Australian
Society of
Exploration
Geophysicists
ACN 008 876 040

Preview

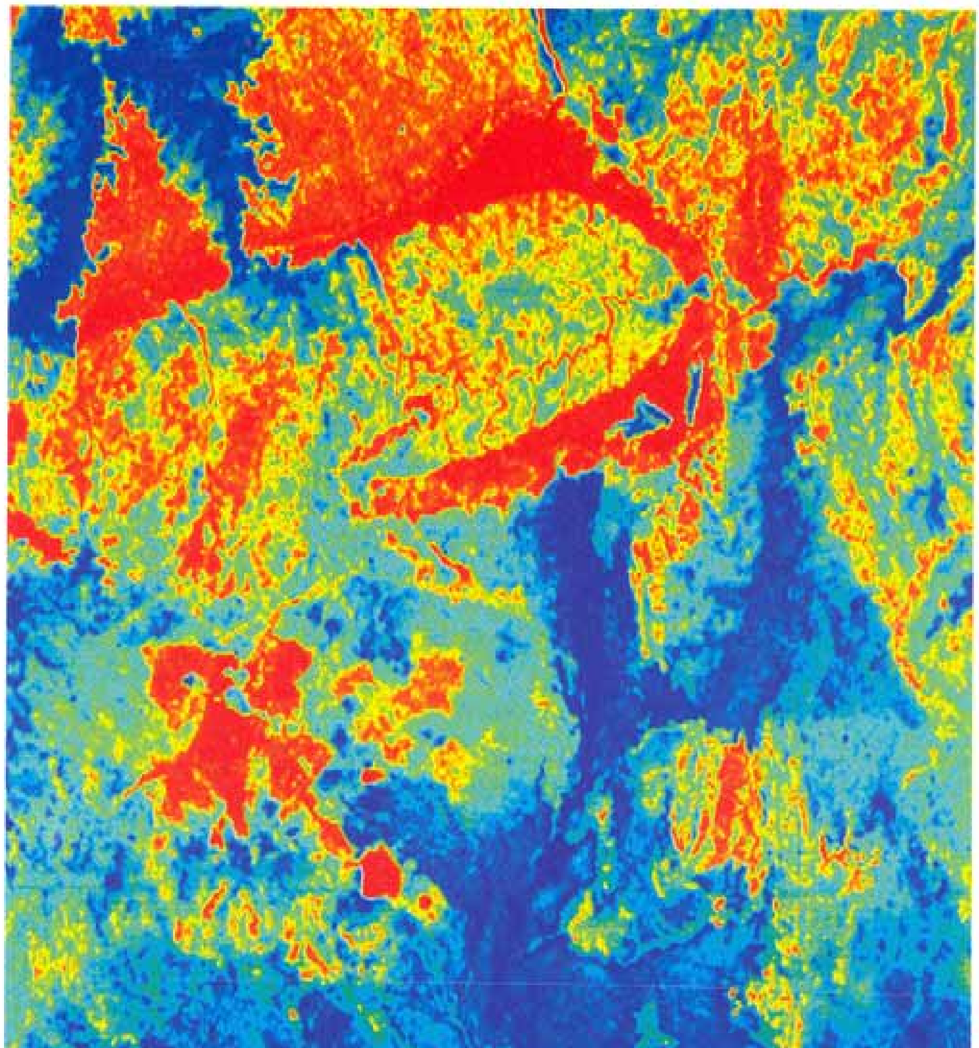
December 1997

Issue No. 71

Special Feature:

Application of Radiometric Data for Soil Mapping

14-18



In This Issue:

Contents

Feature Article

Special Features

Regular Features

HEAD OFFICE:
Suite 14, Portman Place, 220 Boundary Street, Spring Hill Qld 4000
Postal: GPO Box 2179, Brisbane Qld 4001
Tel: 61 7 3832 8607, Fax: 61 7 3832 8245
Email: aseg@enterprisingevents.com.au

PRESIDENT: Mr. Nick Sheard, Tel: (07) 3214 9129
Fax (07) 3214 9122, Email: snsheard@compuserve.com

HON SECRETARY: Mrs. Robyn Scott, Tel: (07) 3307 9663
Fax: (07) 3307 9500, Email: scott.robyn.rl@bhp.com.au

EDITOR: Mr. Henk van Paridon, Tel: (07) 3371 0244
Fax: (07) 3371 0114, Email: henkvanparidon@compuserve.com

ASSOCIATE EDITORS:
Petroleum: Rob Kirk, Tel: (03) 9652 6750 Fax: (03) 9652 6325
Email: kirk.rob.r@bhp.com.au
Position Vacant!
Minerals: Steve Mudge, Tel: (09) 442 8100 Fax: (09) 442 8181
Engineering, Environmental & Groundwater: Geoff Pettifer,
Tel: (03) 5133 9511, Fax: (03) 5133 9579
Email: geoffp@geo-eng.com.au
Academia, Research & Education: Leonie Jones,
Tel: (042) 21 3013 Fax: (042) 21 4250
Email: l.jones@uow.edu.au

Print Post Approved - PP3272687 / 0052, PREVIEW is a publication of the Australian Society of Exploration Geophysicists, circulated to a membership of approximately 1350.

**Artwork and Printing by Jenkin Buxton Printers Pty Ltd
263 Middleborough Road, Box Hill, Victoria 3128
Contact Debbie May, Tel: (03) 9890 4711, Fax: (03) 9898 9677.**

Editor's Desk

By the time that this *Preview* hit's the stands my home office will, hopefully, look more like an office and less like the spare bedroom that it really is. In the process of making some space under our house we had the big clean-out, garage sale and all.

One of the hardest things for me to do was to thin out my books and journals. In the end the decision on journals was obvious. Technical journals will be replaced by CD's and on-line libraries. This gives professionals the ability to perform digital searches without having to unpack boxes or find space on their desks. The SEG's GEOROM is an obvious example. I would like the ASEG to provide all of its publications on line as well as other more mundane material such as FE minutes. It should also prompt more authors to come forward if they know that they have the potential to be immortalised in the big bit bucket in the sky.

Journal hard copies will have a much shorter shelf life than at present. People will still want something to read on the plane or on the bus. After reading or noting the stories of interest the journal will sit on the shelf for maybe a year and then be discarded safe in the knowledge that it can be recalled by a few keystrokes.

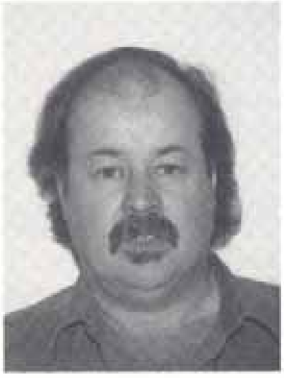
This is likely to effect the nature of the advertisers and the advertisements they place. Advertisers on an electronic page will be able to maintain a fresh image whereas the published ad may become dated. For example a company may change its name or address and essentially erase old ads. This will require societies that publish to review how they approach advertisers and what services they should offer.

In this issue we have a story previously published in the Leading Edge. The ASEG and SEG have agreed to allow story swaps (author's permission not withstanding) exposing members of both societies to the other.

Finally I wish all readers compliments of the season.

Regards
Henk van Paridon, Editor

President's Piece



Earlier this month I attended the annual SEG conference in Dallas. We, the ASEG, were invited to the Council Meeting and SEG Membership Committee Meetings. The Council Meeting was very formal and was basically the changing of the guard.

The ASEG would like to congratulate S. Rutt Bridges (President) and the new committee who have taken over from Fred Hilterman and his committee. On behalf of the ASEG I would also like to congratulate Brian Spies who has worked hard as the Secretary/Treasurer this last year for the SEG.

The Membership Meeting was somewhat disturbing. The aim was to "brainstorm" new ideas for increasing membership within the SEG. Unfortunately, the apparent tunnel vision towards "oil" geophysics pervaded the meeting. There was only scant regard paid to the value of the mineral exploration geophysicist, in fact, a comment was made that "the mineral industry was insignificant". This obviously did not go down well particularly to a mineral geophysicist! Perhaps a more enlightened attitude would see some of our 1399 ASEG members currently not members of SEG to join.

The ASEG was represented at the convention via a booth and some volunteer "exhibitors". I would like to thank, Caleb Aimes, Craig Gumley, John Donohue, Mark Dransfield and Terry Ritchie for representing our society. The booth (see photo) provided a good focal point and a great deal of interest was shown in up and coming AEM Conference, the Radiometric Workshop and the Hobart Conference. About 15 new members were signed up including one Corporate Member - Quantec Geophysics of Canada.

In future years, the ASEG must present a more professional front at these conventions. It has been agreed by the Executive that the ASEG will produce a more permanent exhibit. This can then be used with minimal update at various conferences throughout the year as required (any suggestions on design is welcomed!).

Next calendar year for the ASEG should be quite dynamic and technically excellent year. To date three major events, the AEM Conference, the Radiometric Workshop and the 13th ASEG International Conference and Exhibition, in Hobart are planned [call for papers for this latter is current]. The Executive is also participating in the Visiting Distinguished Lecturer Program hosted by the SEG - details will be published when details come to hand.

The end of 1997 is proving to be a bit turbulent particularly in the mineral side of our game. Change in company fortunes, and metal prices will mean a slow start to 1998, but as one who has seen many of these cycles the market will pick up again - so good luck to all concerned.

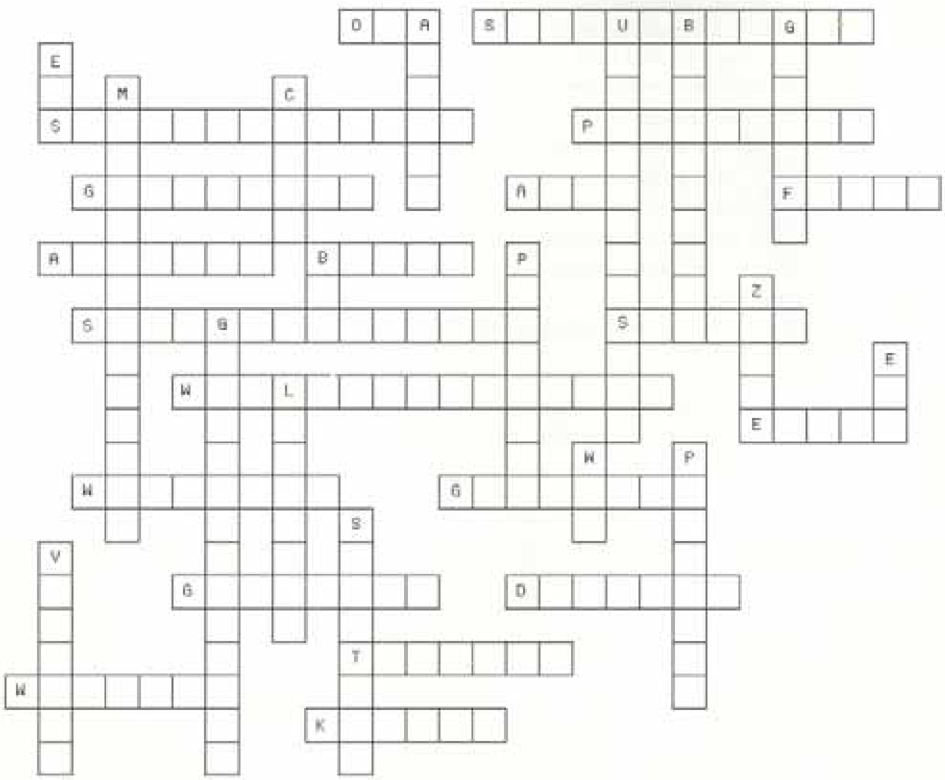
I would like to wish all our members a "Happy Christmas/New Year", and trust that there will be a few ASEG reds remaining in 1998.

S.N. (Nick) Sheard
ASEG President

Doodlebugs Doodling

The following clueless crossword contains the names of companies who have advertised, exhibited or otherwise supported the ASEG. For example the bottom left 'W' word is Western. Happy doodling!

Solution (if you need it) on page 38.



Executive Brief

It is the end of successful year for the Society. Some of the major achievements include the excellent Sydney conference, the Exploration Geophysics DHEM volume, the new publishing arrangement with Jenkin Buxton and the ongoing healthy funds of the Society.

Recently the Federal Executive has been pondering over how best to allocate ASEG funds. As you've read previously, the Federal Executive and the State Branches are preparing their first annual budgets. These will be made available to all members if requested and the Federal Executive budget, when finalised, will be published in Preview. This process has already indicated that the more Federal funds may be made available to the ASEG Research Foundation. To ensure a higher level of funding can be maintained to the R.F., two new corporate membership levels have been proposed which will guarantee part of the membership to the R.F. and provide greater level of service to our corporate members.

The renewal notices for 1998 membership will be sent to all members on 1st December 1997. You will notice a new format which is designed to give members more flexibility with their listings in the Membership booklet. Please note on the form that all members have the opportunity to be listed both alphabetically and geographically. As an additional service, corporate members may nominate in the Corporate Membership "Yellow Pages" section for no additional cost. As usual, advertising in this valuable booklet will be available to corporate and non-corporate members - details of costs will be included with the renewal form or contact Jenkin-Buxton directly (contact details at the back of this issue).

The membership booklet will be included in the April 1998 edition of *Preview* so to take advantage of the free listings, you must return your membership dues and form by the end of January 1998.

Events for the new year are looking good. The ASEG 13th Annual Conference is scheduled for November in Hobart. We are co-sponsoring two Geophysical workshops - the AGSO-ASEG Gamma-Ray Spectrometric Data workshop and the CRCAMET-ASEG International Conference on Airborne EM. Papers from the AEM conference will be edited and published in a special edition of Exploration Geophysics and the Gamma-Ray workshop organisers will contribute articles for Preview. See calendar at the back of this issue for dates and contact numbers.

Financial Status

The financial status of the society at 4th November 1997 is as follows:

Cheque account : $17,353
Cash management account : $176,176
CBA Term deposit : $154,153
Sands Cash management account : $9,568
Sands Term deposit : $40,000

I wish you all a safe and happy Christmas and New Year.

Robyn Scott
Honorary Secretary

Personality Profiles

MIKE ASTEN

CONFERENCE CO-CHAIRMAN 13th ASEG CONFERENCE & EXHIBITION

Michael is a consulting geophysicist in the partnership Flagstaff GeoConsultants, based in Richmond, east of Melbourne, and also holds a part-time appointment as Principal Research Fellow at Monash University. He finds the combination of the two roles ideal, "the best of both worlds". He is involved in interesting interpretation projects with a wide range of exploration companies. In addition he spends time teaching and interacting with a bright group of students who will be the next generation of industry experts.

Before commencing as a consultant early this year, Michael worked for 16 years with BHP Minerals Exploration Department followed by two years with BHP Research. He worked on coal, gold and base metal geophysics all over Australia and in the Americas and Africa. He considers it a very rewarding career travelling around the world to city lights and grass-hut villages enabling him to meet a large group of friends and colleagues the world-over.

Mike worked on the Eloise copper-gold ore-body near Cloncurry (Queensland), where ore-grade mineralisation was discovered after sticking several geophysical pins on the map during an exciting series of surface and borehole electromagnetic surveys.

Mike had a major in Physics from the University of Tasmania and decided to do Geology as a fill-in subject. Sam Carey, that larger than life Professor, caught his interest with a series of lectures on continental drift and global expansion at a time when such theories were barely respectable. Mike was hooked and stayed on to major in Geophysics and subsequently did a PhD at Macquarie University under Prof Keeva Vozoff.

Michael has been active in the SEG and ASEG for ten years. He is an author of 44 papers, regularly provides peer review for both Society's publications, and has served as a special editor for the ASEG and Associate Editor (Mining) for the SEG. He was Vice-President of the ASEG for four years from 1991 to 1995. Mike is delighted that the ASEG Conference will be in Hobart for the first time . As well as a very active Melbourne committee, he is enjoying working with some of his contemporaries from his university days.

Personality Profiles

CRAIG DEMPSEY
CONFERENCE CO-CHAIRMAN
13th ASEG CONFERENCE & EXHIBITION

After completing a geophysics degree at Flinders University in 1977 Craig spent his first year working on short term jobs for the University, Geoex, Kennecott and Western Geophysical before starting a career with Delhi Petroleum. After two and a half years of working on the Western Eromanga and Cooper Basins he decided a change was in order and joined Australian Occidental, originally in Adelaide and then in Perth. Craig stayed with them until they sold their Australian interests to Bond Petroleum in 1984. During this time he worked on seismic data from the Bass Strait, Canning and other North West Shelf basins.

During the sale of Occidental's assets to Bond he took destiny in his own hands and moved to Marathon Petroleum. Initially he worked in the Australian New Ventures Group and then on their Australian operated blocks. When Marathon's Australia-Asia New Ventures Group moved to Perth he was exposed to Asian geology . This led to his transfer to Jakarta as Chief Geophysicist for Indonesia, a position he held for five years. In early 1996 Marathon sold it's Indonesian assets to Clyde Petroleum. Craig and his family decided to move back to Australia rather than Houston and he is presently working for BHPP in Melbourne.

This move has led to his re-involvement with the ASEG as Co-Chairman of the 1998 Hobart Conference. It is re-involvement as, prior to moving to Jakarta, Craig had held the posts of Federal Secretary and Treasurer and was active within the WA Branch. He has attended many ASEG organised conferences and symposia and participates in local branch meetings. Craig is looking forward to the Hobart conference and urges members to take an active role by writing papers, getting their company to purchase exhibition space or sponsorship opportunities and by their attendance.

Preview Deadlines – 1998

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

Calendar Clips

1998

Feb 16-19
EGS/SEG/EAGE Cairo 98. Africa/Middle East Geophysical Conference and Exhibition

February 23-25
International Conference on Airborne Electromagnetics Airborne EM Conference, Sydney

February 26
Gamma-ray Workshop, Sydney

March 8-11
APPEA Convention, Canberra

Mar 23-25
International Conference on Coal Seam Gas & Oil, Brisbane

Jun 20-26
SEGJ/SEG Beijing. Beijing 98 Conference and Exhibition

July 21-24
Western Pacific Geophysics Meeting, Taipei

August
West Australian Basins Symposium, Perth

Sept 13-18
SEG Conference, New Orleans

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

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

Details and more events on Page 39.

Sneak Preview

1998 will be a big year!

- *Student Special Edition*
- *Radiometrics Workshop Edition*
  Membership Handbook
- *4D Seismic Edition*
- *Your suggestion*
- *Conference Edition*

As always your contributions are welcome.

ASEG Branch News

Queensland

Contact details:

President: Gary Fallon
Phone: (07) 3214 9170
Fax: (07) 3214 9111
Email: gnfallon@mim.com.au

Secretary: Andrew Davids
Phone: (07) 3858 0659
Fax: (07) 3369 7840
Email: Andrew.Davids@oca.boral.com.au

Recent months have been quiet for the Queensland Branch with the exception of the running of the inaugural ASEG Golf Classic (see article elsewhere in this issue of *Preview*). The Christmas party is schedule for Thursday, 18th December at Walkabout Creek restaurant, The Gap. In addition, there is a technical meeting planned for December, to coincide with a visit from Chinese delegates presenting research related to coal-seam methane exploration and exploitation.

A committee meeting was held on Monday 24th November. The Branch is gearing up for an exciting 1998, with preliminary planning underway to run a workshop from the SEG continuing education programme. Expressions of interest are sought from other state branches regarding the running of the workshop in other states (on a cost share basis). In addition, we are working on getting the SEG distinguished lecturer to visit Queensland.

I would like to thank all Queensland members for supporting the Branch during 1997, and wish everyone all the best for the festive season.

Andrew Davids
Branch Secretary

New South Wales

Contact details:

President: Timothy Pippett
Phone: (02) 9350 9288
Fax: (02) 9350 9274
Email: tpippett@mail.com

Secretary: Dave Robson
Phone: (02) 9901 8342
Fax: (02) 9901 8777
Email: robsond@nswgs.nsw.gov.au

Our November meeting saw four presentations by Honours' students. Congratulations to Marilyn Braine, Leharne Lay, Jonathan Deutscher and Damien Ewington for there excellent presentations. Marilnn spoke on EM models as a possible correction for gravity, Leharne discussed the some of the theory behind MT, Jonathan spoke on Interferometric SAR in defining 3-D modelling, and Damien discussed high resolution geophysics as GIS application to geological mapping mapping.

The December meeting presentation by Keeva Vozoff and is titled, "Geophysical characterisation of the region around a longwall coal mine at Appin". He will discuss surface EM (LOTEM) and its effect in mapping coal seams 400-500m from surface.

February's meeting and AGM will be held on Wednesday 18th, and will give a lead into the major CRC AMET/ASEG EM Workshop being held in Manly the following week.

Timothy Pippett
NSW Branch President

ACT

Contact details:

Hon. Secretary: Tim Mackey
Phone: (02) 6249 9813
Fax: (02) 6249 9986
Email: tmackey@agso.gov.au

President: Kevin Wake-Dyster
Phone: (02) 6249 9401
Fax: (02) 6249 9972
Email: kwakedys@agso.gov.au

Tim Mackey
Hon. Secretary
ACT Branch ASEG

Western Australia

Contact details:

President: John McDonald
Phone: (08) 9266 7194
Fax: (08) 9266 3407
Email:
mcdonald@geophy.curtin.edu.au

Secretary: Bob Groves
Phone: (08) 9370 1273
Fax: (08) 9370 1273
Email: BobGroves@bigpond.com

VicePresident: Graham Elliott (08) 9530 1230
Treasurer: Andrew Foley (08) 9480 3232

PEOPLE

Terry Crabb has returned from Canada, and Scintrex, to reside in Perth as CEO for airborne contractor Australian Geophysical Surveys Pty Ltd. [AGS] And, with his step into the breech, he has implemented ISO-9002 Quality System - *Model for quality assurance in production.*

Kim Frankcombe, formerly with The Normandy Group, has pulled up stumps and gone in to bat with Southern Geoscience Consultants.

The Branch Secretariat has lost contact with Associate member Michael LENNANE, formerly of OKORP Pty Ltd in West Perth, and associated with the Oil Industry. Any news of his whereabouts would be welcomed.

ASEG-WA/PESA GOLF DAY has been scheduled for Friday, 5 December 1997 and is to be held at the Vines Golf Club. Fees are $35 for ASEG/PESA members; and $40 for non-members. Members will have priority to enter, thereafter non-members will be offered entry. Expressions of interest (or sponsorship) should contact David Howard [Tel.(08) 9222 3331].

TECHNICAL

Student Presentations

The October Technical Meeting was dedicated entirely to student presentations to the Industry.

SUMNER, Jonathan
Exploration Geophysics in the North Kimberley Kimberlite Province of Western Australia.

MCMILLEN, Paul
Magnetic Signature of An Internal Granitoid Contact, Yandal Greenstone Belt, WA.

ISHERWOOD, Michael
The Effects of a Complex Anisotropy on Seismic P-Waves. 2.5D Physical Modelling Experiment.

MORTIMER, Russell
Application of Three-Component Downhole PEM to Nickel Sulphide Exploration in the Eastern Ultramafic Belt, WA.

WHITFIELD, Benjamin
Application of Broadband Electromagnetics to Shallow Salinity Investigations.

DAVIS, Simon
The Expression of Low-Throw Complex Faults in Surface Seismic Data.

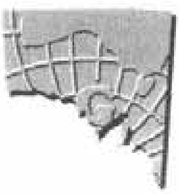
ALLEN, Cliff
A Preliminary Investigation Over An AEM Test Site, Bencubbin, WA.

This year, ASEG-WA awards of *Best Presentation* and *Best Technical Content* will be presented, at the WA Branch AGM, to Jonathan SUMNER and Simon DAVIS, respectively.

SEG Distinguished Instructor Presentation

Ian Jack [BP] is scheduled to come to Perth, on 18 Jun 1998, to present *Time Lapse 3D Seismics for Reservoir Characterisation.*

South Australia



Contact details:

President: Mark Taylor
(Boral Energy Resources Ltd)
Phone: (08) 8235 3827
Fax: (08) 8223 1851
Email: met@sagres.com.au

Secretary: Andrew Shearer
Phone: (08) 8274 7730
Fax: (08) 8373 3269
Email: ashearer@msgate.mesa.sa.gov.au.

1997 is winding down nicely for the South Australian Branch. We have had two technical meetings (and looking forward to a third) and our Melbourne Cup luncheon in that time. David McInnes is busily arranging shipment of this year's ASEG wine orders. Let him know if you don't get your order by mid-December (or the time that this is published, whichever comes ...).

Our October general meeting featured Barry Drummond of the Australian Geological Survey Organisation, whose talk was titled "Using Seismic in the Minerals Industry: A Mineral System Approach". The focus of this talk was not so much on the use of seismic to detect mineralisation directly, but instead to look at applying it to focus on larger scale mineral systems, in order to help delineate prospective areas. He presented results from three field areas around Australia.

Next on the agenda in SA was the Melbourne Cup luncheon (no clues as to the date for this one), which was both well attended and delicious.

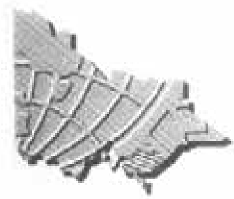
Since then we have also had another general meeting , this one featuring Brian Russell of Hampson-Russell Software Services Ltd. His talk was titled "New Developments in 3D Multiattribute Analysis". His interesting talk concentrated on recent developments in seismic data processing, especially concentrating on the power that the newer interactive workstations are giving the interpreter to experiment with new attributes, etc.

Our second November meeting is yet to be held at the time that this review was written. Nevertheless, we are looking forward to our Annual Student's Night. This year we will have presentations by five local honours geophysics graduates. The subjects of the presentations will, as usual, be quite varied, providing for an interesting evening.

As for December, we are all looking forward to the ASEG SA Christmas Party/Barbeque to be held at our esteemed president's home in the Adelaide hills. Hoping to see a few of you out there.Best wishes from the SA branch.

Michael Hatch
Branch Preview Scribe

Victoria



Contact details:

President: Shanti Rajagopalan
Phone: (03) 9230 1240
Fax: (03) 9230 1199
Email:
shantirajagopalan@expl.riotinto.com.au

Secretary: Dave Boothroyd
Phone: (03) 9412 5685
Fax: (03) 9412 7803
Email: boothroydd@wizza.agvic.gov.au

THE 1997 SELWYN SYMPOSIUM

On the 2nd of October 1997, the ASEG Victorian Branch co-hosted the 1997 Selwyn Symposium with the Victorian Division of the GSA. The theme *"Integration – A paradigm shift to effective regional mapping"* focused on the value of integrating geophysical interpretations into geological mapping programmes.

The event was a resounding success, with high praise from registrants for the quality of speakers. The majority of the audience were of a non-geophysical background, so the symposium offered many an insight into the value of geophysical interpretation in a variety of geological projects. In all, 118 delegates attended the symposium.

Ciaran Lavin.

October Meeting

Three speakers from Monash University presented talks at the Students' Night.

Simon Baker (supervised by Dr "Bear" McPhail and Professor Jim Cull) presented his research on Acid Mine Drainage. Tailings from sulphide ores often weather to sulphuric acid, and subsequent leaching can then pollute the water in a natural aquifer. Examples were provided of the King River system in Tasmania where discharge from the Mt Lyle mine has increased the pH to between 2-3. Vegetation is also affected, and Simon illustrated how GPR surveys can detect the difference between contaminated and fresh water.

Nancy Lammens (supervised by Ass. Prof Mike Hall and Professor Jim Cull) spoke about her magnetic survey off the coast of Cape Otway. Nancy took magnetic measurements with a Caesium Vapour Magnetometer towed behind a fishing boat. She located the three N-S linear features evident in the aeromagnetic data and modelled them. Nancy was also able to isolate additional features that were not observed in the Aeromagnetic data.

Stephen Gorenstein (supervised by Dr Mark Jessel) illustrated the increasing amount of information that is currently coming from the Grampians region of Victoria. He presented geophysical constraints on the structural interpretation of the Grampians Group rocks. Stephen isolated structural features, and, more specifically, indicated that normal faults separated the Grampians Group, the Mt Stavely Volcanics and the Glenthompson Sandstone units. Stephen illustrated that the depth to basement was of the order of 4000m.

Thanks must go to the speakers who gave up a night of their thesis preparations to entertain us all.

November Meeting

Rolf Klotz (R and D Manager (Australia and the Far East) Western Geophysical) presented his thoughts on the concept of Demigration to Zero Offset for pre-stack seismic data. Using a constant velocity DZO, Rolf illustrated how dipping layers were more visible and how the processing technique reduced the dispersal of reflector points with respect to a conventional DMO. Other benefits of a constant velocity DZO are that it is relatively inexpensive, has a greater accuracy in its ability to map structures and is not too complicated. Basically DZO is better able to manipulate the data and easily accounts for 3D structures. Errors are mitigated with a constant velocity DZO as any function used can be inverted to remove its effects on the data.

Rolf also discussed the benefits of a Wave Equation Replacement Layer which removes velocity effects such as Rugose water bottom effect. An initial downward continuation is performed followed by an upward continuation to reduce the effect of the water column and focus on the structures and their geological meaning. This is cost-effective and produces a cleaner and more detailed result.

The Victorian Branch would like to extend its sincere greetings to all members for the festive season and the coming year. We are having our annual Christmas Party at Craig Dempsey's house on the 23rd of November. I would like to thank the committee for their endeavours this year, and remind members that we will be very keen to continue the 1998 meetings in the same way we finished the final meeting of '97 - at Bridie O'Reilly's!!!!!
David Boothroyd (Victorian Branch Secretary).

The 1997/1998 Victorian ASEG Committee are:

President:	Shanti Rajagopalan	(03) 9230 1240
Vice-President:	Geoff Pettifer	(03) 5133 9511
Secretary:	Dave Boothroyd	(03) 9412 5685
Treasurer:	Dave Gamble	(03) 9684 4925
Committee:	Geoff Dunn	(03) 9478 3415
	Mark Dransfield	(03) 9230 1261
	Suzanne Haydon	(03) 9412 7843
	Ciaran Lavin	(03) 9412 5676
	Trevor Lobo	(03) 9799 2192
	Paul McDonald	(03) 9412 7866
	Ron Palmer	(03) 9863 5208

Clean and Green

The Application of Radiometric Data for Soil Mapping

Kerry Slater
Geological Survey of Victoria

Introduction

Understanding the distribution of soils is important for agricultural planning and land use management. Previous soil mapping methods revolved around costly, and time consuming ground mapping. The existing soil maps in Victoria are discontinuous and at different scales. Using radiometric surveys to map soil types has the potential to provide more accurate, high quality maps at faster rates than conventional methods.

Interpretation of airborne radiometric data provides a rapid and useful technique to assist in soil classifications, provided adequate ground truthing is completed. Used in conjunction with geology and digital terrain model, a soil association map can be readily produced.

The Nagambie 1:100 000 map (NAGAMBIE) is located in central Victoria, approximately 100 km north of Melbourne (Fig. 1). A pilot study on NAGAMBIE used detailed radiometric and digital terrain model data, to develop a methodology for soil mapping (Slater and de Plater, 1997). The geophysical data were used in conjunction with standard soil mapping techniques. Ground truthing enhanced the interpretation of radiometric data and improved the understanding of radiometric responses to different soil types. The study produced a soil association map using an alternative approach to conventional mapping methods.

Figure 1. Location of the Nagambie 1:100000 map.

The study area was chosen because of its implications for land planning and management, and the availability of data. It forms part of the Goulburn river catchment that drains the eastern highlands of Victoria. The region is used mostly for irrigation and dry land farming, the better, well-drained soils supporting crops; and the poorer soils, grazing. Increased aquifer recharge, rising water tables and widespread salinisation of soils is a major concern.

Radiometric surveys measure the natural gamma radiation emitted from the upper 50 cm of the earth's surface. The radioactive decay of the three elements K, Th and U emit nearly all the gamma rays radiating from the surface of the earth. Potassium is measured directly using the decay of K-40. Thorium and uranium are inferred from the daughter products of thallium (Tl-208) and bismuth (Bi-214) respectively. The entire spectrum (total count) is also measured. The varying concentrations and distributions of potassium, thorium and uranium, provide an indication of soil and rock characteristics.

The land system approach integrates environmental features including climate, geology, topography, soils and vegetation. Land system maps are developed from aerial photographs, topographic maps and field work. The radiometric method measures different properties to those of existing soil and land system maps.

Methodology

The methodology for the project is summarised in the following steps:

Data

The following data compiled at 1:100000 scale were used:

- radiometric and digital terrain model data from the 1994 Bendigo geophysical survey (Figs2-6);
- recent mapping by the GSV at 1:25000 scale (Edwards, et al., 1997; Slater, 1997), supplemented with the Bendigo 1:250000 geological map (King and Wilkinson, 1975);
- detailed soil map for part of NAGAMBIE (Skidmore, 1993); and
- land system map (Rowan, 1990).

Soil survey

Soil samples were taken at 19 sites. The soil surveys collected information on depth, colour, texture, structure, consistency, coarse fragments, pH, and electrical conductivity (EC). Five soil pits were analysed in detail, and collected information on landscape, soil morphology, pH, salinity, sodicity, dispersion, and land management (Slater and de Plater, 1997).

Soil association map

Due to resource limitations, ground truthing was limited and further work is required to enable better labelling of soil classes. The final soil association map with soil survey sites, consists of 22 classes (Fig. 8).

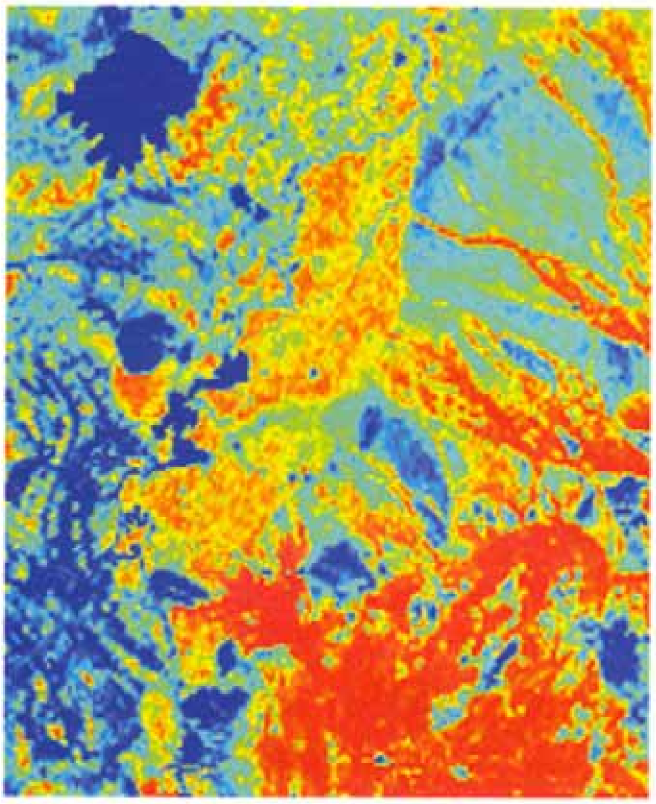


Figure 2. Total Count pseudocolour image (red-high, blue-low).
Data source: AGSO/GSV

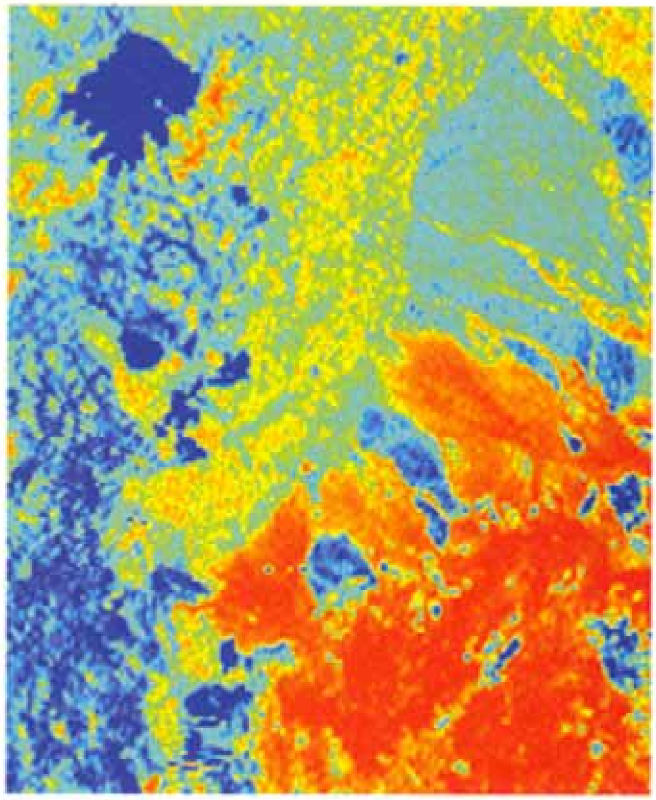


Figure 3. Potassium pseudocolour image (red-high, blue-low).
Data source: AGSO/GSV

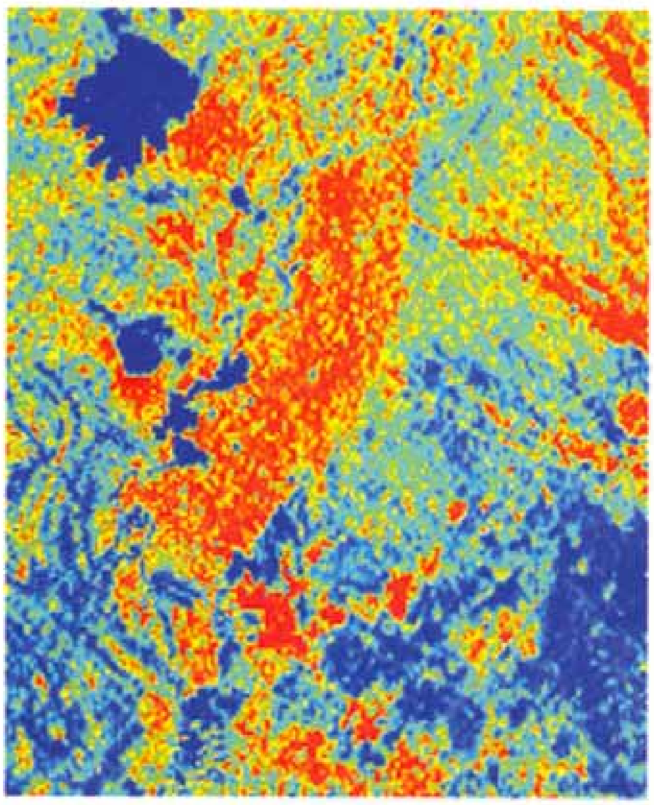


Figure 4. Thorium pseudocolour image (red-high, blue-low).
Data source: AGSO/GSV

Figure 5. RGB ternary image (red-potassium, green-thorium, blue-uranium).
Data source: AGSO/GSV

Nagambie sheet is 46 x 55 km.

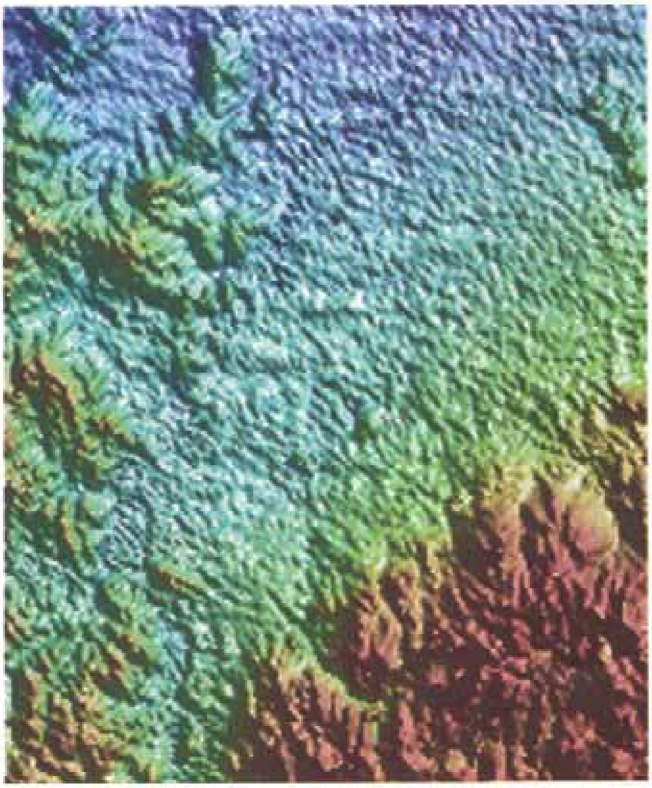


Figure 6. Digital terrain model image (red-high, blue-low).
Data source: AGSO/GSV

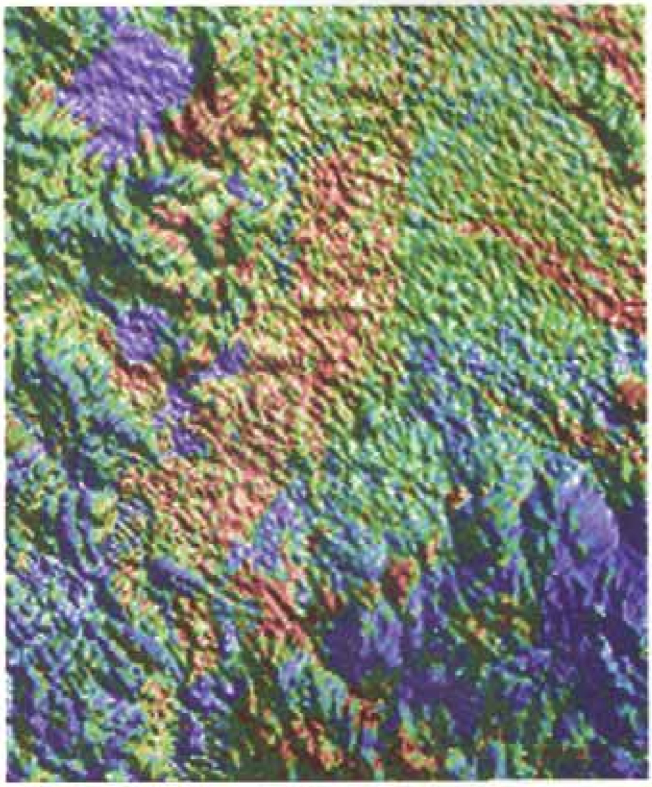


Figure 7. Thorium draped over DTM image (red-high Th, blue-low Th).
Data source: AGSO/GSV

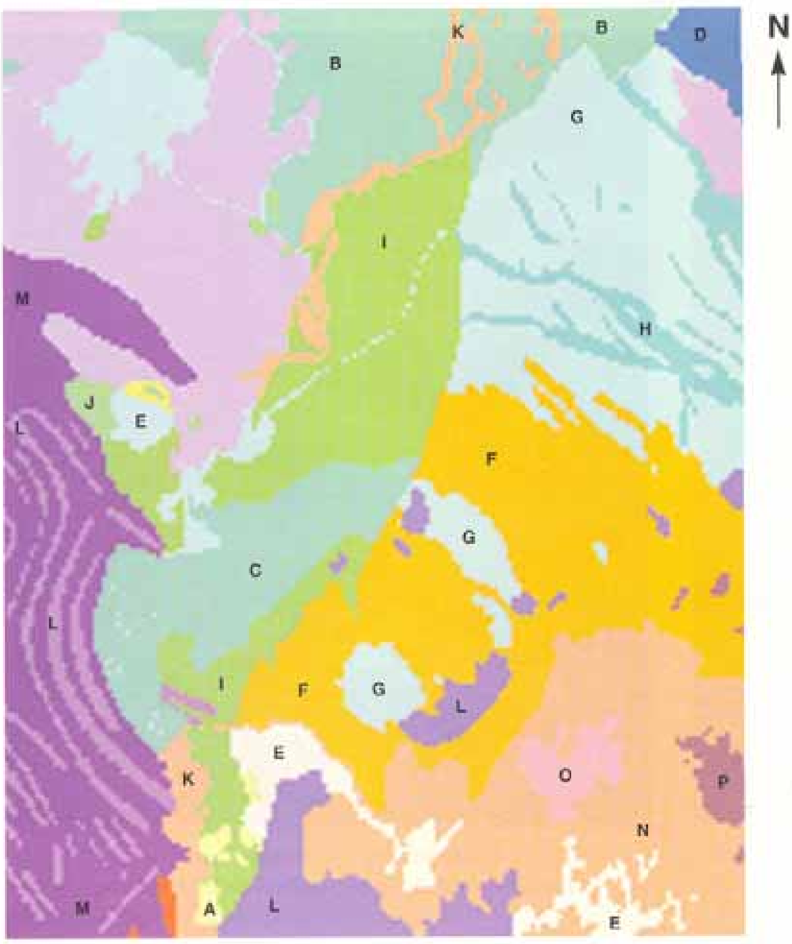


Figure 8. Soil interpretation of the Nagambie 1:100 000 map, Victoria.

LEGEND

A	Tertiary gravels
B	Red chromosols
C	Red chromosols
D	Red chromosols
E	Mangalore Sands & colluvium
F	Sandy soils
G	Loams
H	Alluvial soils
I	Tabilk Red soils
J	Swamp & lake deposits
K	Coonambidgal Formation
L	Shallow stony earths
M	Shallow stony earths
N	Shallow stony earths & granite
O	Shallow stony earths & granite
P	Shallow stony earths & granite

Geophysics

As part of a National Geoscience Mapping Accord, the Australian Geological Survey Organisation (AGSO), flew a geophysical airborne survey over the Bendigo 1:250000 map in 1994 (Franklin, 1995). The survey was flown at 100m altitude with a line spacing of 400m in an east-west direction. The GSV and some exploration companies funded infill flying at 200m line spacing, of the Bendigo 1:100000 map and sections of the Heathcote and Nagambie 1:100000 maps. In NAGAMBIE, the Mitchellstown 1:25000 map contains 200m line spacing data.

Interpretation

The radioelement variation in TC, K, Th and U channels have been used with topography and geology to classify soil type. Data integration and dataset combination played a vital role in the interpretation: for example, draping the radiometric data over the digital terrain model data (DTM), geology and land system map; geology over DTM; radiometric data over previous soil mapping.

The radiometric data was delineated into different groups, based on patterns and anomalies. The radiometric interpretation was correlated with Skidmore's soil mapping (1993). Many of Skidmore's, and Rowan's (1990) units correlated well with areas of distinct radiometric signatures, and are retained in the interpretation. However, better definition of unit boundaries can be outlined from the radiometric data. Some of the boundaries were modified, and a number of new mappable units have emerged from this project.

NAGAMBIE was divided into areas of steeper erosional slopes, depositional footslopes, and flat/alluvial areas using the DTM image (Figs 6 and 7). Within each area, the radiometric response was assessed and the soil forming processes were considered.

Radiometric data generally correlate with geology, surface drainage and geomorphology, although more variations exist in the radiometric data, indicating variations in soils. The small scale land system map (Rowan, 1990), provided only a general overview.

Individual units on the soil association map, may have variable radiometric responses due to any of the following:

- variation in sediment source;
- topography;
- degree of weathering;
- drainage;
- prior stream activity;
- salinity of water discharge;
- degree of source rock metamorphism; and
- extent of compaction or cementation.

Some units have characteristic responses often with little variability. For example, the Tertiary gravels (**A** in Fig. 8) in southern NAGAMBIE display characteristic low radiometric responses.

Red chromosol soils are abundant on the Riverine Plain on NAGAMBIE (**B**, **C**, and **D** in Fig. 8). Soils of class **B** display a mottled moderate potassium and variable thorium responses (Figs 3, 4 & 5). The mottled character in Figure 5 indicate a variable water content in the soils, presumably from irrigation over the Goulburn irrigation district. Soils of this class are sandy loams developing into clays in the B-horizons, with pH and EC increasing with depth. Soils of class C show pH increasing with depth.

Some soils with high potassium responses were acidic (Mangalore Sands and colluvium—**E**, sandy soils—**F**). Sandy soils are potential groundwater recharge zones. However, surficial sand may be covering clay at shallow depth. Soils containing high clay, tend to retain water longer, and are prone to salinisation and poor groundwater recharge.

Soils in areas with high potassium responses are younger than areas with low potassium responses. For example, sandy soils—**F** overprint loams—**G**. This may be the result of the highly mobile potassium, leaching out of the soil over time.

Areas of high thorium responses correspond with high uranium, and high (sometimes moderate) potassium responses (Mangalore sands and colluvium—**E**, alluvial soils—**H**, Tabilk Red soils—**I**, and red chromosols—**D**). Areas of low thorium responses correspond with low uranium and potassium responses (swamp and lake deposits—**J**, Coonambidgal Formation—**K**, and Tertiary gravels—**A**). One pit site showed saline waters, and corresponded to variable uranium responses. At this site, pH, EC and sodicity increased with depth.

Soils developed on Silurian and Devonian bedrock were divided into four classes. The classes are labelled shallow stony earths and duplex soils, based on Rowan's (1990) classification. Topographic high areas, comprising more resistant sandstone, have low potassium and thorium responses (Figs 3-5, 7; **L** in Fig. 8). Low topographic areas, comprising easily eroded silt-dominated units, have high potassium and thorium responses (Figs 3-5, 7; **M** in Fig.8). Increases in silt content correspond with an increase in potassium and thorium. Sands of classes E and F correspond to high potassium responses, influenced by the feldspars of the eroding granite.

Soils developed on granite have been divided into three classes, based on the radiometric data and the DTM. The classes are labelled shallow stony earths, duplex soils, and granite bedrock based on Rowan's (1990) classification. Most of the granite has been mapped as **N** (high potassium and low thorium responses, high topographic area). The other two classes may represent a different phase or later intrusion (**O**—low potassium and moderate to high thorium, high topographic area; **P**—low potassium and thorium responses, topographic low area).

Discussion

Radiometric data in conjunction with other datasets, can focus the fieldwork effort and significantly speed up the mapping process. The most useful datasets in this study were the radiometric and DTM combinations, and geology. Computer generated classifications were ineffectual, in this instance, in giving additional information. It is important to use every available dataset (radiometric data, geology, soil mapping, DTM, Landsat/SPOT, and land system maps). Adequate field work is required to verify soil classes, otherwise, the interpretation remains unconstrained.

Appropriate use of a GIS package provides correlations between geomorphic units, land use, soil type and the radiometric data. The incorporation of land systems information and the production of a GIS package with all the datasets, was beyond the scope of this project. This technique has the potential to provide a quantitative approach to land management and planning.

Further research to improve the understanding and applications of radiometrics for soil interpretation is required before the information can be practically and accurately applied. Additional quantitative work could involve classification, statistical analysis (eg. un-mixing to define end member components), and ground radiometric surveys with follow-up sampling and analysis.

The dataset for each area needs to be looked at on a case by case basis. Poor quality radiometric data may limit its usefulness and application. A number of variables affect the data quality of the airborne surveys. Seasonal moisture variations and irrigation might affect radiometric data, (eg.in wet weather, waterlogged soils will give lower values than drier weather). Radiometric data is sensitive to aircraft configuration. Larger crystal packs record more counts per second but reduce aircraft manoeuvrability, and may require increased ground clearance. Radon gas can often concentrate in the bottom of valleys overnight. This can lead to severe problems affecting the uranium data. This is often a problem in rugged terrains (eg. Eastern Highlands of Victoria). High quality processing of the radiometric data will significantly improve data.

References

Edwards, J., Olshina, A. and Slater, K.R., 1997. Nagambie and part of Yea 1:100 000 map geological report. Geological Survey of Victoria Report 109.

Franklin, R., 1995. Bendigo airborne geophysical survey, 1994 - operations report. Australian Geological Survey Organisation Record 1995/54.

Grasty, R.L. and Minty, B.R.S., 1995. A guide to the technical specifications for airborne gamma-ray surveys. Australian Geological Survey Organisation Record 1995/60.

King, R.L. and Wilkinson, H.E., 1975. Bendigo 1:250 000 geological map. Department of Mines, Victoria

Rowan, J., 1990. Land systems of Victoria, Department of Conservation and Environment.

Skidmore, D.J.P., 1993. Technical Report on the Mapping of Potential Groundwater Recharge in the Nagambie Area, Goulburn Dryland Salinity Management Plan. Unpublished report 1993/69, Hydro Technology, Tatura.

Slater, K.R., 1997. Geological interpretation of geophysical features. In Edwards, J., Olshina, A. and Slater, K.R., 1997. Nagambie and part of Yea 1:100 000 map geological report. Geological Survey of Victoria Report 109.

Slater, K.R. and de Plater, K., 1997. The application of radiometric data for soil mapping - Nagambie 1:100000 map. Geological Survey of Victoria. Technical Record 1997/1. Department of Natural Resources and Environment.

For more information contact: Kerry Slater, Geological Survey of Victoria, Tel: (03) 9412 5686, email: slaterk@wizza.agvic.gov.au.

Spectral Signatures of the Tubridgi Field

Onshore Caranarvon Basin, Western Australia
(Reservoir Imaging and Characterisation: Case History #97-03)

Jim Dirstein
Total Depth (Exploration Services) Pty Ltd

This case history describes the application of spectral analysis to measure the attenuation of seismic frequencies beneath a hydrocarbon accumulation. The spectral analysis method employed is a proprietary technique called SPECTRA developed by Signal Estimation Technology Inc. (SET) of Calgary Canada.

Introduction

The Tubridgi Gas Field is located 30 km west-southwest of Onslow W.A. in the onshore portion of the Carnarvon Basin in Production Licence L9 (Figure 1). The hydrocarbons are entrapped in a northeast-trending anticlinal structure with broad, low relief evident only by depth mapping of seismic two-way-times. The commercial hydrocarbons are trapped in the Cretaceous and Triassic Sandstone reservoirs and are sealed by the Cretaceous Muderong shale. The stratigraphic section at the Tubridgi gas field is shown in Figure 2. Note that a secondary non-commercial gas accumulation within the poor reservoir quality Gearle Siltstone is the likely cause of distortions in the T.W.T structure across the field. The field was discovered in 1981 with the drilling of the Tubridgi-1 well by Pan Pacific Petroleum NL. Ten years later the Tubridgi Gas Field became the first commercial hydrocarbon accumulation to be developed onshore Carnarvon Basin (Thompson).[i]

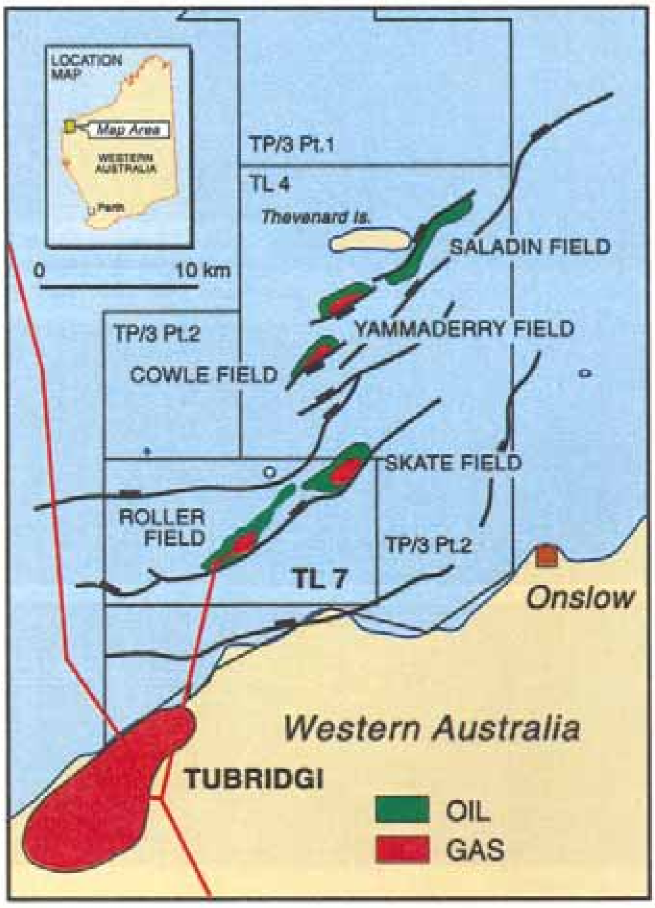


Figure 1. Location Map.

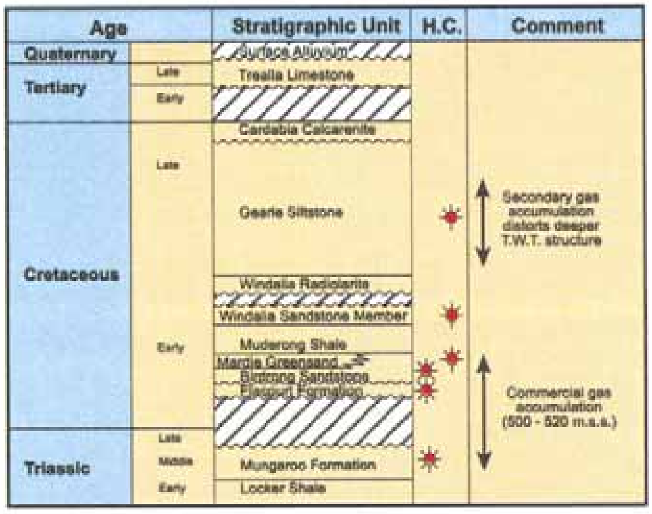


Figure 2. Stratigraphic Section: Tubridgi Field.

Background

While attenuation zones ("dim-spots") have been visually noted on seismic sections associated with some hydrocarbon accumulations for almost twenty years (Taner and Sheriff,[ii] Anstey,[iii] Dobrin[iv] and Sengbush[v]), early attempts at measuring attenuation in the laboratory and from seismic data have had limited success. During the mid eighties, work by Terry Jones[vi] discussing a frequency dependent attenuation model, and experimental work by Bourbie et. al[vii] demonstrating that gas in rock pores attenuates more P wave energy than water, helped set the stage for the further investigation and development of these ideas.

Since 1990, a company called Signal Estimation Technology Inc. has been marketing and using a commercial software package called SPECTRA.[viii] The technique contains several proprietary algorithms that have overcome some of the limitations of previous methods used to measure attenuation from stacked seismic data.

The factors affecting the spectral character of the seismic data generally fit into two categories (Dilay and Eastwood).[ix]

Lithological

The spectral character changes in response to time-thickness variations within a formation or a group of formations. Usually, these variations can be associated with changes in velocity within the formation, stratigraphic pinch-ins pinch-outs, changes in sand / shale ratio, and lateral changes in the impedance of the reservoir.

Petrophysical

Spectral attributes can also be used to estimate the attenuation characteristics of a certain formation. It has been experimentally established that fluid-bearing porous rock formations attenuate seismic waves preferentially (ie. higher frequencies within the seismic band are more severely attenuated than lower frequencies). Generally, gas attenuates more than oil and oil more than water. Klimentos[9] discusses a well logging example and Eastwood and Dilay[10] document a case history using attenuation as measured by the same proprietary technology used in this study.

This case history deals with spectral analysis designed to minimise the lithological effects, thereby isolating the petrophysical effects, namely attenuation.

Procedure

In this study the stacked seismic data was analysed for evidence of attenuation beneath the Tubridgi hydrocarbon accumulation. The line analysed was an NW-SE oriented seismic line (J84A-19) located through the central portion of the field. The seismic data was not reprocessed pre-stack for the spectral analysis. However, the post-stack SPECTRA processing flow followed is shown in Figure 3. The first step was to apply a noise attenuation technique (CARNA) to reduce the levels of coherent and random noise in the data and thus improve

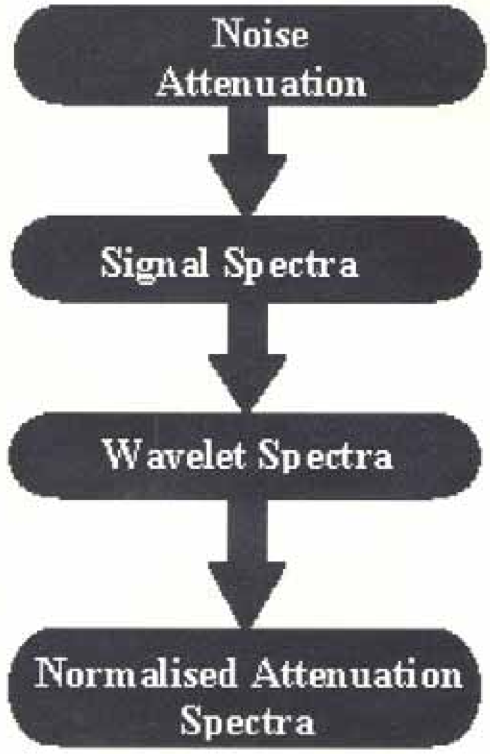


Figure 3. SPECTRA Processing Flow.

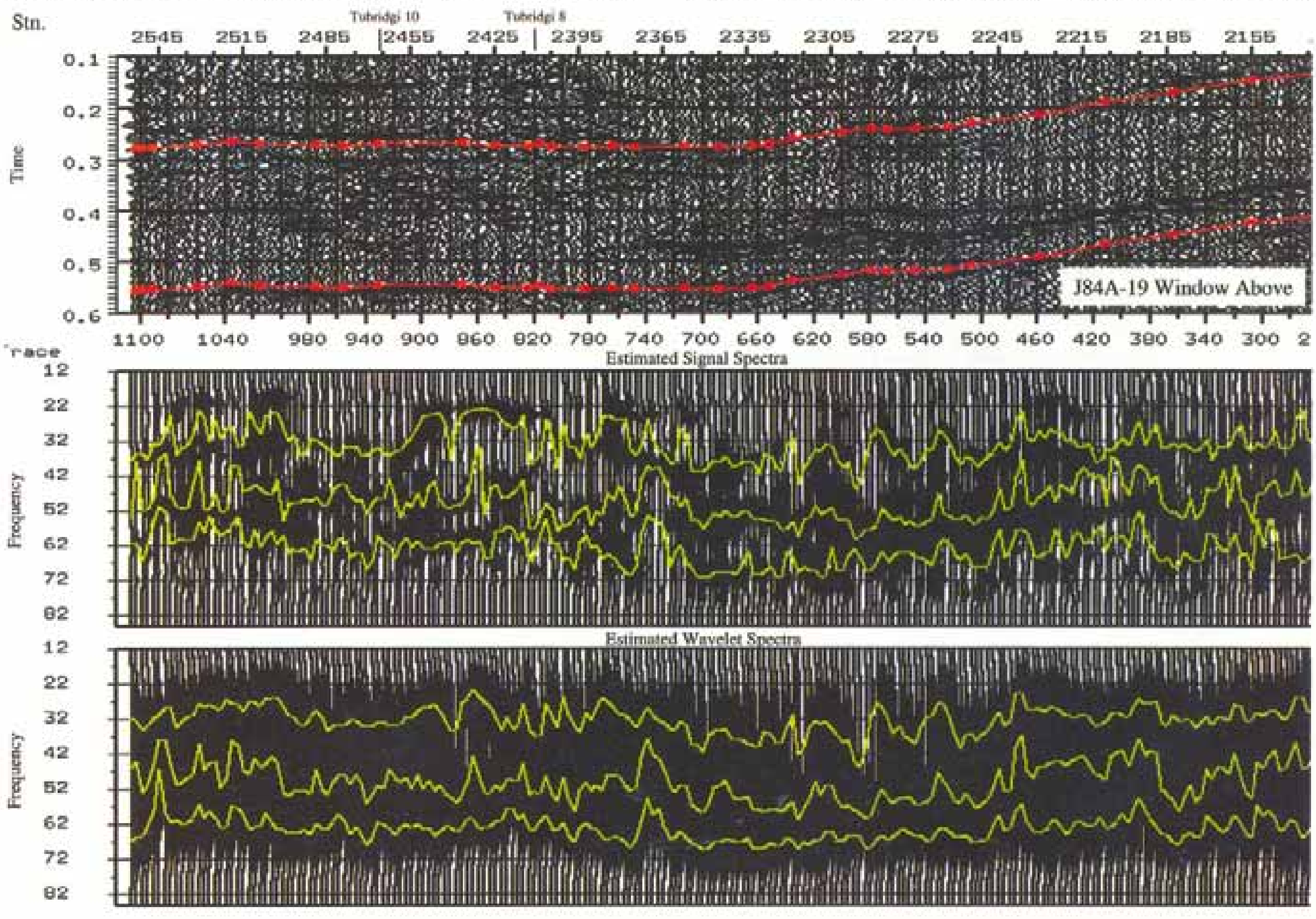


Figure 4. Estimated Signal and Wavelet Spectra: Window Above.

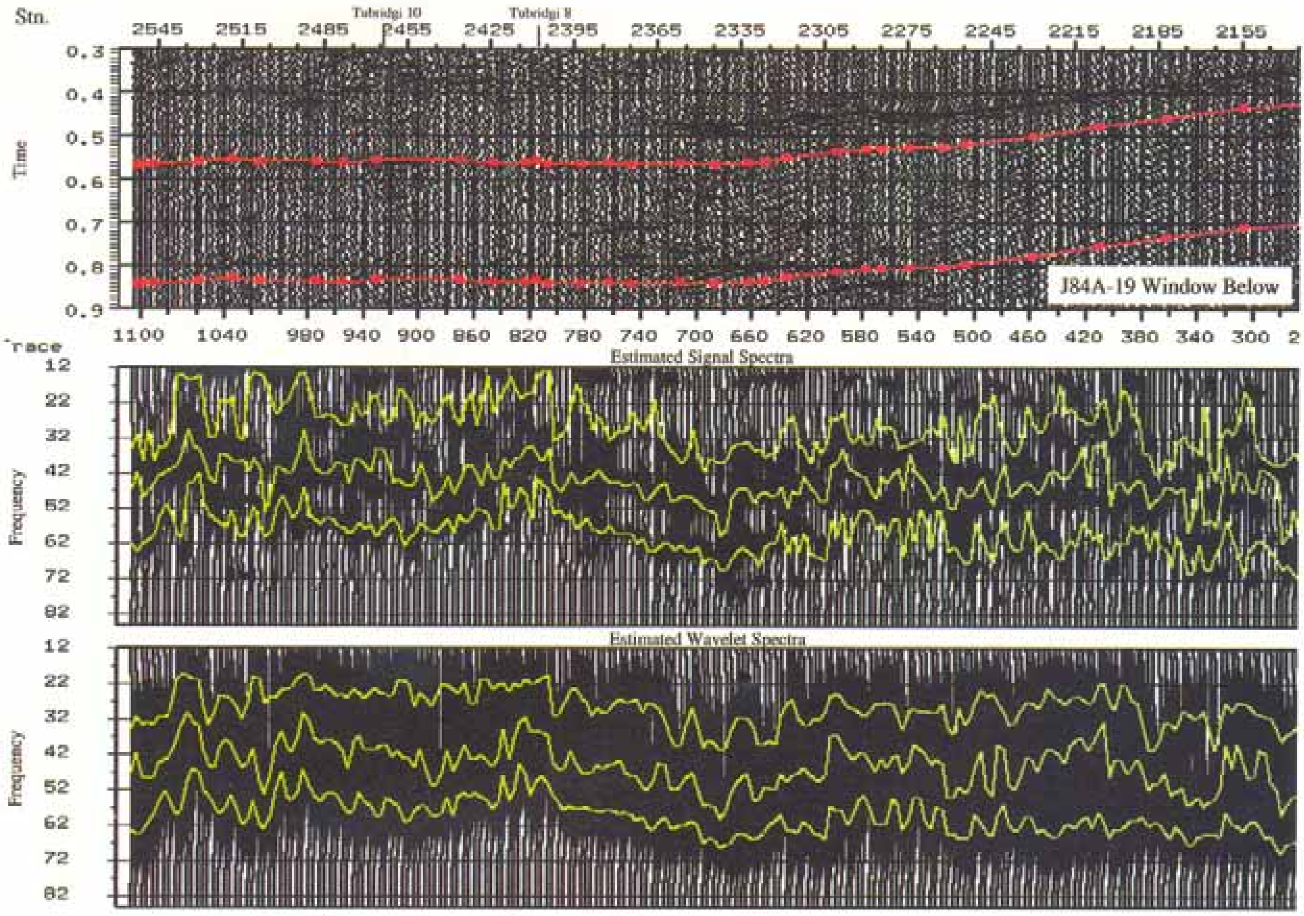


Figure 5. Estimated Signal and Wavelet Spectra: Window Below.

J84A-19 Normalised Attenuation Spectra

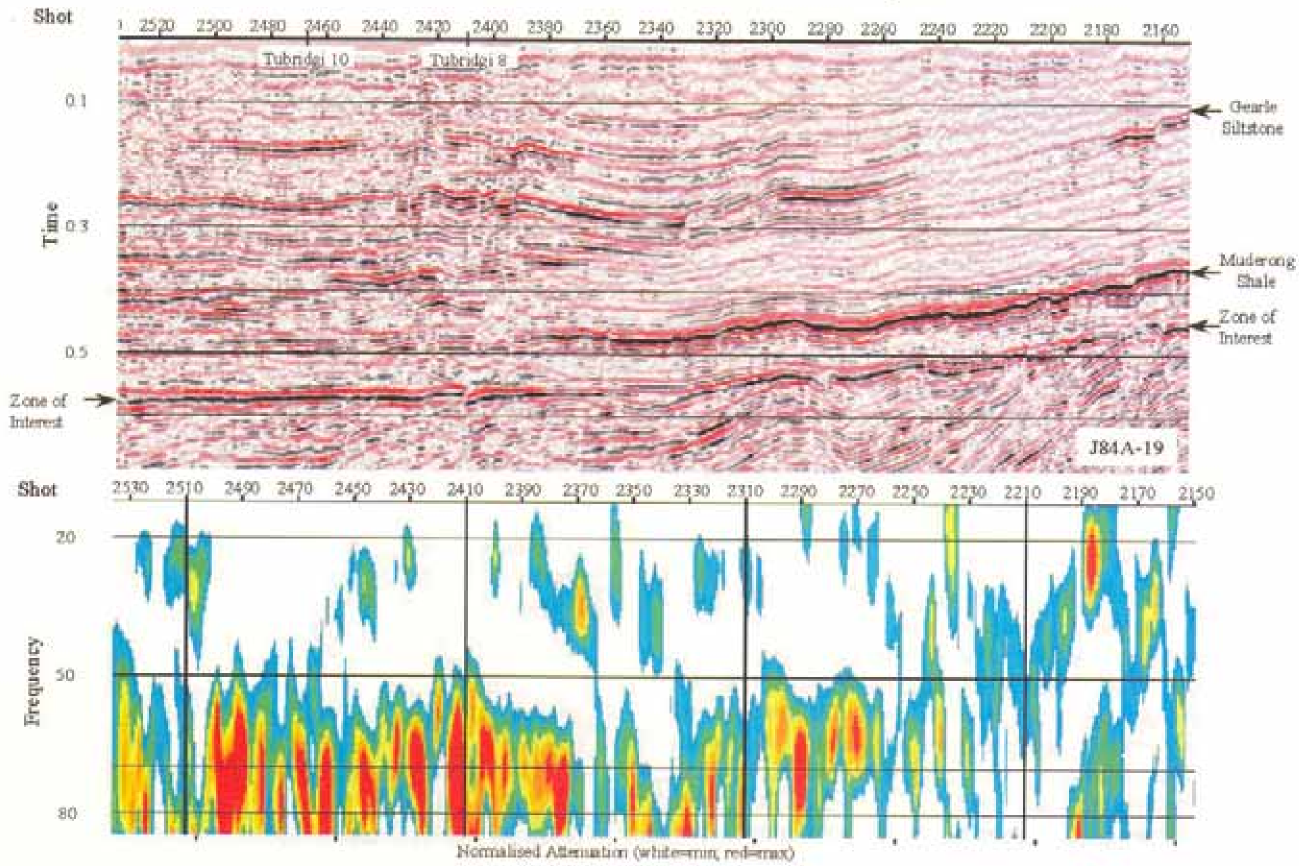


Figure 6. Normalised Attenuation Spectra.

the Signal-to-Noise-Ratio (SNR). CARNA utilises a localised principal component analysis technique developed by Signal Estimation Technology Inc. (SET). Next, the signal spectrum was estimated for each trace from a horizon consistent time window (280 msec), both above and below the zone of interest. These spectra are further processed to estimate attenuation spectra.

Estimated Signal and Wavelet Spectra

The estimated signal and wavelet spectra from the window above the zone of interest are shown in Figure 4. The upper panel shows the seismic with the analysis window highlighted in red. The location of the Tubridgi-8 and Tubridgi-10 gas wells are shown. The middle and lower panels show the estimated signal and wavelet spectra. Note that the vertical axes on the spectral displays represent frequency. The black areas provide an indication of the presence and strength of spectral frequencies in the window of analysis. In this study the window of analysis used was 280 milliseconds to help limit the effects of non-stationarity of the wavelet spectra. The effects of reflectivity are further minimised in determining the estimated wavelet spectra. The 15th, 50th, and 85th percentile frequencies are highlighted in yellow on the estimated signal and wavelet spectra panels to quantify the spectral changes.

Figure 5 shows the estimated spectra from the window below the zone of interest. Examination of the estimated wavelet spectra from the window below shows a subtle shift in the percentile frequencies towards lower frequencies. Comparison of the wavelet spectra from the window above to the wavelet spectra from the window below suggests a loss of higher seismic frequencies below the Tubridgi gas field.

Normalised Attenuation Spectra

The normalised attenuation spectra were then determined using the estimated wavelet spectra from the window above and the window below the zone of interest. The normalised attenuation display is shown below the seismic panel in Figure 6. The normalised attenuation spectra show the attenuation plotted using a dB scale with white representing minimum and red representing maximum attenuation. In this example the normalised attenuation spectra shows that there has been a loss of seismic frequencies (50-80 Hz.) from the window of analysis beneath the Tubridgi gas field compared to the window of analysis above the reservoir.

Summary and Conclusions

The presence of gas in the Cretaceous and Mungaroo Sandstone reservoirs at the Tubridgi field appears to have caused measurable attenuation of higher seismic frequencies. Since the attenuation measurement was made from geophysical archived stacked seismic data and the analysis is independent of phase, this type of spectral analysis may provide a rapid means of extracting useful seismic attributes. The integration of these spectral attributes into current corporate workflows may make a significant contribution in exploration, appraisal and exploitation of new and existing hydrocarbon reserves.

References

i. Thompson, M. "The development geology of the Tubridgi Gas Field", APEA Journal 1992 P.44-55.

ii. Taner, M.T. and Sheriff, R.E., "Application of amplitude, frequency, and other attributes to stratigraphic and hydrocarbon determination", in Seismic Stratigraphy AAPG Memoir #26, P. 301-327.

iii. Anstey, N. A., "Seismic interpretation: The Physical Aspects", IHRDC 1977.

iv. Dobrin , M. B., "Introduction to geophysical prospecting" 1984, McGraw-Hill Book Co.

v. Sengbush R.L., "Seismic exploration methods:" IHRDC.

vi. Jones T. D., "Pore fluids and frequency-dependent wave propagation in rocks" Geophysics, Vol. 51, No 10 (October 1986): P. 1939-1953.

vii. "Acoustics of porous media" Bourbie, T., O. Coussey, and B. Zinzer , Paris: Edit. Technip, 1986.

viii. SPECTRA is a Signal Estimation Technology Inc. product developed by Dr. Maher Maklad.

ix. Dilay A. and Eastwood J., "Spectral analysis applied to seismic monitoring of thermal recovery" Leading Edge, November, Vol 14, No. 11, P. 1117-1122.

x. Klimentos T., "Attenuation of P- and S-waves as a method of distinguishing gas and condensate from oil and water", Geophysics, Vol. 60, No.2 (March-April 1995); P. 447-458.

xi. Eastwood J., and Dilay A. "Seismic monitoring of steam-based recovery of bitumen" Leading Edge, April, Vol 13,No. 4, P. 242-251.

Contact Information

Jim Dirstein
Total Depth (Exploration Services) Pty. Ltd.
21 Churchill Ave, Subiaco 6008
(P.O. Box 1690 West Perth
W.A. 6872) Australia
Mobile: 0419 904 356
Fax: (618) 9382 4308
Phone: (618) 9382 4307
Email: dirstein@iinet.net.au

Andrew Dilay, Maher Maklad
Signal Estimation Technology Inc.
Suite 2020, 633 -6th, Avenue S.W.
Calgary, Canada, T2P 2Y5
Phone: 1 403 262 6260
Fax: 1 403 262 8153
Email: dilay@signal-est.com
Email: msm@signal-est.com

Outcrop interpretation of seismic-scale normal faults in southern Oregon: Description of structural styles and evaluation of subsurface interpretation methods

Russell K. Davies, Michael Crawford, William F. Dula Jr., Mary J. Cole, and Geoffrey A. Dorn
ARCO Exploration and Production Technology, Plano, Texas

(Reprinted from the Leading Edge, August 97)

Faults are critical components of many subsurface hydrocarbon traps. Trap integrity, volumetrics, and reservoir compartmentalization all depend on an accurate interpretation of the fault geometry. Techniques and methods to better define the geometry of the faults in the subsurface have improved over the last several years because of descriptions and models developed from detailed outcrop studies of faults and the optimization of workstation tools and methods to interpret seismic data. Most outcrop descriptions, however, are restricted to faults with small throws and map lengths that are well below seismic scale. This precludes a direct comparison between the fault geometries mapped on the surface and those interpreted in the subsurface from seismic data.

We mapped seismic-scale normal faults and associated structures on a well-exposed surface in southern Oregon to document some of the fault detail and complexity that are often ambiguous in subsurface structural interpretation and to describe common trapping geometries in extensional regimes. The predominant fault style mapped in the outcrop is closely-spaced, overlapping normal fault segments with similar dip directions that share displacement along their length. Displacement along the composite fault zone rotates the footwall into a broad flexure, which sets up a common trapping configuration of anticlinal dip closure away from the fault.

Accurately interpreting the segmentation and structural detail along composite fault zones in the subsurface is limited by seismic data resolution and inefficient seismic interpretation methods. Evaluating variations in attributes displayed on mapped and gridded horizons significantly improves the quality and resolution of the fault interpretation. Two popular methods for structural interpretation of mapped horizons are dip-magnitude and 3-D visualization. We apply these methods to the interpretation of the normal faults in the outcrop exposure to evaluate their effectiveness in interpreting fault and structural detail.

In the following discussion, we first describe the geometries of the observed fault styles in southern Oregon and second evaluate the workstation-based dip magnitude and 3-D visualization interpretation of the fault geometry. A comparison between the two interpretations demonstrates the applicability and effectiveness of the subsurface methods in defining detailed fault geometries on mapped horizons. Next we briefly discuss the effects of data resolution on the interpretation and conclude with examples of fault displacement analysis to demonstrate the systematic variation in fault displacement and its application in fault interpretation.

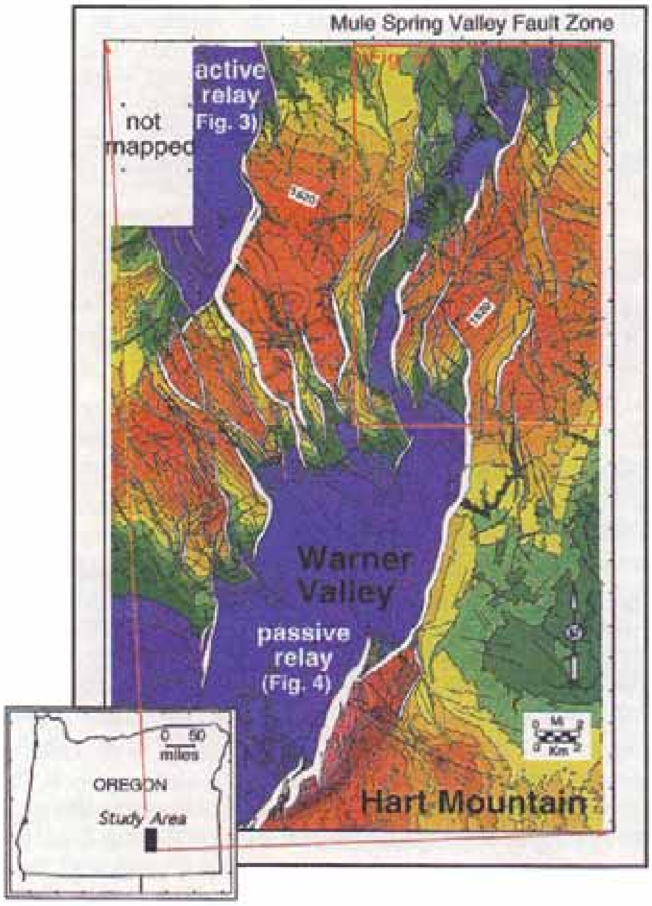


Figure 1. Location of the study area in south-central Oregon and normal fault-gap polygons interpreted from stereo-photo pairs and superimposed on machine-contoured digital topography data (contour interval is 20 m). Red colors are higher elevations and blue are lower elevations. Ticks on downthrown side of hanging wall cut-off trace. Locations of figures discussed in the text are labeled.

Study area

Our study area is a sage-covered basalt plateau in a remote region of south-central Oregon (Figure 1) that is dissected by normal faults, the largest of which have trace length greater than 10 km. Fault scarps form dramatic cliff faces, and some exceed 800 m of relief, which represents the minimum estimate of fault throw. The fault lengths and throw and the relief of the structures mapped from the surface data are above average values for seismic resolution and are similar in scale to hydrocarbon traps in the subsurface.

Regionally-extensive Tertiary basalt flows that cap broad uplifted footwalls of the largest faults dominate the surface geology. At the scale of observation for this study, we ignore isolated flows and stratavolcanoes and consider the regional surface as an analog to a faulted horizon in the subsurface. Topography on the faulted surface is topologically equivalent to a structure map de-rived from a 3-D seismic interpretation of a horizon in the subsurface.

Data

Over the study area, we compared the fault interpretation de-rived from two independent data sets: (1) digital elevation data and (2) stereo-photo pairs. The gridded format for the digital elevation data is similar to that for interpreted subsurface seismic horizons, and therefore workstation applications such as 3-D visualization and at-tribute analysis can be applied for the interpretation of fault traces on the exposed surface.

Elevation contours from 1:24 000 USGS topographic maps were scanned, digitized, and resampled to a square grid with a 20-m spacing. The 20-m horizontal data spacing is comparable to the current standard 3-D seismic line spacing of 12.5 m. The digital topographic data have a vertical resolution of 5-10 m.

We purchased a second digital topographic grid at a 1:250 000 scale over the study area to compare the effects of data resolution on delineating structural detail. The 60-m horizontal spacing of these data is below that of the higher resolution digital elevation data.

Fault traces interpreted from stereo-photo pairs over the surface exposure in Oregon were superimposed on the higher-resolution digital topography. The 1:80 000 scale photo-pairs have a vertical resolution of approximately 3 m. The traces of the slope breaks at the upper and lower boundaries of the fault scarps approximate the footwall and hanging wall cutoffs, respectively. Together these traces define fault-gap polygons. The width of the fault-gap polygon in this case is approximate because of the erosional retreat of the footwall fault trace and burial of the hanging wall fault trace. Contouring the digital surface topography excluding the fault gap polygons produces a map analogous to a seismically-derived, subsurface structure map (Figure 1).

Interpretation of fault and related structural styles. The fault style interpreted from the aerial photos and the structural geometry contoured from the digital elevation data in south-central Oregon are common in regions of extension and are characteristic trapping configurations in the subsurface. The predominant structures are composite fault zones comprised of closely-spaced, overlapping fault segments that rotate the adjoining footwalls into broad flexures (footwall uplift). Both the separation between the terminations of the faults and the overlap are small. Displacement is transferred across relay ramps between the terminations of overlapping segments. Rarely does a fault appear as a single unbroken trace on the map.

The faults along the eastern boundary of Mule Springs Valley at the northern end of the map (Figure 1) are mapped as three prominent overlapping fault segments (Figure 2) The fault zone separates the topographic low of the valley to the west from the broad

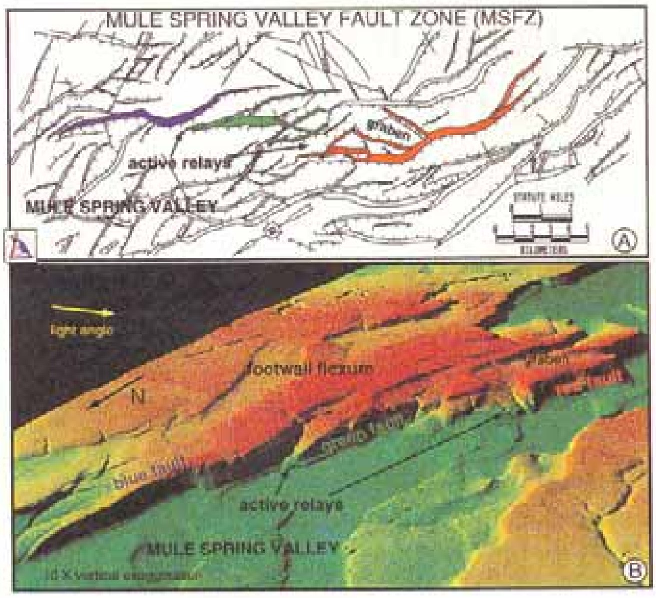


Figure 2. Detail of Mule Spring Valley Fault Zone (MSFZ) in northeastern corner of study area. (a) Map of fault traces. Color-filled polygons are the principal fault segments comprising the fault zone. Colors represent separate fault segments. Ticks on downthrown side of normal faults. (b) Perspective view of the MSFZ from 3-D visualization of the digital elevation data. The viewing direction ("eye" position) is shown in the fault trace map (a).

uplift to the east. Smaller faults adjacent to, and along the curved traces of, the mapped fault segments add a smaller but important contribution to the total deformation. Some of the splays along the length of the individual segments comprising the fault zone may be terminations of small faults that coalesced to form the longer segments.

Displacement along single faults or composite fault zones commonly deforms the footwall into a broad flexure. This footwall uplift with anticlinal (3-way) dip closure away from the fault or composite fault zone is a common trapping configuration mapped in the subsurface. Footwall flexure along single isolated faults, although rare, is an end-member trapping configuration. Maximum closure height occurs near the mid-length of the mapped fault trace, and its lateral limits are the fault trace length.

Multiple fault segments with a common dip direction that overlap at their terminations are more common than single faults, but the trapping configuration on these composite faults is similar to those associ- ated with isolated faults. Closure along these multiple fault segments may extend laterally across regions of overlap between two fault segments. The Mule Spring Valley Fault Zone (MSFZ) is mapped as three separate but structurally complex fault segments. However, the segments behave in consort to rotate the footwall into a broad flexure with a lateral dimension limited by the map length of the composite fault zone (Figure 1). Local footwall flexures along the individual segments perturb the broader footwall uplift. These local footwall highs along the individual segments are connected to the hanging wall along a ramp between the segment terminations. These ramps are referred to as relay ramps or transfer zones.

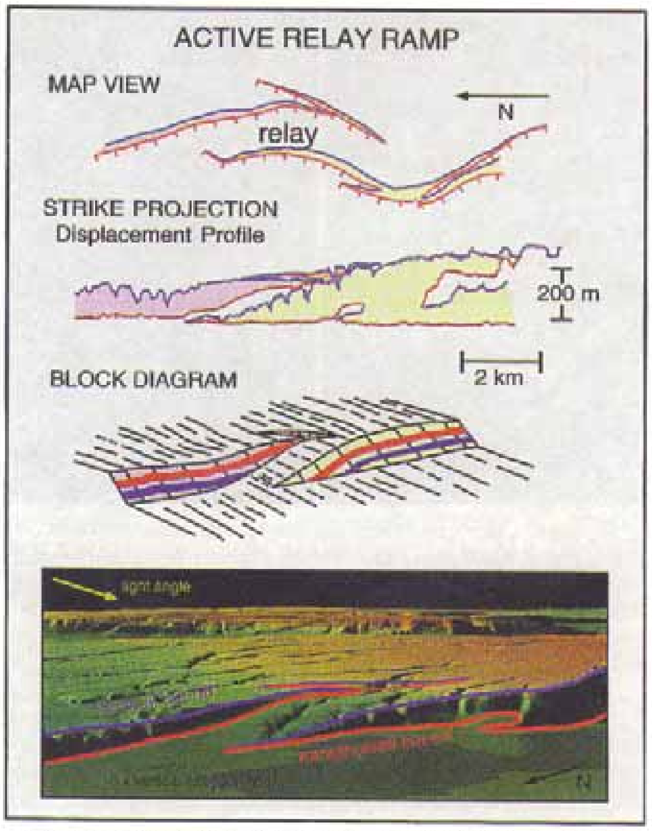


Figure 3. Active relay ramp, dipping section between the terminations of two unconnected fault segments referenced in Figure 2. Juxtaposing the fault cut-off polygons onto a vertical plane parallel to the average strike of the fault produces the displacement profile.

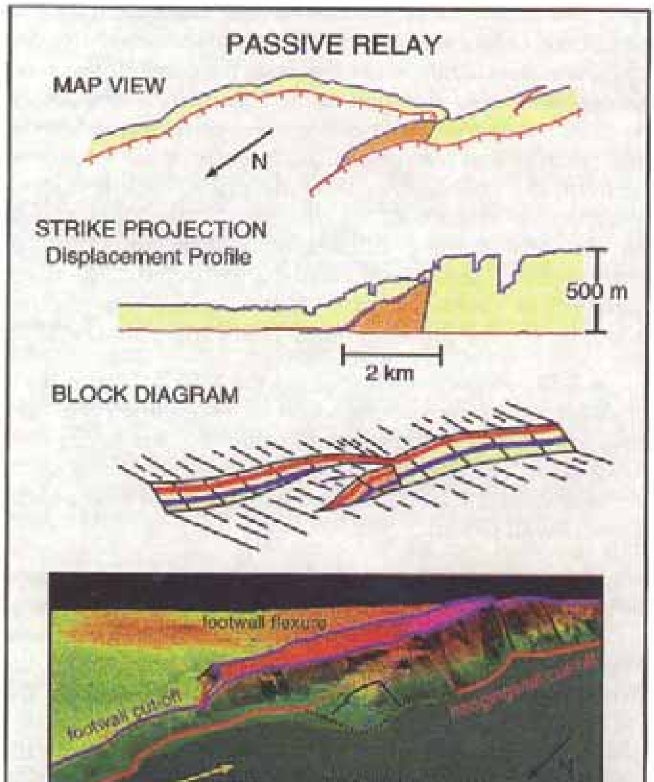


Figure 4. Passive relay ramp, dipping section between two fault segments cut by a fault connecting the two segments. See Figure 2 for location.

Relay ramps are pathways across the composite fault zone and may affect hydrocarbon charge and seal along the zone. The efficiency of hydrocarbon migration from the hanging wall of a composite fault zone to the footwall trap may improve if relay ramps along the zone provide a shorter pathway. Fault seal is negatively affected if the displacement variation along individual fault segments within the relay ramps juxtaposes the reservoir against itself or another permeable horizon allowing cross-fault leakage. Only local footwall uplifts along the individual fault segments would trap the hydrocarbons in this case. Similar variations in displacement are not expected on a single large fault with a map length and maximum uplift like that of a composite fault zone.

In some cases relay ramps are cut by faults that connect the terminations of the two fault segments: displacement is shared between the segments across the relay ramp. We classify these as passive relay ramps. Active relay ramps are the unfaulted ramps between the terminations of separate fault segments.

Active relay ramps occur be-tween the prominent fault segments comprising the MSFZ (Figure 2). Another example of a geometrically simple, active relay ramp occurs between the terminations of two faults in the northwest part of the study area. The ramp dips gently away from the footwall to the hanging wall between the terminations of two fault segments (Figure 3).

A passive relay breached by the intersection of fault segments occurs along the long continuous fault trace at the north end of Hart Mountain (Figure 4). The southern termination of the fault segment curves and intersects the fault segment to the west. Displacement is shared across the connected fault segments. The remnant relay ramp, developed prior to the fault intersection, remains between the terminations of the fault segments and rides passively on the hanging wall with continued displacement on the composite fault.

The geometry of the faults and footwall flexures described here are common in the subsurface in extensional regimes. The critical component in identifying "trap" risk is correctly interpreting the fault geometry. Fault segmentation, for example, has implications to fault seal and charge as described. Methods to map fault detail on an interpreted subsurface seismic horizon have improved over the last several years. In the following sections, we compare the independent fault interpretation from stereo-photo pairs and attribute analyses on the digital elevation data to investigate data quality and quantity on the effectiveness of subsurface methods in resolving the structural interpretation.

Subsurface interpretation methods. Popular subsurface interpretation techniques for defining the fault geometries and structure on a mapped horizon include dip magnitude, 3-D visualization, dip azimuth, reflection strength, amplitude, and residual structure. In this study, we define the fault geometry from dip magnitude analysis of the digital elevation data in south-central Oregon, and discuss 3-D visualization techniques to interpret and describe complex fault geometry.

Dip magnitude

Contouring the magnitude of the first horizontal derivative (dip magnitude) of the topography (structure) is a highly effective method to interpret fault traces. The

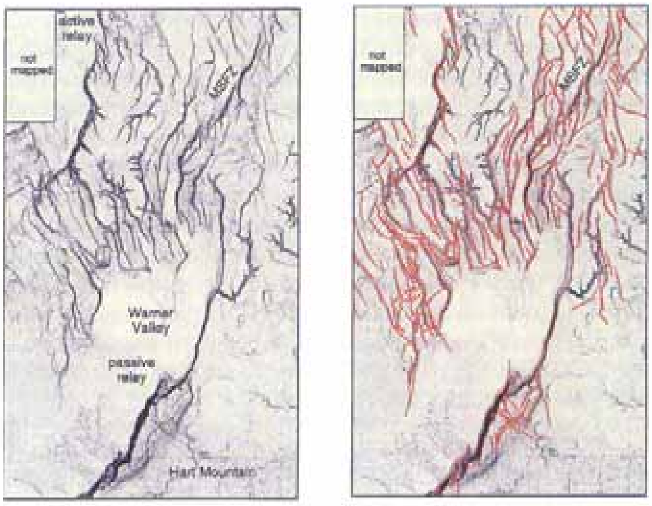


Figure 5. Dip magnitude of digital topography displayed in Figure 2. Steep dips are dark, narrow bands. (a) Dip-magnitude display without interpretation. (b) Interpreted fault trace data from stereo-photo pairs overlying the dip magnitude map showing strong correlation between length and width of interpreted fault traces and narrow bands of steep dip. Fault dip direction is not evident from dip magnitude map.

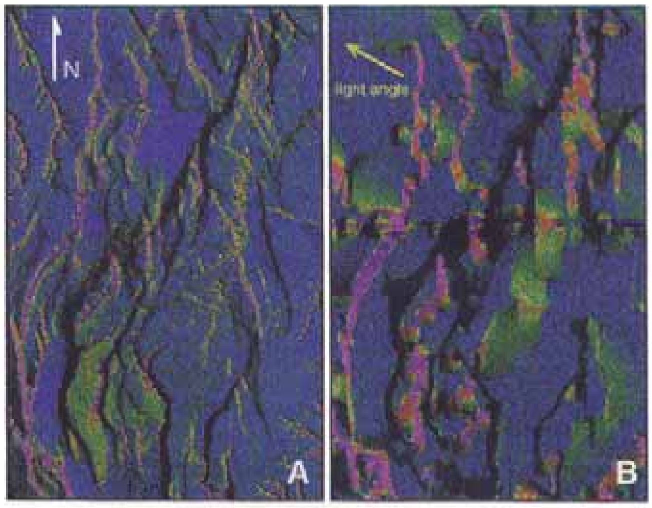


Figure 6. Color-contoured dip magnitude superimposed on structural relief along the MFSZ. Bright purple and shaded relief accentuate the steep dip of east and west-dipping faults, respectively. Blue indicates regions of lower dip. (a) Dip magnitude calculated from the high resolution data set discussed in Figures 2 and 6. (b) Dip magnitude over the same area with a similar color contour interval superimposed on topography with a lower horizontal resolution or greater grid spacing. The horizontal line near the center of the map is a data seam.

portions of the fault surface (fault scarp) that intersect and offset the mapped horizon are a steeply-dipping surface with a narrow range of steep dips. Choosing a color scale to emphasize the steep dips highlights the fault traces.

Steeply-dipping surfaces, displayed as dark polygons on the dip magnitude map calculated from the digital elevation data (Figure 5a), correlate very well with the fault traces interpreted from aerial photos (Figure 5b). The width of the color band delineating the steep dips or faults is equivalent to the fault-gap polygon. The lengths of many of the fault traces on the dip magnitude map are shorter than those from the photo interpretation, because the displacements on the faults at their terminations are below the resolution of the data.

The dip-magnitude display distinguishes the individual fault segments comprising the composite fault zones and detects most of the smallest faults demonstrating the effectiveness of the method in interpreting the detailed fault geometry. The method is also efficient in discriminating between active and passive relays along faults with large displacements if the data resolution is adequate to image the fault trace breaching the relay. Interpreting fault dip direction from the dip magnitude maps, however, is difficult without shaded relief.

3-D visualization

Interactive 3-D visualization of the gridded surface or horizon and interpretation of the faults can significantly improve the quality and speed of the structural interpretation. Choosing an appropriate light angle and color on the surface and exaggerating the relief accentuates the structure. This technique is an effective way to visualize complex fault intersections, separate faults from unfaulted structures with large relief, and quickly and efficiently map fault traces at the hanging wall and footwall breaks. Seismic interpretation and visualization software allow 3-D rotation of the surface and interactive interpretation of the fault traces.

Superimposing horizon attributes onto the gridded surface displayed in 3-D relief can improve the image and enhance the structural detail. Overlaying the dip magnitude calculated for the surface topography along the MSFZ onto a shaded relief image of the structure with a light source dramatizes the structural relief, the fault traces, and their dip direction (Figure 6). Rotating the surface into a true perspective view provides additional information and a more realistic picture of the surface or structural geometry. We describe below some perspective "snapshots" of structures in the Oregon data to demonstrate the impact of 3-D visualization in interpreting fault and structural detail. In these perspective views the color on the surface is contoured topography; the dip magnitude is not superimposed.

A 3-D perspective view along the MSFZ (Figure 2b) is a visual aid to the interpretation of the geometry, extent, and integration of the footwall uplift and the segmented fault zone. The display also emphasizes the contribution and complex intersections of the many small faults along the footwall flexure.

The interpretation and description of relay ramps between fault-segment terminations are also improved by 3-D visualization. A passive relay is often difficult to separate from an active relay if the displacement on the section of the fault breaching the relay ramp is small. The 3-D perspective view and accompanying block diagram show the shared displacement along the fault across the passive relay north of Hart Mountain (Figure 4). This is in contrast to the unconnected fault segments bounding the active relay previously described (Figure 3). The traces of the footwall cut-off of the foremost fault and hanging wall cut-off of the rear fault are subparallel and curve together with the dip of the ramp. This interlinking of the separate fault terminations is known as geometric coherence (e.g., Walsh and Watterson, "Geometric and kinematic coherence and scale effects in normal fault systems," Geological Society Special Publication, 1991).

Effects of data resolution

The dip magnitude displays described above must be interpreted with caution. Some steep dip domains are unfaulted structures (e.g., small folds) that may bias the fault interpretation. In addition, dips calculated from widely-spaced data grids may resolve multiple faults between data points as single faults or alias a single fault by overestimating the fault gap. A dip-magnitude map over the MSFZ, derived for the more widely-spaced data grid with a lower vertical resolution displayed with a similar color scale and light source (Figure 6b), shows much wider dip panels or fault polygons than the same faults mapped from the higher resolution data. Some of the smaller closely-spaced faults, mapped as discrete bands on the high-resolution dip magnitude maps (Figure 6a), are displayed as single broad polygons on the lower resolution maps.

Active and passive relay ramps are easily interpreted from 3-D perspective views and dip-magnitude maps at different levels of resolution if mapped along the largest and more easily resolved faults. Interpreting structural detail is more difficult in the lower-resolution data, however. The fault segments comprising the MSFZ interpreted from the lower resolution data, for example, are poorly resolved and appear connected across relay ramps be-cause the dip on the relay ramps is undifferentiated from the dip on the faults.

Interpreters are often limited to a 2-D seismic grid over an area with structural styles and scale like those described. A more widely-spaced data grid over our study area would further reduce the accuracy in the interpretation.

Visually decimating the Oregon data below the resolution described here, for example, approximates the loss of structural detail. Interpreter-imposed data limitations also occur if the structural interpretation is derived from a grid spaced more widely than the available data; for example, mapping from widely-spaced seismic sections from a 3-D seismic volume.

Displacement analysis. Structural interpretation in low-resolution data can be improved by analysis of the fault-displacement profiles derived from the mapped fault traces. The profile of the fault-gap polygons superimposed onto the structural contour maps shows the variation in displacement of the horizon that intersects the mapped fault. Anomalies in the displacement profile may indicate unmapped structural detail, data problems or interpretation mis-ties.

Projecting the hanging wall and footwall traces of the fault gap polygons onto a vertical plane parallel to the strike of a single fault shows a characteristic and systematic geometry: The displacement is zero at both mapped terminations and increases uniformly to a maximum near the center of the fault. The region of maximum displacement at the fault center corresponds to the position of maximum footwall uplift and greatest structural relief.

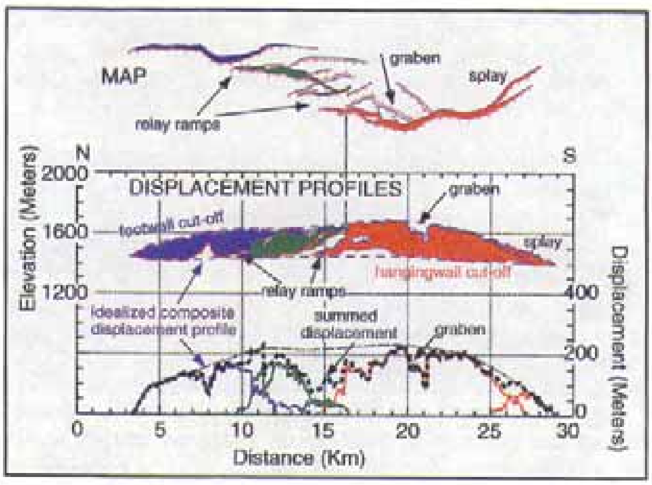


Figure 7. Strike projection of the displacement profile along the MFSZ. Fault segments comprising the zone shown in map view. Displacement profiles displayed by only color-filled polygons have nearly uniform displacement distributions. Anomalies in the summed displacement profile (dotted black line) occur between the terminations of separate segments and at the intersection of splays with the principal fault segments. A nearly uniform profile in the footwall cut-off of the composite zone (dashed purple line) has a large deficiency in the measured displacement. The displacement low is probably distributed among small faults or local folding within or adjacent to the relay ramp.

The displacement profiles along composite fault zones are similar to those along single faults. The combined displacement profiles for the three principal faults comprising the MSFZ, for example, is maximum near the center and tapers uniformly to the terminations (Figure 7).

The displacement profiles for the separate fault segments, however, are unlike those on isolated single faults. The footwall and hanging wall traces along the respective overlapping fault terminations intersecting the relay ramp curve together with the dip of the ramp (Figure 7). This geometric coherence, discussed earlier, has been described along faults at a range of scales. The two remaining traces on the adjacent faults define the uniform profile of the hanging wall and footwall cut-offs for the composite structure.

The profile shapes between the fault terminations are useful in distinguishing active from passive relay ramps. The active relay shows smooth gradients in footwall and hanging wall cut-offs within the overlap of the fault segments (Figure 3). The profiles interlink and give a nearly uniform composite displacement. The passive relay also has smooth displacement gradients along the paired traces of the hanging wall and footwall cut-offs. At the apex of the structure or point of intersection of the two faults, however, a steep increase in gradient ties the ramp to the footwall trace for the composite fault (Figure 4).

Other anomalies in the displacement profile can be attributed to displacement transfer from the mapped fault to an intersecting splay. A marked decrease in displacement occurs at the intersection of a prominent northwest-to-southwest graben that intersects the southern most segment of the MSFZ (Figure 7). Summing the displacement lost to the splay along the composite fault profile would give a more uniform distribution in the displacement profile. Additional fault detail can be detected by recognizing these anomalies along prominent mapped fault segments in the subsurface.

Summing the displacement along the composite fault zones may also show anomalous regions of low displacement that are not observed from the displacement profile. A large deficiency in the summed displacement occurs along the relay ramp at the center of the MSFZ. Deformation mechanisms such as folding or small unimaged faulting along the relay ramp may account for the low displacement.

A nonuniform distribution of displacement remains across the composite fault zones mapped in this study after accounting for the geological effects because of differential erosion and deposition across the fault scarps. Similar problems in subsurface displacement analyses due to erosion, deposition, low signal-to-noise, and interpretation mis-ties may also be manifest as nonuniform distributions of throw. The main point is that simple fault zones and the associated deformation are systematic; areas of nonuniform displacement along their length indicate problems in the interpretation or additional uninterpreted deformation, which may be below the resolution of the data.

Conclusions

Surface exposures of seismic-scale structures that are analogous to hydrocarbon traps in the subsurface provide excellent natural laboratories to analyze structural detail often obscured in seismic data. Digital elevation data over the topography permit the application and evaluation of work-station based horizon interpretation methods to define the structural geometry. The models and descriptions derived from these outcrop studies improve the accuracy of subsurface structural interpretation and thereby reduce trap risk.

Displacement variation along a fault, for example, has been shown to vary systematically along the fault map length. Applying this principle to a poorly-resolved seismic data set can improve the uncertainty in the fault interpretation.

The interpretation methods described in this article are restricted to single interpreted horizons. The current challenge is to fully integrate the structural interpretation throughout the seismic volume and correlate faults across multiple horizons defining the full complexity of the fault surface.

Acknowledgments

We thank ARCO for permission to publish these results and Don Medwedeff and Jeremy Greene for thorough reviews.

Corresponding author: Russell Davies, ARCO Exploration and Production Technology, 2300 W. Plano Parkway, Plano, TX 75075; rdavies@arco.com.

1997 Qld ASEG Golf Classic

On Friday 3rd October, a bunch of diehard employees were graced with prefect blue skies and glorious morning sunshine (typical of this great state). This was the moment of truth - a day to decide which corporate team would be the ultimate winner of the Inaugural 1997 ASEG Golf Classic.

Fourteen teams happily traded the suit & tie for a putter & a pair of Plus Four's and gathered at the St. Lucia Golf Course for a 8:00am shotgun start. To make the day interesting for all teams, a Four Ball Ambrose format (handicaps included) was chosen.

During the day, every shot in and out of the text book was made, from multiple bunker shots to monster drives. Being a warm day the two drinks carts were in high demand. I'm sure some of the teams totally forgot they were here to play golf.

BHP Coal – proud winners of the Golf Classic.

As the dust settled from the bunkers and the fairways, two teams emerged with equal net scores of 54.1 - BHP Coal and ANZ Goodna. BHP Coal was declared the winner (having the best back nine holes). For their fine efforts they received the Perpetual Geco-Prakla Trophy and each a $100 gift voucher from Golf World.

Despite finishing second, ANZ Goodna deserve full acknowledgment for their sizzling round of 61 (gross score). A damn fine achievement!! Each received a groovy golf shirt and a pack of golf balls.

Third place went to Silicon Graphics with a net score of 54.4. A pack of 15 balls should help them improve their game for next year.

To encourage the less fortunate, a prize was presented to the "The Wooden Spooners". This prize was hotly contested by a number of teams. The lucky team was Digicon 2. Each player received a Golf/Breakfast package courtesy of the St. Lucia Golf Club. All four players then competed in the ASEG Putt-Off at the 18th Hole. In front of a very vocal cheer squad, Paul Phythian showed us why he was the best of a bad bunch!! Perhaps the new putter he received may improve his chances for next year??

Additional prizes were handed out for individual performances on the day.

The "Longest Drive" was won by Graham Holt (Silicon Graphics) with a huge hit. Graham received a new golf buggy and dinner for two at "Oxley's on the River".

The "Wooden Spooners" and that putter.

The "Straightest Drive" went to Jamie Buzacott (BHP Coal). For his pin point accuracy he collected a Caddy Rack, golf balls and dinner for two at "Oxley's on the River".

Jeremy Cook (North Ltd) provided a solution to any disputes at the 5th. He produced the shot of the day with an eagle for the "Nearest the Pin - 2nd Shot" prize of an ANZ golf umbrella, iron covers and golf towel.

"Straightest Drive" – they don't get much closer than this.

Ron Bailey (ANZ Toowong) claimed the ANZ "Nearest the Pin - 2nd Shot" prize of a Shark Hat & Pack and a ANZ golf umbrella.

The colourful Rio Tinto Four Skins.

The Silicon Graphics prize for "Nearest the Pin" at the 11th hole was won by John Anderson (BHP Coal). John will be the envy of many when he plays in his new SGI shirt, cap and golf balls.

Tucker Time!!!

Ram Karan (ANZ Goodna) won the 16th Hole "Nearest the Pin", and was rewarded with a flash golf bag.

The last prize of the day was the "Lucky Golfer's" prize being a night for two at the Sheraton Hotel, Brisbane. Dan Mack (Velseis Processing) was an excited man when his name was drawn.

With the formal duties out of the way, it was time to relax and enjoy a delicious Gourmet BBQ and have a few drinks. A chance to sit back and reflect on the day's achievements and disappointments.

From the festive atmosphere floating around during lunch, it was apparent that everybody had a great day. Many are already talking about next year.

The ASEG would like to thank many people for the success the the 1997 ASEG Golf Classic. Thanks must go to Troy Peters for all the assistance given in organising the event. Angela and Terri for serving up the all important beverage to players.

Appreciation must be extended to all companies who provided significant sponsorship for the event. Without such support, a successful social outing would have not been achieved. A special thanks must go to Geco-Prakla for donating the impressive first prize trophy.

Thanks to the following companies:

Schlumberger Geco-Prakla
ER Mapper – Helping people manage the earth
Oil Company of Australia
Brisbane City
Geodrill
Seismic Supply International
digicon geophysical ltd. – A Veritas DGC Company
Geosystems
ANZ
Velseis
Landmark – A Halliburton Company
Sheraton Brisbane Hotel & Towers – ITT Sheraton
The Club House – St Lucia Golf Links
Santos
Geosoft
SiliconGraphics Computer Systems
Cray Research
BPB
ZEH Graphic Systems
Velseis Processing
Triangle Digital – Reproductions Pty Ltd
Protocol Solutions
Tesla Airborne Geoscience
Geoimage
Velocity Data
Mincom

Lastly, the ASEG would like to thank all players who participated in the Golf Classic.

Without players this sporting occasion would have been a non-event!!

SEE YOU ALL NEXT YEAR FOR THE BIGGER AND BETTER 1998 GOLF CLASSIC!!

Cheers,
Howard Bassingthwaighte
Vice-President (Qld Branch)

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)

Industry Briefs

GMA buys SiesX

Geophysical Micro Computer Applications (GMA) Ltd. has signed a Letter of Intent with Paradigm Geophysical Limited to acquire the fully integrated 2D/3D seismic interpretation software know as SeisX.

SeisX was originally developed in Calgary by Photon Systems Ltd. and has been successfully marketed worldwide for seven years. SeisX is a comprehensive application for the interpretation of 2D, 3D, multiple 3D and well data, all within the same project. SeisX is available on both UNIX and Windows NT based platforms.

GMA's acquisition is expected to close in October, 1997 but is dependent upon conclusion of a separate transaction between Paradigm Geophysical Limited and GeoScience Corporation for the purchase and sale of Cogniseis Development, Inc..

Ron Newman, President and Chief Executive Officer stated "We believe the acquisition of SeisX technology could double our revenues for the 1997/98 fiscal year and significantly increase GMA's overall profitability. We are excited about integrating the 2D/3D interpretation technology of SeisX with GMA's existing modelling systems."

GMA is a developer and supplier of geological, geophysical and petrophysical computer-aided exploration (CAEX) software products.

Geophysical Micro Computer Applications Ltd.
http://www.gmacalgary.com

Survey Reveals Global Continuity in Exploration Salaries

Salaries for upper level mineral exploration personnel are established in a worldwide job market with virtually no political boundaries, according to a newly released survey by Western Mine Engineering, Inc. of Spokane, Washington. This survey, the first of its kind ever conducted for the mining industry, was completed earlier this year in cooperation with many of the world's largest mining companies, as well as a number of junior companies.

Eighty percent of the offices responding to the survey reported exploration manager salaries between $65,000 and $104,000 U.S. dollars. Broader disparity is evident at lower salaried jobs such as field geologist and technician. The highest salaries at these levels are paid in the United States, Canada and Australia. The lowest are in parts of Africa, where field geologists earn as little as $5,000 and technicians as little as $1,300 per year.

While salaries are similar between expatriates and nationals working in higher level positions, expatriates tend to receive more in the way of perks, such as trips 'home', housing subsidies and education assistance for dependents.

The complete survey report - which covers 94 exploration offices in 22 countries - can be obtained by contacting:

Western Mine Engineering Inc.
Email: Western.Mine@westernmine.com.

Membership

New Members

Western Australia

Does anyone know the whereabouts of Michael Lennane until recently a WA member of the Society.

Mr Cliff ALLEN
254 Corinthian Road
RIVERTON WA 6148
AUSTRALIA
Email:
callen@geophy.curtin.edu.au

Mr Matthew FLEMING
RGC Goldfields
1/37 Parsons Avenue
MANNING WA 6152
AUSTRALIA
Phone: (09) 442 8110
Fax: (09) 442 8181

Mr Jason McKENNA
7 Hutton Place
WOODVALE WA 6026
AUSTRALIA
Phone: 08 9409 6091

Mr Christopher MANUEL
21 Sasse Avenue
MOUNT HAWTHORN
WA 6016
AUSTRALIA
Phone: 08 9321 6934
Fax: 08 9481 1201

Mr Benjamin WHITFIELD
100 Sydenham Street
KEWDALE WA 6105
AUSTRALIA
Phone: 08 9472 4440

Mr Stefano ZANNONI
7 Wittering Crescent
BALGA WA 6061
AUSTRALIA
Fax: 08 9345 5292
Phone: 08 9345 5292

South Australia

Mr Thomas WEIS
Normandy Exploration
103 King William Street
KENT TOWN SA 5067
AUSTRALIA
Phone: 08 8239 0393
Fax: 08 8464 2299
Email: tvweis@senet.com.au

Tasmania

Mr Timothy CHALKE
239 Tinderbox Road
Tinderbox
HOBART TAS 7084
AUSTRALIA
Phone: 03 6229 3273
Fax: 03 6229 1562

New South Wales

Mr Harry HVISTENDAHL
Corporate Montage
80 Ardhurst Street
NORTH SYDNEY NSW 2060
AUSTRALIA
Phone: 02 9957 3733
Fax: 02 9954 1029

Mr Ian LILLY
SGI
PO Box M42
MONASH PARK NSW 2111
AUSTRALIA
Phone: 02 9879 9500
Fax: 02 9879 9585
Email: ianl@sydney.sgi.com

International

Mr Robert GRASTY
Exploranium
3924 Shirley Avenue
Glouchester
ONTARIO KIV IH4
CANADA
Phone: 1 613 739 4240
Fax: 1 613 739 8702
Email: grasty@hookup.net

Mr Keith MORRISON
Quantec Consulting
PO Box 1170
Waterdown
ONTARIO L0R 2H0
CANADA
Phone: 905 689 0600
Fax: 905 689 6404
Email: keithm@quantec.com

Mr Edward NICHOLS
EMI
1301 S 46th Street
RICHMOND 94208
CANADA
Phone: 510 232 7997
Fax: 510 232 7998
Email: edn@emiinc.com

Mr Paul PASSMORE
Refraction Technology
Dallas2626 Combardy Lane
DALLAS TEXAS 74220
USA
Phone: 214 353 0609
Fax: 214 353 9659

Mr William PERRY
11007 Wortham Boulevard
HOUSTON TEXAS TX 77084
USA
Phone: 647 9025
Fax: 647 0825
Email: billp@wgc.com.au

Mr Bernie SCHAEFFER
Schlumberger Geo Prakla
8560 Park Lane No 40
DALLAS TEXAS 75231
USA
Phone: 214 692 0634

Mr Brian TOELLE
Schlumberger Geoquest
7519 Marble Glen
HOUSTON TEXAS 77095
USA
Phone: 713 513 2652
Fax: 713 513 2038
Email: btoelle@houston.
geoquest.slb.com

Mr Ricardo Fernandez TOME
Geodatos
Roman Diaz 773
SANTIAGO
CHILE
Phone: 56 2 235 1058
Fax: 56 2 235 5512

Mr Alan TRIPP
ARCO
717 WBB
University Of Utah
UTAH 84662-0035
USA
Phone: 801 462 2112
Fax: 801 462 9365

Mr David ULRICH
MIS
8801 S Yale
Tulsa
OKLAHOMA 74137
USA
Phone: 918 497 5559
Fax: 918 497 5557
Email: ulrich@seg.org

Ms Christie WEBB
Geosoft Inc
85 Richmond Street
8th Floor
TORONTO ONTARIO
M5H2C9
USA
Phone: 416 369 0111
Fax: 416 369 9599
Email:
christie.webb@geosoft.com

Mr Raymond WHITTON
High Sense Geo
47 Jefferson Avenue
Toronto
ONTARIO MGKIY3
CANADA
Phone: 1 416 588 7075
Fax: 1 416 588 9789
Email: ray@high-sense.com

Mr Troy WILSON
Geosoft Europe Ltd
12th Floor
85 Richmond Street
TORONTO
CANADA
Phone: 416 369 0111
Email:
troy.wilson@geosoft.com
Email: sliu@agso.gov.au

Change of Address

Western Australia

Justin ANNING
8C John Street
NORTH FREEMANTLE
WA 6159
Ph: 336 4290

Mr Terry CRABB
Australian Geophysical
Surveys
3 Baron Way
JANDAKOT WA 6164
Ph: 08 9414 1266
Fax: 08 9414 1277

Mr Matthew COOPER
Great Central Mines Ltd
PO Box 1594
WEST PERTH WA 6872
Tel: 08 9327 9275
Fax: 08 9322 2033
Email: Matthew@awi.com.au

Mr Mark BRAILEY
PO Box 1071
ROCKINGHAM WA 6168

Robert CORNECT
Does not live at:
(His address is unknown)
145 Waratah Avenue
DALBEITH WA 6009

Kim FRANKCOMBE
Geophysical Consultant
PO Box 8006
Perth Business Centre
WA 6849
Tel/Fax: 08 9370 4164
Email:
kfrankco@ozemail.com.au

Mr Michael HOUSE
Goldfields Exploration Pty Ltd
14 Williams Street
PO Box 862
KALGOORLIE WA 6430

Juile WHITHERS
15 Wheyland Street
WILLAGEE WA 6156
Ph: (08) 9337 3884

South Australia

Mr Iestyn BROOMFIELD
57 Edward Street
MAGILL SA 5072
PH: 08 8338 2792
FAX: 08 8338 2865

Library - Mines & Energy
Resources South Australia
GPO Box 2355
ADELAIDE SA 5001

Mr Reg NELSON
PO Box 1475
MT PARKER SA 5251

Mr Vinod RAJPUT
Santos Limited
91 King William Street
ADELAIDE SA 5000

Victoria

Dr Michael W ASTEN
Flagstaff Geo-Consultants
Suite 2, 337A Lennox Street
RICHMOND VIC 3121
Ph: 03 9421 1077
Fax: 03 9421 1099
Email: MichaelAsten@compuserve.com

Geophyscail Exploration Consultants Pty Ltd
PO Box 2236
RICHMOND SOUTH
VIC 3121
Suite 2
337a Lennox Street
RICHMOND VIC 3121
Ph: (03) 9421 1055
Fax: (03) 9421 1099

New South Wales

Mr Marcello AIELLO
Flat 8
76 Garnet Street
DULWICH HILL NSW 2203

Diane KEMP
Geo Instruments Pty Ltd
348 Rocky Point Road
RAMSGATE NSW 2219
Ph: 02 9529 2355
Fax: 02 9529 9726
Home: 02 9868 4504
Email: dandm@curie.dialix.com.au

Tara PALMER
20 Vle Street
LEURA NSW 2780
Email: dharoon@pnc.com.au
Ph: (02) 4784 3678

If you wish to place your event in our Calendar, contact:

Debbie May,
Jenkin Buxton Printers
263 Middleborough Road
Box Hill, VIC. 3128
AUSTRALIA

Tel: +61 3 9890 4711
Fax: +61 3 9898 9677
Email: jbprint@mail.austasia.net

ACT

Songfa LIU
Australian Geological Survey Organisation
GPO Box 378
CANBERRA ACT 2601
AUSTRALIA
Fax: 02 6249 9982
Phone: 02 6249 9522
Email: sliu@agso.gov.au

Queensland

Bimal BANERJEE
5 Belfairs Street
ROBERTSON QLD 4109

Mr Andrew DAVIDS
Geophysicist
Oil Company of Australia Limited
GPO Box 148
BRISBANE QLD 4001
Ph: 07 3858 0659
Fax: 07 3369 7840
Email: Andrew.Davids@oca.boral.com.au

International

Dr Branko CORNER
PO Box 2055
Swakopmund
NAMIBIA

Mr Phillip HARMAN
Manager Discovery Technology
BHP Mineral Exploration
550 California Street
SAN FRANCISCO CA 94104
USA
Ph: 1 415 981 1515
Fax: 1 415 399 8869

Librarian (Acquisitions)
Institue of Geological & Nuclear Sciences
Box 30-368
LOWER HUTT
NEW ZEALAND

Outokumpu Mining Oy
Kummunkatu 34
83500 OUTOKUMPU
FINLAND

University of Arizona Library Tech Services
Serials A101
1510 E University
Box 210055
TUCSON AZ 85721

Calendar of Events

1998

Feb 16-19
EGS/SEG/EAGE Cairo 98 Africa/Middle East Geophysical Conference and Exhibition
For further details:
Email Barex@ritsec2.com.eg or dyowell@seg.org or Chris.Walker@pgs.com

Feb 23-25
CRCAMET/ASEG International Conference on AEM, Sydney
For further details:
c/- Well Done Events
PO Box 1758
North Sydney
Tel:
Fax:
Email: judyp@welldone.com.au

Feb 26
Recent Developments in Airborne Gamma-ray Spectrometric Data. Manley Pacific Parkroyal, Sydney. Well Done Events PO Box 1758,North Sydney, NSW, 2059
For further details:
Tel: 1800 35 4546 or 61 2 4446 0318
Fax: 1800 35 4547 or 61 2 4446 0319
email judyp@welldone.com.au

Mar 8-11
APPEA Conference, National Convention Centre,Canberra Attn Lynda Gordon APPEA Limited, GPO Box 2201 Canberra, ACT, 2601
For further details:
Tel: (02) 6247 0960
Fax: (02) 6247 0548

Mar 23-25
International Conference on Coal Seam Gas and Oil, Sheraton Hotel, Brisbane Intermedia
For further details:
Tel 07 3369 0477
Fax 07 3369 1512
email csgo98@im.com.au , www.im.com.au/coalseam

Jun 20-26
SEG /SEG Beijing Beijing 98 Conference and Exhibition
For further details:
www.seg.org

July 21-24
AGU, 1998 Western Pacific Geophysics Meeting, Taipei.
For further details:
200 Florida Avenue
Washington DC, 20009, USA
Tel: 1 202 462 6900
Fax: 1 202 328 0566
Email: meetinginfo@kosmos.agu.org
www.agu.org

Sept 13-18
SEG Conference New Orleans
For further details:
www.seg.org

Oct 28-30
Gas Habitats of SE Asia & Australasia,Jakarta,Indonesia Indonesian Petroleum Association
For further details:
Tel: 62- 21 5273663
Fax: 62-21 5219063
email ipa@cbn.net.id , www.ipa.or.id

November 8-12
Australian Society of Exploration Geophysicists 13th International Conference and Exhibition. Hobart Tasmania Australia
For further details:
ASEG Conference Secretariat, 93 Victoria Avenue, Albert Park VIC 3206
Tel: +61 3 9690 6744
Fax: +61 3 9690 7155
email: wsm@latrobe.edu.au

Dec 10-12
SEGJ/SEG/ASEG 4th Int Symposium Fracture Imaging Tokyo
For further details:
email mcdonald@geophy.curtin.edu.au