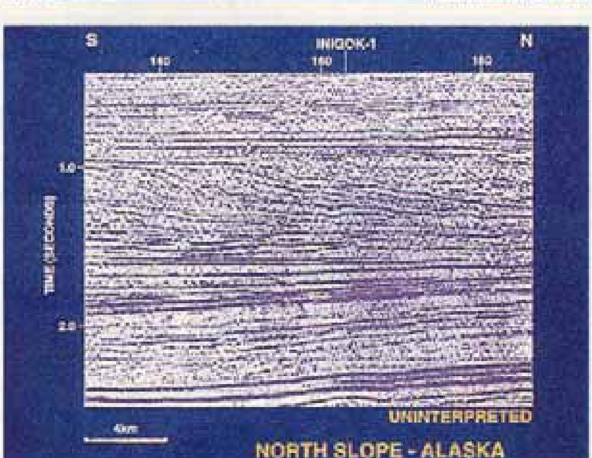
with

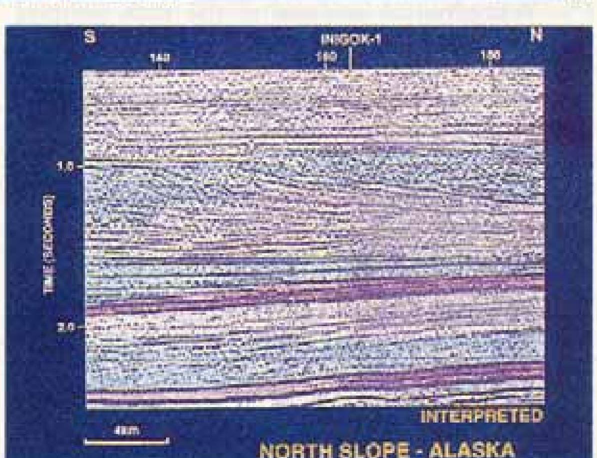
Rob Kirk
BHP Petroleum

The Pebble Shale is a rich source rock on the North Slope of Alaska. Its duration suggests more than one third order sequence is involved. We are probably seeing several third order condensed sections stacking together to give a thin rich source (a composite condensed section). We can see this unit on seismic from its low density and velocity due to the very high organic carbon content.









Seismic tomographic determination of ore boundaries at Scuddles Mine in Australia

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Peter Hatherly, CMTE/CSIRO, PO Box 883, Brisbane, Qld 4067 Australia
Gary Fallon, MIM Exploration, GPO Box 1042, Brisbane, Qld 4001, Australia

Abstract

Results from a seismic tomographic trial at a metalliferous mine in Australia are presented. The objectives of the experiment were to evaluate the application of this technique in the delineation of ore boundaries and characterisation of rock mass. Three component seismic data were recorded underground around three sides of a pillar. Velocity variations across the pillar were mapped using both P- and S-wave travel times. The variations of the mapped velocities along the sides generally coincide with the variations of lithologies already known. The "fast" pyrite mineralisation was discriminated from "slow" host lithologies from the tomograms. The geological circumstances were such that it was not possible to test for the discrimination of economic from uneconomic mineralisation.

Introduction

Scuddles Mine is a zinc-copper mine in Western Australia. The mineralisation is predominantly massive sphalerite, chalcopyrite and stringers in metasediments and massive pyrite. From 17th to 21st April, 1996 a seismic tomographic survey was carried out at Scuddles Mine to examine the use of seismic tomography for ore boundary delineation, rock mass characterisation, and if possible discrimination of economic from uneconomic mineralisation (Fullagar et al. 1996; Luo et al. 1997).

Seismic tomographic techniques have been used for crustal and global structure for more than 10 years. They have also been applied in oil and coal exploration. Basically seismic tomography images the variation of P- and S-wave velocities across survey region. Previous studies show that the variation of rock properties can be successfully mapped out using seismic tomography and a good survey configuration if the variation is greater than 6%. Petrophysical analysis of the rock samples collected at Scuddles derived compressional velocities for pyrite of about 7500 m/s, sphalerite, 4800 m/s and host rock, 5600 m/s (Fullagar et al 1996). A contact between the ore and hanging wall sediments was reasonably well defined and thought to be a sharp contact. The differences of the physical properties are so significant that the location of the various rock boundaries was expected to be obtained using seismic tomography

Field Survey and data processing

The seismic tomographic survey was performed around three sides of three adjacent pillars on 370 Level. Each of the pillars contained massive pyrite, sphalerite, chalcopyrite, footwall stringer zones and hanging wall sediments. The contacts are well determined along the drive way and cross cuts but their trends within the pillars are problematic. In order to achieve high resolution images, a geophone a spacing of 2 m and a shot spacing of 1 m were used. The survey was carried out without any interference with the normal mine operations.

Some 60,000 seismic traces with dominant frequencies from 200 to 1500 Hz were recorded from this experiment. In general, the record quality was excellent. As a priority we have concentrated on the P- and S-wave data from pillar A. In all, 2222 P-wave times and 1623 S-wave times were measured for pillar A, constructing a dense seismic ray coverage across the survey region. Inversion of both P- and S-wave times was performed using MIGRATOM, a software package developed by US Bureau of Mines for seismic tomographic imaging. The seismic ray paths were treated as straight lines in the inversion.

Discussion

Generally the P-wave velocity variations within the pillar (Figure 1) reflect changing lithology. To the bottom right of the P-wave tomogram there is a region of high velocity which coincides with the sulphide mineralisation containing predominantly pyrite and chalcopyrite. The seismic velocities within this block are great than 6,800 m/s and its extent into the pillar is clearly suggested. Within the footwall stringer zone in the bottom left corner, the velocities are below 6,400 m/s. Similar velocities are also evident in the hanging wall. The zone of sphalerite coming into the pillar below the hanging wall from the right does not appear to have been mapped. Possibly it does not extend into the pillar or possibly it becomes more iron rich and assumes a velocity similar to the hanging wall sediments.

S-wave tomogram (Figure 2) has similar pattern to the P-wave tomogram. Higher velocity is also shown in the

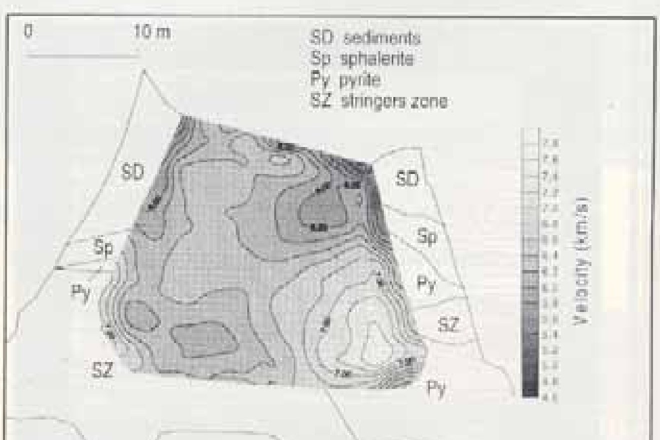

Figure 1. P-wave tomogram of pillar A and generalised lithology.

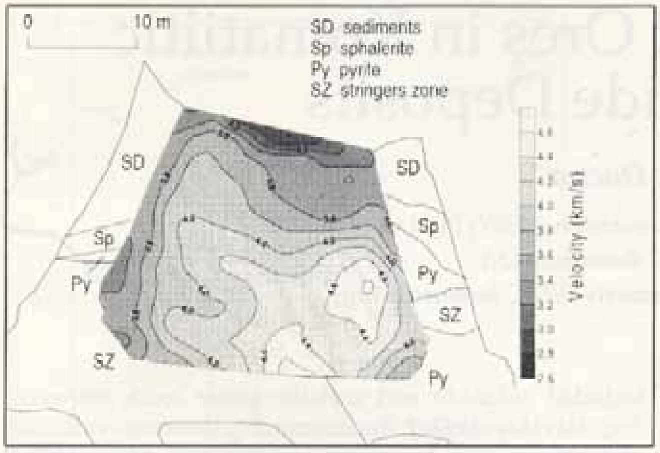

Figure 2. S-wave tomogram of pillar A and generalised lithology.

lower right corner. There is the same sense that this region gently ridges down across the pillar but is defined by a relatively sharp boundary across the top (hanging wall contact?). There are some differences in the extent of the high velocity zone at the base of the pillar which may be due to variations in rock quality.

Some ore boundaries, such as the massive pyrite in the lower right corner and the sediments of hanging wall near the left top appear to be shown in the tomograms. Given the uncertainty of whether the sphalerite actually extended into the pillar, we are unable to say from these results whether economic ore could be distinguished from uneconomic ore. However, work we have undertaken at another site has shown that economic sphalerite can be discriminated from uneconomic pyrite by seismic methods.

Acknowledgment

We would like to thank Brain Evans and Milovan Urosevic of Curtin University for obtaining the survey data. We are grateful to Mark Flemming, Rob Muller and Heather McIntyre of Scuddles Mine for their assistance throughout the experiment. Binzhong Zhou of CSIRO is thanked for helping with data processing. This work has been undertaken by the CMTE in collaboration with the companies sponsoring AMIRA Project P436 (Aberfoyle Resources, Acacia Resources, CRA Exploration, MIM Exploration, Outokumpu, Pasminco and Normandy Mining). Results are published with the permission of these companies.

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P Wave Velocities of Ores in Komatiitic Nickel Sulphide Deposits

"The Rock Doctor"

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G S Turner, WMC Resources Ltd
P K Williams, Resolute Ltd (formerly WMC Resources Ltd)

Introduction

The nickel sulphide ores at Kambalda formed as long ribbon like deposits usually less than a couple of hundred metres wide and less than a few metres thick (Gresham and Loftus-Hills, 1981). After deposition these orebodies were extensively fragmented by a combination of faulting, intrusion and remobilisation. As the exploration effort moves deeper traditional dense drilling techniques used to delineate the ore become more expensive. This has led to an increase in the interest in using high resolution geophysical techniques for ore delineation (Williams, 1996; Fallon et al 1997). Over the last 5 years downhole electromagnetic techniques have been used to great effect in the exploration and delineation of the nickel sulphide orebodies (Turner et al, 1996). WMC and Flinders University have jointly investigated the ability of seismic techniques to produce high resolution images of these orebodies (Sinadinovski et al 1995, Cao and Greenhalgh, 1995). Other groups have also been investigating the applicability of seismic techniques to imaging ore deposits and recently some excellent results have been presented by several authors (Milkereit et al 1996, Pretorious et al 1997).

The applicability of seismic techniques to an environment is a function of the variation of seismic velocity, attenuation, density, the complexity of the variation, and the relationship of the variation with the features that are desired to be imaged. The seismic techniques that are most readily applicable to orebody delineation are tomography and reflection. Seismic tomographic images usually display variations in P-wave velocity in a rock volume calculated from the travel times of seismic waves transmitted through that volume. Seismic reflection images are produced from signals reflected from boundaries where there is a change in acoustic impedance (product of P-wave velocity and density). At Kambalda the nickel sulphide ore normally occurs at the base of a thick sequence of komatiitic (ultramafic) rocks. These komatiitic rocks were extruded on top of a thick layer of basalts. The ore profile grades from massive ore at the base through matrix ore to disseminated ore at the top. Consequently there is usually a sharp geological contact at the base between basalt and massive ore but the contact with the overlying komatiite rocks is far more gradational.

Velocity data from specific mine environments are sparse indeed, especially for target sulphides. Schneider & Emerson (1980) measured Pwave ultrasonic velocities ranging from 5250 to 6111 for pyrrhotitic and pyritic Elura polymetallic ore which presented a strong positive velocity and density contrast to the siltstone country rock. Kobranova (1989) showed a Vp-density plot that included sulphide and metallic lustre oxide minerals. Boguslavskiy (1976) documented ultrasonic velocities and anisotropies for single crystals and monomineral aggregates for some common sulphides.

In this article we present the results of a petrophysical study on the velocities and densities of disseminated, matrix and massive nickel sulphide ores from the Kambalda region Western Australia. Magnetic susceptibilities were also measured. In this Archaean greenstone environment, pyrrhotite-pentlandite-pyrite (± chalcopyrite, magnetite) is the primary economic mineral assemblage in the komatiite hosted orebodies (Gresham & Loftus-Hills, 1981; Cowden & Roberts, 1990). The sulphides generally have fine to medium crystallinity (~0.1 to 0.5 mm grainsize). Iron, nickel and sulphur make up 98% of the ore. The sulphides are classified as massive, matrix or disseminated according to the amounts of sulphide: >80%, 40 to 80%, and <40% respectively. In the massive and matrix ores the sulphides have grain to grain continuity; in the disseminated they do not. The country rocks include a variety of felsic, mafic and ultramafic rocks including sometimes quite sulphidic pyritic and/or pyrrhotitic, barren, cherty metasedimentary units near the nickel sulphides. The dominant country rock silicate mineralogies are talc-carbonate-amphibole-biotite-chlorite, for the mafics; and quartz-feldspar-mica, for the felsics.

Fifty bulk ore samples were obtained from several WMC Resources Ltd mines, trimmed into large blocks (80x80x80 mm) and 500 kHz Pwave velocities measured in three directions (one normal to and two parallel to foliation) under uniaxial load (tens of kN). A similar number of host and country rock samples were also tested. Dry bulk densities, apparent porosities (generally quite low) and magnetic susceptibilities were also determined. So too were galvanic and electromagnetic (inductive) conductivities on cored subsamples, but that data will be presented elsewhere.

Ultrasonic laboratory velocities are quite indicative of the seismic velocities of a sampled coherent subsurface lithological block providing appropriate subsurface conditions such as stress and water saturation are simulated and, where necessary, allowance made for minor dispersion of a few percent per megahertz which can result in ultrasonic velocities being slightly and systematically higher than field values.

Results

The nickel ore and sulphidic metasediment velocity data are summarised in the Table and the nickel ore data are crossplotted against dry bulk density and magnetic

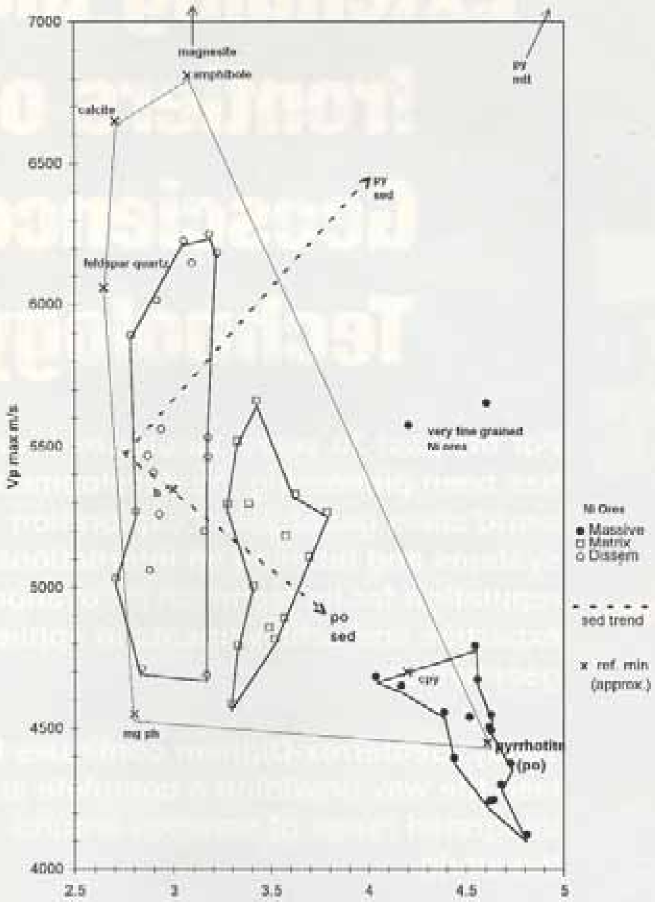

Figure 1.

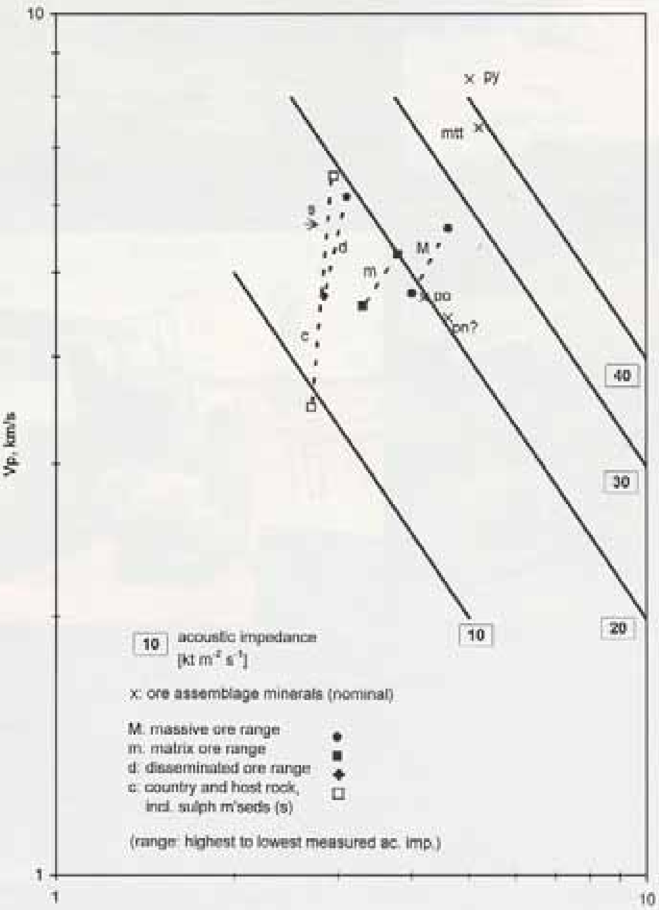

Figure 3.

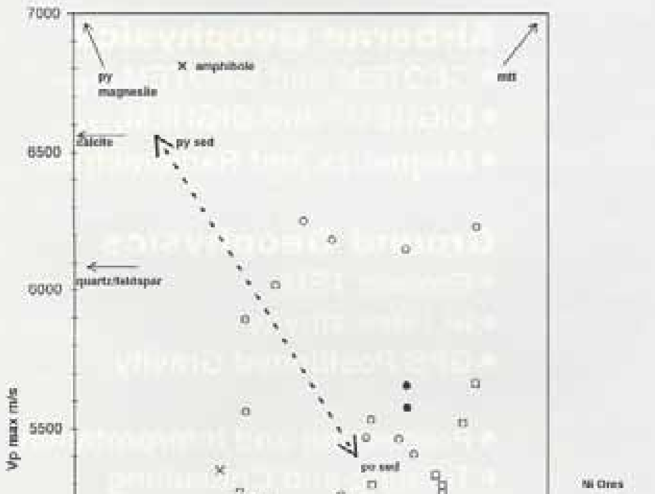

Figure 2.

susceptibility in Figures 1 and 2, respectively, which also show the trends for sulphidic metasediments. Reference minerals have been plotted *approximately* on these Figures for comparison. For DBD: 1 g/cm^3 = 1 t/m^3 = 1000 kg/m^3. These minerals are: amphibole, calcite, quartz and feldspar, the magnesium bearing hydrous phyllosilicates (mg ph: serpentine, talc, chlorite), biotite (b), pyrrhotite (po), chalcopyrite (cpy). Pyrite (py, Vp: 8420 m/s, DBD: 5.02 g/cm^3) and magnetite (mtt, Vp: 7390 m/s, DBD: 5.20 g/cm^3) lie off Figure 1 to the top right, while magnesite lies off to the top left. In Figure 2, the pyrrhotites (monoclinic-ferrimagnetic, hexagonal-anti-ferromagnetic) have been plotted with the paramagnetics: chalcopyrite, amphibole, biotite and the Mg phyllosilicates. Ferrimagnetic magnetite lies off Figure 2 to the top right, while paramagnetic pyrite and magnesite lie off to the top left and diamagnetic quartz, feldspar and calcite lie off to the mid-top left. Pentlandite (the nickel ore mineral) has a density of 4.96 g/cm^3 (Ineson, 1989), its velocity is not known, and as a Pauli paramagnetic it has a very low positive susceptibility. Pyrrhotite is the physically dominant mineral in the massive and matrix ore assemblage with densities of 4.61 and 4.65 g/cm^3 and susceptibilities of around 38000x10^{-6} and 140x10^{-6} SI, respectively, for the monoclinic and hexagonal varities (Clark & Emerson, 1991).

Discussion

The data in the Table are averages; the spread of data can be gauged from the crossplots. Velocities clearly decrease from disseminated (5521 m/s) to matrix

Table of Laboratory Results as Average Values
Kambalda Nickel Sulphide Ores & Sulphidic Metasediments

lithology	ultrasonic Pwave velocity, 500 kHz Vp max m/s	anis]otropy of velocity Vp_{max} as Vp_{min}	dry bulk density DBD g/cm³ t/m³ (x by 10³ for kg/m³)	acoustic impedance as Vp(max) x DBD kt m⁻² s⁻¹ (x by 10⁶ for kg m⁻² s⁻¹)	mag suscept k Six10⁻⁵
mon po Fe_7S_8 *pyrrhotite* *hex po* Fe_9S_{10} *pyrrhotite* *py* FeS_2 *pyrite* *pn* $(Fe,Ni)_9S_8$ *pentlandite* *mtt* Fe_3O_4 *magnetite*					
po-pn-py **massive ore** (n=18)	**4670**	1.08	**4.50**	21.0	13362
po-pn-mtt **matrix ore** (n=14)	**5115**	1.15	**3.48**	17.8	14634
po-pn-mtt **dissem. ore** (n=18)	**5521**	1.14	**2.99**	16.6	6500
po-py metasediments (n=25)	5584	1.07	3.17	17.7	1564

Notes: Country and host rocks comprise metasediments, felsics, mafics and ultramafics. These have: a limited density range, a wider magnetic susceptibility range and a very wide velocity range. Anisotropy is common in country and host rock mag k's and Vp's. Typically for country and host rock:
- densities overlap disseminated ore densities,
- susceptibilities overlap dissem. and matrix ore susceptibilities,
- velocities overlap all ore velocities.

Ranges for country and host rock properties are:
- DBD 2.70 (felsics, seds) to 2.95 (mafics, ultramafics) g/cm³
- mag k 10 x 10⁻⁵ (felsics, seds) to 10,000 x 10⁻⁵ (mafics, ultramafics)
- Vp 3500 (mainly felsics, seds) to 6500 m/s (all rock types)

(5115 m/s) to massive (4670 m/s) ore. These velocities are the maximum values of those measured in the three directions. The massive ore is dominantly pyrrhotite with significant pentlandite (over 20% by volume), minor (usually) pyrite and minor amounts of mafic and felsic minerals from fragments of ancient lava and sediment that lithified with the sulphides. Velocity anisotropy, a consequence of ore banding, is moderate (1.08) in the massive ores and increases slightly in the matrix and disseminated ores (~1.15). Densities clearly reflect the sulphide content and are quite high (4.50 g/cm^3) for the massive ore. The acoustic impedance is the product of velocity and density and controls the seismic reflection coefficients. The massive ore with a value of 21 (kt m^{-2} s^{-1}) exceeds those of the other sulphide types (<18). The density is responsible for the impedance contrast. Magnetic susceptibilities are quite high for the massive and matrix ores owing to the content of monoclinic pyrrhotite and magnetite, respectively. Magnetite also imparts a moderately high susceptibility to the disseminated ore.

Sulphidic metasediments (Bavington, 1981) form prominent horizons within the nickel sulphide orebody ultramafic sequence. Table 1 shows their average properties to be similar to the disseminated ores, but less magnetic.

The velocity-dry bulk density crossplot in Figure 1 shows the distinct fields occupied by the ore types and the trends exhibited by pyritic and pyrrhotitic metasediments. Most of the data plot within the Kambalda system silicate-carbonate-pyrrhotite bounds (where pyrrhotite is assigned a nominal 4450 m/s velocity on the basis of previous work). Velocities alone are not diagnostic but in velocity-density space the massive ores are well defined and unambiguous with regard to other sulphide types. These massive ores trend towards the pentlandite density point (4.96 g/cm3) in the lower right hand corner and it is inferred that very high tenor nickel ore would have a Vp of around 4000 m/s (tenor is the nickel grade of the sulphides). Two of the massive sulphide ores are very finegrained with a uniform distribution of minerals; they plot as high velocity outliers. The lowest massive sulphide velocities were for samples with relatively coarse grain size and prominent splashes and blebs of pentlandite giving a heterogeneous appearance. The positioning of the ore samples within the polygons formed by the constituent minerals is particularly noteworthy. It strongly suggests that the mineralogy is the dominant control on P-wave velocity for these ore samples and that textural effects are a secondary control.

The velocity-magnetic susceptibility crossplot in Figure 2 again shows occupancy of particular regions by the sulphide types. The disseminated and matrix ores trend towards magnetite, while the massive ores cluster near the monoclinic pyrrhotite point. Two of the massive ore types have mainly hexagonal pyrrhotite and these plot nearer the hexagonal pyrrhotite point.

The sulphides' velocities are usefully viewed in the perspectives of densities and magnetic susceptibilities and physical features readily discerned.

The country and host rock densities fall between 2.70 and 2.95 g/cm^3 (Trench et al, 1993); their magnetic susceptibilities span a wide range: 10x10^{-5} to 10 000x10^{-5} SI (McCall et al, 1995); and the velocities measured in this study were between 3500 and 6500 m/s. The higher velocities are associated with tough amphibolites and carbonate rich rocks; the lower velocities were measured for weaker, altered and sheared rock types. These velocities have not been plotted on Figures 1 and 2 as they obscure the sulphides' features. Thus disseminated ore presents no seismic contrast with typical host rocks and while matrix ores may have densities that exceed those of the surrounding host there is no distinctive change in P-wave velocity or acoustic impedance. Only massive Ni ores appear to have a reasonable contrast with the Kambalda host rocks (av.ac. imp. = 18). These ores have a relatively low P-wave velocity and significantly higher density. Overall they show a higher acoustic impedance as depicted in Figure 3 which shows the range of acoustic impedances in velocity-density space. This Figure does not show all the measured data, only the ranges.

Conclusions

A systematic study of Pwave velocity and dry bulk density of nickel sulphide ore and host rock types at Kambalda has shown that mineralogy is the main controlling factor on Vp variation. Texture also has an influence as shown by the grainsize effects and anisotropy which ranges from 1.08 in massive ore to 1.15 in matrix ore and 1.14 in disseminated ore. Despite the strong variation with mineralogy, Vp alone does not uniquely discriminate between rock and ore in this environment. Vp in ore ranges from 4000m/s to 6300m/s. Massive ores dominated by pentlandite and pyrrhotite have velocities at the lower end of this range whilst higher velocities are associated with disseminated ores and ores containing higher concentrations of pyrite. As a result of the wide velocity range, seismic velocity tomograms cannot be used alone to detect and delineate ore zones. Density is the major controlling factor on acoustic impedance in these ores. The acoustic impedance contrast of ore/host contacts are very low with the exception of the contacts with massive ore. These contacts have an impedance contrast of about 15%. Consequently there is a possibility that these contacts could be mapped by seismic reflection if other factors such as sharpness of the boundary and reflector continuity are favourable.

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ANSIR – Call for Project Proposals

The Australian National Seismic Imaging Resource (ANSIR) is Australia's Major National Research Facility (MNRF) in the Earth sciences. It was established in 1997 as a joint venture of the Australian Geological Survey Organisation and the Australian National University as part of the Commonwealth funded MNRF Program (Refer to previous Preview article)

The objective of the MNRF Program is to strategically develop the national science and technology infrastructure in order to keep Australia at the leading edge of key technological developments, and so enhance its scientific and industrial competitiveness.

The establishment of MNRFs recognises that major scientific and technological advances are increasingly dependent on researchers having access to very expensive equipment and facilities beyond the resources of individual institutions to finance. The ANSIR facility provides resources for seismological investigation of the Earth on a wide variety of scales. ANSIR equipment will be available to all bona fide researchers on the basis of merit. However, intending users will have to meet their own project operating costs. ANSIR will call for its first round of research proposals in August this year.

The submission date for the first round of research proposals for equipment time will be 1988 August 10.

ANSIR activities over the last year have focussed mainly on the purchase of new equipment. The instrument pool will be in place for 1999 and will consist of up to 15 broad band portable recording instruments, 50 short period portable recording instruments equipped with both single component (vertical) and three component sensors, a 360 channel reflection recording system, complete with four large P-wave vibrators and one smaller high frequency P-and S-wave vibrator.

Scientists who wish to apply for equipment time should obtain details of costs and copies of the project application forms from either

Dr Barry DRUMMOND (particularly for experiments with the reflection equipment)

ANSIR AUSTRALIAN NATIONAL SEISMIC IMAGING RESOURCE

ANSIR Director
Australian Geological Survey Organisation
GPO Box 378
Canberra ACT 2601
Telephone 02 6249 9381 Facsimile 02 6249 9972
Email drummond@agso.gov.au
OR
Prof Brian KENNETT (particularly for experiments with the portable equipment)
ANSIR Deputy Director
Research School of Earth Sciences, ANU
Canberra ACT 0200
Telephone 02 6249 4621 Facsimile 02 6257 2737
Email Brian.Kennett@anu.edu.au

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

HONOURS AND AWARDS

13th Conference and Exhibition

During the ASEG conference three award categories are presented to members who merit recognition for distinguished service to the Society and to exploration Geophysics. These honours are:

ASEG Gold Medal - for distinguished service to geophysics.

Honorary Membership - for distinguished contributions to the profession of Exploration Geophysics.

Grahame Sands Award - for innovation in Applied Geophysics It is made to a person or persons who has or have been responsible for a significant practical development of benifit to Australian applied geoscience. This could be in the field of instrumentation, data acquisition,interpretation or theory.

With the conference being between November 8-12 it is now time to call for nominations for these awards. Any member of the Society is elighle to nominate applicants by including a seconder and by sending three copies of relevant documentation to:

Chairman Honours and Awards Comittee,
22 Kurraba Rd.
Neutral Bay
NSW 2089

Application will close on September 8, 1998.