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Australian Society of
Exploration Geophysicists

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PREVIEW

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15–18 February 2015
Perth, Western Australia

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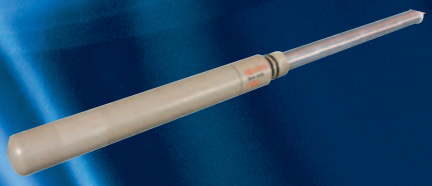

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Editor
Lisa Worrall
Email: previeweditor@aseg.org.au

Associate Editors
Book Reviews: Ron Hackney
Email: ron.hackney@ga.gov.au

Canberra Observed: David Denham
Email: denham@webone.com.au

Data Trends: Guy Holmes
Email: guy.holmes@spectrumdata.com.au

Minerals and Environment: –
Email: –

Seismic Window: Michael Micenko
Email: micenko@bigpond.com

ASEG Head Office & Secretariat
Ben Williams
The Association Specialists Pty Ltd (TAS)
Tel: (02) 9431 8622
Email: secretary@aseg.org.au
Website: www.aseg.org.au

Publisher
CSIRO Publishing

Production Editor
Helena Clements
Tel: (03) 9545 8475
Email: helena.clements@csiro.au

Advertising
Doug Walters
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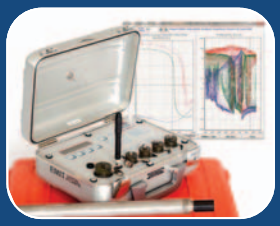

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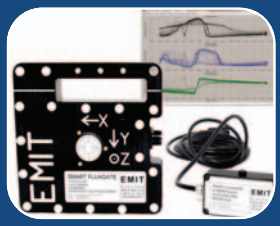

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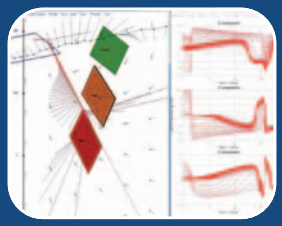

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Lisa Worrall

This issue of *Preview* includes the ASEG-PESA 2015 conference handbook. It will be available online, posted to all ASEG Members and made available to all conference registrants. If you are attending the conference and not a regular *Preview* reader then I hope that the sample of regular *Preview* content that forms the preface to the conference handbook will tempt you to come back for more.

Preview is published bimonthly and is freely available online. It is a forum for the exchange of ideas and information between exploration geophysicists practising in the Asia-Pacific region. The magazine contains news, commentary, book reviews, and feature articles on diverse topics. In the last couple of years these topics have ranged from the history of lodestone, the development of SIROTEM, the application of AEM to potash exploration, and the measurement of gravity with ultra-cold atomic test masses!

This 'cut-down' version of *Preview* features ASEG News, some of our regular commentators and, most particularly, updates on geophysical activities in all of the Australian government (State and Territory) geological surveys. In Australia government surveys compile geophysical data generated by exploration companies, as well as acquiring, processing and interpreting new data. These data are a fabulous resource for companies exploring in Australia and Australian waters and *Preview* is a ready source of information about what Australian government geological surveys are up to.

Plans for *Preview* in 2015 include practical reviews of exploration techniques. The first cab off the rank will be a review of spectral mapping. The release of the Australian National ASTER Geoscience Maps has led to enormous interest in spectral mapping, but there are plenty of traps for young, and not so young, players in the processing and interpretation of spectral data – as *Preview* readers will discover.

The December issue of *Preview* will, once again, focus on geophysical education. All students who complete research projects in geophysics at an Australian University in 2015 will be invited to submit their title, abstract and short bio for publication. A survey of these student abstracts is an excellent guide to what is hot, and what is not, in geophysics in Australia. The December issue will also contain up-to-date information about availability of grants and scholarships.

The ASEG Publications team will be well represented at the ASEG-PESA 2015 conference. As well as looking for fresh copy, we will be looking for feedback on both *Preview* and *Exploration Geophysics*. Please seek us out at the ASEG booth!

Lisa Worrall
Preview *Editor*
previeweditor@aseg.org.au

10.1071/PVv2015n174ASEGnews

Keep calm and do geophysics

I have written a welcome to the 2015 ASEG-PESA Conference elsewhere in this issue. I can well understand that some ASEG Members may not be able to make to the conference because 2014 was not a good year for the geophysical industry. The year started with a gradual decline in metal prices and ended with a big drop in the price of oil. Expenditure on exploration and particularly expenditure on exploration geophysics, being a big ticket item, is usually the first item to be cut from the budget when companies tighten their belts. Unfortunately, that is the way of our industry and the way of the world.

We see 'short termism', or the excessive focus on short-term goals at the expense of long-term interests, all too often in Australian politics and it has prevented major expenditure on public works projects. In exploration short termism has resulted in investors rushing into mineral and oil exploration companies when the prices of metals or oil are high. However, all too often, a deposit discovered in boom times will come into production during a slump, when it may be unprofitable, and the company that holds the deposit ends up sliding into receivership.

In exploration it is sometimes the second or third company to explore an area that finds a significant deposit. Short termism means that it is often the second or third company to own a deposit that will make money from it. As an exploration geophysicist I think it would be great if we could be doing the greenfields work now (during a downturn) and move into brownfields and near deposit studies when prices pick up. Right now there is plenty of open ground to explore and lots of under-utilised professionals, geophysical equipment and drilling rigs. There is also a lot of cash looking for good investment but the investment paradigm we are locked into will not allow long term thinking.

It may only be possible for the industry to break out of short termism with some government intervention, perhaps in the way of investment incentives for greenfields exploration. Such incentives should move towards brownfields as prices improve, but that would be asking too much of our politicians. One only has to look at the mining tax to see how little politicians understand the mining industry and I am not talking about its introduction, more about the euphoria when it was repealed just as iron and coal prices were sliding away and no more tax was payable. Wouldn't it great to be paying a super-profits tax today!!

There was a lot of chest beating about the mining tax which should have been directed at getting the money back into exploration incentives rather than repeal of the tax. Federal governments of both persuasions have long promised exploration incentives and it is time they put their money where their mouth is. But as Daryl Kerrigan would say 'Tell 'em they're dreamin'. All I can say is 'Keep calm and do geophysics'.

Hope to see you at my favourite beach in the early morning during the conference.

On a more pleasing note it seems that governments and education authorities are starting to recognise that we will need scientists in the future. There are far too many students graduating with degrees and with nowhere to go. Whilst I am the first to agree that a tertiary education is a great way to develop as an individual, being underemployed does not particularly help with personal development. I firmly believe that a basic training in languages, mathematics and science, with a bit of history and geography thrown in, should be continued right through to Year 12. I believe I was lucky to go through high school when this was the model, and the extra courses in woodwork, art and music did not do me any harm.

One way we hope to address the need for good basic training in science in schools is through the *Geophysics for Teachers* course being prepared by Adrian Noetzli for the 2015 Conference. At the time of writing this piece we only had two registrants and about ten presenters, but we hope that situation will change before this piece is printed.

On the tertiary education front, many of us feel that there are too many graduates who can run computer programs without an adequate understanding of how the input data was acquired and how the data is being manipulated. Perhaps university administrators are so cowed by Occupational Health and Safety considerations that they no longer can allow students out of the safety of their 'nurseries'. One of the goals for the ASEG in 2015 is to create a course in data acquisition for geologists and geophysicists so that they can understand the pitfalls and errors that can creep into the data during acquisition.

I think that the ASEG website should also be a vehicle for education. Unfortunately we have yet to advance into the modern era on this front. Carina Kemp has done a great job on ensuring that the website actually works and Katherine McKenna has fixed the Members' database so that we can easily pay our dues, buy our wine and access publications. But, that is only the start. I see the future of the website as being the repository of our journals, historical material, workshops proceedings and presentation videos. It is probably too soon attempt this because some of the necessary software is in its infancy and is expensive. I am sure that will change and we will have greater access to all material in the future through various Apps or other means. What we need is a team of younger professionals who want to take this vision forward. Come and talk to me or other Federal Executive members at the conference if you have ideas you would like to implement.

Once again, a great thank you to the Conference Organising Committee. I know, only too well, how much work goes into a conference. The committee has been hard at it and I am sure that, as in previous years, it will be a great meeting.

Greg Street
ASEG President
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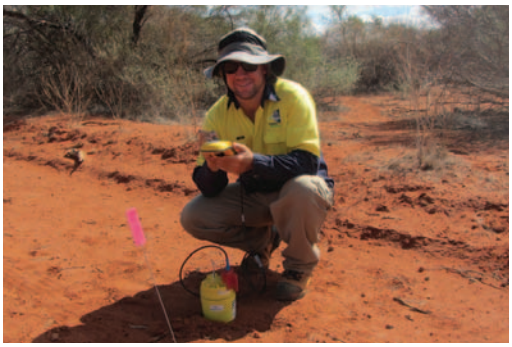

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Welcome to new members

The ASEG extends a warm welcome to new Members approved by the Federal Executive at it's December meeting (see table).

First name	Last name	Organisation	State	Country	Membership type
Adel	Vatandoost	FMGL	WA	Australia	Active
Rod	Lawrence	SMEC Australia	NSW	Australia	Active
Kent	Inverarity	SA Department of Environment, Water and Natural Resources	SA	Australia	Active
Wu	Wen	Chinalco Rio Tinto Exploration Pty Ltd		China	Active O/S
Lee	Horn	Schlumberger Australia	WA	Australia	Active
Cameron	Johnston	MAGSPEC Airborne Surveys Pty Ltd	WA	Australia	Active
Peter	Spencer	MAGSPEC Airborne Surveys Pty Ltd	WA	Australia	Active
Xiajing	Ma	CGG	WA	Australia	Active
Tom	Brooks	Woodside	WA	Australia	Active
Alan	King			Canada	Active O/S
Vince	Rodych	INOVA Geophysical		Canada	Active O/S
Rob	Ross	Qatar Petroleum	WA	Australia	Active
Rebecca	Lowndes	University of Melbourne	VIC	Australia	Student
Ry	Zawadzki	Curtin University	WA	Australia	Student
Mitchell	Ryan	University of Queensland	QLD	Australia	Student
Alban	Haisley	University of Queensland	QLD	Australia	Student
Daniel	Handerson	Indonesian Geophysics Student Association		Indonesia	Student O/S
Md	Kajol	University of Camerino	MC	Italy	Student O/S
Nyakno	Jonah	University of Calabar	CRS	Nigeria	Student O/S
Dane	O'Shea	University of Queensland	QLD	Australia	Student
Matthew	Mayne	Wireline Services Group	WA	Australia	Corporate

Notice of Annual General Meeting

The 2015 Annual General Meeting (AGM) of the Australian Society of Exploration Geophysicists (ASEG) will be held in Sydney on Wednesday 15 April 2015. The meeting will be hosted by the NSW Branch at the Rugby Club (http://www.rugbyclub.com.au/). The address is: Rugby Place, Off Pitt Street, Sydney, NSW 2000.

Drinks will be available from 5.30 pm and the meeting will begin at 6.00 pm.

The business of the AGM is:

- To confirm the minutes of the 2014 AGM;
- To receive from the Federal Executive reports on the activities of the Society during the last preceding financial year;
- To receive and consider the financial accounts and audit reports that are required to be submitted to Members pursuant to the Society's Constitution and to law;
- To report the ballot results for the election of the new office holders for the Federal Executive;
- To confirm the appointment of auditors for the 2015 financial year.

The AGM will be followed by a scientific presentation. The speaker and title will be announced closer to the event.

Invitation for candidates for the Federal Executive

Members of the Federal Executive serve in an honorary capacity. They are all volunteers and Members are encouraged to consider volunteering for a position on the Executive or on one of its committees. Current members of the Federal Executive are listed in *Preview*; please contact one of them if you wish to know more about volunteering for your society.

The Federal Executive comprises up to 12 members, and includes the following four elected members:

(i) President,
(ii) President Elect,
(iii) Secretary, and
(iv) Treasurer.

These officers are elected annually by a general ballot of Members. Phil Schmidt was elected as President Elect in 2014 and as such will stand for the position of President in 2015.

Members wishing to nominate for one of these positions should note that in accordance with Article 8.2 of the ASEG Constitution '…The elected members of the Federal Executive are designated as Directors of the Society for the purposes of the [Corporations] Act.'

The following officers are also recognised in the Society's Constitution and serve on the Federal Executive:

(i) Vice President,
(ii) the Immediate Past President (unless otherwise a member of the Federal Executive),
(iii) the Chairman of the Publications Committee,
(iv) the Chairman of the Membership Committee,
(v) the Chairman of the State Branch Committees, and
(vi) up to three others to be determined by the Federal Executive.

These officers are appointed by the Federal Executive from the volunteers wishing to serve the Society.

Nominations for all positions (except Past President) are very welcome. Please forward the name of the nominated candidate and the position nominating for, along with the names of two Members who are eligible to vote (as Proposers), to the Secretary:

Barry Drummond
ASEG Secretary
Care of the ASEG Secretariat
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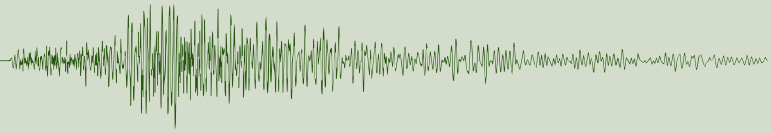
Email: fedsec@aseg.org.au

Nominations must be received via post, fax or email **no later than COB Wednesday 18 March 2015**. Positions for which there are multiple nominations will then be determined by a ballot of Members and results declared at the Annual General Meeting. Proxy forms and further details of the meeting will be sent to Members prior to the meeting by email and made available to Members on the Society's website.



ASEG Federal Executive 2014–15

Greg Street: President (AGC Representative, History and Honours and Awards Committees)
Tel: (08) 9388 2839
Email: president@aseg.org.au

Phillip Schmidt: President-Elect (Publications Committee)
Tel: 0410 456 495
Email: presidentelect@aseg.org.au

Barry Drummond: Secretary
Tel: (02) 6254 7680
Email: fedsec@aseg.org.au

Theo Aravanis: Treasurer (Finance Committee Chair)
Tel: (03) 9242 3327
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Koya Suto: Immediate Past President (International Affairs Committee Chair, Research Foundation)
Tel: (07) 3876 3848
Email: pastpresident@aseg.org.au

Katherine McKenna: Vice President (Membership Committee Chair)
Tel: (08) 9477 5111
Email: membership@aseg.org.au

Kim Frankcombe: Past President (AGC Representative, Conference Advisory Committee and Technical Standards Committee)
Tel: (08) 6201 7719
Email: kfrankcombe@iinet.net.au

Carina Kemp: Webmaster (Web Committee Chair)
Tel: 0412 514 075
Email: webmaster@aseg.org.au

Wendy Watkins (Education Committee Chair)
Tel: (02) 9921 2010
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Tania Dhu (State Branch Representative, Specialist and Working Groups Liaison)
Tel: 0422 091 025
Email: branch-rep@aseg.org.au

Standing Committee Chairs

Finance Committee Chair: Theo Aravanis
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Email: treasurer@aseg.org.au

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Tel: (08) 9477 5111
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State Branch Representative: Tania Dhu
Tel: 0422 091 025
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Honours and Awards Committee Chair: Andrew Mutton
Tel: (07) 3278 5733
Email: awards@aseg.org.au

Publications Committee Chair: Peter Hatherly
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Email: publications@aseg.org.au

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Tel: (08) 8226 2376
Email: technical-standards@aseg.org.au

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Tel: 0408 284 580
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Tel: (07) 3876 3848
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NT Representative: Tania Dhu
Tel: 0422 091 025
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Tasmania

President: Mark Duffett
Tel: (03) 6165 4720
Email: taspresident@aseg.org.au

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Tel: (03) 6226 2477
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Victoria

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Western Australia

President: Kathlene Oliver
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The ASEG Secretariat

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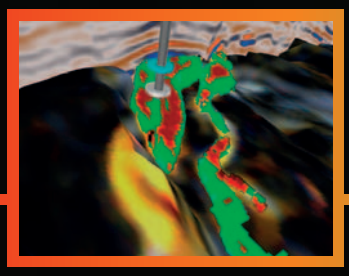

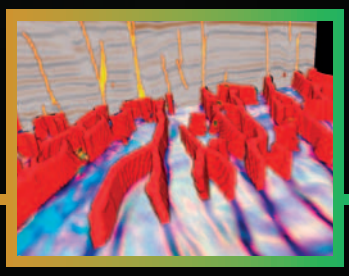

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South Australia & Northern Territory

The SA&NT Branch of the ASEG wound up 2014 with our Annual Christmas Party at the Coopers Alehouse – we celebrated the festive season in style!

The local branch held a number of successful industry events in 2014 with numerous local, interstate and overseas guest speakers, as well as a number of social events. We'd like to thank all of our sponsors for 2014, including Beach Energy, the SA Department of State Development, Geokinetics, Ikon Science, Minotaur Exploration, Petrosys, Santos, Schlumberger, Statoil and Zonge. We hope to have them all back in 2015, with a few new faces too.

The first event for 2015 will be the AGM, to be held in March, once everyone is back from ASEG-PESA 2015 in Perth. We welcome any interested members to the local committee and any commitment, large or small, is appreciated. Please get in touch for more details.

We are also pleased to announce that the Australian Society of Exploration Geophysicists 25th Geophysical Conference and Exhibition, to be co-hosted by PESA, will be held at the Adelaide Convention Centre, 21–24 August 2016. Having grown from a relatively low-key event, first held in the AMF Centre in Adelaide in 1979, to be the premier exploration geophysical conference in the southern hemisphere, it is appropriate that the theme: *Interpreting the Past, Discovering the Future* is reflective of our society's members' ability to change, innovate and grow through time.

As ever, new members and other interested persons are always welcome to local events, as well as the committees for both the local branch and the Conference.

For further details, please contact Luke at luke.gardiner@beachenergy.com.au or 8338 2833.

Luke Gardiner (SA&NT Branch President)

Tasmania

An invitation to attend Tasmanian Branch meetings is extended to all ASEG Members and interested parties. Meetings are usually held in the CODES Conference Room, University of Tasmania, Hobart.

Meeting notices, details about venues and relevant contact details can be found on the Tasmanian Branch page on the ASEG website.

Mark Duffett (Tasmanian Branch President)

Victoria

Victorian Branch Meetings are usually held at The Kelvin Club, 24–30 Melbourne Place, Melbourne. An invitation to attend these meetings is extended to all ASEG Members and interested parties. Meeting notices, details about venues and relevant contact details can be found on the Victorian Branch page on the ASEG website

We look forward to seeing many ASEG Victoria Branch members at meetings in the coming months.

Asbjorn Norlund Christensen (Victorian Branch President)

Western Australia

The WA Branch culminated another busy year with it's Christmas Party and AGM on 3 December. At the AGM we officially elected Kathlene Oliver as President and David Farquhar-Smith as Secretary. Both Kathlene and David, who took over their respective roles in the second half of 2014, look forward to fulfilling the duties of their positions throughout 2015.

The WA Branch held 10 Tech Nights during 2014 with over 500 attendees. In addition, we hosted a number of travelling speakers and workshops. These included one SEG Distinguished Lecturer (Dave Hale), two SEG Honorary Lecturers (Sandeep Chandola and Koichi Hayashi), one SEG DISC presented by Shawn Maxwell, and two OzSTEP workshops presented by Mike Asten and Brian Minty. We've also had the opportunity to host several technical events jointly with the IAG, IAH, EAGE and PESA, all of which were resounding successes.

Maintaining our high level of activity would not have been possible without the help of sponsors. Thank you to all of our generous 2014 sponsors: Schlumberger, GPX Surveys, UTS Surveys, GLOBE Caritas, Geotech, Geosoft, CSIRO, Skytem, Intrepid Geophysics, First Quantum and Mira Geoscience.

Looking to 2015, the Tech Night calendar is taking shape and we're also planning to hold two one-day workshops as well as the Junior Geophysicist's Forum. We are also hosting the ASEG-PESA conference in February and hosting a joint conference with AIH and SPE on tight and shale gas in June.

This year the WA Branch provided financial support to well-deserving geophysics students in WA. The ASEG WA Award program is now in its second year. Congratulations go to Ben Witten (UWA) who was the recipient of the ASEG WA Award for 2014. Thank you to the Awards Committee members Todd Mojesky, Antonio Huizi, Kathlene Oliver and John Joseph for all their efforts in deciding on the deserving recipient. Also congratulations to our best presenter for this year's student night - Matthew Kovacevic (Curtin University). We look forward to watching both of these gentlemen's careers progress within our geophysical community.

We would like to thank the WA Branch committee for all their hard work and dedication throughout 2014, so thanks to Heather Carey, Brett Harris, John Joseph, Kristian Madaschi, Matt Blomfield, Garrett Kramer, Mohammad Khoshnavaz, Regis Neroni and Antonio Huizi. Also thank you to the outgoing President, Anne Tomlinson, for her hard work and dedication to the local branch. The WA Branch is excited about the events planned for 2015 and we look forward to seeing large numbers of our members at these events.

Kathlene Oliver (WA Branch President)

Australian Capital Territory

ASEG ACT Branch had a very busy 2014, with everything from world leading science talks to quiz nights and social outings. Thank you to all our members for helping support our organisation.

In January 2015 many of our ASEG members who work at Geoscience Australia are leading workshops for the National Youth Science Forum for Australia's top Year 11 science students. Geoscience Australia's education centre, staffed by trained educators, hosts the National Youth Science Forum each year. During the two half-day sessions students will be running a small seismic refraction survey, a ground magnetic survey, and undertaking water sampling and core analysis. The workshops provide students with a hands-on experience and the

opportunity to engage with leading scientists and to learn about some of the major geoscience challenges facing Australia. For more information about NYSF go to http://www.nysf.edu.au/.

There is a lot happening in 2015: the ASEG-PESA 2015 Geophysics and Geology together for Discovery Conference in Perth, the ACT local branch AGM (March 2015), two ASEG student scholarships to be awarded, and the best geophysics lectures and workshops - as well as quite a few social events!

I take this opportunity to thank the local ACT Branch 2014 committee for their hard work: Ray Tracey, Ned Stolz, Carina Kemp, Eva Papp and Bill Jones. A particular shout out to our very busy office bearers Millicent Crowe – Secretary, Ross Costelloe – Treasurer and Marina Costelloe – President. We hope to see you at the Geoscience Australia booth at the ASEG-PESA conference!

Marina Costelloe (ACT Branch President)

New South Wales

In **November,** Jason Errey from OEMG-Global gave a talk on a cost benefit analysis of Aquares Resistivity sub-bottom profiling surveys. Jason spoke about the use of geophysics in civil engineering projects and went through a number of case histories, both marine and land, outlining the speed and benefits of the aqua-marine resistivity system. Much discussion followed.

In **December**, Rosemary Hegarty from the Geological Survey of New South Wales gave us a talk on the geophysical activities of the Geological Survey. Rosemary spoke about how the GSNSW aims to improve geophysical data and increase its use. Rosemary also spoke about current activities including the collaborative Southern Thomson Orogen Project (AEM, gravity and MT, between Cobar and the Qld border), and interpretation accompanying the East Riverina regional mapping (Ardlethan area).

An invitation to attend NSW Branch meetings is extended to interstate and international visitors who happen to be in town at that time. Meetings are generally held on the third Wednesday of each month from 5:30 pm at the Rugby Club in the Sydney CBD. Meeting notices, addresses and relevant contact details can be found at the NSW Branch page on the ASEG website.

Mark Lackie (NSW Branch President)

Queensland

We invite anyone who is visiting Brisbane to attend meetings of the ASEG QLD Branch and we are currently looking for speakers for 2015. Meeting notices, information about venues and relevant contact details can be found on the QLD Branch page on the ASEG website.

Fiona Duncan (QLD Branch President)

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Vale: Robert Edward Sheriff (1922–2014)

Photo courtesy of the University of Houston Robert Sheriff Collection.

Dr Robert E. (Bob) Sheriff passed away peacefully at his home in Missouri City, Texas on 19 November 2014 aged 92.

Bob's academic qualifications (BS, MS and PhD) were in Chemistry and Physics. From 1943 to the end of World War II he worked on the 'Manhattan Project' in Oak Ridge, Tennessee on uranium isotope separation. It was there that he met his wife Margaret, another Project employee.

Upon joining Standard Oil (Chevron) in 1950, Bob held various geophysical and managerial positions. He was seconded to management of West Australian Petroleum (WAPET) in 1962–1968. There, amongst other things, he was responsible for the training and recruitment of geophysical staff. As part of this duty in Perth, he produced a 30 page Glossary of Geophysical Terms for internal use. The value of this document was quickly recognised, and it spread to other partners, including Shell. It was passed on to the SEG's Glossary Committee headed by Milton Dobrin. Bob was encouraged to expand it, and the *Glossary of Terms used in Geophysical Exploration* was published in the February 1968 issue of *Geophysics*. The SEG recognised this as a major contribution to geophysical communication by awarding him the Virgil Kauffman Gold Medal in 1969.

With further expansion, the Glossary was adopted and published in 1973 by the SEG as the *Encyclopedic Dictionary of Exploration Geophysics*. Bob solicited contributions from the industry, and it was revised and published again in 1984, 1991, and as the *Encyclopedic Dictionary of Applied Geophysics* in 2002. The number of contributors acknowledged grew from around 40 in 1973, to 75 in 1984, 170 in 1991 and 230 in 2002. The Dictionary grew from 30 pages to 429 pages since its beginning. A valuable key feature of this book is its extended entries. They contain definitions and usages as well as references to enable readers to delve more deeply into these topics. It is still the most widely used geophysical book in the world, and has been translated into at least 75 languages. The SEG has recently established SEG Wiki, and the Dictionary is now available free of charge at wiki.seg.org. This is a fitting move as it is doubtful that another single person could have been found to match the knowledge, enthusiasm and energy to carry on Bob's endeavours and maintain such a major cornerstone of geophysical professional knowledge. A glimpse of Bob's balanced sense of humour and frank honesty can be seen in the title of his TLE article in 1991, *How in the world I came to write the Encyclopedic Dictionary.*

Scientifically Bob was a champion of the use of exploration seismology in oil exploration. His main research interests were 3D seismic interpretation, seismic stratigraphy and reservoir geophysics. He was one of the originators of the geophysical topic *attributes* and is co-author of what some would consider the seminal article in the field, *Complex trace analysis* (*Geophysics* 1979).

Bob was equally well known as a communicator, mentor and teacher. As Margaret is quoted as saying, 'Explaining things that seem obtuse is what Bob does best'. Bob's teaching role became evident after his return from Perth when he began teaching in Chevron's in-house education program in Houston. His association with the University of Houston extended from 1970 as a part time lecturer, to a full time Professorship in 1981 until retirement in 2006, when he was granted an Emeritus Professor title. In a sense, Bob never left U of H, and continued to attend and participate in their weekly seminars.

His involvement in text book writing commenced when Lloyd Geldart, one of his first bosses, invited him to participate in the revision of the text *Applied Geophysics* by Eve and Keys, which was first published in 1926. Authors Telford, Geldart and Keys needed help with digital seismology from Bob. This association led to his being author or co-author of *Applied Geophysics*, *Exploration Seismology*, *Problems in Exploration Seismology and their Solutions*. His other books were *Geophysical Methods*, *Reservoir Geophysics* and *Seismic Stratigraphy*. Margaret holds a degree in geology and her involvement in these publications was significant.

Bob, accompanied by Margaret, travelled widely giving courses around the world. In 1977 he was the SEG's Distinguished Lecturer, and in 1993, he was the ASEG's Distinguished Lecturer. Bob was proud of the fact that he had travelled every continent of the globe, including Antarctica, and claimed to have visited at least 135 countries. In an excursion across a glacier in Antarctica in 1992, Margaret, a long time senior member of the Girl Scouts, fell and injured her wrist. Ever enthusiastic, Bob encouraged her to soldier on, which she did in true Girl Scout tradition. It was only when they got back to Houston that it was discovered that she had indeed fractured her wrist, and it had set itself, though not correctly. It subsequently had to be broken again, and re-set properly. In 1993, Bob and Margaret returned to Perth where he held the distinguished position of Haydn Williams Fellow at Curtin University of Technology in Perth.

Through his publications, university teaching and professional short course presentations, Bob became the most renowned geophysicist in the world. Bob's many achievements have been well acknowledged and recognised. In addition to those already mentioned, the ASEG gave him a Special Commendation Award in 1996, and the SEG awarded him their highest award, the Maurice Ewing Medal for lifetime work in geophysics in 1998. In 1997 the University of Houston College of Natural Sciences and Mathematics gave him a Quest for Excellence Award.

In 1979 Bob was awarded Honorary Member in the SEG, and in 1980 Honorary Membership in the Geophysical Society of Houston. Bob was active in the following professional committees: SEG Academic Liaison Committee, SEG Development/Production Geophysics Committee, SEG Interpretation Committee, SEG Continuing Education Committee and AAPG Geophysical Interpretation Committee. Indeed, he embodied the spirit of the SEG in promoting the science of geophysics and the education of exploration geophysicists and fostering the expert and ethical

practice of geophysics in the exploration and development of natural resources.

The generosity of Bob and Margaret Sheriff is outstanding. They established four Chairs in Geophysics at the University of Houston, and have given nearly $2 million dollars in support of the Department of Earth and Atmospheric Sciences at U of H. Their unshakable belief in holding the family together, regardless of circumstances, is the reason why the Margaret S. Sheriff and Robert E. Sheriff Faculty Chair in Applied Seismology also provides for the travel expenses of the holder's family. They also set up a scholarship through the SEG for international graduate students at U of H.

Bob Sheriff, a giant in the profession of geophysics, is fondly remembered by the legions of people who knew him personally for his friendliness, honesty, generosity with his time and considerable energy. His active career extended from the days of analog recording to the present day exotics of digital seismic analysis. He devoted a large proportion of his lengthy professional life to the dissemination of knowledge and understanding of applied geophysics. I feel that we have all been beneficiaries of Robert E. Sheriff's legacy.

Norm Uren
uren@iinet.net.au

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GSQ: What is happening in Queensland?

The Geological Survey of Queensland (GSQ) is actively engaging in geophysical projects with funding from both the $18 million Greenfields 2020 Program and the new $30 million Future Resources Programme. The money from these programmes is being invested in a variety of geophysical projects, including a substantial amount of new precompetitive data collection (Figure 1). The GSQ is also working on more effective ways of delivering open file data to companies and, as part of wider Queensland Government reforms, working to reform the way geophysical data is reported to the government to ensure that this valuable resource is not lost to future explorers.

Geophysical data collection programmes

The focus for geophysical data collection has largely shifted back to north-west Queensland with the start of the $9 million Mount Isa Geophysics Initiative, part of the Future Resources Programme, in 2014. A major component of the geophysical work programme in Mount Isa is the collection of three new deep crustal seismic reflection surveys. These lines will provide new understanding of major crustal architecture across the entire Mount Isa Inlier and surrounding terranes. They will also improve the understanding of the location and relationships between Phanerozoic basins through central and western Queensland. Broadband magnetotelluric and gravity data is also being collected to complement these seismic lines. Data collection for all three seismic lines was completed in January 2015, with processing and interpretation ongoing.

In addition to the collection of magnetotelluric data along the seismic lines, the GSQ is pioneering the collection of 2D and 3D magnetotelluric surveys on a regional scale. The first of these surveys is the Isa Extension survey collected to the west and northwest of Boulia. This survey includes the collection of more than 800 broadband stations on a 2 km x 5 km grid and over 900 audio magnetotelluric (AMT) stations with a station spacing of 500 m. Data collection of the broadband component and half of the AMT was completed in 2014 with the remaining AMT stations to be collected after the wet season.

Another project being conducted by the GSQ is the trial of the new VTEM Supermax system in the Osborne area, 200 km south of Cloncurry. The aim of this survey is to establish the effectiveness of the high powered EM system in an area where the presence of conductive cover has historically led to very poor depth penetration for airborne EM systems. The main block of the survey will be flown at 1 km line spacing with every second line extended into areas of deeper cover to determine the full depth penetration of the system.

The GSQ is also part of a collaborative project in the Thomson Orogen with Geoscience Australia and the Geological Survey of New South Wales. This project is located in southern central Queensland around the town of Eulo. A combined work programme with gravity, AEM and MT data collection was conducted in 2014-2015 with the hopes of gaining a new understanding of this relatively unknown and potentially prospective area.

Planning is currently underway for data collection in the 2015-2016 financial year, again focused in the Mount Isa region, with surveys currently in the planning phase.

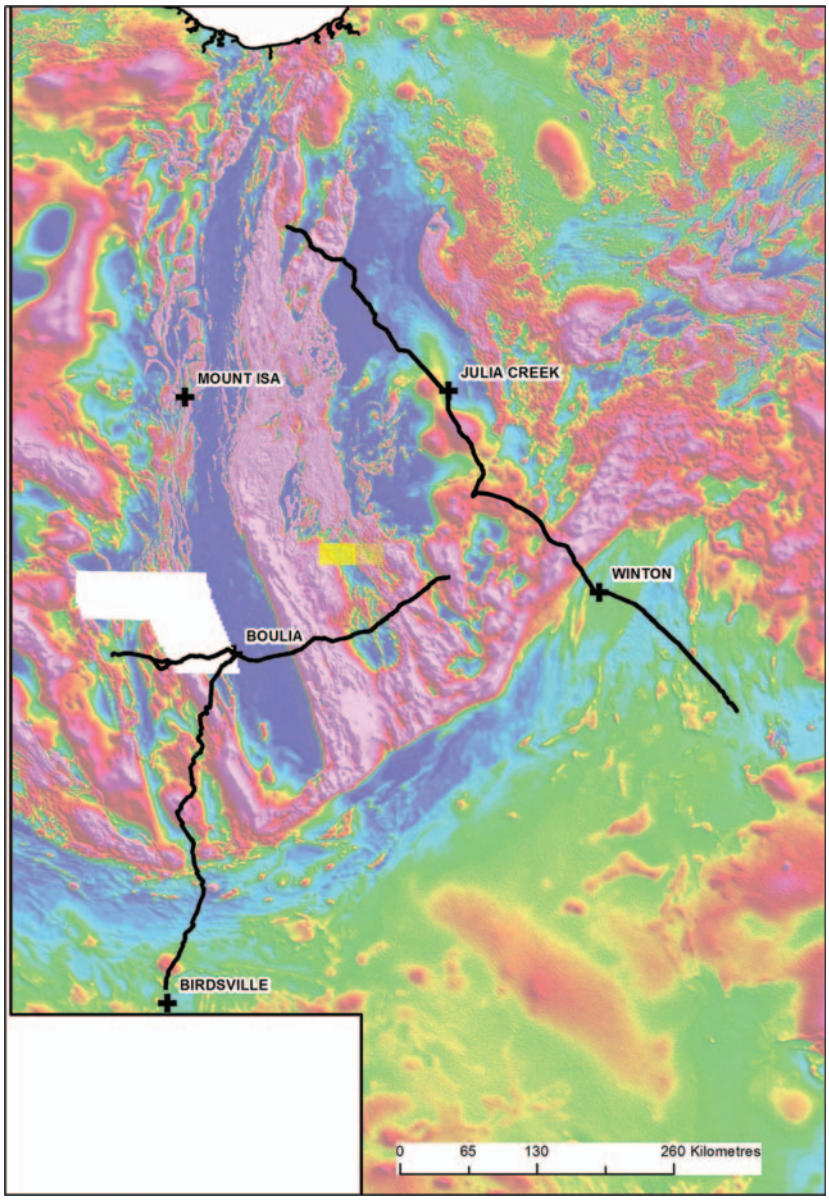


Figure 1. *Geophysical data collection in Mount Isa: deep crustal seismic in black, Isa Extension MT in white and VTEM Supermax survey in yellow.*

QDEX data

The new Queensland Digital Exploration (QDEX) Data system enables the Geological Survey of Queensland's customers to search for and freely download large spatial datasets and forms part of the Queensland Government Open Data Strategy. Previously, data were manually packaged and sold on an ad hoc basis by request or were available as pre-packaged products. The QDEX Data system allows index and spatial searching in a simple web interface and uses Geosoft's DAP Server technology.

The data currently delivered on QDEX Data includes:

- Airborne geophysical survey data including State, Federal, open-range and open file company exploration surveys packaged by survey and state-wide merges of the magnetic and radiometric data
- Ground geophysical data including all gravity data available in Queensland
- Geochemistry including drill hole locations, down-hole assays and geology, and assays of rock chips, stream sediment, soils and whole rock samples packed by broad region
- All available hyperspectral images from the Next Generation Mineral Mapping (NGMM) project
- Seismic survey processed data and field data packaged by survey
- Wireline log data packaged by well
- 3D geological and geophysical models created by the Geological Survey of Queensland staff.

As the system is further established more GSQ data will be available on QDEX Data possibly including GIS packages, mineral occurrence data and other large spatial datasets. All data in QDEX Data has extensive metadata attributed on creation that details the data source, location, creation and modification dates and important information specific for each data type. The metadata also contains keywords to facilitate easy searching, links to QDEX reports or other external links to related information and contact details for the data custodians.

The data on QDEX Data can be accessed via a simple web portal (Figure 2) or via Geosoft Seeker in Oasis Montaj, ArcGIS or MapInfo. The QDEX Data system currently hosts over 3800 data objects totalling more than 317 GB in size. The majority of files in QDEX Data can be downloaded or streamed but some larger files (currently over 4 GB) are not downloadable and must be ordered. This requirement will change as network speeds and capabilities improve.

For more information contact Janelle Simpson Janelle.Simpson@dnrm.qld.gov.au.

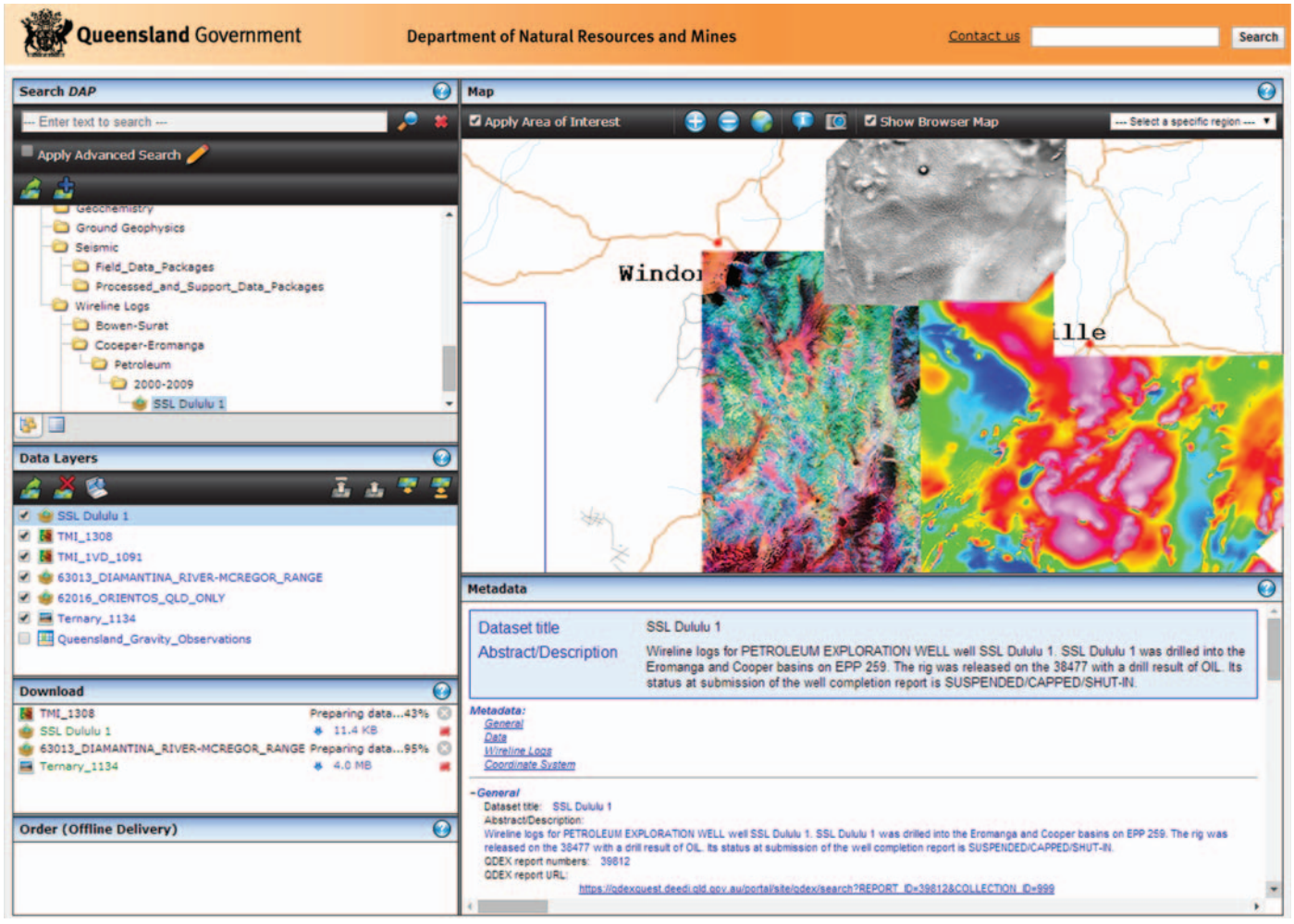


Figure 2. *The QDEX Data flamingo web portal showing the data and metadata view and the different data types available.*

GSNSW: recent and current activities

The Geological Survey of New South Wales (GSNSW) collects and manages geological, geophysical and geospatial data to inform the government, exploration and mining industries and the community about the state's geology, mineral, coal and petroleum resources. Regional work projects are supported by the New Frontiers Exploration Initiative, which is funded by industry through mineral and petroleum annual rental fees – it aims to stimulate investment in under-explored areas within NSW and includes acquisition of pre-competitive geophysical data to provide essential support for geoscience mapping and mineral exploration.Some major projects which acquire and/or evaluate geophysical data are highlighted here, along with other Departmental activities.

New geophysical data evaluates basement geology and structures beneath cover: Southern Thomson Orogen Project

GSNSW is involved in two collaborative ventures that aim to better understand the geological character and mineral potential beneath cover in the Southern Thomson region, straddling the NSW – Queensland border. Multi-disciplinary geophysical, geochemical and geological data are being acquired and interpreted within these projects.

The collaboration between GSNSW, the Geological Survey of Queensland (GSQ), and Geoscience Australia (GA) commenced late in 2013 and geophysical acquisition is now complete for:

- electromagnetic (AEM) data from a regional helicopter survey over the Eulo Ridge (Hungerford area). Inversion products have been released and are available for download. The results provide an indication of conductivity and locally indicate the depth to resistive bedrock along each flight line to a depth of around 300 m (Figure 1).
- gravity readings, AEM flight lines, and magnetotelluric (MT) measurements along two regional geophysical transect lines within NSW, each approximately 250 km in length – a western line between Tilpa and Hungerford, and an eastern line between Gongolgon and Barringun. These will help understand both cover units and also deeper basement and crustal geology to depths of several kilometres.

Interpretation of seismic sections from company and government surveys is being integrated with potential field modelling to provide 3D understanding of critical structural areas, including the Paka Tank Trough and the Olepoloko Fault.

Detailed analytical studies are underway to improve the understanding of the stratigraphic units which have interpreted from geophysics and the few available drill samples. The age constraints and mineralogical associations are being gained by U-Pb and K-Ar isotope work. The mineral systems potential for a range of commodity types is being appraised, including indications of metallic mineralisation discovered under cover during recent company mineral exploration drilling.The next phase in the project will be selection of stratigraphic drilling targets following synthesis of all data. This drilling is anticipated for the 2016–17 financial year, utilising new drilling technology via the Deep Exploration Technologies Cooperative Research Centre.

A second collaborative project commencing in 2015 will be a 3-year ARC Linkage research project between University of Newcastle, GSNSW, GSQ, University of Queensland and Queensland University of Technology. This project aims to test competing geodynamic models for the evolution of the Thomson Orogen, and will involve coordinated research projects to tackle specific geological questions within the context of available geophysical data.

These two collaborative studies will contribute to the understanding of the relationship between the Thomson Orogen and the Lachlan Orogen to its south. They will help define basin and basement structures within the Southern Thomson that may control mineralisation or mineralised terranes. The intended impact of this work is to provide the mineral exploration industry with pre-competitive data, information and knowledge that reduces risk and encourages exploration in the region.

Yathong Trough Seismic Reflection Survey

Final processing will be completed in February 2015 for a deep seismic reflection survey in the Yathong Trough, an eastern sub-basin of the Darling Basin (Figure 2). The results will be used to better define the 3D basin geometry of the Yathong Trough and understand the stratigraphy; indicate possible petroleum systems (thick sandstone reservoir units and proximity to petroleum source rocks); identify deeply buried granites which may generate heat suitable for geothermal energy generation; and help locate suitable areas for carbon dioxide

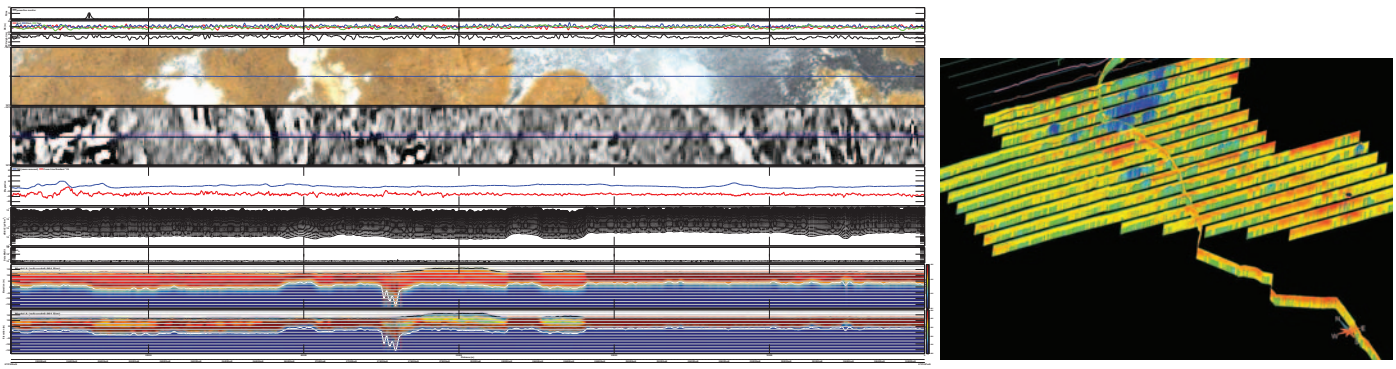


Figure 1. *Example AEM multiplot (left) and perspective survey view (right) for the Southern Thompson region show contrast between near-surface conductive layers of saturated sandstone beds (red-orange) of the Eromanga basin and more resistive areas of granitic basement highs (blue).*

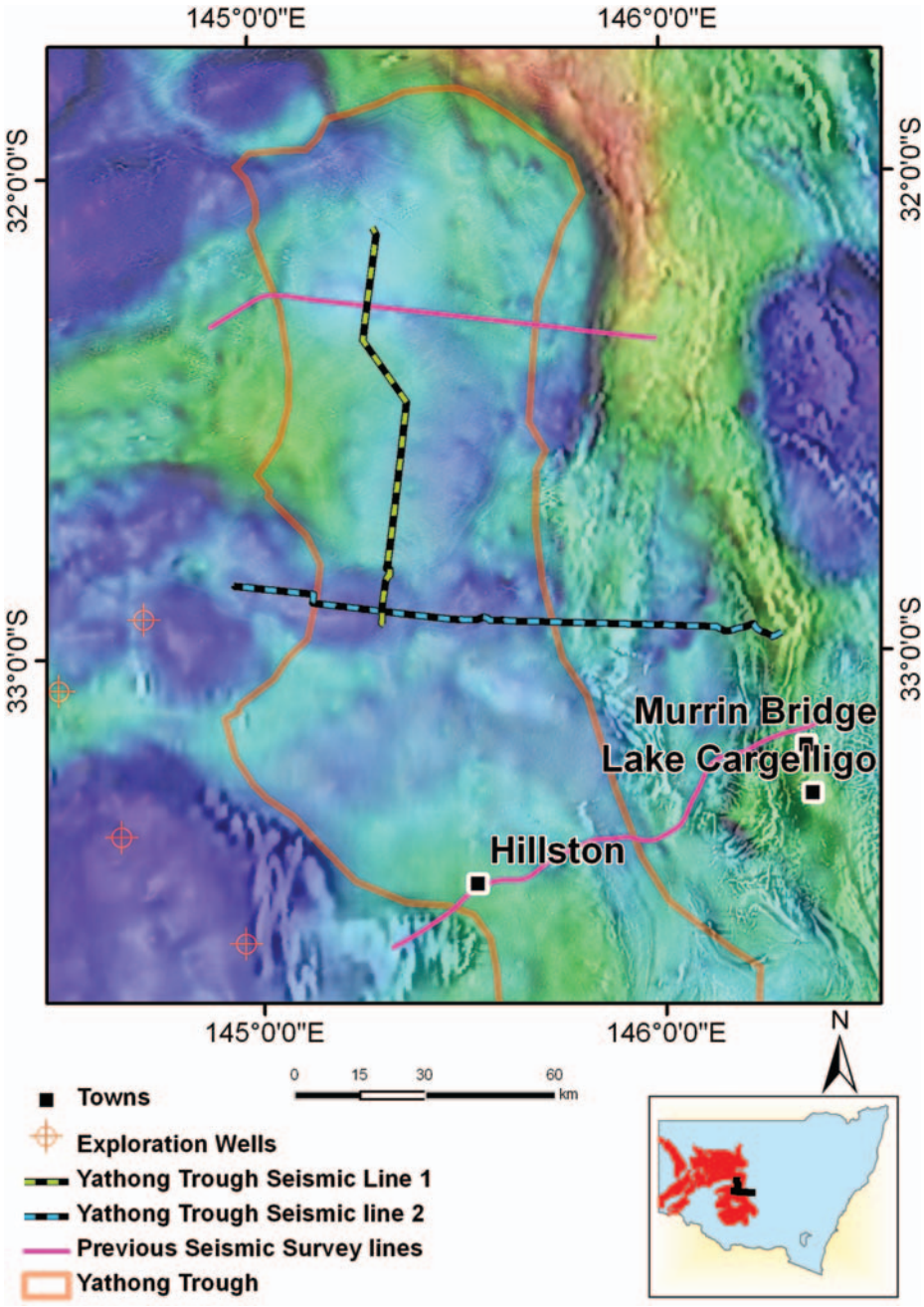


Figure 2. *Yathong Trough 2D Seismic Survey: Background image is greyscale first vertical derivative of total magnetic intensity, underlain by pseudocolour Bouguer gravity data.*

storage. Longer recording for deeper reflections will provide structural framework information for sub-basin basement rocks, and for rocks of the Cobar Basin located immediately east of the trough.

The Yathong Trough has a surface area of about 15 000 km^2 and is considered to be under-explored for petroleum. Two regional east–west seismic lines, each about 120 km long, were acquired in the northern and southern parts of the trough in 2008 by the Onshore Energy Security Programme managed by GA. The rocks within the Yathong Trough were interpreted as a fault-bounded, thick (up to 5 km) sequence of Devonian marine sandstones and mudstones. To date there has been no deep exploration drilling in the trough.

The two new seismic lines total 230 km in length – one north–south, aligned with the long axis of the trough, and a second east–west line running across it. The latter investigates the boundary between the Yathong and Ivanhoe troughs, and the eastern extension of this line includes outcropping Late Silurian to Early Devonian units of the Cobar Basin and major structural elements.

Acquisition, reprocessing and interpretation of geophysical data and spectral imagery in the Wagga area (Central Lachlan Orogen)

Systematic field mapping on the Ardlethan and Barmedman 1:100 000 map sheet areas commenced in 2014. The project integrates field mapping with specialist studies such as geochronology (with GA), palaeontology, spectral analysis, geophysical modelling, reinterpretation of existing seismic lines, 3D modelling of geology and fluid flow, mineral systems, prospectivity analysis, and hydrogeochemistry (with CSIRO). The area is prospective for a range of deposit-styles, including intrusive tin-tungsten deposits (e.g. Ardlethan), orogenic gold, intrusion-related gold, and copper-gold porphyry systems.

High-quality geophysical data in the East Riverina Mapping Project (Figure 3) has been enhanced by recent acquisition, reprocessing and interpretation. Airborne magnetic and radioelement acquisition was previously completed through the area, with line spacing of 250 or 400 m, and flight heights of 60 or 100 m.

Reprocessing of existing radioelement data completed in 2013 (Minty Geophysics) has significantly improved the detail evident in imagery. The Riverina Gravity acquisition programme in 2013 greatly improved the resolution of gravity data in the region. Data was collected by helicopter on 2 km and 1 km grids, with some road traverses in the Ardlethan area. Potential field modelling with be undertaken in 2015, starting along the deep crustal seismic line (GA99AGSL3) acquired in conjunction with GA in 1999. This east-west line runs across the Barmedman and part of the Temora 1:100 000 map sheets.

Dr Robert Hewson (RMIT University) has been studying the application of ASTER and geophysical data to assist mapping and mineral exploration. GSNSW Quarterly Note 140 was published in May 2014 examining these data in the Wagga Wagga and Cobar areas. A second study in the Ardlethan and Barmedman 1:100 000 map sheet areas is scheduled for completion in early 2015.

Ongoing management and delivery of geophysical data

GSNSW strives to continually improve the management and delivery of geophysical data (located data, gridded

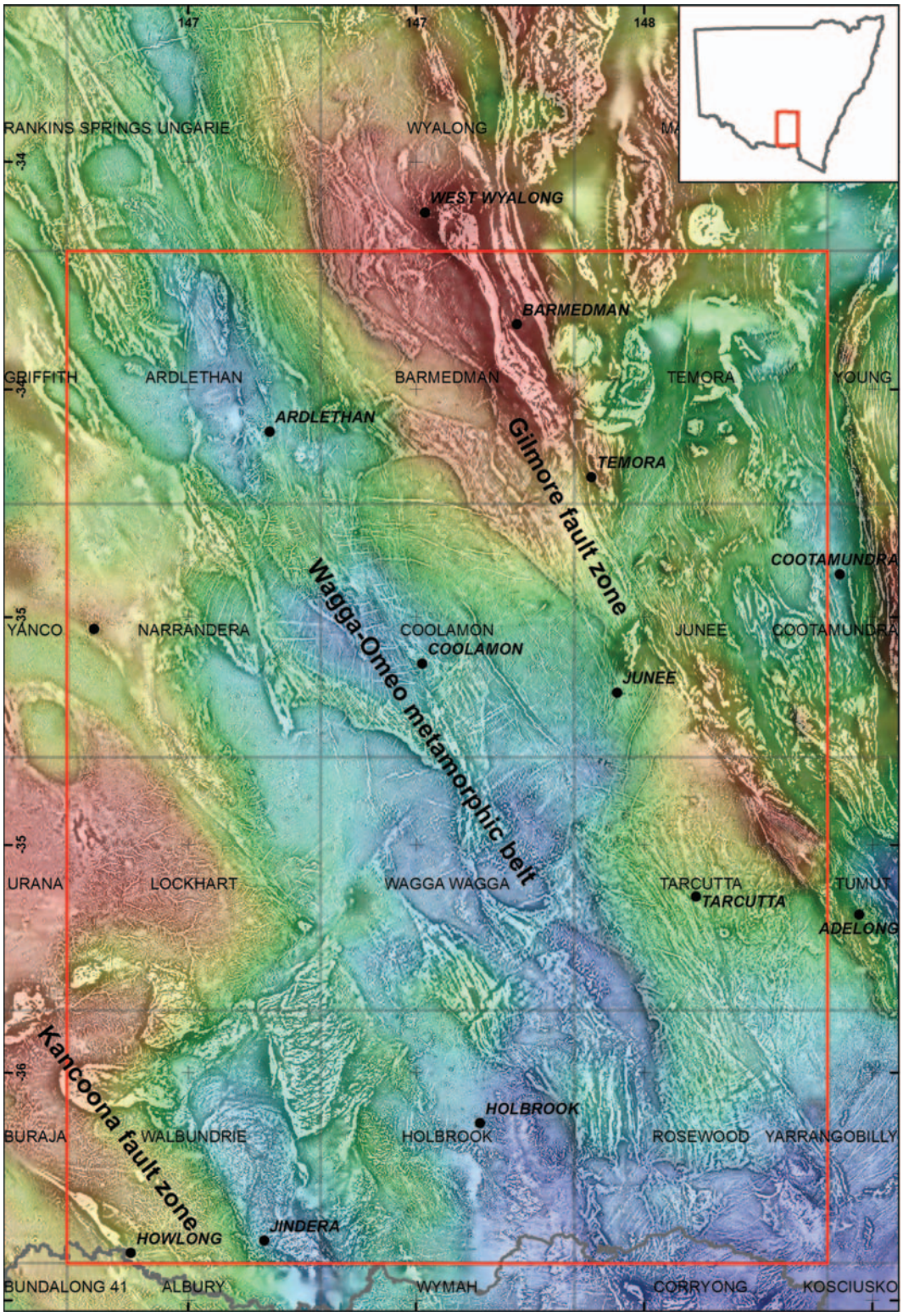


Figure 3. *East Riverina Project location (red box). Background image is greyscale first vertical derivative of total magnetic intensity, underlain by pseudocolour Bouguer gravity data.*

data, and images) to internal projects and to external stakeholders such as the exploration industry, other government agencies, universities and the general public. This includes:

- mobile phone app downloads of the NSW geology map and geophysical images for smartphones and tablets,
- incorporating latest survey acquisitions to enhance the statewide data grid and products, and
- reprocessing problematic regional radiometric surveys to ensure high quality data now that uranium exploration tenements can be sought within NSW.

For more information contact Rosemary Hegarty geophysics.products@trade.nsw.gov.au.

GSV

The Geological Survey of Victoria (GSV) is committed to providing the exploration industry, government and other stakeholders with expert regional-scale precompetitive geoscientific data and knowledge. In recent years the survey has moved away from localised projects, instead implementing a targeted whole of crust minerals system approach to its work programme. A recent major focus of this approach has been work carried out in western Victoria on the Miga Arc, a predominantly undercover Andean-type Cambrian arc system (http://dpistore.efirst.com.au/product.asp?pID=1079&cID=6&c=8227). The backbone of this methodology has been the acquisition of a deep crustal seismic transect in 2009, to which other data can be constrained and correlated. This work led to a collaborative stratigraphic drilling programme with Geoscience Australia (GA) and the DETCRC in 2014–15 to test the geological model. This involved a programme of pre-drilling geophysics run by GA to test the validity of various techniques for determining depth to basement estimations. This work has highlighted a number of geological issues which, in order to be addressed, require more detailed geophysical data. Funding has been allocated for local geophysical surveys including gravity, magnetics, magnetotellurics and seismic reflection to address some of these issues. It is expected that data acquisition will begin in the 2015–16 financial year. The GSV is also involved in collaborative work with Adelaide University acquiring and interpreting crustal scale magnetotelluric data across western Victoria.

Using the workflow already proven to advance mineral systems understanding in central (http://www.energyandresources.vic.gov.au/earth-resources/geology-of-victoria/geological-survey-of-victoria-programs/earth-echoes) and in western Victoria, GSV plan to acquire geophysics along a series of transects in NE Victoria, with the aim of completing a continuous geophysical transect across the strike of the Lachlan Fold Belt in the region of best existing structural and stratigraphic control. The aim is to acquire deep seismic reflection, detailed gravity and MT along a route which crosses, from east-to-west, the Tabberabbera, Omeo, Deddick, Kuark and Mallacoota zones. The geophysics transect will be a definitive test of geometrical predictions arising from the Lachlan Orocline concept (http://www.nature.com/nature/journal/v508/n7495/full/nature13033.html) currently under collaborative development by GSV and GSNSW and modelled conceptually as part of the 3-D Victoria project (http://dpistore.efirst.com.au/product.asp?pID=1098&cID=53) – these predictions include the presence of Macquarie Arc crust at shallow depth beneath the Deddick Zone, and at deeper locations beneath parts of the Omeo and Kuark zones, with a range of fundamental implications for the mineral systems analysis of the region – in NSW the Macquarie Arc has proven world-class mineral deposits. As part of this work, GSV is sponsoring and supervising MSc research to acquire and model detailed gravity data in transects crossing the Buchan Rift of Eastern Victoria. Inversion modelling will deliver a better understanding of depth and the margin geometries of a major rift superimposed over the Deddick and Tabberabbera zones in the Early Devonian.

In July 2014, a ground gravity survey was acquired for GSV by Atlas Geophysics in the Gippsland Basin. The Gippsland Basin Gravity Survey (Figure 1) consisted of 1,213 stations along 12 regional traverses with a nominal station spacing of 500m. The results of this survey enable greater constrains on basement architecture in the west of the basin, and further enrich the statewide gravity database.

Over the past few years, GSV has been involved in a collaboration between ANU, University of Tasmania, FROGTECH, and Mineral Resources Tasmania (Australian Research Council grant LP110100256) to deploy a passive seismic array of 24 broadband stations that straddles Bass Strait, in order to illuminate, for the first time, the 3-D crustal structure beneath Bass Strait. The aim of the project is to further constrain the nature of the geology of this region by providing passive seismic data that can be linked onshore into existing

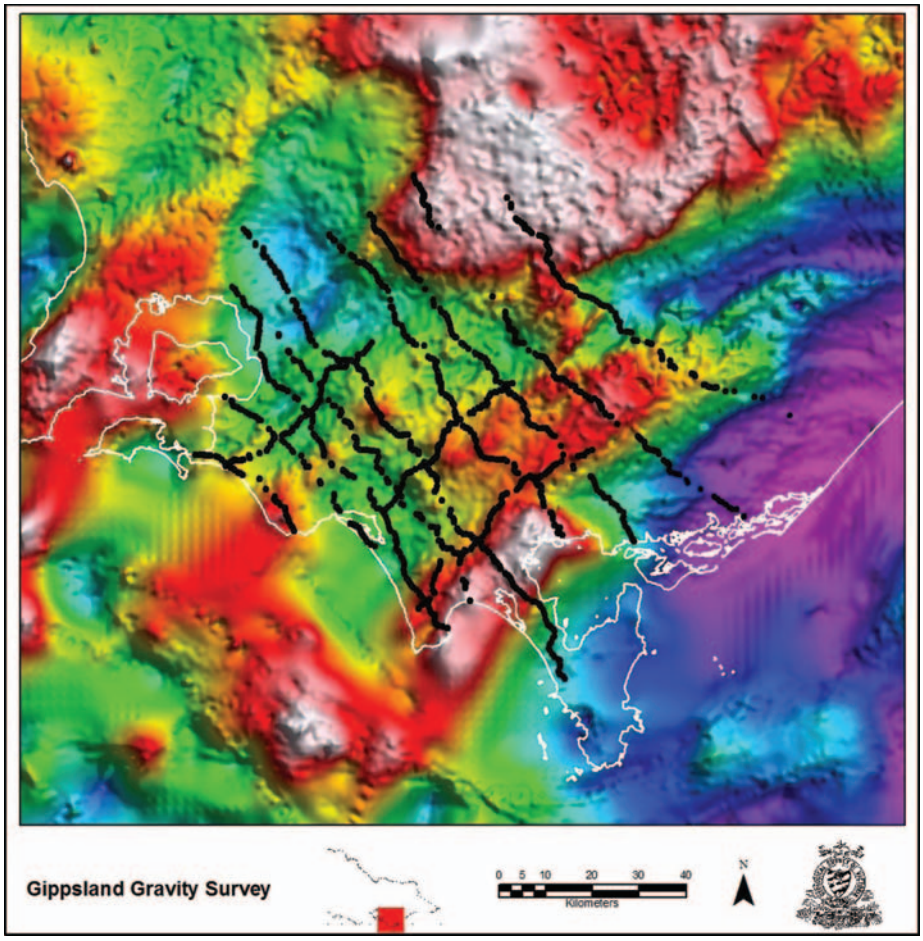


Figure 1. *Gippsland Basin Gravity Survey traverse locations overlayed on regional gravity data.*

passive seismic data from the WOMBAT deployment (eg. http://onlinelibrary.wiley.com/doi/10.1002/grl.50878/abstract), and from similar data in inland Tasmania. The results of the project are becoming available in a series of collaborative research papers (http://www.sciencedirect.com/science/article/pii/S1342937X14002901). Ultimately, this data will feed into development of a crustal-scale geological model of Bass Strait by GSV and MRT that enables unification of existing Victorian and Tasmanian crustal-scale 3-D models, improved correlation of interstate geology, and of the mineral-systems within them.

In addition to the geoscience work carried out by GSV, the Victorian Government's $15 million TARGET initiative is an exploration acceleration initiative which will boost new mineral exploration in Victoria. The initiative includes a $12 million grants programme over 4 years which will see the Victorian Government co-fund exploration works with industry to drive more exploration for minerals in Victoria, particularly for copper and other base metals. The initial grant round is intended to open in the first half of 2015. The initial focus of TARGET will be on exploration in the State's west, north and north-east. Grants will be available for works including drilling, geoscience surveys and laboratory analyses. Exploration projects will be selected on merit, with advice from an expert evaluation panel. Interested potential applicants are encouraged to register their interest. More information and details of how to register interest in the TARGET initiative are available at www.energyandresources.vic.gov.au/TARGET.

Geophysics at MRT: an overview

Geophysics is a cornerstone of Mineral Resources Tasmania's provision of pre-competitive geoscientific data. In addition to curating surveys conducted in Tasmania by explorers and federal government agencies since the 1930s, Mineral Resources Tasmania (incorporating the Tasmanian Geological Survey) and predecessor organisation the Tasmanian Department of Mines have directly and indirectly acquired geophysical data covering all areas of the State. All this data is freely available (unless obtained commercially on mine leases, or within the last five years on current exploration licences) via download from the MRT website.

Potential field data account for a large portion of these holdings, with almost 90,000 gravity stations and hundreds of thousands of line kilometres of magnetic data across Tasmania including King, Flinders and other offshore islands. In the north and west, encompassing the most prospective regions of the State, the aeromagnetic data are supplemented with multichannel radiometrics, all at a line spacing of 200 metres or better (Figure 1). Gravity station coverage in this same area is generally less than 1 km spaced or better.

Frequency domain airborne EM was obtained over extensive areas of western and northwestern Tasmania by MRT in 2003. Surface and downhole electrical and electromagnetic surveys have been conducted successfully by explorers in Tasmania. Data and other records of these investigations are obtainable via MRT's general mineral exploration database, which is completely available online.

MRT's petrophysical database has grown significantly in recent years, building on a major acquisition project conducted in the Mount Read Volcanics and other key components of western Tasmanian geology in the late 1980s. The database contains substantial sonic velocity, conductivity, chargeability, gamma ray spectrometry, thermal and magnetic remanence information in addition to susceptibility and density. All significant components of Tasmanian geology are now represented.

Substantial contributions to Tasmania's geophysical knowledge have been made over several decades by a series of collaborations with the School of Earth Science/CODES at the University of Tasmania. This excellent, mutually beneficial relationship continues to be maintained. Current projects, including second generation 3D geological and geophysical modelling, additionally involve commercial partners, tapping into MRT's 3D modelling expertise.

Geophysical data have played a key role in major mineral discoveries at Savage River (magnetite), Que River (Zn-Pb-Ag-Au-Cu), Avebury (Ni) and Mount Lindsay (Sn), plus extensions to mineralisation at Rosebery (Zn-Pb-Ag), Mount Lyell (Cu-Au) and Renison Bell (Sn).

More information about the data and associated reports outlined in this brief overview can be obtained from Mark.Duffett@stategrowth.tas.gov.au or (03) 6165 4720.

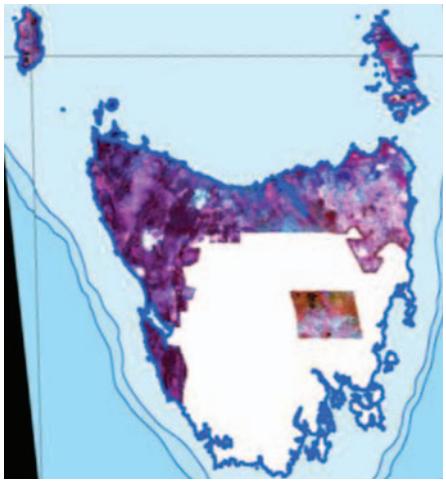


Figure 1. *Extent of high resolution (200 m line spacing or better) airborne radiometric data coverage of Tasmania, excerpted from GA's Radiometric Map of Australia.*

GSSA: Eucla Gawler Seismic Line 13GA-EG1

Seismic line 13GA–EG1 was undertaken in 2013 as a cross-border survey extending from Haig in Western Australia to Tarcoola in South Australia (see Figure 1). The cross-border survey is a collaboration between the Geological Survey of South Australia (GSSA), the Geological Survey of Western Australia (GSWA), Geoscience Australia (GA) and AuScope Earth Imaging. The survey aimed to provide key information about the largely unknown crust between the highly prospective Gawler and Yilgarn Cratons, and to image beneath the thick cover of the Nullarbor Plain.

After completion of the survey in February 2014, GA performed an initial round of processing, culminating in a joint interpretation workshop of the Eastern section of the line in November 2014 (Figure 2). Initial interpretations made by GSSA, GSWA and GA suggest significant variation in depth to the Moho, and complexity in the lower crust. Following the first interpretation workshop, a second round of processing will occur before a second round of interpretations in March/April 2015.

Processed SEG-Y data for the Eastern part of seismic line 13GA-EG1 will be released at SAREIC 2015 (https://www.saresourcesconf.com/). For more information contact Phil Heath philip.heath@sa.gov.au.

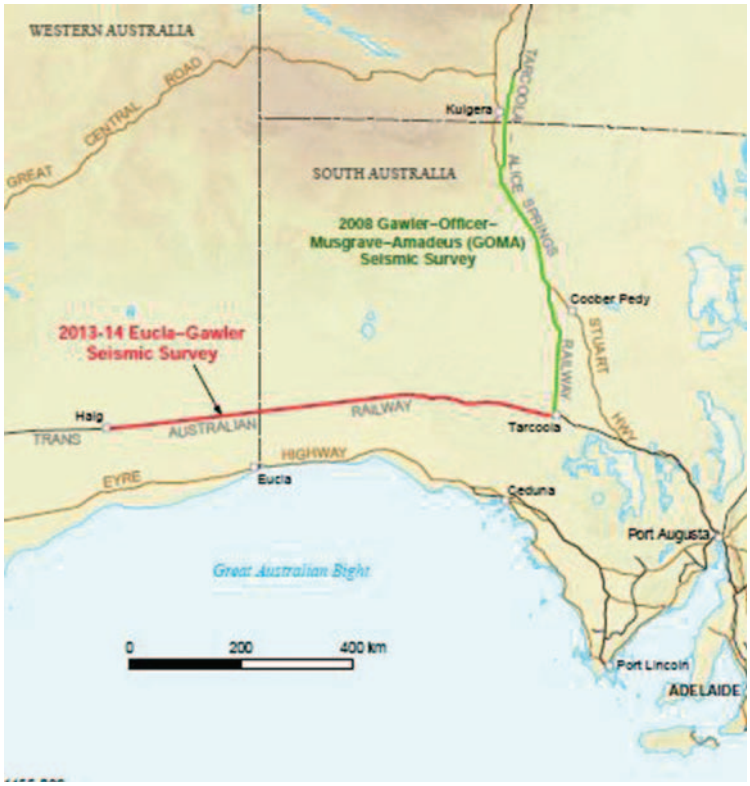


Figure 1. *Location of cross-border Eucla-Gawler survey.*

Figure 2. *Steve Hill (GSSA), Ian Tyler (GSWA) and Richard Chopping (AuScope) interpreting line 13GA-EG1.*

NTGS: Creating Opportunities for Resource Exploration in the Northern Territory

The NT Government's Creating Opportunities for Resource Exploration (CORE) initiative was announced in the 2014 Northern Territory Budget. It delivers $23.8 million over four years, continuing and expanding the 2013 initiative with an additional $2 million annually for an accelerated programme to assess the Territory's shale gas resources and potential.

The initiative focusses on acquiring new precompetitive geoscience information to stimulate exploration, establishing collaborative regional assessments of shale gas potential, providing industry grants for high-risk exploration and promoting programmes to attract investment into resources projects in the Territory. The CORE initiative has a focus on stimulating a new generation of resource discovery in the Territory's onshore sedimentary basins, which have a high potential for unconventional petroleum and large base metals deposits. Programmes include the acquisition of a number of new geophysical datasets (Figure 1). At the completion of the initiative, both the greater McArthur Basin and the Amadeus Basin will have gravity coverage at 4 km spacing or better.

Increased gravity station density over smaller areas is also achieved through collaboration with Industry. The opportunity to infill will continue to be offered to companies operating in the area for future surveys. To date the Southern McArthur Basin, Southern Wiso Basin and West Amadeus Gravity Surveys have been acquired and released. A number of key airborne magnetic and radiometric datasets will also be acquired under the CORE initiative, including the Dunmarra Survey which is currently in progress.

These new geophysical datasets, complimented by the acquisition and compilation of rock property measurements will feed into a three-dimensional model of the greater

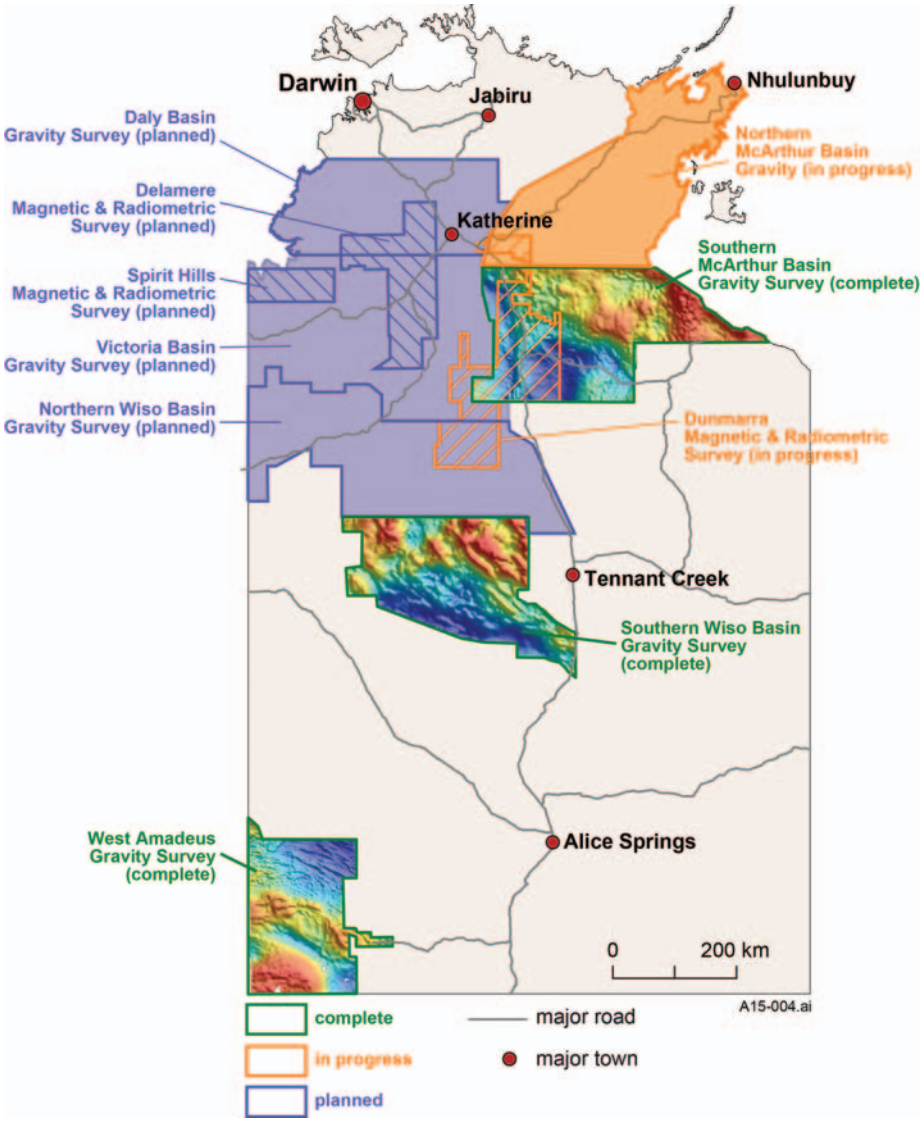


Figure 1. *Location of CORE initiative geophysical surveys that have been completed (green) are currently in progress (orange) or are planned (purple) to commence in the next 18 months.*

McArthur Basin. The model also incorporates structural interpretation, HyLogger™ hyperspectral data and industry seismic data and will be updated over the life of the initiative as new datasets become available.

Images of the new geophysical datasets are available on the Geophysical Image Web Server (http://geoscience.nt.gov.au/giws) and the gridded and located data can be requested from the Minerals and Energy InfoCentre (geoscience.info@nt.gov.au). Results from the first year of the CORE initiative will be highlighted at the Annual Geoscience Exploration Seminar (AGES) 2015 to be held in Alice Springs on 17–18 March (for more information visit www.ages.nt.gov.au).

GSWA: Exploration Incentive Scheme regional geophysics programmes 2009–15

During the past five years, the injection of more than $40 million for geophysical data acquisition as part of the Western Australian government's Exploration Incentive Scheme (EIS) has resulted in an unprecedented amount of new regional geophysical data being released for public access by the Geological Survey of Western Australia (GSWA) at the Department of Mines and Petroleum (DMP) (Figure 1).

Magnetic and radiometric surveys: An accelerated programme of airborne magnetic and radiometric surveys between 2009 and 2012 resulted in the acquisition of almost 3.5 million line kilometres of data in 34 separate contracts to provide complete 'second-generation' coverage of the state with publicly available data at a line-spacing of 500 m or better. ('First-generation' aeromagnetic and radiometric coverage is taken to be the 800 m – 3 200 m BMR survey coverage of Australia flown prior to about 1980.)

This was followed in 2013 and 2014 by a new programme of more detailed surveys with a line-spacing of 100 m over selected areas of the state. The first areas to be surveyed at this resolution were in the Goldfields with the acquisition of 720 000 line-kilometres of data. With the inclusion of non-confidential, high-resolution private company datasets, a significant area of Western Australia, particularly in the south-western half of the state, is now covered by aeromagnetic data at a line spacing of 300 m or less. This data coverage has permitted the compilation of a 40 m resolution grid of the state, believed to be the highest resolution aeromagnetic dataset presently available over such a large area (see *Preview* December 2014).

Gravity surveys: During the same time, 16 new gravity surveys added almost 109 000 new ground stations at a nominal spacing of 2.5 km to the national database. The new data have resulted in contiguous second-generation coverage at a station spacing of 4 km or less of a region extending from the Capricorn in the northwest of the state, through the central Yilgarn Craton and the Albany-Fraser Orogen, to the Eucla Basin in the southeast. ('First-generation' gravity coverage is taken to be the 11 km BMR survey coverage of Australia.)

Early in the regional gravity programme, more detailed gravity and terrain elevation data were acquired in a joint project with Geoscience Australia, Rio Tinto Exploration and Fugro Airborne Surveys (now CGG Airborne) to establish the RJ Smith airborne gravity and gravity gradiometry test range at Kauring, about 100 km east of Perth.

Reconnaissance AEM surveys: The EIS geophysical funding also enabled GSWA to initiate a programme of reconnaissance airborne electromagnetic (AEM) surveys at 5 km spacing following from the success of the Paterson AEM surveys that were carried out by Geoscience Australia in 2008. The Paterson surveys and other reconnaissance Geoscience Australia AEM surveys demonstrated the ability of wide-spaced AEM surveys to determine trends in regolith thickness and to map regional variations in bedrock conductivity under cover.

The first GSWA reconnaissance surveys were undertaken in the area of the Capricorn: a pilot project in conjunction with CSIRO of approximately 2000 line-km at 5.5 km line spacing over the Bryah Basin in 2012 followed by a $2.5 million, 30 000 line-km survey at 5 km spacing covering some 145 000 square kilometres of the central Capricorn Orogen undertaken with Geoscience Australia.

Reflection seismic and magnetotelluric surveys: These regional potential field and AEM surveys were complemented by extensive programmes of reflection seismic and magnetotelluric (MT) surveys along selected traverses throughout the state in cooperation with Geoscience Australia, AuScope, Adelaide University and the Centre for Exploration Targeting (CET) at the University of Western Australia. The network of traverses now allows the construction of quasi-continuous transects through the major tectonic domains of Western Australia providing the potential to map key crustal structures and tectonic boundaries.

Passive seismic surveys: The seismic reflection and MT surveys are themselves being complemented by targeted programmes of passive seismic surveys by GSWA, CET and ANU to provide additional information about large-scale structures to mantle depths. Surveys are presently underway in the areas of the Capricorn and Albany–Fraser Orogens.

Satellite ASTER Geoscience Map of Western Australia: A collaborative venture between GSWA and the Centre of Excellence for Three Dimensional Mineral Mapping led by CSIRO's Minerals Down Under Flagship project saw the release of a series of 'mineral group' composition maps over Western Australia. The project was subsequently extended by CSIRO and other state and territory geological surveys to cover the rest of Australia.

Data interpretation and analysis: GSWA, together with its research partners in CET, CSIRO and Geoscience Australia, is using these extensive and complementary geophysical datasets together with geological mapping and stratigraphic drilling data to create a new generation of 3D geological maps and models at project and craton scales.

The Capricorn seismic, MT and AEM datasets are key inputs to the Science and Industry Endowment Fund (SIEF) UNCOVER project 'Distal footprints of giant ore systems: Capricorn Orogen case study' being undertaken by a consortium of partners including GSWA, CSIRO, CET and Curtin University.

Data delivery: All data acquired from these surveys and results from the analyses are made available for online public access via the DMP and collaborator websites:

- Western Australia Department of Mines and Petroleum: www.dmp.wa.gov.au
- GSWA interactive data delivery system, GeoVIEW.WA: www.dmp.wa.gov.au/geoview/
- GSWA geophysics datasets and compilations: www.dmp.wa.gov.au/geophysics/
- Geoscience Australia Data and Publications Search: www.ga.gov.au/search/
- National Geophysical Archive Data Delivery System (GADDS): www.ga.gov.au/gadds/
- Virtual Geophysics Laboratory: http://vgl.auscope.org/VGL-Portal/
- Pawsey Data Portal: https://data.ivec.org/public/

Besides making the data available, GSWA is also seeking to promote fuller

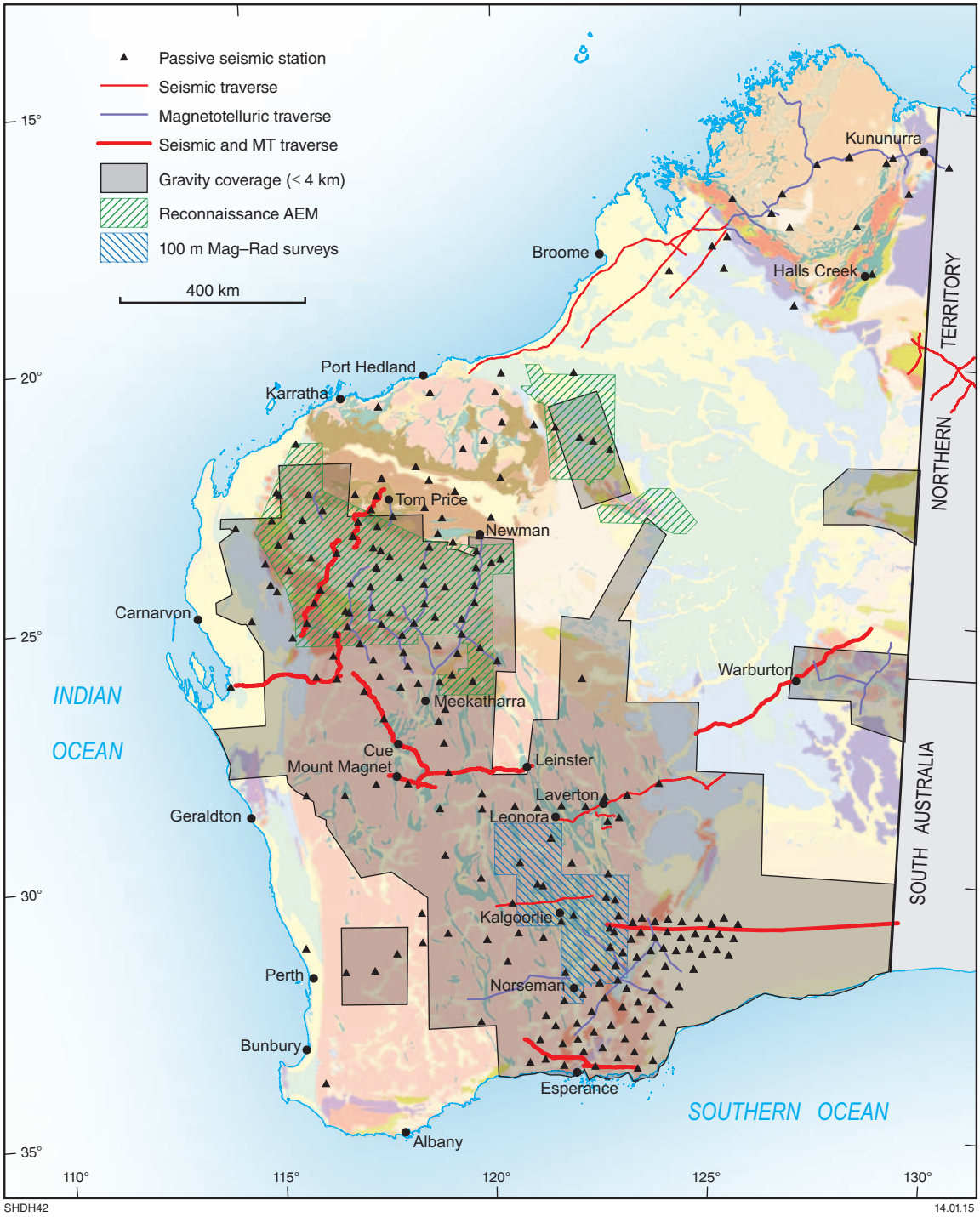


Figure 1. *WA Exploration Incentive Scheme regional geophysics programmes 2009–15.*

utilisation of the data by collaborating with CET in the development of an Integrated Exploration Platform — a suite of software tools that will allow the integration of 2D and 3D geological, geophysical, geochemical and drilling datasets and their derivative products.

Conclusions

The large area of the state of Western Australia — greater than 2.5 million square kilometres, ranked 10th in the world by area if it were a country — has always meant that the provision of regional geoscience data coverage by GSWA has been a slow and expensive process.

The Western Australian government's Exploration Incentive Scheme has gone a long way to change that situation. From being the poor cousin of Australian states and territories in terms of regional geophysical data coverage in 2009, Western Australia can now boast of a wealth of publicly accessible geoscience datasets and products that matches if not surpasses the best in the world.

The impact of the new data, analyses and delivery tools in the perception of the state's prospectivity has been recognised by the elevation of Western Australia to the number one spot in the 2013 Fraser Institute survey of mining companies released in March 2014.

Update on Geophysical Survey Progress from the Geological Surveys of Western Australia, South Australia, Northern Territory, Queensland, New South Wales, Victoria and WA Department of Water (information current on 7 January 2015)

Tables 1–3 show the continuing acquisition by the States and the Northern Territory of new airborne magnetic, radiometric, gravity and AEM data over the Australian continent. All surveys are being managed by Geoscience Australia (GA). Further information is available from Murray Richardson at GA via e-mail at Murray.Richardson@ga.gov.au or telephone on (02) 6249 9229.

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Dunmarra	NTGS	GA	GPX Surveys	28 Jun 2014	103 985	400 m 80 m N–S	36 280	100% complete at 10 Oct 2014	Raw data were supplied to GA on 24 Oct 2014. Final processed data were received for assessment in Nov 2014.	PV 170 – Jun 2014 p. 24	TBA
Coompana	GSSA	GA	GPX Surveys	Not before 7 Feb 2015	255 265	400 m 80 m E–W	The survey covers all or part of Noorina, Wyola, Cook, Coompana, Nullarbor, Ooldea, Maurice, Wells and Birksgate standard 1:250 000 standard Map Sheets. The survey commenced on 7 Feb 2015 with project management by GA and funding from GSSA's PACE 2020 Initiative.				

Table 2. Gravity surveys

Survey name	Client	Project management	Contractor	Start survey	No. of stations	Station spacing (km)	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Sir Samuel-Throssell	GSWA	GA	IMT	19 Jun 2014	11 702	2.5 km regular grid	73 800	100% complete at 7 Sep 2014	Final data expected to be released via GADDS before the end of 2014	PV 171 – Aug 2014 p. 39	17 Dec 2014
West Amadeus	NTGS	GA	Atlas	29 Jun 2014	8127	4 km regular with areas of 0.5, 1 and 2 km infill	45 050	100% complete at 11 Aug 2014	Final data expected to be released via GADDS before the end of 2014	PV 171 – Aug 2014 p. 39	17 Dec 2014
Southern Thomson	GA/ GSNSW/ GSQ	GA	Atlas	17 Jul 2014	3660	8 traverses at 333 m station spacing	TBA	100% complete at 17 Sep 2014	Final data expected to be released via GADDS before the end of 2014	PV 170 – Jun 2014 p. 24	17 Dec 2014
Gippsland	GSV	GA	Atlas	30 Jun 2014	1440	12 traverses at 500 m station spacing	8358	100% complete at 21 Jul 2014	Final data expected to be released via GADDS before the end of 2014	PV 170 – Jun 2014 p. 25	TBA
North McArthur Basin	NT	GA	Atlas	16 Sep 2014	7175	4 km regular grid with areas of 2 km infill; 1 area of traverses spaced 4 km apart with a station spacing of 1 km.	71 030	100% complete at 4 Nov 2014	Preliminary final data were supplied to GA at the end of Nov 2014	PV 171 – Aug 2014 p. 39	The survey covers all or part of Arnhem Bay, Gove, Mt Evelyn, Mt Marumba, Blue Mud Bay, Katherine, Urapunga and Roper River standard 1:250 000 standard map sheets

Table 3. AEM surveys

Survey name	Client	Project management	Contractor	Start flying	Line km	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Southern Thomson Orogen	GA/ GSNSW/ GSQ	GA	Geotech Airborne Ltd	8 Apr 2014	4198 (3327 in survey and 871 in traverses)	5 km E–W	16 270	100% complete at 5 May 2014	Additional work (traverses) over the Paroo and Darling Rivers to examine the potential for new groundwater resources was completed on 5 Jun 2014	PV 168 – Feb 2014 p. 24	The data were released by GA on 28 Aug 2014 via http://www.ga.gov.au/search/index.html#/

TBA, to be advised.

Southern Thomson Orogen VTEM Airborne Electromagnetic Survey

In August 2014 the processed data from the Southern Thomson Orogen VTEMplus® AEM Survey were released in the Phase 1 data release package that is available free of charge from Geoscience Australia's web site (see http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_81852). The Phase 1 package includes the final processed electromagnetic data, waveform files, multiplots, conductivity estimates from the EM Flow® conductivity depth imaging algorithm, and an operations and processing report, all produced by the contractor Geotech Airborne Ltd.

Phase 2 data was released on 24 December 2014 and the package contains two different types of inversion algorithm, a deterministic regularized gradient-based algorithm, which has been called GALEISBS (Roach, 2010), and a reversible-jump Markov chain Monte Carlo algorithm, which has been called GArjMcMC (Brodie and Sambridge 2012; Brodie and Reid 2013). Both algorithms assume a layered earth or 1D conductivity structure. Each airborne electromagnetic sounding is inverted independently and the results are then stitched into combined sections.

The Southern Thomson Orogen is a priority area for mineral systems research. Much of the area lies underneath cover of sedimentary basins and is a poorly-understood element of Australia's geology. The Orogen contains Cambro-Ordovician rocks that have potential for Iron Oxide Copper-Gold (IOCG) resources, porphyry copper-gold and Volcanic-Hosted Massive Sulphide (VHMS) deposits. Survey data will add to knowledge of cover thickness and character and will inform future geological mapping in the region.

10.1071/PVv2015n174p28

2014 commodity prices reviewed

David Denham AM
denham1@iinet.net.au

It's probably a good thing that we can't forecast the future. If we'd known what was going to happen to the price of coal, iron ore and petroleum at the start of 2014 we might have thought it would a good idea to hibernate for a while, or to just take the year off. As we know, that is not allowed and it would not necessarily have been beneficial.

Anyway, I am going to review a few key issues during 2014. These include commodity prices, exploration expenditure and the fate of resource stocks on the Australian Stock exchange (ASX). The commodity data are taken from http://www.imf.org/external/np/res/commod/External_Data.xls, the exploration information from the Australian Bureau of Statistics and the ASX information from The Australian and the Sydney Morning Herald.

The oil price plummets

Who would have thought that the price of crude oil would have dropped (see Figure 1) from $US104/bbl in July to $US60/bbl at the end of December? The global economy did not shrink by more than 40 percent during the same period, so what caused the fall and why?

We all probably know the answer to the first part of the question. The Saudis have upped their oil production to maintain market share and, in a simplistic supply and demand relationship, when supply exceeds demand the price is bound to fall. But, that only begs another question. Why have the Saudis upped their production? And here we can only speculate.

There are two main theories. The first is that the Saudis want to kill off competition from the more costly unconventional oil being produced from shale deposits in the United States of America. The second is that the Saudis are part of a CIA plot to destroy the economies of some of the enemies of the USA such as Iran, Russia and Venezuela. These economies depend on selling oil and if the price drops too much they could run out of money.

It is difficult to support this second theory because North Korea and China are also benefitting from low oil prices. And, while China is not an enemy, it is seen by some in the USA as a dangerous competitor. So, if we run with the first theory, the question is how long will the Saudis want to continue to flood the market? In the long run the Saudis would benefit from a higher oil price, but this is not an issue for them at the moment. My forecast is that the Saudis will cut their output sometime in 2015, the oil price will recover and that by the end of the year it will be back up the at least $US80/bbl – but we shall see!

Coal and iron ore prices continue to fall

The situation with coal and iron ore prices is very different to the situation with the oil price. The price of both commodities has been falling steadily since the beginning of 2011 (see Figure 1). The iron ore price has decreased from $US187/t in February 2011 to approximately $US68/t in December 2014. In other words, the price now is almost one third of what it was in 2011. The reasons for this drop are clear. The growth in the Chinese economy has slowed down and new deposits of iron ore have now come on-line. For Australia the situation is very serious, particularly in Western Australia where the wellbeing of that State is dependent on the value of its iron ore production.

The coal situation is a little different. The decline in price is not only a result of a decline in the economic growth in China but also a result of the global pressure to reduce greenhouse gas emissions. Global emissions of CO_2 continue to rise. The total emissions from fossil fuels, cement and land-use change amounted to 9.9 Gt CO_2 in 2013 (http://co2now.org/). As a result the CO_2 in the atmosphere continues to increase. CO_2 concentrations are now hovering around 400 ppm and have been increasing at about 2 ppm per year for the past 40 years. Sea level has been rising at 3.2 mm/yr and the world's top 10 warmest years have occurred since 2000. Consequently, there is considerable pressure to reduce the number of coal powered power stations and the world's two largest CO_2 producers, USA and China are taking steps to reduce the use of coal. Notice in Figure 1 that before 2007 prices were steady; this cannot be said for more recent years.

Aluminium and gold

The prices for gold and aluminium (Figure 2), while showing considerable

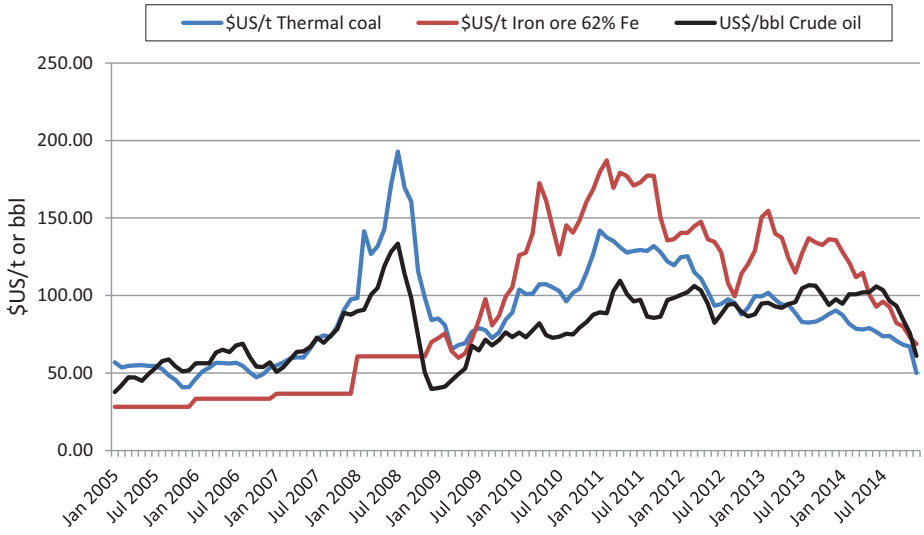


Figure 1. *Monthly prices for thermal coal, iron ore and crude oil from 2005 to 2014. The numbers are all in $US and have not been corrected for CPI inflation.*

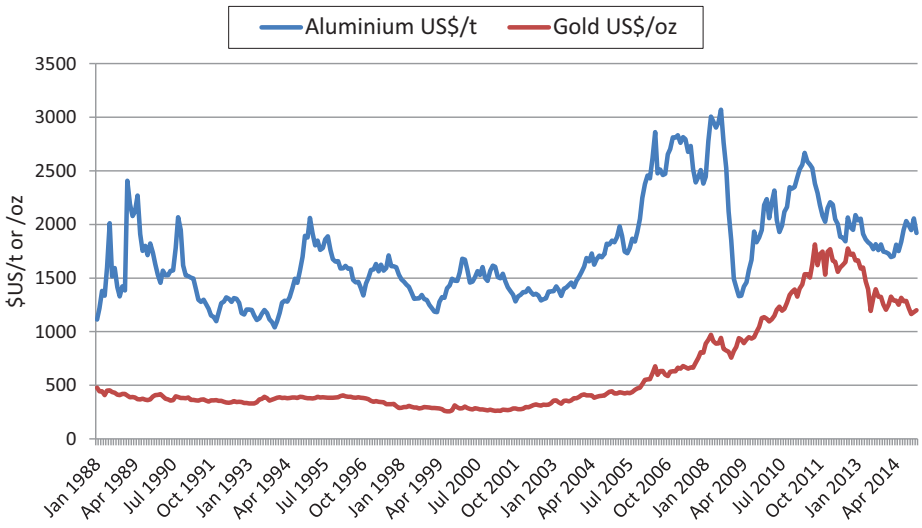


Figure 2. *The price of aluminium and gold from 1988 to 2014. The data have not been corrected for CPI changes.*

volatility, have performed reasonably well. Aluminium's price has increased steadily during the last 25 years. The average price per tonne has increased from $1100/t to $2000/t, which is close to the increase in the CPI from 48.4 to 106.4 over the same period. In comparison, gold has done better since 2006. Its price has increased from $US450/oz to $US1200/oz in December 2014. This is better than the CPI and putting money into your bank. So, it's good to see that some commodities are performing satisfactorily – it's just a matter of trying to pick the winners.

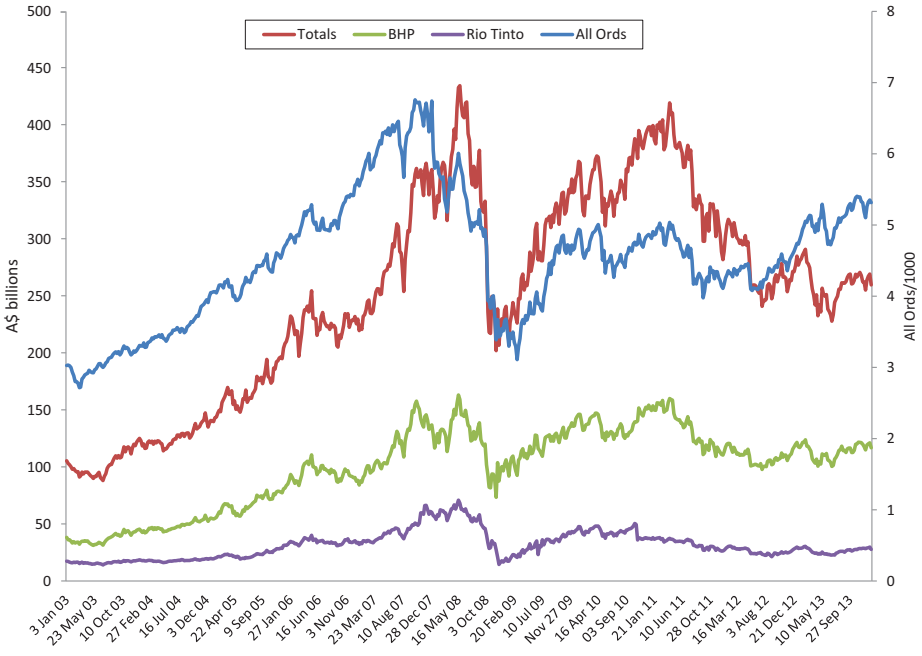


Figure 3. *Market capital of resource companies listed on the ASX between 2000 and 2014. The ASX All Ordinaries index is shown together with the market capital of BHP and Rio Tinto and a total for the market capital of all resource stocks in the top 150 companies. The data have not been adjusted for CPI changes.*

Resource Stocks perform badly on the Australian Stock Exchange

Falling commodity prices played havoc with the value of resource stocks on the ASX. 2014 was the year that BHP, after being on the top of the heap for seven years, slipped from number 1 to number 2 in September and to number 3 in November. The CBA and Westpac are now at the top, with the two other major banks (ANZ and NAB) breathing down their necks. It's a strange world where the most valuable companies just shuffle money around and make nothing while the market value of a company like BHP, which provides the essential resources to sustain our way of life, declines. Figure 3 shows what happened. Notice that changes in the All Ordinaries index and the total market capital correlate well until 2006. At that point the value of resource companies declines and the All Ordinaries index rises.

Petroleum exploration rises, minerals exploration falls

Figure 4 shows how the minerals and petroleum exploration investment has tracked from 1986 through to September 2014. There are two issues of note. The first is that investment in petroleum exploration rose dramatically in 2007 and continues to rise. Over the last two years approximately A$1 billion has been spent on petroleum exploration in each quarter. The second point is that investment in mineral and petroleum exploration was similar until 2012 when investment in the petroleum sector powered ahead. Expenditure on petroleum exploration is now more than twice the level of expenditure on minerals exploration.

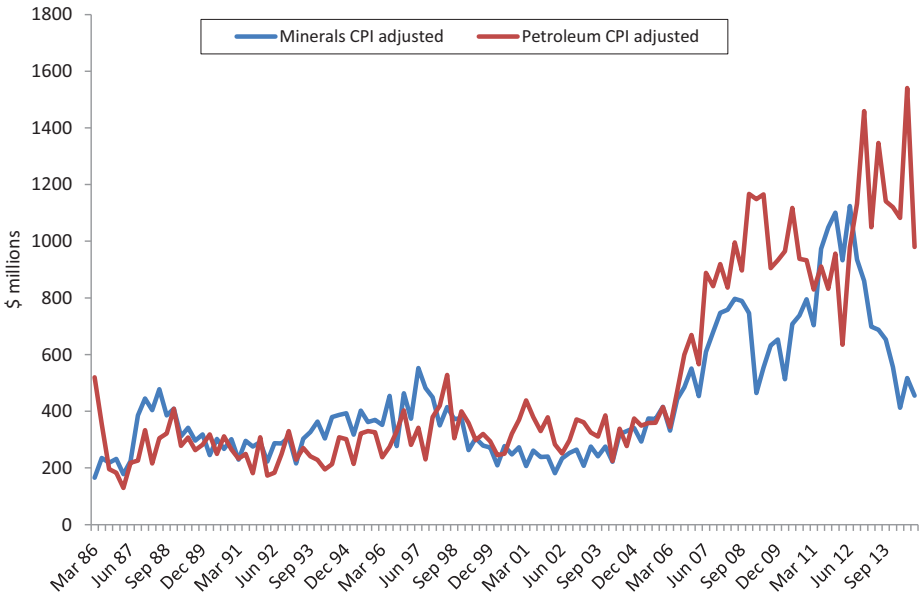


Figure 4. *Quarterly investment in petroleum and mineral exploration between 1986 and September 2014. The data have been normalised to 2014 Australian dollars to allow for CPI changes.*

The big question for the petroleum sector is: how will the dramatic drop in oil prices in the last quarter of 2014 affect the take-up of new exploration leases and the general level of activity? I await the December ABS results with interest.

10.1071/PVv2015n174p31

Commentary

Simple is not always better

Guy Holmes
guy.holmes@spectrumdata.com.au

I was thinking through a project I was working on. It was a project where we had taken some raw seismic field data and processed it in readiness for interpretation. Rather amazingly, the completed dataset was 1/600th of its original size when we were finished. I have experienced this kind of reduction in volume every time I have done this sort of work, but this time it struck me as odd.

Firstly, why should any dataset, after hundreds of hours of work, processing and intellectual input get smaller instead of gaining in size from all of the additional thinking that was put into it? It was kind of like all of my hard work created less instead of more…and, frankly, that was annoying me. It is the job of an interpreter to look for ways to reduce data to information and knowledge (the trees vs the wood etc.) so datasets getting smaller as we move towards an interpretation is to be expected. I guess what was preying on my mind is that in comparison to the original field datasets, I seemed to create less detailed, less informative final data products – shouldn't they be more informative after I put my brain to it?

My gut was telling me that this was less to do with what really should happen with my data and more to do with historical technology foundation stones, laid many years ago, that still drive how we handle our data – even if these foundation stones have no place in today's environment. I decided to dig deeper.

Today field seismic data is generally recorded in SEGD format. SEGD stands for Society of Exploration Geophysics – Format D. The industry started with SEGA then B, C and now we are on SEGD Rev 3 8058 32 bit IEEE demultiplexed (over 20 or so format changes and variations since we started with SEGA), with the last official update being in 2012. So, when I start a typical project, I usually start with SEGD. When I am done with my project and the data has been manhandled, processed and all my intellect put into it, I create a format called SEGY. SEGY, however, is not a smaller more refined version of SEGD, in fact it bears almost no resemblance whatsoever to SEGD. SEGD is so much more complex and data rich that it is usually handled only by specialist companies. In comparison, SEGY is simple and handled by almost everyone in the geophysical community (part of the point of the SEGY format was to make it simple and easily shared) and with that simplicity you lose a lot of depth, richness and provenance. This is because the SEGD format is capable of storing more information, more detail and more metadata (more of just about everything really) than SEGY.

If you follow the seismic acquisition formats used over time, you will see that they have evolved to allow for the significant advancements in acquisition techniques we have developed. But, the final format of SEGY, despite unprecedented advancements in processing technology, is still essentially the same as it was 40 years ago. As we all know, the act of processing data necessitates the need to describe what we did to others to explain the reasoning behind our decision making and the mathematical formulas we applied to the data. But, the final format of SEGY has not expanded over time to allow us to comprehensively document our actions so that this information can at least travel with, or be contained within, the data itself. On the face of it, SEGD appears to have been keeping pace with the evolution of technology given the number of changes that have been made to the format over time, but what of SEGY?

The SEGY format was created when 3D seismic was not commercially available and techniques like 4D seismic, near field and sea bed acquisition had not yet been imagined. Yet the datasets we are currently creating end up wedged into the same format we created when 24 channel 2D seismic was cutting edge. For me, SEGD is like a high definition motion picture starring our favourite actors and actresses with heaps of special effects, CGI and surround sound, and SEGY is like a screen capture of a single frame from the end of the movie – and interpreters are expected to use that single frame to determine the plot and final outcome of the movie.

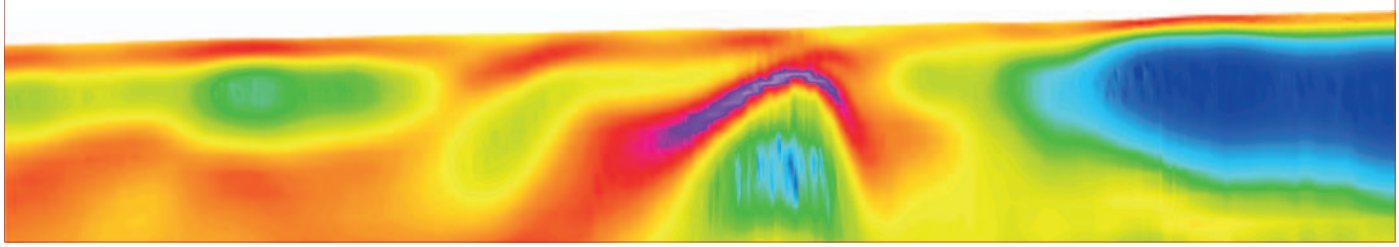
Why would we elect to create our final datasets in a format that has so much less to offer? Well, I think it relates to the following factors:

1. **The fundamental design of the SEGY format has not kept pace with our technological advancements.** The original field format specifications in the 1970s were designed to take in lots of complex detail *en masse* because in the 1970s computer power and RAM were struggling to handle the volumes of data coming in from the recording instruments. A way to receive data *en masse* and write to recording media as fast as possible, with as much detail as possible, was needed. But, this level of detail and complexity had to be pared back for end users. Datasets had to be created that were of a manageable size and compatible with the computer systems and interpretation technology available. Hence, a massive amount of detail from the acquired data had to be tossed out just to wedge it into the ubiquitous and sharable SEGY format. Maybe this was not such a big deal in the 70s when we did not have the advanced acquisition and processing technology we have now. But, the format we use for our final products and interpretations today still provides the same view of the data it did over 40 years ago despite the incredible technological advancements we have made. What if I wanted to 'undo' some of the mathematics applied to the data when it was previously processed and to model the data before the application of that change? Why can't the format itself store what was applied in a more meaningful way, and allow a user to turn it off or to make changes to the mathematical formulas to gain a different perspective of the data? While it is nice to get the data to 1/600th of its original size, it is no longer essential to do so given that our capacity to handle large datasets has expanded dramatically since the 70s. Ironically, it seems one of the major limitations in getting more from today's data is

not a lack of technology, but more that we seemingly remain satisfied with using the same 40 year old format to store our data.

2. **The heavy adoption of the formats in the industry has created reluctance to change.** The user community adopted the practice of simplification quite rapidly. Once adopted, SEGY became the norm and changing it is not going to be easy. The SEGY format was originally created in 1975 and was officially updated only once – in 2002. The update was not at all significant in terms of differences in the data format – more just a small extension to the original format. How could a format written in 1975 still be considered appropriate for today's complex geophysical datasets? Could SEGY have really been so good that it does not need to be improved? My belief is that in 1975 it was certainly a great format but, truthfully, the format has not kept pace with our technological advancements. Seismic acquisition is like paying the cost of producing a big budget motion picture on HD DVD, and our acquisition formats happily handle that level of detail, but when interpreting the data we seem quite prepared to watch that movie on a 1975 black and white television set. Why have we not taken bold steps to improve the situation?
3. **The mounds of technology built to use the data we create would need significant changes and possibly a more 'open source' approach.** Once the use of the simple format became the norm, massive amounts of technology were then built to use the data. Desktop analysis, processing and interpretation systems spread and were rapidly adopted. All of these systems are happy to store your detailed project information including the filters you applied, the decisions you made and the mathematics you used, but the SEGY format itself does not allow you to retain that detail. Why not? Is it that a massive change to the simple format of SEGY would create havoc in the software development community? Would this change possibly break our dependence on the need to retain particular processing software and hardware platforms?

I have tremendous respect for the Society of Exploration Geophysics and the people who wrote the data formats and the software that handles complex datasets and this in no way is a swipe at their efforts. But, I have to ask, are we keeping pace with technological change or is it time for a rethink? I would appreciate any feedback readers can muster on how other formats used in the geophysical industry have evolved over time.



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Jackson Oil Field: a test of modern interpretation tools

Michael Micenko
micenko@bigpond.com

The Jackson Oil Field, located in southwest Queensland, was discovered in 1981 and all the seismic interpretation leading up to the discovery was carried out on paper sections – 2D, of course, because the first and only 3D survey in the basin at the time (Cuttapirie) had just been acquired earlier in the same year. In 1981 I spent several weeks working on the paper sections – picking horizons with coloured pencils and carefully folding each paper display at every line intersection to tie round loops. Then the picked sections were placed on a digitising table and each horizon was painstakingly digitised by hand. The digitised values were then posted on a map, contoured by hand and maybe coloured with pencils.

Today there is good 3D seismic coverage over the field and the data can be readily obtained so I thought I'd try out some of the latest tools in my interpretation kit bag to see how well they work.

First off is an automatic fault picker that I mentioned briefly last year. The fault tracker requires a discontinuity, coherence or similarity attribute volume as input. Recently some new attributes of this type have been developed based on the Grey Level Co-location Matrix (GLCM) and this was a good opportunity to test them against the older, more familiar attributes. The fault picker I tried is still in development and like most automated processes it requires a good input dataset and a good deal of experimentation to select the best parameters to use. I spent a large amount of time applying filters to optimise the data for the fault tracker and the results are quite good (Figure 1). Figure 2 compares the fault sticks picked using a similarity volume with those picked with a GLCM dissimilarity volume as input. The results are similar. Because the GLCM attributes are derived from a large cube of data around the sample point they appear smoother than the standard similarity, but this does not appear to affect the identification of fault sticks. It is now a simple task to create fault surfaces from the fault sticks. Interestingly, the shallow and deep faults in this dataset are related but rarely does the tracker find a fault propagating through the entire section. I attribute this to the geology rather than the software.

Next, I was able to try a horizon auto-tracker using the faults to constrain the picking (Figure 3). These are common now and horizons at the top and base of the zone of interest took much less than an hour to propagate across the whole survey area from as little as a single seed point for each horizon. Two horizons were picked – the 'C' horizon at the top and a marker 'P' at the base. It is interesting to compare the 'C' horizon time map from the auto-tracked 3D with the 1984 time structure map (Figure 4). The broad structural configuration is similar but the 3D version has much more detail. In the mid-80s the two-way time structure map was the main product of an interpretation project although sometimes a depth map was considered necessary. But things have progressed and this is really just the starting point today.

With the top and bottom of the zone of interest defined it is easy to create a horizon cube, which is a volume of closely spaced horizons propagated from seeds on a selected trace. In this example (Figure 5) seed points were selected every 2 ms on a trace near Jackson-1. The horizon cube used only a single pass and it is quite apparent that there are some large gaps between horizons in places. For a full interpretation these gaps should be filled with further passes of the horizon cube tracker.

Once the horizon cube is generated there are a number of options available to the interpreters. They can extract key horizons with ease, identify unconformities across the whole volume and create Wheeler diagrams to unravel the depositional history. Scrolling through the over 130 automatically created horizons in the horizon cube it is easy to select and save key horizons. These usually extend across the area with a consistent seismic signature and could, perhaps, be interpreted as flooding surfaces. Five horizons in addition to the 'C' and 'P' were extracted from the horizon cube. These correspond closely to geological boundaries – near Top Murta Member, an Intra Murta, and near top

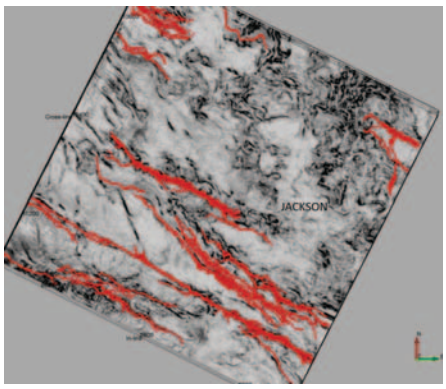


Figure 1. *Automatically picked fault sticks on and above the time slice of similarity attribute at 1719 ms (each side of the volume is about 12 km).*

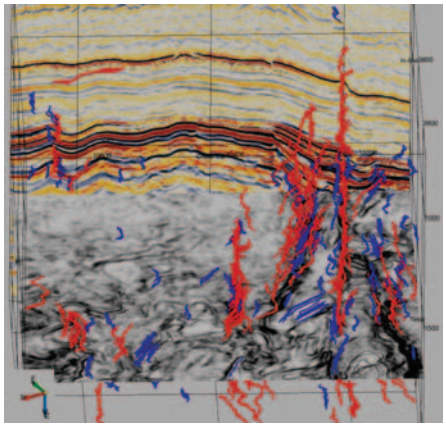


Figure 2. *3D view of auto-tracked faults using similarity (red) and GLCM dissimilarity (blue). The vertical seismic is PSTM line 4100, the horizontal slice is the GLCM dissimilarity at 1719 ms.*

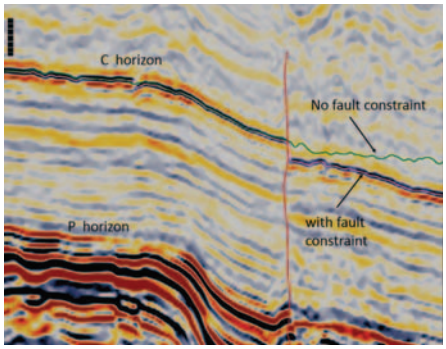


Figure 3. *What a difference the fault makes. Without fault constraints the auto-tracker horizons can easily go astray, even when the correct pick is obvious.*

Namur, Westbourne, Birkhead and Hutton Formations (Figure 5).

Possible unconformities are also simple to identify by calculating the horizon density or number of horizons in a given time window. The more bunched the horizons the more likely it is an unconformity. The result of the Jackson trial is shown in Figure 6. Note, there appears to be some relationship between the unconformities (possible sequence boundaries) and the key horizons (possible flooding surfaces).

Now we are well on the way to recreating the stratigraphic history of the area. Figure 7 is a 3D view illustrating the possible unconformities in an area around Jackson 1. Apart from anything else it demonstrates the difficulty of representing a 3D object on a static 2D surface.

Figure 8 shows a Wheeler diagram constructed along NE-SW trending line 3975. Basically, in this display each horizon is shown as a horizontal line so that the vertical axis is relative geological time (i.e. it is not calibrated to actual time). Blank areas represent either places of erosion or non deposition. On this example some erosion can be recognised at the top Hutton while the section above has had a series of prograding and flooding events as shown by the arrows. This is my quick interpretation and may be totally wrong. Including well information would provide more accurate reconstructions.

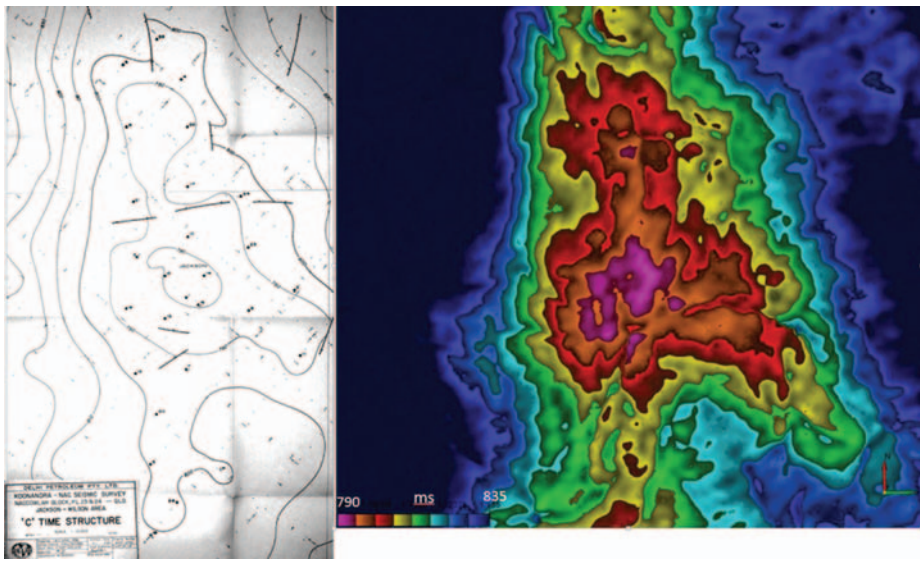


Figure 4. *Jackson Field C horizon TWT structure. Comparison of 1984 map (left, contour interval 10 ms) and 2014 auto-tracked C horizon map (right, colour interval 5 ms).*

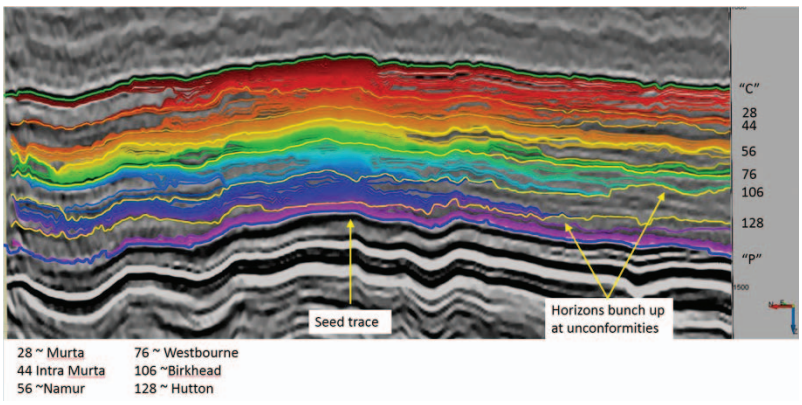


Figure 5. *Line 3975 showing horizon cube. Key horizons extracted from the cube are numbered and shown in yellow.*

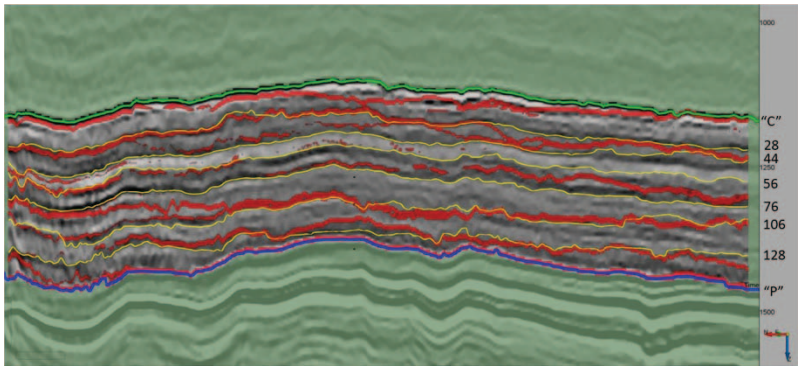


Figure 6. *Line 3975 showing key horizons extracted from horizon cube in yellow and possible unconformities in red.*

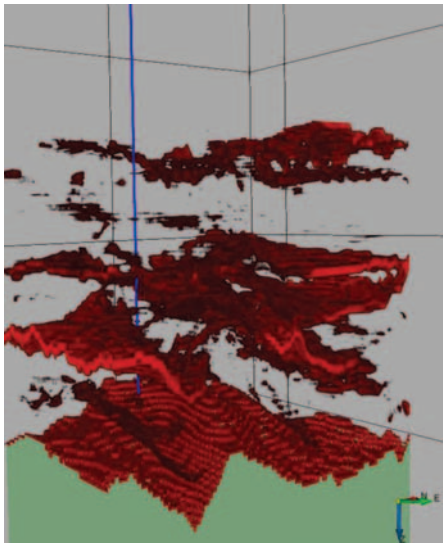


Figure 7. *3D view of unconformity surfaces defined by horizon density around Jackson-1 well (blue) viewed from southeast.*

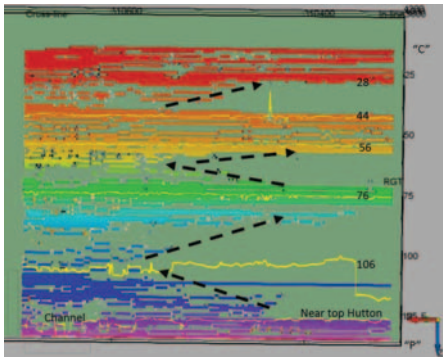


Figure 8. *Wheeler diagram of line 3975 showing erosion at the top Hutton and a series of prograding and flooding cycles. The vertical axis is relative geological time.*

Finally, there are numerous attributes to sift through, including several new ones based on the GLCM. I have not had much luck producing a good example here, although the two attributes shown in Figure 9 can be interpreted in completely different ways with a north-south aligned meander possible on the amplitude map while the GLCM energy shows a more east-west trend of more linear features.

To wrap up, seismic mapping has come a long way over the past 30 years with several new tools available to help make more geologically reasonable interpretations in less time. Because we have been so successful the focus has changed from mapping simple structures to recognising and defining stratigraphic plays and traps using a variety of new tools and techniques. If only we had time to use them all.

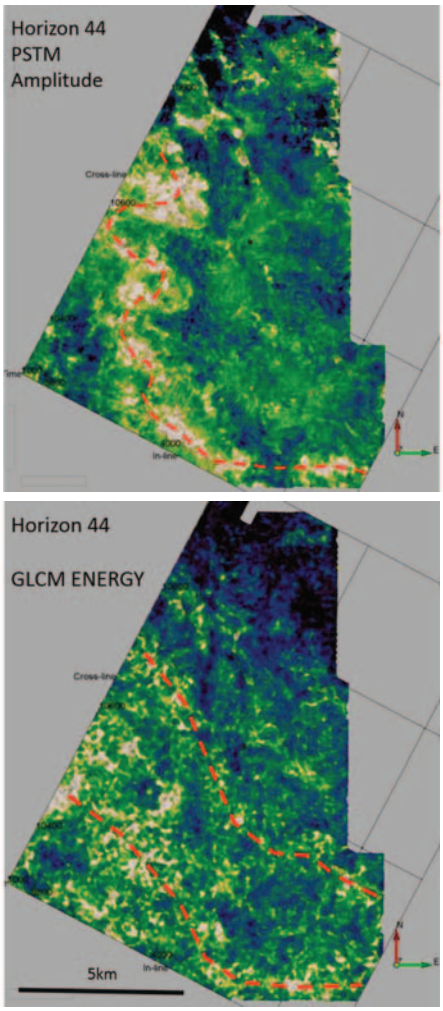
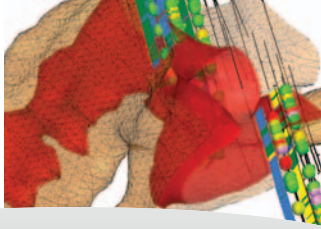


Figure 9. *Selected attribute displays at horizon 44 – Intra Murta. The PSTM amplitude (top) and GLCM energy (bottom) can be interpreted differently (red) without the benefit of well data.*



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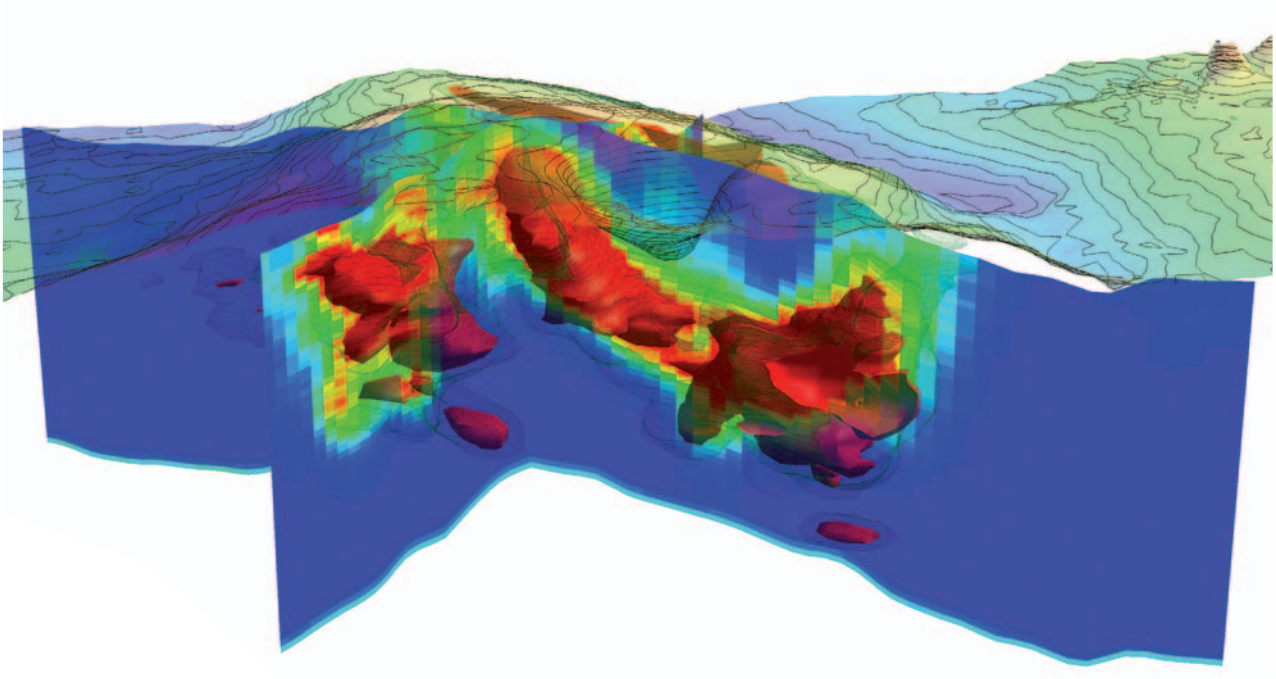

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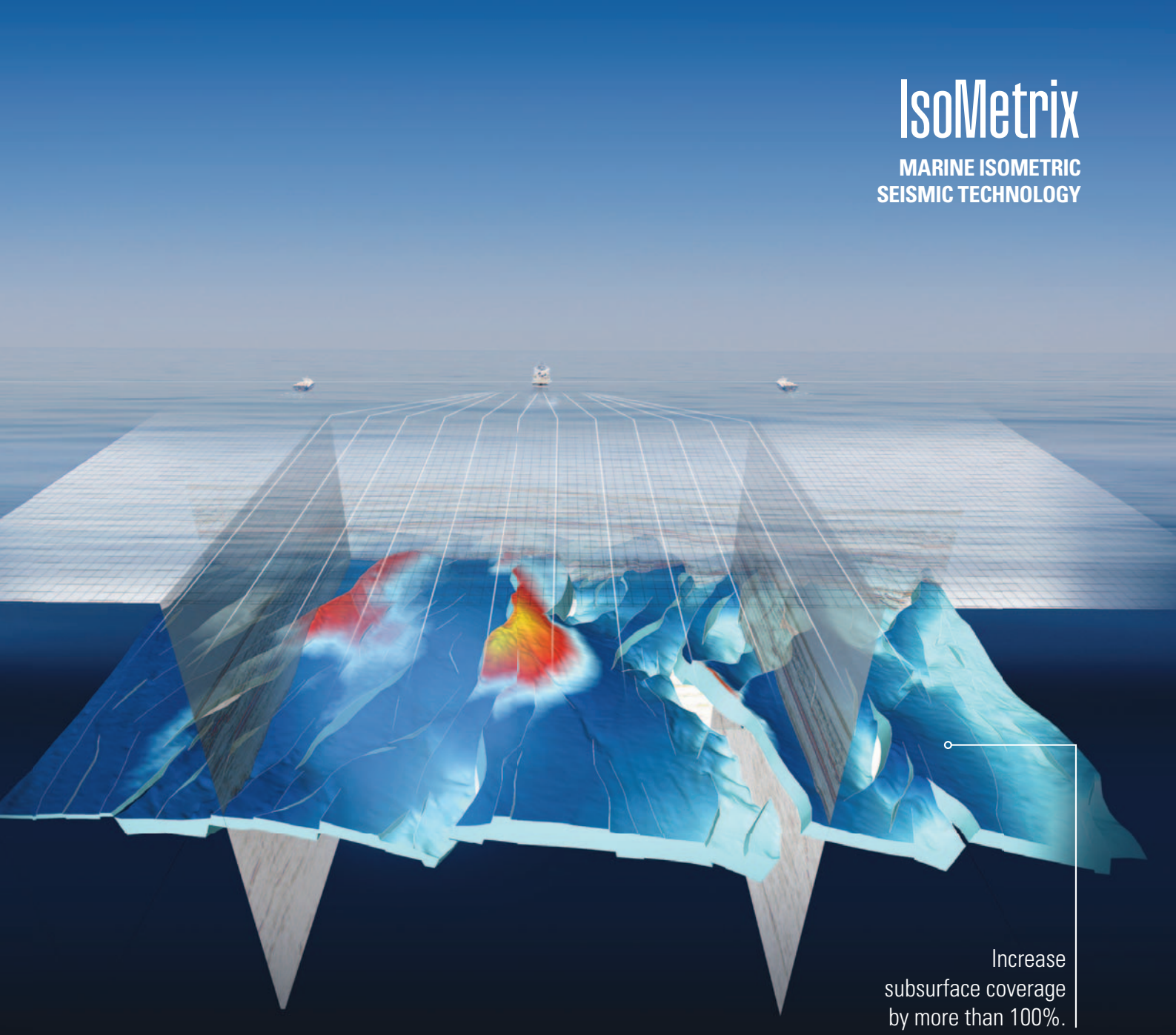

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President's welcome

Welcome to the 24th ASEG Conference in Perth, my home town.

Perth, on the west coast of Australia, is the most isolated city in the world, being more than 2600 km by road from Adelaide, the nearest large city. Perth is a city inextricably linked with mining and oil and with geophysics.

First settled by Europeans in 1831, Perth lies on the ancestral lands of the Noongar people who lived here for more than 30 000 years. They fished and hunted around the area now occupied by the Perth Convention Centre, which at that time was a swamp teeming with birdlife and a breeding area for fish.

European settlement changed the lives of the Noongar people as they became disenfranchised, banished from their homelands, and suffered the ravages of European diseases. Agriculture spread rapidly from Perth with no natural boundaries although the deeply weathered soils of the Mallee belt to the east of Perth were not very fertile and farmers struggled to clear native vegetation and with drought. With clearing came rapid onset of dryland salinity and salinisation of waterways. Geophysics has been shown to be highly effective in defining how parts of the landscape become saline and how farmers can better design remedial actions.

Exploration of the inland yielded very little in the way of mineral wealth until late in the 19th century. On Christmas Day 1885, a prospector called Charlie Hall discovered a 28-ounce nugget at Halls Creek and a rush of almost 15 000 people ensued and petered out within 3 months. It was the start of gold mining in Western Australia that continues today. However, it was not until the discoveries at Coolgardie (1892) and Kalgoorlie (1893) that the great mineral riches of Western Australia were revealed. Like the first European settlement these discoveries changed Western Australia for ever. The population exploded from less than 50 000 to over 250 000 within 10 years and more discoveries followed. Today the Western Australian population is around 2.5 million, of whom around 92% live in the south-west. It remains a sparsely populated state with less than one person per square kilometre.

In the 1880s coal was discovered in the Collie Basin 210 km to the south-east of Perth in a small rift basin. A coal mining industry was established in the 1890s and continues to the present day. The first report of the Bureau of Mineral Resources (now Geoscience Australia), formed in 1946, was a gravity survey to define the extent of the Collie Basin.

Rough Range in the Carnarvon Basin of Western Australia was the first commercial oil discovery in Australia, made by West Australian Petroleum, assisted by the newly formed Bureau of Mineral Resources. In 1966 West Australian Petroleum discovered the first Australian commercial gas-field near Dongara in Western Australia and soon after a pipeline was built to Perth.

While the ASEG was formed in Sydney in 1970, Perth became the centre for mineral geophysics in Australia in the late 1960s and early 1970s when reports of a new IP anomaly could send a junior mineral explorer's shares soaring.

WMC, an innovative exploration company, lead much of the development of new techniques with the adoption of TEM from the USSR and development of SIROTEM with CSIRO to assist in exploring beneath the deep conductive regolith that covers much of the Western Australian landscape.

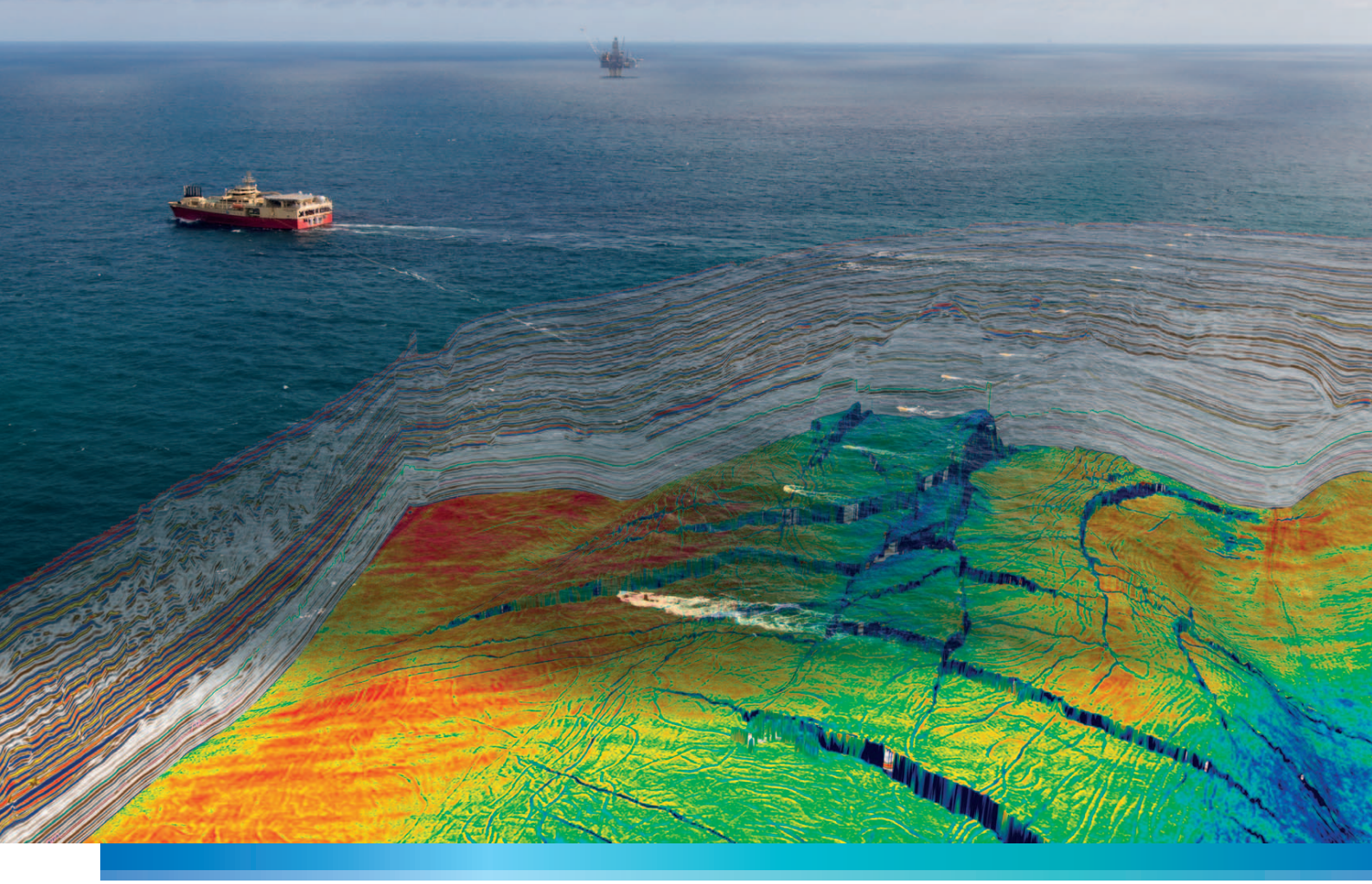
Aerodata, a small West Australian company, pioneered the use of high-resolution airborne geophysics for mapping geology by surveying large areas in the eastern goldfields. A new goldrush ensued when exploration companies realised they could use this tool, not to directly detect new deposits but to map the areas where gold deposits were most likely to occur.

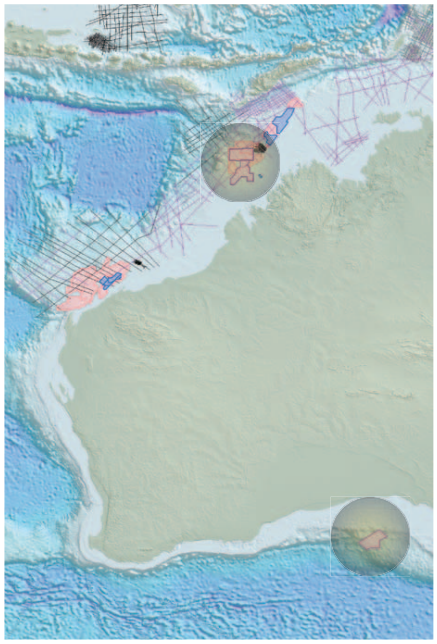
Aerodata and its subsidiary World Geoscience Corporation went on to fly the first high-resolution AEM surveys in Australia using newly digital AEM systems. These surveys were first used for dryland salinity but went on to be used in mapping regolith, detecting palaeochannels for gold deposit and assisting in the discovery of new deposits in a new boom in the 1990s, 100 years after gold was first discovered.

Today Perth is home to a wide range of geophysical service companies in both minerals and petroleum, including Western Geco, PGHS, CGG, ION and GPX Surveys.

On behalf of my colleagues in the ASEG and particularly the Perth community I welcome you to Perth, a boom and bust town that has grown out of mineral wealth into a modern city on the edge of Australia. February is a great time to be in Perth. The weather hopefully will have cooled a little from the summer heat of January.

Greg Street
President ASEG





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BHP Billiton is a leading global resources company. It is among the world's largest producers of major commodities including iron ore, aluminium, coal, copper, manganese, nickel, silver and uranium, with substantial interests in oil and gas. BHP Billiton's principal iron ore operations are based in the Pilbara region of Western Australia and include an integrated system of four major mining hubs, more than 1300 kilometres of rail and two world-class port facilities in Port Hedland. In financial year 2014, Western Australia Iron Ore achieved record production of 225 million tonnes of iron ore per annum (100% basis), with the business projected to grow to 290 million tonnes per annum. This year, the company officially opened its newest iron ore mine, Jimblebar, located 40 kilometres east of Newman, which will continue to play a key role in the growth of the iron ore business. BHP Billiton is committed to the safety of its people and to the communities in which it operates. BHP Billiton Iron Ore's Community Development Program has contributed more than A$275 million over the past five years to health, education, Indigenous development and community infrastructure initiatives in Western Australia.

Silver Sponsors

PGS Petroleum Geo-Services

Petroleum Geo-Services (PGS) is a leading, worldwide geophysical company providing an extensive range of seismic services and products for the petroleum industry, including seismic data acquisition, processing, reservoir monitoring and analysis, interpretation and electromagnetic studies. The company also possesses the world's most extensive 3D MultiClient data library. With its headquarters in Oslo, Norway, the company has over 35 offices worldwide in 25 different countries with larger regional offices in London, Houston and Singapore. The company is listed on the Oslo stock exchange (OSE: PGS).

LOCKHEED MARTIN

Headquartered in Bethesda, Maryland, Lockheed Martin is a global security and aerospace company that employs approximately 113 000 people worldwide and is principally engaged in the research, design, development, manufacture, integration and sustainment of advanced technology systems, products and services.

For more than three decades, Lockheed Martin has provided the world's only moving-based gravity gradiometer capabilities. Gravity gradient data is effectively used to help identify host geologies that are indicative of hydrocarbons or mineral ore bodies. Integration of gravity and other geophysical tools such as seismic, magnetic and electro-magnetics provides for a robust exploration data set.

RioTinto

Rio Tinto is a leading global mining and metals company. Our focus is on finding, mining and processing the Earth's mineral resources in order to maximise value for our shareholders. We have the people, capabilities and resources to supply a world hungry for the metals and minerals that are used in everyday life. Our 66 000 people work in more than 40 countries across six continents, including in some of the most difficult terrains and climates. We are strongly represented in Australia and North America and also have significant businesses in Asia, Europe, Africa and South America. With headquarters in the United Kingdom, our Group comprises Rio Tinto plc – a London and New York Stock Exchange listed company – and Rio Tinto Limited, which is listed on the Australian Securities Exchange. This global presence, and our expertise in technology and marketing, enables us to supply the right product, at the right quality, at the right time. Our major products are aluminium, copper, diamonds, gold, industrial minerals (borates, titanium dioxide and salt), iron ore, thermal and metallurgical coal and uranium. From our diverse portfolio, we supply the metals and minerals that help the world to grow.

Bronze Sponsors

Adrok®

Adrok develops and uses advanced technology to supply geophysical services for locating, identifying and mapping subsurface natural resources. We provide our clients with measurements of the subsurface natural resources, rock types and rock sequences before drilling. We call our technology Atomic Dielectric Resonance. We call our services Predrilling Virtual Logging.

CGG

CGG is a fully integrated geoscience company providing leading geological, geophysical and reservoir capabilities to its broad base of customers primarily from the global oil and gas industry. Its Equipment, Acquisition and Geology, Geophysics & Reservoir (GGR) divisions bring value across all aspects of natural resource exploration and exploitation.

ANGLOGOLDASHANTI

AngloGold Ashanti Ltd is a global gold mining and exploration company with a diverse portfolio of 20 operations in 10 countries. In Australia the company operates the Sunrise Dam (100%) and Tropicana (70% and manager) gold mines.

AngloGold Ashanti produces approximately 4 million ounces of gold annually and is listed on the Johannesburg, New York and Australian Securities Exchanges.

CSIRO

CSIRO is a powerhouse of ideas, technologies and skills for building prosperity and sustainability for government and industry. CSIRO's geophysics capabilities are deployed in cutting-edge research for the minerals and energy resources sectors. Find out how partnering with CSIRO's geophysical expertise can give your company the competitive edge in innovation.

Velseis has built a reputation as a leading Australian seismic contractor with over 30 years experience throughout the Asia-Pacific region, servicing the Petroleum, Coal and Mineral Industries. Velseis has an unrivalled reputation in the acquisition of high resolution seismic data using Vibroseis, explosive and Mini-SOSIE sources. Velseis offers a fully integrated professional service incorporating design, drilling, acquisition, processing and the interpretation of 2D, 3D and multi-component seismic surveys.

Student Day Sponsor

Woodside is Australia's largest independent oil and gas company with world-class facilities and a history of achievement. With the successful start-up of the Pluto LNG Plant in 2012, Woodside now operates six of the seven LNG processing trains in Australia. We are now seeking to expand our exploration portfolio, both within Australia and globally, to generate future growth opportunities for the company.

Conference Dinner Sponsor

Balustrade Sponsor

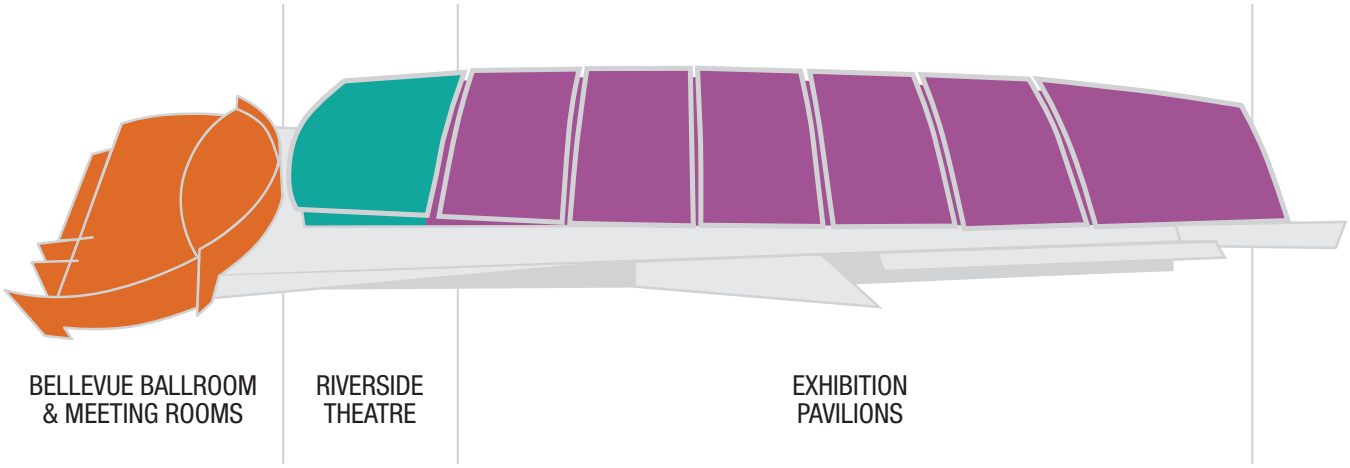
Internet Cafe Sponsor

Website Sponsor

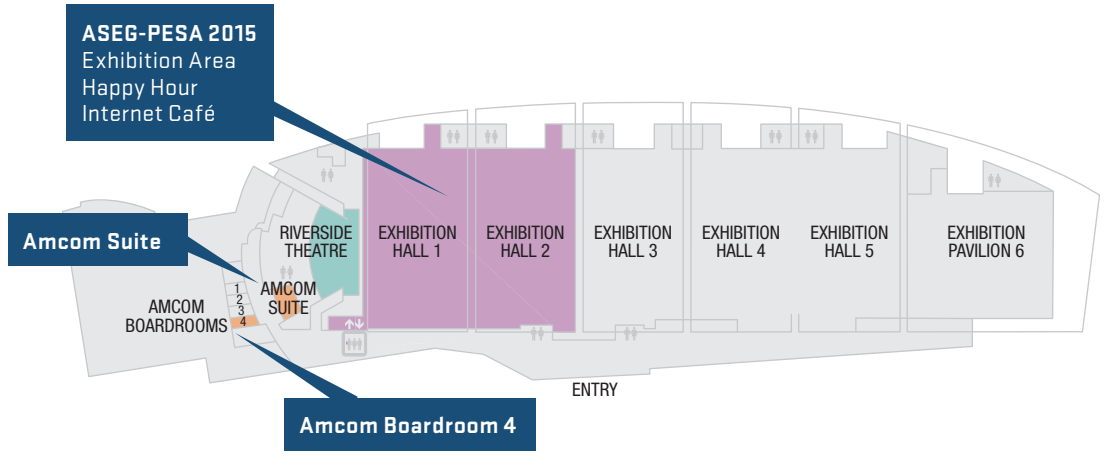
Best Papers Prize Sponsor

USB Sponsor

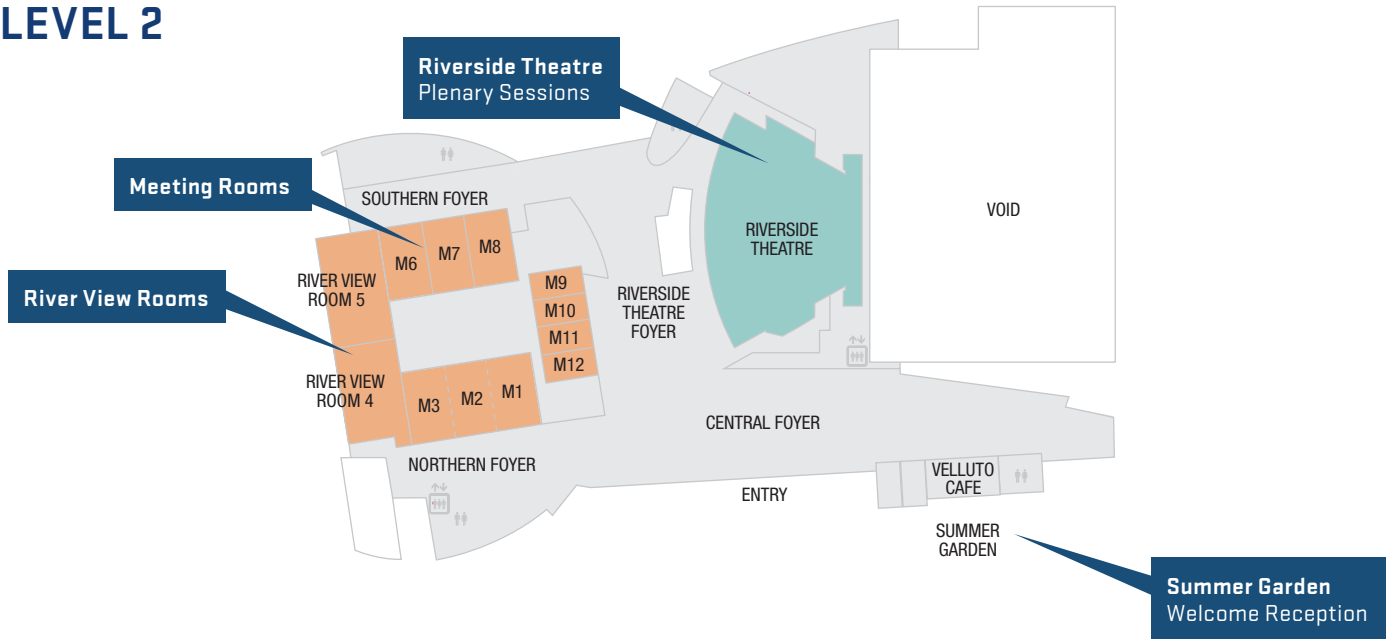
PERTH CONVENTION AND EXHIBITION CENTRE FLOOR PLAN



LEVEL 1



LEVEL 2



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App

ASEG-PESA 2015 has developed a smart phone App which allows you to view the conference programme, abstracts, keynote speaker biographies and communicate with fellow delegates.

To access the App on your smart phone or tablet follow the instructions below. Should you require assistance please see the staff at the registration desk.

1. Open app store/play store
2. Search for Events by EECW
3. Download app
4. Open app
5. Enter your email address
6. Select conference you are attending and submit your password as required
7. You will now have access to the ASEG-PESA 2015 App

Adhoc Meeting Rooms

Location: Meeting Room 11, Level 2, PCEC

Location: The Amcom Suite, Level 1, PCEC

Location: Amcom Boardroom 4, Level 1, PCEC

The Conference provides the perfect opportunity for colleagues across the globe to connect and discuss collaborations, current research and network. The Conference Organising Committee is pleased to provide Meeting Room 11 and the Amcom Suite located on Level 1 at the PCEC (bottom of the stairs near the Riverside Theatre) as a quiet place for you to meet during the Conference. Should you wish to schedule a meeting, please block a time on the timetable located at the Registration Desk including contact person and mobile phone number.

ATM

An automatic teller machine is located on Level 2 adjacent to the Velluto Café.

Banks

All major banks are located within close proximity to the Perth Convention and Exhibition Centre on St Georges Terrace, Perth. Most banks are open from 9.30am – 4.30pm Monday to Friday. Some bank branches may be open on Saturday but check with your hotel Concierge.

Car Rental

Budget Rent a Car: 13 27 27
Hertz: 13 30 39
Avis: 13 63 33

Chargebar

There are three ASEG-PESA 2015 branded Chargebars located in the Exhibition area. The Chargebars offer optimised charge for every device, including tablets, regardless of how many devices are connected at once. Chargebars are easy to use; just find the appropriate charging cable for your mobile device, plug it in and wait by the Chargebar whilst the battery recharges which is around 12 minutes on average.

Please note: The conference organisers request you wait with your mobile device while it charges. No responsibility is accepted for lost or stolen devices.

Child Care

No official arrangements have been made for child care during the Conference. Please check with your hotel who may be able to assist you further with babysitting services during your stay.

Disclaimer

The conference handbook and USB is not an official publication and should not be used as a reference.

Dress

Conference Sessions: Smart Casual
Welcome Reception: Smart Casual
Conference Dinner: Cocktail
Happy Hours & Sundowner: Smart Casual

Indemnity

Should for any reason outside the control of the Conference Organisers, the venue or speakers change, or the event be cancelled, the Conference Organisers shall endeavour to reschedule, but the client hereby indemnifies and holds the Conference Organisers including but not limited to the Host, Organising Committee and EECW Pty Ltd harmless from and against any and all costs, damages and expenses.

Internet

Complimentary wireless internet access is available to all Conference delegates throughout the Perth Convention and Exhibition Centre, to access this you will need to connect to the PCEC wireless Ethernet connection. Once connected the PCEC log in page will appear on your internet browser, click log in and enter the following (please note the details below are case sensitive):

User Name: ASEG-PESA 2015
Password: perth

Map of Perth City

For visitors to Perth, a map of Perth City has been provided in your delegate bag.

Meals

All tea breaks and lunches will be served in the exhibition area located in exhibition Halls 1 and 2, level 1 Perth Convention and Exhibition Centre. For delegates with special dietary requirements, please make your way to the dedicated dietary requirements buffet. For dietary requirements during the conference dinner please make yourself known to wait staff.

Medical Assistance

Should you require medical assistance while onsite at the Perth Convention and Exhibition Centre please see staff at the Registration Desk or visit the Security office on level 1 near the escalators.

Messages

The Conference Secretariat can receive messages, which can be collected from the Registration Desk. The following contact number should be provided for messages +61 (0) 439 912 333. No responsibility will be accepted for undelivered messages.

Mobile Devices

As a courtesy to other participants, please ensure that all mobile devices are on 'silent' mode during all presentations.

Name Badge & Tickets

Delegates must wear their name badge at all times during the conference and in the exhibition area as this identifies them as eligible for catering and entry to Conference Sessions and the Exhibition Area.

Tickets for the various social functions as part of the Conference Programme are available in your registration pack.

Parking

Parking is available at the Perth Convention and Exhibition Centre car park, which is operated by the City of Perth, is open to the public however spaces are often limited by 7.30am. We encourage delegates to arrive early each day of the Conference to avoid any potential parking problems.

Alternate Parking

Given the Convention Centre's car park popularity, alternate parking is available within a short walk of the Perth Convention Centre.

- CPP car park at His Majesty's: Westralia Square
- CPP car park Council House: Central Park
- CPP car park Concert Hall: King Street
- Wilson car park on Terrace Road: Murray Street
- Wilson car park at the Hilton

Poster Set up

Authors are asked to hang their posters between 1200 and 1730 on Sunday 15 February if possible or by 0830 Monday 16 February at the latest. Posters should be hung next to their allotted poster number. Authors are advised to bring their own materials to adhere their poster to the poster board e.g. velcro or pins. Velcro hooks can be purchased at most local newsagents in Perth.

Poster Removal

Authors must remove their posters after 1530 on Wednesday 18 February. Any posters remaining after 1800 will be considered rubbish and will be removed and destroyed by the venue.

Privacy Statement

In registering for this event relevant details may be incorporated into a delegate list for the benefit of major sponsors, exhibitors, EECW Pty Ltd and other parties directly related to the Conference. Please advise staff on the Regsitration Desk if you require privacy.

Public Transport

Perth has an advanced public transport infrastructure system providing frequent train and bus services. Free Central Area Transit (CAT) buses operate within the central business district, allowing passengers to hop on and off with ease and any CAT bus trip within the city is *free*. Please visit www.transperth.wa.gov.au or call 13 62 13 for more information.

Registration Desk

The Registration Desk is located in the Level 2 Foyer of the Perth Convention and Exhibition Centre and will be open as follows:

Saturday, 14 February 2015	0830 – 1700
Sunday, 15 February 2015	0830 – 1900
Monday, 16 February 2015	0730 – 1800
Tuesday, 17 February 2015	0730 – 1700
Wednesday, 18 February 2015	0800 – 1530

Upon registration delegates will be issued with their registration pack including delegate satchel, social event tickets (if applicable) and name badge.

All enquiries in relation to social events, programme information, accommodation and general information may be directed to staff at the Registration Desk.

Smoking Policy

The Perth Convention and Exhibition Centre has a no smoking policy. This policy also applies to the majority of restaurants, bars and shopping centres in Perth.

Speakers' Preparation Area

The Speakers Preparation Room is located on level 2, in Meeting Room 12 at the Perth Convention and Exhibition Centre.

All presenters are required to check into the Speakers' Preparation Room a minimum of two (2) hours prior to your presentation. For presenters speaking prior to lunch time on Monday 16 February we request you check in your presentation between 1500 and 1800 Sunday, 15 February. Due to the large programme, speakers presenting from Tuesday onwards are asked to submit their presentation to the Speakers' Preparation Room from Monday afternoon onwards in order to give those presenting earlier in the week preference.

The audio visual technician should be provided with a copy of your presentation on USB or CD.

The speaker's preparation room will be staffed during the following times:

Sunday, 15 February 2015	1500 – 1800
Monday, 16 February 2015	0730 – 1800
Tuesday, 17 February 2015	0730 – 1700
Wednesday, 18 February 2015	0800 – 1530

Useful Local Telephone Numbers

Ambulance: 000
Police: 13 14 44
Bus & Rail Information: 13 62 13
Swan Taxis: 13 13 30

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Geophysics and Geology together for Discovery

ASEG-PESA 2015

24th International Geophysical Conference and Exhibition
15–18 February 2015
Perth, Western Australia

SECTION 2 EXHIBITION

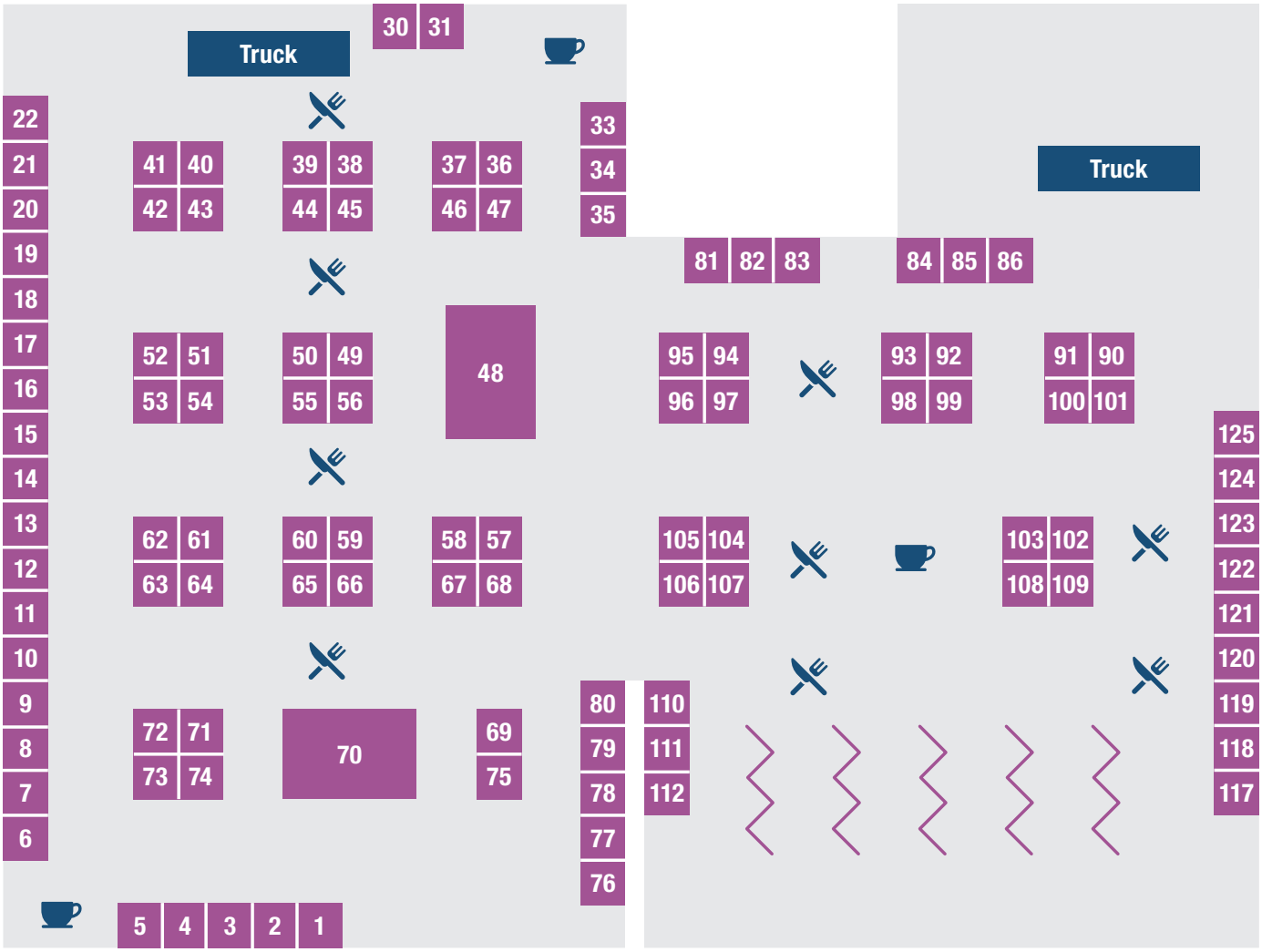
Australian Society of Exploration Geophysicists

PESA Petroleum Exploration Society of Australia

WesternGeco

Platinum sponsor

EXHIBITION FLOORPLAN



Exhibition

Opening Times

Monday 16 February 2015	0830–1800
Tuesday 17 February 2015	0830–1800
Wednesday 18 February 2015	0830–1800

ASEG Sister Societies	
118	South African Geophysical Association
119	European Association of Geoscientists & Engineers
120	Society of Exploration Geophysicists
123	Geophysical Society of Mongolia
124	Society of Exploration Geophysics Japan

Exhibitor Snap Shot	
55	3D-GEO Pty Ltd
110	AARHUS Geophysics APS
86	ABIMS Solutions Ptd Ltd
69	ADROK
95	Advanced Geosciences, Inc.
9	Alpha Geoscience Pty Ltd
68	Archimedes Financial Planning
35	ARKeX Ltd
121	Australian Society of Exploration Geophysicists
94	Borehole Wireline
63	University of Western Australia Geo Research Centres
70	CGG
41	CoRMaGEo Instruments Pty Ltd
5	CSIRO
17	Curtin University
3 & 4	Department Of State Development, Government of South Australia
45	dGB Earth Sciences
11	Dias Geophysical
36, 37, 46 & 47	Dolphin Geophysical
90, 91, 100 & 101	DownUnder GeoSolutions
81 & 82	ElectroMagnetic Imaging Technology
119	European Association of Geoscientists
109	ffA Geosciences
8	FairfieldNodal
19	First Geo
78	Gap Explosive Ordnance Detection
77	Gap Geophysics Australia Pty Limited
102	GBGMAPS
15	Geoimage Pty Ltd
53 & 54	Geokinetics
57	Geological Survey of New South Wales
31	Geological Survey of Western Australia
65	Geological Survey of Queensland
16	Geophysical Resources and Services
123	Geophysical Society of Mongolia
39	GeoProxima
42 & 43	Geoscience Australia
62	Geosensor Pty Ltd – Advanced Logic Technology
61	Geosensor Pty Ltd – Scintrex
104 & 105	Geosoft
6 & 7	Geotech Airborne/UTS Geophysics

Exhibitor Snap Shot	
34	Geotrace Technologies
97	Geovista Ltd
75	GPX Surveys
66	Hiseis
1 & 2	Ikon Asia Pacific
96	Instrumentation GDD Inc.
13	Intrepid Geophysics
59 & 60	ION Geophysical
40	Iris Instruments
20	Iseis & Seismic Source Co
76	Leapfrog Software
10	MAGSPEC Airborne Surveys Pty Ltd
50	Mala GPR Australia
64	Mira Geoscience
22	New Resolution Geophysics
72 & 73	Paradigm Geophysical Ltd
122	Petroleum Exploration Society of Australia
14	Petrosys Pty Ltd
103 & 108	PGS Australia Pty Ltd
33	Pheonix Geophysics Ltd
84 & 85	Polarcus
93	Quantec Geoscience Ltd
44	Radiation Solutions Inc.
92	Robertson Geologging (Asia) Ltd
21	RPS Australia Asia Pacific
12	S2V Consulting Pty Ltd
83	Sander Geophysics
117	SBGf - Sociedade Brasileira de Geofísica
18	Skytem Australia
124	Society Exploration Geophysics Japan
120	Society of Exploration Geophysicists
118	South African Geophysical Association
125	Surtech Systems Pty Ltd
67	Surtron Technologies
56	Tensor Research Pty Ltd
106 & 107	Terrex Group
111 & 112	TGS
49	Thomson Aviation
38	Total Depth
98 & 99	Velseis
79	Vista Clara, Inc.
80	Vortex Geophysics
52	Weatherford
48	WesternGeco
71 & 74	Wireline Services Group
51	Woodside Energy Ltd
58	Zonge Engineering
30	ZZ Resistivity Imaging Pty Ltd

3D-GEO Pty Ltd

3D-GEO provides innovative geotechnical solutions to a broad range of clients, with projects ranging from the extensional basins of Australia, SE Asia and South America to the complex foldbelts of NZ, PNG, Iran, Oman and Pakistan. 3D-GEO has demonstrated expertise in seismic processing/interpretation/ modelling, structural analysis, basin modelling/geochemistry and petroleum engineering.

W: www.3D-GEO.com

Aarhus Geophysics

Aarhus Geophysics offers consulting in airborne geophysics, adopting state of the art approaches for quantitative results. We cover feasibility studies, QA/QC of data acquisition, processing, inversion, data integration, interpretation ranging from (hydro) geological models to mineral exploration targets. The latest addition to our services is modelling of IP from AEM data.

W: www.aarhusgeo.com

ABIMS Solutions Ptd Ltd

ABIMS is a WA-based downhole directional, geophysical and imaging services provider for the global minerals industry. ABIMS is leading the use of optical imagery to generate structural information from RC drilling. With our open hole gyros and imaging tools we can provide fast, detailed, oriented images to improve your geological knowledge.

Contact: Andrew Bewsher, Chief Operating Officer
P: +61 (0)407 780 989
E: bewsher@bmgs.com.au
W: www.bmgs.com.au

ADROK

Adrok develops and uses advanced technology to supply geophysical services for locating, identifying and mapping subsurface natural resources. We provide our clients with measurements of the subsurface natural resources, rock types and rock sequences before drilling. We call our technology Atomic Dielectric Resonance. We call our services Predrilling Virtual Logging

A: 49 West Bowling Green Street, Edinburgh, EH6 5NX, Scotland, UK
Contact: Gordon Stove
P: +44 131 555 6662
E: gstove@adrokgroup.com
W: www.adrokgroup.com

Advanced Geosciences, Inc.

Advanced Geosciences is the manufacturer of the SuperSting with WiFi® resistivity/IP/SP system and the SuperSting Manager Android App enabling brilliant color presentations of the survey in real time. Other products from AGI are the PowerSting high power external transmitter and EarthImager software. Wi-Fi® is registered trademark of the Wi-Fi Alliance®

A: 2121 Geoscience Drive Austin, Texas 78726
P: +1 512-335-3338
F: +1 512-258-9958
E: sales@agiusa.com
W: www.agiusa.com

Alpha Geoscience Pty Ltd

Alpha Geoscience is a diverse geophysical company supplying geophysical instruments, rental, contracting and consulting services to the exploration, mining, environmental, civil engineering, UXO and near surface industries in Australia and around the world.

Alpha is the worldwide distributors for the magROCK magnetic susceptibility meter and the FastSnap TEM System.

W: www.alpha-geo.com

Archimedes Financial Planning

Archimedes Financial Planning assists people to define realistic personal financial goals for wealth creation and preservation, based on their input for what are acceptable risks. The analysis is conducted via a scientific-based approach using the proven techniques of petroleum industry risk management system.

We provide holistic advice for resource industry clients living throughout Australia and internationally – determining realistic goals, optimising investments, superannuation including Do-It-Yourself Super, direct shares, and personal insurances.

Our assessment of what to invest in and when are formed from application of proprietary *Econphysical* techniques that objectively determine if an asset is over or undervalued.

Contact: Noll Moriarty
A: 3-1315 Gympie Rd, Aspley QLD 4034
P: 1300 387 351
E: info@archimedesfinancial.com.au
W: www.archimedesfinancial.com.au

ARKeX

ARKeX acquire, process and interpret multi-client and proprietary Full Tensor Gravity Gradiometry (FTG) data. FTG data shows subsurface density contrasts associated with geological features that can support/constrain geological interpretation.

ARKeX also process and interpret conventional gravity and magnetic data, broker multi-client gravity and magnetic data and provide interpretation software.

W: www.arkex.com

Borehole Wireline

Borehole Wireline was established in 2005 with a burning ambition to provide the highest quality wireline services to the Australian mining industry. Since that time, Borehole Wireline has established an enviable track record in the provision of quality logging data in a safe and reliable manner.

W: www.borehole-wireline.com.au

Exhibition

CGG

CGG is a fully integrated Geoscience company providing leading geological, geophysical and reservoir capabilities to its broad base of customers primarily from the global oil and gas industry. Its Equipment, Acquisition and Geology, Geophysics & Reservoir (GGR) divisions bring value across all aspects of natural resource exploration and exploitation.

CoRMaGEo Instruments Pty Ltd

CoRaMaGeo Instruments is the newest name for geophysical equipment sales, rentals and repairs. CoRaMaGeo is agent for many geophysical products including AGI, Bartington, Radiation Solutions, Sensors & Software, Robertson Geologging, Geonics, and Geometrics. With an experienced base of personnel, we offer strong customer focus and leading-edge solutions backed by reliability and after-sales support.

Contact: John Peacock
A: 78 Wallis Avenue, Stathfield, NSW 2135, Australia
P: +61 (0)411 603 026
E: sales@cormageo.com.au
W: www.cormageo.com.au

CSIRO

CSIRO is a powerhouse of ideas, technologies and skills for building prosperity and sustainability for government and industry. CSIRO's geophysics capabilities are deployed in cutting-edge research for the minerals and energy resources sectors. Find out how partnering with CSIRO's geophysical expertise can give your company the competitive edge in innovation.

Curtin University

Curtin University is a major provider of geophysics and geology graduates to the petroleum, minerals, groundwater and environmental industries in Australia and overseas. With an impressive suite of facilities and expertise, research funding from government and industry, we undertake high impact fundamental and applied research across a range of geosciences.

Department of Mines and Petroleum

The Department of Mines and Petroleum (DMP) is Western Australia's lead agency in attracting private investment in resources exploration and development through the provision of geoscientific information on minerals and energy resources. DMP also regulates and provides approvals relating to mineral titles, collects royalties, and ensures that industry reaches the highest safety, health and environmental standards.

W: www.dmp.wa.gov.au

Department of State Development, Government of South Australia

As part of the South Australian Government, the Department of State Development (DSD) Mineral and Energy Resources Group facilitates mineral, petroleum and geothermal exploration and development within a sustainable framework by providing geoscientific information and data, industry regulation, and legislative and policy development.

W: http://www.dmitre.sa.gov.au/mineral_and_energy_resources

dGB Earth Sciences

dGB Earth Sciences is a software and services company. Software development is centered on OpendTect, the world's leading open source seismic interpretation system. dGB's unique workflows extract more geology from seismic data. Specialties include: Sequence Stratigraphic Interpretation; Attributes Analysis & Seismic Filtering; Quantitative Seismic Interpretation and Fluid Migration Path Interpretation.

W: www.dgbes.com and www.opendtect.com

Dias Geophysical

Dias Geophysical delivers ground geophysical solutions to geoscience challenges through the application of innovative ground geophysical technologies. Dias specializes in resistivity and induced polarization methods and has developed uniquely efficient and effective DCIP systems with integrated safety systems.

W: www.diasgeo.com

Dolphin Geophysical

Dolphin Geophysical is a global, full-range supplier of marine geophysical services. Dolphin operates a fleet of new generation, high capacity seismic vessels and offers contract seismic surveys, Multi-Client projects and processing services and software on a worldwide basis.

W: www.dolphingeo.com

DownUnder GeoSolutions

DownUnder GeoSolutions is an innovative, global geosciences company with a diverse range of capabilities and an integrated service offering that includes:

- Illumination studies
- Quantitative interpretation
- Seismic processing
- Depth conversion
- Depth imaging
- Multi-client studies
- Petrophysics
- DUG software

ElectroMagnetic Imaging Technology

EMIT, now in its 21st year, develops industry-leading instrumentation and software for electrical geophysics. SMARTem24 Receiver Systems – 16 × 24-bit channels, time-series recording and smart signal processing. Maxwell EM software – industry standard for EM applications. DigiAtlantis – borehole magnetometer system for TEM, MMR and Magnetics. SMARTx4 – safe and smart transmitter system.

W: www.electromag.com.au

European Association of Geoscientists

EAGE is a professional association for geoscientists and engineers. Founded in 1951, it is an organization with a worldwide membership (around 18 000 members), providing a

global network of commercial and academic professionals. The association is truly multi-disciplinary and international in form and pursuits.

FairfieldNodal

FairfieldNodal, the leader in seismic nodal technology, offers a full spectrum of revolutionary acquisition systems and technology services, including ZNodal™ systems, a family of true cable-free nodes for any terrain or marine depth. The company, known for its extensive spec-data library, also provides acquisition, imaging, processing and licensing services.

A: 1111 Gillingham Lane, Sugar Land, Texas 77478, USA
P: 281.275.7500
W: www.fairfieldnodal.com

ffA Geosciences

GeoTeric from ffA

GeoTeric is a Geological Expression software that directly translates geophysical data into geological information. Geological Expression is a data-driven, interpreter guided approach for understanding and defining the 3D morphology of the geological elements within the seismic data. GeoTeric gives you the power to advance your interpretation, increase your geological understanding and communicate your concepts.

W: www.geoteric.com

First Geo

First Geo started operations 20 years ago, and today comprises a dedicated team of about 85 geologists, geophysicists and petroleum engineers. The main fields of activities are: Geological and geophysical interpretation, petrophysics, reservoir modelling and simulation, production technology, operation and well site geology.

The main activity in Australia is delivery of the hiQbe™ velocity models to E&P companies and government institutions. The hiQbe™ velocity models is available for several regions on the Australian shelf. First Geo delivers services through the whole subsurface value chain.

W: www.first-geo.com

Gap Geophysics Australia Pty Limited

Gap Geophysics Australia is a progressive Technology Developer and Service Provider to the mineral exploration and environmental geophysics industries. Our main focus is to provide better quality data efficiently and more cost-effectively than with conventional technologies by offering a range of unique services based on proprietary instrumentation.

W: www.gapgeo.com

GBGMAPS

GBGMAPS is a specialist consultancy providing advanced subsurface and structural investigations throughout Australia and Abroad. Through a process of consultation and pre-project planning GBGMAPS can tailor a geophysical solution to provide enhanced subsurface or structural information adding value to geotechnical, engineering or remediation projects.

W: www.gbgmaps.com.au and www.gbgoz.com.au

Geoimage Pty Ltd

Geoimage are Australia's leading independent & multiple award winning specialists in Satellite Imagery and Geospatial Solutions. We have access to data from a wide range of suppliers for Australia and overseas. With decades of experience working within the mining, engineering & oil and gas industries, we are committed to providing solutions that deliver improved outcomes for our clients.

A: 13/180 Moggill Rd Taringa QLD 4068
P: +61 7 3871 0088
E: keiko@geoimage.com.au
W: www.geoimage.com.au

Geokinetics

Geokinetics is an international seismic contractor specialising in acquiring and processing seismic data.Our services include land, shallow water OBC, and TZ. We are experienced in working areas of diverse culture, extreme environmental sensitivity and geologic complexity. Geokinetics offers the most innovative, cost effective and efficient acquisition solutions.

W: www.geokinetics.com

Geological Survey of New South Wales

The Geological Survey of New South Wales is the state's premier geoscience agency, and is a branch of Resources & Energy Division, NSW Trade & Investment. It provides information to government, exploration and mining industries as well as the community about the state's geology, and mineral, coal and petroleum resources.

W: www.resourcesandenergy.nsw.gov.au

Geological Survey of Queensland

The Geological Survey of Queensland (GSQ) provides geoscience and resource information to improve the understanding of the geology and mineral and energy resource potential of Queensland. The GSQ undertakes regional geophysical programs and is the custodian of all geophysical data within the state. Data can freely be downloaded through the new QDEX Data system.

W: www.business.qld.gov.au/industry/mining/geoscience-data-information/gsq

Geophysical Resources and Services

GRS Pty Ltd (est. 2003) provides geophysical consulting services. Our MIMDAS system provides clients with the highest quality electrical geophysical data available today. MIMDAS is capable of acquiring IP, MT & CSEM data. True 3D data acquisition with real-time telluric cancellation. MIMDAS integrates proprietary hardware and custom built software provide a cost-effective field operation.

W: www.consultgrs.com.au

Exhibition

Geophysical Society of Mongolia

W: www.geosociety.mn/

Geoscience Australia

Geoscience Australia is the national custodian of Australia's geoscientific and geospatial information. The agency carries out applied geoscientific research and geospatial mapping programs and provides information to the Australian Government and industry to contribute to enhanced and sustainable economic, social and environmental benefits for all Australians.

W: www.ga.gov.au

GeoProxima

GeoProxima focuses on the application of a recent breakthrough in mathematic analysis to the processing of large datasets of geodata. Our technology is specifically designed for digital data analysis extracting information more precisely, revealing features and objects not accessible using traditional technologies. Moreover, our analysis technique can be fully automated.

W: www.geoproxima.com

Geosensor Pty Ltd – Advanced Logic Technology

ALT – Advanced Logic Technology is a leading developer and supplier of borehole logging equipment and software. The product line includes

- Slim hole geophysical logging systems
- Ultrasonic and optical imaging tools for cased and open hole applications (also high temperature)
- WellCAD – borehole data processing, core description and data presentation software

A: Zoning Artisanal de Solupla, Bât A, Route de Niederpallen, L-8506 Redange, Luxembourg
Contact: Annick Henriette – Bruno Legros – Timo Korth
P: +352 23 649 289
E: sales@alt.lu
W: www.alt.lu

Geosensor Pty Ltd - Scintrex

Scintrex develops, manufactures and sells field survey instruments for Gravity, Magnetics, Induced Polarization and Resistivity. We provide borehole gravity logging services with the GRAVILOG borehole gravimeter. Our sister company, Micro-g LaCoste designs and builds the FG5-X Absolute Gravimeter, TAGS-6 Airborne Gravimeter, MGS-6 Marine Gravimeter and the gPhone-X Monitoring Gravity Meter.

Geosoft

Geosoft software and services advance exploration of the earth's surface and subsurface. We provide solutions for exploration industries, government and the earth sciences, specialising in: earth mapping, earth modelling, GIS mapping, exploration information management and unexploded ordnance (UXO) detection.

W: www.geosoft.com

Geotech Airborne & UTS Geophysics

Combining experience, systems and services, Geotech Airborne and UTS Geophysics are world leaders in airborne geophysical surveying. Our unparalleled processing capabilities and fleet of survey aircraft have established our sound reputation within the industry. Our services include: Active & Passive Electromagnetic, Gravity, Magnetic & Radiometric surveying.

Geotech Airborne & UTS Geophysics – see the difference.

W: www.geotech.ca and www.uts.com.au

Geotrace Technologies

Geotrace is an independent, integrated, reservoir services company which provides subsurface imaging solutions and data integration services to the oil and gas industry. The company is client focused and seeks to assist the client to optimize operations through the application of leading edge technology and highly experienced personnel.

W: www.geotrace.com

Geovista Ltd

Geovista manufacture and supply a comprehensive range of dependable tools for borehole geophysics, imaging and borehole directional surveys. These cover most borehole data requirements for mineral exploration, exploitation, site investigation and groundwater. Products include loggers, winches, stackable logging sondes, televiewers, borehole cameras, downhole geophone, downhole P&S microseismic and gyro directional survey sondes

A: Unit 10 Cae Ffwt Business Park, Glan Conwy LL28 5SP, United Kingdom
P: +44 (0)1492 573399
F: +44 (0)1492 581177
E: geovista@geovista.co.uk

GPX Surveys

GPX Surveys is a global service provider specialising in the collection, processing and interpretation of airborne and ground geophysical data. GPX Surveys offers fixed-wing and helicopter airborne Magnetics, Radiometrics, Electromagnetics and Gravity surveys. For ground geophysics, GPX Surveys offers Induced Polarisation, Resistivity, surface and borehole Electromagnetics, Radiometrics, Magnetics and Gravity.

W: www.gpxsurveys.com.au

Hiseis

HiSeis's application of Seismic technology to the Minerals industry will add mine life to mature operations, make new discoveries at depth and under cover, and shorten the time line to discovery. 3D seismic technology is a game changer.

W: www.hiseis.com

Ikon Asia Pacific

Ikon Science builds solutions for the most challenging E&P problems worldwide, combining bold innovation with proven

cross-discipline collaborative workflows. With deep expertise in Rock Physics, Seismic Inversions, 4D, Geopressure and Geomechanics, we deliver reliable quantitative subsurface predictions of the key reservoir properties needed to plan safe, cost effective wells and design optimal development strategies.

W: www.ikonscience.com

Instrumentation GDD Inc.

Since 1976, GDD manufactures, sells, rents and develops innovative, leading edge rugged ground IP, TEM and EM geophysical instruments used in: mining exploration, oil & gaz, geothermal, water, etc. Check www.gdd.ca for the 32C IP Receiver, 10KW-4800V-10A IP Transmitter, TEM Receiver NordicEM24, etc. GDD sells worldwide and provides outstanding aftersales service.

Intrepid Geophysics

Intrepid Geophysics develops software and provides services for potential field geophysics. Intrepid Geophysics has a strong reputation in geophysical processing and interpretation, as well as in software development. Products and services provided by the team are distinguished from the competition through their innovativeness and ability to solve customer problems.

W: www.intrepid-geophysics.com

ION Geophysical

ION is a leading provider of technology-driven solutions to the global oil and gas industry. Our offerings are designed to help companies reduce risk and optimise assets throughout the E&P lifecycle. For more information visit iongeo.com.

W: www.iongeo.com

Iris Instruments

IRIS Instruments is designing, manufacturing and marketing geophysical equipment for DC Resistivity Sounding and Imaging (SYSCAL), Induced Polarization (VIP, ELREC), Magnetic Resonance (NUMIS) and Electromagnetic (PROMIS) methods.

The fields of application concern Mining Exploration, Groundwater surveys, Geotechnical studies and Environmental investigations.

Orleans, France
W: iris-instruments.com

ISeis & Seismic Source Co

Seismic Source Co and iSeis Co are sisters companies based in Oklahoma with worldwide sales and representation. SSC is the world's largest producer of source control systems which are used with every recording system in the market, both cabled and cableless. Its vibroseis control products have various advantages for 2/3D and even 4D land surveys, given the 'Enhanced Vibroseis' capability. Impulsive source control systems have other unique features. iSeis has developed the world's only cableless system with guaranteed real time QC transmission - Sigma. It is used in the world's toughest environments for both active and passive acquisition.

W: www.iseis.com

Leapfrog Software

Leapfrog® is a 3D geological modelling software suite for the mining, hydrogeology and geothermal energy industries. Leapfrog is setting the standard in geological modelling. It creates the time and opportunity to reduce geological risk for both the users and their organisations.

W: www.leapfrog3d.com

MAGSPEC Airborne Surveys Pty Ltd

MAGSPEC Airborne Surveys is an airborne geophysics company specialising in magnetic and radiometric survey. Our goal is to provide the best service in operations, aviation, acquisition and processing. With our combined knowledge, experience, expertise and skill we strive to deliver the best data in a timely and cost effective manner.

W: www.magspec.com.au

Mala GPR Australia

Mala GPR Australia is the exclusive distributor of MALÅ Geoscience Ground Penetrating Radar instruments and ABEM range of seismographs, time-domain EM and geo-electrical instruments. We specialise in enabling the industry to utilize the geophysical technologies on the highest possible level. Whether your organisation require rentals, outright purchase, staff training or instrument servicing, Mala GPR Australia can assist you.

W: www.malagpr.com.au

MiraGeoscience

We supply the mining industry with cost-effective, multi-disciplinary, 3D and 4D earth modelling and data management solutions for mineral exploration, resource evaluation, and geotechnical hazard assessment.

We tightly integrate the industry's best modelling technology with advanced data processing across a range of geoscience applications. We believe in a quantitative solution that focuses asset teams on a shared interpretation that delivers better, faster business decisions.

W: www.MiraGeoscience.com

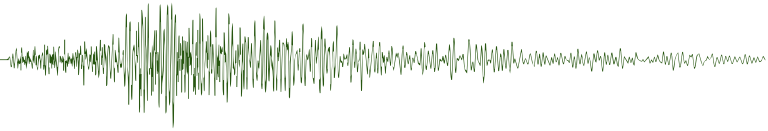
New Resolution Geophysics

New Resolution Geophysics (NRGTM) is an airborne geophysical company specialising in the collection of airborne magnetic, radiometric and gravity data. The company was formed in 2005 with the objective of providing a technically superior, efficient and professional service. Focusing on the African continent, the company has completed over 2 500 000 line km of survey in over 41 countries.

W: www.airbornegeophysics.com

Paradigm

Paradigm is the largest independent developer of software-enabled solutions to the global oil and gas industry. Paradigm easy-to-use technology and workflows provide customers with deeper insight into the subsurface by combining leading-edge



science, high-performance desktop and cluster computing, and scalable data management, delivering more accurate results and productivity without compromise.

W: www.pdgm.com

Petroleum Exploration Society of Australia

The Petroleum Exploration Society of Australia (PESA) is a non-profit association of individuals involved in the exploration of oil and gas with over 2000 members. Its purpose is to promote professional and technical aspects of the upstream petroleum industry, via:

- Monthly Technical Luncheons
- Networking Events
- Technical Evening Talks
- Continuing Education

W: www.pesa.com.au

Petrosys Pty Ltd

Petrosys is the industry leader in mapping, surface modelling and data management software solutions delivering direct connectivity with the most popular exploration, production and GIS data sources. Petrosys produces high quality maps and surface models. It manages, edits, and analyses the underlying information, including the specialised seismic, well and geoscience data used in the search for oil and gas.

W: www.petrosys.com.au/events/

PGS Australia Pty Ltd

Petroleum Geo-Services (PGS) is a leading, worldwide geophysical company providing an extensive range of seismic services and products for the petroleum industry including seismic data acquisition, processing, reservoir monitoring and analysis, interpretation and electromagnetic studies. The company also possesses the world's most extensive 3D MultiClient data library. With its headquarters in Oslo, Norway, the company has over 35 offices worldwide in 25 different countries with larger regional offices in London, Houston and Singapore. The company is listed on the Oslo stock exchange (OSE: PGS).

W: www.pgs.com

Phoenix Geophysics Ltd

Founded in 1975 in Toronto, Canada, Phoenix Geophysics is the world leader in onshore electromagnetic (EM) geophysical instrumentation and services. Phoenix has exported both natural-source (MT/AMT) and controlled-source (CSEM) equipment to over 80 countries including Australia.

The Phoenix booth will provide information on MT, AMT,CSAMT,TDEM, FDEM, TDIP and FDIP equipment and software.

W: www.phoenix-geophysics.com

Polarcus

Polarcus is a pure play marine geophysical company with a pioneering environmental agenda, specialising in high-end towed streamer data acquisition from Pole to Pole. Polarcus operates a fleet of high performance 3D seismic vessels incorporating an innovative design and advanced maritime technologies for improved safety and efficiency. Polarcus offers contract seismic surveys and multi-client projects worldwide and employs over 500 professionals. The company's principal office is in Dubai, United Arab Emirates.

W: www.polarcus.com

Quantec Geoscience Ltd

Quantec Geoscience specialises in advanced, data-intense, deep exploration geophysical solutions using resistivity, IP and MT technologies. Since 1986 we have successfully completed over 5,000 projects globally for the geothermal, mining and oil & gas industries. We provide full service from survey design, through acquisition, all the way to final interpretation.

W: www.quantecgeoscience.com

Radiation Solutions Inc.

Radiation Solutions manufactures low level radiation detection instruments for geophysical, environmental and industrial applications. The instrumentation is designed for precise measurement and suitable for rugged environments. Products consist of the RS-500 airborne system, RS-700 carborne system plus several handheld gamma ray scintillometers and spectrometers including the newest model the RS-330.

Robertson Geologging (Asia) Ltd

Robertson Geologging Ltd is the market leader in the design, manufacture and supply of slim-hole, digital wireline logging systems. Our tools provide lightweight, highly accurate and versatile solutions that can be used for water-well management, geotechnical and mining surveys, shallow oil/gas operations and unconventional resources.

Contact: Steve Parry
A: 24th Floor Conduit Tower, 20 Conduit Road,
Mid Levels Hong Kong
P: +852 650 33486
E: steveparry@geologging.asia
W: www.geologging.com
W: www.geologging.asia

RPS Australia Asia Pacific

RPS Energy provides independent consulting services to the oil and gas sector involving integrated technical, commercial, project management and training support in the fields of geosciences, engineering and HS&E. Our aim is to help energy sector clients develop their resources across the complete life-cycle, combining our technical and commercial skills with an extensive knowledge of environmental and safety issues.

P: +61 8 9211 1111
W: www.rpsgroup.com.au

S2V Consulting Pty Ltd

S2V Consulting provides technical and business consulting services to the oil and gas industry. Our offerings encompass

Environment, Technical Safety + Risk, Process + Facilities and Subsea + Pipelines. For our geophysical clients our Environment team offers comprehensive support from early stage approvals (Environment Plans, Oil Pollution Emergency Plans) and stakeholder management through to operational support and regulator liaison.

W: www.s2vconsulting.com

Sander Geophysics

Sander Geophysics Ltd (SGL) provides worldwide airborne geophysical surveys for petroleum and mineral exploration, and geological and environmental mapping. Founded in 1956, SGL's services include high resolution airborne gravity, magnetic, electromagnetic, and radiometric surveys, using fixed-wing aircraft and helicopters. Gravity surveys are offered with Sander Geophysics' industry leading AIRGrav system.

W: www.sgl.com

SBGf - Sociedade Brasileira de Geofísica

W: http://sys2.sbgf.org.br/portal/

SkyTEM

SkyTEM airborne electromagnetic systems do what no other single airborne geophysical system can do – map the near surface in high resolution whilst simultaneously acquiring accurate measurements to depths of 600 m or more. SkyTEM is globally accepted as the leading technology for high resolution airborne EM mapping programmes.

W: www.skytem.com

Society of Exploration Geophysics Japan

GJ consists of its members who have experiences in geophysical exploration and related fields, and members who support the activities of the Society. The President represents the Society.

The General Meeting of Members is the legislative body of the Society. SEGJ holds an Annual General Meeting every year, and the President summons a Special General Meeting, when necessary. The Representatives consists of 80–120 persons, who are elected by all Active Members. The Officers of the Society are 10–20 Directors and one or two Auditors, who are elected by votes of the Representatives on the General Meeting. The President and two Vice-Presidents are elected by mutual votes of the Directors. The Directors form the Board of Directors, and the Board executes the duties of the Society. The Auditors inspect the administrative and financial matters of the Society.

W: www.segj.org/index_e.html

Society of Exploration Geophysicists

The Society of Exploration Geophysicists is a not-for-profit organization whose mission is connecting, inspiring, and propelling the people and science of geophysics. The Society, has more than 33 000 members (and growing) in 138 countries. We fulfill our mission through our publications, conferences, forums, websites, and other educational opportunities.

W: www.seg.org/seg

South African Geophysical Association

SAGA was founded in 1977 to foster and encourage the development of Geophysics in South Africa and has since grown to over 350 members worldwide.

SAGA hosts regular monthly talks, produces a topical newsletter, presents shorts courses annually, and runs biennial technical meetings.

A: Suite #417, Private Bag X19, Gardenview South Africa 2047
P: +27 (083) 780 7209
F: +27 (086) 660 5640
E: admin@sagaonline.co.za
W: www.sagaonline.co.za

Surtech Systems Pty Ltd

Founded in 1997, Surtech Systems provides superior wireline & MWD services for Mining and Oil and Gas operators. With twenty three wireline logging trucks and six free standing units we can supply our customers data any time and place. Our services include Borehole Geometry, Nuclear, Resistivity, Acoustic and Imaging logs.

A: Surtech Systems Pty Ltd, 56B Paramount Drive, Wangara, WA 6065
P: +61 8 9302 6224
E: admin@surtech.com.au
W: www.surtech.com.au

Surtron Technologies

Surtron offers a comprehensive range of slim-hole wireline logging, down-hole surveying, data interpretation, and client training to the mining, petroleum, environmental, and civil engineering industries within Australia, South East Asia and West Africa. The company is the largest privately held logging company operating in Australia, and maintains a fleet of over thirty mobile logging units throughout the country.

W: www.surtron.com.au

Tensor Research Pty Ltd

Tensor Research in partnership with Pitney Bowes Software develops and maintains ModelVision and specialises in potential fields research covering forward and inverse modelling, processing, filtering, analysis and visualisation of magnetic and gravity data. They work with the latest generation of instruments including full tensor gravity and magnetic systems, cross-wing gradient, fluxgate and total magnetic field instruments. They also sell and specialise in QuickMag and Discover PA.

W: www.tensor-research.com.au

Terrex

The Terrex Group utilises the latest geophysical technology and draws on its personnel's extensive experience to provide high-quality land, transitional zone and shallow marine seismic acquisition services. Operating cabled and cable-less recording systems, we offer multiple source options including man and heli-portable dynamite, 15 000 lb EnviroVibes through to 62 000 lb AHV-IV vibrators for the deepest surveys.

W: www.terrexseismic.com

Exhibition

TGS

TGS provides multi-client geoscience data to oil and gas E&P companies worldwide. In addition to extensive global geophysical and geological data libraries that include multi-client seismic data and digital well logs, TGS also offers advanced processing and imaging services, interpretation products, permanent reservoir monitoring and data integration solutions.

W: www.tgs.com

Thomson Aviation

Thomson Aviation based in Griffith, Australia continued to consolidate its territory of operations in 2014. Regional offices in Perth, Pretoria and Jakarta assist Thomson to now routinely fly high resolution fixed-wing and heli-borne magnetics and radiometrics and gravity surveys around the world.

Thomson Aviation also increased the services it offers, to include helicopter-towed time-domain electromagnetic surveying using the latest SOURCE-TEM system through a partnership with Source Geophysics.

W: www.thomsonaviation.com.au

Total Depth

At Total Depth we approach technical challenges using hybrid workflows created from existing and newly developed technology. The aim is to use these workflows to develop data driven models and independently validate existing models help ing to address elements of non-uniqueness. Our services involve aspects of attribute processing, analysis, interpretation and integration with geological data.

W: www.totaldepth.com.au

UWA Geo Research Centres

Petroleum Geoscience encompasses a broad range of geological and geophysical research to develop advanced techniques for enhanced exploration and recovery of subsurface hydrocarbons, and long-term injection and storage of greenhouse gases in deep rock formations. Geoscientists face important challenges related to the needs of the world:

- How can we help supply world energy while preserving the environment?
- How can we find and produce hydrocarbon energy clearly and efficiently?
- How can we help reduce GHG emissions to mitigate global climate change?

Velseis

Velseis has built a reputation as a leading Australian seismic contractor with over 30 years experience throughout the Asia-Pacific region, servicing the Petroleum, Coal and Mineral Industries. Velseis has an unrivalled reputation in the acquisition of high resolution seismic data using Vibroseis, explosive, and Mini-SOSIE sources.

Velseis offers a fully integrated professional service incorporating design, drilling, acquisition, processing and the interpretation of 2D, 3D and multi-component seismic surveys.

W: www.velseis.com.au

Vista Clara

Vista Clara develops and manufactures advanced NMR instrumentation for groundwater, mining, environmental, and geotechnical applications. A cutting-edge product line of surface, downhole, and laboratory NMR tools are sold and rented internationally with committed customer support. Vista Clara also provides expert on-site training and field services at economical daily rates.

W: www.vista-clara.com

Vortex Geophysics

Vortex Geophysics provides contract electrical geophysical services specialising in high power electromagnetic surveys (DHEM, FLEM and MLEM), induced polarisation (IP) and magnetometric resistivity surveys (MMR) both on the surface and down hole. Vortex Geophysics sets a high standard in safety (AS4801), the environment and quality.

W: www.vortexgeophysics.com.au

Weatherford

Better mineral logging starts with better technology: To help maximise the value from limited exploration program budgets, Weatherford's Slimline has the products to ensure clients' minerals exploration programs can answer the needs of the investors, mine planners, geotechnical engineers, mining engineers, preparation plant designers and mine managers.

W: www.weatherford.com

WesternGeco

WesternGeco provides land and marine seismic acquisition technologies and techniques for unrivalled subsurface imaging in any environment. Our geophysical services and products enable accurate measurements for the most detailed insight into subsurface geology and rock properties, so you can be certain that you always have the information you need to make the best decisions. Your success. Our focus.

Schlumberger is the world's leading supplier of technology, integrated project management and information solutions to customers working in the oil and gas industry worldwide. With approximately 126 000 employees working in more than 85 countries, Schlumberger provides the industry's widest range of products and services from exploration through production.

W: www.slb.com

Wireline Services Group

Wireline Services Group (WSG) is a Western Australian Company that was establish in 2001 to provide high quality wireline and directional services. The company has grown to now have over 60 professionals working across a range on commodities and geographic locations. The central tenets of service, quality and efficiency has seen the group continue to expand into new markets.

WSG has five divisions, each providing local wireline solutions for our clients with global support from our facility in Perth, Western Australia. Our current divisions are:

- **Pilbara Wireline Services**: 17 units, operating in WA, NT and SA, focused on hard rock logging for the mining industry.
- **Coal Seam Wireline Services**: 7 units operating in Qld, NSW and Vic, focused on CSG and coal clients.
- **PanPacific Wireline Services**: 3 units operating in Canada and Chile, focused on base metals and geotechnical clients.
- **Drillhole Data Services**: provides data processing, QA and interpretation services.
- **Drillhole Navigation Systems**: provides high speed North Seeking Gyroscopic Surveying services.

Our Perth Head Office provides all "back office" services to our field operations, allowing our local companies to concentrate on customer service and delivering above expectations. Our Perth Head Office also houses our tool repair workshop, ensuring efficient turnaround of all equipment maintenance and repairs.

W: www.wirelineservices.com.au

Woodside Energy Ltd

Woodside is Australia's largest independent oil and gas company with world-class facilities and a history of achievement.

With the successful start-up of the Pluto LNG Plant in 2012, Woodside now operates six of the seven LNG processing trains in Australia.

We are now seeking to expand our exploration portfolio, both within Australia and globally, to generate future growth opportunities for the company.

W: www.woodside.com.au

Zonge Engineering

- Zonge is a geophysical specialist in the development and application of broadband electrical and electromagnetic methods
- Zonge survey professionals have the expertise and the experience needed to deliver safe surveys on time, on budget and with high production rates.
- Zonge commits to exceeding the safety requirements of clients.

Survey methods

High Powered IP/resistivity. High Powered EM. NanoTEM. Controlled and Natural source Magneto-Telluric techniques (CSAMT, AMT, MT). Down hole including EM, IP, NMR and MMR

W: www.zonge.com.au

ZZ Resistivity Imaging Pty Ltd

ZZ is a Australian-based geophysical instrument manufacturer. Our main products are the most advanced 61-channel resistivity/IP meter FlashRES-UNIVERSAL, 3,000W/1,200V booster transmitter and 2.5D inversion software. We also specialise in providing crosshole resistivity/IP survey for detecting ore-bodies that are missed by drilling and collecting deep geological structure information between boreholes.

P: +61 8 8261 0527
E: sales@zzgeo.com
W: www.zzgeo.com

10.1071/PVv2015n174p75

Geophysics and Geology together for Discovery

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SECTION 3 ABSTRACTS

Australian Society of Exploration Geophysicists

PESA Petroleum Exploration Society of Australia

WesternGeco

Platinum sponsor

Day 1: Monday 16 February 2015

1030–1210
Day 1 Session 1 Stream A

PETROLEUM – MARINE SEISMIC ACQUISITION

EVOLUTION OF MARINE ACQUISITION TECHNOLOGY AFTER WIDE AZIMUTH

Nick Moldoveanu[1]*
[1]Schlumberger

Seismic exploration in the deep-water Gulf of Mexico was based for many years on the 3D acquisition method and, as a result, significant oil discoveries were made and most of the plays were found below salt or in intra-salt-body basins. The quality of the seismic data acquired in deep-water subsalt environments was occasionally satisfactory for exploration purposes, but, in most cases, it was not good enough to support an accurate earth model for reservoir development. The main challenges for data interpretation are: incomplete reservoir illumination, poor signal-to-noise ratio of the subsalt events and poor seismic resolution. Developments in the last decade in marine seismic acquisition and data processing were driven to solve these challenges.

One reference point in the evolution of marine seismic technology in the last decade was the introduction of wide azimuth acquisition (WAZ). Introduced in 2006 by British Petroleum in the Gulf of Mexico, the method was quickly adopted by the industry as a seismic technology to explore the complex subsalt geologic structures where improved subsurface illumination and signal-to-noise ratio are required. The introduction of WAZ started a period of several innovations in the seismic industry: dual-sensor streamer acquisition, full-azimuth towed streamer acquisition, broadband seismic measurements on both the source and receiver sides, long-offset marine acquisition, simultaneous shooting, and multimeasurement streamers. Challenges in processing wide-azimuth data lead to new developments in velocity model building based on tomography and full-waveform inversion, 3D demultiple methods, 3D anisotropic imaging with reverse time migration, and other improvements in computational methods.

The presentation will review the latest innovations in marine seismic acquisitions with examples of applications, and will discuss the geophysical benefits and limitations, as well as specific survey design and processing aspects related to each method.

FAST CYCLE TIME BROADBAND SEISMIC FOR EXPLORATION

Peter Chia[1]*, *Adam Smith*[1] *and Cameron Dinning*[2]
[1]Shell Australia
[2]Shell Deep Water, Borneo

As commitment seismic for exploration permit WA-477P, Shell acquired a 3D broadband seismic survey utilising variable depth streamers and a multi-level airgun source. The application of this combined technology for the first time in Australian waters was intended to attenuate seismic ghosts inherent in conventional seismic surveys. The successful deployment of the method has brought new insights into the processing and interpretation of broadband seismic that raise challenges in providing the deliverables necessary for exploration turnaround cycle time. By tailoring the processing workflow, while investigating and testing new algorithms, products were available to meet exploration requirements to mature prospects for early decisions.

NEW INSIGHTS INTO THE NORTH TARANAKI BASIN FROM NEW ZEALAND'S FIRST BROADBAND 3D SURVEY

Marjosbet Uzcategui Salazar[1]*, *Malcolm Francis*[1] *and Tristan Allen*[1]
[1]Schlumberger

For decades, the Taranaki basin has been New Zealand's only producing basin whilst exploration for large new hydrocarbon discoveries has moved to more frontier basins. Statistically speaking, the Taranaki basin should still hold numerous large fields; however, the information currently available is not sufficient to solve the challenges in understanding the petroleum system. The North Taranaki basin has widespread 2D seismic coverage and numerous wells that have not encountered commercial accumulations. This is attributed to the structural complexity in the basin and the absence of necessary information to help understand the basin evolution. An oilfield services company identified the North Taranaki graben as one area that has huge potential yet to be understood. A modern broadband, long-offset 3D survey was modelled and expected to provide the necessary information to finally understand the petroleum system and provide evidence for material hydrocarbon accumulations. In this investigation we assess the hydrocarbon potential of the basin using the newly acquired data. Advanced acquisition techniques were implemented for increased coverage and bandwith, including continuous line acquisition, sliding-notch broadband acquisition and imaging techniques, and delta source, resulting in a full broadband acquisition. Raypath distortions and depth uncertainty are significantly reduced processing through vertical transverse isotropy (VTI) anisotropic Kirchhoff prestack depth migration with a geologically constrained velocity model. Resolution of the deepest sections in the central graben have identified structures never before seen, as well as fault definition critical to understand charge. Here, we demonstrate the potential of the basin that has been unlocked thanks to the technology advances in acquisition and processing. 3D seismic interpretation and amplitude-versus-offset (AVO) analysis support the renewed potential of the basin.

1030–1210
Day 1 Session 1 Stream B

PETROLEUM – 4D SEISMIC MONITORING 1

OVERBURDEN HETEROGENEITIES INFLUENCE ON TIME-LAPSE SEISMIC REPEATABILITY: A FINITE DIFFERENCE MODELLING STUDY

Lisa Gavin[1]* *and Gary Hampson*[1]
[1]Chevron ETC

One of the aims of time-lapse seismic feasibility studies is to determine whether a desired time-lapse signal is distinguishable from incoherent noise. Acquisition parameters play a key role in repeatability, with source-receiver positioning errors commonly being regarded as the most important issue. A normalised root-mean-square (N RMS) variogram analysis measures the effect of source-receiver geometry differences on observed non-repeatability of traces. The overall trend of the variogram is strongly controlled by the heterogeneous characteristics of the overburden. We investigate the influence of heterogeneity on seismic repeatability using a NRMS variogram on synthetic data. We generate synthetic seismic data (with no incoherent noise) from velocity models with a variety of overburden characteristics and run finite-difference simulations over them. Variograms are generated from the synthetic data and show similar trends to those observed in real seismic data. We demonstrate that the length of the coherent signal of a target reflector (derived from the variogram) is directly related to the size and position in depth of the heterogeneity.

4D SEISMIC OVER THE PYRENEES FIELDS

Guy Duncan[1]*, *Kon Kostas*[1], *Mauricio Florez*[1], *James Cai*[1], *Tom Perrett*[1], *James Stewart*[1] *and Stas Kuzmin*[1]
[1]BHP Billiton

In this paper we present a case study of 4D seismic acquired over the Pyrenees Fields, offshore Western Australia. The Pyrenees trend was discovered with the drilling of the West Muiron-5 discovery well in 1993 which found oil and gas within the Pyrenees member sandstones. Production at Pyrenees started in 2010.

Before the start of production, a dedicated 4D baseline survey was recorded over the fields in 2006. A detailed modelling study concluded that a 4D monitor survey would provide useful information for reservoir surveillance and infill drilling decisions. The monitor survey was acquired in 2013, and the overall quality of the 4D was excellent with high 4D signal strength and low 4D noise.

The 4D response at Pyrenees is broadly consistent with the modelling. The main response is softening of the reservoir caused by gas coming out of solution produced by a pressure drop within the reservoir. The 4D response to changes in oil saturation is small. Incorporating the 4D interpretation into field development is ongoing, and so far it has been useful for refining the stratigraphic model, determining fault seal integrity, and determining the sealing capacity of intra-field faults.

ESTIMATION OF RESERVOIR FLUID SATURATION FROM SEISMIC DATA: AMPLITUDE ANALYSIS AND IMPEDANCE INVERSION AS A FUNCTION OF NOISE

Rafael Souza[1]* *and David Lumley*[1]
[1]The University of Western Australia

Noise in seismic data can create significant challenges for the integration of 4D information into seismic history matching procedures. Impedances derived from a seismic inversion are usually compared to impedances provided by the coupling between a fluid flow and a petro-elastic model. The problem is that uncertainties associated with noise in seismic data are rarely carried though all the seismic inversion steps. And the noise in seismic data can alter the correlation between acoustic impedance and fluid saturation, resulting in erroneous estimates of reservoir properties.

We hypothesize that the amplitude domain could be a better option than the impedance domain for seismic history matching, considering seismic noise. To verify this hypothesis we analyse amplitude and impedance changes as a function of water saturation and seismic noise. We demonstrate that the noise in seismic data causes higher variations on seismic inversion results than on amplitudes. A cross-domain comparison suggests that these impedance variations can be as high as their values derived from the seismic baseline survey.

These results indicate that matching time-lapse seismic and fluid flow data in the amplitude domain may be more reliable than using the impedance domain – in the presence of strong seismic noise. Errors in seismic data, such as noise, need to be considered when undertaking seismic history matching, and proper uncertainty analysis is required for accurate reservoir predictions.

4D INVERSION OF BOREHOLE GRAVITY DATA FOR MONITORING FLUID FRONTS

Hyoungrea Rim[1]* *and Yaoguo Li*[2]
[1]KIGAM
[2]Colorado School of Mines

Monitoring fluid movement is an important component in enhanced oil recovery (EOR) and CO2 sequestration. The newly available slim-hole gravimeter operating at high temperature offers a new avenue for such monitoring efforts because of the direct sensitivity to the change in the density distribution. We present a time-lapse gravity inversion algorithm for recovering the front of injected fluid using borehole gravity measurements. We assume that the horizontal extent of the fluid can be represented by a polygon with known but variable thickness and density contrast due to fluid substitution. We represent the evolution of the front as a 4D function of the spatial position and time since the initiation of the injection. The inversion can be carried out either independently at discrete time points or as a single inversion simultaneously over all time points. We demonstrate that the latter approach is superior in that it is more stable and offers improved capability in detecting break-through events at later times. In this paper, we will describe the details of the two inversion approaches, including two different model objective functions in polar coordinates and the nonlinear solution strategies. We will illustrate the advantages and drawbacks of independent and simultaneous 4D inversions using numerical examples.

1030–1210
Day 1 Session 1 Stream C

PETROLEUM – SEISMIC SIGNAL PROCESSING

TRUE-AZIMUTH 3D INVERSE SCATTERING SERIES METHOD FOR INTERNAL MULTIPLE ATTENUATION

Min Wang[1]* *and Barry Hung*[1]
[1]CGG

Removal of internal multiples is a long-standing problem and is still very challenging for the industry. The inverse scattering series (ISS) method is one of the advanced approaches addressing this issue. It is a data-driven approach that can predict all internal multiples without any prior knowledge of subsurface information.

In this paper, we discuss the implementation of a true-azimuth 3D ISS method which takes into account the 3D nature of the earth. It is applicable to both wide-azimuth data (land or marine) and conventional marine streamer data. We apply the approach on a synthetic example as well as real data acquired from the Santos Basin, offshore Brazil. The results show that the 3D approach predicts the multiples well because it takes into account the out-of-plane contributions of the internal multiples. As a result, all the internal multiples are strongly attenuated from the data while primaries are well preserved.

ADAPTIVE PRIMARY-MULTIPLE SEPARATION USING 3D CURVELET TRANSFORM

Xiang Wu[1]* *and Barry Hung*[1]
[1]CGG

In this paper, we propose a method to enhance the separation of primaries and multiples by utilizing the ultra-sparseness property of the 3D curvelet transform. By extending our earlier work on the 2D method, our current 3D primary-multiple separation method takes into account the coherence between neighbouring gathers, and extends the Bayesian Probability Maximization (BPM) based separation mechanism into the 3D curvelet domain. The primaries and multiples are differentiated by utilizing the traces of neighbouring gathers in an additional dimension; this further promotes their separation compared to the 2D curvelet domain method. Moreover, this 3D curvelet domain separation method produces robust results regardless of the ordering of data as long as they are organized in a volumetric manner. Additionally, we have also introduced a 3D spatiotemporal constraint for handling the deviation from linearity or planarity of the seismic events. We demonstrate the improvement of the 3D curvelet domain primary-multiple separation method on synthetic and field data examples, by comparing the results with those produced by existing separation methods.

IMPROVING IMAGING THROUGH SPECULAR AMPLITUDE ENHANCEMENT IN THE LOCAL ANGLE DOMAIN

Karl Hosgood[1]*, *Masako Robb*[1], *Zvi Koren*[1] *and Duane Dopkin*[1]
[1]Paradigm Geophysical

We present a method to improve imaging in the local angle domain (LAD) decomposition and imaging system. This system uses the entire recorded data to generate true-amplitude, angle-dependent or angle and azimuth dependent imaging gathers (Koren and Ravve 2011). These gathers have the ability to distinguish the wavefields by their directional components: Specular (continuous structural surfaces) and diffraction (discontinuous objects such as small-scale fractures and faults). The high-energy values associated with the specular directions can be used to enhance the continuous objects to obtain a diffraction-free, sharpened image of highly complex areas. We propose that the specular enhancement in the LAD system be used to re-evaluate existing land and marine (including narrow-azimuth legacy) seismic data to obtain more detailed high-resolution images without the need to acquire additional 3D data about existing assets.

INTERFEROMETRIC OBC SURFACE RELATED MULTIPLE ATTENUATION

Kunlun Yang[1]*, *Lubo Liu*[1], *Barry Hung*[1] *and Joe Zhou*[1]
[1]CGG Singapore

Surface-related multiples in Ocean Bottom Cable (OBC) data cannot be removed by directly applying standard SRME, which requires sources and receivers that are surface consistent. The ray paths needed for a complete surface-multiple prediction can be achieved by combining streamer and OBC data. The combination allows fully data driven SRME to be extended to OBC data. However, streamer data is not always available.

In this paper, we demonstrate that the required data to predict surface-related multiples in OBC data can be constructed using inter-source and inter-receiver interferometry, and the multiples can then be predicted similarly as in SRME. The work flow does not require knowing any subsurface information.

1030–1210
Day 1 Session 1 Stream D

MINERALS – EXPLORATION CASE STUDIES 1

+40 YEARS OF GEOPHYSICS IN PILBARA AND BEYOND

Asmita Mahanta[1]*
[1]BHP Billiton

The Pilbara region of North West Australia is one of the world's major iron ore provinces. Geophysical techniques have been applied routinely for exploration of iron ore. The first known application of a geophysical technique in mineral exploration was, in fact, the use of a magnetic method in the search for iron.

This presentation summarises the use of geophysical techniques in iron ore exploration over the last half century. Magnetic methods have been the most favoured, followed by gravity. EM has been applied in niche areas, such as in the exploration for CID. However it is time to venture beyond conventional techniques and start focusing on future developments in geophysics that promise yet greater benefits to mining generally and iron ore exploration in particular.

GEOPHYSICAL RESPONSES OVER THE CANNINGTON AG-ZN-PB DEPOSIT-QUEENSLAND

Ken Witherly[1]* *and I Graeme Mackee*[2]
[1]Condor Consulting
[2]Geo Discovery Group

The Cannington Deposit is high grade Ag-Zn-Pb deposit found in 1990 by BHP Minerals drilling in isolated 1000 nT aeromagnetic feature. Following the discovery of Cannington, numerous airborne, ground and borehole surveys have been carried out which overall, provided some assistance at better defining the ore system but did not lead to the discovery of new major deposit in the area.

While Cannington possessed a clear magnetic response, the presence of a thick conductive cover made the use of EM and electrical techniques challenging. BHP used Cannington as a test ground for a variety of new techniques including a ground SQUID EM sensor, modified airborne EM technology (higher power and lower base frequency) and over 10 years after discovery, the first ever Falcon airborne gravity gradiometer survey in Australia.

THE CAMELWOOD AND MUSKET NICKEL DEPOSITS – DISCOVERY OF A NEW NICKEL SULPHIDE CAMP IN THE NORTH-EASTERN GOLDFIELDS OF WESTERN AUSTRALIA

Antonio Huizi[1]*, *Ian Mulholland*[2] *and William Belbin*[2]
[1]Southern Geoscince Consultants
[2]Rox Resources

The Camelwood and Musket nickel sulphide deposits are significant recent discoveries, located within the Mt Fisher Greenstone Belt, in the northern goldfields region of Western Australia. Camelwood was the first deposit to be discovered, in December 2012, from a reverse circulation (RC) drilling campaign designed to test a coincident airborne electromagnetic (AEM) and geochemical anomaly.

The original objective of the AEM surveys was to detect massive sulphides known to be associated with gold mineralization at the old Mt Fisher gold mine. However, a number of discrete, late-time EM anomalies were identified along an interpreted ultramafic sequence on the eastern boundary of the greenstone belt. The EM anomalies represented classic nickel sulphide mineralisation targets.

Ground time-domain electromagnetic (TEM) surveys, down-hole TEM (DHTEM) surveys, and extensive drilling have been carried out since then, resulting in a JORC compliant resource at Camelwood (1.6Mt @ 2.2% Ni) and the discovery of the Musket deposit.

The application of the AEM method was instrumental in the discovery of the Camelwood nickel deposit. Systematic use of ground and down hole geophysical methods has been valuable in delineating the resource at Camelwood and in the discovery of the Musket deposit. The discovery of Camelwood and Musket proves the potential of the Mt Fisher Greenstone belt to host significant nickel sulphide mineralisation.

1030–1210
Day 1 Session 1 Stream E

MINERALS – GRAVITY AND MAGNETICS 1

MAGNETIC MAPPING OF RIVER CHANNEL AND PALAEOCHANNEL DEPOSITS – AN EXAMPLE FROM TEETULPA, SOUTH AUSTRALIA

Clive Foss[1]*, *Gary Reed*[2], *Tim Keeping*[2] *and Marc Davies*[2]
[1]CSIRO
[2]Geological Survey of South Australia

High-resolution, low-level aeromagnetic surveys of the Teetulpa gold field in the Nackara Arc, South Australia, map the distribution of magnetic minerals in the alluvial cover, in the form of linear anomalies with a dendritic pattern typical of drainage systems. These anomalies are not evident in the regional aeromagnetic data flown at wider line spacing and higher elevation. Combination of the high resolution magnetic field data with mapping of present day drainage is an important input to gold exploration of the area. The magnetic anomalies can be modelled and inverted, and this might provide quantitative information to indirectly target and evaluate gold resources. Sampling and statistical analysis of relationships between the gold and magnetic minerals within the alluvium are required to form the basis for any such study.

AUTOMATED ESTIMATION OF UNCERTAINTIES IN A 3D GEOLOGICAL MODEL OF THE SANDSTONE GREENSTONE BELT, YILGARN CRATON, WESTERN AUSTRALIA

Ruth Murdie[1]*, *Florian Wellman*[2] *and Klaus Gessner*[1]
[1]Geological Survey of Western Australia
[2]University of Aachen

Geological models that represent the structure of the subsurface, are becoming a regular product of geological surveys. It is widely accepted that the sparse data at depth and the ambiguity of structural interpretations of geophysical data lead to inherent model uncertainties . The analysis and visualisation of model uncertainties is therefore the scope of current research.

We here apply a recently developed method to estimate uncertainties to a 3D model of the Sandstone Greenstone Belt in the Archean Yilgarn Craton in Western Australia. On the basis of errors in geological parameters, a suite of probable models is generated and analysed. Our results show that visualisations of unit probability and information entropy provide suitable methods analyse uncertainties in this geological model.

3D JOINT GRAVITY AND MAGNETIC INVERSION AT REGIONAL SCALE – WHAT CAN IT TELL US ABOUT GEOLOGY?

Alan Aitken[1]*, *Mark Lindsay*[1], *Lutz Gross*[2] *and Cihan Altinay*[2]
[1]University of Western Australia
[2]University of Queensland

No abstract available.

PALEO-DRAINAGE AND STRUCTURAL DEFORMATION DURING GONDWANA BREAKUP: INSIGHTS FROM THE 3D GEOMETRY OF THE BUNBURY BASALT

Hugo Olierook[1], Nicholas Timms[1], Renaud Merle[1] and Fred Jourdan[1]*
[1]Curtin University

The Cambrian Miga Arc developed above a continent-dipping subduction zone active along the east Gondwanaland margin. At the end of the Cambrian, the arc-complex was accreted to the margin in an Andean-like convergent scenario – important for understanding base metals prospectivity in western Victoria. Understanding the Miga Arc is challenging. The geology is complex, the arc fragmented and poorly exposed – mostly buried by Grampians Group, the Murray Basin, or young lava flows. An exposed arc fragment at Mt Stavely has a characteristic magnetic character, can be interpreted beneath younger cover rocks and, in combination with other geological constraints, can be used to infer several additional arc fragments in far western Victoria. Explaining the complex present-day arc fragment configuration has required advanced understanding of Tasmanides tectonics. A key breakthrough is the realisation that a template for Siluro-Devonian deformation developed for the adjacent Lachlan Fold Belt can also be applied to retro-deform Miga Arc aeromagnetic data. Once restored, a pre-Silurian Miga Arc configuration comprises two sub-parallel fault slices, each quite continuous along-strike – a greatly simplified template for mineral exploration and target selection, and a start-point for understanding the Cambrian deformation that originally accreted the Miga Arc and the metallic mineralisation developed within it.

1030–1210
Day 1 Session 1 Stream F

NEAR-SURFACE – GROUNDWATER GEOPHYSICS 1

COMPILATION OF A RESISTIVITY ATLAS OF DANISH LITHOLOGIES BASED ON DIRECT RESISTIVITY MEASUREMENTS AND WIRELINE LOGGING DATA

Ingelise Møller[1] Flemming Jorgensen[1], Verner H. Sondergaard[1], Claus Ditlefsen[1] and Anders V. Christiansen[2]*
[1]*Geological Survey of Denmark*
[2]*Aarhus University*

Electrical conductivity, or its inverse, the resistivity, is an important geophysical property within groundwater mapping. It is known to correlate empirically to lithology, primarily through clay minerals and pore water ions. Although, in Denmark, geoelectric and electromagnetic surveys have been carried out for decades, no systematic, nationwide study on the relationship between resistivity and lithology has been carried out.

We present a procedure for generating a resistivity atlas based on resistivity measurements, which can be related directly to specific and well described soil samples. Data are obtained from archives, literature and the Danish national databases. The procedure implies a restricted use of wireline logging data in combination with direct measurements on samples, resulting in resistivity distributions for specific lithologies or geological formations. The use of documented high-quality data ensures reliable results, reflecting actual resistivity of a specific lithology.

This procedure is illustrated on clay till. The resistivity variations obtained for this lithology seems to be related to real compositional variations, which reflect the process of forming the clay till.

Our procedure is likely to provide equally reliable results for other main lithologies. Future detailed studies, in particular on sediments with low clay content, should consider resistivity differences related to the degree of saturation and variations in the formation water resistivity.

OPTIMIZING AIRBORNE ELECTROMAGNETIC (AEM) INVERSIONS FOR HYDROGEOLOGICAL INVESTIGATIONS USING A TRANSDISCIPLINARY APPROACH

Ken Lawrie[1], Niels B. Christensen[2], Ross S. Brodie[1], Jared Abraham[3], Larysa Halas[1], Kokpiang Tan[1], Ross C. Brodie[1] and John Magee[1]*
[1]Geoscience Australia
[2]Aarhus University
[3]XRI International

High-resolution hydrogeophysical data are increasingly acquired as part of investigations to underpin groundwater mapping. However, optimization of AEM data requires careful consideration of AEM system suitability, calibration, validation and inversion methods.

In modern laterally-correlated inversions of AEM data, the usefulness of the resulting inversion models depends critically on an optimal choice of the vertical and horizontal regularization of the inversion. Set the constraints too tight, and the resulting models will become overly smooth and potential resolution is lost. Set the constraints too loose, and spurious model details will appear that have no bearing on the hydrogeology. There are several approaches to an automatic choice of the regularization level in AEM inversion based predominantly on obtaining a certain pre-defined data misfit with the smoothest possible model.

However, we advocate a pragmatic approach to optimizing the constraints by an iterative procedure involving all available geological, hydrogeological, geochemical, hydraulic and morphological data and understanding. In this approach, in a process of both confirming and negating established interpretations and underlying assumptions, the inversion results are judged by their ability to support a coherent conceptual model based on all available information. This approach has been essential to the identification and assessment of MAR and groundwater extraction options in the Broken Hill Managed Aquifer Recharge project.

ADVANCING GEOPHYSICAL METHODS FOR GROUNDWATER EVALUATION AND MANAGEMENT

Rosemary Knight[1]*
[1]Stanford University

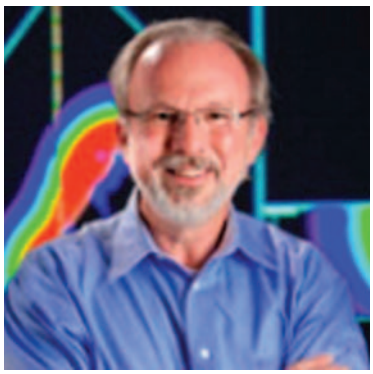
There is increasing use, throughout the world, of groundwater as the primary source of freshwater. The evaluation and management of this resource requires information about the extent and connectivity of groundwater aquifers, the contained volume of producible water, the changes in stored water, and the processes that can impact the quantity and/or quality of the water. Such information is required at a density of spatial and temporal sampling best provided by various forms of geophysical data. For the past decade, we have been working in partnerships with groundwater districts and managers to advance the use of geophysical methods as a central component of groundwater evaluation and management. Examples include the use of surface and logging nuclear magnetic resonance to estimate water content and hydraulic conductivity, electrical resistivity tomography for imaging saltwater intrusion along the California coast, and satellite InSAR data for estimating changing hydraulic head levels in confined aquifers in the San Luis Valley, Colorado. Such examples illustrate the tremendous potential for – and need for – geophysical methods to ensure the long-term health of our groundwater resources.

1330–1510
Day 1 Session 2 Stream A

PETROLEUM – PASSIVE SEISMIC

MICROSEISMIC FRAC MONITORING: YESTERDAY, TODAY AND TOMORROW

Peter Duncan[1]*
[1]MicroSeismic



Horizontal drilling and hydraulic fracturing have fathered a rebirth in the North American oil and gas business. Microseismic monitoring of the frac's has led to a new and more complete understanding of what really happens during pumping, leading to better frac design. This talk will focus on the technology of frac monitoring, past, present and future, and what it means to the industry. Case histories will be used to illustrate the state of the art in data analysis and interpretation.

VELOCITY MODEL ESTIMATION BY FULL WAVEFORM INVERSION OF TIME-LAPSE 4D PASSIVE SEISMIC ARRAY DATA

Rie Kamei[1]* *and David Lumley*[1]
[1]University of Western

In passive-source monitoring, an accurate velocity model is important to precisely estimate microseismic source locations, and to understand changes in reservoir properties. In this study, we employ frequency-domain full waveform inversion in order to obtain a high-resolution velocity model by exploiting full wavefields. We demonstrate the feasibility of the method for a surface geophone array by inverting for time-lapse 4D velocity changes in a realistic subsurface model. Our method successfully estimates the small velocity changes of a few percent within layers of 10s of meters, even for a single passive seismic source event. The analysis of wavepaths and gradients suggests that keys for the successful inversion are the use of full wavefields (both first and scattered arrivals), the vicinity of velocity changes to the source, and the wide-aperture surface array.

PASSIVE SEISMIC IMAGING AT DEPTH USING AMBIENT NOISE FIELDS RECORDED IN A SHALLOW BURIED SENSOR ARRAY

Nader Issa[1]* *and David Lumley*[1]
[1]University of Western Australia

A small scale field trial of a buried receiver array is used to generate passive recordings during a period of minimal human activity at the site of the array. We carefully analyse the data to reveal a number of valuable insights. In particular, we find that shallow burial of the geophones improves noise levels significantly and in a strongly frequency dependent manner. By isolating ambient seismic noise, which is a significant noise contribution in the frequency range from 3Hz to 30Hz, we show it is possible to utilize this seismic energy for the purpose of deep imaging. We successfully use advanced techniques of seismic interferometry to produce images to reservoir depth (~2km) and below, which show very good agreement with 3D seismic images taken on site.

1330–1510
Day 1 Session 2 Stream B

PETROLEUM – 4D SEISMIC MONITORING 2

STOCHASTIC TIME-LAPSE INVERSION OF A CO2 SEQUESTRATION SYNTHETIC SEISMIC DATA

Mateus Meira[1]* *Boris Gurevich*[1,2], *James Gunning*[2] and *Roman Pevzner*[1,3]
[1]Petrobras/Curtin University
[2]CSIRO
[3]CO2CRC

The objective of this work is to assess the effect of noise and parameterisation on the performance of the stochastic time lapse inversion. To do so, a noise-free synthetic dataset created for a feasibility study of an actual CO2 sequestration project (CO2CRC Otway Project) was inverted and used as a baseline. Noise (random and coherent) was added to the seismic data, input parameters changed and the results were compared with the baseline case.

The findings for wrong parameterisation cases were very encouraging and consistent with the theory.

When random noise was added to the input seismic data the algorithm was able to recover the true model within an acceptable margin of error. However, addition of coherent noise affected the inversion result significantly. Only when the root-mean-square (RMS) amplitude level was comparable to the one in the difference volume the algorithm was able to actually differentiate the noise from the signal.

These findings support the idea of a careful processing to avoid coherent noise and a judicious interpretation when it is unavoidable. Finally a new indicator was developed to calculate the improvement in detectability after the input of new data using the stochastic time lapse inversion.

INTEGRATING 3D SEISMIC AND HYDRAULIC UNITS TO IMPROVE RESERVOIR PROPERTY MODELS

Mohammad Emami Niri[1]* *and David Lumley*[1]
[1]University of Western Australia

We present a new method for reservoir property modeling based on integration of 3D seismic data and hydraulic flow units, and apply it to an example of a producing reservoir offshore Western Australia. Our method combines hydraulic unit analysis with a set of techniques for seismic reservoir characterization including: rock physics analysis, Bayesian inference, pre-stack seismic inversion and geostatistical simulation of reservoir properties.

Hydraulic units characterize regions and properties of fluid flow in porous permeable media, and are defined at well locations. However, usually the number of wells and their lateral coverage is extremely limited. In contrast, the lateral resolution of 3D seismic data is excellent, and this can be used to extend hydraulic unit analysis away from well locations into the 3D reservoir volume. We develop a probabilistic relationship between each of the hydraulic units defined at well locations, and the 3D seismic information. Reservoir models jointly constrained by 3D seismic and hydraulic unit analysis can therefore be useful to improve the production history matching process.

USING TIME-LAPSE VSP DATA TO CONSTRAIN VELOCITY-SATURATION RELATIONS

Boris Gurevich[1,3]*, *Mohammed Al Hosni*[1], *Roman Pevzner*[1], *Thomas Daley*[2] and *Eva Caspari*[1]
[1]Curtin University
[2]LBNL
[3]CSIRO

Quantitative interpretation of time-lapse seismic data is an ongoing challenge. Understanding the velocity-saturation relations and changes caused by CO_2 injection play an important role for the application of seismic monitoring techniques to carbon dioxide storage projects.

High uncertainties associated with well log measurements affected by borehole conditions can affect our ability to constrain a rock physics model. Seismic measurements, such as Vertical Seismic Profile (VSP), that span both the near-well region and far beyond the borehole can provide good control for correcting these measurements and reducing the uncertainties thereafter.

In this paper, we analyse the observed time delays in time-lapse VSP data from the Frio CO_2 injection test site by employing an integrated approach of rock physics and seismic forward modelling to reduce uncertainties in the choice of the dry frame modulus and velocity-saturation relations. First, we confirmed the quality of pre-injection well logs velocities with VSP data. Afterwards, we use inverse Gassmann relations to calculate the dry frame properties of the reservoir with different input parameters for the grain moduli with fluid substitution applied for uniform saturation of brine and CO_2. Finally, forward modelling of the results is implemented to compare the response with field VSP data.

Our investigation shows that VSP data can help constrain the choice of dry frame modulus, and thus the velocity-saturation relation. The rock physics model best matches the VSP results using large grain moduli and uniform saturation for fluid substitution.

MULTI-OBJECTIVE OPTIMIZATION FOR RESERVOIR MODELLING AND SEISMIC DATA MATCHING: PROOF OF CONCEPT AND FIELD APPLICATION

Mohammad Emami Niri[1]* *and David Lumley*[1]
[1]University of Western Australia

We present a new method to generate reservoir models by combining geostatistical simulation and optimization of multiple objective functions; including seismic data matching (i.e. a reservoir model seismic matching loop). Our method is used to estimate static reservoir models by simultaneously integrating several datasets including well logs, geologic information and various seismic attributes. The key advantage of our proposed method is that we can define multiple objective functions for a variety of data types and constraints, and simultaneously minimize the data misfits. Using our optimization method, the resulting models converge towards Pareto fronts, which represent the sets of best compromise model solutions for the defined objectives. We test our new approach on a 3D object-oriented reservoir model, where variogram-based simulation techniques typically fail to produce realistic models. Our results indicate that improved reservoir facies and porosity models and flow-unit connectivity can be obtained with this new multi-objective optimization approach.

1330–1510
Day 1 Session 2 Stream C

PETROLEUM – POTENTIAL FIELDS + SEISMIC

ESTIMATION OF A PETROPHYSICAL MODEL VIA JOINT INVERSION OF SEISMIC AND EM DATASETS

Fabio Miotti[1], *Ivan Guerra*[1], *Federico Ceci*[1], *Andrea Lovatini*[1], *Mehdi Paydayesh*[1], *Graham Milne*[1], *Margaret Leathard*[1], *Ajai Sharma*[1] *and Garrett Kramer*[1]*
[1]Schlumberger

Reservoir characterization objectives are to estimate the petrophysical properties of the prospective hydrocarbon traps and to reduce the uncertainty of the interpretation. In this framework, we present a workflow for petrophysical joint inversion of seismic and EM attributes to estimate the petrophysical model in terms of porosity and water saturation. This study realizes the joint inversion within the probabilistic structure provided by the Bayesian theory. The algorithm is applied to a real hydrocarbon exploration scenario to evaluate its contribution to the interpretation phase. 3D volumes of estimated porosity and saturation, show how the joint inversion of acoustic impedance and electrical resistivity can provide a quantitative description of the reservoir properties and with it a measure of uncertainty, which is consistent with the petrophysical model and observations.

AIRBORNE GRAVITY GRADIOMETER SURVEYING OF PETROLEUM SYSTEMS UNDER LAKE TANGANYIKA, TANZANIA

Douglas Roberts[1]*, *Priyanka R. Chowdhury*[2], *Sharon J. Lowe*[2] *and Asbjorn Norlund Christensen*[2]
[1]Beach Energy
[2]CGG

Beach Energy has been the sole interest holder and operator of the 7200 km^2 Lake Tanganyika South block since 2010. The block is located within the western arm of the East African Rift System. The prospectivity of the lake sequence was enhanced by large oil discoveries in the similar geological environment of Lake Albert in Uganda and in the eastern part of the rift in Kenya. The lack of wells drilled in the lake to date make predicting sedimentary sections difficult. In 2010 Beach Energy commissioned CGG to fly a FALCON® Airborne Gravity Gradiometer (AGG) and a high-resolution airborne magnetic (HRAM) survey over the Lake Tanganyika South block in order to map the basin structural framework and the depth to magnetic basement. The AGG survey facilitated the imaging of the architecture of the rift zone and the interpreted sediment thickness provided an indication of prospective petroleum target areas. This information was used to plan a subsequent 2D marine seismic survey, which was shot in 2012. The preliminary results from the 2D marine seismic survey has confirmed a rifting structure similar to that encountered further north at Lake Albert in Uganda. A number of targets over tilted fault blocks, low-side rollovers and mounded features, have been identified for follow-up from the seismic sections. Natural oil seeps evident on the surface of Lake Tanganyika, which have been sampled and analyzed by Beach Energy, also indicate that a working petroleum system is present in the sedimentary section of the rift beneath the lake.

NEW GEOLOGICAL INSIGHTS FROM THE BARBWIRE TERRACE USING FALCON DATA, CANNING BASIN

Tony Rudge[1]*, *Jurriaan Feijth*[2], *James Dirstein*[3] *and Stano Hroncek*[4]
[1]Buru Energy
[2]CGG Airborne
[3]Total Depth
[4]Geoproxima

The Barbwire Terrace in the Canning Basin has always presented explorers with an enigma. It has long held interest for hydrocarbon explorers and also mineral explorers looking for 'Mississippi Valley Type' sulphide mineralisation, being on the opposite side of the Fitzroy Trough to the Lennard Shelf (host to multiple oil fields and MVT's in the Cadjebut/Kapok area) (Copp, 2008).

Seismic interpretation on the Barbwire Terrace has been difficult, not only due to the paucity of modern reflection seismic data, but also due to the difficulty in imaging through the carbonate/dolomites of the Pillara and Nullara sections.

The Airborne Gravity Gradiometry (AGG) survey was designed to capture a large comprehensive grid of geophysical information about the southern margin of the Fitzroy Trough. The survey is instrumental in providing a greater understanding of an area of the Canning Basin that is poorly understood, yet has had many hydrocarbon shows and indications.

While CGG undertook a more traditional workflow of interpreting the AGG, aeromagnetics and seismic data, a parallel approach, using Geoproxima processing technology (differential geometric analysis for digital data) provided additional insights on features and objects not readily recognisable using traditional colour bar stretches and sun illumination.

INTEGRATED INTERPRETATION AND SIMULTANEOUS JOINT INVERSION OF 3D MARINE CSEM AND SEISMIC DATASETS

Federico Ceci[1]*, *Massimo Clementi*[1], *Ivan Guerra*[1], *Marco Mantovani*[1], *Andrea Lovatini*[1] *and Garrett Kramer*[1]*
[1]Schlumberger

One of the most complex seismic challenges is the imaging of thick salt bodies, the detection of their base and flanks, and imaging underlying units. To achieve good seismic imaging, the complementary use of non-seismic methods is one of the recommended solutions. Electromagnetic (EM) methods, such as magnetotellurics (MT) and controlled source electromagnetics (CSEM) are sensitive to the presence of salt bodies thanks to the high resistivity contrast with respect to sedimentary units. We present an integrated workflow applied to re-image wide azimuth (WAZ) seismic data acquired by Schlumberger using EM data acquired by EMGS over 35 blocks in the Keathley Canyon, in the Gulf of Mexico to reduce risk in exploration decisions and improve seismic deliverables. Seismic and EM data are utilized first in a cooperative workflow through localized seismic imaging reverse time migration (LSI RTM) to validate new salt structures highlighted by the single domain 3D anisotropic CSEM and MT inversions. They are then fed into a simultaneous joint inversion (SJI) to update a multi-property earth model (velocity and resistivity) by jointly minimizing the CSEM data misfit, the seismic residual move-outs and a relationship between the two properties.

1330–1510
Day 1 Session 2 Stream D

MINERALS – EXPLORATION CASE STUDIES 2

GEOPHYSICAL RESPONSE OF THE TROPICANA GOLD DEPOSIT

Keith Martin[1]*
[1]AngloGold Ashanti Limited

The Tropicana Gold Mine is located 330 km east-northeast of Kalgoorlie, Western Australia. Discovered in August 2005 the deposit is the first world-class gold resource discovered in high-metamorphic grade gneissic rocks, in an Archean terrane not previously thought to be prospective for gold.

The contrast in petrophysical properties of host rocks observed across the Tropicana gold mine enable geophysical methods to assist in mapping the deposit. Geophysical methods applied at Tropicana include; regional aeromagnetics and gravity, high-resolution airborne magnetics, gradient array Induced Polarisation (IP), pole-dipole IP, detailed gravity, MIMDAS IP, 2D seismic reflection, 3D seismic reflection, helicopter TEM, and SPECTREM.

Initial gradient array IP combined with geochemical analysis of aircore drilling samples provided the most cost effective method to direct early diamond and RC drill testing of auger and soil anomalies. Integration of all available data within a 3D Common Earth Model (CEM) facilitates lithology constrained 3D potential field and 3D IP inversions. When combined with the lithological packages, structural architecture, alteration assemblages and zonation, and geochemical signatures the 3D CEM provides a powerful means of delineating ore positions and exploration targets.

GEOPHYSICAL RESPONSE OF THE ATLÁNTIDA CU-AU PORPHYRY DEPOSIT, CHILE – AN UNDERCOVER DISCOVERY IN AN OLD DISTRICT

Matthew Hope[1]* *and Steve Andersson*[1]
[1]First Quantum Minerals

The discovery of the Atlántida Cu-Au-Mo porphyry deposit is a recent example of exploration success under cover in a traditional mining jurisdiction. Early acquisition of geophysics was a key tool in the discovery, and in guiding resource definition drilling, throughout the lifecycle of the project. Review of the geophysical response of the deposit with respect to its lithological distribution and petrophysical properties has allowed it to be fully characterised despite no mineralisation being exposed at surface. Data acquired over the project includes induced polarisation, ground and airborne magnetics, gravimetry, and petrophysics.

The distribution of the key lithologies is demonstrated to be readily defined, via a combined application of susceptibility and density properties, which agree well with geophysical data acquired at surface. This is in contrast to the electrical properties, which instead map the extent of mineralisation associated with the hydrothermal system, via chargeability, and the location of copper bearing sulphides via resistivity.

In combination these characteristics can be used to infer depth to exploration targets and potential for high grade mineralisation in a geological context. Future exploration will be increasingly reliant on the understanding of the surface manifestations of buried deposits in remotely acquired data. This review summarises the application and results of these principles at the Atlántida project.

PASSIVE AIRBORNE EM AND GROUND IP\RESISTIVITY RESULTS OVER THE ROMERO INTERMEDIATE SULPHIDATION EPITHERMAL GOLD DEPOSITS, DOMINICAN REPUBLIC

Jean Legault[1]*, *Jeremy Niemi*[2], *Jeremy Brett*[3], *Shengkai Zhao*[1], *Zihao Han*[1] *and Geoffrey Plastow*[1]
[1]Geotech Ltd.
[2]GoldQuest Mining Corp.
[3]MPH Consulting Inc.

The Romero gold copper zinc silver deposits are located in the Province of San Juan, Dominican Republic, approximately 165 km west-northwest of Santo Domingo. Romero and Romero South orebodies contain stratabound gold mineralization with copper, silver and zinc of intermediate sulphidation epithermal style. The gold mineralization is associated with disseminated to semi-massive sulphides, sulphide veinlets and quartz-sulphides within quartz-pyrite, quartz-illite-pyrite and illite-chlorite-pyrite alteration.

Ground DC resistivity and induced polarization (DCIP) supported by ground magnetics remain the main targeting tools for drill follow-up along with geologic mapping and geochemistry. However ZTEM passive airborne electromagnetics have recently also been applied with success for reconnaissance mapping of deep alteration and increased porosity regionally.

Our case-study compares ground DCIP and airborne EM-magnetic geophysical responses, supported by 3D inversions, over the known Romero and Romero South Au-Cu-Zn-Ag intermediate sulphidation deposit area.

1330–1510
Day 1 Session 2 Stream E

MINERALS – GRAVITY AND MAGNETICS 2

CONSTRAINING REGIONAL SCALE FAULT ARCHITECTURE IN THE SOUTHERN NEW ENGLAND OROGEN: INTEGRATION OF SEISMIC, MULTISCALE EDGES AND SURFACE MAPPING

Jamie A. Robinson[1*], *Glen Phillips*[1] *and Lisa Nix*[1]
[1]Geological Survey of New South Wales

Regional scale fault structures are considered a first order control on hydrothermal ore systems. Recognition and delineation of such features is essential for search space reduction and project selection in exploration. The New England Orogen in northeastern New South Wales has significant potential for the discovery of new hydrothermal ore systems. However, limits to interpretation of broad scale geophysics in the region and limited exposure for ground-based mapping have hampered the recognition of the first order fault architecture in many areas.

As part of the Geological Survey of New South Wales 3D mapping program, we aim to further the understanding of strike extensive and depth penetrative regional scale fault architecture in the southern New England Orogen. The workflow for constraining the regional 3D fault architecture involves integrating a limited number of deep seismic lines with broader gravity and magnetic wavelet-based multiscale edges. All the geophysical data sets are further constrained by the Geological Survey of New South Wales' seamless geology mapping and surface structural orientation data. The work to date demonstrates correlation between the lateral position of multiscale edges and their dip inferred from upward continuation, with steeper dipping structures interpreted in seismic lines. Strike orientations of edges, or systematic breaks in edges, are broadly consistent with structural orientations previously recognised in mapping, but often not at the true regional scale as suggested by edge continuity. Known hydrothermal ore systems in the southern New England Orogen display a strong correlation with the deeply penetrating edges.

A NEW INTERPRETATION OF CAMBRIAN BASEMENT GEOLOGY INCREASES THE PROSPECTIVITY FOR CU PORPHYRIES IN WESTERN VICTORIA

Phil Skladzien[1*], *Ross Cayley*[1], *David Taylor*[1] *and Mark McLean*[1]
[1]Geological Survey of Victoria

Recent Geological Survey of Victoria work has confirmed the presence of the Miga Arc, a buried Andean-type Cambrian arc system in western Victoria.

Geophysical data sets, particularly magnetics and gravity, were interpreted to characterise the regional tectonic setting, and to gain a deeper understanding of poorly exposed bedrock of the southern Miga Arc, within the Geological Survey of Victoria's Willaura Cu Porphyry project area.

Geophysical interpretation and modelling, and field mapping of Cambrian bedrock has identified new regional Late Silurian dextral faults which are important in understanding the distribution of Miga Arc rocks in western Victoria. The updated bedrock interpretation together with new geochemical results has significantly expanded the potential exploration fairway for Cu porphyries in rocks associated with the buried Miga Arc.

Key words: Miga Arc; Mount Stavely Volcanic Complex; Lachlan; Delamerian; geophysical modelling; Cu porphyry; dextral strike-slip faults.

3D GRAVITY AND MAGNETIC MODELING – ITS PAST AND FUTURE CONTRIBUTION TO UNDERSTANDING THE GEOLOGY OF AUSTRALIA

Richard Lane[1*]
[1]Geoscience Australia

Geoscience Australia (a.k.a. BMR and AGSO) pioneered the acquisition of regional gravity and magnetic data to aid geological mapping. These data revealed for the first time the extent and nature of the major tectonic elements of the Australian continent. In the 1980's, airborne survey and major exploration companies extended this concept to higher resolution at the province scale, further bringing the geology into focus. Qualitative interpretation of this type of information in 2D plan view has proved invaluable. Thoughts turned to 3D modeling and interpretation. Despite an array of software tools to perform the modeling, we are yet to feel that it has really met expectations. As we move into the future, the grand challenge for us all will be to inject more geological knowledge ("prior information") into the modeling. Technology in the form of better geophysical data acquisition capabilities, improved software tools, High Performance Computing facilities, and novel ways to integrate interpretations and visualize 3D spaces will all contribute to the solution. However, user input will remain the key ingredient for success. Injecting geological knowledge into the modeling process and understanding the results that modeling provides will enable us to reveal more detail of the 3D subsurface structure and to identify and manage the resources that are hidden therein.

1330–1510
Day 1 Session 2 Stream F

NEAR-SURFACE – GROUNDWATER GEOPHYSICS 2

AN INVESTIGATION OF THE HIDDEN PRECIOUS WATER RESOURCES OF DAMPIER PENINSULA USING AIRBORNE ELECTROMAGNETIC METHOD

John Joseph[1]* *and Josephine Searle*[2]
[1]Geophysical Consultany Services
[2]Department of Water Western Australia

An airborne electromagnetic (AEM) survey was carried out over the Dampier Peninsula, North of Broome, WA during September-October, 2012. The key objectives of this geophysical survey funded by the Department of Water was (i) to obtain a better understanding of the nature of the contact between the base of the Broome Sandstone and the underlying siltstone; (ii) to identify areas of water retentive clay layers in the near surface, (iii) to create a map of the water table; (iv) to study the detailed geometry of the near shore saline intrusion; and thus (v) assist the conceptualisation of the hydrogeology and determine the quantity and quality of available groundwater resources for the benefit of local communities, government and industry. The survey was conducted using SkyTEM, a helicopter-borne time domain AEM system.

The processed AEM data for each of the survey lines were examined and inverted using the industry standard inversion techniques. The results were then compared with available bore-hole geophysical logging as well as the regional geophysical, geological and hydrogeological data. Apart from successfully mapping the depth to water table for the whole project area, this survey has clearly delineated the thickness of Broome Sandstone, shallow impermeable layers within the Broome Sandstone and areas of possible saline sea water intrusions. The survey has also successfully identified a WNW-ESE trending lineament (a basement high) and couple of NW-SE trending structural features (such as fault structures) from the central part of the survey region. The regional geophysical data images obtained from Department of Mines & Petroleum supports this finding.

ADIABATIC PULSES ENHANCE SPEED AND SENSITIVITY OF GEOPHYSICAL SURFACE NMR MEASUREMENTS FOR GROUNDWATER INVESTIGATIONS

Elliot Grunewald[1]*, *Denys Grombacher*[2] *and David Walsh*[1]
[1]Vista Clara, Inc.
[2]Stanford University

We present a new approach to improve the sensitivity and efficiency of geophysical surface nuclear magnetic resonance (NMR) measurements. An extremely powerful tool in groundwater investigations, surface NMR inherently has a relatively low signal-to-noise ratio (SNR), which sometimes necessitates long survey times for signal averaging. In pursuit of faster survey speeds, we show that replacing the standard on-resonance excitation pulse with an adiabatic, frequency-swept pulse can provide significant increases in the NMR signal amplitude. This increase results from the fact that adiabatic pulses can excite larger volumes of groundwater more efficiently than conventional pulses. Using numerical simulations and full-scale field experiments, we show that adiabatic pulses can provide a factor of ~3 increase in signal, and suggest other advantages for groundwater imaging. The signal increase alone allows for data of equivalent SNR to be acquired in a fraction of the time required for conventional on-resonance pulses. Ultimately these improvements can allow surface NMR to be exploited in an expanding range of applications.

USING AIRBORNE EM AND BOREHOLE NMR DATA TO MAP THE TRANSMISSIVITY OF A SHALLOW SEMI-CONFINED AQUIFER, WESTERN NSW

Ko Piang Tan[1]*, *Ross S. Brodie*[1], *Larysa Halas*[1] *and Ken Lawrie*[1]
[1]Geoscience Australia

The Broken Hill Managed Aquifer Recharge (BHMAR) project aimed to define key groundwater resources and aquifer storage options in the lower Darling River floodplain of western NSW. The project was multi-disciplinary and utilised airborne electromagnetics (AEM), borehole nuclear magnetic resonance (NMR) and LiDAR DEM data and lithological, hydrostratigraphic and hydrochemical information to develop a suite of hydrogeological and groundwater property maps and products.

This abstract discusses the methods and results of estimating the transmissivity of the semi-confined target aquifer. Hydrostratigraphy and hydraulic texture classes were mapped by interpreting the AEM data in conjunction with borehole geophysics and lithological information. Aquifer transmissivity was statistically derived by combining borehole NMR hydraulic conductivity estimates with the mapped 3D distribution of texture classes and hydrostratigraphic units. Using a statistical and GIS approach, the derived aquifer thicknesses in the key areas ranged from 20 to 40 m and the lower and upper transmissivity bounds ranged from 1 to 10 m^2/d, and 10 m^2/d to 1000 m^2/d, respectively.

AN EFFICIENT AND AUTOMATIC PROCEDURE FOR INTEGRATING RESISTIVITY AND BOREHOLE INFORMATION FOR LARGE SCALE GROUNDWATER MODELLING

Anders Vest Christiansen[1]*, *Nikolaj Foged*[1], *Pernille Marker*[2], *Peter Bauer-Gottwein*[2] *and Esben Auken*[1]
[1]Aarhus University
[2]Technical University of Denmark

We present an automatic method for parameterization of a 3D model of the subsurface, integrating lithological information from boreholes with resistivity models through an inverse optimization, with the objective of creating a direct input to groundwater models. The parameter of interest is the clay fraction, expressed as the relative length of clay-units in a depth interval. The clay fraction is obtained from lithological logs and the clay fraction from the resistivity is obtained by establishing a simple petrophysical relationship, a translator function, between resistivity and the clay fraction. Through inversion we use the lithological data and the resistivity data to determine the optimum spatially distributed translator function. Applying the translator function we get a 3D clay fraction model, which holds information from the resistivity dataset and the borehole dataset

in one variable. Finally, we use k-means clustering to generate a 3D model of the subsurface structures, which we then use as direct input in a groundwater model. We apply the concept to the Norsminde survey in Denmark integrating approximately 700 boreholes and more than 100 000 resistivity models from an airborne survey in the parameterization of the 3D model covering 156 km^2. The final five-cluster 3D model is input to a groundwater model and it performs equally well or slightly better than traditional groundwater models from the area.

1530–1710
Day 1 Session 3 Stream A

PETROLEUM – FULL WAVEFORM INVERSION 1

FULL MODEL WAVENUMBER INVERSION

Tariq Alkhalifah[1]*
[1]KAUST

The promise of full waveform inversion (FWI), granted we could (completely) simulate the conditions in which our field data were acquired, including an accurate representation of the physics involved, is a model of the Earth capable of generating synthetic data that resembles (fits) our field data; No deghosting, no filtering, in fact, no processing is theoretically required as the goal in this case is a model of the Earth, not a seismic section. However, we still have a long way to go, as we usually resort to approximate physics and many assumptions, and yet, we still fail to converge to that promise. The high nonlinearity of the inversion problem with the large number of model points necessary to properly represent the resolution of interest (or need) in our model are prime reasons for the ill convergence.

The long wavelength components of the velocity model usually constrain the general geometrical behavior of the wavefield (the kinematics), observed in our data, while the short wavelength components are responsible for the scattering (the reflections themselves as events in our data). Since FWI is based on comparing the observed and modeled data, free of wavefield geometrical utilization, it usually requires that the long (and at depth and with complex media, the middle) wavelength components of the model be accurate enough to provide modeled data that is within a half cycle of the observed data. These long wavelength components are usually estimated from tomography or migration velocity analysis (MVA) methods. They, however, usually contain too low of a wavelength to fit the cycle skip criteria for all reflections in the data, especially those reflections corresponding to deeper reflectors. We are, specifically, missing the "middle" model wavenumbers necessary to help us transition from the geometrical features of the wavefield to the scattering ones. The analysis of the sensitivity of our conventional (and even FWI-in-mind enhanced) data to the model points show that such lack of middle wavenumbers is a serious problem at depth, and specifically the depths we tend care about in our industry.

In this presentation, we investigate two potential solutions to this problem, beyond requiring low frequency to be acquired. To combat this problem we shift our focus from the data domain to the model domain in which we devise an approach to explicitly control the wavenumbers that we introduce to the model at different stages of the inversion. Such controls are admitted naturally by scattering angle filters. An explicit control on the model wavenumbers provided by the scattering angle of the FWI gradients can help us maneuver model wavenumber gap. This is especially true in anisotropic media where such filters are applicable to the individual parameter models necessary to represent such the anisotropic model; A feature not accessible though data domain decimation and data hierarchical implementations, as all parameters share the same data. Though the physics involved in creating the data and the obvious acquisition limitations will eventually impose bounds on the model wavenumbers we may be able to extract, a proper integration of image domain analysis to the FWI objective will help us widen the model wavenumber spectrum that we can extract from the data. Thus, the combination of scattering angle filtering and an objective that utilizes MVA and FWI are at the heart of making FWI work, and hopefully help us converge to it's promise. During this presentation, I will share many examples that demonstrate the assertions made in this summary.

HIGH RESOLUTION ANISOTROPIC EARTH MODEL BUILDING ON CONVENTIONAL SEISMIC DATA USING FULL WAVEFORM INVERSION: A CASE STUDY OFFSHORE AUSTRALIA

Bee Jik Lim[1]*, *Denes Vigh*[1], *Stephen Alwon*[1], *Saeeda Hydal*[1], *Martin Bayly*[1], *Chris Manuel*[2], *Dimitri Chagalov*[2], *Gary Hampson*[3] *and Dimitri Bevc*[3]
[1]Schlumberger
[2]Chevron ETC APGC
[3]Chevron ETC RnD

We present a case study from the North West Shelf of Australia where the complexity of the overburden consists of several thin multi-level channel systems filled with a combination of anomalously high or low velocity sediments. Not accounting for these strong velocity variations accurately, can lead to subtle image distortions affecting the underlying section down to and including the reservoir level. This can have significant impact on the volumetric estimates of reserves in place. To resolve these complexities in the overburden, full waveform inversion (FWI) was utilized to generate an updated earth model exploiting both early arrivals and reflection events. One caveat to using full waveform inversion is the need for low frequencies to be present in the seismic data, or, the initial starting velocity model must contain the correct low wavenumber components. However, conventional seismic data acquired at shallow tow depths are usually band limited particularly at the very low frequencies. Our case study will discuss these issues along with other limitations that this "conventional data" presented along with the

workflows and quality control methods adapted to this data in order to converge to a plausible, high resolution earth model.

MAKING ANISOTROPY IN PSDM DEPTH-VELOCITY MODELS CONFORMAL WITH GEOLOGY AND VELOCITY. CASE STUDY FROM THE NW AUSTRALIAN SHELF

Sergey Birdus[1]*, *Llew Vincent*[2], *Alexey Artemov*[1] *and Li Li*[1]
[1]CGG
[2]Hess Exploration Aus

We propose and successfully apply on a real 3D seismic dataset from the North-West Australian shelf a new technique that uses well information to correlate anisotropy with velocity for localized lithology driven anomalies. We assume that localized variations in both velocity and anisotropy are caused by changes in the lithology (shale vs carbonate vs sandstone etc). This should result in some correlation between anisotropy anomalies and velocity anomalies. We use well information to establish such a correlation. Our technique produces geology conformal PSDM anisotropic velocity models and reduces depth misties.

1530–1710
Day 1 Session 3 Stream B

PETROLEUM – BOREHOLE GEOPHYSICS

INSTANTANEOUS FREQUENCY-SLOWNESS ANALYSIS APPLIED TO BOREHOLE ACOUSTIC DATA

Marek Kozak[1]* *and Jefferson Williams*[1]
[1]SuperSonic Geophysic

The methods most frequently used to process borehole acoustic data are based on semblance analysis. Two most commonly utilized semblance implementations are: slowness-time coherence and slowness-frequency coherence. Both of them are relatively robust under noisy well conditions. They deliver slowness value across the receiver array, and, as the quality control measures, coherence peak value and frequency dispersion curve.

Semblance processing might be substituted by instantaneous frequency-slowness method based on complex wave form analysis. Instantaneous frequency -slowness delivers rich set of quality control measures. Among them are the velocities, the goodness and standard deviation across the receiver array, and instantaneous frequency and slowness wave forms computed between adjacent receiver pairs. Furthermore, since computations are performed across adjacent receivers, the vertical resolution is limited to the offset between receivers. Thus the effect of multiple semblance peaks observed while the receiver array is passing through the high acoustic impedance contrast is eliminated. Also, the method is capable to detect underperforming receivers. Finally it can help to control mixed acoustic mode conditions.

Instantaneous frequency-slowness method delivers robust results under good to moderately noisy well data. The set of quality measures it delivers is much broader than the one generated by the semblance method.

LOOK AHEAD RIG SOURCE VERTICAL SEISMIC PROFILE (VSP) APPLICATIONS – CASE STUDIES

Muhammad Shafiq[1]*, *Konstantin Galybin*[1] *and Mehdi Asgharzadeh*[1]
[1]Schlumberger

Borehole Seismic has played vital role in aiding the better understandings of the conventional and unconventional reservoirs around the world in the last few decades. In VSP technique we have an advantage of listening and measuring the formation velocities at seismic scale in the vicinity of the formations while on contrary in surface seismic measurements, it is done from surface.

In vertical seismic profile (VSP) technique, the direct arrivals are recorded in addition to the reflections below current sensor depth, which makes it feasible to use the reflections to predict ahead of current depth, detailed methodology will be discussed in the paper.

In this paper, we will discuss a case history where look-ahead VSP have been successfully employed by reducing the pre-drill depth uncertainty of reservoirs from tens of meters to within a meter. Schlumberger's down-hole seismic tool was used to acquire intermediate look-ahead VSP. The data was acquired in open hole, few hundred meters above the target intervals. Fast-track processing of the field data and timely delivery of a high quality product allowed a rapid interpretation, which resulted in significant savings in relatively high cost offshore environment.

AUTOMATED STRUCTURE DETECTION AND ANALYSIS IN TELEVIEWER IMAGES

Daniel Wedge[1]*, *Eun-Jung Holden*[1], *Mike Dentith*[1] *and Nick Spadaccini*[2]
[1]Centre for Exploration Targeting
[2]The University of Western Australia

Borehole televiewer data is an important source of data on structural and stratigraphic discontinuities in both the mining and petroleum industries. Manually picking features in downhole image logs is a labour-intensive and hence expensive task and as such is a significant bottleneck in data processing. It is also a subjective process. We present a new algorithm and workflow for automatically detecting and analysing planar structures in downhole acoustic and optical televiewer images. First, an image complexity measure highlights areas most suitable for automated structure detection. Changes in the image complexity can be used to locate geological boundaries. Second, structures are automatically detected, with each structure having an associated confidence level; users can apply a threshold to the confidence values to adjust the quality and quantity of the detected structures based on the image quality and geological complexity. Third, structures that have been detected but that do not meet the structure confidence threshold can be interactively assessed and if necessary selected. We also provide tools for rapidly picking sets of equivalent structures and reducing structures to a set of representative picks.

IMAGING BY MULTIPLES: A CASE STUDY IN THE CARNARVON BASIN

Konstantin Galybin[1], Fargana Exton[1] and Efthymious Efthymiou[2]*
[1]Schlumberger
[2]Chevron Australia

Vertical Seismic Profiling (VSP) is renowned for its high resolution images of the subsurface. By and large, the images derived are beneath the well. Now a new technique allows imaging above the borehole by utilizing free surface multiples as a secondary source. A number of conditions need to be met for this technique to successfully meet its objectives. This paper presents a case study of data acquired recently in the Carnarvon basin and processed to derive an image above the well. The high-resolution, multiple-free VSP image allows verification of the shallow part of the subsurface. This information can be used to identify drilling hazards, faults and generally improve subsurface interpretation. The result can also be used to overcome the limitations of poor cementing which often causes casing ringing noise, which in itself is detrimental to VSP imaging. Subsequently, the size of the VSP image for this survey was increased by a factor of 2, thus greatly improving the value of acquisition.

1530–1710
Day 1 Session 3 Stream C

PETROLEUM – ROCK PHYSICS 1

CHANGES IN MICROSTRUCTURE AND MINERALOGY OF ORGANIC-RICH SHALES CAUSED BY HEATING

Marina Pervukhina[1], Yulia Uvarova[2], Alexey Yurikov[3], Natalia Patrusheva[4], Jeremie Dautriat[1], David N. Dewhurst[1] and Maxim Lebedev[1]*
[1]CSIRO Energy
[2]CSIRO Mineral Resources
[3]MIPT
[4]OOO Geosphera

Understanding of microstructural changes in gas shales caused by their thermal maturation is of practical importance for evaluation of extractability of hydrocarbons from these low permeability reservoirs through methods such as sweet spot mapping from surface seismic.

Two organic-rich shales (ORS), one with extremely high total organic carbon (TOC) and the other extremely low TOC are chosen for this study. The Upper Jurassic Kimmeridge Shale from and the Upper Cretaceous Mancos Shale contain around 23% and 1% TOC, respectively. Samples are subjected to temperatures in the range of 300 to 510°C. Changes in their mineralogical composition, TOC, weight and microstructure with temperature increase are monitored.

The Kimmeridge Shale shows rapid decomposition of the organic matter at the temperatures of 370–390°C. This process is accompanied by fracture development and propagation. The Mancos Shale exhibits shrinkage of the solid organic matter with mobile bitumen expulsion and relocation. No fracture development is directly observed in microtomograms. Further work has to be done to understand whether the ability of shale to develop a fracture network depends on its TOC content, the mineralogical composition of its inorganic matrix or on other parameters.

EFFECTIVE MEDIUM MODELLING THE EFFECTS OF SATURATION ON THE JOINT ELASTIC-DIELECTRIC PROPERTIES OF CARBONATES

Tongcheng Han[1], Michael Ben Clennell[1], Marina Pervukhina[1] and Matthew Josh[1]*
[1]CSIRO

The effects of saturation on the joint elastic-dielectric properties of porous medium is important for the understanding of elastic and electromagnetic wave propagation phenomena as well as quantifying hydrocarbon content in partially saturated reservoir rocks. We studied theoretically for the first time the cross-property relations between elastic velocity and dielectric permittivity (the joint elastic-dielectric properties) of carbonates with a unified microstructure. The effects of porosity and water saturation on the joint elastic-dielectric properties were also studied using validated self-consistent effective medium models for elastic velocity and dielectric permittivity. The results offered an important new possibility for estimating in situ carbonate porosity and hydrocarbon saturation using joint velocity-permittivity crossplots from co-located sonic and dielectric surveys.

JOINT EFFECT OF CAPILLARY FORCE AND FLUID DISTRIBUTION ON ACOUSTIC SIGNATURES IN ROCKS SATURATED WITH TWO IMMISCIBLE FLUIDS

Qiaomu Qi[1] and Tobias Müller[2]*
[1]Curtin University
[2]Mineral Resources Flagship, CSIRO

Capillary forces control the spatial distribution of pore fluids during two phase flow. Capillarity and fluid distribution are known to influence seismic signatures. By comparing recently developed capillarity-patchy saturation models for different fluid-patch distributions, we obtain an understanding of the underlying connection between capillarity and velocity and attenuation in patchy-saturated reservoir rocks. Our results show that, for the same gas saturation and patch size, P-wave velocity as well as attenuation manifest differently for various fluid distributions. The key parameter in controlling these characteristics is the specific surface area of the fluid patches. This work provides further insights into the relation between the seismic signatures and the two phase flow underpinning saturation information.

INTEGRATION OF STRATIGRAPHIC & ROCK PHYSICS MODELS TO GENERATE SYNTHETIC SEISMIC DATA

Mohammed Alkaff[1], Boris Gurevich[1], Cedric Griffiths[1] and Mahyar Madadi[1]*
[1]Curtin University

Stratigraphic forward modelling (SFM) is an important subsurface modelling method. A numerical SFM program, such as the Sedsim software used in this study, is able to quantitatively model the sedimentation process with time in order to predict rock properties away from well data.

Although numerical SFM is a powerful technique, it is important to quantify and minimise the uncertainty in the resultant

stratigraphic model. This uncertainty can be reduced by producing synthetic seismic traces from the results of the stratigraphic model. This simulated seismic may then be compared to observed seismic over the same area and the parameters of the stratigraphic model modified based on the results of the comparison.

In order to generate synthetic seismic from the results of a stratigraphic model, sediment properties from the stratigraphic model must be converted to acoustic properties. This becomes challenging at inter-well locations, or locations with little or no well control. Fortunately, such conversion can be achieved by the application of a suitable rock physics model even at those challenging locations.

The integration of a Sedsim stratigraphic model and the Velocity-Porosity-Clay (VPC) rock physics model in the Cornea field, Browse Basin, Australia shows the importance of integrating geological and geophysical methods in order to reduce uncertainty when predicting subsurface properties.

1530–1710
Day 1 Session 3 Stream D

MINERALS – EXPLORATION CASE STUDIES 3

DISCOVERY OF THE EUREKA VOLCANOGENIC MASSIVE SULPHIDE LENS USING DOWN-HOLE ELECTROMAGNETICS

Mike Whitford[1]*, *Jacob Paggi*[1] *and Daniel Macklin*[1]
[1]Independence Group NL

The Eureka massive sulphide lens is the first new discovery of VMS mineralisation at the Stockman Project since 1979. The discovery was made in early 2013 through the integration of geophysical techniques, particularly down-hole electromagnetics, with a robust geological interpretation.

The lens is located approximately 350 m northeast of the Currawong deposit, immediately along strike and beneath the Bigfoot lens at a depth of 360m. Though surface EM methods played key roles in the discovery of the main deposits at Currawong and Wilga, airborne and fixedloop EM surveys failed to detect the Eureka lens due to its moderate conductance and increased depth. Interpretation of subtle DHTEM responses in two exploration drill holes was a key component of the discovery. Additional geological input, including short wavelength infrared modelling and structural reinterpretation, presented a compelling drill target, which led to the discovery of the Eureka massive sulphide lens.

HELICOPTER AFMAG (ZTEM) EM AND MAGNETIC RESULTS OVER SEDIMENTARY EXHALATIVE (SEDEX) LEAD-ZINC DEPOSITS AT HOWARD'S PASS IN SELWYN BASIN, YUKON

Jean M. Legault[1]*, *Ali Latrous*[1], *Shengkai Zhao*[1], *Nasreddine Bournas*[1], *Geoffrey Plastow*[1] *and J.J. O'Donnell*[2]
[1]Geotech Ltd
[2]Selwyn Chihong Mining Ltd

In 2008 Geotech flew a regional scale 24 675 line-km survey covering a 25 000 km^2 area (1 km line spacing) in the Selwyn Basin. The survey footprint straddles eastcentral Yukon and overlaps into the western Northwest Territories. In March 2013 Yukon Geological Survey purchased the survey data, and in November 2013, released the data publicly. The Selwyn Basin area is prospective for SEDEX-style Pb-Zn-Ag mineralization and the ZTEM survey data provide insights into regional structures and plutons in the region. The Howard's Pass SEDEX deposits at the southeastern edge of the Selwyn Basin survey area host a combined ~250 million tonne resource with ~4.5% Zn and ~1.5% Pb. Major NW-SE to ESE and minor NNW-SSE linear conductive trends correlate with known regional geologic, structural and inferred mineral trends. Circular conductive anomalies surrounding resistivity highs reflect porich hornfels surrounding intrusive plutons. 2D-3D computer inversions reveal a correlation between enhanced conductivity along strike and the clustering of deposits at Howard's Pass.

IDENTIFICATION OF MASSIVE SULPHIDE TARGETS USING THE GALVANIC SOURCE EM (GSEM) SIGNAL FROM A SUB-AUDIO MAGNETIC (SAM) SURVEY AT THE FAR SOUTH PROJECT, WESTERN AUSTRALIA

William Peters[1]*, *Yvonne Wallace*[1], *Daniel Card*[1], *Keith Gates*[2], *Mal Cattach*[3] *and Bill Peters*[1]
[1]Southern Geoscience Consultants
[2]Saracen Mineral Holdings Ltd
[3]Gap Geophysics Australia

The Far South project is located five kilometres along strike from the Deep South mine, where gold mineralisation is commonly associated with semi-massive pyrrhotite and pyrite. Data from a Sub-Audio Magnetic (SAM) survey set up in galvanic configuration were acquired over the project principally to map stratigraphy and structure using the on-time Magnetometric Conductivity (MMC) and Total Magnetic Intensity (TMI) responses. The off-time Galvanic Source EM (GSEM) data were subsequently extracted from the raw data and examined. Four late time anomalous responses were identified. Two of these responses are strong late-time (>45 ms) anomalies up to 350 m in strike length, and the remaining two are weaker mid-time, more subtle and less diagnostic responses. Follow-up Moving Loop Transient Electromagnetics (MLEM) and Fixed Loop Transient Electromagnetics (FLEM) surveys confirmed well defined conductive responses over all four follow-up areas. Modelling of the GSEM data over the two strongest anomalies is in good agreement with modelling of the MLEM/FLEM data, confirming the ability to identify and model conductive targets from SAM GSEM data. The two weaker GSEM responses could not be reliably modelled and use of the MLEM/FLEM data was necessary to produce robust models. The identified conductors were all interpreted as having good exploration potential, and a subsequent drill program intersected the source of all four as sulphide zones of varying widths and types.

FOLLOW-UP DRILL HOLE SURVEYING TO DETERMINE UNIDENTIFIED EM TARGETS

Paul Mutton[1]*
[1]Touchstone Geophysics

In these two case histories, drill hole surveying using down-hole electromagnetic surveys and wireline conductivity probes are used to determine the source of geophysical targets that remained unidentified after initial drill testing.

In the first example, after drilling the identification of the geophysical target remained uncertain, despite surface EM surveys determining it had a high conductance. Subsequent DHEM and conductivity surveys were clearly able to locate and define the targeted conductor.

In the second example, deep AMT targets could not be identified after drill testing. Using data from an AEM survey over the same area, and after subsequent DHEM surveying, it appears that the targets are probably artefacts of complex (frequency dependent) conductivity in the near surface soils and regolith.

Targeting errors are very costly. These examples emphasise how critical follow-up drill hole surveying can be to resolving unidentified geophysical targets and ensuring that exploration practices are sound and efficient.

1530–1710
Day 1 Session 3 Stream E

MINERALS – GRAVITY AND MAGNETICS 3

CONSTRAINTS ON INTERPRETING MAGNETIC SPECTRAL DEPTHS

Roger Clifton[1]*
[1]NT Geological Survey

It is now possible to automate the extraction of magnetic depths over large areas as depth profiles. A depth profile is a graph of the probability of a layer at each depth. Presented in the form of a transect, depth profiles allow layers to be traced across significant distances. The appearance of discontinuous layers, and multiple layers, raises questions for interpretation, here addressed with modelling. Modelling of layers requires simulating the heterogeneity of the material. Accordingly, a method of modelling is demonstrated where flat prisms are populated with very large numbers of dipoles and their fields accumulated for spectral analysis.

Thick layers give a depth signal in the transects about 20 m below their top surface. The distinction is minor given that the layer is assumed to extend across a 20 km square.

In general, only one depth signal credibly represents the depth of its source. Multiple layers can be picked out ontraverses when the deeper layer is sufficiently more magnetised than the layer above it. A weaker depth signal appears closer to a stronger signal. Signals within 100 m of each other tend to merge. The sensitivity of the method is significantly better when the survey has been flown north-south rather than east-west. Near-surface layers are not picked up by the method. The sampling frequency of the original survey dictates how close to the surface estimates can be provided. A rough rule of thumb is that no reliable depth estimates can be expected for sources shallower than half the flight line spacing.

CONSTRAINING GRAVITY GRADIENT INVERSION WITH A SOURCE DEPTH VOLUME

Cericia Martinez[1]*, *Daniel Wedge*[2], *Yaoguo Li*[1] *and Eun-Jung Holden*[2]
[1]Center for Gravity, Electrical, and Magnetic Studies, Department of Geophysics, Colorado School of Mines
[2]Centre for Exploration Targeting, The University of Western Australia

Efficiently extracting the maximum amount of information from gravity gradient data is challenging. Interpretation often takes place in either the data domain or model domain. Here, we present a workflow that utilizes two interpretation techniques that can result in better characterization of the subsurface. Using a method that estimates depth to source, we obtain a depth volume of estimated source locations. The depth volume is then used to constrain inversion of gravity gradient data in the form of a reference model and 3D model weighting. We demonstrate that this combined approach improves the ability to recover sources at depth.

REMANENT MAGNETISATION INVERSION

Peter Fullagar[1]* *and Glenn Pears*[2]
[1]Fullagar Geophysics
[2]Mira Geoscience Asia

Remanent magnetisation is an important consideration in magnetic interpretation. In some cases failure to properly account for remanence can lead to completely erroneous interpretations. In general the strength and orientation of remanence are unknown. Two main strategies have been pursued for “unconstrained” inversion of large data sets. One strategy is to invert quantities, such as total magnetic gradient (3D analytic signal), which are insensitive to magnetisation direction. The inverted property is then magnetisation amplitude. Another strategy is to invert for the magnetisation vector, allowing its three components to vary freely. These approaches are useful, but the resulting magnetisation models are highly non-unique.

When interpreting magnetic data in tandem with geological modelling there is greater potential to infer remanence parameters. Non-uniqueness is reduced if the shape of magnetic domains is constrained, especially if the susceptibility is known and if remanence can be assumed uniform. Accordingly, inverting for the remanent magnetisation of individual homogeneous geological units of arbitrary 3D shape is the subject of this paper. Our remanent magnetisation inversion (RMI) approach can be regarded as a generalisation of parametric inversion of simple geometric bodies.

If susceptibility is known, the optimal remanent magnetisation vector within each selected unit is determined via iterative inversion. Sensitivity to change in magnetisation is determined in the x-, y-, and z-directions, and the perturbation vector is found via the method of steepest descent. If the susceptibility is unknown, the optimal susceptibility of each unit (subject to bounds) can be determined via a similar inversion procedure.

The geological units can carry remanent magnetisation, but it is fixed during this stage. The susceptibility and/or remanence inversions can be repeated, if necessary, to refine the magnetic parameters. Self-demagnetisation and interactions are taken into account when susceptibilities are high.

THE APPLICATION OF THE SIGNUM TRANSFORM TO THE INTERPRETATION OF MAGNETIC ANOMALIES DUE TO PRISMATIC BODIES

Jeferson de Souza[1]* *and Francisco J.F.F. Ferreira*[1]
[1]Laboratorio de Pesquisas em Geofisica Aplicada

The Signum transform is a simple derivative-based method for qualitative and quantitative interpretation of magnetic anomalies from discrete sources. The methodology is based on the normalization of a filtering function, which is a derivative of the anomalous field or function of this, by its absolute value. The filtered anomalies have only two values (+1 or –1) and the causative sources are represented by the positive values. The transform has been applied to three different functions, namely the first order vertical derivative of the magnetic anomaly, the first-order vertical derivative minus total horizontal derivative and second-order vertical derivative

For a vertical magnetisation the edges of the sources can be recognised from the locations where one or more of the spatial derivatives change its sign: the zero crossover point. The zero cross over point and actual source edge are separated by an amount which depends on the dykes depth and the type of data being transformed. Thus, actual edge locations are easily computed from the Signum transformed data.

The method performs well when closely spaced sources cause anomalies to overlap. Imagery based on the Signum transformation of first and second-order derivative based transforms of the magnetic data combines the advantages of the resolution of the second-order transform with the greater stability of the first-order transform.

1530–1710
Day 1 Session 3 Stream F

NEAR-SURFACE – GROUNDWATER GEOPHYSICS 3

DERIVATIVE ANALYSIS OF GEOPHYSICAL BOREHOLE TRACES

Aaron Davis[1]* *and Niels Christensen*[2]
[1]CSIRO
[2]Aarhus University

We present a derivative analysis method that automatically detects and selects layers in any geophysical borehole trace. Using a wavelet analysis, we delineate relevant boundaries from inflection points. This allows for the automatic, objective detection of layers.

Our software classifies layers based on importance in the geophysical data, and allows a user to select blocked layers based on total number of layers detected, a portion of the total layers, minimum layer thickness or the number of layers detected using a minimum operator width.

We demonstrate the effectiveness of the layer blocking technique with some field examples in Western Australia and New South Wales for aquifer detection and soil classification.

THE APPLICATION OF AEM TO MAPPING SEA-WATER INTRUSION AT LA GRANGE, WA

David Annetts[1]*, *Richard George*[2], *Tim Munday*[1], *Tania Ibrahimi*[1], *Kevin Cahill*[1], *Robert Paul*[2] *and Aaron Davis*[1]
[1]CSIRO MRF
[2]DAFWA

We describe interpretation of an AEM survey around the La Grange allocation area, WA. This survey was designed to map aquifer bounds and the sea water intrusion, and then to assess groundwater in the region, and to facilitate planning water use.

The simple, stratified nature of sediments of the western onshore Canning Basin allowed us to use blocky layered earth models and we found that five-layer models were the most parsimonious. After deriving surfaces representing the top of the Jarlemai siltstone and the top of the sea water ingress, we were able to effectively characterise the spatial characteristics of the sea water intrusion.

We found that in places, sea water intruded 40 km inland, and could be found at a depth of over 250 m.

AIRBORNE ELECTROMAGNETIC SURVEY FOR WATER SUPPLY PLANNING – CANE RIVER, WESTERN AUSTRALIA

James Reid[1]* *and Geoff Peters*[2]
[1]Mira Geoscience
[2]International Geoscience

A SkyTEM airborne electromagnetic survey was flown in the Cane River area near Onslow, Western Australia in 2011, in order to assist groundwater investigation and borefield development. The survey yielded a range of information relevant to future groundwater investigations.

The detailed geometry of the nearshore saline intrusion has been successfully defined in three dimensions. The intrusion occurs in the unconfined aquifer above the impermeable Muderong Shale.

A broad zone of low conductivity has been mapped within the alluvium and Trealla Limestone, which has been interpreted to indicate the extent of relatively fresh groundwater. The low conductivity zone has greatest extent in the 10–20 m depth slice. Between 20–50 m depth, the low conductivities are confined to the downstream part of the Cane River. At these depths, the low conductivities extend further to the eastern side of the river than to the west. This result suggest that it may be possible to expand the existing borefield to the east in areas without clay cover, while retaining a reasonable buffer from the nearshore saline intrusion.

A number of shallow granite bedrock highs have been identified in the northern and central parts of the survey area, many of which have not been intersected by existing drilling. The upper weathered and/or fractured parts of the granite may have potential as aquifers where they are not overlain by impermeable clays. However the margins of the granite should be avoided where they are in contact with the onlapping Muderong Shale, which is associated with poor water quality.

3D GEOLOGICAL MODELLING OF A BURIED-VALLEY NETWORK BASED ON AEM AND BOREHOLE DATA

Anne-Sophie Høyer[1]*, *Flemming Jørgensen*[1], *Peter Sandersen*[1] *and Ingelise Møller*[1]
[1]Geological Survey of Denmark

In former glaciated areas buried tunnel valleys can often be found. These buried erosional structures can be highly decisive for groundwater recharge and groundwater flow. Delineation of the architecture and infill of the structures are therefore very important in relation to groundwater mapping. The dense data coverage offered by airborne electromagnetic methods makes it possible to map and model the buried valley structures with a high degree of detail. The delineation of the individual valleys and the mapping of the internal cross-cutting relationships are dependent on the geological interpretation, which is founded on the knowledge about geological processes and the regional geology.

In this study, we have investigated a relatively small study area in Denmark with SkyTEM and lithological log data as the main data sources. The area is characterised by a network of cross-cutting buried tunnel valleys, which have been incised into impermeable Paleogene clay deposits. The geological interpretation of the SkyTEM data resulted in modelling of 21 buried valleys belonging to at least 7 different generations. Manual voxel modelling of the infill of these valleys, as well as the surroundings, resulted in a geological 3D model consisting of 43 different units. Most of the valleys show heterogeneous infill, characterized by a predominant lithology (for instance meltwater sand) with local occurrences of secondary lithologies (for instance clay till). In the majority of the valleys, meltwater sand is the main lithology, but clay till and meltwater clay deposits are also commonly found. Due to the heterogeneity of the infill, proper modelling of this type of geology requires voxel modelling instead of layer modelling.

Day 2: Tuesday 17 February 2015

0830–1010
Day 2 Session 1 Stream A

PETROLEUM – FULL WAVEFORM INVERSION 2

RANDOMIZED ALGORITHMS IN EXPLORATION SEISMOLOGY

Felix Herrmann[1]*
[1]UBC

As in several other industries, progress in exploration seismology relies on the collection and processing of massive data volumes that grow exponentially in size as the survey area and desired resolution increase. This exponential growth – in combination with the increased complexity of the next generation of iterative wave equation-based inversion algorithms – puts strain on our acquisition systems and computational back ends, impeding progress in our field. During this talk, I will review how recent randomized algorithms from Compressive Sensing and Machine Learning can be used to overcome some of these challenges by fundamentally rethinking how we sample and process seismic data. The key idea here is to reduce acquisition and computational costs by deliberately working on small randomized subsets of the data at a desired accuracy. I will illustrate these concepts using a variety of compelling examples on realistic synthetics and field data

FULL WAVEFORM INVERSION COMPARISON OF CONVENTIONAL AND BROADBAND MARINE SEISMIC STREAMER DATA, NW SHELF AUSTRALIA

U. Geun Jang[1]* *and David Lumley*[1]
[1]University of Western Australia

The lack of low-frequency information in conventional marine seismic streamer data inhibits the success of frequency-domain full waveform inversion (FWI). Low frequencies are typically absent in marine seismic data due to the low-cut spectral responses of airgun sources and hydrophone receivers, and the fact that the air-water interface produces source and receiver ghost reflections which create notch frequencies in the data amplitude spectrum. Advances in broadband streamer acquisition, such as the variable depth towed streamer, allow us to extend the low and high bounds of the useful frequency bandwidth in the seismic data spectrum. We illustrate the application of frequency-domain FWI to two 2D seismic data sets acquired simultaneously offshore North West Australia. Both data sets were acquired together, one with a conventional streamer, and the other with a variable depth streamer configuration. Our examples demonstrate that the FWI results are clearly superior when using the broadband variable depth streamer data, compared to using the conventional streamer data.

DO WE REALLY NEED A VERY ACCURATE STARTING VELOCITY MODEL FOR FULL WAVEFORM INVERSION?

Fabio Mancini[1]*, *Kenton Prindle*[1] *and Tom Ridsdill-Smith*[1]
[1]Woodside

Full Waveform Inversion (FWI) has recently emerged as one of the most exciting new techniques in the seismic industry, with the potential to deliver incredibly detailed velocity models. We applied FWI to 2D lines from the Exmouth basin, Western Australia. Results showed that FWI can produce excellent high resolution velocity models even if the starting velocity model is far from perfect providing that the input data is rich in low frequencies.

0830–1010
Day 2 Session 1 Stream B

PETROLEUM – FAULTS AND STRUCTURES

3D SEISMIC ANALYSIS OF NORMAL FAULT GROWTH AND INTERACTION WITHIN A GRAVITATIONAL DETACHMENT DELTA SYSTEM IN THE CEDUNA SUB-BASIN, GREAT AUSTRALIAN BIGHT

Alexander Robson[1]*, *Rosalind King*[1] *and Simon Holford*[1]
[1]University of Adelaide

We use three-dimensional (3D) seismic reflection data to determine the structural evolution of thin-skinned listric fault growth, at the extensional top of a gravitationally driven delta system, in the central Ceduna Sub-Basin. We present analysis of a strike and dip-linked extensional fault system, which is decoupled at the base of a marine mud interval of late Albian age. The fault system is oriented NW-SE with strike-linkage of fault segments and dip-linkage through the Santonian interval which connects a Cenomanian-Santonian period of kilometre scale fault growth and post-Santonian normal faulting. Understanding the growth of listric faulting requires quantifying heave and throw, which involves simplistic depth conversion of fault plane time measurements to establish a fault plane model to translate throw into fault plane displacement. Our analysis constrains fault growth into six evolutionary stages: [1] early Cenomanian nucleation and isolated radial propagation of fault segments; [2] substantial segment linkage established by the latest Cenomanian; [3] late Santonian cessation of a majority of fault growth; [4] heavy erosion at continental breakup of Australia and Antarctica (c. 83 Ma); [5] early Campanian independent nucleation of the post-Santonian fault system; and [6] fault assemblages fully linked by the Cenozoic, with continued accumulation of displacement. The structural evolution of this fault system is compatible with the ‘isolated fault model’.

In particular, we emphasise the importance of dip-linkage in this fault system, which controls the present day geometry of the fault array.

KINEMATIC RECONSTRUCTION OF THE HASTINGS BLOCK, SOUTHERN NEW ENGLAND OROGEN, AUSTRALIA

Paul Lennox[1]*, *Jie Yan Paul Lennox*[1], *Bryce Kelly*[1] *and Robin Offler*[2]
[1]University of New South Wales
[2]University of Newcastle

This research project uses 3D geological modeling software to build a 3D structural surface model of the Permo-Carboniferous rocks in the northern Hastings Block (NHB). The model is being built using comprehensive strike and dip structural data and a digital elevation model. It is designed to unravel a comprehensively mapped, complexly folded, extensively faulted geological sequence where there are no well-log data. The new 3D model will enable testing of the validity of existing tectonic models, which will assist in constraining the relative timing of fault development, testing fault emplacement of the block, and verification of the number and orientation of folding events in the NHB.

Fault-block analysis has highlighted shortcomings with the existing geological map of the NHB. Fault movement history shows early movement south of the NHB and later initial movement around the northern and northeastern margins of the NHB. Fault movement termination was probably during the Hunter-Bowen Orogeny after folding of the NHB. Preliminary 2D restoration indicated the NHB was compressed (folded) and then extensively faulted.

QUANTITATIVE SONIC TRANSIT TIME ANALYSIS DEFINES MULTIPLE PERMIAN–CRETACEOUS EXHUMATION EVENTS DURING THE BREAKUP OF GONDWANA

Hugo Olierook[1]* *and Nicholas Timms*[1]
[1]Curtin University

The Perth Basin in southwestern Australia has an extended history involving multiple regional unconformity-forming events from the Permian to Cretaceous. The central and southern Perth Basin is the closest basin to the relict triple junction of eastern Gondwana and comprises a complete Permian to Recent stratigraphy, thus recording the full history of the breakup events. We use sonic transit time analysis to quantify the magnitudes of net exhumation and the minimum differences in net exhumation across different time intervals (here called 'interval exhumation') for four stratigraphic periods from 37 wells. We were able to quantify the minimum interval exhumation of the Permian–Triassic, Triassic–Jurassic, Early Cretaceous breakup and post-Early Cretaceous events. The Permian–Triassic and Triassic–Jurassic events recorded spatially varied exhumation, up to 1000 m, across sub-basins. These localized variations are caused primarily by reverse (re-) activation of NW- and N-striking faults in the Permian–Triassic and Triassic–Jurassic events, respectively. The Valanginian breakup unconformity (~133 Ma) records approximately 400 m of basin-wide interval exhumation during the breakup of Gondwana, which implies a change to relatively uniform exhumation on a regional scale. Using published uplift rates for volcanic and non-volcanic passive margins, estimates of the time required for 400 m of exhumation vary from 6 to 20 Ma, respectively. A volcanic margin is far more likely given that post-breakup sedimentation commenced 2–7 Ma after breakup. Lastly, post-breakup interval exhumation ranges from 0 to 800 m. The highest values are in the hangingwall blocks of faults. Up to 200 m may be locally caused by reverse fault re-activation due to the present-day compressional stress state of Australia. The remainder is attributed to regional exhumation caused by dynamic topography in the last 50 Ma.

A PROSPECTIVE DEEP BASIN IN SOUTHERN PAPUA NEW GUINEA?

Michael Alexander[1]*, *Robert Marksteiner*[2] *and Corine Prieto*[1]
[1]Integrated Geophysics Corporation
[2]Consultant for BP

ExxonMobil's development of the Hides area to the northwest, and Inter Oil's giant gas discoveries at Elk and Antelope to the east, have revitalized exploration in the intervening area of PPL 319-PRL 13, southern Papuan Basin. With only limited seismic and well data available, the most time- and cost-efficient exploration option for the permit holder was to fly and interpret an airborne gravity and magnetic survey covering the permits and the adjacent surround.

After completion of acquisition and processing, the gravity/magnetic data were analysed both qualitatively and quantitatively. Existing seismic data were reprocessed and reinterpreted. We then integrated the results by means of 2D structural models incorporating surface geology, seismic, and subsurface data in order to reach solutions compatible with all data sets.

The final interpretation revealed what appeared to be a large, deep Jurassic basin which we have named Kikori Basin. If confirmed, it could be a hydrocarbon kitchen feeding both internal and surrounding prospective fold and fault structures. Several target leads in and around the deep basin were selected for detailing by a new seismic program which is not yet completed.

0830–1010
Day 2 Session 1 Stream C

MINERALS – MT METHODS 1

3D MAGNETOTELLURICS FOR MINERAL EXPLORATION BENEATH COVER

Graham Heinson[1]*, *James Komenza*[1,2] *and Dennis Conway*[1]
[1]University of Adelaide
[2]Santos

As a consequence of diminishing shallow mineral resources, the exploration industry has turned its focus to deeper targets. For this reason, the magnetotelluric (MT) method has gained much attention due to its unique penetration in regions of thick cover sequences. As the setting and geometries of mineral deposits are often complex, 3D models are required for their interpretation.

However, there has been little critical analysis of the ability of 3D MT surveys to recover structural geometry. A comparison of

synthetic model responses demonstrate that while MT is greatly sensitive to conductive and symmetrical bodies at depth, its resolution for detecting finite 3D bodies is significantly reduced under conductive regolith cover. Although 2D inversions can recover the geometry of finite conductive bodies, it is possible to successfully interpret 2D survey data using 3D inversion algorithms. Utilising all components of the impedance tensor, off-profile 3D conductive structure can be obtained from 2D survey data alone.

THE 3D JOINT INVERSION OF MT AND ZTEM DATA

Daniel Sattel[1]* *and Ken Witherly*[2]
[1]EM Solutions LLC
[2]Condor Consulting, Inc.

MT and ZTEM data were inverted with a number of 2D and 3D algorithms to recover the subsurface conductivity structure of an area of interest. A 2D inversion algorithm was used to model the magnetotelluric TM and TE mode impedances and the ZTEM tipper data, separately. The derived conductivity-depth sections don't show much agreement, possibly indicating the conductivity structure of the area to be highly three-dimensional.

A 3D inversion algorithm was used to invert the MT and ZTEM data, separately and jointly. Overall, there is good agreement between the derived conductivity structures. This suggests that a joint inversion can extract successfully the combined subsurface conductivity information from the two data sets.

NATURAL FIELD ELECTROMAGNETICS USING A PARTIALLY KNOWN SOURCE: IMPROVEMENTS TO SIGNAL TO NOISE RATIOS

Lachlan Hennessy[1]* *and James Macnae*[1]
[1]RMIT University

We aim to provide a novel approach to processing and interpretation of natural fields electromagnetic (EM) data through automated interpretation of sferic source parameters provided by the World Wide Lightning Location Network (WWLLN). Accurate sferic time stamps obtained from WWLLN are hypothesised to improve signal to noise ratios (SNR) through precisely controlled extraction of sferics with amplitudes both above and below observed noise levels in time series audio-magnetotelluric (AMT) measurements. Averaging of extracted data of equal source moment increases signal in proportion to the square root of the number of averages whilst decreasing noise since data between sferic events is inconsequential and can be discarded. Knowledge of source characteristics allows further improvements to data quality to be achieved through discrimination of sferic sources that do not meet the required assumptions of AMT. Since sferic propagation occurs primarily along great circle paths, antipodal sferics propagating around the reverse side of the earth can in principle be extracted for inclusion as additional signal. These increases in SNR afford reduced measurement time and an increase in data quality, leading to more cost effective exploration. Use of source information is unique amongst existing approaches to time domain AMT. The existing approaches are often limited in application to signals with amplitudes well above the noise level.

ARMIT sensors developed at RMIT are sensitive to natural EM fields generated by worldwide lightning activity and can measure up to 40 sferics per second. We collected AMT data using one such sensor in order to carry out an initial feasibility study on our hypothesis. Preliminary results are encouraging and demonstrate that WWLLN data are accurate and efficient enough to predict useful sferic arrival times. Future efforts will be applied to characterizing waveform similarity and investigating the relationship between stacking techniques and data reliability. This may improve SNR and hence the prediction of subsurface geological structure.

THE EFFECT OF HIGHLY MAGNETIC MATERIAL ON ZTEM DATA

Daniel Sattel[1]* *and Ken Witherly*[2]
[1]EM Solutions
[2]Condor Consulting

ZTEM data acquired across the Humble magnetic anomaly of almost 30 000 nT were analyzed for the presence of a magnetic gradient response and the effects from elevated magnetic susceptibilities.

The response of moving the receiver coil through the magnetic-field gradient peaks at 0.01 Hz and drops off strongly with frequency. Lacking information about the field strength at the base station precludes the comparison of amplitudes between computed gradient responses and the survey data, but the comparison of response shapes suggests that the gradient responses are too small to have a noticeable effect on the survey data.

The 3D inversion of the magnetic survey data indicates magnetic susceptibility values as high as 2.0 (SI). Forward-modeling the ZTEM response for these κ–values combined with resistive half-spaces indicates that the response amplitudes and shapes strongly depend on the background resistivities. Ignoring the elevated κ-values during an inversion can result in the underestimation of conductivities and other artifacts, such as the mapping of patterns that resemble crop circles. For an environment such as Humble, with deep-seated zones of elevated κ-values, the shallow inverted conductivity structure appears to be reliable, but the deeper structure should be interpreted with caution.

0830–1010
Day 2 Session 1 Stream D

MINERALS – MINE SCALE GEOPHYSICS 1

STEP-CHANGES IN GEOSCIENTIFIC INPUTS TO MINING VALUE CHAIN CONFIGURATION

John Vann[1]*
[1]Anglo American PLC

The revolution in computational power and integrated geoscience modelling approaches over the past decade is set to accelerate. Geoscientists (collectively; geologists, geometallurgists, mineralogists, geochemists and importantly geophysicists) will lead a transformation in the way the mining value chain can be conceived, evaluated and operated. The emerging capability to process large numbers of stochastic images of the mineralised system – each characterised by rich multivariate information – will allow better decision-making about alternative value chain configurations in the face of uncertainty. While this decision making has obvious implications for capital decisions in project evaluation, it has equally dramatic possibilities for real-time optimisation of existing operations. The advent of more flexible, highly configurable and in many instances automated and intelligent approaches to mining and mineral processing is perfectly timed to enable these inputs to deliver step-changes in value.

IMPROVING RESOURCE DENSITY MODELS VIA SURFACE GRAVITY INVERSION

Chris Wijns[1]*
[1]First Quantum Minerals Ltd

Density is one of the fundamental physical properties required in a mining operation, underpinning the calculation of ore tonnages and thus metal produced. The resource density model captures this information, but is often based on a relatively sparse collection of density measurements. Gravity data are a direct reflection of the true distribution of subsurface density, and can be used to improve the resource model. The example of the Ravensthorpe nickel laterite mine illustrates the improvement in the resource density model that results from combining high resolution surface gravity with the set of borehole logged density readings.

SEISMIC RESONANCE MODES FOR MINE ROOF STABILITY MONITORING

Andrew King[1]*
[1]CSIRO

This work aims at the detection of instabilities in underground mine roadway roof, with the goal of predicting and preventing roof failure and collapse.

Openings in the rock have their own resonances, due to the propagation of seismic waves in the rock around the opening. If the surrounding rock is damaged or fractured, this would result in the resonant frequencies decreasing. An experiment was set up in an underground mine to detect these resonances and see how they change in the process of rock degradation leading up to collapse.

Accelerometers were grouted into a mine roadway roof, along with displacement and stress sensors. Waveforms from mining-induced microseismic events were recorded. The spectra of the coda of these events were used to search for resonances. Strong resonance modes were indeed seen, which were stable over time. The resonance frequencies did decrease in the days prior to roof collapse, in parallel with measured stress changes. At the time when significant movement was detected in the roof rocks, the resonance modes changed completely, probably due to delamination of the rock causing seismic decoupling. This means that resonance modes could be used for roof stability monitoring.

0830–1010
Day 2 Session 1 Stream E

MINERALS – PETROPHYSICS

A MOVING 3 COMPONENT FLUXGATE MAGNETOMETER TO MEASURE REMANENT AND INDUCED MAGNETIZATIONS IN DRILL CORE

Clive Foss[1]*, *Keith Leslie*[1] *and Wayne Stuart*[1]
[1]CSIRO

We have developed a 3 component magnetometer which can be drawn along a track to produce a detailed 3 component mapping of a traverse of up to 3 metres length. One of the main applications for this instrument is to rapidly map both remanent and induced magnetizations within drill-core. Continuous sections of up to 2.5 metres of drill core are logged by running the magnetometer along the side of the core. Multiple runs following successive rotations of the core enable separation of fields arising from remanent magnetization (which rotates with the core) from induced magnetization (which does not). A first-pass interpretation of the multi-track data is made using a string of dipoles as equivalent sources. More detailed model inversions are applied if required. Broken sections of core are logged with sufficient gaps between sections that the anomalies from each are well separated.

EVALUATION OF BANDED IRON FORMATION USING MAGNETIC SUSCEPTIBILITY

Robert Howard[1]*
[1]Case Consulting Pty

In a banded magnetite deposit where assays gave no indication of concentrate yield, information required for process plant design was derived from downhole magnetic susceptibility logs.

Early analysis showed poor correlation between Davis Tube Recovery (DTR) and downhole magnetic susceptibility. The role of anisotropy in this relationship was identified and a correction factor applied to bring all data to an equivalent core to bedding angle. The result was a very high definition measure of in-situ magnetite distribution from which product yield estimates could be made.

The definition of ore type according to magnetic susceptibility profile enabled the content of potential Run of Mine ore to be characterised. Information required for front end plant design relating to economic cut-off grade, magnetic separator configuration and waste rock volumes could be estimated at an early stage of project development.

The use of geophysical data has now been applied successfully to other banded formations where conventional mining block models fail to deliver the resolution of data required by process engineers.

A METHODOLOGY FOR DENSITY DETERMINATION FROM CORE IMAGERY AND ASSAYS

Adel Vatandoost[1]* *and Peter Fullagar*[2]
[1] *CODES, University of Tasmania*
[2] Fullagar Geophysics Pty Ltd

Density is an important physical parameter due to its influence on ore resource and reserve estimation. The most efficient form of density measurement is gamma-gamma logging. However, downhole density logging is rarely conducted in non-ferrous metalliferous mines. Accurate prediction of density from core images could provide an alternative means for continuous density estimation.

A Geotek Multi-Sensor Core Logging system has been used to record petrophysical properties and also core imagery on archival drill core from Ernest Henry mine, Queensland, Australia for geometallurgical studies. Mineral grades estimated from the classified core images were not sufficiently reliable for density prediction. However, the fractional volumes can be adjusted to ensure consistency with assay data.

A linear programming algorithm was developed for this purpose. Given corrected volumes and mineral densities, it was then possible to predict density continuously along the drill hole. At Ernest Henry the average relative error between image-based density and Geotek gamma-gamma density was 3.5%.

CASING CORRECTION OF SLIMLINE DENSITY LOGS FOR IRON ORE EXPLORATION

James Wordsworth[1]*, *Fredy Giraldo*[1] *and Julian Morales*[1]
[1]Weatherford

Slimline geophysical logs are frequently used worldwide in iron ore exploration because they provide key data for ore evaluation. Application can be limited by the fact that many formations associated with iron ore deposits are friable, increasing the occurrence of borehole collapse before geophysical logs can be obtained. A cased-hole correction scheme for density logs based on an existing technique developed for oil and gas (C–thru) has been developed. The technique enables accurate and reliable near-spaced density measurements in a cased-hole (or through-rods) environment by recharacterising the response equations of the density tool to account for the casing or rods. The method effectively treats the casing or rods as part of a "modified" density tool. The method means that it is possible to obtain quantitative data when the logging tools are run inside the drilling rods. The application of this technique minimizes the risks associated with logging unstable open holes in iron ores, and can reduce costs and operation times.

0830–1010
Day 2 Session 1 Stream F

NEAR-SURFACE – ARCHAEOLOGICAL GEOPHYSICS

AN OVERVIEW OF AUSTRALIAN ARCHAEOLOGY: A NEAR SURFACE GUIDE

Fiona Hook[1]*
[1]Archae-Aus Pty Ltd

As a topic "Australian archaeology" is immensely vast and covers close to 60 000 years of history with initial colonisation by the ancestors of Aboriginal Australians through to the maritime and industrial archaeology of more recent immigrants. During this keynote I will delve into the history and prehistory of Western Australia as evidenced through the results of exiting new research projects ranging from the enigmatic rock art of the Kimberley through the Pleistocene use of dusty caves in the Pilbara to the shipwrecks in the depths of the Roaring Forties.

GEOPHYSICAL REMOTE SENSING OF A HISTORICAL ABORIGINAL GRAVESITE IN QUAIRADING, WESTERN AUSTRALIA

Lisa J. Gavin[1]*, *Thomas Hoskin*[1], *Ben Witten*[1], *Jeffrey Shragge*[1], *Adrian Petersen*[1] *and James Deeks*[1]
[1]The University of Western Australia

Burial sites have extreme cultural significance to societies around the world. Until recently, insufficient recognition of Aboriginal heritage in Australia has led to a very poor

understanding and documentation of many culturally significant locations, including burial sites. In some cases, sites have been preserved through the efforts of local people; however, others were subsequently redeveloped or even completely destroyed. Local Aboriginal people are usually the best source of information regarding these locations and can identify broad regions with historical significance, but seldom do they provide precise details about individual grave locations. There are still many Aboriginal gravesites throughout Australia where the exact burial locations are unknown. Locating gravesites – and doing so in a way that minimises site disturbance – is paramount to any investigation and preservation program. For efficient investigation of large areas, geophysical remote sensing provides practical and non-invasive tools for investigation of large poorly documented burial areas.

The UWA Society of Exploration Geophysicists Student Chapter, in conjunction with the South West Aboriginal Land and Sea Council, acquired several near-surface geophysical surveys over a known aboriginal burial site near Quairading, Western Australia. Multiple techniques were used to delineate possible grave locations, including ground penetrating radar (GPR), magnetics and conductivity. While work is ongoing with the data processing and integration, and future surveys are planned, early indications show anomalies that may be related to burial locations.

GEOPHYSICAL SURVEY RESULT OF ANCIENT TURKISH TOMBS

Tseedulam Khuut[1]*, *Ichinkhorloo Bayanmunkh*[1] *and Takayuki Kawai Niigata*[2]
[1]*Mongolian University of Science and Technology*
[2]Niigata University, Japan

Archaeological methods involve excavation, which is time consuming. Sometimes, this effort may not be very cost-effective since there are risks of damaging or missing the archaeological remains. On the other hand, information about the location, depth, size and extent of buried archaeological remains may be determined by means of geophysical investigation, which is carried out easily and quickly on the surface without disturbing or damaging the buried archaeological structures. Mining activity associated with increased, small-scale miners using metal detectors to plunder and to damage archaeological objects in Mongolia. In order to protect archaeological objects and remains, we carried out archaeo-geophysical research work in Bulgan province, central Mongolia. Archaeologists believe ancient remains' history related to seventh century. We carried out magnetic survey, GPR measurement, and resistivity tomography in ancient remains, and successfully detected in buried objects.

1030–1210
Day 2 Session 2 Stream A

PETROLEUM – STRATIGRAPHY AND FACIES 1

INTEGRATION OF SEISMIC STRATIGRAPHY AND SEISMIC GEOMORPHOLOGY FOR PREDICTION OF LITHOLOGY; APPLICATIONS AND WORKFLOWS

Henry Posamentier[1]*
[1]Independent Consultant and ex-Chevron

As high-quality 3D seismic data has become widely available, stratigraphic interpretation has significantly improved our ability to predict the subsurface distribution of lithologies. Stratigraphic interpretation of seismic data involves the integration of stratigraphy and geomorphology, with integrated section and plan view images yielding robust interpretations of stratigraphic architecture and associated lithology. Key aspects of successful application of seismic stratigraphic analysis are: (1) integrating section and plan views in an iterative workflow, (2) understanding and recognizing geologically-meaningful patterns both in section and plan view, and (3) having efficient and creative workflows to quickly analyze geophysical data.

Seismically-derived geologic interpretations can have significant impact on exploration and production in the following ways:

Geology: (1) prediction of lithology, (2) prediction of compartmentalization, (3) development of depositional analogs, (4) Enhanced understanding of geologic processes.

Geophysics: (1) provides depositional context for geophysical analyses (e.g., DHI analysis, reservoir properties from seismic), and (2) quality control for geophysical processing.

Numerous examples from a variety of different depositional settings will be shown and key workflows will be illustrated.

GEOPHYSICS OF STRATIGRAPHIC FACIES IDENTIFICATION: EMERGENT PHASES OF SELF ORGANIZATION AND THE MALLAT SCATTERING TRANSFORMATION

Michael Glinsky[1]*
[1]Halliburton

A framework for the analysis of stratigraphic facies as emergent phases of self organization will be presented. An example will be given of turbidite deposition that is governed by a system of partial differential equations. It will be shown how the boundary

conditions and coefficients of the PDEs parameterize a phase space that is divided into distinct phases, or what is more commonly called facies. A method of renormalization of the texture of geologic outcrops, seismic data, and well logs will be presented that gives the scale dependance of the PDE coefficients and boundary conditions. This specification of the running coupling coefficients or S-matrix of the physics gives the form of the PDE as well as the coefficients and boundary conditions. Practically this gives a unique fingerprint, or "attribute" (technically a metric) of the geologic facies. The mathematical framework is based on the Mallat Scattering Transformation – an iterative wavelet transformation.

1030–1210
Day 2 Session 2 Stream B

PETROLEUM – LABORATORY MEASUREMENTS

JOINT INVERSION OF P-, AND S-WAVE TRAVEL TIMES FOR CHARACTERISATION OF ANISOTROPIC MATERIALS USING LASER DOPPLER INTERFEROMETRY MEASUREMENTS

Andrej Bóna[1]*, *Boris Gurevich*[1], *Roman Pevzner*[1], *Maxim Lebedev*[1] *and Mahyar Madadi*[1]
[1]Curtin University

We used laser Doppler interferometer for measuring the displacement on the sample surface. These measurements allow us to clearly separate different wave types, whose picked travel times are used for estimation of VTI anisotropy parameters. One of the observations in this study is the very strong amplitude of critically refracted SP wave at the measurement surface. We confirmed the characteristics of this wave by numerical modelling. We used this wave to improve the estimates of the anisotropy. The observed strong amplitude of this wave can have strong implications for the interpretation of ultrasonic measurements.

BROADBAND LABORATORY MEASUREMENTS OF DISPERSION IN THERMALLY CRACKED AND FLUID-SATURATED SODA-LIME-SILICA GLASS

Yang Li[1]*, *Emmanuel David*[1], *Ian Jackson*[1] *and Douglas Schmitt*[1]
[1]Australian National University

To better understand the dispersion of seismic velocities arising from stress-induced fluid flow, broadband laboratory measurements have been conducted on a range of synthetic samples. Forced oscillation methods providing access to low frequencies (mHz – Hz) were combined with measurements at MHz frequencies with ultrasonic methods. Either fully dense soda-lime-silica glass or aggregates of sintered glass beads were subject to broadband tests before and after thermal cracking under dry, argon- and water-saturated conditions in sequence. Crack closure effects under pressure are observed on all samples. A systematic increase in shear modulus, attributed to the suppression of 'squirt' flow, has been monitored on the low-porosity (approximately 2%) cracked glass-bead specimen with both argon and water saturation at ultrasonic frequency. The use of samples with different porosities varying from 0 to 6% promises to distinguish the roles of pores and cracks in fluid-flow-induced dispersion.

STRESS-ASSOCIATED SCATTERING ATTENUATION AND INTRINSIC ATTENUATION FROM ULTRASONIC MEASUREMENTS

Li-Yun Fu[1]*, *Yan Zhang*[1], *Wei Wei*[1], *Bing Zhang*[1] *and Zhenxing Yao*[1]
[1]Institute of Geology and Geophysics, Chinese Academy of Sciences

Acoustic attenuation has been proved to be an indicator of stress changes in solid structures. Acoustic coda, as a superposition of incoherent scattered waves, reflects small-scale random heterogeneities in solids. Acoustic coda attenuation, as a combination of intrinsic attenuation and scattering attenuation, contains information on stress changes as a result of changes in the physical state of small-scale heterogeneous structures. Based on the ultrasonic measurements of a rock sample with intra-grain pores and fractures under different pore-pressure induced effective stresses, we compute the stress-associated coda attenuation quality factors QPC and QSC as a function of frequencies. Based on the digital heterogeneous cores of the sample, the experimental results are validated and corrected with numerical results by the finite-difference simulation of Biot's poroelastic equations and the Monte Carlo simulation of multiple scatterings, respectively. The quality factors characterize its scale dependence of scattering attenuation on stress variations in rocks. We compare them with the intrinsic attenuation quality factors QP and QS calculated by the spectral ratio method and BISQ model, respectively, from ultrasonic measurements. Comparisons demonstrate that the scattering attenuation is much stronger, particularly when ultrasonic wavelengths are comparable to the scale of pores and grains. The intrinsic and coda attenuations versus increasing effective stresses present quite different nonlinear features, where QPC and QSC show a greater sensitivity to pore pressure than QP and QS.

X-RAY COMPUTED TOMOGRAPHY INVESTIGATION OF STRUCTURES IN CLAYSTONE AT LARGE SCALE AND HIGH SPEED

Gerhard Zacher[1]*, *Thomas Paul*[1], *Annette Kaufhold*[2] *and Werner Graesle*[2]
[1]GE Sensing & Inspection Technologies
[2]Federal Institute for Geosciences and Natural Resources

In the past years X-ray Computed Tomography (CT) became more and more common in geo-scientific applications and is used from the µ-scale (microfossils) up to the dm-scale (cores or soil columns). Hence a variety of different systems was adapted to these applications.

In the present paper we investigate CT results from an Opalinus Clay core (diameter ~100 mm) considering the 3D distribution of cracks. Two CT systems are compared both, with specific ad- and disadvantages: the large and flexible phoenix v|tome|x L300 high energy CT scanner and the high throughput speed|scan CT 64 helix CT system (both GE Measurement & Control).

The results are compared regarding the contrast resolution, spatial resolution, and scanning speed. The fast medical scanners provided a quick overview whereas the microfocus tube provided a more detailed view on cracks.

1030–1210
Day 2 Session 2 Stream C

MINERALS – MT METHODS 2

INTERPRETATION OF RESISTIVITY AND MAGNETIC ANOMALIES FROM THE FOX RIVER SILL, TRANS HUDSON OROGEN, CANADA

Ian Ferguson[1], Darrell Epp[1], Thamara Saturnino[1], Marcelo Orellana[1], Jim Craven[2] and Alan Jones[3]*
[1]University of Manitoba
[2]Geological Survey of Canada
[3]Dublin Institute for Advanced Studies

The Fox River Belt is a sequence of rocks at the margin of the Proterozoic Trans Hudson Orogen in Canada that have been intruded by the Fox River Sill, a stratiform ultramafic–mafic sill. An earlier 2D magnetotelluric (MT) study of the sill revealed a conductor that is spatially correlated with a sheared serpentinite unit in the Lower Central Layered Zone of the sill. Re-analysis of the data from 10 MT sites lying on a 1.4 km north–south profile, approximately perpendicular to geological strike, across a 1 km wide portion of the sill produced a resistivity model containing a conductor with an average resistivity of <1 ohm.m.

Using aeromagnetic data from a profile subparallel to the MT profile, a geologically constrained magnetic model of the sill was constructed. Empirical susceptibility-magnetic mineral content relationships were used to estimate the magnetite content of the different geological units from the magnetic model. The results indicated a susceptibility of 0.2 SI for the sheared serpentinite unit, suggesting a magnetite content of ~5% which compares with petrological estimates of up to 10%.

The bulk resistivity of geological units in the resistivity model was interpreted in terms of metallic mineral content using published resistivity relationships and a range of connectivity models. Integration of these results with magnetic and geological analyses suggests the enhanced conductivity in the sheared serpentinite is a result of a higher degree of magnetite interconnectivity due to the shear fabric. The analysis also reveals that although portions of the adjacent Marginal Zone in the sill contain concentrations of magnetite similar to those in the sheared serpentinite, the significantly higher resistivity of the Marginal Zone can be explained by a lower degree of magnetite interconnectivity.

DEEP CONDUCTIVITY ANOMALY OF THE DARLING FAULT ZONE – IMPLICATIONS FOR FLUID TRANSPORT IN THE PERTH BASIN

Thomas Hoskin[1], Klaus Regenauer-lieb[2] and Alan Jones Dias[3]*
[1]University of Western Australia
[2]CSIRO
[3]Dublin Institute for Advanced Studies

The Darling Fault Zone (DFZ) is one of the largest lineaments in the world, mapped over approximately 1000 km. It is a long-lived feature with imprints of multiple deformation phases with multiple orientations since the Archean. Although it is still topography forming in some areas, and therefore must have recent activity, its seismic quiescence reduces the perceived need for scientific investigation into the extent and physical properties of this crustal scale fault. Seismic activity is common in the south west of Western Australia and evidence suggests these are located on faults that communicate with the DFZ. It is therefore paramount to have more detailed understanding on the fault architecture and the role of fluids in lubricating aseismic slip.

Magnetotelluric (MT) data are acquired along transects across the Perth Basin and the western margin of the Yilgarn Craton providing deep, high resolution data about the electrical structure of the DFZ. In this contribution we focus on the interpretation of the data, details on the acquisition and analysis are presented in the poster session.

Using impedance tensor analysis and 2D modelling techniques, we map the DFZ to the base of the crust, confirming it as a lithospheric feature. We reveal a complex pattern of deep-seated conductivity associated with the foot wall of the DFZ that persists to depth. Resistivity models are used to estimate porosity on the DFZ, identifying a more complex internal structure for the DFZ than generally considered, with important implications for fluid transport in the basin.

RESISTIVITY STRUCTURES OF WESTERN VICTORIA, AUSTRALIA FROM 2D AND 3D MODELLING OF MAGNETOTELLURIC DATA

Sahereh Aivazpourporgou[1], Stephan Thiel[1], Patrick Hayman[2], Naser Meqbel[3], Louis Moresi[4] and Graham Heinson[1]*
[1]University of Adelaide
[2]Monash University
[3]Helmholtz Centre Potsdam
[4]Melbourne University

A long period magnetotelluric (MT) survey, comprising 39 sites over an area of 270 by 150 km, has identified partial melt within the thinned lithosphere of Quaternary Newer Volcanics Province (NVP) in southeast Australia. MT inversion models reveal several important tectonic features and unravel critical information about the tectonics of the area. The models have imaged a conductive anomaly beneath the NVP at ~40-80 km depth, which is consistent with the presence of 1.5–4% partial-melt in the lithosphere. The conductive zone is located within thin juvenile oceanic lithospheric mantle, which was accreted onto thicker Proterozoic continental lithospheric mantle, suggesting that the NVP origin is due to decompression melting within the asthenosphere, promoted by lithospheric thickness variations in conjunction with rapid shear. In addition, inversion modelling shows that there is a conductivity contrast across the Moyston Fault that suggests the transition from Proterozoic continental lithospheric mantle under the Delamerian Orogen to the Phanerozoic lithospheric mantle under the Lachlan Orogen.

CARPENTARIA CONDUCTIVITY ANOMALY REVISITED WITH PRELIMINARY MAGNETOTELLURIC RESULTS FROM THE SE MT ISA SURVEY 2014

Millicent Crowe[1] and Peter Milligan[1]*
[1]Geoscience Australia

The region to the east of Mt Isa has complex electrical conductivity, with conductive basin sediments overlying the deeper Carpentaria Conductivity Anomaly (CCA). Early magnetotelluric (MT) model results show alignment of the CCA with aeromagnetic, gravity and seismic features, together

implying that they define the major structural edge of the Mt Isa Block. Profile MT data acquired during the previous 20 years have helped refine the position and depth of the CCA. New MT and deep seismic reflection data have recently been acquired in 2014 along a NW to SE profile, funded by the Geological Survey of Queensland's Greenfields 2020 Program in conjunction with Geoscience Australia. These new data provide further evidence of the complex nature of the crustal conductivity in this region. Induction vectors indicate that the CCA itself is braided into several zones which may define deep-seated fracture systems.

1030–1210
Day 2 Session 2 Stream D

MINERALS – MINE SCALE GEOPHYSICS 2

GEOSTATISTICALLY AND DRILLING CONSTRAINED MAGNETIC INVERSION FOR PREDICTING MINERALISATION AT THE BASIL CU-CO DEPOSIT

Matthew Zengerer[1]*
[1]Intrepid Geophysics

The Basil Cu/Co deposit comprises a 26.5 Mt JORCcompliant inferred resource of copper and cobalt, grading 0.57% Cu and 0.05% Co. It lies in the Harts Range, central Australia, within the Riddock Amphibolite of the Irindina Province. The deposit coincides with a prominent anomaly in aeromagnetic data. Intersections of mineralisation at depth follow the magnetic anomaly trend. Analysis of drilling within the mineralised zone determined a spatial association between pyrrhotite with high magnetic susceptibility and chalcopyrite, with no other significant magnetic mineralisation present.

A study was commissioned to examine if geophysical inversion could predict the distribution of mineralisation, using pyrrhotite as a proxy for chalcopyrite, from the surface to the drillhole intersections, as well as predicting further mineralisation at depth or in the vicinity of the deposit. Commercial software was chosen for performing geostatistical analysis, 3D geological modelling, forward modelling and stochastic inversion.

Petrophysical data from core and information on mineralisation from drilling were used to constrain 3D geological modelling of mineralisation based on domain kriging of susceptibility data and sulphur assays. Magnetic data was conditioned for inversion in Intrepid software. Sensitivity testing of results to source depth and distribution was performed using 3D forward modelling. Alternative 3D geological models were tested during inversion for their behaviour and adherence to observed drilling data and the limitations imposed by the sulphide distribution in the geostatistics.

The resulting initial geological model had known property voxels from drilling fixed and surrounding property voxels locally interpolated from kriging. Using these as a seed, geophysical inversion was performed alternating property and lithology inversion, until a desired minimum misfit with the observed magnetics signal was reached.

The new predicted mineralisation distribution was compared with estimated mineralisation shells from conventional geostatistical modelling and found to be in good agreement, with reliability increasing closer to the surface.

MAGNETIC MODELLING AND GEOLOGICAL MODELLING COME TOGETHER AT THE KINTYRE URANIUM DEPOSIT

Andrew Fitzpatrick[1]* *and Penny Large*[1]
[1]Cameco Corporation

We present a case study whereby unconstrained magnetic modelling accurately defined the altered host lithology of the Kintyre Uranium deposits, verified by detailed geological modelling. The Kintyre Uranium deposits are hosted by a sequence of iron and carbonate rich meta-pelites, which makes it an ideal target for magnetic prospecting. As part of the resource definition, magnetic modelling and geological modelling were performed over the Kintyre deposit independently. In the process of further refinement of the magnetic model through incorporation of geological constraints it was determined the two models were already highly complementary and further modelling was not warranted, particularly at the resolution of the magnetic data. This case study demonstrates that in some geological environments, unconstrained geophysical models can adequately map stratigraphy and structure for drillhole target generation.

MINE SCALE CONSTRAINED GEOPHYSICAL INVERSION; A CASE STUDY AT THE DARLOT-CENTENARY GOLD MINE

Sarah Monoury[1]*, *Ben Jupp*[1] *and Andrew Foley*[2]
[1]SRK Consulting
[2]Gold Fields

SRK Consulting (SRK) conducted a geological and geophysical modelling study of the Darlot-Centenary Gold Mine, Western Australia. This study defined geological boundaries in areas where drilling was limited, allowing for targeting of potential extensions to the gold mineralisation. 3D geological modelling of the structural setting and geometry of gold mineralisation within the deposit has shown a strong relationship between gold grade and a magnetic sub-domain within the Mount Pickering Dolerite. The magnetic dolerite domain is considered as a more prospective unit and a target for exploration drilling.

To define the boundaries of the dolerite multiple unconstrained magnetic inversion, models were conducted. This was followed by geologically constrained inversions. The resulting models were consistent and both methods are capable of resolving the prospective magnetic dolerite domain. However, the constrained inversion model ultimately provided a better representation of the geometry of the folded dolerite units. Using the inversion modelling, SRK was able to provide greater certainty in the subsurface geometry of the prospective Mount Pickering Dolerite, providing greater accuracy for the potential near mine exploration targets.

BLIND TEST OF MUON GEOTOMOGRAPHY FOR MINERAL EXPLORATION

Joel Jansen[3]*, *Douglas Bryman*[1] *and James Bueno*[2]
[1]University of British Columbia
[2]CRM GeoTomography Technologies Inc.
[3]Teck Resources Limited

Muon geotomography is a new geophysical imaging technology that creates 3D images of subsurface density distributions. Similar in concept to computed tomography scanning, muon geotomography uses naturally occurring cosmic radiation that gets attenuated when traversing matter. Cosmic ray muon data were acquired in the Pend Oreille Zn-Pb mine in Metaline Falls, Washington State, USA without prior knowledge of the presence or absence of ore bodies. The resulting 3D density distribution indicated a substantial volume of rock with higher density than the host stratigraphy above the survey location. Subsequently, a model of existing ore shells based on drill core data was provided and a simulation of the expected muon tomography data was found to be consistent with the muon geotomography measurements. This is the first blind test demonstration of muon geotomography applied to mineral exploration.

1030–1210
Day 2 Session 2 Stream E

NEAR-SURFACE – ENGINEERING GEOPHYSICS

DEVELOPING URBAN AND MINING GEOPHYSICAL INSTRUMENTS AND METHODS: PUSHING THE BOUNDARIES

Alireza Malehmir[1]*
[1]Uppsala University

It is becoming increasingly evident that our understanding of the geological conditions in the shallow subsurface is limited. This is especially apparent in large cities and areas covered by lakes where underground infrastructure such as tunnels, subways and train stations have to be constantly developed or expanded to facilitate the daily life and transportation. The degree to which we can understand geological conditions such as these also has great economical and environmental effects for mine planning. What makes these environments similar and challenging targets for geophysical investigations are the various sources of noise and restriction (both in time and space), which require the equipment to be versatile and to produce minimal disruption as well as fast to set up and pack. Direct observations of the subsurface are cumbersome, expensive and sometimes impossible. However, if properly designed and implemented, geophysical methods are capable of imaging detailed subsurface structures and can successfully be used to provide crucial information for site characterizations, infrastructure planning, brown- and near-field exploration and mine planning. To illustrate the potential of geophysical methods in these environments, I will show prototype seismic and EM instrumentation and their applications that are especially geared for noisy environments and areas where high-resolution images of the subsurface are needed. The presentation will be supported by several examples from these two areas.

MULTICHANNEL 3D GROUND PENETRATING RADAR – ADVANCES IN CIVIL INFRASTRUCTURE SCANNING

Lee Tasker[1]* *and Kathleen McMahon*[2]
[1]University of Western Australia
[2]Draig Geoscience Pty. Ltd.

The scope of this paper is to highlight improvements in Ground Penetrating Radar (GPR) as an infrastructure condition assessment tool, in particular through the use of multichannel 3D GPR.

Multichannel 3D GPR is a relatively new and alternative infrastructure scanning tool which can assist geophysicists and engineers in providing 100% sub-surface coverage of an investigation area, where site access is possible. Advantages of an increased level of subsurface coverage using multichannel 3D GPR includes providing the user with improved accuracy in highlighting and quantifying regions that may require further invasive testing for future maintenance programs and also possible long-term monitoring.

This paper briefly discusses current applications of standard GPR for infrastructure condition assessments and how multichannel 3D GPR can improve knowledge of the sub-surface in these application areas.

Visualisations of multichannel 3D GPR data outputs with interpretations have been presented to illustrate the improved subsurface information made available from this method. The example presented is an approximately 4 m long section of multichannel 3D GPR data acquired along the surface of a reinforced concrete-lined tunnel.

DETECTION OF DEEP BURIED METAL OBJECTS WITH THE ULTRATEM

Stephen Billings[1]*, *Malcolm Cattach*[1] *and Michael Laneville*[2]
[1]Gap Geophysics Australia
[2]MMG LXML Sepon

The UltraTEM Deep metal detection system combines a rugged, fast-switching transmitter with a powerful custom designed generator and one to ten three-component receiver coils that collect time-domain electromagnetic induction data across a wide time-range. The roving receiver is operated inside a fixed loop of copper cable, typically 30–150 m long and 5–50 m wide. The large size of the loop results in a slow falloff in primary field with depth and effective excitation of deep buried unexploded ordnance as well as other metal objects such as Ground Engaging Tools (GET). We describe the results of an extensive trial of the UltraTEM system at a magnetically challenging site in Laos. The UltraTEM was able to detect all seeded items buried at depths down to 5 m across a wide range of site conditions. Subsequent work with the system at a different site demonstrated an ability to detect GET to depths of at least 3.0 m in a magnetite stockpile.

1330–1510
Day 2 Session 3 Stream A

PETROLEUM – STRATIGRAPHY AND FACIES 2

SEISMIC GEOMORPHOLOGY OF MIXED-INFLUENCE COASTAL-DELTAIC SYSTEMS

Simon Lang[1]*
[1]Chevron

Recognition of mixed processes on coastal-deltaic systems end members (relative power of W- wave, T -tide and F-fluvial processes) is important for both exploration and reservoir characterization. Mixed-influence systems impart asymmetry and heterogeneity that impact prediction of subsurface lithology (facies), static modelling of various connectivity scenarios, and ultimately exploration to development well planning. Numerous detailed studies of these mixed-influence systems from modern analogs, outcrop and core, and log data requires calibration with high resolution seismic visualisation.

Although typical stacking of genetic units (5–25 m parasequence-scale) is at or below the resolution limits of most 3D seismic data, focused seismic stratigraphic workflows can image detailed geomorphic plan-forms, which reflect features at the limits of detection (<10 m).

A range of seismic stratigraphic workflows are illustrated (single and multiple datums, horizon slicing, flattening, optical stacking, channel/feature chasing, and attribute calculations) with a variety of example seismic datasets. These workflows can produce detailed images of complex facies juxtapositions at or near the detection limit. Specifically, we show examples of varying degrees of wave, fluvial and tidal influence, recognized by characteristic plan-form features at element to complex scales including (but not limited) to the following:

1. High to low reflectivity, continuous elongate arcuate, divergent to subparallel reflections (either convex or concave in a basinward direction), indicative of wave-dominated (W), to wave-dominated, but tide-influenced (Wt) strand-plains and associated down-drift chenier-plains (Tw).

2. High reflectivity, continuous and sinuous channel-form reflection features adjacent to sets of recurved-lineations (convex-basinward), interpreted as the trace of tide-influenced estuarine channels (Tf) or distributary channels (F, Ft).

3. Transparent seismic reflections with internal channel-forms, and dendritic or reticulate planforms, indicative of tide-dominated shorelines including tidal flats and associated tidal creeks (T, Tw, Twf).

4. High to low reflectivity, continuous or discontinuous, low- to high-sinuosity channel-form reflections, either isolated or amalgamated, indicative of fluvial-dominated channel belts, and associated abandoned meander loops (F, Ft), associated with a background of transparent to highly reflective continuous to discontinuous reflections, representing the alluvial or coast-deltaic floodplain.

This approach can assist prediction of reservoir connectivity in wave-dominated systems, with the recognition of internal baffles and local barriers associated with shale-prone parts of the depositional system, both within and between parasequences.

QUATERNARY ISOLATED CARBONATE BUILD-UPS IN THE TIMOR SEA (NW AUSTRALIA) – UNDERSTANDINGS AND IMPLICATIONS

Muhammad Mudasar Saqab[1]* *and Julien Bourget*[2]
[1]Centre for Petroleum Geoscience and CO_2 Sequestration
[2]University of Western Australia

Distribution and growth history of isolated carbonate build-ups (ICBs) is controlled by complex interplay between various tectonic, eustatic, and oceanographic parameters. Quaternary ICBs in the Timor Sea (NW Australia) are located in tropical waters, and at present they form clusters of ~150 build-ups, developing 2 to 85 km from the edge of a wide continental shelf. The tectonic evolution of the Timor Sea lead to regional changes in the oceanography and flexural deformation of the NW Bonaparte Basin, which in turn had a major impact on the evolution of ICBs. Flexure-induced fault activity produced structural topography for the growth of ICBs over 'highs', while oceanic current through Timor Trough provided warm and nutrient-rich water. Our results demonstrate that, despite potentially good conditions for carbonate production, ICBs did not form until the Mid Pleistocene (ca. 0.582–0.8 Ma BP). This age corresponds to the onset of repeated, high-amplitude (+120 m) sea level fluctuations with rapid deglacial rises and slow falls. Thus, we infer that the NW Australia ICBs formed due to: (1) structural shaping of the margin; (2) oceanographic changes, and; most importantly, (3) onset of repeated short-term transgressions reactivating the carbonate production along isolated highs. The distribution and growth of ICBs could be useful to understand the evolution of ancient ICBs that formed along very wide shelves and epeiric seas.

GEOMORPHOLOGY AND SEISMIC STRATIGRAPHY OF THE EARLY CRETACEOUS DELTA IN THE VLAMING SUB-BASIN AND IMPLICATIONS FOR SEAL QUALITY

Chris Southby[1]*, *Megan Lech*[1], *Liuqi Wang*[1] *and Irina Borissova*[1]
[1]Geoscience Australia

The early Cretaceous South Perth Shale has been previously identified as the regional seal in the offshore Vlaming Sub-basin. The South Perth Shale is a deltaic succession, which infilled a large palaeotopographic low in the Early Cretaceous through a series of transgressive and regressive events. A study undertaken at Geoscience Australia has shown that the seal quality varies greatly throughout the basin and in places has very poor sealing properties. A re-evaluation of the regional seal based on seismic mapping determined the extent of the pro-delta

shale facies within the South Perth Shale succession, which provides effective sealing capacity.

New sequence stratigraphic interpretation, seismic facies mapping, new and revised biostratigraphic data and well log analysis were used to produce palaeogeographic reconstructions which document the distribution of depositional facies within the South Perth Shale and reveal the evolution of the early Cretaceous deltas.

Our study documents spatial variations in the seal quality and re-defines the extent and thickness of the regional seal in the offshore central Vlaming Sub-basin. It provides an explanation for the lack of exploration success at some structural closures and defines constraints on the possible location of valid plays.

1330–1510
Day 2 Session 3 Stream B

PETROLEUM – THEORETICAL STUDIES

BROADBAND DATA FROM FLAT STREAMERS: CONSIDERATIONS FOR ACQUISITION AND PROCESSING

Edward Hager[1]* *and Phil Fontana*[1]
[1]Polarcus

Broadband acquisition aims to improve the bandwidth of seismic data, which in practice means extending the low-frequency end of the spectrum without limiting the high-frequencies beyond the natural earth response (Q-factor). These "unconventional" techniques focus on the receiver-side ghost, and commonly used are co-located velocity and pressure sensors and dual-depth hydrophone or variable depth hydrophones, which either capture phase or timing differences respectively of the receiver ghost. All these methods rely on processing to achieve the final receiver side de-ghosted data as the "dumb sum" of the measurements will lead to poor results, or post-stack broadband data in the case of slant streamer. With sufficient signal-to-noise in the data it is possible to de-ghost the receivers towed at a moderate single depth by tuning the acquisition design, with consideration of the source emission response in combination with the streamer reception response. A test line was acquired that shows the equivalency of slant streamer and flat depth streamers in terms of post-stack amplitude spectra, showing that the acquisition design and pre-stack deghosting processing methodology is effective in providing broadband data.

LINKING ELECTRICAL AND HYDRAULIC CONDUCTIVITY THROUGH MODELS OF RANDOM RESISTOR NETWORKS

Alison Kirkby[1]* *and Graham Heinson*[1]
[1]University of Adelaide

We present models of random resistor networks to relate electrical resistivity to fracture permeability in the upper crust. In this approach, the upper crust is modelled as a network of resistors that are randomly assigned to be either electrically and hydraulically conductive or resistive based on a network-wide probability of connection. In the models presented here, the conductive resistors are assigned resistance values based on a constant fracture diameter of 1 mm and a fluid resistivity of 0.1 Ωm, with variable fault length distributions and probabilities of connection. We have found that the permeability is very sensitive to both of these parameters, increasing to 8.33×108 times the matrix permeability in the fully connected case. The resistivity is less sensitive, increasing by a factor of 1000.

LAYER-INDUCED SCATTERING ATTENUATION AND VTI ANISOTROPY – NW SHELF AUSTRALIA SYNTHETIC STUDY

Roman Pevzner[1], *Tobias Muller*[2], *Andrej Bona*[2] *and Boris Gurevich*[1,2]*
[1]CSIRO
[2]Curtin University

Seismic attenuation and anisotropy in the overburden can significantly affect seismic image quality, including amplitudes of the target horizons. Therefore, understanding magnitudes, causes and spatial distribution of attenuation and anisotropy is important for seismic imaging and reservoir characterization. Thin layering can cause both scattering attenuation and anisotropy. These phenomena can only be significant, if there is a strong contrast in elastic properties between the layers. We present a case study from North-West Shelf of Australia, where presence of shallow stiff carbonate layers can be responsible for deterioration of seismic data quality through both attenuation and anisotropy.

PRESTACK TIME MIGRATION IN COMMON SOURCE DOMAIN WITHOUT VELOCITY MODEL

Mohammad Javad Khoshnavaz[1]*, *Andrej Bona*[1] *and Milovan Urosevic*[1]
[1]Curtin University

Most of the migration techniques require an input velocity model. Velocity analysis is one of the most critical stages in seismic data processing. Standard ways to find the velocity model are constant velocity stack and Semblance velocity analysis, which can be time consuming and labour intensive. In this work, we introduce a new approach to obtain the migration velocity and the relevant pre-stack time migration algorithm that is time effective and does not require any input velocity model prior to imaging. The velocity components, in each point in a common source gather, are achieved by calculating the radius of the curvature of seismic reflected wave-front. The corresponding velocity formula is a function of local derivatives of two way travel times with respect to the position of receivers. Computational experiments with synthetic seismic data examples confirm the theoretical expectations and demonstrate the feasibility of the proposed technique.

1330–1510
Day 2 Session 3 Stream C

MINERALS – ELECTRICAL-ELECTROMAGNETIC METHODS

CORRECTING EM SYSTEM BANDWIDTH LIMITATIONS

James Macnae[1]*
[1]RMIT University

All EM transmitters, sensors and data acquisition systems have bandwidth limitations. Transmitters have upper bandwidth limitations due to finite slew rate issues, and systems have a lower bandwidth set by the base frequency used.

Receivers and data acquisition systems ideally should have a flat bandwidth response that spans the transmitted signal bandwidth. The data acquisition system should sample fast enough to capture the highest frequencies of interest, with anti-alias filters to prevent data contamination from unwanted signals. Sensors however may have physical bandwidth limitations, for example fluxgates and feedback MT sensors may have an upper corner frequency of a few kHz, and ARMIT and feedback MT sensors have lower corner frequencies in the sub 1 Hz range. In many cases, the sensor corner frequency can be mathematically described as a single- or multi-pole response. In this case, it is possible to exactly deconvolve the data to exactly correct for the sensor imperfection. A limitation of this process is that noise as well as signal may be amplified in this correction process.

Without correction, data may be incorrectly modelled or interpreted. This paper illustrates the correction of fluxgate (mostly a time delay of hundred or more microseconds), ARMIT 2 (where a significant but exact correction is required), ANT23 feedback and 3D3 dBdt data.

USING INDUCTION COIL SENSOR OPTIMIZATION TECHNIQUES FOR DESIGNING COMPACT GEOPHYSICAL TRANSMITTERS

Joseph Hamad[1]* *and James Macnae*[1]
[1]RMIT University

We have developed and tested code to optimise electromagnetic (EM) sensors to improve performance of the ARMIT B field induction coil sensor at desired frequencies. We aim to use the optimised parameters to develop a compact air core transmitter, which will form the basis for developing a compact ferromagnetic core transmitter. Techniques for optimising induction coil sensors are well established in literature and use analytical equations for the objective and constraint functions. Alternatives for EM sensor design are also well documented. In contrast, the design of compact transmitter systems needed for portability or in boreholes have limited discussion in the literature and have many more design constraints than sensors. Our ultimate intention is to use established sensor optimisation techniques to build a compact transmitter with sufficient magnetic dipole moment.

PARETO EFFICIENT MULTI-OBJECTIVE JOINT OPTIMISATION OF EM DATA

Sebastian Schnaidt[1]* *and Graham Heinson*[1]
[1]University of Adelaide, Electrical Earth Imaging Group

Jointly inverting different data sets can greatly improve model results, provided that the data sets are sensitive to similar features. Such a joint inversion requires assumed connections between the different geophysical data sets, which can either be of analytical or structural nature. Classically, the joint problem is expressed as a scalar objective function that combines the misfit functions of all involved data sets and a joint term accounting for the assumed connection. This approach has two major disadvantages: Firstly, by aggregating all misfit terms a weighting of the data sets is enforced, and secondly, false models are produced, if the connection between data sets differs from the assumed one. We present a Pareto efficient multi-objective evolutionary algorithm, which treats each data set as a separate objective, avoiding forced weighting. The algorithm jointly inverts one-dimensional datasets from different electromagnetic techniques and also treats any additional information as separate objectives, rather than imposing them as a fixed constraint. Additional information can include, for example a priori models, seismic constraints, or well log data. Statistical analysis of the final solution ensemble yields an average one-dimensional model with associated uncertainties. Furthermore, the shape and evolution of the Pareto fronts is analysed to evaluate dataset compatibility and to judge if the assumed connection between datasets was valid.

DETERMINATION OF MODEL RELIABILITY IN 3-D RESISTIVITY AND I.P. INVERSION

M. H. Loke[1]*
[1]Geotomo Software

Mineral deposits frequently have complex structures that can only be resolved by 3-D inversion of resistivity and I.P. data. A nonlinear optimisation routine is commonly used to create a 3-D model from the measured apparent resistivity and I.P. data. It is particularly important to be able to assess the reliability of the anomalies seen in the inversion model before further tests are conducted. In this paper, we examine the model resolution (MR) and volume of investigation (VOI) approaches in determining model reliability. The MR method produces sections that are easier to interpret but more computationally intensive that puts practical limitations for models with more than 50000 cells. The VOI method can be used for any data set where an inversion can be carried out, but produces sections with more complex patterns and prone to local artefacts. Either method should be used for any interpretation to discern anomalies that are likely to be supported by the data.

1330–1510
Day 2 Session 3 Stream D

MINERALS – NEW WAYS TO ANALYSE DATA

COMBINING MACHINE LEARNING AND GEOPHYSICAL INVERSION FOR APPLIED GEOPHYSICS

Anya Reading[1]*, *Matthew J. Cracknell*[1], *Daniel J. Bombardieri*[2] *and Tim Chalke*[3]
[1]University of Tasmania
[2]Mineral Resources Tasmania
[3]Mira Geosciences

Machine learning and geophysical inversion both represent ways that the applied geophysicist might gain knowledge from field observations and remote sensed data. The two approaches represent contrasting philosophies based respectively on statistics and physics. Both potentially add insights which might help constrain 3D geology by geophysical means. Machine learning uses patterns in data to provide statistically controlled predictions, e.g. of lithology. In contrast, geophysical inversion relies on modelling the physical response of 3D geological block geometry in a deterministic manner. Although both approaches are widely used, it is not currently commonplace in applied geosciences to make use of a combined approach.

We present an example which aims to refine the 3D geology in a prospective region of west Tasmania. Although the region is geologically well-mapped, thick vegetation and significant topography present a challenging set of conditions under which to refine the lithology and block geometry to a level of detail which will support the next generation of exploration. We use multiple layers of remote sensed geophysical data to provide probabilistic information on near-surface lithology extent using the Random Forests classifier.

We show how the statistical, robust, output from the machine learning exercise can be used to guide the construction of improved volume geometry within a 3D GOCAD geological and geophysical modelling environment. This enables better constraints to be supplied to the geophysical inversion with resulting improvements in the detail of the 3D geology.

COMPARISON BETWEEN MANUAL AND AUTOMATED TARGETING FOR NOLANS BORE-STYLE RARE EARTH ELEMENT (REE) DEPOSITS

Sharon Lowe[1]*, *Lisa Vella*[1], *Richard Brescianini*[2] *and Kelvin Hussey*[2]
[1]Southern Geoscience
[2]Arafura Resources Ltd

A manual litho-structural interpretation of airborne magnetic, radiometric and digital elevation model (DEM) data over the Nolans Bore rare earth element (REE) deposit, in northern Australia, has identified additional REE targets in the area. These targets were compared to automated targets generated using a Levenberg-Marquardt neural network (LMNN) analysis of the data.

A number of different quantitative analyses were performed: one with only the geophysical data as an input and one that included the structural interpretation. The geophysical data needed modification for use in the LMNN algorithm, as the known deposit is anomalous in its absence of magnetite and a corresponding magnetic anomaly. Therefore, a shallow depth slice was extracted from a 3D inversion model of the magnetic data and the magnetic susceptibility values were inverted to form anomalies over non-magnetic regions. A Th/U ratio was calculated from the measured single radioelement responses. The structural interpretation was modified to incorporate only those faults oriented in the direction of the controlling structures at the known deposit. DEM data were used as a mask to ensure that targets were found in low-lying areas where the radiometric data is influenced less by topography or masks the underlying bedrock.

It was found that the interpreted targets closely match the predicted targets, but that the predicted targets yielded smaller, more specific locations for follow-up work.

THE FUTURE OF MINERAL EXPLORATION – AND WHAT IT MEANS FOR GEOPHYSICS

Jon Hronsky[1]*
[1]Western Mining Services

The global mineral exploration industry is currently perhaps a decade or two into the most important transition in its several thousand year history – the move from a world where discovery was primarily about surface prospecting (in various form) to a world where important future discoveries will be blind, with little or no surface expression. This transition is, and will continue, profoundly influencing all aspects of our industry, from financing and government policy through to targeting methods and detection technologies. Geophysics will play an increasingly central role in the exploration industry as this transition progresses, as it did in the analogous transition in the history of the petroleum exploration industry about a century ago. However, this future for geophysics will not simply be doing more of the same – the relationship of geophysics to the exploration industry will need to evolve significantly to enable cost-effective exploration performance in this future world. Some of the required key areas of development include; (a) better characterisation of mineral systems at multiple scales from the continental to the deposit, (b) improved integration between geological and multi-parametric geophysical observations at multiple scales, (c) improved capabilities to image critical deep-seated ore-controlling structures and perhaps metal-enriched deep source regions which are cryptic in near-surface data and (d) more specific rather than just more sensitive detection technologies, which reduce the usually high false-positive rate of geophysical targets. An important strategic enabler for these required advances will be ever increasing access to supercomputing capability. However, the potential of

entirely new physical techniques cannot be overlooked either, with Muon tomography having recently been applied to mineral exploration for the first time.

1330–1510
Day 2 Session 3 Stream E

NEAR- SURFACE – SHALLOW SEISMIC 1

ADVANCES IN SEISMIC SURFACE WAVE ANALYSIS AND INTEGRATION WITH BODY WAVES DATA

Laura Valentina Socco[1]*
[1]Politecnico di Torino

In the last decade the analysis of surface wave dispersion has become a standardly applied technique in near surface seismic exploration. The method has evolved from the local estimation of 1D VS profiles, based on the inversion of surface wave fundamental mode, to more sophisticated approaches that can provide reliable velocity models in complex geological settings presenting 2D/3D velocity distributions, with the inversion including higher modes and other guided waves. To retrieve comprehensive velocity models, surface wave and body wave data can be extracted from the same seismic records and inverted jointly, imposing structural and petrophysical constraints and overcoming the inherent limitations of both body and surface wave techniques. More recent developments of surface wave methods are aimed at adapting tomographic techniques used in earthquake seismology to small scale exploration data.

INTEGRATED REFLECTION AND REFRACTION PROCESSING OF AN ULTRA-SHALLOW SEISMIC SURVEY

Alan Meulenbroek[1]*
[1]Velseis & University of Queensland

Velseis Pty Ltd acquired and processed an ultra-shallow seismic reflection survey designed to image targets with a depth of less than 50m, including the structure of the weathering layer. Several experimental sources were implemented, each with unique frequency and amplitude characteristics.

Reflection processing was not routine since the target of interest was the weathering zone itself. Due to this, a combination of reflection and refraction processing was used in order to develop an integrated image and interpretation of the near-surface.

The results from the different processing techniques, including refraction (reciprocal method and tomography), reflection, and a depth converted stack, provide an internally consistent interpretation of the base of weathering and layering within the weathering.

IS IT TIME TO MODERNIZE NEAR-SURFACE REFRACTION SEISMOLOGY WITH FULL WAVEFORM METHODS?

Derecke Palmer[1]*
[1]University of New South Wales

Historically, near surface refraction seismology has focused almost exclusively on inverting first arrival traveltimes to generate spatially varying models of the seismic velocities in the weathered and sub-weathered regions. This study describes two approaches to full waveform near surface refraction seismology, using common offset gathers (COG) and the refraction convolution section (RCS). Full waveform refraction methods can improve the resolution and characterization of the routine mapping of the base of the weathering, through stacking, flattening and spectral analysis.

Full waveform refraction methods can usually reveal first and later events wherever reflection events are recorded within the refraction Fresnel zone. In most cases, full waveform refraction methods can provide more detailed images of the sub-surface structure than can be obtained with low resolution 1D refraction traveltime tomography.

The amplitudes of first and later events are related to the head coefficient, which in turn, is a simple ratio of the specific acoustic impedances. Both the density and the P-wave modulus models of the near surface, which are derived from the head coefficient and the seismic velocities, can be employed for more comprehensive characterization of the regolith for geotechnical and groundwater investigations, as well as for starting models for full waveform inversion.

Full waveform methods represent a new frontier for the modernization of near surface refraction seismology. They offer the opportunity for more effective implementation of exploration refraction seismology through extracting greater value from the data.

1530–1710
Day 2 Session 4 Stream A

PETROLEUM – STRESS & SEALS

INTEGRATING GEOLOGY & GEOPHYSICS TO ASSESS SEAL RISK – AN EXAMPLE OF SEISMIC INTERPRETATION TO ADDRESS SAND JUXTAPOSITION ACROSS FAULTS

Leonardo Molinari[1]*, *Vickie Foster*[1] *and Efthymios Efthymiou*[1]
[1]Chevron Australia

Understanding the geological risks is an essential process while exploring for hydrocarbons and seal risk is considered the

primary reason for unsuccessful wells around the world. This paper focuses on a simple seismic interpretation workflow to address fault-seal sand juxtaposition risk in a structurally complex area. The geological nature of the fluvial reservoirs in the study area, combined with tilted fault blocks provides an effective sealing mechanism to trap hydrocarbons but also enhances leak points. The workflow uses 3D seismic data to analyse juxtaposition of sand bodies across faults, with some geophysical limitations. The presented method has been successfully applied to the study area and has significant implications in exploration pre-drill risks and post-drill evaluations. The results of this study reinforce the necessity to integrate a multidisciplinary evaluation with latest technology to obtain reliable subsurface assessments that effectively translates to better business decisions and improved exploratory success rates.

THE ROLE OF SEAL INTEGRITY IN THE VLAMING SUB-BASIN (PERTH BASIN) FOR PRESERVATION OF HYDROCARBON ACCUMULATIONS

Irina Borissova[1]*, *George Bernardel*[1], *Chris Southby*[1] *and Megan Lech*[1]
[1]Geoscience Australia

The offshore Vlaming Sub-basin, located in the southern part of the Perth Basin, is a Mesozoic depocentre estimated to contain over 12 km of sediments. It has several potential source rock intervals, good reservoir and seal pairs and an active petroleum system. The reasons for a lack of exploration success in this basin have been re-assessed by analysing fault reactivation and signs of hydrocarbon seepage. A recently completed study integrated structural mapping with analysis of fluid inclusion results. New data and interpretations show that a number of synrift faults with signs of reactivation in seismic data also have Fluid Inclusion Stratigraphy (FIS) anomalies above the regional seal. Many previously identified plays rely on the post-rift South Perth Shale for a seal. Our analysis suggests that many faults were reactivated after the deposition of the South Perth Shale, with some showing signs of present-day reactivation. Reactivated faults provided migration pathways for generated hydrocarbons; therefore, no accumulations were formed at these locations. The study provides insight into the location of leaky structures and areas with potentially valid plays in the Vlaming Sub-basin.

OBLIQUE REACTIVATION OF INHERITED FABRICS IN RIFT BASINS: APPLICATIONS TO THE NORTHERN CARNARVON BASIN

Chris Elders[1]*
[1]Curtin University

Rift basins are typically developed on heterogeneous continental crust. Inherited basement fabrics exert a fundamental control rift basin geometry, and on the geometry of individual faults. Many rift basins are also the result of multiple rift episodes and early formed structures will exert further control on the way in which faults evolve in subsequent rift events.

Inherited fabrics and fault reactivation are often invoked to explain rift orientation and segmentation, often with little independent evidence for their existence. However analogue models of orthogonal and oblique rifts show that predictable fault patterns result from the partitioning of stress between pre-existing structures and superimposed extension directions. The Northern Carnarvon Basin provides an ideal laboratory in which to test these models. High resolution 3D seismic data allows detailed imaging of fault patterns developed during separate Lower-Middle Jurassic and Lower Cretaceous rift events. Fault patterns clearly reveal the influence of older structures, most likely related to Carboniferous and Permian rifting, enabling contemporaneous stress patterns to be revealed.

EVOLUTION OF DETACHED LISTRIC FAULT SYSTEMS IN THE CEDUNA DELTA, BIGHT BASIN: INSIGHTS FROM 3D SEISMIC DATA

Jane Cunneen[1], *Matthew Kovacevic*[1]* *and Chris Elders*[1]

Deformation of the Cretaceous Ceduna Delta system is dominated by gravitationally driven listric extensional faults. They were initiated as strongly listric faults during deposition of the Cenomanian White Pointer deltaic sequence, coincident with the final stages of rifting and break up between Australia and Antarctica. The faults were progressively reactivated during deposition of the post break up Santonian to Maastrichtian Hammerhead deltaic sequence, propagating upwards as relatively planar sequences associated with narrow zones of downward converging secondary faults.

Individual faults segments maintain a characteristic curved geometry in map view which link together to form relatively long continuous NW-SE trending faults which rotate to a NNW orientation in the west of the study area (towards the break of slope at the edge of the delta top). Previously unrecognised N-S trending faults that are confined to the lower part of the sequence control some of the segmentation of the NW-SE trending faults.

Understanding the evolution of these fault systems will help to better define the risks associated with Cretaceous plays in this highly prospective frontier petroleum province.

1530–1710
Day 2 Session 4 Stream B

PETROLEUM – SEISMIC IMAGING THEORY

SOLVING THE 3D ACOUSTIC WAVE-EQUATION ON GENERALIZED STRUCTURED MESHES: A FDTD APPROACH

Jeffrey Shragge[1]*
[1]University of Western Australia

The key computational kernels of most advanced 3D exploration seismic imaging and inversion algorithms involve calculating solutions of the 3D acoustic wave equation, most commonly with a finite-difference time-domain (FDTD) methodology. While well suited for regularly sampled rectilinear computational domains, FDTD methods seemingly have limited applicability in scenarios involving irregular 3D domain boundaries and mesh interiors best described by non-Cartesian geometry (e.g., surface topography). Using coordinate mappings and differential geometry, I specify a FDTD approach for generating numerical solutions to the acoustic wave equation that is applicable to generalized 3D coordinate systems and (hexahedral) structured meshes. I validate the method on different computational meshes

and demonstrate the viability of the modelling approach for 3D non-Cartesian imaging and inversion scenarios.

Key words: Finite difference, reverse-time migration, 3D acoustic wave propagation, seismic modelling.

PERFORMANCE OF THE DOUBLE ABSORBING BOUNDARY METHOD WHEN APPLIED TO THE 3D ACOUSTIC WAVE EQUATION

Toby Potter[1]*, *Jeffrey Shragge*[1] *and David Lumley*[1]
[1]University of Western Australia

The double absorbing boundary (DAB) is a new high-order absorbing boundary condition for the scalar acoustic wave equation. It suppresses scattered waves at the edge of a boundary layer in computational domain boundary by using destructive interference analogous to a noise-cancelling headphone. This method has advantages in that it addresses some of the shortfalls in existing boundary conditions, such as the need for tuning in Perfectly Matched Layers or complex formulations at corners such as in high-order absorbing boundary conditions. We extend the original formulation of the DAB to three dimensions and higher-order stencils. Through numerical simulation we test the performance of the DAB by comparison with a reflecting boundary. We find that the DABC is a broadband attenuator with a power attenuation of 20–30 dB using only six boundary cells. Increasing the order of the method improves accuracy for wavelengths less than 10 cells, whereas increasing the layer width does not improve accuracy. The method shows promise as a robust and computationally efficient boundary condition for seismic applications.

CROSS-CORRELATIVE LEAST-SQUARES REVERSE TIME MIGRATION – THEORY AND FIELD APPLICATIONS

Yi Xie[1]*, *Lian Duan*[1], *Yi Xie*[1] *and Graham Roberts*[1]
[1]CGG

We introduce a new practical least-squares reverse-time migration (LSRTM) scheme and derive a steepest descent method for optimal imaging by adapting reverse-time migration (RTM) and demigration (RTDM) as the migration and modelling operators to maximize the cross-correlation between simulated and acquired seismic data. Through real data experiments, we demonstrate that the proposed LSRTM provides high quality images with balanced amplitudes, improved focusing and enhanced resolution. The method is also capable of removing the free surface ghosts generated in towed streamer acquisition and filling holes in the imaged structures due to imperfect acquisition.

Together with impedance perturbation technique, the proposed method is a useful tool for both seismic imaging and inversion.

SEISMIC PRISM WAVES GENERATED BY SEAFLOOR CANYONS AND THEIR EFFECTS ON SUBSURFACE IMAGING

James Deeks[1]* *and David Lumley*[1]
[1]University of Western Australia

Complex seafloor bathymetry can create significant challenges for subsurface imaging and geologic interpretation of seismic exploration and monitoring data. Steep seafloor canyons that cut through continental shelf areas can produce very strong seismic wavefield distortions. Neglecting such wavefield complexity can result in inaccurate velocity models, significant imaging errors, misleading amplitudes and uncertain geologic interpretations. In this paper we investigate the kinematic and dynamic effects of seismic "prism waves" generated by seafloor canyons. Prism waves are waves that undergo multiple primary reflections at scattering interfaces before propagating to the recording sensor array. We demonstrate that strong prism waves can be generated for realistic seafloor canyon geometries, and show how their adverse effects can contaminate the seismic imaging process.

1530–1710
Day 2 Session 4 Stream C

MINERALS – ATOMIC DIELECTRIC RESONANCE

LARGE DEPTH EXPLORATION USING PULSED RADAR

Gordon Stove[1]* *and Kees Van Den Doel*[2]
[1]ADROK
[2]University of British Columbia

We present an overview of the Adrok radar scanning technology and describe experimental results that suggest that ground penetrating radar can be utilized to much greater depths in selected environments than commonly assumed. High frequencies were found to penetrate very little, but the low frequency component had very low losses. Results were analysed to estimate the skin depth and interpreted in terms of a constitutive model incorporating Maxwell's equations with conductivity and polarization losses. To explain these results we hypothesize that moisture penetrates limestone only relatively superficially and once the outer wet layer is penetrated the conductivity and therefore the losses are greatly reduced. In a second experiment we successfully detected the reflection of the radar pulse from a body of water through 350 m of rock. A numerical simulation of the model confirmed that these results do not contradict theoretical expectations for dry limestone.

GOLD AND SULFIDE TARGETING USING ATOMIC DIELECTRIC RESONANCE (ADR)

Simon Richards[1]*, *Gordon Stove*[2] *and Barrett Cameron*[3]
[1]Citigold Corporation Ltd
[2]ADROK
[3]Rapid Geophysics

The lack of modern mining in Charters Towers is linked to the difficulties associated with accurately pinpointing high-grade gold-bearing lodes on host fractures. A geophysical survey of the Charters Towers area has been carried out by ADROK using a non-destructive, non-invasive surface-based technique termed Atomic Dielectric Resonance (ADR). A vertical log is generated for selected sites and the resonance energy (E-ADR) used to pinpoint sulphide-bearing lodes within granitic host rocks below the site. Preliminary results show that the technique can successfully pinpoint sulfide and associated gold mineralisation to a depth of up to 1000 m. A total of nine scans or "Virtual Boreholes" over three main ore-bearing fractures in Charters Towers have correctly identified the depth and presence of known sulfide ore zones with a maximum depth error of 13 m. In some scans, the presence of anomalies at unexpected depths is interpreted to represent potential sulfide targets. The ADR technique is particularly useful in Charters Towers, for example,

where other techniques such as TEM, magnetics, gravity or seismic reflection surveying cannot be used due to access or other anthropogenic factors. Results so far indicate that the technique represents a significant advance in the pre-drilling identification of target sulfides.

1530–1710
Day 2 Session 4 Stream D

MINERALS – CRC DET DOWNHOLE TECHNOLOGIES

COILED TUBING DRILLING AND REAL-TIME SENSING – ENABLING 'PROSPECTING DRILLING' IN THE 21ST CENTURY?

Richard Hillis[1]*
[1]Deep Exploration Technologies CRC

New Tier 1 discoveries are critical to maintaining Australia's mineral resource inventory without continuing decline in the grade of mined resources. Such discoveries are becoming less common because, increasingly, remaining prospective, under-explored areas are obscured by deep, barren cover. Improving the rate of Tier 1 discoveries requires a step change in mineral exploration techniques that may be provided by 'prospecting drilling', i.e. extensive drilling programs that map mineral systems beneath cover, enabling geophysical and geochemical vectoring towards deposits during a single drilling campaign. The rationale for 'prospecting drilling' is provided (i) a dataset of antimony from the Kalgoorlie district of Western Australia, and; (ii) analysis of hypogene alteration systems of IOCG deposits in South Australia. The technological platform for 'prospecting drilling' must include low cost drilling due to the dense subsurface sampling required. This may be provided by transferring coiled tubing (CT) drilling technology, with its continuous drill pipe on a reel, from the oil and gas sector. CT drilling can be complemented by real-time downhole and top-of-hole sensing providing petrophysics, structure/rock fabric, geochemistry and mineralogy. The first manifestation of real-time, downhole sensing is DET CRC's newly developed autonomous sonde that is deployed by the driller and logs natural gamma radiation as the dill rods are pulled. Experimentation on real-time, top-of-hole sensing (on drill cuttings from diamond cored holes) has successfully demonstrated geochemistry and mineralogy determination with the necessary depth-fidelity. At the target cost of $50/metre, CT drilling could cost-effectively undertake 'prospecting drilling' in large, covered provinces such as the IOCG-prospective Gawler Carton of South Australia.

LOGGING DURING DIAMOND DRILLING – AUTONOMOUS LOGGING INTEGRATED INTO THE BOTTOM HOLE ASSEMBLY

Andrew Greenwood[1]*, *Anton Kepic*[1], *Anna Podolska*[1], *Christian Dupuis*[2] *and Gordon GlobalTech*[3]
[1]Curtin University
[2]Université Laval
[3]Global Tech Corporation

Logging total count gamma data while diamond drilling an HQ borehole has been achieved using an autonomous shuttle. The shuttle is integrated into the Bottom Hole Assembly (BHA) prior to drilling. Logging is initiated at the beginning of each core run and the shuttle unit continuously logs at 1 second intervals. Continuous logging combined with the relatively slow rate of penetration of diamond drilling results in high fidelity logs at 1–5 cm intervals. The data is collected by the drilling crew, who download and email the data at the end of each core run for near real time analysis. Little to no interruption to the normal drilling process is experienced once the Shuttle has been integrated into the BHA. Autonomous logging while diamond drilling enables the collection of in-situ rock property measurements, without the risks and costs associated with later wireline logging. This value is added to the drilling process at little expense.

EVALUATION OF THE LOOKING AHEAD CAPABILITY OF CONVENTIONAL BOREHOLE RADAR

Binzhong Zhou[1]* *and Matthew van de Werken*[1]
[1]CSIRO Energy Flagship

There is a strong need to develop real-time imaging technologies to enable the driller to 'see' the subsurface structures ahead of the drill-bit and around the borehole during borehole drilling. One of the ways to realise such imaging while drilling is to use borehole radar (BHR) techniques. In this paper, a conventional non-directional mono-static BHR will be evaluated for its forward-looking capability by using the data collected at an abandoned mine site at Brukunga, South Australia. Here we demonstrate that the conventional BHR can be electrically coupled on to a conductive wire or drill-rod whilst a guided wave is induced along the axial wire or drill string making it possible for imaging ahead of the drill-bit by integrating the BHR with the steel drill string. The drill-rod ahead of the BHR acts as a forward-looking antenna. When the guided wave travels to the end of the drill-bit, part of the energy is reflected by the drill-bit and the remaining energy radiates in front of the drill-bit, and is reflected by the geological/electrical discontinuities, recorded by the BHR. The forward-looking capability of the BHR is about 2-6m in the tested borehole section.

1530–1710
Day 2 Session 4 Stream E

NEAR-SURFACE – SHALLOW SEISMIC 2

THE APPLICATION OF GEOPHYSICS TO THE SPORT OF CRICKET

Timothy Dean[1], *Ben McCarthy*[1]*, *Pieter Claassen*[1] *and Raquibul Hassan*[2]
[1]Curtin University
[2]The University of Sydney

Over the years interest in sports science has boomed with current research in using technology to monitor athlete performance and the motion of balls or other equipment during a game. The contributions of Geophysics to sport are, as far as we have found, only indirect until now. We used the seismic method, specifically a 48-channel seismic acquisition system, coupled with basic processing, to locate the position at which a cricket ball impacted the pitch with an accuracy of ±10 cm. Previously this could only be done using expensive television-based systems.

AN ONSHORE AND OFFSHORE SEISMIC INVESTIGATION ACROSS A CREEK

Koya Suto[1]*, *David King*[2] *and Nadia Vellar*[3]
[1]Terra Australis Geophysica Pty Ltd
[2]Marine & Earth Sciences Pty Ltd
[3]Jacobs Group (Australia)

A seismic survey across a river with refraction and multichannel analysis of surface waves (MASW) methods was carried out to investigate the ground condition for design of a bridge across Iron Creek near Hobart, Tasmania.

The survey had onshore and offshore components. Therefore it was necessary to use a hydrophone cable as well as land geophones. A sledge hammer was used as an onshore seismic source and a small airgun across the creek.

The result is presented as P-wave velocity section from the refraction analysis and S-wave velocity section from MASW. Two boreholes onshore indicated the depth of basalt with very high strength at 8 metres on west bank and 3 metres on east bank. These depths correspond to P-wave velocity about 1400 m/s and S-wave velocity about 600 m/s. The sections showed the depth of this strong basalt increases in the creek up to about 10 metres, and it is the deepest in the eastern side of the creek. With this information, necessity of expensive offshore drilling was eliminated.

CAN NEAR-SURFACE VELOCITY STRUCTURE BE IMPROVED VIA DISPERSION ANALYSIS OF CONVENTIONAL REFLECTION DATA?

Shaun Strong[1]* *and Uni Steve Hearn*[1,2]
[1]Velseis Pty Ltd
[2]University of Queensland

A recent ultra-shallow 3C survey provides an attractive dataset for evaluation of surface-wave dispersion analysis, for improving knowledge of the near-surface. The primary motivation is for S-wave reflection processing, but with potential for P-wave static control. Finite-difference modelling and real data analysis suggests maximum-offset should be set at several times the investigation depth. This study suggests the geophone interval should be less than 10m, and single phones are preferred. An inverted near-surface S-wave section provides structural information complementary to that available from P-wave refraction.

Day 3: Wednesday 18 February 2015

0830–1010
Day 3 Session 1 Stream A

PETROLEUM - ROCK PHYSICS 2

SEISMIC SCREENING FOR HYDROCARBON PROSPECTS USING ROCK-PHYSICS ATTRIBUTES

Per Avseth[1]*
[1]Norwegian University of Science & Technology

Rock-physics templates (RPT), in combination with seismic AVO inversion data, can be used to screen for hydrocarbon prospects during exploration. With the improved quality and increased use of elastic seismic inversion, there has recently been a paradigm change in prospect mapping in the oil industry, and quantitative interpretation has become a widely used jargon. Rock-physics models are essential in that they help in converting elastic parameters from inversion data to reservoir parameters. Rock physics models plays an important role in many of the stages of seismic AVO inversions; including the petrophysical log evaluations, well ties and wavelet estimation, the setting of parameter constraints during the inversion, and the interpretation of the inversion results in terms of reservoir properties. Rock-physics models can also be used to quality check and modify the low-frequency model used in seismic AVO inversion, and to assess the quality and uncertainties of inverted elastic parameters. In this presentation we will demonstrate the use of rock-physics models during the different stages of seismic inversion, and how these can improve our ability to reveal hydrocarbon-associated anomalies.

RELATIONSHIP BETWEEN SHEAR WAVE AZIMUTHAL ANISOTROPY, SAND-SHALE CONTENT AND DEPTH IN THE EXMOUTH SUB-BASIN, WESTERN AUSTRALIA

Lisa J. Gavin[1]* *and David Lumley*[2]
[1]Chevron, ETC
[2]The University of Western Australia

Anisotropy characterisation from surface seismic, VSP and borehole measurements is notoriously difficult. This is mostly due to limitations in parameterising the stiffness tensor constants required give an accurate representation of the anisotropic material. The Exmouth Sub-Basin has very strong anomalous horizontal stress conditions; in some areas the maximum horizontal stress (σhmax) can exceed the vertical stress (σv). There are many data examples across the Sub-Basin showing the influence of strong azimuthal anisotropy (AA). Qualitative observations of log data demonstrate that there is greater amounts s-wave anisotropy (γ) in the sand dominated sediments than in the shale dominated and the AA is greater in shallower clastic sediments than deeper. In this paper we compare data observations of AA fast and σhmax azimuths in the Exmouth Sub-Basin, which show consistent trends when plotted geographically. We then outline a methodology to determine a relationship between γ and Vshale (shale volume ratio versus sand and shale volume) from logs with existing γ and Vshale data and then extend the method to incorporate the total vertical depth (subsea) of the log (TVDss). We test this methodology on a well taking a "blind test" approach, predicting Vsslow, γ and Vshale. We also test the methodology on original logs and ones upscaled using Backus averaging to a typical seismic resolution. Our results show that we can accurately predict AA and Vshale, especially when the logs depth is incorporated, removing depth trends.

ROCK PHYSICS AND QUANTITATIVE INTERPRETATION USING LAMBDA-MU-RHO IN THE SHIPWRECK TROUGH, OTWAY BASIN

David Close[1]*, *Randall Taylor*[1] *and Sebastian Nixon*[1]
[1]Origin Energy

A rock physics study and AVO modelling study has been completed to assist in the interpretation of seismic amplitude and AVO anomalies in the Shipwreck Trough of the offshore Otway Basin of southeastern Australia. Elastic log data, core data (both full and sidewall) and associated thin section analysis of composition and texture were available on a number of wells; and these data are important in calibrating proposed rock physics models that suggest incorporating cement is critical to understanding anomalies in seismic inversion volumes and measured log data.

Lithoprobability volumes based on conventional interpretation paradigms, such as low Vp:Vs values indicating gas presence, that do not incorporate an understanding of the rock physics lead to biased interpretations. Ratios in particular can be misleading as there is ambiguity about whether an anomalous ratio is driven by the numerator or denominator. As a classic gas indicator low Vp:Vs values are interpreted to be driven by a decrease in Vp associated with gas replacing brine in a rock. Using Lamé Impedance terms λρ and μρ, however, provides an alternative interpretation template that does not utilise ratios and can improve insight into rock properties. As in this case study, using LMR can be an important tool when shear velocity has increased relative to the compressional velocity irrespective of any pore-fluid change.

We propose that due to quartz cement in the reservoir rocks of the Shipwreck Trough both gas and brine sandstones exhibit very low Vp:Vs, creating substantial challenges to the use of a standard rock physics template. In LMR space, however, the low Vp:Vs data points are clearly characterized by a high shear rigidity – an important point to recognize and incorporate into AVO interpretation workflows.

0830–1010
Day 3 Session 1 Stream B

PETROLEUM – BROADBAND SEISMIC PROCESSING

UNLOCKING THE FULL POTENTIAL OF BROADBAND DATA WITH ADVANCED PROCESSING AND IMAGING TECHNOLOGY, A CASE STUDY FROM NWS AUSTRALIA

Jingyu Li[1]*, *Joe Zhou*[1], *Peter Chia*[2], *Henry Ng*[1], *Sergey Birdus*[1], *Keat Huat Teng*[1], *Ying Peng Phan*[1], *Jason Sun and Yi He*[1]
[1]CGG
[2]Shell

The high costs associated with hydrocarbon exploration in deepwater have led to an increased business demand for acquisition and processing of high-resolution broadband seismic data. In this paper, we review our experience of working on the Shell Sandman 3D survey, which was acquired using variable-depth streamers and synchronized multi-level sources. We focus on the key factors that influence the surface seismic temporal resolution and the technologies that provide solutions to these challenges: (1) source deghosting using source designature with near-field hydrophone data; (2) receiver deghosting using the 3D deghosting algorithm; and (3) compensation for the Earth absorption using centroid frequency shift Q tomography (FS-QTOMO) and QPSDM. The extra-wide bandwidth obtained from these processes provides a final image with detailed resolution that enhances quantitative characterization, not only for shallow geo-hazards but also for resolving relatively thin reservoirs in the deep section. Therefore, we can conclude that broadband seismic methodologies coupled with advanced seismic processing techniques, provide an effective solution for generating high-resolution seismic images, especially in challenging areas.

PRE-STACK DEGHOSTING: BRINGING OUT THE SEISMIC BANDWIDTH IN LEGACY MARINE DATA

Jun Zhou[1]*, *Peter Chia*[2], *Hassan Masoomazdeh*[1], *Xuening Ma*[1] *and Teck Goh*[1]
[1]TGS
[2]Shell

Broadband seismic processing has been proven in marine seismic data obtained with new acquisition techniques. However, we are challenged with what can be achieved towards improving the bandwidth of many legacy seismic data in our library, of which the acquisition configuration and parameters were lacking of information for proper broadband processing requirements, such as accurate receiver depths.

This paper demonstrates some of the broadband processing techniques we applied on legacy 3D and 2D data to bring out the bandwidth and improve the quality of the signal of legacy seismic data.

IMAGING THROUGH SHALLOW GAS: INTEGRATING BROADBAND ACQUISITION, PROCESSING AND HIGH-END MODEL BUILDING FOR IMPROVED IMAGING OF DEEPER TARGETS

Gavin Menzel-Jones[1]*, *Jan Rindschwentner*[2], *Chui Huah Lim*[2], *Bee Jik Lim*[1] *and Saeeda Hydal*[1]
[1]Schlumberger
[2]Petrofac

We present a case study offshore Malaysia, shallow gas features in the overburden distort the seismic imaging at the target level. While a multifaceted approach involving a combination of seismic acquisition and processing strategies were used to improve the bandwidth of the seismic data, particularly for the low-frequency content of the seismic image, several distortions still existed at the target level. The prominent structural sag evident at the reservoir level is a typical indication that the overlying shallow gas velocity model needed to be resolved and incorporated into a depth migration algorithm.

To resolve the transversally and laterally variant velocity features in the shallow gas areas, a solution that consisted of full waveform inversion (FWI) and high-resolution reflection traveltime tomography was utilized to produce an accurate compressional velocity model. To further resolve the amplitude and phase distortions at the reservoir level due to shallow gas effects, Q tomography was incorporated into the model building phase to derive a space-variant 1/Qmodel and Q compensation was integrated within depth migration.

The integrated approach of broadband receiver acquisition, data processing strategies and high-end Earth model building has cumulatively improved the imaging of the reservoir below the shallow gas anomalies.

INNOVATIVE PROCESSING APPROACHES TO OVERCOME SAMPLING SPARSENESS AND IRREGULARITY IN 3D OBC SEISMIC DATA OFFSHORE ABU DHABI

Shotaro Nakayama[1]*, *Mark Benson*[1], *Tarek Matarid*[1], *Kamal Belaid*[1], *Mikael Garden*[2] *and Dmitry Zarubov*[2]
[1]ADMA-OPCO
[2]Schlumberger Geosolutions Abu Dhabi

Due mainly to commercial and operational constraints, seismic data are often sparsely and irregularly sampled, leading to several challenges in processing of 3D OBC seismic data offshore Abu Dhabi.

Conventional linear noise attenuation techniques are not effective with Scholte waves as they are usually aliased with typical sampling interval in 3D OBC seismic data, and sometimes scattered because of near-surface heterogeneity. To address this, we apply model-based surface wave attenuation, Surface Wave Analysis Modeling and Inversion (SWAMI), which enables an estimate of local near-surface properties by analysing dispersion curves. Thus, both direct and scattered Scholte waves are effectively modelled and attenuated without suffering a lack of spatial sampling. We also highlight the shortcomings of the application of interferometry to scattered noise attenuation for sparse acquisition geometry.

Matching Pursuit Fourier Interpolation (MPFI) is then implemented to deal with insufficient sampling in crossline direction caused by acquisition geometry. MPFI employs anti-aliasing capability so optimum data reconstruction can be performed for any frequency ranges. In addition to regularization aspect, MPFI with 5D implementation (4 spatial coordinates and time) is targeted to densify receiver line interval and extend source lines, which consequently enhances fold, offset and azimuth distributions of the data.

0830–1010
Day 3 Session 1 Stream C

MINERALS – AIRBORNE ELECTROMAGNETICS 1

QUASI3D INVERSION OF AIRBORNE EM DATA

Robert Ellis[1]* *and Ian MacLeod*[1]
[1]Geosoft Inc.

Full 3D inversion of AEM data is not generally available to minerals explorers because of limitations in current algorithms

and computer resources. Consequently we must resort to approximations to full 3D AEM inversion to support today's exploration projects. One form of approximation is to reduce the dimensionality of the inverse problem from 3D to 1D and while layered earth inversion has proven fast and effective in practice, it has limitations in 3D environments. To address these limitations we propose a physically motivated approximate 3D AEM inversion: Quasi3D inversion. Full 3D EM inversion requires calculation of the 3D induced current in the earth whereas the Quasi3D approximation is based on a full 3D inversion but with a simplified, approximate, induced current flow in the earth. We demonstrate the Quasi3D approximation by comparing its response over the interface of a quarter-space model with the full AEM response, and then demonstrate Quasi3D inversion on a challenging synthetic model and on field data. From our work we conclude that the Quasi3D approximation is an effective and efficient approximation which should aid in the interpretation of AEM data for today's exploration projects.

PARAMETRIC 3D INVERSION OF AIRBORNE TIME DOMAIN ELECTROMAGNETICS

Michael McMillan[1]*, *Douglas Oldenburg*[1], *Eldad Haber*[1] *and Christoph Schwarzbach*[1]
[1]University of British Columbia

Conventional voxel-based inversion algorithms can encounter difficulties when inverting airborne time-domain electromagnetic data in three dimensions. In certain environments with these codes, it can be challenging to delineate sharp boundaries between geologic units with large conductivity contrasts and to accurately image thin conductive targets. Furthermore, spurious circular inversion artifacts, known as ringing, can occur around conductive targets.

To address these issues we have developed a parametric inversion code that can be used to find the optimal location, shape and conductivity value of a single anomaly in a homogeneous or heterogeneous background. The algorithm incorporates a Gauss-Newton optimization scheme in conjunction with a level set formulation to outline the anomaly of interest, and can be combined with a conventional voxel-based algorithm in more complicated geologic settings.

The code is shown to be successful with a synthetic data set over a thin dipping plate, and two field data sets. For the synthetic scenario, the parametric inversion recovers the true dip and size of a conductive target with no a priori information. The algorithm also accurately defines the extent of a diamondiferous kimberlite pipe and a dipping massive sulphide deposit beneath a conductive overburden.

RAPID 3D INVERSION OF AIRBORNE TEM DATA FROM FORRESTANIA, WESTERN AUSTRALIA

Peter Fullagar[1]*, *James Reid*[2] *and Glenn Pears*[2]
[1]Fullagar Geophysics Pty Ltd
[2]Mira Geoscience

VPem3D performs 3D inversion on time-integrated (resistive limit) data. Conversion to resistive limits delivers a massive increase in speed since the TEM inverse problem reduces to a quasi-magnetic problem. The time evolution of the decay is lost during the conversion, but the information can be largely recovered by constructing a starting model from CDIs or 1D inversions.

We have carried out preliminary inversion of VTEM dBz/dt data from the Forrestania EM test range. The inversion places a weak conductor at a depth and location consistent with the known target. Run time is a few minutes, a fraction of that required by a full 3D EM inversion.

AUTOMATED AIRBORNE EM ANOMALY PICKING AND 3D MODEL FITTING

James Macnae[1]*
[1]RMIT University

A number of algorithms for the transformation of airborne EM data to 3D conductivity distributions have been developed in the past few years. This paper describes a MATLAB implementation of the Annan spectral method to permit the automatic detection and fitting of vortex and current gathering responses from discrete targets.

The method used consists of (1) AEM System definition, (2) pre-calculation of a large number of system specific AEM responses for target geometries of interest, (3) Conversion of data to stitched 1D CDI through EMFlow with conversion to equivalent step response data, (4) response – background separation, (5) successive brute force fitting of every "possible" anomaly to every successive line segment of data, (6) selection and refinement of acceptable models based on error criteria.

This paper presents results of the application of the method to fixed-wing Geotem data from Queensland and Sweden.

0830–1010
Day 3 Session 1 Stream D

MINERALS – GEOLOGY FROM GEOPHYSICS 1

STRUCTURE AND STRATIGRAPHY FROM AEROMAGNETICS IN SEDIMENTARY BASINS

David Isles[1]*
[1]Southern Geoscience Consultants

Sedimentary rocks commonly contain sufficient magnetic mineral to yield coherent signal in modern aeromagnetic surveys. Careful acquisition procedures and astute application of conventional processing methodology allow the signal from the

sedimentary section to be recognised and isolated from that of 'basement', facilitating focused interpretations of each these geological domains.

Spectral separation filtering underpins this process, providing imagery of magnetic sources that lie at differing depths. The integration and interpretation of the resulting 'spectral depth windows' follows the steps used to integrate aeromagnetics with geology in 'hard-rock' domains. A substantial phase of basic observations on the aeromagnetic imagery is the fundamental first step, and commitment to the integration of the best available geology to yield lithostratigraphic and structural framework interpretations completes the initial task. Forward and inverse modelling constrains the qualitative geological interpretation, and enables hypotheses formed during that interpretation to be tested.

The two examples presented show the virtues of separation filtering and the style of geological interpretation that can be derived using the aeromagnetic data as the driver. The Amadeus Basin example presents a 'feast' of shallow magnetic rock units, many of which are probably magnetic stratigraphic marker horizons. These yield a thought-provoking interpretation of structure and stratigraphy in the upper sedimentary section. The discordance between the geometries of the shallow and deep magnetic rock units raises the likelihood of a major detachment structure between the two geological domains.

The aeromagnetic data from the second example, in the Galmoy Pb-Zb district in Ireland, presents major challenges. Separation filtering yields a set of very low amplitude but strongly coherent spectral depth windows which, when interpreted, provide a range of structural and stratigraphic features that relate directly to the mineralised environment. The successful application of aeromagnetics in this erstwhile 'non-magnetic' geological domain is testimony to the value of the technique in most, if not all sedimentary basins.

STRUCTURAL GEOPHYSICS – GEOLOGICAL PRINCIPLES APPLIED TO GEOPHYSICAL DATA

Peter Betts[1]*
[1]Monash University

The fundamental precept of structural analysis is that descriptions of geometry lead to interpretations of kinematics and the dynamics of geological systems. Controls of the formation of structures at all scales depend on the starting material heterogeneity, and the anisotropy and time dependence mechanical response of the materials. Processes that control mechanical response at the small scale (~1 cm) may be quite different to those at the regional scale (>1 km), the flow fields and structures that develop can be similar and therefore can be interpreted in similar ways. This approach is second nature in structural geology but is also easily applicable to analysis of regional geophysical datasets such as aeromagnetic and gravity data. Structural geophysics is a discipline defined by Jessell and Valenta (1996), where structural methodology and interpretation could be applied to regional geophysical datasets to unravel 3D architecture and overprinting relationships. Geophysical datasets are increasingly used in conjunction with structural analysis, and as a stand-alone tool, to resolve regional crustal architecture and geological evolutions, particularly in remote regions and areas of limited outcrop, or where there is some ambiguity in how structure can be determined in the third dimension. Importantly, aeromagnetic data is also effective interpret regional kinematics of major shear zones and high strain zones at different scales. Applying structural kinematic analysis to regional geophysical datasets informs a broad range of disciplines including, but not limited to structural analysis, plate reconstruction, tectonic analysis, and prediction of mineral systems in exploration. In the context of resource exploration 3D and kinematic analysis allows you to predict Earth structuring that controls mineralisation, but more importantly allows prediction of favourable sites of dilation and fluid flow. In this presentation will highlight many of the principles of 3D geometry and kinematic analysis and illustrate how they improve our understanding of geological architecture and dynamic processes of the Earth.

0830–1010
Day 3 Session 1 Stream E

MINERALS – HARD ROCK SEISMIC 1

SEISMIC EXPLORATION OF THE WORLD'S DEEPEST GOLD AND PLATINUM OREBODIES IN SOUTH AFRICA – OVERVIEW OF THE PAST, PRESENT AND A LOOK INTO THE FUTURE

Musa Manzi[1]*
[1]University of the Witwatersrand

Without doubt, the geologically complex Witwatersrand Basin in South Africa is by far the most important known gold-producing province. It has produced about one-third of the gold ever mined, worldwide. Gold mining in the goldfields takes place at depths ranging from 500 to 4200 m below surface. Many call

the underground workings the 'devil's workplace'. This means that there are an increasing number of technical challenges in exploration and optimizing new resources, with rising costs and reduced effective mine designs. There are about 20 or more gold ore bodies (quartz pebble conglomerates) that have been mined, or are currently in production. Furthermore, the Bushveld Complex of South Africa is estimated to contain about 70% of the world's reserves of platinum group elements. The most important platinum ore bodies are the Merensky Reef and the UG2.

This paper presents the past and current research activities on the use and implementations of seismic methods for gold and platinum exploration and deep mine planning and designs. It, particularly, presents a state-of-the-art in seismic design and acquisition, processing, interpretation of the seismic data as well as modelling of strato-structural complexies of the basin using advance techniques. The current challenges and possible future solutions are further discussed with special emphasis on the reflection seismic imaging limitations. For example, reflection seismic data acquired on the surface in the Witwatersrand Basin and Bushveld Complex have wavelengths of approximately 60–100 m, providing vertical seismic resolution of approx. 20 m. Consequently, it is difficult to resolve the top and bottom of thin reefs (~1 m in thickness) due to seismic wave interference as well as to detect faults with throws less than 20 m. However, gold reefs as thin as 20 cm to 1 m are currently the main targets for deep mining and faults that crosscut these reefs with throws as small two meters may present difficulties to deep future mining operations. Recent research work has further demonstrated that some of these minor faults may act as conduits for ingress of water and flammable gas into underground workings.

There has been more of hard-rock reflection seismics undertaken in South Africa than anywhere else in the world. Therefore, this paper attempts to answer the following trickier question: Will seismic application in the mining industry in South Africa accelerate or decline in the coming years?

USING SEISMIC REFLECTION PROFILES TO MODEL 3D GEOLOGY OF VMS DISTRICTS IN THE RAAHE-LADOGA BELT, FINLAND

Suvi Heinonen[1], Pekka J. Heikkinen[2], Ilmo T. Kukkonen[2] and David B. Snyder[3]*
[1]Geological Survey of Finland
[2]University of Helsinki
[3]Geological Survey of Canada

Volcanogenic massive sulphide (VMS) deposits of Pyhäsalmi, Vihanti and Outokumpu in Finland belong to the same mineralized belt but are different in terms of age and detailed deformation history. Results of sonic and density logging show that in these mining camps rock formations hosting the known ore deposits are reflective which encourages the use of seismic reflection method for mapping the subsurface geological structures. A network of seismic reflection profiles was acquired in each study site and these data are utilized in the geological 3D-modeling and deep mineral exploration.

SEISMIC EXPLORATION FOR VOLCANOGENIC MASSIVE SULPHIDES: THE DEGRUSSA COPPER-GOLD MINE, WESTERN AUSTRALIA

Jai Kinkela[1], Sasha Ziramov[2], Aleksandar Dzunic[1] and Paul Hilliard[3]*
[1]HiSeis Pty Ltd
[2]Curtin University
[3]Sandfire Resources NL

Traditional geophysical prospecting techniques used for mineral exploration rarely provide either the depth of penetration or resolution required to accurately target orebodies at depth. Based on this, the seismic reflection method was trialled over a known VMS orebody at the DeGrussa copper-gold mine, Western Australia, in the hope of providing a viable exploration tool for deeper depths of investigation. However, a structurally complex geologic setting and a thick, highly variable regolith caused significant challenges in the processing of the seismic data.

An initial 3D survey was not successful in imaging the orebody, so a follow-up downhole and 2D survey was acquired to address the potential issues. After verifying the in-situ seismic properties of the orebody through zero-offset Vertical Seismic Profiling (VSP) and increasing the down-dip offset range in the follow-up 2D survey it was found that the target provided a clear and unambiguous seismic response. However, a deep and variable regolith continued to cause significant issues during the imaging phase. This was overcome by applying a tomography-derived velocity field to a Kirchhoff migration, which produced outstanding results.

Numerous tests and extensive data analyses eventually verified the seismic technique as a viable exploration tool for the region, with the direct detection of the target orebody.

1030–1210
Day 3 Session 2 Stream A

PETROLEUM – SEISMIC IMAGING PRACTICE

INCORPORATING NEAR-SURFACE VELOCITY ANOMALIES IN PRE-STACK DEPTH MIGRATION MODELS

*Ian Jones[1]**
[1]ION GX Technology

Unresolved velocity anomalies in the near-surface degrade deeper imaging. As a consequence, great care needs to be taken to ensure that all significant near-surface effects have been dealt

with before attempting to build the deeper parts of a velocity depth model. All ray paths that pass through a near-surface velocity anomaly will be affected by it, distorting the subsurface response about half a cable length to either side of the anomaly. The distorted region actually extends beyond a half cable length due to the influence of the Fresnel zone: in other words, we are really dealing with wavefronts rather than hypothetical rays.

In the context of this review, by "near surface" I refer to features whose fold of coverage in CRP gathers is either too low or near the practical limit for autopickers to be able to determine residual moveout, and/or whose lateral extent is too small for ray-based methods to perform reliably (i.e. features with lateral velocity changes occurring over distances less than several times the dominant wavelength of the seismic wavefronts reflected from them).

Here, I'll describe current industrial practice for building complex near-surface models, which is based on a range of approximate techniques (depending on whether just the geobody geometry alone is discernible, or whether its velocity distribution as well is known), as well as the more complete solution offered by the emerging technology of waveform inversion. It will be shown that, although usually painstaking, a suitable near-surface velocity model can often be obtained.

ANISOTROPIC DEPTH IMAGING IN PRESENCE OF STRESS: TRANSVERSELY ISOTROPIC OR ORTHORHOMBIC?

Olga Zdraveva[1]*, *Robert Bloor*[1] *and Dave Nichols*[1]
[1]Schlumberger

Presence of oriented stresses and fractures in the subsurface can pose significant challenge when imaging wide-azimuth and multi-azimuth data using transverse isotropy as an approximation to describe the medium. We describe the key components of an orthorhombic model-building and updating workflow for depth imaging in areas affected by stress. We discuss several different options for deriving the initial parameters describing orthorhombic medium and their dependencies on the geometry of the available seismic data.

We demonstrate the effectiveness of the workflow on real data from the Gulf of Mexico. Compared to transversely isotropic imaging, the orthorhombic imaging flattens the common-image-point gathers in all azimuths and results in improvements of image focussing.

A STABLE TOMOGRAPHIC SOLUTION FOR ANISOTROPIC EPSILON – A TOOL TO AID IN EXPLORING FOR OIL IN THE NORTHERN CARNARVON BASIN

Ed Lewis[1]* *and Shane Westlake*[2]
[1]ION-GXT
[2]Finder Exploration

AVO studies have typically been used in the search for gas on the North-West Shelf for decades, but its use for identifying oil filled reservoirs has been limited by the effective meaningful angle range obtainable from the seismic data.

We have performed tomographic updates of the anisotropic parameter epsilon to obtain flatter and cleaner gathers out to a much higher angle range than traditional anisotropic assumptions. This then gives the ability to use the data for AVO much more effectively.

1030–1210
Day 3 Session 2 Stream B

PETROLEUM – RESERVOIR CHARACTERIZATION 1

USING AVO TO MAP COOPER BASIN PERMIAN SANDS IN THE PRESENCE OF COAL

Stephanie Tyiasning[1]* *and Dennis Cooke*[1]
[1]The University of Adelaide

Cooper basin Toolachee and Patchawarra sands are difficult to map due to strong seismic reflections from Permian coals. Seismic amplitudes are mainly driven by coal thickness instead of lithology (sand vs shale). We proposed a method for obtaining better sand prediction. This method uses AVO intercept (I) and gradient (G) and the Extended Elastic Impedance (EEI) to highlight the subtle differences between coal-shale and coal-sand interfaces. We test this method by creating several wedge models to understand the effect of coal thickness and lithology on seismic amplitudes. Results are compared with a more traditional method that recognizes a 'channel' pattern on stacked seismic and uses a geologic facies model to locate sand with respect to that channel. For the 3D survey used here, our EEI-AVO method 'finds' sand in locations predicted by the traditional facies model method as well as in new locations.

TARGETED INTERPRETATIVE REPROCESSING FOR RESERVOIR CHARACTERISATION – A CASE STUDY USING THE SATYR FIELD

Dan Gillam[1]*, *Gavin Ward*[1] *and Matthew Waugh*[1]
[1]Chevron Australia Pty Ltd

The large isolated gas bearing channel belts of the Mungaroo Formation are for the most part easily identified on marine surface seismic (MSS). However a more quantitative interpretation of the reservoirs is often impeded by a combination of seismic noise and complex reservoir characteristics. Many sands are at or below tuning thickness and their amplitude response is affected by varying degrees of diagenesis. The presence of acoustically soft carbonaceous siltstones further compromise any quantitative interpretation.

Using the Satyr field as a case study, this paper illustrates how recent advances in seismic processing are able to help mitigate some of the issues affecting MSS, such as free-surface multiple contamination. The paper then explores ways in which the resulting seismic products can be enhanced and manipulated to better discriminate lithologies, such as organic siltstones and cemented intervals. Wells within the Satyr seismic volume are used to demonstrate the improved reliability of reservoir quality estimates in support of field development planning. It is concluded that in certain instances targeted reprocessing of conventional MSS data using modern processing flows can go a long way towards delivering what might otherwise only hope to be achieved through a dedicated broadband acquisition.

PROSPECT VALIDATION USING GEOLOGICAL EXPRESSION IN A GAS DISCOVERY, OFFSHORE MOZAMBIQUE

Adrien Bisset[1], *Gaynor Paton*[1]*, *Nicholas Cooke*[1], *Peter Szafian*[1] *and Roger Gruenwald*[2]
[1]Foster Findlay Associates Australia Pty Ltd
[2]SASOL Petroleum International

This study attempts to gain a better insight into the controls on an under-saturated gas discovery, offshore Mozambique, using Geological Expression techniques such as High Definition Frequency Decomposition (HDFD) and multi-attribute classifications with synthetic wedge modelling being used to better understand the results. HDFD highlights known hydrocarbon bearing sands as high magnitudes and shows that structural processes are dominant in controlling their distribution. Observations from the Chaos divided by Envelope attribute lead to gas chimney interpretations and show that faults may be acting as migration pathways for hydrocarbons into and out of the reservoir. The Interactive Facies Classification tool confirms preconceived ideas of a later stage inversion, shows potential deposition fairways and sand-sand juxtaposition across faults confirming that faults are not acting as baffles to fluid flow. Finally synthetic wedge modelling of the reservoir provides an explanation for similar colour responses of the HDFD RGB blend above and below the gas-water contact. We observe that, even though thickness is a dominant controlling factor on the colours in the RGB blend, pore fill plays a role and allows a single stratigraphic layer to be divided based on it. These techniques aided in better understanding and risking the reservoir.

VOLCANIC ROCK CHARACTERISATION USING THE CONCEPT OF EXTENDED ELASTIC IMPEDANCE: A CASE STUDY FROM MIDDLE JURASSIC GAS RESERVOIR IN OFFSHORE WESTERN AUSTRALIA

Syed Iftikhar Arsalan[1]*, *Kapil Seth*[1] *and Keiichi Furuya*[1]
[1]INPEX

Successful identification of volcanic rocks is critical in reservoirs where they have been previously intersected. This is because they impact on reserve estimates and influence fluid flow behaviour. Various studies using seismic inversion data were performed to try to characterise volcanic rocks in a sandstone reservoir in the Plover Formation. We noted that traditional techniques such as cross-plots between P-Impedance (Ip) and Vp/Vs was not very effective in this reservoir due to significant facies overlap at seismic resolution and inversion data quality. Therefore volcanic rock identification was attempted using advanced seismic attribute analysis. This involved testing and evaluating other elastic attributes, either individually or in combinations, to try and segregate volcanic rocks from other lithofacies.

Two approaches were adopted to find out a suitable single attribute to identify the volcanic rock: (i) scaling of elastic logs with a non-elastic trend; (ii) generating a single attribute using Ip, Is and LMR cross-plots. Log and seismic scale analysis proved the suitability of both methods in volcanic rock identification. Subsequently, Extended Elastic Impedance (EEI) was applied to generate the EEI equivalent of those single attribute yielding positive results.

1030–1210
Day 3 Session 2 Stream C

MINERALS – AIRBORNE ELECTROMAGNETICS 2

UTILIZING MASSIVELY PARALLEL CO-PROCESSORS IN THE AARHUSINV 1D FORWARD AND INVERSE AEM MODELLING CODE

Casper Kirkegaard[1]*, *Kristoffer Andersen*[1], *Tue Boesen*[1], *Anders Vest Kristiansen*[1], *Esben Auken*[1] *and Gianluca Fiandaca*[1]
[1]Aarhus University

While the forefront of AEM research is focusing on the challenges of 3D modelling, the wide AEM community still rely on less sophisticated computational techniques for their calculations. Inversion of large time domain AEM surveys still prove a computational challenge within a 1D formulation, and require much more computational resources than can be delivered by an office workstation. Emerging Monte-Carlo based 1D Bayesian inversion schemes provide another example of applications that are currently limited by the 1D forward modelling rate.

In this abstract we describe our research in modifying the AarhusInv AEM inversion code to utilize next generation massively parallel co-processors. While our results are early and based on very little optimization, we still achieve comparable levels of performance (>80%) from a single co-processor and a 48 cpu core server. We estimate that performance on the co-processor can be speeded up by approximately another 4x with a limited amount of code restructuring/rewriting.

SHARP SCI: A NEW PRACTICAL TOOL FOR BLOCKY MODELS RECONSTRUCTION

Andrea Viezzoli[1]*, *Giulio Vignoli*[2], *Anne-Sophie Høyer*[2] *and Ahmad Behroozmand*[3]
[1]Aarhus Geophysics Ap
[2]GEUS
[3]Stanfor University

In general, a priori information and assumptions are necessary to invert geophysical data. The problem is to formalize this knowledge in the appropriate way. The Sharp Spatially Constrained Inversion (sSCI) approach presented in this paper represents a contribution in this sense. Using the gradient support, it extracts from multilayer inversion the minimum number of -relatively homogeneous- resistivity domains needed to fit the AEM data, retrieving in this way their sharp boundaries. The sharp transitions are, to some extent, similar to those normally achieved with few-layer inversion -which however requires prior determination of the number of layers and may generate artefact in case of unexpected complex geologies. Results obtained from synthetic and experimental data illustrate the concept and prove that the sSCI can be superior to standard multilayer inversions in mapping sharp spatial resistivity transitions.

ARTIFICIAL NEURAL NETWORKS FOR EFFICIENT REMOVAL OF COUPLED AIRBORNE TRANSIENT ELECTROMAGNETIC DATA

Casper Kirkegaard[1]*, *Kristoffer Andersen*[1], *Casper Kirkegaard*[1], *Nikolaj Foged*[1] *and Esben Auken*[1]
[1]Aarhus University

Modern airborne transient electromagnetic (ATEM) surveys typically span thousands of line kilometres requiring careful data processing. When surveys are flown in populated areas data processing becomes particularly time consuming, since the acquired data is contaminated by couplings to manmade conductors (power lines, fences, pipes, etc.). Coupled soundings must be removed from the dataset prior to inversion, but since the signature of couplings can be subtle and difficult to describe in general terms it has so far remained mostly a manual task.

Here we train an artificial neural network (ANN) to recognize coupled soundings in previously processed data and use this network to identify couplings in other data. The approach provides a dramatic reduction in the time required for data processing, since one can directly apply the network to the raw data. We describe the neural network we use and present the inputs and normalizations required for maximizing the effectiveness of the network. We present the training state and performance of the network and finally compare inversions based on manually processed data and ANN processed data. The results show that a well trained network can produce a high quality processing of ATEM data, which is either ready for inversion or in need of minimal manual processing. The results are very promising and can significantly reduce the processing time and cost of large ATEM surveys.

QUASI-3D INVERSION OF FULL SIZE AEM DATASETS

Esben Auken[1]*, *Gianluca Fiandaca*[1], *Casper Kirkegaard*[1] *and Anders V. Christiansen*[1]
[1]Aarhus University

We present a new algorithm for quasi-3D inversion of airborne transient electromagnetic data (AEM). The algorithm uses a 3D voxel grid for the model domain while the forward response and derivatives are calculated using interpolated "virtual" 1D models collocated at the AEM measurement points. The algorithm efficiently decouples the model domain from the practical spatial sampling, which is often dictated by the landscape, ground installations etc., rather than the optimal model resolution. The algorithm uses sparse storage with efficient solvers and it scales linearly with both the number of CPU's and with the survey size. This means that it can be used to invert entire surveys of thousands of kilometres on small multiprocessor servers priced at less than 5000 Euro. The algorithm allows inputting a-priori information from boreholes, joint inversion with ground based electrical/electromagnetic data and modelling of flight altitude and shift parameters.

1030–1210
Day 3 Session 2 Stream D

MINERALS – GEOLOGY FROM GEOPHYSICS 2

GEOCHEMISTRY, THE NEW GEOPHYSICS?

Scott Halley[1]*
[1]Minerals Mapping Pty Ltd

Both geochemical and geophysical responses of earth materials are governed by mineralogy. It should therefore come as no surprise that geochemical and geophysical patterns are strongly correlated. Using a strong acid digest and a combined ICP MS/AES analytical package, we can now analyse half of the periodic table with very low detection limits, for around the same real dollar cost that Au plus base metals would have cost 30 years ago. With the new analysis methods, we can classify rock types, quantify the intensity of alteration, as well as map pathfinder metals. Integrating chemistry with geophysical data adds a new level of understanding to the meaning of the geophysical patterns. An example from Zambia shows a district-scale alteration map. Correlation with airborne radiometrics and magnetics allows interpolation between sample points, and extrapolation across a whole province. The hydrology of an entire sedimentary basin can be mapped from the combination of data.

PRACTICAL GEOLOGICAL MAPPING UNDER COVER USING ELECTROMAGNETIC DATA

Gavin Selfe[1]*
[1]GRS Consulting

As the world's 'easy' mineral deposits on surface are increasingly discovered, it becomes more and more necessary

for geo-scientists to explore under cover. Southern Africa has vast expanses of young cover in the form of Kalahari sands and the Karoo sequence, and this cover is ignored at one's peril. The big challenge is to map the geology beneath these young sequences, using a variety of techniques to increase the validity of the interpretation. Instead of relying purely on magnetics and gravity, various electromagnetic (EM) techniques are discussed, ranging from airborne EM surveys to 2.5D audio magneto-telluric (AMT) surveys and high-temperature SQUID EM surveys. Datasets are presented from current base metal exploration projects in Botswana, South Africa and Zambia, and the innovative use of these in some cases is demonstrated. The emphasis is on interpreting the general structure and geology, using all available datasets, in ways that benefit the overall exploration strategy. The important role of understanding physical rock properties by using downhole geophysical logging (petrophysics) is also discussed, and related to the geological interpretation. The varying levels of success of some of these methods at a prospect scale are highlighted.

1030–1210
Day 3 Session 2 Stream E

MINERALS – HARD ROCK SEISMIC 2

KEVITSA NI-CU-PGE DEPOSIT, NORTH FINLAND – A SEISMIC CASE STUDY

Sasha Ziramov[1]*, *Aleksandar Dzunic*[2] *and Milovan Urosevic*[1]
[1]Curtin University
[2]HiSeis

A 3D seismic survey was designed, acquired and processed by HiSeis Pty Ltd in 2010 at the Kevitsa NiCu-PGE deposit. The objectives of the survey were the definition of sub-vertical structures (knowledge of which could assist in the design and characterisation of the slopes of the proposed open pit), and mapping out the general structural setting of the mafic intrusive. The 2010 processing of the Kevitsa 3D seismic data was accelerated to meet engineering design deadlines. Although this phase of work was restricted to processing sequences that were not amplitude consistent and to the post stack migration algorithm, never-the-less the resultant product achieved good resolution of the complex structural setting. The dataset was re-processed in 2014 with the goal of preserving relative signal amplitudes, in order that the volume could be inverted into an acoustic impedance cube. Another reason for re-processing was to improve imaging in shallow depth, by improving the static solution and velocity model used for imaging. Both of these processes are considered to be crucial steps in hard rock seismic data processing. Considerable improvement was achieved through the application of a pre-stack time migration (PSTM) algorithm. Conventional 3D deepmove out corrections (DMO), followed by a post-stack migration algorithm proved to be insufficient to handle the lateral changes of velocities. Consequently, pre-stack time imaging was attempted to aid in handling the highly complex velocity field. The goal was to derive a velocity model appropriate to the geologic environment in order to place events in their correct positions, to properly focus the energy, to avoid introduction of false structures and to flatten the image gathers. The Kevitsa 3D seismic dataset is considered as being of high quality and as the data volume contains a statistically significant number of log measurements, it is deemed suitable for the seismic inversion.

SEISMIC VOLUMETRIC INTERPRETATION OF STEEPLY DIPPING FAULTS IN A DISSEMINATED COPPER SYSTEM IN KEVITSA, NORTHERN FINLAND

Muhammad Shahadat Hossain[1]*, *Milovan Urosevic*[2] *and Chris Wijns*[2]
[1]Curtin University
[2]First Quantum Minerals

Improved mining technology and scarcity of near–surface deposits is forcing the mining industry to explore deeper in the search for economic mineralisation. Reflection seismic is one of the few geophysical methods that have sufficient resolution at depth to constrain geological information of an ore deposit at the drilling scale. Reflection seismic methods can be used to reduce drilling costs by focusing the drilling in strategically important areas. Seismic volumetric interpretation techniques have advantages over conventional interpretation techniques, where the interpretation is done by slicing the volume in 2D planes. Volumetric interpretation is performed in 3D and in real time, by applying various opacity and transparency filters to the seismic volume from different angles, which enables in–depth understanding of the volume. This initial stage of volumetric interpretation is followed by mapping the interfaces and associated structures of exploration interest.

A 3D high–resolution seismic dataset was collected to investigate steeply dipping to sub–vertical structures in Kevitsa, northern Finland. Automatic fault extraction using a modified ant–tracking workflow was performed on the seismic volume. The faults extracted using ant–tracking have acceptable correlation with the currently available geological interpretation.

SEISMIC IMPEDANCE INVERSION WITH PETROPHYSICAL CONSTRAINTS VIA THE FUZZY CLUSTER METHOD

Duy Thong Kieu[1]* *and Anton Kepic*[1]
[1]Curtin University

Seismic impedance inversion produces results that should be better for geological interpretation. However, seismic impedance inversion in mineral exploration normally suffers from poor signal-to-noise, and a lack of well control normally assumed for the process. To counter these problems we have developed an approach that exploits the fact that the geology in these environments often has fewer distinct geological units so we can restrict the number of physical parameters possible. A model-based seismic impedance inversion method using fuzzy c-means clustering to constrain inversion with petrophysical information has been developed. Using synthetic examples, we show that our method effectively recovers the true model even when the data is strongly contaminated by noise. This method is applied to seismic data from a US gold mining district and the results are reasonably consistent with well log data. The impedance images provide a better basis for geological interpretation than reflection images alone.

LASER DOPPLER INTERFEROMETRY (LDI) TO OBTAIN FULL STIFFNESS TENSOR: A CASE STUDY ON A DEFORMATION ZONE IN SWEDEN

Pouya Ahmadi[1]* *and Alireza Malehmir*[1]
[1]Uppsala University

Estimation of elastic anisotropy, which is usually caused by rock fabrics and mineral orientations, has an important role in exploration seismology and a better understanding of crustal seismic reflections. If not properly taken care of during data processing steps, it leads to wrong interpretation and/or distorted seismic image. In this work, a state-of-the-art under the development Laser Doppler Interferometer (LDI) device is used to measure phase velocities on the surface of rock samples from a major poly-phase crustal scale deformation zone (Österbybruk Deformation Zone) in the Bergslagen region of eastern Sweden. Then, a general inversion code is deployed to invert the measured phase velocities to obtain full elastic stiffness tensors of two samples from the deformation zone.

At the end, results are used to correct for the anisotropy effects using three dimensionless Tsvankin's parameters and a non-hyperbolic moveout equation. The resulting stacked section shows partial reflection improvement of the deformation zone compared with the traditional isotropic processing approach. This illustrates that rock anisotropy contributes to the generation of the reflections from the deformation zones in the study area although they do not show significant density contrast with their surrounding rocks.

ABSTRACTS

1330–1510
Day 3 Session 3 Stream A

PETROLEUM – UNCONVENTIONAL OIL AND GAS

CULTURAL AND TECHNICAL ISSUES WITH DEVELOPMENT OF UNCONVENTIONAL RESERVOIRS IN AUSTRALIA

Dennis Cooke[1]*
[1]University of Adelaide

Will development of unconventional reservoirs (tight gas, shale gas and CSG) in Australian proceed as in North America? What aspects of Australian development are more favorable? And what aspects will make development in Australia more difficult or expensive?

Australia currently has a more challenging cost structure than North America, but there are some distinct hidden advantages in Australia's oil and gas permitting laws. Australia's gas market appears to be much more attractive, at least for the short to mid-term. And the environmental issues are playing out in Australia in a very similar manner to North America.

Inside Australian companies developing unconventional resources, there is a debate over competing development philosophies that is largely hidden from public view; this is the debate between a low cost factory-like pattern drilling program versus an expensive up-front investment in geoscience data that will hopefully lead to a more economic drilling and completion solution.

Within the subsurface technical realm, a common mantra in North America now is "every shale gas play is different" – meaning that a technical solution for shale gas development in one basin may not work in another basin. With this view, shale gas development in Australia will not be any more or less challenging than trying to adapt Barnett shale gas solutions to the Eagle Ford shale (which is highly successful) or to the largely disappointing Woodford Shale. But there is one significant development challenge common to Australian basins that has not been experienced in North American: higher tectonic stress and higher differential stress. These higher stresses can lead to horizontal fracture stimulation treatments instead of the expected and more favorable vertical frac treatments.

While it is still too soon to pick the successful and unsuccessful unconventional plays in Australia, this talk will attempt to highlight the critical drivers in that success.

VALUABLE LESSONS FROM ACQUIRING 3D SEISMIC FOR COAL SEAM GAS

Andrew Aouad[1]*, *Randall Taylor*[1], *Neil Millar*[1] *and David Dorling*[1]
[1]Origin energy

A land 3D seismic survey was carried out in the Surat and Bowen Basins with the specific objective of imaging Coal Seam Gas reservoirs. Use of nodal acquisition technology allowed the survey to be designed around numerous obstacles while collecting a full range of azimuths and offsets. These were maintained through processing to provide well imaged structures and pre-stack data for quantitative interpretation.

UNCONVENTIONAL RESOURCE EVALUATION AND APPLIED GEOPHYSICS UTILISING LMR

David Close[1]* *and Marco Perez*[2]
[1]Origin Energy
[2]Apache Canada

Over the last decade the oil and gas industry has delivered conceptual and technical changes that have entirely changed the fundamentals of natural gas supply in North America. Underpinning the step change in natural gas reserves and market ready supplies has been the change in the perception of fine-grained, organic rich rocks (i.e. shales – although of course not all shales are organic rich). No longer are such rocks viewed only as source and seal candidates, but also as source rock reservoirs or shale gas plays.

Although the geological continuity of shale gas plays have led to the production-line style operations seen across North America

in mature unconventional plays, it is not "factory-style" efficiency improvements in isolation that allow the economic exploitation of shale gas. The large number of fit-for-purpose technologies, introduced by operators and service companies, has been critical in increasing production while keeping costs flat and/or reducing costs and time to production.

3D seismic data play a key role in unconventional developments as a unique look-ahead dataset. The role of seismic, however, has evolved to be far more than simply a tool for mapping major structures. For example, through AVO inversion we are able to make predictions regarding elastic properties of the formations of interest. The integration of AVO inversion data with engineering and rock physics data is providing new avenues of data exploitation. Seismic data are also being used to predict closure stress and stress anisotropy, which can be calibrated with data and analysis from hydraulic fracturing. Additionally, the integration of surface seismic data with microseismic provides a means of fine-tuning the estimation of stimulated rock volume.

1330–1510
Day 3 Session 3 Stream B

PETROLEUM – REGIONAL BASIN STUDIES

INTERPRETATION AND MODELLING OF NEW BROWSE BASIN AIRBORNE MAGNETIC DATA FOR IGNEOUS ROCKS AND BASEMENT

Ron Hackney[1]*, *Rowan Romeyn*[1] *and Claire Orlov*[1]
[1]Geoscience Australia

The Browse Basin on Australia's North West Shelf is a NE-trending Paleozoic to Cenozoic depocentre that contains more than 15 km of sediments. These sediments host significant hydrocarbon reserves, some of which are currently under development. The basin also has the potential to store large volumes of carbon dioxide. Recently-acquired aeromagnetic data over the Browse Basin provide new impetus for studies of the nature of basement, the role of structural inheritance and controls on the distribution of volcanic rocks.

Initial interpretation of the new magnetic data has utilised magnetic source polygons and depth estimates derived from the tilt-angle filter. Exploration wells that intersect mainly volcanic flows or tuffaceous rocks tend to lie on or adjacent to source polygons. Computed tilt depths show that these sources tend to coincide with the depth to the top of volcanics in wells and that tilt depths extend deep into the basin (up to ~10 km). The magnetic susceptibility distribution inferred from minimally-constrained, regional-scale inversion models also indicates that magnetic anomalies arise from features deep in the basin and within basement. These results highlight the importance of understanding the role of volcanic rocks in basin evolution and their influence on reservoirs that may host hydrocarbons or that may be suitable for CO2 storage.

USING POTENTIAL FIELD DATA TO MAP SALT DISTRIBUTION IN THE WESTERN OFFICER BASIN, WESTERN AUSTRALIA

Jane Cunneen[1]*, *Warick Crowe*[2] *and Geoff Peters*[2]
[1]Curtin University
[2]International Geoscience

The Neoproterozoic western Officer Basin has a total fill of up to 8 km and a depositional history with similarities to other Australian basins, particularly the Amadeus Basin. Exploration has been limited due to the size and remoteness of the basin; therefore potential field data can be a useful and cost-effective tool to assess petroleum prospectivity.

Salt distribution and mobilisation in the Officer Basin has been significantly underestimated due to a lack of quality seismic data. This study uses satellite, digital terrain, magnetic, gravity and seismic data to show the existence of mobilised salt much further west than previously suggested, with significant implications for future exploration in the region.

SCIENTIFIC OCEAN DRILLING AND THE CAPABILITIES OF THE IODP DRILLSHIP JOIDES RESOLUTION

Neville Exon[1]* *and Mitchell Malone*[2]
[1]Australian IODP Office, Australian National University
[2]US IODP Office, Texas A&M University

Scientific ocean drilling uses several drill ships to work on global scientific problems. These include changes over various time scales in climate, biology and oceanography, extreme life forms beneath the sea bed, planetary dynamics and geological hazards. The International Ocean Discovery Program (IODP) involves 27 countries, including Australia and New Zealand, and is the world's largest scientific geoscience program. One IODP drill ship, JOIDES Resolution, is working in our general region at present and for several years to come. Although the primary aim of the work is purely scientific, deep stratigraphic wells are always of interest to the petroleum exploration industry. This talk will cover IODP in general, ocean drilling in our region, and the capabilities of the JOIDES Resolution.

3D GEOPHYSICAL MODEL OF THE GLYDE BASIN, NORTHERN TERRITORY, BASED ON CURVATURES DERIVED FROM AIRBORNE GRAVITY GRADIENT DATA

Carlos Cevallos[1]* *and Peter Kovac*[1]
[1]CGG

This paper presents automatic 3D geophysical model generation based on equivalent pseudodepth slicing of the shape index of the equipotential surfaces derived from airborne gravity gradient data. The method is carried out in three steps. First, the pseudodepth slices of the vertical gravity gradient and the magnitude of the differential curvature components are generated. Second, the equivalent pseudodepth slices of the shape index are generated. Finally, 3D interpolation is carried out to obtain the final model.

The method is applied to FALCON airborne gravity gradiometer data from the Glyde Basin, Northern Territory and compared to an independently interpreted, integrated 3D geological Earth model.

1330–1510
Day 3 Session 3 Stream C

MINERALS – AIRBORNE ELECTROMAGNETICS 3

THE SUPERPARAMAGNETIC RESPONSE OF TRANSIENT AEM DATA

Daniel Sattel[1]* *and Paul Mutton*[2]
[1]EM Solutions LLC
[2]Touchstone Geophysic

Several lines of VTEM data flown at different system elevations across a known sulphide body and surface cover with elevated superparamagnetic (SPM) properties were analysed with MAXWELL, layered-earth inversions, LEROIAIR and LEROI. The SPM material was modelled with frequency-dependent magnetic susceptibilities at shallow depth.

Due to their slow late-time decay, SPM responses can be confused with responses of deep conductors and vice versa. Depending on the parameter weighting used, 1D inversions model all late-time responses as deep conductive material or as surficial SPM material. However, the joint 1D inversion of data acquired at different system elevations manages to recover a deep conductor from the sulphide anomaly and elevated SPM values at the location of the SPM response. For the modelled parameters, the VTEM data sets from two elevations (at 70 and 80 m) require a vertical separation of about 10 m to allow for the discrimination between the SPM and sulphide responses. For lower system elevations, less sensor separation is necessary due to the strong gradient of the SPM response.

We suggest that two vertically separated receivers could be used to measure the AEM gradient and depending on the flying height of the transmitter, the vertical offset of the receivers should be between 2 and 40 m.

RESTORATION OF DISTRIBUTED IP INFORMATION IN AIRBORNE-TIME DOMAIN ELECTOMAGNETIC DATA

Seogi Kang[1]* *and Douglas W. Oldenburg*[1]
[1]University of British Columbia

We propose a methodology to generate a 3D distribution of pseudo-chargeability from airborne time domain electromagnetic data. The processing flow is as follows: (a) Apply 3D inversion to TEM data to restore a background conductivity. This might involve omitting responses that are obviously contaminated with IP signals, such as negative transients in coincident loop surveys. The recovered background conductivity is assumed to be uncontaminated by IP signals. (b) Compute the TEM response from the background conductivity and subtract it from the observations. This yields the dIP data, and reduces the EM coupling. (c) The background conductivity is likely not exactly the earth conductivity, but we assume that the major effects of this inaccuracy will lead to a large scale, smoothly varying perturbation to the dIP data. If this correct, then these can be recognized and removed. (d) The final data are linearly related to a pseudo-chargeability through a sensitivity function that is analogous to that employed in usual DC-IP ground surveys. (e) The dIP data at various time channels can be inverted individually. The pseudo-chargeability models may be useful in themselves or they may be further processed to estimate Cole-Cole, or equivalent, parameters. We demonstrate our procedure on a field data set from Mt. Milligan. In the field example, we identify chargeable targets that show no indication of negative transients in the raw data. From the images we can make inferences about the relative strength and geometries of the chargeable bodies.

AIRBORNE INDUCTIVE INDUCED POLARIZATION CHARGEABILITY MAPPING OF VTEM DATA

Karl Kwan[1], *Alexander Prikhodko*[1], *Jean M. Legault*[1]*, *Geoffrey Plastow*[1], *Joe Xie*[2] *and Keith Fisk*[3]
[1]Geotech Ltd
[2]Yunnan Tin Australia
[3]Geotech Airborne Ltd

Airborne inductive induced polarisation (AIIP) effect has been widely recognized in airborne time domain EM system data. AIIP chargeability mapping opens new and exciting areas in mineral exploration for airborne time domain EM systems in the search for sulphides and clay minerals. An AIIP chargeability mapping tool based on CSIRO/AMIRA Airbeo is created for VTEM data, with examples from Mt Milligan, British Columbia, Canada and Tullah, Tasmania. Using the Cole-Cole frequency dependent resistivity, the tool examines the VTEM decay data spectrally and selects the decay associated with the lowest RMS error from a set of decays generated by varying chargeability m and time constant within specific ranges, giving a constant frequency factor c, while the background resistivity is inverted. The parameter mo used to generate the decay is the AIIP apparent chargeability.

DETERMINING COVER VARIABILITY IN THE CAPRICORN OROGEN WITH AIRBORNE EM

Yusen Ley-Cooper[1]*, *Tim Munday*[1] *and Tania Ibrahimi*[1]
[1]CSIRO

This paper focuses on elucidating cover variability throughout the Capricorn Orogen in Western Australia. We use, as a baseline, data from a widely spaced airborne electromagnetic (AEM) fixed-wing survey acquired for the Geological Survey of Western Australia in 2014. The Capricorn 2013 AEM survey is the largest AEM survey by area flown in Australia to date, covering over 146 300 km2. The Capricorn Orogen is a highly mineral prospective under explored orogeny located between the Pilbara and the Yilgarn Craton. Whilst the western part of the Orogen is particularly well exposed, and as a result the surface geology, geological history tectonic setting is well understood, the north west and eastern regions are characterised by a variably thick and complex regolith. The region is relatively under-explored, although host to significant mineralisation, including mesothermal orogenic gold, copper–gold volcanogenic massive sulphides, and channel iron ore deposits. In a region of variable cover, geophysical (aeromagnetic, electromagnetic and gravity) and geochemical techniques are critical aids to the mapping of lithostratigraphic units that are covered by regolith materials, but also in providing an understanding of the regional geological factors that control the mineralisation. Here we discuss some initial results from the smooth model layered earth inversion of 30,119 line km of AEM data. We consider sections from geologically contrasting parts of the Orogen. The results show the complexity and variability of conductive cover in the region and suggest some areas in the orogen could be beneath

200m of transported and in-situ regolith cover. The regional regolith framework that is being developed from the AEM data will provide a basis for better understanding and interpreting regolith geochemistry that has been acquired across a region, particularly where outcrop is limited.

1330–1510
Day 3 Session 3 Stream D

MINERALS – GEOLOGY FROM GEOPHYSICS 3

GEOSCIENCE DATA INTEGRATION: INSIGHTS INTO MAPPING LITHOSPHERIC ARCHITECTURE

Graham C. Begg[*1,2], *William L Griffin*[2], *Suzanne Y O'Reilly*[2] *and Lev Natapov*[2]
[1]Minerals Targeting International PL
[2]ARC Centre of Excellence for Core to Crust Fluid Systems/GEMOC

In order to develop a 4D understanding of the architecture of the entire lithosphere, it is necessary to embrace integration of multi-disciplinary, multi-scale data in a GIS environment. An holistic understanding has evolved whereby geologic, geochemical and geophysical signals are consistent with a subcontinental lithospheric mantle (SCLM) dominated by a mosaic of domains of Archean ancestry, variably overprinted by subsequent tectonothermal events. Pristine Archean SCLM is mostly highly depleted (high Mg#), low density, high velocity and highly resistive, and preserves intact Archean crust. There is a first order relationship between changes to these signals and the degree of tectonothermal overprint (by melts, fluids). Continental crust is comprised largely of reconstituted Archean components, variably diluted by juvenile addition, symptomatic of the various overprinting events. These events impart crustal fabrics and patterns dictated by SCLM architecture, influenced by the free surface and crust-mantle decoupling.

BUILDING EFFECTIVE MINERAL SYSTEM MODELS; THE IMPORTANCE OF MERGING GEOPHYSICAL OBSERVATION WITH GEOLOGICAL INFERENCE

Ken Witherly[1]*
[1]Condor Consulting, Inc.

As the discovery of shallow, high grade deposits for essentially all commodities continues to decline, explorers have to increasingly search for deposits at greater depth and with increased amounts of cover material. As a result, the direct detection of deposits becomes problematic and there needs to be a much greater reliance on secondary or tertiary signatures or halos of deposits to define the likely presence of the target. The mineral system approach is a means by which the overall environment in the earth which has been changed due to emplacement of a deposit in both space and time is characterized at a variety of scales. If we are able to understand the reasons for these changes and then systematically track them in the earth, explorers have a powerful new tool to identify deposits at depth. For this approach to be successful it will require a degree of integration between geology, geophysics and geochemistry not previously undertaken.

1330–1510
Day 3 Session 3 Stream E

MINERALS – MISCELLANEOUS 1

GEOPHYSICS IN GREENFIELDS REGIONS TO DETERMINE COVER THICKNESS: PRE-COMPETITIVE DRILLING IN THE STAVELY REGION OF VICTORIA

Anthony Meixner[1]*, *Aki Nakamura*[1], *Malcolm Nicoll*[1] *and Sarlae McAlpine*[1]
[1]Geoscience Australia

Fifteen pre-competitive stratigraphic holes have been drilled to test geological and mineral system models in the 'greenfields' Stavely region of western Victoria. Prior to drilling, seismic reflection and refraction, gravity, and airborne magnetic data were used to estimate the thickness of cover at the selected drill sites. This analysis also tested the reliability of the geophysical techniques in a range of geological conditions.

Comparisons with preliminary drilling data indicate that seismic refraction data successfully predicted cover thickness at six out of seven sites. Estimates of depth to magnetic source at the top of basement, derived from airborne magnetic data successfully predicted cover thickness at eight of ten sites. Seismic reflection

was the least reliable technique with one out of four successful predictions. However, despite their success rate, neither the refraction nor the magnetic data gave reliable cover thickness estimates where cover materials were highly magnetic or had high seismic velocities.

PROCESSING GRAVITY GRADIENTS TO DETECT KIMBERLITE PIPES

Thomas Meyer[1]*
[1]Lockheed Martin MST, New Ventures - Gravity Systems

A modelling and pattern recognition-based approach is applied to processing airborne gravity gradient data for kimberlite exploration. The carrot-like bodies with low density crater facies that typify kimberlite pipes are particularly amenable to this treatment. Results for small and medium-sized pipes buried deeply beneath nominal geologic clutter are promising. Details regarding various error rates provide valuable input to exploration programs and the framework can include any data type. A three-class problem is formulated to address the case of false positives. A first example is worked for low density shallow depressions that closely mimic gravity images of pipes, providing insight to what is needed from a survey fidelity standpoint to effectively mitigate false positives.

HIGH PRECISION TERRAIN CORRECTIONS FOR NEXT GENERATION AIRBORNE GRAVITY DATA

T. Aravanis[1], *M. Grujic*[1]*, *J. Paine*[2] *and R. J. Smith*[3]
[1]Rio Tinto Exploration
[2]Scientific Computing
[3]Greenfields Geophysics

This paper describes a method of improving the estimation of terrain effects in airborne gravity or gravity gradient data by closer sampling of the terrain and flight path in areas of steep topography and integrating spot estimates over the actual flight path measurement interval. Simulated estimates of terrain effect over an actual flight path in rough terrain are used to demonstrate the expected improvement in terrain corrections and target recognition. Integrating the gravity gradient of the terrain along the flight path of an airborne gravity gradiometry survey is a necessary part of terrain corrections for the upcoming generation of highly accurate gravity gradiometers. The effect of spatial integration does not generally need to be considered in the data processing workflow of current instruments.

THE VALUE OF A COMBINED APPROACH: INNOVATIVE MINERAL EXPLORATION TECHNIQUES IN THE IRISH ZN-PB OREFIELD

Simone De Morton[1]*, *Malcolm Wallace*[1], *Christopher Reed*[2], *Chad Hewson*[2], *Patrick Redmond*[2], *Eoin Cross*[2] *and Conor Moynihan*[2]
[1]University of Melbourne
[2]Teck Namibia

The Early Carboniferous stratigraphy of the Irish Midlands contains one of the world's major Carbonate-hosted zinc-lead orefields covering a region of approximately 8000 km^2. The large-scale nature of the sedimentary fluid flow systems that produce these ore deposits suggest it is necessary to understand not only the nature of mineralisation, but also the nature of the basin in which it is hosted. In this study we integrate typical methods of stratigraphic analysis (core and outcrop logging) with recently acquired seismic reflection data and gamma ray logs to ascertain the relationship between the stratigraphic and structural setting of the Ballinalack Zn-Pb deposit and the wider host basin (Dublin Basin).

Geometric relationships between layers as revealed by seismic reflection, in conjunction with detailed lithological analysis has shown extensional tectonism was the main driving force of sedimentation in the Dublin Basin. A period of significant extensional tectonism first occurred in the late Tournaisian (Moathill Event, ~348 Ma) and was accompanied by faulting and regional subsidence. This was followed by a period of relative tectonic quiescence, before a second period of tectonism during the lower Viséan (Tober Colleen Event, ~345 Ma) resulted in regional subsidence, but without significant faulting. Major subsidence associated with these events produced strong transgressions in the Dublin Basin, interspersed with periods of regression. This view of the tectonic history of the Irish Carboniferous basin contrasts with previous interpretations that suggest the Lower Carboniferous represents an overall deepening sequence. The suggested earlier timing of fault movement has implications for arguments about the origin of Irish-type Zn-Pb deposits and the necessity (or not) for having active faulting during mineralisation. These novel results reveal the value of a combined approach to sedimentary basin analysis.

1530–1710
Day 3 Session 4 Stream A

PETROLEUM – RESERVOIR CHARACTERIZATION 2

INSIGHTS OF DIELECTRIC MEASUREMENTS FROM CUTTINGS RECOVERED ALONG THE DEEPEST OFFSHORE WELL IN THE WORLD (NANKAI TROUGH ACCRETIONARY PRISM): IODP EXPEDITION 338, SITE C0002F

Lionel Esteban[1]*, *Matthieu Cauchefert*[1] *and Matthew Josh*[1]
[1]CSIRO-ESRE

A total of 109 cuttings were recovered during the IODP expedition 338 in site C0002F down to 2005 mbsf. A special dielectric end-load probe was designed and used for the first time at sea on this sample collection to measure dielectric and electrical conductivity from 10 kHz to 6 GHz. The whole dataset was compared to specific surface area (SSA), mineralogy from XRD measurements and resistivity log while drilling acquired during the expedition to understand the relationship between fluid, clays and lithologies. The dielectric results revealed to be very powerful to: (i) understand the clay composition and content; (ii) re-calibrate cutting depths; (iii) detect unit boundaries and (iv) detect conductive and not-conductive fault systems.

USING MULTIVARIATE DATA CLASSIFICATION ON FRONTIER EXPLORATION BASINS TO ENHANCE THE INFORMATION VALUE OF SUBOPTIMAL 2D SEISMIC SURVEYS FOR UNCONVENTIONAL RESERVOIR CHARACTERIZATION

Andrea Paxton[1]*, *David Handwerger*[1], *Roberto Castaneda-Aguilar*[1], *Don Stachiw*[2] *and Roberto Suarez-Rivera*[1]
[1]Schlumberger
[2]Northern Cross Yukon

We developed a workflow that allows integrating legacy 2D seismic surveys with modern log and core data, validating their consistency, classifying them into rock classes with consistent properties, propagating material properties across each of these rock classes, and using this information to improve reservoir characterization and the assessment of their hydrocarbon resource potential. As proof of concept, we analyzed two intersecting 2D seismic lines shot in 2001 in a frontier basin in Canada to determine the distribution of reservoir quality. Each of these had been separately prestack inverted, but have modern core and log data (as well as legacy log data) which were integrated with the inverted attributes.

Results identify a most prospective class for reservoir quality within the zone of interest, and show that it increases in thickness to the south in the seismic section.

1530–1710
Day 3 Session 4 Stream B

PETROLEUM – RESERVOIR CHARACTERIZATION 3

ENHANCED DELINEATION OF RESERVOIR COMPARTMENTALIZATION FROM ADVANCED PRE AND POST-STACK SEISMIC ATTRIBUTE ANALYSIS

Mauricio Herrera Volccan[1]*, *Clark Chahine*[1] *and Leigh TrueLove*[1]
[1]Schlumberger

Reservoir compartmentalization has a huge bearing on fluid flow within hydrocarbon reservoirs, and can impact overall recovery during field development. Small and sub-seismic faults can have a dramatic effect on the compartmentalization within a reservoir, but until recently they have not typically been incorporated into fault interpretations. This can be due to data fidelity and the amount of time needed to manually pick them. Their omission from the interpretation – and ultimately reservoir models – means the understanding of reservoir compartmentalization is incomplete, hence solving this problem is critical to improve production. Approaches that automatically identify and extract faults from seismic volumes are available. These automated methods aim to emphasize discontinuities within seismic volumes and are usually focused on poststack data. However, they need preconditioned inputs that are often based around a coherence algorithm. This preconditioning aims to suppress noise but can inflict data degradation, which may diminish smaller features in the seismic volumes. This article proposes an enhanced approach using a new combination of preconditioning steps designed to avoid these degradation problems. It also proposes the use of prestack seismic data, which has not traditionally been used for this purpose. Analysis of various pre-stack elements is displayed to show it can delineate more features than poststack data alone in certain noisy areas, such as gas effects or low frequencies. Finally, it demonstrates that the best approach combines results from pre- and poststack analysis to produce a more complete picture of reservoir compartmentalization.

SEISMIC WAVEFORM CLASSIFICATION: RENEWING THE INTEREST IN BARROLKA FIELD, SW QUEENSLAND, COOPER BASIN

Yahya Il Basman[1]*
[1]Santos

Seismic wave form classification techniques have been used to significantly improve the efficiency of the interpretation of the Barrolka field 3D seismic survey. Pattern recognition of seismic shape based on a neutral network has proven to be powerful approach in reducing risk associated with characterising and predicting the extent of the Barrolka field's historically elusive PC30 reservoir. This technique resulted in recent drilling success with development wells intersecting predicted reservoir and resulting in exceptional initial gas rates, a contrast to the field complex's 30 years low drilling success. This study has rejuvenated interest to convert the field's large contingent resource to reserves.

1530–1710
Day 3 Session 4 Stream C

MINERALS – RADIOMETRICS

MONITORING AIRBORNE GAMMA RAY SPECTROMETER SENSITIVITIES USING THE NATURAL BACKGROUND

Robert Grasty[1]*, *Martin Bates*[2] *and Ania Smetny-Sowa*[2]
[1]Gamma-Bob Inc.
[2]Sander Geophysics

In many airborne gamma-ray surveys, uranium and thorium sources are required to verify that the airborne system maintains the same sensitivity for each survey flight. Recently, due to radioactive material regulations, it has become increasingly difficult to transport these radioactive sources around the world. Measurements of the natural radioactivity of the ground, recorded as part of source tests carried out in Tanzania were analysed. These data involved three different aircraft at two bases of operation. The results have shown that in all cases the potassium and thorium background measurements were more consistent than the measurements from the uranium and thorium sources. In addition, the variations in the potassium and thorium measurements could be reduced even further by removing the effect of airborne radon daughter fluctuations using stripping ratios derived from measurements on concrete calibration pads.

THE 3D INVERSION OF AIRBORNE GAMMA-RAY SPECTROMETRIC DATA

Brian Minty[1]* *and Ross Brodie*[2]
[1]Minty Geophysics
[2]Geoscience Australia

We present a new method for the inversion of airborne gamma-ray spectrometric line data to a regular grid of radioelement concentration estimates on the ground. The method incorporates the height of the aircraft, the 3D terrain within the field of view of the spectrometer, the directional sensitivity of rectangular detectors, and a source model comprising vertical rectangular prisms with the same horizontal dimensions as the required grid cell size. The top of each prism is a plane surface derived from a best-fit plane to the digital elevation model of the earth's surface within each grid cell area.

The method is a significant improvement on current methods, and gives superior interpolation between flight lines. It also eliminates terrain effects that would normally remain in the data with the use of conventional gridding methods.

1530–1710
Day 3 Session 4 Stream D

MINERALS – GEOLOGY FROM GEOPHYSICS 4

GEOLOGICAL UNCERTAINTY AND GEOPHYSICAL INVERSION

Mark Jessell[1]*
[1]Centre for Exploration Targeting

One of the major challenges for geophysical inversion schemes is to retain geological meaning during the inversion process. In voxel-based methods based on prior geological models we are typically forced into a manual reinterpretation of smooth petrophysical images in terms of discrete structures and lithostratigraphy.

Recent work in the characterisation of geological uncertainty has demonstrated the inherent weaknesses in classical 3D geological model building strategies. The analysis of 3D geological uncertainty provides several pathways to improved geophysical inversion. The uncertainty can be characterised at the local scale to provide constraints on petrophysical inversions, and at the global scale to provide end-member geologically and topologically distinct prior models. Although in its infancy, geological uncertainty analysis shows promise in workflows aimed at integrating geological and geophysical constraints in 3D.

1530–1710
Day 3 Session 4 Stream E

MINERALS – MISCELLANEOUS 2

BAD COLOUR MAPS HIDE BIG FEATURES AND CREATE FALSE ANOMALIES

Peter Kovesi[1]*
[1]Centre for Exploration Targeting

Many colour maps provided by vendors have highly uneven perceptual contrast over their range. It is not un-common for colour maps to have perceptual flat spots that can hide a feature as large as one tenth of the total data range. The opposite can also occur whereby perceptual discontinuities in the colour map can induce the appearance of false anomalies. This paper presents a set of design techniques that allow colour maps to be constructed with uniform perceptual contrast across their full range. The most important factor in designing a colour map is to ensure that the magnitude of the incremental change in perceptual lightness of the colours across the map is uniform. The rate of incremental change in hue or saturation of the colours in the map prove to be relatively unimportant when one is seeking to discern features at fine spatial frequencies. Accordingly, the colour maps pre-sented here are designed in CIELAB colour space. In contrast to RGB this colour space provides a perceptual organization of colours in terms of their lightness, hue and chroma/saturation which facilitates the design process. The utility of the colour maps presented here is demonstrated using a simple test image that allows the perceptual uniformity of colour maps to be readily evaluated.

QUANTIFYING MODEL STRUCTURAL UNCERTAINTY AND FACIES PREDICTION FOR LOCATING GROUNDWATER SUPPLIES IN TIMOR-LESTE USING AEM DATA

Burke Minsley[1]* *and Yusen Ley-Cooper*[2]
[1]U.S. Geological Survey
[2]CSIRO

Geological structures key to understanding groundwater resources in Timor-Leste's Baucau Plateau are mapped using an airborne electromagnetic (AEM) survey. A comprehensive assessment of model structural uncertainty is conducted using a Bayesian Markov chain Monte Carlo algorithm, and an approach for translating geophysical to geological model uncertainty is introduced. A prominent feature of the Baucau survey is a very high-contrast transition from resistive limestone materials to conductive clays, which is well-resolved from the AEM analysis. The inferred 3D geometry of potentially water-bearing limestone units that overly relatively impermeable clays is a key outcome of this analysis, and will be the focus of future ground-truthing efforts.

10.1071/PVv2015n174p129

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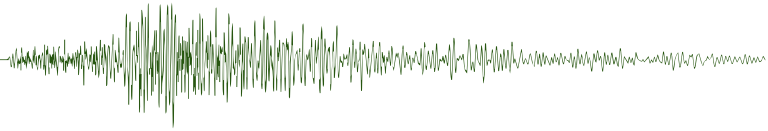

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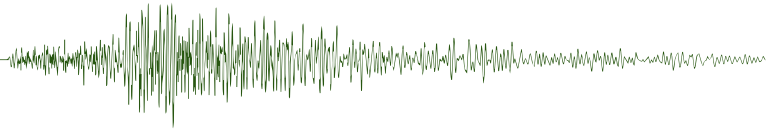

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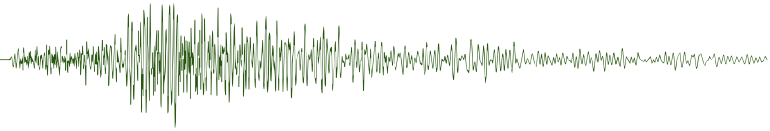

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MINERALS – 21ST CENTURY EXPLORATION: METHODS AND TECHNOLOGIES

1. RESISTIVITY AND INDUCTION POLARIZATION TECHNIQUE FOR MAPPING HEMATITE RICH AREAS IN IRAN

Ida Hooshyari Far[1]*, *Anton Kepic*[1] *and Shahriar Javadipour*[2]
[1]Curtin University
[2]TESLA Explorer Engin

Hematite mineralisation loses magnetic susceptibility as it oxidizes. The absence of a significant magnetic response means that exploration using magnetic methods is ineffective.

Mineralogy of the study area shows the mineralisation is generally dominated by iron oxides, mainly hematite, but it also contains anomalous concentrations of sulphides. For this reason the induced polarisation-resistivity method can potentially be used during exploration since the sulphides increase chargeability. The induced polarisation-resistivity method is cost efficient and relatively fast.

In this study, we examined the applicability of the induced polarisation-resistivity method for iron ore exploration in Iran. The interpretation of the results was constrained by known geology and confirm that this technique is a possible alternative to magnetic exploration methods.

2. A COMPARISON OF 3D DCIP DATA ACQUISITION METHODS

David Farquhar-Smith[1]* *and Darcy McGill*[1]
[1]Quantec Geoscience Ltd

Several approaches to 3D DC resistivity are examined by using data acquired by a high resolution pole-dipole omnidirectional 3D DCIP survey that successfully mapped a known mineralised zone. Subsets of the real-world data are used to examine the effects of reduced numbers of receiver dipoles and also reduced numbers of current injections. To compare the full-scale 3D survey results with other commonly-used systems, a third data subset simulates an offset-injection type survey. The results show that the high-density omnidirectional method produces superior resolution of geologic structures compared to other methods that collect less dense and directionally biased data.

3. RESULTS FROM SGL'S AIRGRAV AIRBORNE GRAVITY SYSTEM OVER THE KAURING AIRBORNE GRAVITY TEST SITE

Luise Sander[1]* *and Stefan Elieff*[1]
[1]Sander Geophysics

A Sander Geophysics AIRGrav airborne gravity system was flown over Geoscience Australia's Kauring airborne gravity test site. Comparisons with both Geoscience Australia ground data and airborne gravity gradiometer data acquired by CGG using the Falcon system are presented. A series of band pass filters of the vertical gravity and vertical gravity gradient are employed to highlight performance at different wavelengths. While the Falcon system is best suited to the shortest wavelengths present at the Kauring test site, the AIRGrav system is also able to resolve relatively short wavelength features. This is due to noise reduction through the oversampling present with tight line spacing, combined with the unique characteristics of the AIRGrav system. Additional results with wider line spacing more commonly employed in airborne gravity surveys are shown using data acquired over both the Kauring test site and Papua New Guinea.

4. 3D JOINT INVERSION OF GRAVITY GRADIOMETRY AND MAGNETIC DATA IN SPHERICAL COORDINATES WITH CROSS-GRADIENT CONSTRAINTS

Haoran Wang China[1]*, *Yaoguo Li*[2] *and Chao Chen*[1]
[1]University Of Geosicences
[2]Colorado School of Mines

Earth observing satellites offer exciting new opportunities to study the large-scale regional or global lithospheric structures by producing reliable potential-field data sets including gravity, gravity gradiometry, and magnetic data that are publicly accessible. Joint inversions may offer an effective means of utilizing these different types of data to improve the construction lithospheric models. In this paper, we develop a joint inversion algorithm for satellite gravity gradiometry and magnetic data in the spherical coordinates for simultaneously constructing the density and susceptibility distributions in the lithosphere. Given the undetermined relationship between the two different physical properties, we apply the cross gradient to constrain the two recovered models so they structurally similar. We use a synthetic data example to illustrate the algorithm and its potential benefits. We will also demonstrate the algorithm by applications to field data sets in the presentation.

5. AN IMPROVED TILT DERIVATIVE METHOD COMBINED WITH THE MMTS E USING IN FRACTURE SYSTEM IDENTIFICATION FOR THE SWIR 49°E AREA

Qiuge Wang[1]*, *Chao Chen*[1], *Zhikui Guo*[1], *Shuangxi Zhang*[1], *Haoran Wang*[1] *and Duan Li*[1]
[1]China University of Geosciences (Wuhan)

Seafloor hydrothermal sulfide deposits occurring at plate boundaries and convergent plate boundaries are mainly concentrated in extensional tectonic belt with abundant fault structure, which is always correlated with the severe potential field signals changes. Considering the common magnetic anomaly components cannot reflect the field sources correctly as magnetic field around the ocean ridges is extremely infected by the residual magnetism, based on the obvious superiority of the magnitude magnetic transforms (MMTs) centricity and low dependence on the magnetization vector direction, we used the MMTs for geological boundaries identification. We improved the Tilt derivative method to indentify the boundaries of the geological structure on the basis of both the MMTs E and R, and find that the MMTs E combined with the improved Tilt derivative method performs better . We applicant this method in the 49° E zone (48°E~52°E, –39°S~–37°S) of the Southwest India Ridge (SWIR), with the help of the 2-arc minute high resolution magnetic model EMAG2, the fault system distribution of the study area was obtained and described primarily.

6. 3D IP INVERSION OF AIRBORNE EM DATA AT TLI KWI CHO

Seogi Kang[1]*, *Douglas W. Oldenburg*[1] *and Michael S. McMillan*[1]
[1]University of British Columbia

In this study, we revisit three airborne EM surveys over Tli Kwi Cho (TKC). These consist of a frequency domain DIGHEM data

set, and two time domain surveys, VTEM and AeroTEM. Negative transients have been recorded in both of the time domain surveys and we interpret these as arising from chargeable bodies. The kimberlite pipes are referred to as DO-27 and DO-18. We look in more detail at the transient data and apply the ATEM-IP inversion procedure to recover a 3D pseudo-chargeability distribution. Important components of the analysis involve estimating a background conductivity for the region. For DO-27 we have used a 3D parametric inversion to recover the conductivity from TEM data. The IP signal for the inversion is obtained by subtracting the time domain responses estimated by EM inversion from the observed background signal. This process also removes EM coupling noise that might be contaminating the data. The resultant IP data are inverted with a linear inverse approach using the sensitivity from the background conductivity. This yields a 3D model of pseudo-chargeability.

7. NEAR SURFACE SEISMIC INVESTIGATION OF THE REGOLITH IN SOUTH AUSTRALIA

Stephanie Vialle[1]*, *Konstantin Tertyshnikov*[1], *Sinem Sinem*[1] *and Bai Chun Sun*[1]
[1]Curtin University

Investigation of the regolith is an important part of mineral exploration. Large areas are overlaid by the regolith rocks and recent trends show an increase in exploration under cover. Thorough regolith exploration involving geophysical techniques is required for deep mineral discoveries. Knowledge about regolith structure and properties is necessary for designing mines and production as well.

A short 2D seismic profile was acquired to investigate regolith structure and properties at the Hillside prospect, situated on the Yorke Peninsula, South Australia. A small 3D dataset has also been acquired to evaluate the potential for seismic imaging of deep structures. The survey was designed to be able to collect useful data for various types of seismic analysis simultaneously. Data analysis included processing and interpretation of surface, refracted and reflected waves. The study also involved an application of diffraction imaging to detect faults and fracture zones.

The experiment has demonstrated a cost effective near surface seismic setup that is capable of obtaining a comprehensive set of information about the sub-surface. The results include imaging of the regolith's structure, estimating dynamic elastic properties of the ground and obtaining images of deep structures.

8. GEOLOGICAL KNOWLEDGE DISCOVERY AND MINERALS TARGETING FROM REGOLITH USING A MACHINE LEARNING APPROACH

Matthew Cracknell[1]*, *Anya Reading*[1] *and Patrice de Caritat*[2]
[1]University of Tasmania
[2]Geoscience Australia

We identify and understand the diverse nature of Ni mineralisation across the Australian continent using Self-Organising Maps, an unsupervised clustering algorithm. We integrate remotely sensed, continental-scale multivariate geophysical/mineralogical data and combine the outputs of our machine learning analysis with Ni mineral occurrence data. The resulting Ni prospectivity map identifies the location of Ni mines with an accuracy 92.58%. We divide areas of prospective Ni mineralisation into five clusters. These clusters indicate subtle but significant differences in regolith and bedrock geophysical/mineralogical footprints of Ni sulphide and Ni laterite deposits. This information is used to identify and understand the nature of potential Ni targets in regions where prospective bedrock mineralisation is concealed by regolith materials. Our machine learning approach can be applied to the analysis of other mineral commodities and at local-/prospect-scales.

9. HYDROPHONE DESIGN UTILISING SPECTRAL-SHIFTS FROM STRAIN-OPTIC INTERACTIONS

Vladimir Bossilkov[1]*, *Anton Kepic*[1] *and Anna Podolska*[1]
[1]Curtin University

Alternative technologies for the production of hydrophones using optical sensing are reviewed with respect to performance and manufacturability. Sensor designs utilising spectral shifts as a result of strain-optic interactions are uncommon, and we believe they merit further investigation as geophysical sensors due to good sensitivity and relative ease of manufacture Specifically, a Long Period Fibre Grating placed onto a mandrel appears to be as promising candidate as a future compact hydrophone sensor.

A mathematical model has been created for a compliant mandrel coupled with a Long Period Fibre Grating inscribed into plastic fibre. The modelling results indicate that such a sensor should provide a sensor of minimal size, with desirable sensitivity characteristics. Compared to the Rayleigh based optical fibre sensors being evaluated in geophysical applications currently the modelled sensor is predicted to have significantly greater sensitivity, with the mandrel acting as a mechanical amplifier. The main limitation of the spectral shift method is the number of sensors that can be multiplexed on a single fibre. However, a combination of time-domain and wavelength domain multiplexing could significantly increase the number of sensors per fibre to usable numbers for geophysical applications.

10. HARMONISING DIVERSE 3D GEOMETRIES IN A HARD ROCK ENVIRONMENT FOR PRE-STACK IMAGING

Sasha Ziramov[1]* *and Milovan Urosevic*[1]
[1]Curtin University of Technology

Four 3D seismic surveys were acquired by HiSeis Pty Ltd over two years across an existing mining camp. The main objective of these seismic surveys was definition of structures which could assist characterization of mineralised zone that consists mainly of massive sulphides.

Initial processing of seismic data started shortly after acquisition in 2011. Preliminary products have shown great promise in resolving complex structural environments and showed potential for direct targeting form seismic data. Our motive for reprocessing the dataset was in integration of all 2011 and 2012 seismic data in an amplitude consistent routine which could bring new value for amplitude based analysis of massive sulphide bodies. Conventional 3D deep-move out corrections (DMO), followed by a post-stack migration algorithm has not been successful in merging diverse datasets. Considerable improvement was achieved through the application of pre-stack time migration (PSTM) algorithm. This allowed us to use unique bin size for all merged seismic surveys.

Successful imaging of merged datasets has been challenged. The main reason was that 3D seismic datasets had vastly diverse offset and azimuth distribution. Highly irregular migration fold coverage is an obvious problem which had to be overcome by exclusion of unsuccessful imaged events prior to stacking.

11. MODELLING USING RECEIVER WAVEFORM AND THE UNEXPECTED IMPORTANCE OF SYSTEM POSITION

Adam Smiarowski[1]* *and Daniel Sattel*[2]
[1]CGG
[2]EM Solutions LLC

Conductivity-depth sections (CDI) produced from a recent airborne TEM exploration survey showed a poor fit to the expected geology of the area (a known conductive layer was appearing deeper than expected). The source of the problem was found to be the use of an incomplete description of the system geometry which had the effect of dramatically scaling the secondary field. In many modelling programs, including in this case EMFlow, the system geometry may be used to determine transmitter-receiver coupling which is used to compute the apparent primary field. This paper explains why system geometry can be critical for precise modelling of TEM data. By specifying the correct transmitter orientation and de-rotating receiver pitch for both primary and secondary fields, the match between known geology and CDI depth was greatly improved.

12. BUILDING A MACHINE LEARNING CLASSIFIER FOR IRON ORE PROSPECTIVITY IN THE YILGARN CRATON

Andrew Merdith[1]*, *Thomas Landgrebe*[1] *and Dietmar Müller*[1]
[1]EarthByte Group, University of Sydney

High resolution, large-scale geophysical data have recently become readily and freely available for the majority of the Australian continent; yet there have been few efforts to create a synthesis of these datasets for mineral exploration. Considering the rising cost of finding new deposits and the recent economic downturn, there is a focus on using low expenditure, large-scale explorative techniques to assist in finding deposits. Using sophisticated machine learning algorithms coupled with increases in computational power, we present a methodology that tests and trains a classifier using six geophysical datasets in conjunction with 37 iron ore locations in the Pilbara Craton that accurately predicts the locations of iron ore deposits throughout the Yilgarn Craton. Our selected classifier uses principal component analysis and mixture of Gaussian classification with reject option, and it successfully identifies 88% of iron ore locations. We use cross-validation (10 fold, 70% testing 30% training) to ensure the generalisation of our classifier. We apply our classifier to the Yilgarn Craton, an area not used for the training and testing phase, and compare the predictive confidence map to previously published locations of iron ore occurrences. We find that our classifier correctly locates key known Yilgarn iron ore deposits, in addition to highlighting other areas that could potentially be prospective for iron ore.

13. 2D CROSS-GRADIENT JOINT INVERSION OF MAGNETIC AND GRAVITY DATA ACROSS THE CAPRICORN OROGEN IN WESTERN AUSTRALIA.

Adrian Misael Leon Sanchez[1]* *and Luis Alonso Gallardo Delgado*[1]
[1]Centro De Investigacion Cientifica Y De Educacion Superior De Ensenada, Baja Cal

In order to contribute to the recent efforts to produce a combined interpretation of the Capricorn Orogen in Western Australia, we performed the 2D cross-gradient joint inversion of the gravity and magnetic data available along the trace of the seismic section 10GA-CP2. This methodology establishes that even in the absence of analytical relationships between the physical properties underlying disparate geophysical methods, we expect a degree of structural similarity in the images that they provide. Our results show that the major subsurface structures interpreted on the seismic section are readily detected by the 2D cross-gradient joint inversion. We also illustrate how this structural framework acquires further geological significance when the framed density and magnetization properties are interpreted together and correlated to the expected geological materials within the Capricorn orogen.

14. IDENTIFYING TECTONIC NICHE ENVIRONMENTS OF SOUTH AMERICAN PORPHYRY MAGMATISM THROUGH GEOLOGICAL TIME: A SPATIO-TEMPORAL DATA MINING APPROACH

Nathaniel Butterworth[1]*, *Daniel Steinberg*[2], *Dietmar Müller*[2], *Stephen Hardy*[2], *Simon Williams*[1] *and Andrew Merdith*[1]
[1]EarthByte, University of Sydney
[2]NICTA

Porphyry ore deposits are well known to be associated with arc magmatism related to subduction on the overriding plate. Furthermore, the regional mechanisms for magmatism and the resulting formations of porphyry deposits are well established. Specific parameters leading to these events have been inferred, but not formally tested. We aim to identify the specific set of tectono-magmatic parameters that result in a subducting slab producing particular types of magmatism on the overriding plate, and their link to the formation of ore deposits. We use a four-dimensional approach to reconstruct age-dated magmatism back through space and time to isolate the tectono-magmagic parameters leading to the formation of a metalliferous deposit during subduction. By utilising machine learning techniques we identify and quantify geodynamic parameters that are robust predictors of back-arc magmatism and porphyry formation. The 'random-forest' ensemble and 'support vector machines' learning classification methods are employed to prioritise parameters that are considered influential in the development of magmatism and the subsequent metallogenesis of porphyry ore deposits. We find that a combination of convergence rates and directions, seafloor age, subduction obliquity, and the distance to a trench edge help predict whether magmatism and related ore deposits occur.

15. CUTTING THE LINE IN WIRELINE WITH AN AUTONOMOUS SONDE

Anna Podolska[1]*, *Anton Kepic*[1], *Andrew Greenwood*[1], *Christian Dupuis*[2] *and Gordon Stewart*[3]
[1]Curtin University
[2]Univereite Laval
[3]Globaltech

Rock core has long been one of the pillars of mineral exploration strategy. This strategy, however, is becoming less viable as the depth of exploration targets continue to increase. Exploration strategies based on physical and chemical attributes of the rock-mass measured in-situ have the best chances to deliver efficient exploration programs by providing new data channels that can be used to improve the models of the deposits. Unfortunately, the logistic costs of acquiring these data using conventional wire-line methods have precluded their widespread use in the mineral industry.

The autonomous sonde concept presented in this work drastically reduces the logistics costs of acquiring in-situ measurements. The autonomous sonde has been developed to integrate fully with the normal operations of current drill rigs. As such, it requires no specialised operator or equipment and no rig modifications.

In this work, we present the results of field trials of the autonomous sondes at two Australian field sites. In the first experiment, we show that a pressure transducer can be used to evaluate the position of the sonde and to depth register the natural gamma data. In the second experiment, we show data acquired when the autonomous sonde protrudes through the bottom of the drill string and is brought back to surface by pulling up the rods. The results show a good repeatability between logging runs and data quality compares favourably to traditional wireline data.

16. 1D MAGNETOTELLURIC FORWARD MODELLING WEB APP

Andrew Pethick[1]* *and Brett Harris*[1]
[1]Curtin University

Geophysical computing within the cloud appears to be the way of the future. The instantaneous, on-demand character of modern life is now firmly established. We present an integrated 1D magnetotelluric forward modelling web app. This basic web app combines a scientific python back end and a front end built upon PHP and HTML5 web technologies. It has also been packaged as an easy to install plugin for the popular Wordpress framework. The application simulates the 1D magnetotelluric response over any isotropic geo-electrical earth model. MT forward modelling can be performed on any internet enabled device containing a HTML5 compliant browser with our WebMT application. This includes mobile phones, tablets and desktop PCs. This research demonstrates one approach to geophysical web application development and promotes future development and innovation within the geophysics community.

17. IMAGING THE ELECTRICAL LITHOSPHERE OF SOUTH AUSTRALIA - 2D PROFILES AND PRELIMINARY RESULTS OF AUSLAMP SA

Stephan Thiel[1]*, *Graham Heinson*[2] *and Steve Hill*[1]
[1]Department of State Development
[2]University of Adelaide

The Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) has the goal of mapping the electrical resistivity of the Australian lithosphere to constrain the geodynamic framework of the continent. Between August 2014 and May 2015, 125 long-period magnetotelluric (MT) data will be collected across the Gawler Craton and the south-eastern part of South Australia at intervals of 50 km. Results will be compared to existing 3D models highlighting enhanced conductivity in the sub-lithospheric mantle of the Gawler Craton. Initial results of 1D depth transformations show a significant change in resistivity at mantle lithosphere depths (100 km). The results will also be tied to the newly acquired Eucla MT line and a new 1000 km NS MT profile extending north from the central Gawler Craton into the Arunta Province, NT.

MINERALS - GEOLOGY FROM GEOPHYSICAL DATA

18 . MAPPING SANDSTONE-HOSTED URANIUM MINERAL SYSTEMS IN THE CALLABONNA SUB-BASIN (SOUTH AUSTRALIA) USING AEM

Marina Costelloe[1]*
[1]Geoscience Australia

The Frome TEMPEST® airborne electromagnetic (AEM) survey was designed to provide reliable pre-competitive AEM data to aid the search for energy and mineral resources around the Lake Frome region of South Australia. Flown in 2010, a total of 32 317 line km of high-quality airborne geophysical data were collected over an area of 95 450 km^2 at a flight line spacing mostly of 2.5 km, opening to 5 km spaced lines in the Marree–Strzelecki Desert area to the north. Interpretations of the data show the utility of regional AEM surveying for mapping crucial elements of sandstone-hosted uranium mineral systems as well as for mapping geological surfaces, structures and depth of cover over a wide area. Data from the Frome AEM survey allow mineral explorers to put their own highresolution AEM surveys into a regional context. Survey data were used to map and interpret a range of geological features that are associated with, or control the location of, sandstone-hosted uranium mineral systems, and have been used to assess the uranium prospectivity of new areas to the north of the Flinders Ranges.

19. INSIGHTS INTO THE CONTINENTAL STRUCTURE OF SOUTHEAST AUSTRALIA AND TASMANIA FROM PASSIVE SEISMIC AND MAGNETIC DATASETS

Esmaeil Eshaghi[1]*, *Anya Reading*[1], *Michael Roach*[1], *Matthew Cracknell*[1], *Daniel Bombardieri*[2] *and Mark Duffett*[2]
[1]University of Tasmania
[2]Mineral Resource Tas

The continental crust of southeast Australia is a complex and highly prospective area. Southeast Australia comprises the Delamerian and Lachlan Orogenies which, together with the Eastern Tasmania Terrane, are understood to have Phanerozoic

basement. In contrast, the Western Tasmanian Terrane comprises areas of exposed Neoproterozoic basement which were assembled along the proto-Pacific margin of East Gondwana. In this study, the crustal structure across southeast Australia and Tasmania is considered using seismic and aeromagnetic methods. We use previous passive seismic results and present a new analysis of magnetic data. The Curie temperature, the temperature at which magnetic rocks lose their magnetisation, is investigated using spectral analysis of aeromagnetic data and the Curie point depth (CPD) is consequently determined. CPD is compared to the depth of the seismic Moho discontinuity throughout the study area.

The Moho depth and newly calculated CPD throughout the study area vary from ~20 to >38 km and ~25 to >45 km, respectively. The CPD is slightly shallower than the Moho across the study area. The Delamerian and Lachlan Orogenies are underlain by a 30–35 km and ~40–50 km deep Moho respectively, while average CPD depths are ~30 and ~28 km for these regions. A relatively shallow CPD is observed in the northeast of the study area and corresponds to Cainozoic volcanism in eastern Australia. The shallow Moho beneath Tasmania supports the idea of crustal thinning during Gondwana breakup. In Tasmania, CPD increases in depth from ~21 km in the northwest to >31 km in north. This is consistent with variations in the depth of the Moho from 25 km in the northwest to 37 km in the north.

20. NEW GRAVITY IN THE MUSGRAVE RANGES, SOUTH AUSTRALIA

Philip Heath[1]*
[1]Geological Survey of South Australia

A gravity survey has been undertaken on the Alcurra, Agnes Creek and Tieyon 1 : 100K mapsheets, in the eastern portion of the Musgrave Ranges, South Australia. A total of 821 readings were collected, incorporating 689 new stations, 88 repeats and 44 base measurements. The data highlights new features giving insight into the underlying geological structure, including a gravity high near Doug's Well.

21. DEEP CRUSTAL STRUCTURE OF THE CAPRICORN OROGEN FROM GRAVITY AND SEISMIC DATA

Abdulrhman Alghamdi[1]*, *Alan Aitken*[1] *and Michael Dentith*[1]
[1]University of Western Australia

The integration of geophysical data including deep seismic reflection, receiver function and gravity data provides the ability to image the deep crustal structure of Capricorn Orogen. In this study, we aim to reconcile seismic models of crustal structure with gravity measurements.

S-wave seismic velocities from receiver function models were converted to P-wave velocity and density. Geology interpreted from deep seismic reflection profiles was depth converted based on the velocity data.

An initial density model was constructed based on the depth converted seismc interpretation and densities estimated from velocities. To match observed variations in Bouguer anomaly the initial densities were modified based primarily on the comparability the wavelength of Bouguer anomaly and calculated gravity response of the model.

We found that the Bandee Seismic Province (BSP) has a high density compared to the density of the adjacent regions and the underlying lower crustal blocks. This province, a 'deep crustal seismic terrane' without surface expression, recognised from the seismic data. Sensitivity testing suggests the mantle, the lower crust and the upper crust are less likely sources of the coincident high gravity anomaly. This observation is supported by receiver function models that reveal a high S-wave seismic velocity in mid-crust.

Importantly, the region of higher density in the middle crust, unlike the BSP, does not extend south of the Talga Fault. This suggests the Talga Fault is a more significant structure than suggested by previous interpretations and the area around its surface outcrop may be more prospective than previously thought.

22. THE SOUTHERN THOMSON OROGEN AEM SURVEY

Ian Roach[1]*, *Ross Brodie*[1] *and Marina Costelloe*[1]
[1]Geoscience Australia

The Southern Thomson Orogen airborne electromagnetic (AEM) Survey was flown in 2014 using the Geotech VTEMplus® AEM system. The AEM survey was designed by Geoscience Australia, and its partners the geological surveys of New South Wales and Queensland, to help solve geological problems in the Southern Thomson Orogen as part of the UNCOVER Initiative of the National Mineral Exploration Strategy.

Survey results indicate variable depth of penetration governed by conductive cover, primarily the Cretaceous Rolling Downs Group, and saline groundwater in broad ephemeral drainage systems including salt lakes and channel country around the Paroo River. The unconformity between the Paleozoic rocks of the Eulo Ridge (a partially-exposed palaeotopographic high) and the overlying Mesozoic and Cenozoic cover is well mapped in the central part of the survey area. The survey data reduce risk to explorers in the area by decreasing uncertainty regarding depth of cover for drilling activities and advising where ground and airborne electromagnetic methods can be expected to produce reliable results.

23. MAGNETOTELLURIC IMAGING OF A PALAEOZOIC ANDEAN MARGIN SUBDUCTION ZONE IN WESTERN VICTORIA

Graham Heinson[1]*, *Michael Stepan*[1], *David Taylor*[2], *Kate Robertson*[1], *Phil Skladzien*[2] *and Goran Boren*[1]
[1]University of Adelaide
[2]Geological Survey of Victoria

A 450 km long transect of broadband (200 Hz – 2000 s) magnetotelluric (MT) sites spaced between 1 and 5 km apart, has been collected across the Palaeozoic Delamerian-Lachlan Orogens in western Victoria. The bandwidth of responses yields resistivity constraints between a few tens of metres in near-surface cover to sub-Moho depths. The passive nature of the source-field means that the MT responses have been collectively assembled in several tranches over ten years, with the last section across the transition between the Orogens collected in June 2014. The MT coverage now completely coincides with a deep crustal reflection seismic transect to generate complementary insight of the crustal structure. We report on preliminary modelling and interpretation.

24. 3D GEOLOGY FROM POTENTIAL FIELD GEOPHYSICS: APPLICATIONS TO BATHURST MINING CAMP, EASTERN CANADA

Desmond Fitzgerald[1], Hernan Ugalde[2], William Morris[3] and H. Holstein[4]*
[1]Intrepid Geophysics
[2]Paterson Grant Watson Limited
[3]McMaster University
[4]Aberystwyth University

Interpretation methods and tools for geophysics datasets continue to evolve. Advances in clustering algorithms, the use of implicit functions to create 3D surfaces, new algorithms to estimate source depths and dips, and the availability of clever computational geometry libraries, contribute to the discipline of potential field interpretation techniques, allowing for a much more explicit statement of implied 3D description. While traditional scalar measures of potential fields have benefited from applying new ideas, perhaps more exciting is the reduction in ambiguity imposed from gradient measurement when used as the basis for field interpretation. Full tensor gravity gradiometry in particular, allows for 2D fault dip and throw calculations. Direct detection of high density bodies and faults via state-of-the-art gravity gradiometry is now a reality. Bodies greater than 200 m in lateral extent are detectable. Implicit 3D structural geology modelling techniques derived from gravity curvature attributes of the observed gravity field present a leading edge technique for defining structurally controlled near surface geology geometry. A demonstration from the Bathurst camp dataset is given.

25. CASE STUDIES IN INTEGRATED GEOLOGICAL AND GEOPHYSICAL 3D MODELLING: VALUE ADDED TO EXPLORATION AND MINING PROJECTS

Hernan Ugalde[1] and Iris Lenauer[2]*
[1]Paterson, Grant and Watson Limited
[2]SRK Consulting (Canada) Onc

The integration of geophysical with litho-structural models represents a valuable tool for better understanding of subsurface geometries of lithological contacts. Improved subsurface models add value to mineral exploration projects. Geophysical data is used to enhance and validate litho-structural models. The regular distribution of geophysical data allows lithologies and faults to be extended from observed locations into the subsurface. Geological models are validated and improved by comparison of the geophysical signal calculated from the model geology with the observed signal. Discrepancies between modeled and observed signals highlight areas requiring refinements of the geological model. The case studies present examples of how iterative modeling of geological and geophysical data will result in an improved final product. The calculated geophysical signal from two distinct geological interpretations shows how well a certain litho-structural model conforms with the geophysical data. Applications include determining the position of rocks of distinct physical properties, checking the geometry of faults and extending mapped structures into inaccessible/covered areas.

26. A MAGNETOTELLURIC SURVEY OF THE NORTH PERTH BASIN: A TECHNICAL CASE STUDY

Thomas Hoskin[1], Klaus Regenauer-Lieb[2] and Alan Jones[3]*
[1]Universty of Western Australia
[2]CSIRO
[3]Dublin Institute for Advanced Studies

Original motivation of this study was to understand important structures with a proven geothermal signature associated with high temperatures in the shallower basin and high flow rates in the aquifers. Anomalous temperatures are recorded around the Beagle Ridge and significant flow rates observed near the Urella Fault, factors important to unconventional geothermal prospects. The focus of this study was therefore a detailed geophysical investigation of several Geothermal Exploration Permits (GEPs) in the North Perth Basin.

Two Magnetotelluric (MT) surveys are conducted over target areas in the North Perth Basin and adjoining tectonic domains to provide information about the electrical conductivity regime of the basin and western margin of the Yilgarn Craton. Existing geophysical data in this part of the basin are sparse and electrical data for the basin in general is limited to shallow Time Domain Electromagnetic (TDEM) data targeting superficial aquifers.

High-resolution MT data, acquired between 2011 and 2013, provide information on mid-deep crustal rocks. In addition, new gravity data and joint interpretation of these data sets are undertaken to improve the geological model of the North Perth Basin and test some existing hypotheses.

We present a best practice case study and workflow for data acquisition and filtering, robust dimensionality analysis and removal of distortion effects from impedance tensor estimates. 1D and 2D inversions are found to be largely sufficient for the majority of these data while 3D modelling provides an additional tool to verify results. Finally, modelling of gravity data and integrated interpretation ensures robust geological models for the area are consistent with all data available.

We conclude with several inferences about the geology in this area. (1) Electromagnetic and gravity data does not seem to support significant crustal thinning beneath the basin. (2) The Dandaragan Trough appears deeper than generally modelled. (3) Extremely high conductivities persist to depth in the basin.

27. EVALUATION OF AUTOMATED LITHOLOGY CLASSIFICATION ARCHITECTURES USING HIGHLY-SAMPLED WIRELINE LOGS FOR COAL EXPLORATION

Tom Horrocks[1], Eun-Jung[1] and Daniel Wedge[1]*
[1]Centre for Exploration Targeting, University of Western Australia

Wireline logs are a supplemental data source to conventional core logging. The recent explosion of machine learning algorithms has provided researchers with ample opportunity to develop automated statistical tools for classifying lithology from wireline logs, which geologists can use to produce first-pass interpretations or to validate existing interpretations. Such automated interpretations can be particularly valuable information in the case of missing or damaged core samples. There exists, however, a need to evaluate said machine learning algorithms in the case where available wireline logs contain a wide range of different logs which are highly-sampled.

This paper explores different machine learning algorithms and architectures for lithology classification using wireline data from project area Jundah East, 60 km north-west of Wandoan, Queensland, which is well known for coal mineralisation. We used seven well logs each containing 19 wireline logs sampled at 1 cm-1, available through the Queensland Digital Exploration (QDEX) data system. Three popular supervised machine learners, namely the Naïve Bayes classifier, Support Vector Machine, and Multilayer Perceptron (an artificial neural network), are tested under two architectures: committee (one classifier per well log) and singular (one classifier for all well logs). The results show the Naïve Bayes classifier, although computationally simple, achieves good results in general when training using a committee architecture on a large data set. For coal classification in particular, it achieved the sensitivity score of 0.79 and the specificity score of 0.97. While the committee and singular architectures generated similar results, the committee architecture provides the benefits of faster computation time as well as a flexible platform for the training of additional well logs.

28. THE GRANITES-TANAMI OROGEN SUBSURFACE GEOMETRY AS REVEALED BY AN INTEGRATED POTENTIAL FIELD GEOPHYSICAL AND GEOLOGICAL STUDY

David Stevenson[1]*, *Leon Bagas*[1] *and Alan Aitken*[2]
[1]Centre for Exploration Targeting and ARC Centre for Excellence for Core to Crust Fluid Systems, the University of Western Australia
[2]Centre for Exploration Targeting, the University of Western Australia

The Granites Tanami Orogen (GTO) in central Australia is a significant gold producing province. Future exploration will be facilitated by determining the structural controls on mineralisation and crustal evolution of the orogen. A whole of crust model has been generated through the multi-scale integration and interpretation of geophysical, geological and remote sensing data.

The architecture of the orogen is that of a basin that has been inverted, deformed and intruded during: (a) the collision between the Kimberley and Tanami basins along the Halls Creek Orogen to form the North Australian Craton; and (b) during the amalgamation of the North Australian Craton with the Central Australia Craton. These continent-continent collisions have resulted in a complex structural framework, which is further complicated by deep weathering and extensive regolith across the region. Reconnaissance style outcrop mapping coupled with potential field interpretation has identified two main phases of deformation. The first regional deformation event resulted in north- to northeast-trending isoclinal fold trains of wavelengths ~10 km or greater. These folds are recognised through the interpretation of joint gravity and magnetic anomalies and are confirmed in outcrop. Gold mineralisation within the GTO is coincident with the second regional deformation event, which is recognised in regional aeromagnetic data as poly-phase deformational interference patterns caused by the refolding of earlier folds around axes trending E to ESE.

This defining of upper crustal architecture to structural features observable in sparse outcrop coverage could not be sufficiently identified without this combined geology and geophysical approach.

29. INTERPRETATION OF 3D HIGH-RESOLUTION SEISMIC DATA COLLECTED OVER AN IOCG DEPOSIT IN SOUTH AUSTRALIA

Muhammad Hossain[1]*, *Milovan Urosevic*[1] *and Anton Kepic*[1]
[1]Curtin University

A 3D high–resolution seismic dataset was acquired to investigate typically complex IOCG deposits in Hillside, South Australia. Petrophysical data measured from the core samples and the density data supplied by the mining company were utilised during the volumetric interpretation. However, petrophysical data show that the boundaries between gabbro and metasediments may not generate acoustic impedance contrast to be clearly detected by seismic reflection method. The base of the top cover is mappable throughout the cube and the tops of the major formations have agreement with magnetic data. The faults extracted from the seismic volume using ant-tracking attribute have good agreement with the company supplied geological interpretation based on the drilling information.

30. GEOSCIENTIFIC INVESTIGATION OF A REMANENT ANOMALY – TEETULPA, SOUTH AUSTRALIA

Tim Keeping[1]*, *Clive Foss*[2], *Philip Heath*[1] *and Gary Reed*[1]
[1]Geological Survey of South Australia
[2]CSIRO

We investigate a small (100 m width) 150 nT amplitude magnetic anomaly delineated in a high-resolution aeromagnetic survey in the Teetulpa Goldfield of the southern Flinders Ranges. We believe that the anomaly is due to a kimberlite pipe, part of a field already known in the general region. As is quite common with kimberlites, the magnetization is clearly dominated by remanence. Modelling the anomaly reveals that the source is very shallow, and would have outcropped at some stage. Follow-up ground geophysical, geochemical and biogeochemical investigations are planned to establish a methodology for integrated studies as follow-up to high resolution aeromagnetic surveys.

31. MAGNETIC MODELLING AND INTERPRETATION OF THE HAY-BOOLIGAL ZONE AND ITS BASEMENT

Astrid Carlton[1]*
[1]Geological Survey of NSW

Little is known about the basement of the Hay–Booligal Zone (located in NSW). Magnetic modelling of long wavelength anomalies within the Hay–Booligal Zone indicates that the Hay–Booligal basement consists of serpentinised ultramafic material at depths of 6 to 12 km. This supports interpretation that the Hay–Booligal basement could be similar to the Selwyn Block in Victoria and rather than a crystalline microcontinent.

Also, interpretation of short wavelength semi-parallel TMI anomalies near the previous boundary of the Hay–Booligal Zone has lead to the adjusted the boundary of the Hay–Booligal and Bendigo zones.

32. DEFINING MAJOR STRUCTURES AND THEIR DEPTH EXTENT UNDER COVER IN THE SOUTHERN THOMSON OROGEN, NEW SOUTH WALES

Rosemary Hegarty[1]* *and Michael Doublier*[2]
[1]Geological Survey of New South Wales
[2]Geoscience Australia

Regional geophysical datasets are critical to the task of uncovering the basement geology of the southern Thomson Orogen in far western New South Wales. As part of a National Collaborative Framework project, aeromagnetic, gravity and seismic data have being processed and interpreted to construct the structural framework. Subdivision into structural domains has been validated and constrained by geological information, relying on observations and measurements from sparse drill holes and outcrops.

Boundaries between structural domains are complex and poorly understood. This study aimed to recognise major faults and, where possible, define their displacements, depth extent, and understand their dynamics and timing. Analysis of available company and government seismic surveys provided details for some of the major fault systems such as the Olepoloko Fault, Culgoa Lineament, and also for many newly recognised fault trends

The seismic interpretations were reconciled with deep sourced aeromagnetic and gravity gradients that were enhanced by multiscale edge analysis. The structural framework will underpin geochronology and mineral systems studies as the Southern Thomson Orogen project continues.

34. IMPROVING MODELLING OF AEM DATA AFFECTED BY IP, TWO CASE STUDIES

Andrea Viezzoli [1]*, *Vlad Kaminski*[2], *Yusen Ley-Cooper*[3], *Lyndon Hardy*[4] *and Gianluca Fiandaca*[1]
[1]Aarhus Geophysics Aps
[2]KM Geophysics
[3]CSIRO
[4]Abra Mining

Modelling IP parameters, including dispersive resistivity, from AEM data showing clear IP effects is possible. Using the spatially constrained inversion approach, with forward response that account for the full Cole and Cole model, we recover realistic chargeability and 'IP corrected' resistivities sections from two VTEM datasets, from Canada and Australia. The 'IP corrected' resistivity sections often show better agreement with known geological features, while improving dramatically the data fit, with respect to those obtained without IP modelling. While the majority of the IP effect originate from shallow chargeable layers, there also seems to be some positive correlation between an isolated deep chargeable anomaly and known base metal deposit location.

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36. A CASE FOR REGIONAL SEISMIC REFLECTION SURVEY IN THE GAWLER CRATON, SOUTH AUSTRALIA

Okan Evans Onojasun[1]*, *Kepic Anton*[1], *Urosevic Milovan and Ziramov Sasha*[1]
[1]Curtin University

With the discovery of the world class Olympic Dam iron oxide copper deposit in 1975 by the Western Mining Corporation (WMC), the entire Gawler Craton, South Australia has been subjected to intense exploration by mining community as well as researchers using multidisciplinary exploration approach (geology, geophysics and tectonic analysis) in search of similar deposits. Potential field geophysical methods are traditionally used for exploration of mineral deposits. However, these methods are often lacking depth of penetration or resolving power. As the search for minerals moves towards exploring for deeper structures due to depletion of the near surface deposits, there is a compelling need to develop new and innovative deep exploration tools to meet the global demand for metal. Seismic methods which provide high resolution images at any depth are receiving more attention from the mining community. 3D seismic reflection method in particular provides a possibility for delineation of very complex geological structures and associated rock types. As powerful as 3D seismic method might be, it has never been tested on a tenement scale. No arguments for regional 3D seismic exploration have been proposed probably because a cost-benefit analysis has never been conducted at such scale. In this study we analyse such cases and its benefits in the case of deep cover as is found over large areas of SA where potential for finding new mineral systems is relatively high.

37. GRAVITY ANOMALIES AS TRAP SITES IN PROSPECTIVITY MODELLING OF THE EASTERN GAWLER COPPER-GOLD BELT

Tom Wise[1]* *and Laszlo Katona*[1]
[1]Geological Survey of South Australia

A geoprocessing methodology has been developed to capture potential field anomalies from residual gravity and reduced to pole total magnetic intensity (RTP TMI) datasets. Anomalies captured using this process are converted to GIS polygons and attributed with descriptive statistics of the underlying grids. The polygons are subsequently included as criteria in a GIS analysis to target IOCG-style deposits beneath extensive cover in the Eastern Gawler Craton. The application of gravity anomaly polygons within this study was as potential trap sites, based on the assumption that a localised increase in density manifested as an anomalous gravity response may be associated with mineral accumulation. The characterisation of residual potential field anomalies for use in prospectivity modelling has resulted in the accurate identification of existing deposits of IOCG-style mineralisation and has suggested additional targets warranting further investigation.

38. SUPERVISED NEURAL NETWORK TARGETING AND CLASSIFICATION ANALYSIS OF AIRBORNE EM, MAGNETIC AND GAMMA-RAY SPECTROMETRY DATA FOR MINERAL EXPLORATION

Karl Kwan[1], *Stephen Reford*[2], *Djiba Maiga Abdoul-Wahab*[3], *Douglas H. Pitcher*[1], *Nasreddine Bournas*[1], *Alexander Prikhodko*[1], *Geoffrey Plastow*[1] *and Jean M. Legault*[1]*
[1]Geotech Ltd
[2]Paterson, Grant and Watson
[3]CPG/PRDSM

The amount of multi-disciplinary (geology, geophysics, remote sensing, etc.) and multi-parameter geophysical (potential field, EM, gamma-ray spectrometry, etc.) data available for mineral exploration is ever increasing. The integration and analysis of the data require effective and efficient search engines or data mining tools. The search engines will take the signatures of known mineral deposits or interpreted mineralization targets ('key words'), search the data space and return potential new targets ('matches'), thus providing locations to the decision makers for follow-up. Two supervised feed-forward multilayer neural network (NN) search algorithms will be presented and analysed. The utility of the NN search tools will be demonstrated with the integration and analysis of airborne electromagnetic (EM), magnetic and radiometric data for mineralization targets in Iullemmeden Basin, Niger.

39. ACOUSTIC PROPERTIES OF ROCKS COMPACTED FROM POWDERS

Maxim Lebedev[1]*, *Olga Bilenko*[1], *Yulia Uvarova*[2] *and Maxim Lebedev*[1]
[1]Curtin University
[2]CSIRO

During the drilling process core samples often are damaged and proper measurements on samples cannot be performed. The objective of this study is to investigate rock powders and evaluate how their seismic properties relate to the seismic properties of their corresponding rocks. Consolidated and poorly consolidated rocks and fine powders made of those rocks have been used in this study to assess such possibilities. A comparison between the seismic properties of dry powders to the properties of wet powders has been done. A correlation in mechanical properties (Young's modulus and Poisson's ratio) between compacted powder and samples from host rock has been found.

40. VTEM AIRBORNE EM, AEROMAGNETIC AND GAMMA-RAY SPECTROMETRIC DATA OVER THE CERRO QUEMA HIGH SULPHIDATION EPITHERMAL GOLD DEPOSITS, PANAMA

Karl Kwan[1], *Alexander Prikhodko*[1], *Jean Legault*[1]* *and Geoffrey Plastow*[1], *John Kapetas*[2] *and Michael Druecker*[2]
[1]Geotech LTD
[2]Pershimco Resources

In March 2012, a helicopter-borne VTEM electromagnetic (EM), magnetic and radiometric survey was flown over the Cerro Quema high sulphidation epithermal gold deposits in Panama. Geophysical signatures, including Airborne Inductive Induced Polarization (AIIP) effect, characteristic of high sulphidation epithermal gold deposits were observed in the EM, magnetic and radiometric data over the known deposits. This success points to the applicability of regional helicopter EM-Mag-Spec surveys for the exploration of similar high sulphidation epithermal gold deposits to depths <500 m in weathered terrains.

41. APPLICATION OF SEISMIC ATTRIBUTES FOR CONSTRAINING MAGNETOTELLURIC INVERSION

Cuong Le[1]*, *Brett Harris*[1], *Eric Takam Takougang*[1] *and Andrew Pethick*[1]
[1]DET CRC, Curtin University

Unconstrained inversion of surface magnetotelluric data generates non-uniqueness solutions. Boundaries derived from seismic reflectively images have the potential to substantially improve MT inversion. Seismic should be highly beneficial where significant and strong reflectors can reasonably be associated with contrast in electrical conductivity across well-defined relatively continuous boundaries. We show how seismic reflections can assist in defining such inversion controls as the smoothness penalty across known boundaries. We apply and compare a range of cooperative inversion strategies using large scale co-located magnetotelluric and seismic reflection field data sets from the Carlin style gold district in Nevada USA.

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43. CONSTRAINED MAGNETIC MODELLING OF THE WALLABY GOLD DEPOSIT, WESTERN AUSTRALIA

Sasha Banaszczyk[1]*, *Yvonne Wallace*[2] *and Mike Dentith*[1]
[1]University of Western Australia
[2]Southern Geoscience

The Wallaby Gold deposit is located 25 km southwest of Laverton within the Eastern Goldfields Province of Western Australia. Gold mineralisation is hosted within a mafic conglomerate, intruded by a south-plunging magnetite-actinolite-epidote-calcite altered syenite pipe. Regions of low susceptibility within the pipe are associated with gold mineralisation.

Airborne magnetic data from the Wallaby Gold deposit was inverted using the University of British Colombia Geophysical Inversion Facility MAGINV3D code to produce a 3D model of the subsurface magnetic susceptibility.

Magnetic susceptibility measurements acquired at 1m intervals on diamond drill core were used to constrain the results of the inversion. This was facilitated using the Sparse Constraint Model Builder, which creates a physical property model based on existing geological, geophysical or geochemical measurements to then be applied within the UBC-GIF inversion code.

The constrained inversion defined regions of low magnetic susceptibility within the outer high magnetic susceptible zones of the alteration pipe and potential mine-scale structural features can be interpreted. This is useful information given the structural control on gold mineralisation at Wallaby and its association with regions of reduced magnetic susceptibility.

44. GEOLOGICAL AND GEOTECHNICAL CHARACTERISATION USING GEOPHYSICAL LOGS - AN EXAMPLE FROM ADRIYALA LONGWALL PROJECT OF SINGARENI COLLIERIES, INDIA

Binzhong Zhou[1]*, *Makesh Shanmukha Rao*[1] *and Gudlavalleti Uday Bhaskar*[1]
[1]Singareni Collieries Company Limited

The studies conducted at Adriyala longwall block of Singareni Collieries Company Limited (SCCL) in the state of Telangana, India conclude that geophysical logs comprising electrical, density, neutron, caliper, Full Waveform Sonic (FWS) and acoustic images can provide reliable geological and geotechnical models required for longwall mining. The basic lithological details, sedimentary features and associated geotechnical risks are interpreted using these logs. The P wave velocities obtained from sonic logs are correlated with the lab determined strength parameters such as uniaxial compressive strength (UCS), Tensile Strength (TS) and Young's Modulus. The empirical equations provided a means to construct UCS map of interburden strata of coal seams from sonic data and optimised depending on core data. The Geophysical Strata Rating (GSR) similar to Coal Mines Roof Rating (CMRR) and Rock Mass Rating (RMR) has also been applied to assess the competency of interburden strata right at the exploration stage itself. The in situ stress directions and master cleats orientation are determined from the acoustic image logs. The integrated study of various maps prepared from geological and geophysical inputs provided an effective means to analyse the competency of immediate overburden and roof of Seam-I, which is considered for longwall mining.

Back analysis of behaviour of strata will allow developing predictive models and appropriate strata control strategies to be applied at Adriyala and other mines and also for multiseam extraction.

45. PREDICTIVE MODELLING FOR IRON ORE EXPLORATION TARGETING: CASE STUDY: 5–7 BT XAUDUM IRON ORE EXPLORATION TARGET (BOTSWANA)

Iuma Martinez[1]*, *Alistair Jeffcoate*[1], *Gaetan Fuss*[2], *Mike de Wit*[1], *McDonald Kahari*[1] *and Omphile Ntshasang*[1]
[1]Tsodilo Resources Ltd
[2]Ecole nationale superieure de geologie

The principal objective of the research was to determine an exploration target estimate for the Xaudom Iron Ore project. Geophysical data inversion modelling was carried out and the results calibrated against local drill hole interpretation-based geological models. The results compared favourably and enabled a number of correction factors to be established. Subsequent drilling and geological modelling have yielded NI 43–101 compliant resources that are similar to the initial inversion based modelling estimates within optimised pit shells, showing the robustness of the Exploration Target technique. The approach discussed here may be useful for delineating exploration targets for other magnetite-rich iron mineralized areas faced with complex deformational histories.

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46. OPEN SOURCE SOFTWARE FOR 1D AIRBORNE ELECTROMAGNETIC INVERSION

Ross Brodie[1]* *and Murray Richardson*[1]
[1]Geoscience Australia

Geoscience Australia is releasing into the public domain software for the inversion of airborne electromagnetic (AEM) data to a 1D conductivity depth structure.

The software includes two different algorithms for 1D inversion of AEM data. The first is a gradient based deterministic inversion code for multi-layer (smooth model) and few-layered (blocky-model) inversions. The second is a reversible-jump Markov chain Monte Carlo stochastic inversion algorithm suitable for assessing model uncertainty. A forward modelling program and some other ancillary programs are also included. The code is capable of inverting data from all of the commercial time-domain systems available in Australia today, including dual moment systems.

The software is accessible in three forms. As C++ source code, as binary executables for 64 bit Windows® PCs, and as a service on the Virtual Geophysics Laboratory (VGL). The code is fully parallelized for execution on a high performance cluster computer system via MPI or a multi-core shared memory workstation via OpenMP.

47. USING AMT IN THE ZAMBIAN COPPERBLET (ENTERPRISE AND KANSANSHI CASE STUDY)

Adouley Guirou[1]*
[1]First Quantum Minerals

During 2012 and 2013 First Quantum Minerals, through its Zambian exploration team, acquired about 300 line km of audio magnetotelluric (AMT) data for copper and nickel exploration in the north-western Zambian copper belt. Kansanshi copper mine and the new Enterprise nickel deposit are the survey locations. I discuss major aspects of the projects, including but not limited to major outcomes and difficulties encountered, as well as solutions for future data acquisition in similar geological settings. Basement faults and many geological features were identified over Enterprise, and dome structures in Kansanshi. However, limiting factors such as mine equipment noise, accessibility, swamps, tropical rain forest and wild life caused difficulties during the survey. Stacking data for a longer time and focusing on lower frequencies will significantly reduce data noise, but survey costs will increase due to slower survey rates. The geological information gained from these surveys has ensured that AMT remains a preferred exploration tool for sedimentary-hosted copper and nickel.

48. A MAJOR GEOPHYSICAL EXPERIMENT IN THE CAPRICORN OROGENY, WESTERN AUSTRALIA

Mike Dentith[1], Alan Aitken[1], Sasha Banasazczyk[1], Mark Lindsay[1], Jeffrey Shragge[1], Perla Piña-Varas[1], David Annetts[2], James Austin[2], Yusen Ley-Cooper[2], Tim Monday[2], Brian Kennett[3], Ruth Murdie[4] and Huaiyu Yuan[5]*
[1]University of Western Australia
[2]Mineral Resources Flagship, CSIRO
[3]Australian National University
[4]Geological Survey of WA
[5]Macquarie University

A major geophysical experiment has begun in the Capricorn Orogen in Western Australia. Orogen-scale passive seismic and magnetotelluric surveys are on-going and preliminary results suggest have successfully delineated the base of the crust and major structures and tectonic boundaries. Airborne electromagnetic data have successfully mapped features in the near-surface such as palaeovalleys.

The integration of the different geophysical datasets with each other and with parallel geological studies are intended to lead to a better understanding the Capricorn Orogen and develop exploration approaches and appropriate toolkits that significantly improve our ability to prospect under cover.

49. CROSS-HOLE REFLECTION SEISMIC TO DELINEATE A RELATIVELY THIN VOLCANOGENIC MASSIVE SULPHIDE DEPOSIT IN SHALE HOSTED ENVIRONMENT

Felix Menu[1], Andrew Greenwood[1] and Anton Kepic[1]*
[1]DET CRC Curtin University

The seismic reflection method is a high resolution technique that can be used in many exploration environments including mineral exploration. However, mountainous terrain, depth of burial and the steepness of ore bearing structures pose a challenge to the application of surface seismic in mineral exploration. The cross-hole seismic method may present an alternative approach under such conditions. Presented here is a synthetic study examining the capability of the cross-hole seismic method to delineate a volcanogenic massive sulphide ore body in a shale hosted environment.

A simple model typical for volcanogenic massive deposits in Tasmania has been considered. There, an elongated steeply dipping volcanogenic massive sulphide deposit with an average thickness of 10 m is seated within a shale rock. The primary aim of the modelling is to test the capability of the technique to delineate relatively medium sized, steeply dipping volcanogenic massive sulphide lens in shale hosted environment. A second objective is to use the technique to prospect for extensions to mineralization along steeply dipping reflectors.

Synthetic cross-hole seismic records were generated using a 120 Hz energy source. Kirchhoff VSP migration was applied to wavefield separated shot records and Pre-stacked Depth Migrated images created. The resulting migrated images correlate well with the position and dip of the ore body demonstrating the potential of the cross-hole reflection technique to delineate steeply dipping ore structures in challenging environments.

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50. A WORKFLOW FOR COOPERATIVE INVERSION OF SEISMIC AND MAGNETOTELLURIC DATA

Eric Takam Takougang[1], Brett Harris[1] and Anton Kepic[1]*
[1]Curtin University

We present a cooperative inversion approach for acoustic impedance using seismic and magnetotelluric data. In this approach, the magnetotelluric data, sensitive to the resistivity of rocks are used to get the large scale background spatial trends of the acoustic impedance model, while the seismic data are used to get the small-scale features. The connections between resistivity and elastic properties of rocks are obtained from petrophysical relationships derived from borehole data. Structural constraints derived from seismic are used to improve the magnetotelluric inversion. We present an application of this technique to synthetic data derived from previous interpretation of seismic and magnetotelluric models in a mineral province. The synthetic example shows how an improved result is obtained using our cooperative inversion workflow.

51. A STRATEGY FOR MAGNETIC DATA INTERPRETATION IN SOUTH CHINA SEA

Shuling Li[1], Yaoguo Li[2] and Xiaohong Meng[1]*
[1]China University of Geosciences
[2]Colorado School of Mines

Directly interpreting total-field magnetic anomaly data in the South China Sea (SCS) can be difficult because of the complex patterns associated with low-latitude anomaly projection and the presence of remanent magnetization. Additional difficulty arises from the fact that the ambient field direction, thus, the total-field anomaly projection direction, varies over a wide range in the area. To alleviate these difficulties, we present a strategy by using magnetic amplitude data analyses and inversion. Equivalent source processing is used to calculate the amplitude data in the space domain since the wavenumber-domain method is no longer applicable due to low and highly variable inclination. The amplitude data serve the role of reduction-to-pole (RTP) transformation for structural interpretation. We then carry out the amplitude inversion to generate a 3D subsurface distribution of effective susceptibility. The inversion results show that this approach is feasible and effective in SCS.

52. BROAD-SCALE LITHOSPHERIC STRUCTURES OF THE AUSTRALIAN CONTINENT FROM 3-D INVERSION OF OBSERVATORY AND MAGNETOMETER ARRAY DATA

Liejun Wang[1], Adrian Hitchman[1], Andrew Lewis[1], Peter Crosthwaite[1] and Bill Jones[1]*
[1]Geoscience Australia

An exploratory 3-D model of the electrical conductivity structure of the Australian continent is presented. The model is derived from the inversion of vertical magnetic-field transfer functions from the Australia-wide Array of Geomagnetic Stations.

The model reveals conductivity differences beneath Archaean cratons in Western Australia, enhanced-conductivity anomalies between Archaean cratonic regions and beneath Phanerozoic terranes in eastern Australia.

53. LOCALIZED SMART INTERPRETATION – A DATA DRIVEN SEMI-AUTOMATIC GEOLOGICAL MODELLING METHOD

Mats Lundh Gulbrandsen[1]*, *Mats Lundh Gulbrandsen*[1], *Torben Bach*[2], *Knud Skou Cordua*[1] *and Thomas Mejer Hansen*[1]
[1]University of Copenhagen
[2]I-GIS

Localised Smart interpretation (LSI) is a method that infers a statistical model, which describes a relation between the knowledge of a geologist (as quantified by geological interpretation) and the available information (such as geophysical data, well log data, etc.) that a geologist uses when he/she interprets. This model is then used to perform semi-automatic geological interpretation wherever the same kinds of attributes, as used for the initial interpretation, are available. The statistical model is inferred using a combination of a regularized least squares method and cross validation. In this study, we demonstrate the applicability of the method to predict the depth to a low resistivity subsurface layer, based on interpretations from a geological expert, using a 19-layered resistivity model obtained from inversion of airborne electromagnetic (SkyTEM) data.

This study shows that LSI is capable of making prediction with great accuracy. The method is fast and is able to handle large amounts of data of different origin, which suggest that the method may become a very useful approach to assist in geological modelling, based on increasingly large amounts of data of different nature.

54. SPM EFFECT IN GLACIAL TILL

Markku Montonen[1]*
[1]FQM FinnEx Ltd

The SPM effect is not traditionally associated with glacial tills. However, effects of viscous magnetization, i.e. superparamagnetism, are observed in many places in Northern Finland in high sensitivity and low frequency time domain ground EM surveys. These effects are typically observed on late time channels and they have a very good correspondence with magnetic anomalies. Usually there is also a clear reverse frequency domain RE component anomaly observed simultaneously with the SPM effect. In Ni ore prospecting it is essential to be able to recognize SPM effect because it has a response similar to a deep seated massive nickel ore body i.e. a deep seated very high conductivity conductor. Characteristic feature for SPM effect in time domain dB/dt data is its 1/t decay which can be used as a means to recognize this phenomenon. We also discuss alternative methods to recognize SPM effect.

55. THE NATURE OF CHANGING PORE SPACE AT AN IN-SITU WEATHERED/FRESH ROCK INTERFACE AND ITS EFFECT ON THE RESISTIVITY SIGNATURE, DARGUES REEF GOLD DEPOSIT, MAJORS CREEK NSW

Sanjay Govindan[1]* *and Eva Papp*[1]
[1]The Australian National University

Hydrothermal Au – Cu mineralisation at Majors Creek, NSW has led to the formation of disseminated sulphides throughout the host granodiorite body. Mineralisation in overburden and shallow bedrock occurs in sparse concentration settings such as quartz veins and potassic alteration. Distinguishing between alterations zones, mineralising features and the fresh-weathered rock boundary is paramount to explorers.

A combination of DC electrical resistivity and CT scanning was employed to delineate the weathered-fresh rock boundary, potential mineralising features and areas of differing alterations. A 500 m survey line was constructed over a known area of mineralisation and passed directly over a drill core sample. CT scanning data will define pore space characteristics of alteration and weathering states of the host granodiorite.

This study has the potential to spark future research into shallow surface exploration throughout the Majors Creek area, building on a potential relationship between, pore space, apparent resistivity and overburden-bedrock characteristics.

56. THE QMETER – A PORTABLE TOOL FOR REMANENCE AND SUSCEPTIBILITY

Phillip Schmidt[1]*
[1]MagneticEarth

Breiner (1973) described a method to separate induced magnetisation from remanent magnetisation of a drill core or hand sample using a total field magnetometer, thereby allowing the Königsberger ratio (Q) to be calculated. However, the method does not seem to be in general use, and nor has there been any improvement to the method despite recent developments that greatly facilitate data acquisition using handheld devices or notebook computers. Here a new fluxgate based pendulum instrument is described that allows a more controlled implementation of Breiner (1973)'s method.

The instrument accommodates samples of varying sizes although best results are yielded using regular, cubic or cylindrical, shaped samples. The instrument is portable and powered from a USB port of a notebook or similar computer. Sensitivity is high enough to yield accurate results for rocks that cause significant magnetic anomalies (~Am-1). However, for high Q rocks susceptibility is lost in the noise, and likewise for low Q rocks, remanence is lost in the noise.

The instrument is designed to quickly screen core samples at the drill site, or in a core shed, to alert the exploration team if significant remanence is present in which case the magnetic model of the target may require reconsidering. The instrument is not a replacement for laboratory measurements but potentially should save exploration costs by indicating when laboratory measurements should be undertaken.

57. NMR ON IRON RICH CORES AND CUTTINGS – THE IMPORTANCE OF SHORT TES

Timothy Hopper[1]*, *Daksh Parashar*[1], *Einar Orn Fridjonsson*[2], *Matt Carroll*[3] *and Mike Johns*[3]
[1]NMR Services Australia
[2]University of Western Australia

The moisture content of iron ore is a critical factor in determining its subsequent processing, transportation, quality and general handling. In particular, high moisture content can lead to extremely dangerous liquefaction of the ore during sea-transportation, with major financial and safety implications. NMR has long been used to measure moisture content in rocks but the presence of magnetic materials such as iron affects the NMR signal leading to data that cannot be interpreted by known

methods.

There has recently been interest in determining how the properties of the rock affect the NMR signal, particularly where there are different concentrations of magnetic materials or rocks with different mineralogical properties. There has, however, been less work in determining how the measurement techniques should be changed to accommodate these systems.

In this work we measure iron rich rock cores and show the importance of selecting an appropriate echo time in the CPMG sequence. We show that longer echo times can lead to estimations of a T2 distribution that is not representative of the system. This in turn would lead to inaccurate measurements of the water content. We demonstrate the importance of short echo times and show that for the systems studied in this work, an upper limit of 0.4 ms should be imposed.

MINERALS – VALUE OF PETROPHYSICS TO EXPLORATION SUCCESS

58. A NEW APPROACH PROVIDES OPPORTUNITIES FOR SPECTRAL GAMMA ANALYSIS IN BOREHOLES FOR MINERAL EXPLORATION

Ida Hooshyari Far[1]*, *Anton Kepic*[1] *and Anna Podolska*[1]
[1]Curtin University

Wide-spread application of gamma ray logging system in mineral exploration has long been desired by the mining industry, but not achieved. New developments in borehole logging approaches the Deep Exploration and Technologies Commonwealth Research Centre (DET CRC) have recently created Logging-While-Drilling tools, named the Autosonde and Shuttle, to measure natural gamma ray activity during drilling process. The Shuttle in particular will allow the collection of high quality natural gamma spectra by placing a sensor on the core-barrel and logging whilst drilling; a much slower process than wireline logging. Thus, a new approach collecting gamma data provides opportunities to use natural gamma radiation data in ways not normally done with conventional wireline tools.

We have used a prototype spectral gamma sensor using BGO crystal on a wireline to simulate the data that will be collected by a shuttle system to demonstrate the data quality and to test whether more sophisticated data analysis of spectral attributes such as the ratio of Photo-electric to Compton gamma bands, or "heavy minerals indicator", will further lithological information than the standard K, U, Th analysis. Our preliminary results indicate that spectral data collected by the Shuttle will allow the heavy mineral indicator to be used and opens the possibility of better lithology identification tools.

59. CLASSIFICATION OF GEOCHEMICAL AND PETROPHYSICAL DATA BY USING FUZZY CLUSTERING

Duy Thong Kieu[1]*, *Anton Kepic*[1] *and Cornelia Kitzig*[1]
[1]Curtin University

In this study, the fuzzy c-mean clustering method was used in an unsupervised manner to automatically classify the different lithologies present at the Hillside prospect (Yorke Penninsula, SA). The algorithm was applied to various combinations of petrophysical and geochemical data to identify the combination that returned the most accurate result and the smallest combination that provides a nearly identical success as the best. We show that by using a combination of geochemical and petrophysical data the likelihood of a correct classification increases by 5% compared to analysing only geochemical data, and by over 20% compared to analysing only petrophysical data.

However, using a few common elements and a few petrophysical values we can achieve almost the same success rate as the best result. Improvements in pretreatment and conditioning of the data should allow the fuzzy cluster algorithm yield even better results. In addition to showing that combining petrophysical and elemental analysis is more robust, we demonstrate that if we could add some targeted elemental analysis to logging while drilling (LWD) then robust automated lithological logging becomes feasible.

NEAR-SURFACE – ADVANCES IN NEAR SURFACE SEISMIC

60. NEAR-SURFACE INVESTIGATION USING HIGH-RESOLUTION SEISMIC REFLECTION TECHNIQUES

Ghunaim Al-Anezi[1]
[1]King Abdulaziz City for Science & Technology

The shallow seismic technique has been used to see subsurface, 595 meters of high resolution seismic reflection profile were carried out. The data were acquired using a Strata Visor with 48-channel, 40 Hz geophones and a vibroseis "IVI Minivib" system as a seismic source. Seismic reflection data were recorded using a CMP (common mid-point) acquisition method. The results for Al muzahimiyah Line are good and show a considerable improvement in signal to noise ratio. There were some problem during processing such as multiples, noise and it was so difficult to see first break because of high frequency. Signal to noise ratio was good in general. Frequent testing was carried out to improve the signal.

NEAR-SURFACE – ENVIRONMENTAL AND ENGINEERING GEOPHYSICS

61. D-LUX: A NEW WAY TO ASSESS THE SAFETY OF EMBANKMENT BY 3D ELECTRICAL SURVEY

Seokhoon Oh[1]*, *Heuisoon Lee*[2] *and Hojoon Chung*[3]
[1]Kangwon National University
[2]Geolux Inc.
[3]Human & Earth Inc.

A new array, D-Lux, for effective safety assessment of embankment by electrical resistivity survey was proposed and an applied field case was presented. In the D-Lux array, a positive line source is placed on the upstream reservoir along the embankment and a negative line source is located at downstream, expecting the electric current would flow through the embankment in the perpendicular way and its equipotential lines are parallel to the embankment if the material is in normal state. The use of line source clearly brought out the horizontal variation of the material. Any anomalous region is displayed by modified tomography map measured between potential poles crossing the embankment. This approach provided an electric potential map by forward modeling that fitted the observed tomography map and may be converted into resistivity map for

quantitative interpretation. In the field case, the qualitative potential map showed to infer the dominant flow of electric current and the quantitative resistivity map displayed the state of the core material.

62. COMBINED USE OF CONTROLLED-SOURCE AND RADIO-MAGNETOTELLURIC METHODS FOR NEAR SURFACE STUDIES

Mehrdad Basatni[1], *Alireza Malehmir*[2]* *and Alexandros Savvaidis*[3]
[1]Geological Survey of Sweden
[2]Uppsala University
[3]ITSAK

Combination of the controlled source and radio magnetotelluric, the so-called CSRMT, method has been used in modelling near surface electrical resistivity structures with the main aim of studying mineralization and engineering issues. In the controlled source mode, we used a remotely controlled double horizontal magnetic dipole that transmits signal in the frequency range 1–12.5 kHz. The signal sources for the RMT method are the distant radio transmitters in the frequency range 14–250 kHz. Three near surface case studies are presented in this work. In the first case, conductive hydrothermal stockwork copper deposits in an area in Iran were modelled in 2D and the results were compared to the existing borehole information. In the second case located in Greece using the CSRMT method we could model the location and geometry of a subvertical fault that was covered by conductive quaternary sediments. In the third case from Sweden, 3D resistivity models from the inversion of CSRMT data were used to determine presence and boundaries of quick-clay formation and a coarse-grained layer that is in turn responsible for a peculiar retrogressive landslide type in the study area. The three case studies have proven that a combination of controlled source and radio magnetotelluric methods has a considerable potential in addressing near surface problems. Comparison between the existing borehole data and the resistivity models from the inversion of the CSRMT data in each study area revealed reasonable correlation in delineating target structures especially depth to the good conductors. However, special attention needs to be given when using the CSMT data, especially at lower frequencies where they may be affected by the near-field phenomenon.

63. DETERMINING THE BASALTIC SEQUENCE USING SEISMIC REFLECTION AND RESISTIVITY METHODS

Abdulrahman G. Alanazi[1]* *and Ayman N. Qadrouh*[1]
[1]King Abdulaziz City

This study was carried out in Harat Rahat (south of Almadinah Almonwarah) using seismic reflection and resistivity methods. The main objectives of this study are to determine the extent of the basaltic layer and to define the subsurface faults and fractures that could affect and control the groundwater movement in the study area. A 2D seismic profile was acquired and the result shows that the subsurface in the study area has a major fault. We obtained a well match when the seismic result was compared with drilled wells. As a complementary tool, the resistivity method was applied in order to detect the groundwater level. The results of the resistivity method showed that six distinct layers have been identified. The interpretation of these six layers show that the first three layers, the fourth layer, the fifth layer and the bottom of the section indicated various subsurface structures and lithologies; various basaltic layers, fractured basalt, weathered basement and fresh basaltic layers, respectively. It is obvious that the eventual success of geophysical surveys depends on the combination with other subsurface data sources in order to produce accurate maps.

64. EXPERIMENTAL STUDY OF NONDESTRUCTIVE GEOPHYSICAL METHODS FOR EVALUATING THE CONDITION OF CONCRETE STRUCTURES

Majed Almalki[1]
[1]King Abdulaziz City for Sciences And Technology

It is often necessary to evaluate the integrity and reliability of concrete structures that are exposed to extreme environmental conditions over a long period of time. This paper presents a range of nondestructive geophysical methods, including Ultraseismic, Parallel Seismic, and Impulse Response techniques that use elastic-wave properties to inspect concrete-foundation structures. These approaches depend on basic waveform properties such as wave speed, amplitude, and frequency. The goal of this research is to obtain an appropriate test procedure and identify parameters for (i) verifying the wave reflected from internal concrete defects, and (ii) identifying the effective depth of a pre-built test foundation. To do so, we have established an experimental laboratory to calibrate and check the reliability of the measured data and understand the wave properties for different concrete conditions (i.e. fractures). We concluded that the aforementioned geophysical approaches could provide vital information for quality control and rehabilitation purposes.

66. PROCESSING AND INTERPRETATION OF SHALLOW-WATER SEISMIC DATA FOR CO_2 INJECTION

Hyeon-Gyu Kim[1]*, *Minjun Kim*[1], *Rongtao Gao*[2] *and Geosolu Myong-ho Park*[1]
[1]Korea National Oil Corporation
[2]Schlumberger

2-D seismic data were acquired in Yeong-il Bay of Korea in search of proper prospects for CO_2 injection into an offshore basin. The unfavourable situation for operation and very shallow water prevented the operator from obtaining quality data. Small number of channels and short offsets incapacitated velocity analysis and migration. Main efforts have been thrown into finding out the best processes to attenuate linear noises and strong short-period multiples raised from the shallow water that masked the whole data. The processing methods ascertained to be useful for this purpose are DENOISE, DWD (deterministic water-layer demultiple), and τ-p deconvolution, which were applied by using Omega 2 processing system. The resultant images are successfully free from the strong noise and revealed the geological structures obscured by the noise.

The processed data were geologically interpreted to identify the prospective formations in the basin so as to inject carbon dioxide into them.

67. AUTOMATED AIRBORNE EM AND BOREHOLE DATA INTEGRATION FOR DEPTH TO BEDROCK EXTRACTION

Andreas Pfaffhuber[1]* *and Craig Christensen*[1,2]
[1]Norwegian Geotechnical Institute
[2]Queen's University at Kingston

Airborne electromagnetic (AEM) was used to supplement a geotechnical investigation for a highway construction project in Norway. Variable bedrock threshold resistivity hindered efforts to track depth to bedrock, motivating us to develop an automated algorithm to extract depth to bedrock from both boreholes and AEM data. We developed two variations of this algorithm: one using simple Gaussian or inverse distance weighting interpolators, and another using ordinary kriging and combined parameter probability distribution functions.

Evaluation shows that for preliminary surveys, significant savings in boreholes required can be made without sacrificing bedrock model accuracy. However, issues with AEM noise and data quality likely reduced the comparative advantage that including AEM provided. Moreover, AEM cannot supersede direct sampling where the model accuracy required exceed the resolution possible with the geophysical method. Nevertheless, using AEM in the way can still reduce the number of required boreholes and hence reduce site investigation costs because we can identify high probability zones for shallow bedrock, identify steep or anomalous bedrock topography, and estimate the spatial variability of depth.

NEAR-SURFACE – GROUNDWATER AND CONTAMINANT MAPPING

68. HYDROGEOPHYSICS FOR INFORMED WATER MANAGEMENT DECISIONS IN THE ANANGU PITJANTJATJARA YANKUNYTJATJARA (APY) LANDS OF SOUTH AUSTRALIA

Andrew Parsekian[1], Aaron Davis[2], Tim Munday[2], Denys Grombacher[3], Brady Flinchum[1], Kevin Cahill[2] and Michael Hatch[4]*
[1]University of Wyoming
[2]CSIRO
[3]Stanford University
[4]University of Adelaide

The Anangu Pitjantjatjara Yankunytjatjara (APY) Lands of South Australia is an arid environment and the population relies largely on groundwater resources for potable water and agricultural needs. Historically, locating productive wells in the region has been hit-and-miss and even if a water source was found, the quality may be unreliable. In this project, we seek to improve the water security in the APY lands by demonstrating that surface Nuclear Magnetic Resonance (NMR) and Time-Domain Electromagnetic (TEM) geophysical measurements are able to map local aquifers and quantify ground water resources, thereby optimizing site selection for potential future wells. Surface NMR is directly sensitive to water and TEM measurements detecting the electrical conductivity structure and able to image the subsurface over large areas – all entirely non-invasively and with minimal risk of disturbing sites of importance to the local Aboriginals.

69. FIRST EVIDENCE OF T2^*IN SNMR MEASUREMENTS WITH SQUID SENSORS

Aaron Davis[1], Mike Mueller-Petke[2], Raphael Dlugosch[2], Matthias Quietsch[3], James Macnae[4] and Ronny Stolz[5]*
[1]CSIRO
[2]LIAG
[3]Friedrich-S-University
[4]RMIT University
[5]LIPT

We discuss the theoretical development of the measurement of the t2 component from a surface nuclear magnetic resonance (SNMR) experiment using superconducting quantum interference devices (SQUIDS) as a point B-field receiver.

We discuss the differences between point receivers compared to traditional coincident-loop receivers, and demonstrate the first measurements of T2 with a SQUID sensor at the hydrogeophysical test site in Schillerslage, Germany.

70. MAPPING OF ELECTROMAGNETIC NOISE IN A MAGNETIC RESONANCE SOUNDING CONTEXT

Jakob Juul Larsen[1], Esben Dalgaard[1], Philip Christiansen[1] and Esben Auken[1]*
[1]Aarhus University

The applicability of magnetic resonance sounding in mapping the water content and the hydrological properties of the sub-surface in industrialized areas is severely limited by electromagnetic noise. Efficient ways of mitigating the noise must be developed before the technique can become a ubiquitous tool. In this paper we demonstrate an instrument developed for efficient mapping of noise at a given site prior to a magnetic resonance sounding. The instrument consists of two small induction coils connected to a digital oscilloscope controlled by a PC. Using the instrument, measurements of the electromagnetic noise are easily performed at several places within the site. Signal processing of the measurements provide a quantified understanding of the contributions from different noise sources, primarily powerline harmonics and impulsive noise. Further the spatial distributions of the noise components are also obtained. Based on this knowledge the optimum spot for a magnetic resonance sounding with the least distortion by noise can be identified. The instrument is now in routine use at the Hydrogeophysics group at Aarhus University.

71. SURFACE NMR TO IMAGE AQUIFER PROPERTIES IN A MAGNETIC SUBSURFACE

Denys Grombacher[1], Andrew Parsekian[2], Aaron Davis[3], Tim Munday[3], Brady Flinchum[2], Kevin Cahill[3], Michael Hatch[4] and Rosemary Knight[1]*
[1]Stanford University
[2]University of Wyoming
[3]CSIRO
[4]University of Adelaide

Surface Nuclear Magnetic Resonance (NMR) is a non-invasive geophysical technique providing the ability to image and investigate aquifer properties. In order to produce reliable images and interpretations of subsurface properties accurate modelling of the underlying physics is required. In magnetic environments, where the background magnetic field varies spatially, challenges can arise that lead to difficulty accurately

modelling the excitation process and interpreting the signal's time dependence. We demonstrate using field data collected in the Anangu Pitjantjatjara Yankunytjatjara (APY) Lands of South Australia that neglecting the influence of the magnetic environment can significantly alter the final images and interpretation of the subsurface structure and properties.

73. GEOSTATISTICAL ANALYSIS OF THE RELATIONSHIP BETWEEN AIRBORNE ELECTROMAGNETIC DATA AND BOREHOLE LITHOLOGICAL DATA

Adrian Barfod[1]*, *Ingelise Møller*[1] *and Anders V. Christiansen*[2]
[1]GUES
[2]The HydroGeophysics Group, Aarhus University

We present a large-scale study of the relationship between dense airborne SkyTEM resistivity data and sparse lithological borehole data.

Airborne electromagnetic (AEM) data contains information about subsurface geology and hydrologic properties; however extracting this information is not trivial. Today, geophysical data is used in combination with borehole data to create detailed geological models of the subsurface. The overall statistical relationship is, however, not widely known. The objective of this study is to develop a method for understanding the relationship between petrophysical properties and lithology, and apply this to get a better understanding of large-scale petrophysical structures of the subsurface.

The data sampling is carried out in a scheme where data is interpolated onto the position of the boreholes. This allows for a lithological categorization of the interpolated resistivity values, revealing different distribution functions for lithological categories.

A very large and extensive dataset is available in Denmark through the national geophysical and borehole databases. These databases contain all geophysical and borehole data in Denmark and covers a large part of its surface. By applying the proposed algorithm to all available airborne electromagnetic data, detailed maps of the large-scale resistivity-lihology structures on a National scale in Denmark are constructed.

NEAR-SURFACE – NEAR SURFACE OTHER

74. PERFORMING HIGH RESOLUTION SEISMIC REFLECTION FOR MAPPING BAUXITE LAYERS

Ayman N. Qadrouh[1], *Abdulrahman G. Alanez*[1], *Ibraheem K. Hafiz*[1], *Khyzer Munir*[1] *and Mazen M. Al Yousif*[1]
[1]KACST

The seismic method is able to produce highly accurate images of the Earth's subsurface. Having such detail is not only an important factor in mining, but also in civil engineering. Bauxite exploration attracts both government and industrialists to invest in it because of the high percentage of aluminum present. The economic importance of extracting aluminum from bauxite encouraged us to take this challenge; to image bauxite layers by using a high-resolution seismic reflection method at Al Qassim, Saudi Arabia. Since the subsurface structure of the area is complex, this high-resolution reflection method was carried out along a 2D line with geophone and source interval, with settings at 5 m. The result for the seismic section shows that the depth and thickness of the bauxite layer varied between 20 to 34 m, and 3 to 7 m respectively. In addition, the bauxite layer was sandwiched between clay layers. In order to achieve an even more precise depth than presented by seismic section alone, we tied the drilled wells to the seismic data and we accomplished a well match with an approximation error of 1–2 m, which may have been caused by the upper clay layer or by very shallow loose subsurface material. The seismic method thus applied shows the ability to detect significant details within the near surface of the earth, and is considered more cost-effective than only drilled wells.

PETROLEUM – 4D/BROADBAND SEISMIC/EMERGING TECHNOLOGIES

75. ENHANCED VIBROSEIS: THE NEXT STEP IN LAND 2D – 4D

Robert Heath[1]* *and Spencer Rowse*[2]
[1]ISeis
[2]AnalySeis LLC

The field of vibroseis has seen various advances over recent decades which have been mostly of a gross nature. These include the development and operation of heavier vibrators, improvements in positioning and tracking, the deployment and control of larger numbers of vibrators acting either as part of a fleet or as individual sources. More subtly, improved QC brought about by incorporation into the source decoder of sufficient recording channels which may better define vibroseis signatures has also been available to suitably equipped crews. Meanwhile, some seismic land recording systems also have been able to keep up with these source-related improvements, with the majority of advances made in cableless and hybrid systems which can work with large numbers of independent sources thanks to real time QC options, ease of deployment and a mix-and-match approach of recording system architectures.

The basic assumptions in terms of the frequency and force put into the ground, however, remain fixed on the notion of weighted sum ground force (WSGF) as espoused by Sallas in the 1980's. Most source control equipment and QC methods are still built on the premise that this is a sufficiently good approximation for most circumstances.

However, even basic testing with load cells and/or down hole sensors reveal that this assumption is poor at low frequencies, and potentially significantly inaccurate at high frequencies. The problems resulting from this incorrect WSGF-approach are important limiting factors in terms of taking the next steps in vibroseis productivity and data quality improvement. This is true not only for typical land 2D/3D surveys but also the shortcomings of the WSGF approach may seriously limit the progress that may be made on land 4Ds where far more accurate understanding of source characteristics is essential.

Initial results using The Enhanced Vibroseis method shows the potential to solve many of these issues and may be seen as the next major step the industry needs to make to progress this form of land acquisition.

78. DEGHOSTING OF OVER/UNDER TOWED-STREAMER SEISMIC DATA WITH WAVEFIELD EXTRAPOLATION

Xizhu Guan[1]*, *Li-Yun Fu*[1] *and Wei Wei*[1]
[1]Institute of Geology and Geophysics, Chinese Academy of Sciences

In marine seismic acquisition, ghost effect due to the strong reflection of the sea surface causes serious notch trap in the spectrum. Ghost effect can be reduced by over/under towed streamer acquisition. Howerver, most of deghosting technology for over/under streamer acquisition is based on seismic kinematics method, which cannot effectively solve the ghost wave interference and brings incomplete ghost suppression and distortion of the effective signal. In this paper, we propose a new deghosting method for over/under streamer acquisiton based on analytical fk-domain seismic wavefield extrapolation characterized by high computing efficiency. Cases studies of synthetic and real seismic datasets demonstrate that our seismic wavefield extrapolation based on Fourier transform ensures the consistency of the seismic amplitude and phase of over/under streamer seismic data and significantly eliminates the amplitude and phase error of far offset especially for the long streamer condition, which helps to decouple the real wave and the ghost wave and fill notch effect in the spectrum.

80. IMPROVED VERTICAL AND LATERAL RESOLUTION IN INVERTED TOWED STREAMER EM DATA AS A FUNCTION OF INCREASED DATA DENSITY

Atle Aamodt[1]*, *Kathrin Flisnes Bergh*[1], *Jenny-Ann Malmberg*[1] *and Jenny-Ann Mattsson*[1]
[1]Petroleum Geo-Services

The towed streamer EM marine controlled source electromagnetic (mCSEM) system facilitates cost effective dense spatial data acquisition. Resistivity imaging of the subsurface is dependent on both the spatial and source frequency coverage in the mCSEM data. In particular, the inversion performance can be improved with respect to the resolution by increasing the density of the subsurface image points.

In this study, different settings of sources and receivers are investigated in a series of 2.5D anisotropic inversions. Both vertical and horizontal resolution capabilities of the EM inversions are tested by modelling two resistive anomalies displaced vertically and horizontally, respectively, and by using different acquisition data density for the inversions.

The cases with denser data coverage showed an overall better representation of the targets compared to the sparser cases. Further, the inversion resolution is dependent on the noise level. A higher data density appears to stabilise the inversions and also makes them less susceptible to the noise. Hence, our results emphasize the importance of acquiring sufficiently dense data to ensure robustness of CSEM inversions.

PETROLEUM – ACQUISITION TO INTERPRETATION CASE STUDIES

81. WIDE LINE SEISMIC ACQUISITION TECHNIQUE IN A HILLY TERRAIN OF ONSHORE MYANMAR

Seehapol Utitsan[1]*, *Tosapol Tongpet*[1], *Suppakarn Thanatit*[1] *and Wirote Wetmongkongorn*[1]
[1]PTTEP

Myanmar's onshore block EP-2 is a small exploration concession with high potential structures located on the eastern side of the Irrawaddy River. One of the major anticlinal structures can be mapped based on surface geological survey, but the recent 2D seismic data has extremely poor quality due to a severe static and strong side scattered noise. Although the size of this prospect is attractive, the subsurface uncertainties are considered too risky for further drilling operation. An alternative acquisition technique called "2D-wide line" was firstly implemented in Myanmar. Its results provide better stack sections, more reliable velocity function and higher geological probability of success.

82. APPLICATION OF 3D ITERATIVE SRME FOR SHALLOW WATER DE-MULTIPLE, A CASE STUDY ON DATA FROM PHU QUOC BASIN IN OFFSHORE VIETNAM

Hao Zhang[1]*, *Barry Hung*[1], *Jiwei Jia*[1], *Zhengmin Zhang*[1] *and Anh Tien Ho*[2]
[1]CGG
[2]PVEP

This paper presents our continuous effort on multiples attenuation in shallow water environment. The seismic data were acquired at various locations along the offshore of Vietnam, and the interpretation of the data is made difficult due to the presence of shallow water related multiples. Previously, we have demonstrated a two-step workflow of applying first shallow water de-multiple (SWD) and then surface related multiple elimination (SRME) to handle shallow water multiples. This workflow has been proven to be effective as it has been applied on many marine seismic surveys.

In this paper, we expand our current workflow by incorporating the data before and after SWD as the dual input for 3D SRME model prediction, namely 3D iterative SRME for shallow water for targeting higher order peg-leg surface related multiples that includes the seafloor as one of the multiple generators. Apart from being data driven, 3D iterative SRME for shallow water also takes into consideration the spatially varying nature of subsurface structures.

We demonstrate, through the real-data examples, that our workflow provides an optimal multiple attenuation solution in the shallow water environment.

83. INTERPRETING 2D SEISMIC WITH THE ASSISTANCE OF FALCON® AIRBORNE GRAVITY GRADIOMETER DATA IN THE CANNING BASIN

Jurriaan Feijth[1]*, *Carlos Cevallos*[1], *Tony Rudge*[2] *and Peter Edwards*[2]
[1]CGG
[2]Buru Energy

The interpretation of 'vintage' seismic data acquired in underexplored frontier basins is often challenged by their sparse

coverage. This example from the Canning Basin illustrates how FALCON® Airborne Gravity Gradiometer (AGG) data greatly enhances the 2D seismic interpretation, facilitating exploration in such frontier basins.

The initial seismic interpretation was performed by Buru Energy, and given the 'vintage' data, was limited at best. The integration of the AGG, magnetic, well, and other available data allowed the improvement of seismic interpretation. A basement structure map, and two intra-sedimentary structure maps were produced, resulting in an overall geological model.

In particular, the initial seismic interpretation of seismic traverses perpendicular to strike across the AGG survey could be significantly improved by using images of the AGG data and AGG profile data (GDD and gD). The AGG data and the structure maps were used to constrain fault locations and depths as well as thickness distributions of geological units. The interpreted seismic traverses were validated by 2.5D gravity modelling, ultimately resulting in a conceptual geological model.

This is a key-method to constrain the interpreted geology, providing a more confident interpretation of 'vintage' reflection seismic data with sparse coverage.

84. A SEISMIC SURVEY AT THE REGION NEAR THE MOUTH OF FUJI RIVER, SHIZUOKA PREF., JAPAN

Toshiyuki Yokota[1], Shinji Kawasaki[2], Yasuhisa Tanaka[2] and Katsuya Noda[2]*
[1]AIST
[2]JGI Inc.

It is very important to know the subsurface structure and depositional environment from the coastal to the shallow sea region, when studying groundwater flow. However, when we acquire geophysical survey data, since the data acquisition methods of both land and marine cannot successfully acquire the data at the domain from the coastal to the shallow sea regions, such regions are often left as blank of geophysical surveys. Furthermore, in our country, such domains are generally highly developed and even setting up geophysical survey lines are difficult. Therefore, we are investigating the geophysical survey methods appropriate for the surveys beneath the coastal to the shallow sea region. We are also developing the evaluation methods for such regions. Therefore, we conducted a seismic reflection survey to image the subsurface structure of coastal to the shallow sea region of the mouth of the Fuji River, Shizuoka, Japan where the Fujikawa-kako fault group exists, and checked applicability of the technique. As a result, we obtained subsurface structure down to the 5000 m.

85. NEOGENE OBLIQUE EXTENSIONAL SYSTEM IN THE NORTH-WESTERN BONAPARTE BASIN, AUSTRALIA

Muhammad Mudasar Saqab[1] and Julien Bourget[1]*
[1]University of Western Australia

The North-western Bonaparte Basin offers a very good opportunity to understand the nature of oblique extension system, where Neogene flexure-induced extension was superimposed obliquely to the Mesozoic rift-related structures. The Mesozoic trends strongly control the distribution and style of the younger Neogene structures, both at regional and local scale. The younger Neogene activity produced a new set of NE trending, right-stepping en echelon faults and reactivated the older faults. In addition, episodes of stratigraphic growth provide critical evidence regarding the timing of fault activity. Results demonstrate that, in the study area, main fault activity occurred in several pulses during the latest Miocene to Late Pleistocene. These episodes of fault activity correspond to recently constrained regional tectonic events i.e., the initial collision of the Australian Plate with the Banda Arc, the episodes of uplift of the Timor Island and the timing of lithospheric flexure.

86. NORTH SEA CASE STUDY: HEAVY OIL RESERVOIR CHARACTERIZATION FROM INTEGRATED ANALYSIS OF TOWED STREAMER EM AND DUAL-SENSOR SEISMIC DATA

Atle Aamodt[1] and Kerry Key[2]*
[1]PGS
[2]Scripps Institution of Oceanography

Integrated analysis of geophysical data can provide valuable information on reservoir properties, on the basis of which exploration, appraisal, and development decisions can be made. Hence, we have introduced a quantitative interpretation workflow that integrates dual-sensor seismic and Towed Streamer controlled-source electromagnetic (CSEM) data. The workflow was designed to facilitate a reliable extraction of the complementary information from the two datasets. The seismic contribution starts with a depth-converted sparse horizon model to initialize the EM inversion, but it is not placed rigidly. This makes good sense when taking into account the uncertainties in seismic data, in the time to depth conversion, and more importantly, the fact that a reservoir can be hydrocarbon-charged to an unknown degree corresponding to the spill-point or less. We show how this approach enables a robust and reliable workflow for integrating EM and 3D seismic data with data examples acquired in an area with the complex geology of the Bressay, Bentley and Kraken (BBK) fields in the North Sea. The three heavy oil reservoirs are injectites, located in close proximity to other high resistivity settings, such as the shallow gas in the overburden, regional Balder Tuff and granite intrusions, resulting in challenging imaging issues.

87. FAULT LINKAGE AND REACTIVATION ON THE NORTHERN MARGIN OF THE DAMPIER SUB-BASIN

Chris Elders[1] and Sam McHarg[1]*
[1]Curtin University

The north-west margin of the Dampier sub-basin is characterised by a strongly segmented fault pattern. NE trending faults define the edge of the Rankin Platform, and separate it from the Kendrew Trough. However a secondary set of NNE trending faults define smaller scale graben on the edge of the Rankin Platform that preserve Lower and Middle Jurassic sediments. This strongly suggests oblique reactivation of an inherited NE trending basement fabric under WNW oriented extension during Middle Jurassic extension.

PETROLEUM – FWI/VELOCITY ESTIMATION/SEISMIC IMAGING

89. REDUCING DATA STORAGE IN REVERSE TIME MIGRATION

Weijia Sun[1]*, *Li-Yun Fu*[1] *and Zhengxing Yao*[1]
[1]Institute of Geology And Geophysics Chinese Academy Of Sciences

Prestack reverse time migration (RTM) requires extensive data storage since it computes wavefields in forward time and accesses wavefields in reverse order. We first review several successful schemes that have been proposed to reduce data storage, but require more computational redundancies. We propose two effective strategies to reduce data storage during RTM. The first strategy is based on the Nyquist sampling theorem, which involves no extra computational cost. The fact is that the time sampling intervals required by numerical algorithms or given by field records is generally several times smaller than that satisfied by the Nyquist sampling theorem. Therefore, we can correlate the source wavefields with the receiver wavefields at the Nyquist time step, which helps decrease storage of time history. The second strategy is based on a lossless compression algorithm, which is widely used in computer science and information theory. The compression approach reduces storage significantly at a little computational cost. Numerical examples show that the two proposed strategies are effective and efficient.

90. RECIPROCITY PRINCIPLE IN FINITE DIFFERENCE MODELLING OF WAVES IN ELASTIC MEDIA

Kevin Ung[1]*, *Andrej Bona*[1] *and Mahyar Madadi*[1]
[1]Curtin University

Reciprocity principle has been used in a number of seismic applications. This principle relates the two wave fields with interchanged source and receiver locations, where the radiation patterns of the source and receiver are interchanged as well. In extending this principle to be used in real-world scenarios where radiation patterns vary in different locations, a number of experiments to determine the validity of this principle were conducted. Given the proliferation of the numerical modelling in today's geophysical data processing and imaging, the verification of validity of the reciprocity theorem for the modelling algorithms is important. We found that the reciprocity principle is not upheld for some instances of finite difference modelling due to the implementation of the free surface boundary condition. In the case of absorbing boundary conditions however, good reciprocity relation can be achieved.

91. BOREHOLE HYDROPHONE EXPERIMENTS FOR A NEAR-WELL INVESTIGATION AT AN AQUIFER STORAGE AND RECOVERY SITE, MIRRABOOKA, WESTERN AUSTRALIA

Majed Almalki[1]* *and Brett Harris*[2]
[1]King Abdulaziz City for Sciences And Technology
[2]Curtin University

We present borehole experiments conducted at the Mirrabooka Aquifer Storage and Recovery (ASR) site, Perth, Western Australia. Our aim is to investigate a potential method to aid in constructing hydraulic or reactive transport modelling. Two acquisition techniques were implemented to collect the data: (i) walkaway vertical seismic profiling and (ii) zero-offset vertical seismic profiling (ZVSP). These borehole experiments were conducted simultaneously in two monitoring wells: M345-109 and M345-408. The ZVSP experiments were completed in such a way that the data could be acquired at 0.5-m hydrophone intervals over a highly heterogeneous production interval. Dense ZVSP was applied to characterise aquifers above and within the ASR production zone and to assess the field parameters for imaging proposes. We demonstrated the effect of borehole coherent noise (i.e., tube waves) and the low-velocity vadose zone (i.e., variably cemented concretionary rocks). Near-surface heterogeneity resulted in large travel-time statics of ±4 ms as well as wavelet variations at each position of the free-falling weight-drop source. The processing of the reflected wave field yielded high-resolution subsurface imaging for the target layers, confirming the existence of flat-horizon layers of Osborne and Leederville formations. We demonstrated that there is the potential for vertical seismic profiling methods to be applied in shallow weakly consolidated sandstone aquifers.

92. IMAGING COMPLEXITY IN THE EARTH – CASE STUDIES WITH OPTIMISED RAY TOMOGRAPHY

Ed Lewis[1]*, *Zhijiang Luo*[1] *and John Brittan*[1]
[1]ION Geophysical

In the past 10 years, the resolution of tomographic solutions has seen a continuous increase because of evolving sophistication in methodologies and technology. A vital issue in the data domain is accuracy and density of residual move-out picks that are used to derive tomographic velocity-model updates. A new automated method allows for precise tracking of accurate residual move-out on pre-stack depth-migrated gathers and consequently the fast determination of dense, high quality travel time residuals for seismic tomography. The determination of small-scale anomalies ultimately leads to flatter pre-stack depth-migrated gathers and consequently better-focused structural images.

93. VELOCITY ANALYSIS USING ZERO-OFFSET ATTRIBUTES IN COMMON SOURCE DOMAIN

Mohammad Javad Khoshnavaz[1]*, *Milovan Urosevic*[1] *and Andrej Bona*[1]
[1]Curtin University

Most of the migration techniques require an input velocity model. Velocity analysis is one of the most critical stages in seismic data processing. Standard ways to find the velocity model are constant velocity stack and Semblance velocity analysis, which can be time consuming and labour intensive. In this work, we introduce a new approach to obtain the migration velocity and the relevant pre-stack time migration algorithm that is time effective and does not require any input velocity model prior to imaging. The velocity components, in each point in a common source gather, are achieved by calculating the radius of the curvature of seismic reflected wave-front. The corresponding velocity formula is a function of local derivatives of two way travel times with respect to the position of receivers. Computational experiments with synthetic seismic data examples confirm the theoretical expectations and demonstrate the feasibility of the proposed technique.

94. HORIZONTAL RESOLUTION OF SEISMIC ACQUISITION GEOMETRIES

Wei Wei[1]*, *Li-Yun Fu*[1] *and Weijia Sun*[1]
[1]Chinese Academy of Sciences

Spatial sampling has a crucial influence on the horizontal resolution of seismic imaging, but how to quantify the influence is still controversial especially in complex media. Most of the studies on horizontal resolution focus on the measurement of wavelet widths for seismic migration, but neglect to evaluate the effect of side-lobe perturbations on spatial resolution. The side-lobe effect, as a migration noise, is important for seismic imaging in complex media. In this article, with focal beam analysis, we define two parameters to represent the horizontal resolution of an acquisition geometry: the width of the main lobe (WML) along the inline and crossline directions and the ratio of the main-lobe amplitude to the total amplitude (RMT) in a focal beam. We provide examples of typical acquisition geometries to show that how spatial sampling affects the horizontal resolution, measured in terms of WML and RMT values. WML defines the horizontal resolution to image the target, whereas RMT describes the clarity of the imaging. Migration noise reduces with increasing RMT, indirectly improving both the vertical and horizontal resolutions of seismic imaging. Case studies of seismic migration with 3D seismic data demonstrate how the acquisition geometries with different WML and RMT values influence the performance of seismic imaging. A prior WML and RMT analysis to predict the quality of acquired datasets can optimize acquisition geometries before the implementation of seismic acquisition.

95. ROBUST SEISMIC REFLECTION Q TOMOGRAPHY THROUGH ADAPTIVE MEASUREMENT OF SPECTRAL FEATURES

Kefeng Xin[1]*, *Yi He*[1] *and Yi Xie*[1]
[1]CGG

In this paper, we describe a robust Q tomographic inversion approach for estimating the subsurface volumetric Q field by using reflection seismic data. The inversion process involves two key stages: adaptively extracting dissipation time information from the change of spectral features of the seismic data in the presence of noise, and integrating the picked dissipation time information from both pre-migration CDP gathers and post-migration CIGs into a ray-based grid tomography for Q model building. This approach can be used together with the Q-PSDM technique to provide better images by honouring the actual wave-paths in both Q estimation and Q compensation. The Q-PSDM results show the reliability of this approach when using it to perform Q estimation in both conventional and broadband seismic data processing.

PETROLEUM – NO SUB-THEME ALLOCATED

96. LATERAL VELOCITY VARIATIONS IN THE DARAI LIMESTONE, PAPUA NEW GUINEA FORELAND

Andrew Nelson[1]* *and Ben Turner*[2]
[1]Horizon Oil Ltd
[2]Dayboro Geophysical

A combination of exploration and appraisal drilling results from wells on three adjacent discoveries in the Papuan Basin, western Papua New Guinea foreland, shows significant lateral velocity variation across the more than 1 km thick Darai Limestone. Investigation suggests that these are due to alteration, including dolomitisation, of the limestone. Most alteration appears associated with small scale faulting which is typically crestal. Seismic processing velocities are key to establishing the velocity profiles between wells required for depth conversion. Seismic forward modelling studies based on predicted high velocity bodies show processing velocities can develop an oscillatory behaviour in the vicinity of abrupt lateral velocity changes similar to those that may accompany dolomitisation. Similar results are observed on some of the field data.

97. APPLICATION OF ROCK PHYSICS AND SEISMIC INVERSION FOR THE DETERMINATION OF RESERVOIR ARCHITECTURE AND CONNECTIVITY FOR COAL SEAM GAS FIELD DEVELOPMENT

Mirza Ahmad[1]* *and Stephen Tyson*[2]
[1]Petroleum Geoscience Program
[2]University of Queens

Fluvial systems host coal seam gas reservoirs in various fields of Queensland. However, the lateral heterogeneity of reservoirs properties within these reservoirs can be significant and determining the distribution of these reservoirs is a challenge. This study attempts to predict coal distribution by applying rock physics and post-stack seismic inversion on data set of Scotia field of the Surat Basin. According to rock physics analysis, coal beds have significantly low density. Consequently, this gives low P-impedance as compared to surrounding lithology. Therefore, inverted P-impedance and density volumes can be used to predict coal distribution and connectivity of different coal seam reservoirs. Theoretically, density volumes may provide accurate prediction, but this requires execution of comprehensive pre-stack inversion workflow. We only used a model based P-impedance inversion technique to create P-impedance volumes in order to better image the reservoir and connectivity. Extracted horizon slices by using cutoff based on rock physics analysis, successfully highlights architecture of coal beds. Computed average P-impedance within zone of interest can provide information regarding promising zones for exploration of coal seam gas. Blind test for P-impedance prediction at well locations reveals reasonable match for coal prediction using this method.

98. MARINE EM SURVEYS ON COASTAL SHELF AND TRANSITION ZONES

Igor Ingerov[1]*
[1]Advanced Geophysical Operations And Services Inc. (AGCOS)

Seabed EM surveys in shallow water environments have a number of specific particularities. Specifically, there is difficulty with hermetical sealing of EM instruments and the necessity of overcoming electromagnetic noise caused by underwater currents and sea surface disturbances. Another problem is the inability to employ large ocean going vessels in many areas, while the use of small vessels increases the demands on the size and weight of the equipment. There are also certain positive aspects in this, pertaining to the ability to use reliable acoustic communication between the marine EM instrument positioned on the seabed and the sea surface, as well as the use of beacons for identifying the location of the bottom apparatus. In this paper, discussed is a

shallow marine EM data acquisition equipment complex that allows efficient use of standard ground EM instruments for carrying out investigations at a sea depth interval of 0–200 m. This complex consists of 2x – 4x – 5-channel marine EM systems.

99. LA LOBE EARLY CRETACEOUS FAN-DELTA (CAMEROON ATLANTIC BASIN)

Mbida Yem[1]*, *Yéné Atangana Joseph Quentin*[1] *and Nguema Ponce*[2]
[1]University of Yaounde I
[2]Geosc. Dpt., Nat. Hydrocarbons Co

From the Campo onshore to the Malabo-Victoria volcanic line, the Cameroon Atlantic Basin comprises two main segments: the Ekité-Kordofan transform-fault basin and the Wouri-Yassem deep-graben structure separated by the Yassoukou-Tissongo-Ossa reverse fault. The major morphologic features of the Ekité-Kordofan transform-fault basin are Kribi-Campo half-graben and the Elombo-Nkoundou internal shear zone.

Detailed analyses of long offset pre-stack depth migrated seismic sections enabled mapping of buried fan-delta at approximately 20 km southwest of the Kribi-La Lobe river mouth. The fan is up to 25 km wide, 4km thick and is morphologically expressed in the form of bank clinoform sequences. By correlation of seismic records with borehole data from adjacent areas, it appears that the fan is divided in two morphologic divisions (upper and lower fan). The lower fan uniformly returns transparent weak seismic record, with intermittent internal reflections. In contrast, the upper fan is characterized by acoustically high amplitude clinoform reflections. Within this package, listric growth faults are common, and the fan tends to mound up were salt domes are present beneath Bedoulian-Aptian boundary. These results opened up Aptian-Albian fan-delta play of the Cameroon Atlantic Basin and help to introduce new hydrocarbon concepts and exploration opportunities.

PETROLEUM – PETROLEUM OTHER

100. MULTIPLE ATTENUATION USING NON-LINEAR PREDICTIVE OPERATORS IN F-X DOMAIN BY VOLTERRA SERIES COEFFICIENTS

Alireza Khoshnavaz[1]*, *Hamidreza Siahkoohi*[2] *and Mohammad Javad Khoshnavaz*[3]
[1]IAU University
[2]The University of Tehran
[3]Curtin University

One of the most common artefacts in seismic records is multiples. To have more interpretable images, they must be removed or at least be attenuated. Prediction of such artefacts is being done using two different theories: linear and non-linear predictive theories. Coherent artefacts have linear and non-linear shapes in time-offset domain. Nonlinear artefacts have the shape of Chirp in time-frequency domain. Therefore, modelling and reconstruction of such artefacts using linear operators do not work efficiently. In this paper, we explain the deficiencies of the linear predictive theory for prediction and reconstruction of seismic data. As an improvement on linear predictive theory, we describe the non-linear predictive filters using Volterra series. Our main effort is to rebuild the signals so that they have the minimum difference from the original recorded signals. We compare the relevant results obtained by both linear and nonlinear prediction techniques. We also optimised the previous algorithms to find the best Volterra coefficients. The ability of the theories to remove the seismic multiples is also demonstrated. Different synthetic examples have been used to illustrate the applicability of the mentioned techniques to predict and reconstruct the seismic wave-front and to attenuate the multiples.

101. ON THE EFFECTIVENESS OF GEOPHONE ARRAYS FOR ATTENUATING AMBIENT NOISE

Ben McCarthy[1]*, *Timothy Dean*[1], *J. Christian Dupuis*[2] *and Laval Raquibul Hassan*[3]
[1]Schlumberger
[2]Université Laval
[3]University of Sydney

Historically, arrays have been used to attenuate ambient noise under the assumption that the level of attenuation is directly proportional to the square root of the number of sensors in the array. Given the availability of high channel-count point-receiver systems and the cost associated with laying out large arrays this assumption of 'spatial randomness' requires further analysis. Using measurements of ambient noise made at various sites in Perth, Australia with closely spaced geophones we show that ambient noise is strongly correlated over distances of up to 10 m. This correlation reduces the signal-to-ambient-noise performance of an array considerably. The correlation coefficient can be modelled using an exponential function and the correlation-distance used to determine the efficient geophone spacing.

The optimum geophone spacing on days with a low wind speed (<10 km/h, observed on 27% of days in the area) is 15 m. For days with a very high wind speed (>80 km/h) the optimum spacing is 2.5 m, although this wind speed is very uncommon, occurring on average less than once each year. For more than 90% of days the wind speed is such that the optimum geophone spacing required for ambient noise suppression is 7.5 m.

102. THE IMPACT OF TILTED GEOPHONES ON LAND SEISMIC DATA QUALITY

Ben McCarthy[1]*, *Pieter Claassen*[2] *and Timothy Dean*[3]
[1]WesternGeco
[2]Bureau of Meteorology Melbourne
[3]Schlumberger

The moving coil geophone is still the most commonly used sensor for land seismic surveys despite the introduction of other sensors. Modern geophone development has reached the stage where the signal recorded is of very high quality, but it can still be affected by the geophone being placed on an angle relative to the vertical ('tilt').

This paper describes the acquisition and analysis of field measurements using tilted geophones. It is shown that the critical angle of the 10 Hz geophones used for this test is 55°. For data recorded using vertically placed geophones separated by only 10 cm the perturbation level (the difference between the data recorded by adjacent geophones) averaged 8% and increased to more than 50% at tilt angles of 40º. The level of perturbation is heavily dependent on the orientation of the tilt angle relative to the source-detector axis, for example, for a geophone tilted at an angle of 30°, the perturbation varied between 14% and 48%.

The obvious solution to these issues is to record data using sensors that have been planted extremely carefully or to use other sensors, such as digital accelerometers or 3C sensors that have the effect of tilt removed during processing.

103. THE PRESENT-DAY STRESS FIELD OF AUSTRALIA: NEW RELEASE OF THE AUSTRALIAN STRESS MAP

Mojtaba Rajabi[1]*, *Mark Tingay*[1], *Rosalind King*[1] *and Dennis Cooke*[1]
[1]The University of Adelaide

The present-day stress field is important for a range of earth science disciplines including petroleum and geothermal geomechanics, mine safety, neotectonics and seismic hazard assessment. So far, many studies have been carried out to understand the state of stress in different parts of the world and the results reveal that the contemporary tectonic stress field can range from being uniform over large areas (100s-1000s of kilometres) to being highly varied over short distances (10s-100s of meters) due to interaction of different parameters. One of the most well-known examples of a heterogeneous stress pattern is observed in the Australian continent, which displays a wide range of stress orientations from province to province that, unlike all other major plates, are not aligned with absolute plate motion.

The Australian Stress Map (ASM) project was started in 1996 to compile a public data set of maximum horizontal present-day tectonic stress information to determine and understand the state of stress in the Australian crust. The early phases of the ASM revealed that plate boundary forces provide the first-order control on the present-day stress pattern. However, all models of the stress field have failed to replicate the stress pattern in Eastern, and particularly north-eastern, Australia. The ASM project commenced again in 2012 with a primary aim of building up the database in Eastern Australia, such as new hydrocarbon provinces, and to help better establish the controls on the Australian stress field at scales ranging from tectonic plate down to individual fields and wells. To date, we have interpreted more than 400 borehole image logs in coal seam gas, mineral and conventional petroleum wells. The results show that local sources of stress (i.e. second and third orders) play a key role in the stress pattern of Australia which is an important issue for geothermal and unconventional exploration and production.

104. VARIATION OF NATURAL FRACTURE ORIENTATIONS IN THE CARNARVON BASIN'S RANKIN PLATFORM AND DAMPIER SUB-BASIN, NWS, WESTERN AUSTRALIA

Adam Bailey[1]*, *Rosalind King*[1], *Simon Holford*[1] *and Joshua Sage*[2]
[1]Australian School of Petroleum
[2]Beach Petroleum

Natural fractures in the Carnarvon Basin's Rankin Platform and Dampier Sub-Basin are identified using electrical resistivity image logs from 10 petroleum wells. In-situ stresses are diagnosed for the area using data from these and four additional wells, with these results indicating it likely that this study area hosts a relatively isotropic in-situ stress field.

Identified fractures occur at all orientations, and demonstrate no dominant trend. They do not reflect the in-situ stresses, nor the dominant north-northeast to northeast fault strikes. Rather, they most closely reflect the orientation of more local structures which the wells are adjacent to, demonstrating that natural fracture populations may be more dependent on local structure than dominant regional trends.

105. STUDY ON INTERNAL MULTIPLE ELIMINATION METHOD ON LAND SEISMIC DATA

Luqing Cao[1]* *and Tianyue Hu*[1]
[1]Peking University

Multiple is a tough issue in recent years, especially the internal multiples in deep earth. In this paper we proposed to construct virtual events to predict internal multiples. Then adopt the mean value multi-channel adaptive subtraction method for matching the multiple model and seismic data. However, the results depend on the parameters closely. We propose to apply the dynamic time wrapping method in order to accomplish the precise matching. And the regression of multiples can effectively improve the internal multiple elimination results when internal multiples are interfered with effective signal.

106. RELATIONSHIP BETWEEN RADIOGENIC HEAT GENERATION AND HIGH SUBSURFACE TEMPERATURES IN SEDIMENTARY BASINS IN WESTERN AUSTRALIA

Mike Middleton[1]
[1]WA Dept. Mines & Petroleum

Higher than normal subsurface temperatures are found in the Perth and Carnarvon basins in Western Australia. Both basins are known to be underlain by granitoid rocks which may possess higher than normal levels of the elements uranium and thorium, which in turn contribute to heat generation in those rocks. Airborne and ground radiometric data confirm the presence of radiogenic-granitoid rocks surrounding the Perth Basin, which are believed to be the cause of the observed elevated subsurface temperatures in that basin. Heat generation in these granitoid rocks typically ranges between 2 and 20 μWm^{-3}. New radiometric data for crystalline rocks, inferred to underlie the high subsurface-temperature regions of the Carnarvon basin, also indicate regions of anomalously high uranium and thorium. Brief reference to other high-radiogenic rocks in Western Australia and possible implications for heat flow is also made. One and two dimensional static heat-flow models, incorporating new upper-crustal radiogenic information, for the Perth and Carnarvon basins have been developed. The models are used to review the thermal history of these basins.

107. CENOZOIC SURFACE UPLIFT FROM SOUTH WESTERN AUSTRALIAN RIVERS

Nicholas Barnett-Moore[1]*, *Nicolas Flament*[1] *and Dietmar Muller*[1]
[1]Sydney University

Embedded within Earth's topography is a constantly evolving fluvial network sensitive to variations in horizontal and vertical motions, driving sediment transport from elevated sources to sedimentary basins. The notion that a river acts as a 'tape recorder' for positive vertical displacements suggests that changes in spatial and temporal characteristics of surface uplift can be deduced through the analysis of longitudinal river profiles. The relative tectonic quiescence of the Australian continent during the Cenozoic makes it an excellent natural laboratory to study recent large-scale variations in surface uplift, often linked with mantle convective processes. Here, we analyse X longitudinal river profiles from south Western Australia.

Major knickzones in the longitudinal profiles of rivers in southwest Australia suggest recent surface uplift. Given the lack of recent large-scale tectonic activity in that region, this uplift requires an explanation. Applying an inverse algorithm to river profiles of south Western Australia reveals that this surface uplift started in the Eocene and culminated in the mid-late Neogene. The surface uplift rates deduced from this river profile analysis generally agree with independent geological observations including preserved shallow-marine sediment outcrops across the Eucla Basin and south Western Australia. The timing of this event is also to be compared with offshore stratigraphic sections to link onshore surface uplift to offshore sedimentation. We show that the interplay between global sea level and long-wavelength dynamic topography associated with south Western Australia's plate motion path over the remnants of an ancient Pacific slab is a plausible mechanism driving this surface uplift.

108. GEOPHYSICAL AND GEOCHEMICAL CONSTRAINTS ON CRETACEOUS-CENOZOIC MAGMATISM ALONG THE SOUTHERN AUSTRALIAN MARGIN

Fun Meeuws[1], Simon Holford[1] and John Foden[1]*
[1]University of Adelaide

Increasing levels of exploration along rifted continental margins, such as the southern Australian margin, has led to growing recognition of the detrimental impacts of magmatic activity on hydrocarbon prospectivity. Key exploration risks include the impact of intrusions on seal integrity, reservoir quality, source rock maturation and migration pathways. However, the extent and distribution of volcanic rocks along continental margins, such as the Australian southern margin, and the processes by which magma is transported through sedimentary basins are still poorly understood despite the wealth of available seismic datasets. Although classified as a 'non-volcanic' rifted margin, our analysis shows that an extensive and largely undescribed record of Cretaceous-Cenozoic magmatic activity is preserved within the sedimentary successions of the rift basins located along the southern Australian margin. The combination of seismic reflection data and geochronological and geochemical data shows that this magmatic activity cannot be solely attributed to continental break-up and related decompressional melting processes or the presence of a hotspot or plume.

109. PROBABILISTIC ANALYSIS OF EM DATA SENSITIVITY AND INVERSION ACCURACY

Joel Skogman[1] and Erik Bjornemo[1]*
[1]PGS Technology

Towed streamer EM data offer a possibility to generate a resistivity model of the earth within the sensitivity range of the EM survey, using procedures such as inverse modelling. There is, however, an inherent non-uniqueness in the problem due to noise, uncertainties, finite number of measurement positions and field components. To assess the model uncertainty, and analyse the data information content, we propose the Bayesian method of calculating probabilities for model parameters within a given set of models. Real towed streamer EM noise applied to synthetic EM data in a 3D model, similar to Barents Sea conditions, was used for the evaluation.

The result of this work is a formulation of the posterior probability distribution for a set of sub surface resistivity model parameters. By analysing these probability functions we find that we are able to evaluate how a change in the data, e.g. different frequencies, sensor positions, noise levels or complexity of background, affect the probability of finding a model close to the true model.

110. SEISMIC WITHOUT SENSORS – DISTRIBUTED VIBRATION SENSING

Ben McCarthy[1], Timothy Dean[2], Arthur Hartog[2] and Bernard Frignet[2]*
[1]WesternGeco
[2]Schlumberger

Making seismic acquisition quicker and/or cheaper requires removing one or more of four major components: the source, the sensors, cables connecting the sensors, or the recording system. In this paper we describe how fibre-optic cables can be used as sensors in a distributed vibration sensing system.

111. OPERATIONS SUMMARY DURING RISERLESS DRILLING TO >7700 MBSL IN THE JAPAN TRENCH FOR IODP EXPEDITION 343 & 343T JFAST AND DISCUSSION OF THE RELATIONSHIP BETWEEN DRILLING PARAMETERS AND ROCK DAMAGE

Virginia Toy[1], Sean Toczko[2], Nobu Eguchi[2], Lena Maeda[2], Ikuo Sawada[2], Tonokazu Saruhashi[2] Fred Chester[3] and Jim Mori[4]*
[1]University of Otago
[2]CDEX, JAMSTEC, JAPAN
[3]Texas A&M University
[4]Kyoto University

During IODP Expedition 343: The Japan Trench Fast Drilling Project (JFAST), five boreholes were drilled from the D/V Chikyu in >6800 m water depth. Three of these crossed the main fault target. A logging-while-drilling (LWD) hole that penetrated to 850.5 meters below seafloor (mbsf) (total depth [TD] = 7740 meters below sea level [mbsl]) was documented using a suite of LWD tools. From an adjacent partially cored hole drilled to 844.5 mbsf (TD = 7734 mbsl) 21 cores were acquired that spanned the two main fault targets. During the follow-up expedition 343T a third borehole was drilled to 854.8 mbsf (TD = 7752.3 mbsl) and a simple temperature observatory was deployed in the wellhead. The drilling operation, which lasted 88 days, was very technically challenging. Notably, the drill string had to be withdrawn a number of times due to high seas, and technical issues.

In certain intervals, rather than core we recovered loose, subrounded fine gravel clasts of the two major lithologies penetrated to those depths (silt and mudstone). Particle shape and size of these clasts was analysed. Results demonstrate (1) particle shape variations apparent visually are not easily quantified, (2) there are distinct variations in particle size distributions. We discuss whether these relate to variations in drilling parameters.

PETROLEUM – QI/ROCK PHYSICS/SEISMIC GEOMORPHOLOGY/STRATIGRAPHY

112. SPECTRAL DECOMPOSITION INFLUENCE ON AVO EFFECT

Thierry Bertolino[1] *and Mauricio Herrera Volcan*[1]
[1]Schlumberger

Delineating the extend of a producing reservoir is one of the main challenge of exploration and development interpreters. Our approach to address this challenge is to use "spectral decomposition" of pre-stack data couple with an AVA/AVO studies (Amplitude Versus Angle/Offset).

Seismic spectral decomposition is a known method to determine more accurately the lithology of an area of interest. AVO effect are used to identify and quantify the extend of a fluid anomaly in a potential reservoir. Combine together, the aim of this method is to provide a better delineation of the producing area. A shared earth approach will be used in order to perform cross validation of the results at each step.

The first step is a 1D study well bore centred:

Using well logs information: Vp (compressional velocity), Vs (Shear velocity) and the density to compute a first set of synthetic gather that will constitute our reference. The chosen well has an AVO effect and should be visible on this reference set.

A real set of pre-stack gather at the well bore will then go through a series of tests to identify the best frequency bandwidth that identify more accurately the AVO effect.

In a second phase, this frequency bandwidth will be used to produce two results:

A 3d set of gather with this optimum bandwidth. Producing Gradient and the Intercept of this set, a cross plot of those attributes should confirm the result of the 1D study and will help to delineate the AVO effect spatial extent.

An inversion based on this spectral decomposition should help to delineate more accurately the reservoir lithology

Those results unified well bore information, seismic pre and post stack data, frequency analysis and inversion results. The analysis will tend to demonstrate that lithology and gas anomaly can be better mapped using combined methodology, compare to a juxtaposition of methods.

113. SEISMIC ATTRIBUTES SUCCEEDED IN DETECTING AND DETERMINING THE FEATURES OF INCISED VALLEY FILL SANDSTONE

Saad Almalki[1]* *and Matthew Totten*[2]
[1]King Abdulaziz City For Science And Technology
[2]Kansas State University

The main objective of this study is to focus on detecting incised valley fill sandstone in the upper Morrow formation and determining its width, thickness and edges by using appropriate seismic attributes. There are seismic attributes that can display the features of channels and incised valley in seismic horizon slice very clear.

In this study, Coherence, Discontinuity along dip, Relative Amplitude change with X and Y attributes were used to detect the incised valley fill sandstone. Spectral decomposition attribute was used to determine the thickness of the incised valley fill sandstone by using frequencies from 10 Hz to 70 Hz. Most positive and negative curvatures attribute were used to determine the valley's edge. Coherence and discontinuity along dip attributes succeeded to detect the valley and also succeeded to map its width in acceptable resolution. Discontinuity along dip shows its width clearer than coherency.

As for Spectral decomposition, it displayed subtle changes in the incised valley fill sandstone. As for most positive and negative curvatures, positive curvature may indicate highs in structure and less compaction over the incised valley-fill sandstone axis. On another hand, most negative curvature shows the edge of incised valley-fill sandstone and its centre may show shale deposition. As for relative amplitude change with X and Y, they succeeded to determine the direction and the width of incised valley-fill sandstone.

114. GEO-PRESSURE VARIATIONS IN THE CARNARVON AND BROWSE BASINS FROM BOTH SEISMIC AND WELL ANALYSIS

James Leven[1]*, *Ivar Meisingset*[1], *Julian Coker*[1] *and Finn Johansen*[1]
[1]First Geo

A careful analysis of the geopressure regime in one hundred wells on the North West Shelf (NWS) is integrated with an analysis of apparent overpressure derived from the regional hiQbe™ velocity model. The well analysis is a traditional pressure interpretation, considering all available data and all types of overpressure. The hiQbe™ analysis is based on velocity data, and can therefore detect compaction disequilibrium overpressure. The calibration and integration of these two forms of analysis give new insight into the regional distribution of potentially overpressured rocks in the NWS, and provides a good basis and guidance for well planning.

115. APPLICATION AND POTENTIAL ERRORS OF PALYNOLOGY AND VITRINITE REFLECTANCE AS TOOLS FOR OUTCROPS STRATIGRAPHY RESTORATION; A CASE STUDY OF EARLY CRETACEOUS STRZELECKI GROUP COASTAL OUTCROPS, WEST GIPPSLAND, VICTORIA, AUSTRALIA

Hamed Aghaei[1]*, *Mike Hall*[1] *and Barbara Wagstaff*[2]
[1]Monash University
[2]Melbourne University

Vitrinite reflectance and palynology are potential approaches for stratigraphy correlation and restoration mainly because they can provide maximum palaeo-temperature and relative age of the sediments respectively. Moreover, fluvial sediment stratigraphic restoration is complex due to several reasons such as unknown size of the sediments. This study presents application of these methods in restoration of non-marine Strzelecki Group, well-exposed along the coastline near the Wonthaggi Township, south Victoria, Australia, and shows how they can support each other's results and cover the potential errors. About 20 km of the coastal outcrops were mapped, logged, and sampled for palynology and VR. Stratigraphy was reconstructed based on maximum palaeo-temperature and an estimated palaeogeothermal gradient of 50oC/km. The restored stratigraphy column was then divided into several blocks based on palynology. The restored

stratigraphy reveals syn-depositional fault activity and provided new ideas on the amount of erosion and preserved section of this group in Wonthaggi area. However, several scenarios were discussed in terms of variation in final results versus using thermally altered VR samples, restoration solely based on VR and restoration using only palynology data. In conclusion, VR and palynology can be hired for fluvial sediment stratigraphic restoration, however, attention needs to be paid in absence of one of the methods.

116. IODP EXPEDITION 356: DRILLING TO REVEAL A 5 MILLION YEAR CARBONATE AND SUBSIDENCE HISTORY ON THE NORTHWEST SHELF OF AUSTRALIA

Stephen Gallagher[1]*, *Craig Fulthorpe*[2], *Kara Bogus*[3], *Andrew Heap*[4], *Neville Exon*[5] *and Malcolm Wallace*[1]
[1]The University of Melbourne
[2]University of Texas
[3]Texas A & M University
[4]Geoscience Australia
[5]Australian National University

The late Cenozoic carbonates of the Northwest Shelf are important subsidence history archives that also cause significant sonic velocity problems affecting seismic imaging of underlying strata. Despite their substantial thickness and areal extent, these carbonates have been sampled only in engineering foundation boreholes and as cuttings and rare sidewall cores in petroleum wells. In August-September 2015 the International Ocean Discovery Program (IODP) will drill a transect of shelf to shelf margin cores in this region. Six sites will be drilled over 10° latitude from the Perth Basin to the Bedout sub-basin by RV JOIDES Resolution with continuously cored penetrations of 300 m to 1.1 km. An array of shipboard and post-cruise biostratigraphic, sedimentological and geochemical analyses will be carried out on these cores to achieve three primary aims:

1. Provide empirical input into the spatiotemporal patterns of subsidence along Northwest Australia that can be used to place fundamental constraints on the interaction between Australian plate motion and mantle convection and to ground truth geodynamic models.
2. Determine the timing and variability of regional oceanographic features in order to understand the controls on Neogene carbonate stratigraphy and reef development.
3. Obtain a tropical to subtropical climate and ocean archive, directly comparable to deep-ocean oxygen isotope and ice-core archives, to chart the variability of the Australian monsoon and the onset of aridity in northwestern Australia.

Each site will be triple cored using a combination of Advanced Piston Coring (APC), Extended Core Barrel (XCB) and Rotary Core Barrel (RCB). An array of downhole measurements will be taken using three standard IODP tool string configurations: the triple combination (triple combo), Formation MicroScanner (FMS)-sonic, and Versatile Seismic Imager (VSI). These will be used to correlate the cores to regional multichannel seismic profiles in order to gain a better understanding of Northwest Shelf stratigraphy and neotectonics.

117. MONTE-CARLO SIMULATION OF STRESS-ASSOCIATED ULTRASONIC SCATTERING ATTENUATION

Wei Wei[1]*, *Li-Yun Fu*[1] *and Weijia Sun*[1]
[1]Chinese Academy of Sciences

Seismic coda waves scattered by small-scale hetero-geneities contain information on stress changes of the medium, as a result of changes in the physical state of materials. Based on the ultrasonic measurements under different stresses for a cylindrical sandstone sample, we investigate the influence of stress changes on ultrasonic S-coda attenuation and aim to characterize its stress-dependent pattern. Considering the complexity of ultrasonic coda waveforms measured from finite-size rock samples in laboratory experiments, the Monte-Carlo simulation is employed to synthesize ultrasonic envelopes, which by incorporating the effect of multiple scatterings and boundary reflections on coda waves. The optimal simulation parameters, estimated by minimizing the residual between the observed and synthesized envelopes, indicate that the rock sample under study presents moderate heterogeneities. The relationship between attenuation and stress is similar for direct and coda S waves and remains fairly stable in the range of high effective stresses around 30–60 MPa, with less stress sensitivity. Enhanced attenuation for both types of waves occurs at lower effective stresses, but with coda attenuation much faster and stronger, presenting a quite different nonlinear behaviour with respect to stress. Coda attenuation increases drastically at extremely low effective stresses below 15 MPa because of the increase in rock compliance, showing much greater sensitivity to high pore pressure than intrinsic attenuation. This study improves our understanding of the mechanism of ultrasonic coda attenuation and its scaling dependence on stress.

118. A LABORATORY STUDY OF THE 'BARREL SHAPE' EFFECT IN A VISCOELASTIC CYLINDRICAL SAMPLE AT SEISMIC FREQUENCIES

Vassily Mikhaltsevitch[1]*, *Maxim Lebedev*[1] *and Boris Gurevich*[1]
[1]Curtin University

The "barrel shape" effect caused by axial pressure applied to a cylindrical acrylic sample was studied using a low-frequency laboratory apparatus utilizing stress-strain relationship, which was developed to measure the complex Young's moduli of elastic materials at seismic frequencies, confining or axial pressures from 0 to 70 MPa, and strain amplitudes 10-8–10-7. To increase the effect, the experiments were performed at axial pressures only. The elastic and anelasic parameters of the 15 cm length sample were measured with strain gauges glued in the middle of the sample and at two centimetres from one of the ends at axial pressures of 7 MPa and 15 MPa. Our experiments show that all measured parameters are independent from the location of the strain gauges on the sample. These results confirm that the barrel shape of the sample caused by applied stress does not affect reliability of low-frequency laboratory measurements.

119. CHANGES IN ELASTIC PROPERTIES OF ARTIFICIAL SHALES DUE TO COMPACTION

Roman Beloborodov[1]*, *Marina Pervukhina*[1], *Lionel Esteban*[1] *and Maxim Lebedev*[1]
[1]CSIRO Energy

The effects of compaction on elastic properties of shales and their anisotropy are important for seismic imaging, seismic to well tie and borehole stability issues. Compaction trends in shales remain poorly studied, but it is well known that porosity of shales rapidly decreases with the increase of burial depth due to mechanical compaction and chemical transformation of clays in particular. These processes affect all the physical properties of shales including their elastic moduli, electrical conductivity and permeability.

In this experimental work we study changes in the anisotropic elastic properties of artificial shales caused by mechanical compaction. Investigation of anisotropy is performed on two specimens made of kaolinite and quartz powder mixtures: (1) 75% / 25 % and (2) 60% / 40%, respectively. An uniaxial stress is applied progressively to achieve distinct levels of porosity. Ultrasonic P- and S-wave velocities in the specimens are measured at every stage of the compaction. Thomsen's anisotropy parameters are calculated from these velocities. Qualitative characteristic of microfabric anisotropy is performed using micro-CT image analysis.

The results allow to conclude that at a given level of porosity of the specimen 2, with 40% of quartz, has higher compressional and shear velocities than the specimen 1 with only 25% of quartz. However, the specimen 1 shows higher degree of elastic anisotropy than the specimen 2 due to higher fraction of anisotropic clay.

PETROLEUM – UNCONVENTIONAL HYDROCARBONS/ PASSIVE SEISMIC

122. FEASIBILITY OF USING PASSIVE SEISMIC DIFFRACTIONS FOR IMAGING AND MONITORING

Andrej Bóna[1]*, *Roman Pevzner*[1], *Konstantin Tertyshnikov*[1] *and Mamdoh Alajmi*[1]
[1]Curtin University

We present a feasibility study of using passive seismic data for imaging of diffractors. Imaging and characterisation of seismic diffractors is important for many applications of seismic methods, including carbon geosequestration, since in sedimentary setting the diffractors are associated with terminations of layers at faults, as well as edges of the zones altered through the reservoir depletion or fluid (e.g. CO2) injection. One of the findings is that the diffracted waves from ambient sources can be sometimes incorrectly interpreted as active seismic sources that might lead to wrong conclusions about induced seismicity of processes generating the ambient noise, such as injection of fluids in the subsurface.

123. EXTENDED IMAGING CONDITIONS FOR PASSIVE SEISMIC DATA

Benjamin Witten[1]* *and Jeffrey Shragge*[1]
[1]University of Western Australia

Seismic monitoring at injection sites (e.g. CO_2 sequestration, hydraulic fracturing) has become an increasingly common tool amongst oil and gas producers. The information obtained from these data is often limited to seismic event properties (e.g. location, initiation time, moment tensor), the accuracy of which greatly depends on the assumed or estimated elastic velocity models. However, estimating accurate 3D velocity models from passive array data remains a challenging problem. Extended imaging conditions (eICs) for passive wave-equation imaging algorithms represent a key step towards generating – and verifying – elastic velocity models. By extending imaging conditions away from zero-lag in time and space we can better evaluate the focusing of a given event based on the principle that waves focus at zero lag only when the velocity models are "correct". We demonstrate that given an elastic medium and multi-component recordings, we can propagate and correlate microseismic P- and S-wavefield modes to compute eICs for P- and S- velocity perturbations. We observe that the maximum correlation deviates from the zero-lag in time and space for a P/S cross-correlation imaging condition when using an incorrect P- and/or S-wave velocity, and thus there is sensitivity to velocity error not observable when using individual wavefield components.

124. AN IMPROVED METHOD FOR LOCATION OF MICROSEISMIC EVENTS WITH LOW SIGNAL-TO-NOISE RATIOS

Yuyang Tan[1]*, *Chuan He*[1] *and Xiaochen Hou*[1]
[1]Peking University

An improved method is proposed in this paper for microseismic source location. The primary goal of this method is to improve the location accuracy for microseismic events with low signal-to-noise ratios (SNR). In contrast to the prevalent location approach, two innovations are implemented in the proposed method. First, instead of using the hodogram, the source azimuth is estimated from a probability distribution function, and second, a new objective function is employed in grid search algorithm to find the source position. The proposed method has been tested using synthetic data examples. The results show that, for these cases, the absolute errors of the estimated source azimuth and position are less than 1° and 3 m, respectively, which proves that an improvement in location accuracy can readily be achieved using the proposed method.

125. MICROSEISMIC LOCATION: USING BOTH P AND S WAVES WITH NEW METHODS

Tanghua Li[1]*, *Hanming Gu*[1] *and Hao Yan*[1]
[1]China University Of Geosciences(Wuhan)

In this paper we develop a new method on the basis of the two exist two methods, using both P and S waves recorded with surface array and borehole data. The new microseismic location method take the full advantage of Generalized Pattern Search Method and Simulated Annealing Method, improving the location accuracy. We use this method to do the cast study. Consequently, using both P and S waves information in the location technique reduces the position uncertainty as compared to single P or S wave relative location. And it will be more applicable to low signal-to-noise ratios data.

126. PASSIVE SEISMIC IMAGING WITHOUT VELOCITY MODEL PRIOR TO IMAGING

Mohammad Javad Khoshnavaz[1]*, *Andrej Bona*[1] *and Milovan Urosevic*[1]
[1]Curtin University

There are two types of passive seismic monitoring: down-hole and surface monitoring. In this paper, we introduce a new surface monitoring technique that does not require trigger time and any seismic velocity information prior to imaging. Therefore, this technique can be considered as a velocity independent monitoring technique. We have calculated the radius ot the curvature of the propagated wave-front from the passive source to the receivers deployed on the surface. The passive source coordinates are expressed in terms of the curvature. Computational experiments with synthetic data examples confirm the theoretical expectations and demonstrate the practical feasibility of the proposed technique.

127. MEASURING ELASTIC PROPERTIES TO DETERMINE THE INFLUENCE OF TOC ON SYNTHETIC SHALE SAMPLES

Yazeed Altowairqi[1]*, *Reza Rezaee*[1], *Brian Evans*[1] *and Milovan Urosevic*[1]
[1]Curtin University

This paper describes the factors that control elastic properties of organic shale, which is crucial for exploration and successful gas production from unconventional reservoirs. Mechanical and dynamic elastic properties are main shale characteristics that are not yet well understood as there have been a limited number of investigations involving organic rich shale samples. Synthetic shale core samples whose clay mineralogy, non-clay mineral content and Total Organic Carbon (TOC) content are known can be used to study variations of elastic parameters in a controlled experimental environment including in-situ stress conditions.

More than 20 synthetic shale samples were created for our investigations under reservoir stress conditions with different mineral composition and TOC percentage. Ultrasonic transducers were used to measure body wave velocities, which were then used to calculate the elastic properties of different shale samples. The results demonstrate that P- and S-wave velocities vary with changing TOC under isotropic stress conditions. It is shown that the velocities of P-and S-waves are inversely proportional to TOC content. In addition, the increase in the TOC produced a decrease in density from approximately 2.4 g/cc to 2.15 g/cc and increase in porosity from approximately 16% to 20%.

128. DETERMINATION OF TOTAL ORGANIC CARBON (TOC) IN TIGHT RESERVOIR USING EMPIRICAL MODE DECOMPOSITION-SUPPORT VECTOR REGRESSION (EMD-SVR): A CASE STUDY FROM XX-1 BASIN, WESTERN CHINA

Xinmin Ge[1]*, *Yang Wang*[1], *Yiren Fan China*[2], *Zhuoying Fan*[1] *and Shaogui Deng*[1]
[1]China University of Petroleum
[2]University of Houston

In the process of formation evaluation for tight reservoirs, extracting quantitative information of kerogen is a potentially important factor. Moreover, Total Organic Carbon (TOC) is not strongly correlated with geophysical well logging data. In this paper, a combinatory algorithm for nonlinear regression based on Empirical Mode Decomposition (EMD) and Support Vector Regression (SVR) is proposed. On the basis of depth matching, sensitive well logging parameters are preferred by core calibration. That, which means should be used to denoise, is a key issue for acquiring precise and high quality data. Then, intrinsic mode functions (IMF) decomposed by EMD algorithm is established and applied for denosing. Further, denoised data is classified into two categories, one for training and the other for validating. Aiming for TOC predicting model, SVR is implemented both for training and predicting, and simultaneously some conventional methods such as ΔlogR, back propagation artificial neural networks (BP-ANN), and multiple linear regressions are also exerted for comparisons. The result shows that EMD-SVR is the best solution for TOC predicting, with the highest correlation coefficient and the smallest mean squared errors. Likewise, this algorithm is applicable for other reservoirs like shale gas.

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SECTION 5
BIOGRAPHIES

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Pouya Ahmadi's background is mainly in physics based at Uppsala university, Sweden, While I was doing my Master in Geophysics under supervision of one of the best teachers and I should say friends 'Alireza Malehmir'. Now I am a PhD student in Curtin University hoping for a bright future.
pouya.ahmadi@postgrad.curtin.edu.au

Sasha Aivazpourporgou is from Iran and has done her undergraduate and Master degrees in Physics and Geophysics back home. She moved to Australia in 2009 to do a PhD in magnetotelluric at Monash University and managed to finish it in November 2013. She is now working as a research assistant at Monash University and enjoys doing Yoga and cooking good food when she is out of her office and not in front of her laptops.
s_aivazpour@yahoo.com

Michael Alexander received the professional degree of Gp.E from Colorado School of Mines in 1952. Immediately following graduation he joined Humble Oil (now ExxonMobil) as a geophysicist and began his career on a seismic land crew in North Texas. He subsequently worked as an assistant operator (instrument technician) on a Louisiana marsh crew, then as operator on an offshore seismic crew. That was followed by assignments in seismic interpretation and seismic data processing. He was a member of ExxonMobil's first digital seismic processing team. He was selected to help form a new Gravity/Magnetics Section for ExxonMobil and was involved with numerous interpretation projects both domestic and overseas. He retired as Section Supervisor in 1991 with 38 years of service. In 1995 Michael began a second career as a consulting geophysicist for Integrated Geophysics Corporation, specializing in integrated interpretations of magnetic, gravity, *seismic, and geologic data.*
michael.alexander@igcworld.com

Alan Aitken
alan.aitken@uwa.edu.au

Mohammed Alkaff received his BSc in geophysics from the University of Calgary, Canada in 2007. He then, joined Saudi ARAMCO where he worked with the Reservoir Characterization department. He is currently working on his MPhil degree at Curtin University, WA, Australia.
alkaff_m@yahoo.com

Tariq Alkhalifah is a professor of geophysics in the division of Physical Sciences and Engineering at King Abdullah University for Science and Technology (KAUST). He assumed his duties there in June 2009. Prior to joining KAUST, Tariq was a research professor and director of the Oil and Gas Research Institute at King Abdulaziz City for Science & Technology (KACST). He has also been associate research professor, assistant research professor and research assistant at KACST. From 1996 to 1998, Tariq served as a postdoctoral researcher for the Stanford Exploration Project at Stanford University, USA. He received the J. Clarence Karcher Award from the Society of Exploration Geophysicists (SEG) in 1998 and the Conrad Schlumberger Award from the European Association for Geoscientists and Engineers (EAGE) in 2003. He is a member of SEG and EAGE. Tariq received his doctoral degree in geophysics (1997) and master's degree (1993) in geophysical engineering from the Colorado School of Mines, USA. He holds a bachelor's degree (1988) in geophysics from King Fahd University of Petroleum and Minerals, Saudi Arabia.
tariq.alkhalifah@kaust.edu.sa

Kristoffer Andersen received his PhD in physics in 2013 and has been employed as a post doctoral researcher in the Hydrogeophysics group at Aarhus University since then. His current research includes AEM data processing and AEM 3D forward modeling.
kka@geo.au.dk

David Annetts is a geophysicist who specialises in the analysis and interpretation of electromagnetic prospecting data. He has alternated between industry and academia since the early 1990's and has degrees from The University of Sydney and Macquarie University. In his current role with CSIRO, he studies the application of electromagnetic prospecting methods to conventional and non-conventional targets and is interested in applications of Bayesian philosophies to geophysical interpretation. He is a member of the ASEG, EAGE and the SEG.
david.annetts@csiro.au

Andrew Aouad graduated from The University of Sydney with a Bachelor of Science, Honours in Geophysics and Geology in 2004. He worked in mineral exploration in Australia before moving into land seismic acquisition with Veritas DGC (subsequently CGG) in the Middle East and West Africa. He returned to Australia to complete a Masters of Science at the Australian National University, before starting with Origin Energy in 2009 as a geophysicist in Origin's seismic operations group. Andrew currently works as geophysicist on Origin's Coal Seam Gas assets, undertaking processing, QI and interpretation.
andrew.aouad@originenergy.com.au

Syed Iftikhar Arsalan is Senior Development Geophysicist with INPEX. His core area of work and research interest is in the area of Inversion studies to facilitate reservoir characterization and predict reservoir behaviour. He has over 10 years of experience in performing reservoir studies in various offshore basins of India and Australia. At INPEX he is working for ICHTHYS field development. Arsalan holds a M.Sc.Tech degree in Applied Geophyscis from Indian School of Mines, Dhanbad, India.
arsalan.syed@inpex.com.au

Esben Auken is professor in hydro geophysics. The research fields of his group includes airborne electromagnetic, MRS and ERT/IP. The research group develop numerical algorithms for data processing and inversion, instruments and user friendly GUI software. Projects are worldwide.
esben.auken@geo.au.dk

Per Avseth is a geophysical advisor at Tullow Oil in Oslo, Norway, and adjunct professor in geophysics at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. Per received his M.Sc. in Applied Petroleum Geosciences from NTNU in 1994, and his Ph.D. in Geophysics from Stanford University, California, in 2000. Per worked as a research geophysicist at Norsk Hydro in Bergen, 2001-2006, and a consultant at Rock Physics Technology (2006-2008) and Odin Petroleum (2008-2012) in Bergen, Norway. Per's research interests include applied rock physics and AVO analysis for quantitative seismic exploration and reservoir characterization.
pavseth@yahoo.com

Yahya Basman joined Santos in April 2013 as Senior Geophysicist in SW Queensland Upstream Gas Development. Born and raised in Manila, completed Bachelor of Science degree in Geology in University of the Philippines. MSc degree in Petroleum Geoscience.
yahya_basman@yahoo.com

Graham Begg has 29 years experience in the mining and minerals exploration sector, plus a PhD from Monash University in tectonics and ore deposit geology. Since 2002 he has also spearheaded research with the GEMOC group at Macquarie University, Sydney, aimed at creating the first detailed understanding of the architecture and history of the full continental lithosphere (crust and mantle) globally. This new knowledge seeks to revolutionise our understanding of continental evolution, geodynamic processes, and the controls on ore-forming systems, and thereby facilitate a breakthrough in greenfields mineral discovery. He has commercialised this Intellectual Property through his consulting company Minerals Targeting International Pty Ltd.
graham@mineralstargeting.com

Peter Betts is an academic at Monash University and is an Associate Professor in structural geology in the School of Earth, Atmosphere, and Environment and Associate Dean Research Training in the faculty of science. Pete is also a Director of a consulting company, PGN Geosciences, that specializes is structural geology, geophysical modelling and interpretation, and 3D modelling. Pete has been a geologist/geophysicist for more than 20 years and has a diversity of research and industry experience. He research interests include geophysical analysis of Proterozoic basin systems, Proterozoic tectonics and plate reconstruction, and geodynamic modelling and geophysical interpretation of modern tectonic settings. He is currently undertaking research in the Red Sea, geodynamical modelling of accretion at convergent plate margins and constructing a 3D model of the Australian continent. Pete's industry engagement has seen him undertake work in Australia, South America, North America, West Africa and northern Europe, targeting a variety of commodities including Au, Cu, Pb, Zn, U, and Ni.
Peter.Betts@monash.edu

Sergey Birdus works as a Depth Processing Supervisor with CGG in Perth. After receiving PhD in Geophysics in Kiev University in 1986 he worked as a lecturer for Kiev State University, a researcher in R&D departments in major Russian service geophysical companies and in several positions with Paradigm Geophysical in Moscow and Perth before joining Veritas in 2006. Sergey is involved in challenging depth processing projects from Australia and AP region.
sergey.birdus@cgg.com

Andrej Bóna received his MSc in theoretical physics from Czech Technical University in Prague in 1997, and PhD in applied mathematics from University of Calgary in 2002. From 2002 to 2003 he was a post-doctoral fellow at Memorial University in Canada, where he subsequently worked as assistant professor till 2007. He is currently associate professor at Department of Exploration Geophysics, Curtin University. His research interests include seismic anisotropy and imaging. He is a member of SEG, EAGE and ASEG.
a.bona@curtin.edu.au

Irina Borissova is a senior geoscientist working in Geoscience Australia Resources Division since 1993. In the past 20 years she contributed to a number of projects, particularly to geological studies of frontier areas. Irina has been working on petroleum prospectivity assessments of the Southwest margin sedimentary basins since 2004. In 2011-2013 she led CO2 storage prospectivity assessment of the Vlaming Sub-basin and her presentation is based on the results of this study. Currently she is leading a project on regional structure and petroleum prospectivity of the northern Houtman Sub-Basin, which involves acquisition and interpretation of the new 2D seismic data.
irina.borissova@ga.gov.au

Carlos Cevallos is a senior interpretation geophysicist at CGG Airborne in Perth Australia. His previous work was at the Geological Survey of NSW, Noranda and The University of Queensland. He is a physicist whose current interests are to integrate geological and geophysical data and to find new ways to interpret potential field data. He holds a B.Sc. degree from UNAM, Mexico, a M.Sc. degree from CICESE, Mexico, and a Ph.D. degree from Macquarie University, Australia.
cevallos54@hotmail.com

Peter Chia is a principal geophysicist with Shell Australia. Graduated with a BSc in Geophysics from the University of Manitoba, Canada he starts his career with Shell in 1984 and has since worked in seismic operations, processing and QI with Shell and briefly with CGG. He is a member of EAGE and ASEG.
peter.chia@shell.com

Pedro Chira Oliva received his diploma in Geological Engineering (UNI-Peru/1996). He received his MSc., in 1997 and PhD., in 2003, both in Geophysics, from Federal University of Par (UFPA/Brazil). He took part of the scientific research project '3D Zero-Offset Common-Reflection-Surface (CRS) stacking' (2000-2002) sponsored by Oil Company ENI (AGIP Division - Italy) and the University of Karlsruhe (Germany). Currently he is full Professor at the Institute of Coastal Studies (IECOS) of UFPA. His research interests include seismic stacking and seismic modeling. He is member of GOCAD consortium (France) and SBGf.
chira@ufpa.br

Anders Vest Christiansen has been working with inversion and modelling of airborne EM data for many years. Over the last years the focus has moved towards integration with e.g. geological and hydrological data to produce more accurate and usable end-user products. He is an Associate Pprofessor at the Hydrogeophysics Group at Aarhus University, Denmark.
anders.vest@geo.au.dk

Roger Clifton
joan.barton@nt.gov.au

David Close is a geoscientist with a background in reservoir modelling and quantitative geophysics with a focus on unconventional resource evaluation. He has previously worked in Mexico, U.S.A and Canada in addition to his current role with Origin in Brisbane, Australia. David is an active member of a number of professional organizations, including PESA, ASEG, SEG, CSEG and AAPG. David is currently the Exploration Manager for Onshore Australia and Unconventionals for Origin Energy.
david.close@originenergy.com.au

Dennis Cooke's long-term research interest is seismic reservoir characterization: specifically, the use of linear and non-linear inversion techniques to extract information about fluids and lithologies from seismic data. Over that past few years, he has also been looking at unconventional reservoirs and how stress and natural fractures interact with hydraulic fracture stimulation treatments. Dennis is currently dividing his time between two endeavors: 'GeoFrac', an industry-sponsored research consortium at the University of Adelaide's Australian School of Petroleum and his own geophysical technology business.

Dennis' past positions include Chief Geophysicist at Santos and interpreter and QI technical support at Arco International. Dennis has held positions as Vice President of the SEG and President of the ASEG. His professional society focus is on providing technical education to 'early career' geoscientists. He received his Ph.D. in geophysics from the Colorado School of Mines and an undergraduate degree in geology from the University of Colorado.
dennis.a.cooke@gmail.com

Millicent Crowe completed BSci (Hons) in geology and geophysics at the University of Adelaide looking at AEM and MT as a combined exploration method. In 2013 she joined Geoscience Australia as a Graduate and in 2014 was united with the Geophysical Acquisition and Processing Section.
millicent.crowe@ga.gov.au

Jane Cunneen received her BSc (Hons) degree in geology in 1997 and her PhD in structural geology in 2005, both from the University of Western Australia. She is currently working as a Research Fellow in petroleum geology at Curtin University, Western Australia. She has worked in both the petroleum and minerals exploration industries, including in onshore and offshore basins in Australia, and also spent seven years with UNESCO developing the tsunami warning system for the Indian Ocean. Member: PESA, and PESA WA Treasurer (2014-15).
Jane.Cunneen@curtin.edu.au

Aaron Davis is a geophysical researcher at the Kensington offices of the CSIRO in the Australian Resources Research Centre. He is interested in the applications of electromagnetic methods for groundwater exploration, detection and aquifer characterisation.
aaron.davis@csiro.au

Simone De Morton is conducting PhD research at the University of Melbourne on tectonisms and sedimentology in the Carboniferous Dublin Basin and the way in which this influences development of Irish-type Zn-Pb mineral deposits.
s.demorton@student.unimelb.edu.au

Jeferson De Souza has a BA in Physics (Education) from Universidade Federal do Paraná (1999), a M.Sc. in Geophysics from Observatorio Nacional (2002) and a Ph.D. in Physics from Centro Brasileiro de Pesquisas Fasicas (2007). Visiting Research Fellow - CET-UWA (2014).
jdesouza@ufpr.br

James Deeks is a geophysics PhD student at The University of Western Australia with a background in physics. He has conducted research in several areas of complex seismic wave propagation using finite difference modelling.
james.deeks@research.uwa.edu.au

Guy Duncan is a Geophysical Advisor with BHP Billiton Petroleum. He obtained his PhD in geophysics from Melbourne University. Early in his career he worked as a scientist at BHP's research laboratories in Newcastle, Australia. There he was involved in the development of seismic methods for resource exploration and production in the mining industry, such as cross-hole seismic tomography and in-seam seismic methods. Since 1995, he has been with BHP Billiton's petroleum division, working in various technical roles in a number of geographical locations. The main emphasis of his work has been in seismic imaging, quantitative interpretation, 4D seismic and development geophysics. Guy is a member of the ASEG, SEG and PESA.
guy.duncan@bhpbilliton.com

Peter Duncan is Founder, President and CEO of MicroSeismic, Inc. a Houston-based oil field service company specializing in hydraulic fracture stimulation surveillance and evaluation. He holds a Ph.D. in Geophysics from the University of Toronto. His early career as an exploration geophysicist was with Shell Canada and then Digicon Geophysical, first in Calgary then in Houston. In 1992 he was one of 3 founders of 3DX Technologies Inc., a publicly traded independent oil and gas exploration company. Duncan was 2003-04 President of the Society of Exploration Geophysicists (SEG). Duncan was the Fall 2008 SEG/AAPG Distinguished Lecturer speaking on the subject of Passive Seismic at 45 venues around the world. He is an Honorary Member of SEG, the Canadian Society of Exploration Geophysicists (CSEG), the Geophysical Society of Houston (GSH) and the European Association of Geoscientists and Engineers (EAGE). He received the Enterprise Champion Award from the Houston Business Journal in 2010, the World Oil Innovative Thinker Award in 2011, and the EY Energy, Cleantech and Natural Resources National Entrepreneur of the Year Award for 2013.
pduncan@microseismic.com

Chris Elders is Chevron Professor of Petroleum Geology at Curtin University. Prior to that he spent 20 years at Royal Holloway, University of London where he ran the highly successful MSc in Petroleum Geoscience, as well as working with the Fault Dynamics Research Group.
chris.elders@curtin.edu.au

Robert Ellis joined Geosoft Inc. in 2009 and is currently Principal Scientist, Earth Modelling, helping to lead the development of geophysical modelling and inversion capabilities in support of resource exploration. Prior to joining Geosoft Inc., he was a Principal Geophysicist/Global Practice Leader for BHP Billiton for 13 years where he worked on the development and deployment of practical modelling and inversion applications to support BHP Billiton's global exploration activities. Dr. Ellis also spent over a decade in academic research on inversion methods.
robert.ellis@geosoft.com

Mohammad Emami Niri is currently pursuing a PhD degree in petroleum geophysics at centre for Petroleum Geoscience and CO2 Sequestration (CPGCO2), University of Western Australia.
emamim01@student.uwa.edu.au

Lionel Esteban is a petrophysicist at CSIRO with experience in conventional-unconventional petroleum reservoirs, working on experimental paleomagnetism-environment magnetism, flow properties, thermal, electrical, and electro-magnetic properties, all integrated/calibrated against logging analysis/interpretations. His current research focuses on low permeability reservoirs (shales/gas shales, sediments and tight gas) to understand clay mineral relationships with mechanical and petrophysical parameters controlling the flow properties and sealing capacity. He also works on geothermal reservoirs, carbonates and iron ore deposits to characterise fluid-rock interactions. Lionel is also involved in several IODP/ODP expeditions targeting gas hydrates and active tectonics environments combining experimental and logging dataset.
lionel.esteban@csiro.au

Neville Exon has had a varied and rewarding career in geoscience since 1963, most of it at the Australian Geological Survey (now Geoscience Australia), and has nearly 200 geoscience publications to his credit. Since 1969, he has

participated in nearly 50 marine geoscience surveys on Australian and foreign vessels. He wrote successful proposals for two Ocean Drilling expeditions in the Australian region, both of which he joined, one as co-chief scientist. He is now the Program Scientist responsible for the scientific administration of the Australian and New Zealand IODP Consortium (ANZIC) at the Australian National University.
Neville.Exon@anu.edu.au

Ian Ferguson received his Ph.D. in geophysics in 1988 from the Australian National University. He has been a professor in the Department of Geological Sciences at the University of Manitoba since 1990.
ij_ferguson@umanitoba.ca

Andrew Fitzpatrick received a BSc(Hons) in geophysics from Curtin University and a PhD in geophysics from the University of Tasmania. He's worked previously at Geoscience Australia and CSIRO, prior to joining Cameco Australia. He's currently Chief Geophysicist at Cameco Corporation working across Australia and Canadian projects. His research interests are predominantly in applied electrical and electromagnetic methods for mineral exploration and groundwater applications.
andrew_fitzpatrick@cameco.com

Clive Foss is leader of the CSIRO Magnetics and Gravity Team based at North Ryde, Sydney.
clive.foss@csiro.au

Li-Yun Fu is a professor of Institute of Geology and Geophysics, Chinese Academy of Sciences.
lfu@mail.iggcas.ac.cn

Peter Fullagar holds a Ph.D. in geophysics from the University of British Columbia. He has over 30 years experience in exploration and mining geophysics. He worked for WMC Exploration Division, Ecole Polytechnique de Montreal, CSIRO Exploration & Mining, and Rio Tinto Exploration, before establishing Fullagar Geophysics Pty Ltd in Brisbane in 1998. During the past 16 years he has consulted privately to exploration and mining companies, and has developed geophysical modelling & inversion software. Peter is a member of ASEG and SEG, and is an Adjunct Professor at University of Queensland. He is currently based in Vancouver.
peter@fullagargeophysics.com

Konstantin Galybin has earned a PhD in Mathematical Geophysics from the University of Western Australia in 2006. Subsequently he joined Schlumberger Australia in a special postgraduate program with focus on wireline operations and petrotechinical expertise. He was a field engineer and participated in numerous wireline logging jobs in the Perth Basin. Since 2007 he focused on borehole seismic technology within the Petrotechnical Services segment of Schlumberger . He had become the borehole seismic team leader in 2013 and his main focii are: VSP survey design and processing, interbed multiple analysis, VSP inversion and anisotropy.
kgalybin@slb.com

Lisa Gavin is an intern at Chevron ETC and a geophysics Ph.D. Candidate at The University of Western Australia. She graduated with first class honours in geophysics from Curtin University in 2010. She is a member of ASEG, SEG and EAGE.
lisa.gavin@research.uwa.edu.au

Dan Gillam has a B.Sc. (hons) from Queensland University of Technology and a Ph.D. from University of Adelaide. Dan joined Chevron in Perth in 2010 working on the Gorgon CO2 Injection Project and in the Appraisal and NOJV Team. Prior to joining Chevron Dan worked at Woodside on a variety of offshore and onshore projects. He has recently moved from Chevron to InterOil in Singapore.
gillamdan@gmail.com

Michael Glinsky received a B.S. degree in physics from Case Western Reserve University in 1983 and a Ph.D. degree in physics from the University of California, San Diego in 1991. His doctoral research on magnetized pure electron plasmas was recognized by the American Physical Society as the outstanding thesis in the United States (1993 Simon Ramo Award). Before enrolling in graduate school as a National Science Foundation Graduate Fellow, he worked as a geophysicist for Shell Oil Company. After graduate school, he worked as a Department of Energy Distinguished Postdoctoral Research Fellow at Lawrence Livermore National Laboratory for 5 years. He then worked for three years at the Shell E&P Technology Co. doing research on Bayesian AVO and 4D inversion. After being the Section Leader of Quantitative Interpretation for BHP Billiton Petroleum, he moved into the BHP Billiton corporate center where he was Manager, Resource R&D. He worked for CSIRO for two years as their CEO Science Leader and was an Adjunct Professor of Physics at University of Western Australia. Currently he is a Senior Technology Manager, Integrated Interpretation Group, for Halliburton following being a Research Director for ION Geophysical where he focused on quantitative interpretation for unconventionals. He has published over 28 papers in the refereed scientific literature on subjects as varied as plasma physics, signal processing for oil exploration, x-ray diagnostics, application of exterior calculus to theoretical mechanics, and laser biological tissue interactions. He received the 2004 CSIRO Medal for Research Achievement for his research on petroleum reservoir characterization.
glinsky@qitech.biz

Robert Grasty Gamma-Bob Inc., formed by Dr. Bob Grasty, is a consulting company specializing in airborne and ground gamma ray spectrometer surveying. Bob was previously head of the airborne gamma ray survey section of the Geological Survey of Canada. Bob's main contribution to ground and airborne gamma ray surveying has been the development of techniques for mapping both natural and man-made radioactivity. Bob has worked extensively with industry and government organizations both in Canada and around the world and regularly serves as a consultant to the International Atomic Energy Agency.
grasty@rogers.com

Andrew Greenwood is currently a research Fellow at Curtin University. After completing his MSc in Geophysics at the University of Auckland in 2001 he worked in New Zealand and Australia for geophysical consultants in the coal and metaliferous mining industries. More recently he has worked for Curtin University, Centre for High Definition Geophysics in hard rock seismic applications before embarking on a PhD which he completed in 2013. His PhD work investigated Vertical Seismic Profiling in hard rock environments with alternative technologies. Professional interests are in seismic and borehole techniques.
a.greenwood@curtin.edu.au

Mark Grujic Since completing his Bachelor of Science with Honours in Geophysics at Monash University, Mark has worked as a geophysicist at Rio Tinto. He was initially based in Perth, working closely with the team developing the VK1 airborne

gravity gradiometer. Mark is now based in Santiago, Chile, where he is searching the Chilean copper belts for the next big deposit.
mark.grujic@riotinto.com

Elliot Grunewald is Chief Geophysicist at Vista Clara, Inc. and a specialist in NMR technology for groundwater applications. He received his Ph.D. in Geophysics from Stanford University in 2010.
elliot@vista-clara.com

Boris Gurevich Received his MSc in exploration geophysics from Moscow University in 1981, and Ph.D. in 1988. From 2001 was appointed Professor at Curtin University (co-sponsored by and CSIRO) in Perth, Australia, where he currently serves as the Head of Department of Exploration Geophysics and Director of the Curtin Reservoir Geophysics Consortium (CRGC), and leads the Geophysical Monitoring Project within the CO2CRC. His research interests include rock physics, seismic wave propagation, and seismic imaging.
B.Gurevich@curtin.edu.au

Ron Hackney is a Senior Geoscientist within the Energy Systems Group at Geoscience Australia. Prior to joining Geoscience Australia in 2008, Ron was Junior Professor for Solid Earth Geophysics at the University of Kiel (Germany). He undertook a postdoc at the Free University of Berlin and completed his PhD at the University of Western Australia in 2001. Ron also holds an MSc in Geophysics from Victoria University of Wellington and a BSc(Hons) from the Australian National University.
ron.hackney@ga.gov.au

Edward Hager is with Polarcus as Area Geophysicist, Asia Pacific region. He has over 20 years in the seismic industry with experience in acquisition, processing, imaging and survey design.
ed.hager@polarcus.com

Scott Halley has consulted to more than 100 mining and exploration companies in more than 25 countries in the last six years. Having worked as an exploration geologist for 20 years prior to specialising as a geochemist means that Scott understands how geochemistry can be practically and effectively applied to exploration and mining problems. Advances in technology mean that there are significant changes in the quality of commercially available geochemical and mineralogical analysis methods every few years. One of Scott's aims is to ensure that his clients are using the most appropriate methods and deriving the full benefit from their data. As well as consulting, Scott is a regular presenter in the CODES MSc (Econ Geol) short course series, and a regular invited speaker at international geology conferences. Scott is the recipient of the Gibb Maitland Medal for 2012. The Gibb Maitland Medal is awarded by the Geological Society of Australia - Western Australia Division for substantial contributions to Western Australian geology, in particular for contributions in the field of mineral resources exploration. Scott Halley received a BSc (Hons Class I) from the University of Tasmania (1982), and a PhD from Australian National University (1987). He worked as an exploration geologist for a number of Australian and international companies until 2006. Since then, he has run his own consulting business, specialising in exploration geochemistry, particularly in the use of multi-element ICP geochemistry and SWIR analysis to map far-field expressions and alteration mineral zonation patterns around hydrothermal systems.
minmap@westnet.com.au

Joseph Hamad is a PhD candidate at RMIT University. From 2010 to date Joseph has worked as a crew leader and a processing geophysicist at Vortex Geophysics mainly contracting to BHP Billiton West Musgraves and Nickel West operations. His research interest and aims are to improve borehole electromagnetic methods, which mainly focuses on improvements to geophysical sensors and compact transmitters.
yjhamad@gmail.com

Suvi Heinonen PhD (b. 1982) has been working in Geological Survey of Finland since February 2014. She has formerly been working in the Institute of Seismology of University of Helsinki and in Pryry Finland Oy. Her PhD research (2013) in University of Helsinki concerned the use of seismic reflection profiling for deep mineral exploration in crystalline bedrock.
suvi.heinonen@gtk.fi

Graham Heinson is a professor of Geophysics, a position he has held since 2010. Our group work on EM and Electrical Methods for resource exploration. We were Eureka Prize Finalists for towed EM for salinity mapping in 2005. Last year we were winners of The Australian Innovation Prize for Minerals and Energy, for our new approach to monitoring of geothermal fracking. We have a large group of 5 post docs, two technical staff, ten PhD student and numerous honours. We are mainly working on groundwater mapping and monitoring asscoiated with resource development, and regional-scale mineral exploration.
Graham.Heinson@adelaide.edu.au

Lachlan Hennessy is PhD candidate at RMIT University studying under the supervision of Professor James Macnae. He is currently carrying out research concerning the use of lightning source information in processing and interpretation of natural fields electromagnetic data. From 2010 to 2014 he worked at Newexco Services as a project geophysicist, consulting to junior and mid-tier base metals explorers.
s3138162@student.rmit.edu.au

Mauricio Herrera Volccan G&G business owner and senior Geophysicist, specialized in SI, QI and in the integration of multi domains in our exploration platfrom. Involved in many evaluation, with only successes.
MVolcan@slb.com

Felix Herrmann received his Ph.D. degree in Engineering Physics from the Delft University of Technology (the Netherlands) in 1997. Felix was a visiting scholar at Stanford's Mathematics Department in 1998, a post-doctoral fellow at MIT's Earth Resources Laboratory from 1999 to 2002, and a senior Fellow at the UCLA's Institute for Pure and Applies Mathematics in 2004. Felix is currently professor at the Department of Earth, Ocean, and Atmospheric Sciences of the University of British Columbia. Felix is director of the UBC-Seismic Laboratory for Imaging and Modeling (SLIM), which he founded in 2003. His research interests include theoretical and applied aspects of exploration seismology, compressive sensing, and large-scale optimization. Felix is the principal investigator of the industry- and NSERC-supported research programs SINBAD and DNOISE. Felix serves as a deputy editor of Geophysical Prospecting and on advisory boards of the UBC-Pacific institute for the Mathematical Sciences, the UBC-Institute for Applied Mathematics, and on the Academic Advisory Committee of the Harbin Institute of Technology (China). Felix is a member of the European Association of Geoscientists & Engineers (EAGE); the Canadian Society of Exploration Geophysicists (CSEG); the

Society of Exploration Geophysicists (SEG); the Society of Industrial and Applied Mathematics (SIAM), and the American Geophysical Union (AGU).
fherrmann@eos.ubc.ca

Richard Hillis is CEO of the Deep Exploration Technologies CRC which is developing transformational technologies for mineral exploration. He graduated BSc (Hons) from Imperial College (London) and PhD from the University of Edinburgh. Richard was previously Mawson Professor of Geology and Head of the Australian School of Petroleum (University of Adelaide). He has published ~200 papers in petroleum geomechanics and basin tectonics. Richard and colleagues recently sold technology spin-off company JRS Petroleum to Ikon Science and he has interests in geothermal energy, being previously a director of ASX-listed Petratherm. Richard is a director of AuScope, an NCRIS company, and is a Fellow of ATSE.
RichardHillis@detcrc.com.au

Fiona Hook has a 25 year career in Australian Indigenous archaeology working across the continent. She is the managing director and executive archaeologist for the cultural heritage management firm Archae-aus, based in Fremantle, Western Australia. Fiona is currently the National President of the Australian Archaeological Association and National Vice-President of the Australian Association of Consulting Archaeologists. She is an Adjunct Lecturer in Archaeology at the University of Western Australia, a Research Associate on the Australian Research Council (ARC) Discovery grant 'The Barrow Island Archaeology Project: the dynamism of maritime societies in northern Australia' awarded to the University of Western Australia and is an ARC Linkage Partner on the 'Dating the Aboriginal rock art of the Kimberley region, Western Australia - landscape geochemistry, surface processes and complementary dating techniques' awarded to the University of Melbourne. Fiona's research interests include: Indigenous hunter-gatherer landscape use; hunter-gatherer petroglyph analysis; economics of marine shell collection; and cultural heritage management practice and theory.
fiona@archae-aus.com.au

Matthew Hope after starting my career with Fugro Airborne Surveys in 2003 I moved over to the mining company world looking for nickel in Australia with BHP Billiton. After this I got the gold bug and joined Barrick Gold searching for gold of various styles in Australia, Africa and the Tethyan belt. Most recently I have joined First Quantum to get exposure to the workd of copper moving with my family to be based in Santiago, Chile and exploring for porphyry sysetms across South America. I am currenyl completting my Masters in Ore Deposit Geology at the University if WA.
matthew.hope@fqml.com

Karl Hosgood graduated the post graduate Honours program in Petroleum Exploration Geophysics at Curtin University of Technology. He spent five years as a data processor, mostly onboard seismic acquisition vessels for WesternGeco. He joined Paradigm in 2004 where he has been working with Processing and Imaging software solutions and in developing Seismic Interpretation workflows. Karl has worked with the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) using Paradigm processing and imaging software to build velocity models and image deep crustal features in the Nankai Trough subduction zone. Currently Karl is promoting Paradigm's Earth Study 360 technology as an advanced local angle domain imaging solution.
Karl.Hosgood@PDGM.com

Thomas Hoskin is currently completing his final year (hopefully) of his PhD at the University of Western Australia. He studies Geology and Political Science at UWA, completing his degrees in 2009 with honours in Geology. He has developed a keen interest in geophysics for a wide range of application, particular renewable energy exploration and archaeological investigations. His PhD focuses on characterisation of the Perth Basin using EM techniques to identify structures important for Geothermal Exploration.
thomas.hoskin@research.uwa.edu.au

Muhammad Hossain was born in Bangladesh. He completed BSc honours in Geology from Bangladesh and went to the US for a Master's degree in Geology. Then he moved to Australia and started his PhD in Exploration Geophysics at Curtin University in June 2012.
muhammad.hossain@student.curtin.edu.au

Robert Howard I come with a metallurgical background in both operations and research with working experience in the USA, New Zealand, South Africa and Australia. This included directorships in major mining and metals companies working on integration and growth strategy. Leadership positions have also been held in resource companies and global engineering consultancies in the delivery of mining and processing studies. The experience of working at the interface of several disciplines now directs the activities of a consultancy focussed on the delivery of front end process plant solutions. This is achieved by developing an understanding of in-situ resource properties.
Bob@caseconsulting.net.au

Anne-Sophie Høyer finished her phD in December 2012. The phD concerned the geophysical mapping of a complex glaciotectonic environment - using especially AEM and seismic data. Since the phD, Anne-Sophie has worked as a research scientist for the Geological Survey of Denmark and Greenland, where she works with 3D geological modelling for groundwater purposes.
ahc@geus.dk

Jon Hronsky is currently a Principal of Western Mining Services (WMS), a consultancy group with offices in Perth and Denver that provides strategic-level services to a wide range of groups across the global mineral exploration industry. Together with WMS colleagues, Jon helps teaches a popular course on Senior Exploration Management that trained over 250 senior industry professionals. Jon is also Chairman of the board for the Centre for Exploration Targeting, an industry focused research group based at the University of WA and Curtin University in Perth, and an Adjunct Professor at both the University of WA and Macquarie University. In addition, Jon is a Director of Encounter Resources, a Western Australian focused base-metals junior explorer that has discovered and is actively exploring a large greenfields copper prospect in the Paterson Province. Prior to his current role, Jon was Manager of Strategy and Project Generation for BHP Billiton's global mineral exploration group, and before that Global Geoscience Leader for WMC Resources. His exploration targeting work at WMC led to the discovery in 2000 of the West Musgrave NiS province in WA. Jon was awarded the Gibb Maitland Medal in 2005, the highest award of the WA Division of the Geological Society of Australia and was the 2009 Society of Economic Geology Distinguished Lecturer. Jon is also currently Chair of the Australian Geoscience Council, the peak body for geoscience-related professional organisations in Australia and Chair of the External Advisory Committee to CSIRO's exploration-related research effort.
jon.hronsky@wesminllc.com

Antonio Huizi completed his undergraduate studies in his home country of Venezuela majoring in Geophysics. Since then, he has gained over 10 years experience in geophysical exploration for minerals, as well as engineering and environmental applications, both in field-based data acquisition and consulting roles. This has seen him work throughout Latin America, Southeast Asia, the South Pacific and Australia, applying geophysical methods, including gravity, magnetics, electromagnetics, induced polarisation, resistivity and radiometrics, to the search for gold, nickel, base metals, and rare earth elements. Antonioa's current role spans survey planning and management to data processing and interpretation, including 2D and 3D modelling. He has built a strong geological knowledge, which he applies to the litho-structural interpretation of potential field data and target generation from prospect to regional scale.
antonio@sgc.com.au

David Isles is a geophysics graduate of Melbourne and Adelaide Universities and has worked predominantly in 'hard-rock' exploration since 1975, covering a range of mineral commodities. He has focused on exploration applications of aeromagnetics for much of that time, contributing to projects Australia-wide and in the Middle-East, Canada, India and Africa. With geological colleagues, Dave has run courses in aeromagnetics since 1988. His former employers include BHP Minerals, World Geoscience and Grenfell Resources and he currently provides consulting services through Southern Geoscience. He is a non-executive director of ASX-listed Mineral Deposits Ltd and is a member of ASEG, SEG and AIG.
david.isles@sgc.com.au

Nader Issa is a Research Assistant Professor at the University of Western Australia. His research includes geophysical techniques for monitoring with permanent arrays, with particular interests in the monitoring of CO2 geosequestration, passive seismic methods and advanced sensor technologies. He received a PhD in Physics from the University of Sydney in 2005 and BSc (Hons) from Monash University, majoring in Mathematics and Physics.
nader.issa@uwa.edu.au

U Geun Jang
ugeun.jang@uwa.edu.au

Joel Jansen is Chief Geophysicist at Teck Resources Limited in Vancouver, Canada and has been a mining geophysicist for 19 years, including 9 years based in Mexico, Chile, and Australia. He is a Professional Engineer in British Columbia and earned a B.Sc. (Hons) in Geological Engineering and an M.Eng. in Geophysics from Queen's University. At Teck he's been fortunate enough to be involved with a variety of non-conventional geophysical surveys, including muon geotomography.
joel.jansen@teck.com

Mark Jessell is a Winthrop Professor and Western Australian Fellow at the CET UWA having recently arrived from France where he was a Directeur de Recherche with the Institut de Recherche pour le Développement, where he started the West African Exploration Initiative (WAXI). His scientific interests revolve around microstructure studies (the Elle platform), integration of geology and geophysics in 2 and 3D (the Noddy project), and the tectonics and metallogenesis of the West African Craton (WAXI). His current Fellowship is focused on improving the links between geological and geophysical data analysis in 3D via analysis of the geological and topological uncertainty.
mark.jessell@uwa.edu.au

Ian Jones is Distinguished Advisor based in ION GX Technology's UK data processing center. He holds a Ph.D. in geophysical signals processing, an M.Sc. in seismology, and a joint-honors B.Sc. in Physics with Geology. He joined ION GXT in 2000 after spending 15 years in R&D with CGG in London and Paris. His areas of interest include velocity model building and seismic imaging, and he regularly teaches the EAGE/SEG continuing education course "An introduction to velocity model building", and is an external lecturer at Imperial College London and at the University of Leeds. In 2003 he was awarded the EAGE's Anstey Medal for "Contributions to the depth imaging literature", and in 2012 was made the SEG Honorary Lecturer for Europe in recognition of his "Contributions to advancing the science and technology of geophysics". Ian has published three books and over 40 articles on signal processing and imaging.
Ian.Jones@iongeo.com

John Joseph obtained his MSc degree in Geology & Geophysics from CUSAT, India and Ph.D degree from the University of Tokyo, Japan. Prior to relocating to Australia he served as a Research Associate at Indian Institute of Geomagnetism (IIG), Mumbai, India, as a New Energy & Technology Development (NEDO) Fellow at Geological Survey of Japan, as a JSPS Fellow at AIST-Tsukuba, Japan and as a Post-Doctoral Fellow at Tokai University, Japan and was involved in both Marine and Airborne Geophysical Researches. In Australia he served as a Senior Lecturer of Exploration Geophysics (CRC-LEME Funded) at University of Adelaide for FIVE years and then moved to Geophysical Service Industry and served as the Principal Geophysicist @ UTS-Geophysics and then at GroundProbe-Geophysics. John based in Perth and is currently practicing as an independent consultant to Mining, Ground water and Petroleum Exploration sectors. He is an active member of ASEG-WA committee and a recipient of many prestigious awards and recognitions from India and Japan.
john_joseph@iprimus.com.au

Rie Kamei is a Research Assistant Professor at University of Western Australia. She has obtained her PhD from University of Western Ontario, Canada with the theme of full waveform inversion. She has been working on developing full waveform inversion on active and passive seismic data, and on applying the methodology on various filed data.
rie.kamei@uwa.edu.au

Seogi Kang PhD student in UBC-GIF: 2012/09 – Current
Master Degree: 2010/03 – 2012/03
skang@eos.ubc.ca

Mohammad Javad Khoshnavaz did his BSc in physics in Arak University, Arak, Iran. He completed his MSc in exploration seismology in IAU, North Branch of Tehran, Iran. He is a PhD candidate in the Department of Exploration Geophysics at Curtin University, Perth, Western Australia. His focus in his research is on seismic imaging.
mj.khoshnavaz@postgrad.curtin.edu.au

Tseedulam Khuut is currently a professor of Geophysics at Mongolian University of Science and Technology in Mongolia. She is received a B.S. and M.Sc degree in exploration geophysics from Mongolian University of Science and Technology and the Ph.D. in Environmental Studies from the Tohoku University of Japan
cee_0105@yahoo.com

Duy Thong Kieu is a PhD student in Department of Exploration Geophysics, Curtin University
duythong.kieu@postgrad.curtin.edu.au

Andrew King received a B.Sc. (Hons) in geophysics from the University of the Witwatersrand in 1987, and a Ph.D. in geophysics from Macquarie University in 1999. From 1988 to 1993 he worked for Anglo American, first on interpretation of seismic and potential field data for gold exploration, then doing research and development on airborne electromagnetic systems. In 1999 he joined CSIRO in Brisbane, Australia, working on mine seismology. He had a three-year fellowship with NIOSH in Eastern Washington, doing research in geotechnical applications of seismic monitoring, and is now back with CSIRO in Perth working in passive seismics more generally.
andrew.king@csiro.au

Jai Kinkela graduated from Curtin University and spent a brief stint in the petroleum sector before joining HiSeis in 2011. He now works as a project geophysicist involved mainly in the processing and interpretation of hard rock seismic data.
j.kinkela@hiseis.com

Alison Kirkby obtained her MSc in Geology from the University of Auckland in 2008. From 2008 to 2013 she worked in the Geothermal Section at Geoscience Australia (GA) where she contributed to the collection of new heat flow data and the development of heat flow modelling techniques. Alison is currently working towards a PhD in Geophysics with GA and the University of Adelaide where she is looking at characterising resistivity anisotropy using MT data and interpreting it in terms of the distribution of fractures and permeability.
Alison.Kirkby@adelaide.edu.au

Casper Kirkegaard with an educational background in technical physics Casper Kirkegaard started his geophysics career as a programmer in the Hydrogeophysics group at Aarhus University in 2006. In 2011 he concluded his ph.d studies within the same group, and has since then functioned as a research fellow and manages the groups software development. His main research interests include AEM, high performance computing and forward/inverse modeling.
casper.kirkegaard@geo.au.dk

Rosemary Knight is a professor in the Geophysics Department at Stanford University and a senior fellow, by courtesy, with the Woods Institute for the Environment. Rosemary is the founding director of the Center for Groundwater Evaluation and Management (gemcenter.stanford.edu) - a research initiative to demonstrate and develop news ways of using geophysical methods for groundwater applications. Her teaching interests include groundwater geophysics and general education courses designed to engage all students in learning about planet Earth. Rosemary has worked with various professional societies to advance the use of geophysical methods for groundwater evaluation and management. She is a former vice-president of the Society of Exploration Geophysicists, former associate editor of Water Resources Research, and was a co-founder and first chair of the Near-Surface Geophysics Focus Group in the American Geophysical Union. Rosemary earned bachelor and masters degrees in geological sciences from Queen's University, Canada; and her Ph.D. in Geophysics from Stanford in 1985. She then joined the faculty of the University of British Columbia, returning to Stanford in 2000.
rknight@stanford.edu

Matthew Kovacevic is an Honours student in the School of Exploration Geophysics at Curtin University. He is graduating at the end of 2014 at which point he will join the Chevron Australia Graduate Program.
matthew.kovacevic@hotmail.com

Peter Kovesi is a member of the Geophysics and Image Analysis Group within the Centre for Exploration Targeting at The University of Western Australia. His current work involves applying computer vision techniques to geological and geophysical images, with particular interests in feature detection, texture analysis, and visualisation techniques.
peter.kovesi@uwa.edu.au

Marek Kozak was born in 1953 in Warsaw Poland. He has obtained Ph.D in Electrical Engineering and master degree in Computer Science both from Warsaw University of Technology. In 1991 he has moved to USA and jointed Magnetic Pulse Inc. of Fremont in California. During that period he was instrumental in induction and full wave dipole acoustic tool development. From 1994 till 1999 he has run the company. In 2000 he has co founded SuperSonic Geophysical LLC. He is co author of several patents and multiple white papers.
marek@acousticpulse.com

Garrett Kramer
gkramer@slb.com

Richard Lane is a Senior Geophysicist - Analyst, Advisor, Strategist and R&D Manager - at Geoscience Australia. He has extensive experience in the private, service provider, and government sectors, and specialises in minerals and petroleum exploration, airborne geophysics, computational methods, and geoinformatics. He obtained a B.Sc (Hons), Geology and Geophysics, from the University of Melbourne in 1983. Since then, he has been a Geophysicist with CRA Exploration Pty Ltd (1984-1997), and Chief Geophysicist (Product Development Division) at Fugro Airborne Surveys (FAS) / World Geoscience Corporation (WGC) (1997-2001), before joining AGSO / GA in 2001.
rjllane@gmail.com

Simon Lang joined Chevron Energy Technology Company in Houston in Feb 2013, as a senior stratigrapher within the Clastic Stratigraphy team (Earth Science Department), in particular focused on consulting on applications of seismic geomorphology within the company. He was previously with Woodside Energy Ltd. in Perth, where he led the Sequence Stratigraphy & Reservoir Analysis team since 2005. As a senior geological adviser, he has worked on a broad range of Australian and international assets in both exploration and development. His experience ranges from fluvial, coastal-deltaic to deepwater clastics (and some carbonates) from basins of all geological ages throughout Australasia and SE Asia. Other areas he has worked on include basins within Azerbaijan, Brazil, Kazakhstan, Kenya, Libya, Mauritania, Mozambique, Russia, Thailand, USA and Venezuela amongst many others. He has been involved in geoscience research implementation, including teaching classes and field courses on sequence stratigraphy and reservoir analysis. This was built on 13yrs of teaching & research at the Queensland Uni. of Technology (1992-1999) and University of Adelaide, Australian School of Petroleum (1992-2005), during which time he supervised numerous graduate students. Simon's research interests and publications have focused on sedimentology and sequence stratigraphy of dryland and

coal-bearing fluvial-, and coastal-deltaic systems, in addition to deepwater and carbonate systems. The focus has largely been on reservoir analogues for hydrocarbon exploration & development, and CO2 sequestration. He received his Ph.D. from the University of Queensland, Australia (1994) focused on fluvial sedimentology and basin evolution, which he completed whilst working for the Geological Survey of Queensland. Simon was PESA Distinguished Lecturer in 2011.
Simon.Lang@chevron.com

Ken Lawrie is Director, Strategic Groundwater Science, in Geoscience Australia. Ken has a PhD in structural and economic geology from Glasgow University, and over 30 years experience in geoscience research for the petroleum, minerals and environmental sectors. Ken joined Geoscience Australia in 1995, and has led many projects applying cutting-edge technologies and systems analysis methodologies adapted from the resources sector for groundwater and environmental hazard mapping and assessment.
Ken.Lawrie@ga.gov.au

Jean Legault is chief geophysicist (interpretation) for Geotech Ltd. who has worked in mineral exploration geophysics since 1985. He specializes in passive and active source airborne electromagnetics and their geologic interpretation.
jean@geotech.ca

Paul Lennox has spent over thirty years researching regional geological problems. He has supervised honours and postgraduate studies of petroleum fields around the world. This current talk involves his PhD student constructing a 3D model of an area which Paul mapped within a fore-arc block, out of position within the Southern New England Orogen.
p.lennox@unsw.edu.au

Ed Lewis is Depth Imaging supervisor at ION GXT in Perth.
Ed.Lewis@iongeo.com

Yusen Ley-Cooper is a research scientist at CSIRO in the Mineral Resources Research Flagship. Scientific interests His main area of research is in Airborne and ground electromagnetics. He looks at ways on interpreting and integrating geophysical surveys with Geology and data from other sources. Yusen uses inversion as a tool to assist him in interpretations and predictions of structure, for unveiling physical properties of the Earth's underlying materials such as aquifer architecture and mineral deposits. Background He obtained a Bachelor of geophysical engineering from National Autonomous University of Mexico (UNAM), where he majored in environmental and hydro-geophysics. Was awarded a Doctorate in 2007 from Monash University. Had a post-doctoral appointment at RMIT University in the applied physics department. Worked at Geoscience Australia in Geospatial and Earth Monitoring Division. Current activities Some of the projects that Yusen has recently been involved with; are: o Using geophysics in exploration focused on unveiling mineralization for a variety of commodities o Applying AEM to the characterization of overburden architecture o Employing airborne EM in assisting long term outback water solutions in Musgrave province and the Eyre Peninsula in South-Australia. o Using (EM) techniques to help characterise sedimentary coastal aquifers and variations associated with groundwater quality, and salt-water intrusions. o Combining the use of airborne and NMR techniques in order to find sources of ground water in Timor Leste. Yusen collaborates with colleagues in research organisations and industry on exploration projects mainly dealing with electrical and electromagnetic methods; for mineral prospecting and groundwater/environmental applications.
yusen.ley@csiro.au

Jingyu Li has 4 years of professional experience in geophysical exploration industry, all with CGG. As a geophysical project leader, he leads a 3D marine project focusing the northwestern offshore Australia. Mr. Li graduated from Peking University in China with a MSc degree on geophysics.
jingyu.li@cgg.com

Yang Li is currently a Ph.D. candidate in Prof. Ian Jackson's group of rock physics at the Australian National University.
yang.li@anu.edu.au

Bee Jik Lim graduated at University of Science, Malaysia in 1999; Bsc in Geophysics. She is currently Area Geophysicist, responsible for the technology development and deployment in Asia-Pacific (ASA) region, located in Perth, WA.
BLim1@slb.com

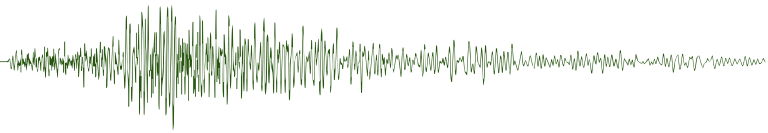
M.H. Loke graduated with a Ph..D in Earth Sciences from the University of Birmingham, U.K. in 1994. He is the director of Geotomo Software that provides software for 2D and 3D resistivity and IP surveys. He is a member of the Editorial Board of the Journal of Applied Geophysics and Near Surface Geophysics. He is a member of the SEG, ASEG, EAGE and EEGS. His present research interests are in fast 2D and 3D inversion methods for geoelectrical data, optimisation of electrode arrays for 2D and 3D surveys, time-lapse inversion techniques and parallel programming techniques in geophysical modelling.
drmhloke@yahoo.com

Sharon Lowe is a senior geophysicist with Southern Geoscience Consultants in Perth. She has over 15 yearsexperience in mineral and petroleum exploration. She has a B. Sc (Hons) degree from the University of the Witwartersrand. She is an active member of ASEG, SEG and PESA.
sharon@sgc.com.au

James Macnae is a gold medallist of the ASEG and has made major contributions in geophysical electromagnetic methods. He advanced sensors and instrumentation, AEM and AIP including unmanned systems, unexploded ordnance detection, interpretation and visualization methodology for EM, salinity mapping, and crustal conductivity sounding.
james.macnae@rmit.edu.au

Asmita Mahanta has 18 years of experience in mineral exploration, both greenfield and brownfield area in various commodities, including base metal, diamond and iron ore. Currently manages the Geophysics team in BHP BIlliton Iron Ore.
asmita.m.mahanta@bhpbilliton.com

Alireza Malehmir obtained a PhD degree (2007) in geophysics from Uppsala University, Sweden. He worked as a post-doctoral fellow (2008) at the Geological Survey of Canada on 3D seismic imaging of deep-seated massive sulfide deposits. He returned back to Uppsala in November 2008 as an assistant professor in controlled-source seismology where he is now an associate professor in applied geophysics. His research interests include 2D/3D geophysical modeling using integration of seismic reflection data with potential field data and available geological data, and 2D/3D geophysical imaging in hard rock environment and near surface geophysics. He has been leading or involved in



several research projects in countries such as Sweden, Finland, Canada, Iran, South Africa and Zambia. He is currently leading a SEG-GWB (Geoscientists Without Borders) funded project in Sweden focusing on the applications of geophysical methods to study clay-related landslides and a larger project on the development of multicomponent seismic and electromagnetic methods for urban underground infrastructure planning. He is a member of SEG, EAGE and EGU, serves in the editorial board of Nature Scientific Reports and is acting or acted as a guest editor (and associate editor) for two special sections in Geophysics and Interpretation journals.
Alireza.Malehmir@geo.uu.se

Fabio Mancini started his career in seismic processing at CGG in London. After three years he undertook a PhD in Geophysics at the University of Edinburgh and then worked at Total, first in research then in their seismic processing team. After five years he joined Hess in their technology group. Three years later he joined Woodside where is currently working in the Sub-Surface technology team. His main professional interests are in seismic processing and velocity model building.
fabio.mancini@woodside.com.au

Keith Martin is Chief Geoscientist with the Planning and Technical Group at AngloGold Ashanti Limited. Today he leads a team of specialists to assist Greenfield and near mine Brownfield exploration. He obtained a BSc in Geophysics from Curtin University in 1984. Since then, he has been a Geophysicist with Water Resources in the Northern Territory (1985-1993), Senior Geophysicist with WMC Resources (1993-2002), Senior Geophysicist with AngloGold Exploration South America (2002-2004), and Chief Geophysicist AngloGold Ashanti (2005-2013). Keith's industry experience has seen him in Australia, Argentina, Canada, Chile, China, Colombia, Brazil, DRC, Mongolia, Peru, Russia, South Africa, Tanzania, USA and West Africa, exploring for Au, Cu, and Ni.
kmartin@anglogoldashanti.com.au

Cericia Martinez is currently pursuing a Ph.D. in the Department of Geophysics at the Colorado School of Mines. She received her B.S. in Geophysics from Colorado School of Mines in May 2009. Her current research focuses on the use of airborne gravity gradiometry. Her interests are in applied inversion and interpretation methodologies for potential field data.
cericia.martinez@uwa.edu.au

Musa Manzi received a PhD degree (2013) in geophysics from the University of the Witwatersrand. He has collected a host of local and global awards for his internationally ground breaking work on 3D seismic reflection technique, which is central to South African gold mining. After his PhD, he joined Wits University where he holds a geophysics-lectureship position in the School of Geosciences. He is actively involved in the research projects using 3D reflection seismic exploration for platinum, gold, oil and gas. He has published many research papers in some of the leading international geophysics journals. In 2013, he won an international award for the Best Paper published in Geophysics of the Society of Exploration Geophysicists (SEG). He has been involved in several hard-rock seismic projects in countries such as South Africa, Sweden and Botswana.
musa.manzi@wits.ac.za

Ben McCarthy
bmccarthy@slb.com

Michael McMillan PhD student at the University of British Columbia. Worked for 3 years with Newmont Mining in Denver prior to returning to graduate school. I enjoy competing in triathlon, and will race at the 2014 Ironman world championships in Kona, Hawaii.
mmcmilla@eos.ubc.ca

Mateus Meira has been a Reservoir Geophysicist at Petrobras for 8 years. He holds a Bachelor in Physics and a Master's degree in Geophysics at the Universidade Federal da Bahia-Brazil. He is currently enrolled in a PhD program in Geophysics at Curtin University-Australia.
mateus.meira@postgrad.curtin.edu.au

Tony Meixner graduated in 1995 from the Australian National University with a BSc (Hons) in Geophysics. He joined Geoscience Australia in 1996 as a potential field geophysicist. During this time he has been involved in the processing, interpretation and modelling of potential field data. His interests include depth to magnetic source modelling where he has used a variety of methods to map the thickness of cover.
tony.meixner@ga.gov.au

Gavin Menzel-Jones is an Earth Modelling Geoscientist with Schlumberger and is currently based in the Kuala Lumpur office. He holds a Joint Master's in Applied Geophysics from the IDEA League partner universities of TU Delft, ETH Zurich, and RWTH Aachen. He also holds a B.Sc. in Physics from the University of British Columbia in Canada. His experience ranges from seismic to non-seismic methods, where he previously worked as an Electro-Magnetic Geophysicist for Geosystem SRL.
GMenzel-jones@slb.com

Alan Meulenbroek graduated from the University of Queensland in 2006 with first-class honours in geophysics. Since joining Velseis he has worked in field acquisition and R&D, with current research focusing on geophysical inversion and multicomponent seismology. He is enrolled in a part time Ph.D. degree at the University of Queensland. He is a member of ASEG, SEG and EAGE.
alanm@velseis.com

Thomas Meyer is the Manager of Advanced Engineering Technology for Lockheed Martin's Gravity Systems line of business located in Niagara Falls, NY, USA. He is the technical lead for all research programs and develops new concepts for gravity measurement and processing. Tom holds numerous patents for instrumentation design and navigation, and has received the Corporation's highest awards for teamwork and individual technical excellence.
tom.j.meyer@lmco.com

Burke Minsley has been a Research Geophysicist with the U.S. Geological Survey since 2008. He received a Ph.D. in Geophysics from the Massachusetts Institute of Technology in 2007. His research interests include airborne electromagnetics and uncertainty quantification for informing geological and hydrological problems.
bminsley@usgs.gov

Brian Minty graduated from Rhodes University (BSc) in 1976 with majors in mathematics and physics. He then received a BSc (Hons) (1977) in geophysics from the University of the Witwatersrand, an MSc (Cum Laude, 1982) in exploration geophysics from the University of Pretoria, and a PhD (1997) from the Australian National University. Early in his career,

Brian worked for the Geological Survey of South Africa (1977-1981), and Hunting Geology and Geophysics (1982-1986). In 1986 he joined Geoscience Australia, and soon found himself in a research role. He has published techniques for mapping cesium fallout, the micro-levelling of airborne magnetic data, the estimation of atmospheric radon background, and the multichannel processing of airborne gamma-ray spectrometric data. He also developed a methodology for the automatic merging of gridded airborne geophysical survey data. After 25 years with Geoscience Australia, and its predecessors, Brian started his own consultancy (Minty Geophysics) in 2011.
Brian.Minty@mintygeophysics.com

Nick Moldoveanu started his career with Schlumberger in 1989, and had varying assignments in data processing, software development, geophysical support for acquisition and processing, seismic survey design, and the development and commercialization of seismic acquisition and processing technologies. Currently, Nick is a global geophysical advisor for seismic solution design and modeling at Schlumberger, Petrotechnical Services. Before Schlumberger, Nick worked for Geological and Geophysical Oil Prospecting Company (IPGG), Bucharest, Romania, as field geophysicist, seismic interpreter, seismic technology analyst, data processing manager and technical director of the IPGG seismic computer center. Nick has a diploma in geophysics from the Romanian Oil, Gas, and Geology Institute, Faculty of Geology and Geophysics, and a diploma in mathematics from University of Bucharest. Nick has over 60 published technical papers, holds 15 patents, and has 8 patent applications under review.
moldoveanu1@slb.com

Leonardo Molinari is a exploration geologist originally from Brazil. Have been working with Chevron for many years and in many locations around the world. He have been in Australia since 2012, and have worked in Chevron's exploration acreage in the Carnarvon basin and currently working on the Great Australian Bight.
leonardo.molinari@chevron.com

Ingelise Møller is a senior research geophysicist at the Geological Survey of Denmark and Greenland. She holds a PhD in geophysics from the Aarhus University, Denmark. She has about 15 years of experience of applying geophysical methods, in particular electrical and electromagnetic methods to groundwater and other near-surface applications through several national and international research projects.
ilm@geus.dk

Sarah Monoury
smonoury@srk.com.au

Ruth Murdie arrived at the Geological Survey in 2103 and is working with Klaus to produce 3D geological models as part of the products that the Survey produces. Previously has worked in the gold mining industry in Kalgoorlie and for the CTBTO in Vienna.
ruth.murdie@dmp.wa.gov.au

Paul Mutton Paul has been working an exploration geophysicist for 18 years and is now working as an independent geophysical consultant at Touchstone Geophysics. He specialises in Mineral Exploration and has previously worked at Southern Geoscience Consultants, Western Mining, and World Geoscience. He lives with his young family in the Perth Hills, Western Australia.
paul@touchstonegeophysics.com.au

Shotaro Nakayama is working for Subsurface Technology Division of Abu Dhabi Marine Operating Company called ADMA-OPCO as a geophysicist. Shotaro is currently responsible for seismic data acquisition and processing projects offshore Abu Dhabi and also involved in reservoir characterization works. Shotaro joined INPEX Corporation in 2007. Shotaro worked on seismic data acquisition and processing projects onshore Libya and offshore Suriname as well as G&G studies offshore Malaysia, Brazil and Suriname till 2010. After that, Shotaro moved to ADMA-OPCO as a secondee from INPEX Corporation. Shotaro has made presentations in technical conferences organized by AGU, IUGG, SPE, EAGE and IPTC, and have published papers in Journal of Structural Geology, Techtonophysics and FirstBreak as an author and co-author.
snakayama@adma.ae

Hugo Olierook completed his undergraduate degree in 2011 from Curtin University in Western Australia. After brief work experience with the Geothermal Centre of Excellence, he started his PhD at Curtin, looking into building a 3D structural and stratigraphic model of the southern Perth Basin. During this time, he has explored many different geological and geophysical techniques to get the most out of the area.
h.olierook@postgrad.curtin.edu.au

Gaynor Paton is Director of Geosciences with ffA. Gaynor's background prior to ffA was as a Physicist working on research and clinical imaging projects in the National Health Service (NHS) for over 10 years. As Director of Geosciences, Gaynor heads up GeoTeric Services offering world-wide, this includes project work, client training and consultancy projects. She also coordinates the R&D performed by her team of geoscientists on innovative geological expression Workflows that are making full benefit of GeoTeric, the geological expression software developped by ffA.
Gpaton@ffa-geosciences.com

Derecke Palmer graduated with a BSc and MSc from Sydney University, and with a PhD and DSc from UNSW. He received the Grahame Sands Award for Innovation in Applied Geoscience from the ASEG, and the Reginald Fessenden Award from the SEG for his contributions to near-surface refraction seismology.
d.palmer@unsw.edu.au

Andrea Paxton is a Senior Rock Physicist with Schlumberger Geosolutions in Perth, Australia. She graduated with a B.Sc. in Earth Science from the University of Glasgow in 2003. She has been working in the Petroleum industry for various service companies for 11 years, joining Schlumberger in 2006. Andrea's work experience includes core analysis, petrophysical formation evaluation, rock physics analysis and seismic reservoir characterization in petroleum provinces of Australia and New Zealand, South East Asia, and the North Sea.
APaxton@slb.com

Marina Pervukhina is Petrophysics Team Leader at CSIRO Earth Science and Resource Engineering Department. Marina is a physicist by background with a BSc and MSc in Applied Physics and Mathematics received from the Moscow Institute of Physics and Technology, Russia, and a Ph.D. in Geophysics from the Kyoto University, Japan. Marina's main research interests are theoretical and numerical rock physics, borehole geophysics and petrophysics.
marina.pervukhina@csiro.au

William Peters is a dual qualified geophysicist and geologist with over 40 years experience in geophysical exploration globally. He has experience in virtually all types of geophysics and geological environments. Bill has consulted to companies, governments and the United Nations on geophysical exploration for diamonds, gold, base metals, PGEs, iron ore, manganese, mineral sands, REEs, uranium, and petroleum in Australia, Africa, Asia, Europe, North America, and South America. This has included survey planning and management, data processing, interpretation and target generation using seismic, potential field, electrical and electromagnetic techniques in the air, at surface and downhole. With his extensive background in global mineral exploration, he works closely with clients to advise on all aspects of exploration in addition to geophysics. Bill is a co-founder and director of Southern Geoscience Consultants.
bill@sgc.com.au

Henry Posamentier helped pioneer and develop the modern approach to sequence stratigraphy, blending the disciplines of sedimentology, stratigraphy, and depositional systems analysis, largely within the context of oil and gas exploration. During the past decade he pioneered and popularized the discipline of seismic geomorphology, which, when integrated with seismic stratigraphy, leverages both 2D and 3D seismic data to better understand the paleogeographic distribution of lithologies. He received his B.Sc. in geology in 1970 at the City College of New York, his M.A. in geology in 1973, and his Ph.D. in 1975, both from Syracuse. After a brief career in academia at Rider University (Assistant Professor of Geology (1974-1979)), Henry joined the oil and gas industry, working for assorted leading oil and gas firms. He currently works a Senior Geological Consultant for Chevron Corporation in Houston. Among his accomplishments, he was a Fulbright Fellow to Austria (1971-1972); the AAPG Distinguished Lecturer to the United States (1992-1992), former Soviet Union (1996-1997), Middle East (1998-1999), and Europe (2005-2006); recipient of the Pettijohn Medal for excellence in sedimentology from the Society for Sedimentary geology (SEPMSEPM)(2008); recipient of the William Smith Medal for contributions to applied and economic aspects of geology from the Geological Society of London (2010); and the Robert Berg Award for Outstanding Petroleum Research (2012).
hposamen1@gmail.com

Toby Potter In 2013 I completed my Ph.D in astrophysics at the University of Western Australia. My thesis topic focused on passive array imaging and 4D full waveform inversion of an expanding supernova remnant. After making a decision to stay in Perth I obtained a position in the Centre for Energy Geoscience at the University of Western Australia. I am currently working on optimizing 3D reverse time migration and have a keen research interest in tackling difficult physics problems with high performance computing.
toby.potter@uwa.edu.au;tobympotter@gmail.com

Qiaomu Qi received a B.S. (2011) degree in geophysics from Chengdu University of Technology, China. He is currently a Ph.D. in Curtin University of Technology. His research interests include wave propagation in partially saturated media and rock physics. He is a member of EAGE and SEG.
qiaomu.qi1@postgrad.curtin.edu.au

Aparna Raman is the Managing Director of Schlumberger Australia and the Geomarket Manager of Schlumberger Australasia, a position she assumed in January 2014. Based in Perth, she is responsible for over 20 Schlumberger businesses across Australia, New Zealand, PNG and Timor Leste. Previously, Aparna has held a variety of senior positions within Schlumberger internationally including Vice President of Well Services for Asia Pacific (Kuala Lumpur, Malaysia), North American Business Transformation Manager (Houston, USA), New Technology Development Manager for Hydraulic Fracturing Equipment (Houston, USA), Well Services and Coiled Tubing Drilling Operations Manager in Alaska (Anchorage, USA) and Regional HR Manager in Europe/Africa/Russia (Paris, France). Aparna holds a degree in Mechanical Engineering from the University of Texas at Austin. She joined Schlumberger as a Field Engineer in the U.S. Gulf of Mexico in 1996.
ramanap1@slb.com

Anya Reading leads the Computational Geophysics & Earth Informatics Group, Earth Sciences, University of Tasmania where she has also taught geophysics since 2007. Previously at Australian National University and University of Edinburgh. Current research focus on computational innovations in geophysical data inference is built upon over 20 years of practical experience of observational geophysics.
anya.reading@utas.edu.au

James Reid holds B. Sc. (Hons.) and M. Sc. Degrees in Geophysics from the University of Sydney and a Ph. D. in Geophysics from Macquarie University. He is currently a Principal Geophysicist with Mira Geoscience in Perth, Western Australia, and has previously held positions with the University of Tasmania and Groundprobe Geophysics. His main technical focus is on applications of airborne electromagnetic methods to mineral and groundwater exploration.
jamesr@mirageoscience.com

Simon Richards completed his PhD at Newcastle University 2005 where he used gravity methods to image the 3D sub-surface geometry of granite plutons. He then moved to the Research School of Earth Sciences at ANU where, using structural geology and seismic tomography he generated the first comprehensive 3D and 4D models of subducting slabs. In 2009 Simon accepted a lecturing position in structural geology at James Cook University. Since 2012, Simon has worked for Nautilus Minerals and now for Citigold Corporation where he is head of Geology, Exploration and Geophysics.
simonrichards4dearth@gmail.com

Hyoungrea Rim has been working in Korea Institute of Mineral Resouces (KIGAM) since 2002 as a sinor researcher, and also colloborating Yaoguo Li in Colorado School of Mines since 2009. His major subject is airborne survey and specially co-work with Yaoguo Li as developing gradiometry and 4D inversion of gravity data.
rhr@kigam.re.kr

Douglas Roberts is Operations Manager for Beach Energy Limited. In this role he is responsible for conduct of onshore and offshore seismic and other geophysical surveys for Beach operated areas. Doug has been at Beach for over 13 years and has conducted 49 2D and 3D surveys both onshore and offshore. Doug held similar positions with Origin Energy (formerly Boral Energy and Sagasco Resources) for over 22 years. Doug is a member of ASEG, SEG and PESA.
doug.roberts@beachenergy.com.au

Jamie Robinson has a background in structural geology applied to controls on hydrothermal ore systems. His currently work for the Geological Survey of New South Wales is focused on developing province and regional scale 3D geological models.

He has previously worked in gold and base metal exploration and also led mineral systems projects in gold, base metal and uranium systems during his time at CSIRO.
jamie.robinson@trade.nsw.gov.au

Alexander Robson completed his honours degree in 2013 in petroleum geology and geophysics at the Australian School of Petroleum and commenced his PhD candidature at the beginning of 2014. His PhD is focused on the structural and geomechanical evolution of the Bight Basin, Australia, using 2D and 3D seismic data.
alexander.robson@adelaide.edu.au

Tony Rudge has worked at Buru Energy as a Senior Geophysicist for the last 6 years and his interests include seismic acquisition/interpretation and the integration of potential field data in geophysical workflows. He has previously worked at Central Petroleum and CGG.
tonyrudge@buruenergy.com

Muhammad Mudasar Saqab did his BSc and MSc in Applied Geology from Pakistan with high distinctions. He worked at Pakistan Petroleum Limited (PPL) for about two and half years as trainee exploration geologist. In 2012, Mudasar received PhD scholarship at the University of Western Australia where he is currently working on the Neogene evolution of the north-western Bonaparte Basin.
muhammadmudasar.saqab@research.uwa.edu.au

Daniel Sattel holds a Ph.D. in geophysics from Macquarie University, where he specialized in electromagnetics. He worked for World Geoscience/Fugro Airborne Surveys in Perth from 1996-2004, where he was involved in the development of EM software and the interpretation of airborne EM data. In 2004 he moved to Golden, Colorado, from where he works as an independent consulting geophysicist.
dsattel@comcast.net

Gavin Selfe has 25 years' experience in the minerals exploration industry and currently consults to many varied exploration companies in Africa. Much of his work is dedicated to deep-seeing geophysical techniques for geological mapping under cover. He specialises in interpreting geology from airborne datasets as well as ground-based gravity, EM and AMT. He graduated in 1987 with a dual major in geology and geophysics. He subsequently worked as a geophysicist for De Beers and Anglo American for 15 years and was based in an exploration office in West Africa for 5 years. His experience includes diamonds, gold, nickel, copper, platinum, iron ore and zinc exploration. He has given papers at numerous conferences, and is ex-president of the South African Geophysical Association (SAGA).
grsconsult@mweb.co.za

Sebastian Schnaidt I was awarded a Bachelor (2009) and a Master (2011) degree in Physics, from the University of Goettingen, Germany, before starting as a geophysicist and PhD candidate at the University of Adelaide's Electrical Earth Imaging Group (EEI) and I am part of the Deep Exploration Technologies Cooperative Research Centre (DET CRC).
sebastian.schnaidt@adelaide.edu.au

Muhammad Shafiq is Geophysics Domain Champion for Schlumberger Australia. Shafiq has more than 20 years of industry experience and has worked in different technical and management positions in Asia, middle east and Africa. Since July 2010, he is based in Perth and covering Austrlia, New Zealand and PNG region. Shafiq holds master degree in Geophysics from Quaid-e-Azam university Islamabad, Pakistan. He is a member of several local and international technical societies.
mshafiq@slb.com

Jeffrey Shragge is the Woodside Professor of Computational Geoscience and an Associate Professor in the Schools of Earth and Environment and Physics at the University of Western Australia. He received his Ph.D. (Geophysics) in 2009 in computational seismology with the Stanford Exploration Project at Stanford University. He was presented with the 2010 J. Clarence Karcher award for 'Excellence in early-career research' by the Society of Exploration Geophysicists. His research interests are in the fields of 3D and time-lapse (4D) seismic imaging and inversion, and high-performance scientific computing.
jeffrey.shragge@uwa.edu.au

Phil Skladzien is a senior geophysicist with the Geological Survey of Victoria. He gained a B.Sc. Honours degree in geophysics from the University of Adelaide in 1997, and has since worked in both petroleum and mineral exploration, for private industry and government. He joined the GSV in 2006 and his most recently work has been focused on the tectonic history and structural interpretation of western Victoria
phillip.skladzien@dsdbi.vic.gov.au

Laura Valentina Socco, (1966), is presently Associate Professor in Applied Geophysics at the Politecnico di Torino, where she took her PhD in environmental geo-engineering and her master degree in civil engineering. Her research work is focused on near surface problems with particular attention to surface wave methods and geophysical data integration. She is author of about 100 peer reviewed scientific publications. She is member of EAGE Research Committee, Vice-chairwoman of EAGE Near Surface Division Committee, and is Assistant Editor of "Geophysics". She was Honorary Lecturer for SEG in 2013 and has been awarded with honourable mention in the category best paper in Geophysics in 2011 and 2012. She has been principal investigator for many research projects financed by national and international institutions and private companies. She teaches Geophysical Prospecting for Petroleum Engineering.
valentina.socco@polito.it

Chris Southby is a geoscientist in the Geoscience Australia Resources Division, Energy Systems Group. He completed his Honours at Australian National University in 2004, on palaeo-climate geochemistry of corals from Papua New Guinea. Since joining Geoscience Australia in 2005 he has contributed to a number of projects including, the National Carbon Mapping and Infrastructure Plan. He is currently contributing to the regional seismic interpretation and petroleum prospectivity of the Houtman Sub-basin.
chris.southby@ga.gov.au

Rafael Souza Rafael has a Bachelor degree on Physics from the State University of Campinas, Master in Reservoir Engineering from the same University. After some industry experience Rafael joined the Centre for Petroleum Geoscience and CO2 Sequestration at UWA, as a PhD Candidate.
rafael.medeirosdesouza@research.uwa.edu.au

Gordon Stove is co-founder and managing director of Adrok Limited, a global pioneer in the development and application of geophysical remote sensing diagnostic technology, used

predominately for the hydrocarbon and mineral industries. A BSc (Hons) Graduate in Geography from the University of Edinburgh, Gordon has helped develop Adrok's intellectual property portfolio, managed its technology developments and its global services business. Kees van den Doel has been Senior Research Associate at the University of British Columbia since 2000. He holds a PhD in physics from the University of California at Santa Cruz (1984) and a PhD in Computer Science from the University of British Columbia (1998). He has publised over 60 scientific papers in the area of modeling and simulation. His current research activities focus on computational and modeling aspects of inverse problems in applied geophysics.
gstove@adrokgroup.com

Shaun Strong graduated from University of Queensland with a first-class honours degree in geophysics (B.Sc.(Hons)) in 2003. After a short period doing gravity acquisition, he joined Velseis, working in the production processing division and later in Research and Development. Shaun is also undertaking a PhD at the University of Queensland. His current research interests include multi-component seismic, seismic acquisition methodology, and improving seismic processing techniques.
sstrong@velseis.com

Koya Suto born in Japan. B.E and M.E graduate in Exploration Geophysics from Mining College, Akita University. Studied further in the University of Adelaide. Koya worked for the petroleum industry as a seismic geophysicist for 25 years. He translated he Microtremor Survey Method's by Prof Okada, published by SEG. In 2003, Koya established Terra Australis Geophysica to service the engineering industry using the surface wave seismic method. He is an Honorary Membership of ASEG and President 2013-2014. He was awarded a Service Certificate from ASEG, Recognition of Merit from SEG Japan. He is also a member of EAGE, EEGS and AGS.
koya@terra-au.com

Ko Piang Tan KP completed his PhD in regolith geology at ANU in 2001 and has since involved in projects interpreting AEM and borehole geophysical information to map groundwater salinity and hydrogeological systems in sedimentary environments. Some of the investigations include the River Murray corridor, Ord River and Northern Territory coastal plain.
kokpiang.tan@ga.gov.au

Lee Tasker has 8 years of professional geophysics experience and has worked internationally and domestically on projects in the engineering geophysics, environmental, groundwater and exploration fields in Australia, Mongolia, New Zealand, Pakistan and Papua New Guinea. Academically Lee has a Master's in Physics (MPhys) from Cardiff University, UK and a Graduate Diploma in Science (GradDipSci) in Geophysics from Victoria University of Wellington (VUW), NZ. Currently Lee is a Geophysics Consultant at Draig Geoscience and also a PhD candidate at the University of Western Australia.
lee.tasker@research.uwa.edu.au

Stephanie Tyiasning originally from Indonesia, Stephanie Tyiasning graduated from the University of Adelaide in 2011 with a bachelor's (Honours) degree in Petroleum Geoscience. She then continued with doing a PhD in Geophysics at Australian School of Petroleum, The University of Adelaide under the guidance of Dr. Dennis Cooke. Her research focuses on seismic AVO inversion and reservoir charaterisation on Cooper Basin unconventional reservoir.
stephanie.tyiasning@adelaide.edu.au

Marjosbet Uzcategui Salazar has been with Schlumberger since 2007, having worked as interpretation geoscientist since 2010. My current role is to assess the hydrocarbon potential of sedimentary basins using 2D and 3D seismic datasets. Previously, I worked as seismic engineer on board acquisition vessels doing data processing in remote locations offshore Angola and Nigeria for 2 years. I hold a MSc. in Integrated Petroleum Geosciences from Aberdeen University.
msalazar6@slb.com

John Vann is Group Head of Geosciences for Anglo American PLC, where his global brief covers technical, innovation and governance aspects of geosciences across the value chain. He is a geologist and geostatistician with over 25 years of experience across nearly all commodities. He holds geology degrees (BAppSc from RMIT and BSc(Hons) from U New England), MSc in Geostatistics from U Leeds and MBT from the Australian Graduate School of Management (UNSW). John currently holds Adjunct academic positions at the Universities of WA, Adelaide and Queensland. He is a fellow of AIG and AusIMM as well as being a member of SEG, GSA and a lifetime member of the IAMG.
john.edward.vann@gmail.com

Adel Vatandoost Adel has over ten years of experience in mineral industry in the fields of exploration geophysics, mining geology, geometallurgy and applied research. Adel holds a BSc degree in Mining Engineering, an MSc in Geophysics and a PhD in the field of Geometallurgy. He is currently a Senior Geometallurgist at Fortescue Metals Group focusing on geometallurgical characterisation of Iron ore deposits in Pilbara, Western Australia.
avatandoost@fmgl.com.au

Andrea Viezzoli earned his Ph.D. in geophysics from Monash University. Andrea manages Aarhus Geophysics Aps since 2009. Author of several publications, he is interested in all aspects of airborne EM. Lately, he is been mainly active modelling IP from AEM data.
andrea.viezzoli@aarhusgeo.com

Min Wang received a PhD in Solid Mechanics from Tsinghua University (China) in 2007. She joined CGGVeritas as processing geophysicist in 2007 and then worked as research geophysicist from 2009. Her main interests are seismic data processing such demultiple, denoise and data reconstruction.
Min.Wang@cgg.com

Daniel Wedge joined the Geophysics and Computational Analysis group in CET in 2010. Prior to that he completed a PhD in Computer Science and then worked in industry developing image and video processing algorithms. His work primarily focuses on extracting features from various geophysical and geological images, and data visualisation problems.
daniel.wedge@uwa.edu.au

Mike Whitford
Mike.Whitford@igo.com.au

Chris Wijns has been the Group Geophysicist since late 2008 for First Quantum Minerals, a company that mines and explores for copper and nickel around the world. Previously, Chris held a similar role with gold miner Resolute Mining Ltd, following completion of a PhD at UWA and CSIRO in 2004. Prior to this, Chris studied geophysics degrees in Canada, and worked in gold exploration in West Africa for Placer Dome before moving to

Australia in 1999. He has enjoyed working inside sizeable companies for the opportunity to have constant interaction with geologists, geochemists, and assorted engineers. Chris fancies himself as a geophysicist who tries to become a bit more of a geologist and geochemist with every passing year.
chris.wijns@fqml.com

Ken Witherly graduated from UBC (Vancouver Canada) with a BSc in geophysics and physics in 1971. He then spent 27 years with the Utah/BHP Minerals company during which time as Chief Geophysicist, he championed BHP's programs in airborne geophysics which resulted in the development of the MegaTEM and Falcon technologies. In 1999, Ken helped form a technology-focused service company that specializes in the application of innovative processing and data analysis to help drive the discovery of new mineral deposits.
ken@condorconsult.com

James Wordsworth B.App. Sc (Physics), MBA(Finance)., is the Global Operations Manager for Slimline at Weatherford, based in the USA. He has worked extensively in minerals exploration, mainly in Australia and New Zealand, since joining BPB in 1996. His focus within Weatherford is improving Slimline answer products for mining clients and expanding awareness of borehole logging within the global mining exploration community.
jim.wordsworth@weatherford.com

Xiang Wu is working in CGG as a Senior Research Geophysicist. He obtained his Ph. D. from National University of Singapore in 2011 and joined the R&D department of CGG since then. His research interest covers denoise and demultiple of seismic processing, and he has published works on series of works on multiple and noise attenuation in curvelet domains.
xiang.wu@cgg.com

Yi Xie graduated from Tsinghua University with PhD in engineering. He has been actively working on seismic data processing techniques, particularly in the area of seismic imaging and inversion. He is a member of SEG and EAGE.
yi.xie@cgg.com

Kunlyn Yang is a Senior Research Geophysicist and has been working in CGG Singapore for 7 years, mainly focusing on multiple attenuation and signal processing.
kunlun.yang@cgg.com

Gerhard Zacher is application engineer at the product line phoenix|x-ray of GE Sensing & Inspection Technologies working on 2D and 3D x-ray inspection including CT measurements and interpretation. He's a geophysicist with more than 10 years experience in environmental and engineering geophysics, mainly 2D and 3D interpretation of EM data. GE Sensing & Inspection Technologies is a leading company in 2D microfocus and nanofocus x-ray inspection and high resolution 3D computed tomography.
gerhard.zacher@ge.com

Olga Zdraveva holds degrees in applied geophysics and applied mathematics from univercities in Bulgaria. She is a geophysical Advisor and Imaging Chief Geophysicist in SLB-Geosolutions. Olga's main interests and work has been in developing multi-disciplinary workflows and tools for anisotropic model building for Depth Imaging.
OZdraveva@slb.com

Matthew Zengerer received his Undergraduate degree in Geology and Geophysics from Flinders University in 1998 and an Honours degree in Geophysics from the University of Tasmania in 1999. Since then he has had a varied career working for both the minerals and oil and gas industries in processing, interpretative and modelling geophysics, with occasional stints as a geologist. He turned to full time consulting in 2009 and began to specialise in integrated 3D geological and geophysical modelling for basin, geothermal and minerals exploration. He is now a technical manager at Intrepid Geophysics, based in Melbourne.
mattz@intrepid-geophysics.com

Binzhong Zhou studied his Ph.D. from Flinders University of South Australia. He is currently a principal research scientist with CSIRO Energy Flagship. Prior to CSIRO, he worked for Chengdu University of Technology, Wiltshire Geological Services, and Oxford University. His research effort is directed to improving the scientific understanding of how geophysical measurements can be used to improve the mining industry's ability to delineate orebodies and geological structures, understand the geotechnical characteristics of host rocks, improve mine design, reduce mining safety risks, and increase mine production and profitability.
Binzhong.Zhou@csiro.au

Jun Zhou received PhD from University of New England and currently working as an area geophysicist with TGS image Asia Pasific
Jun.Zhou@tgs.com

Sasha Ziramov is a geophysicist with extensive experience in seismic exploration, data processing and depth imaging. Currently works as a lecturer at Curtin University of Technology. Prior to joining Curtin, he worked as lead geophysicist in Geokinetics for the period of 6 years, processing various 2D/3D land and OBC seismic datasets. Graduated from the Faculty of Mining and Geology, University of Belgrade, with MSc degree in geophysics in 2004.
sasha.ziramov@curtin.edu.au

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SECTION 6
SOCIETY MEMBERSHIP

Australian Society of Exploration Geophysicists

PESA Petroleum Exploration Society of Australia

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Email: secretary@aseg.org.au Website: www.aseg.org.au

Application for Membership 2015

INSTRUCTIONS FOR APPLICANTS

1. Determine the membership level you wish to apply for, according to the eligibility criteria outlined in Section 2.
2. Fill out the application form. Note that applicants for Active Membership must nominate a proposer and a seconder who are Active Members of ASEG. Student members must include a Supervisors Name and Signature. Under exceptional circumstances the Federal Executive Committee may waive these requirements.
3. Attach the appropriate dues and submit the two pages of your application to the Secretariat at the address shown on the top of this page, retaining a copy of this page for your own records. If payment is to be made by credit card, the application may be sent by fax.

Section 1. Personal Identification

Surname			Date of Birth
Given Names			Mr / Mrs / Miss / Ms / Other
Address			
		State	Post Code
Organisation			
Phone (W)	Fax (W)		
E-mail			
Phone (H)	Fax (H)		
Mobile			

Section 2. Choice of Membership Grade (Tick one)

- ❑ Active — Please complete all sections
- ❑ Associate — Please complete all sections (3 and 4 are optional)
- ❑ Student — Please complete the separate Student Membership Application Form

Active – an applicant must be actively engaged in practising or teaching geophysics or a related scientific field. Conditions for Active Membership include a relevant academic qualification. Any person who does not have such qualifications, but who has been actively engaged in the relevant fields of interest of the Society for at least five years, shall also be eligible for Active Membership upon the discretion of the Federal Executive Committee.

Associate – an applicant must be actively interested in the objectives of the Society. Associate Members are automatically eligible for election to Active Membership after five years as an Associate Member.

Student – an applicant must be a full-time graduate or undergraduate student in good standing, registered at a recognised university or institute. Eligibility for Student Membership shall terminate at the close of the calendar year in which the Student Member ceases to be a graduate or undergraduate student. The duration of a Student Membership is limited to five years.

Section 3. Academic and Professional Qualifications

Month/Year (From – To)	Organisation/Institution	Position/Degree (incl. Major)	Professional Record Only: Years of Independent Work

Section 4. Nominators (Must be ACTIVE Members of ASEG)

Nominator	Name	Postal or e-mail address	Phone/Fax
Proposer			
Seconder			

Section 5. Membership of Other Societies

Australian:

❑ Aus IMM Grade _____ ❑ AIG Grade _____ ❑ GSA Grade _____ ❑ PESA Grade _____

International:

❑ AAPG Grade _____ ❑ EAGE Grade _____ ❑ SEG Grade _____ ❑ SPE Grade _____

❑ Others _____

Section 6. ASEG Membership Directory Record

Please complete this section for the ASEG membership database.
The ASEG Membership Directory is published in April. The same information is included in the ASEG Web site (www.aseg.org.au)

Employment area:

❑ Industry ❑ Contract/Service Provider ❑ Government ❑ Student
❑ Education ❑ Consulting ❑ Other _____

Type of Business:

❑ Oil/Gas ❑ Ground Water/Environmental ❑ Coal ❑ Survey/Geotechnical/Engineering
❑ Minerals ❑ Petrophysics/Log Analysis ❑ Research/Education ❑ Data Acquisition
❑ Solid Earth Geophysics ❑ Archaeology/Marine Salvaging ❑ Computer/Data Processing ❑ Other _____

Section 7. Payment Details (This document will be an Australian Tax Invoice when you have made payment)

MEMBERSHIP GRADES AND RATES	
❑ Active/Associate (Australia)	$148.00
❑ Active/Associate (New Zealand/Rest of the World)	$135.00 (GST is not included in this price)

Section 8. Preview & Exploration Geophysics

The association produces a magazine called Preview and the journal Exploration Geophysics.
All Australian members will automatically receive a hard copy of Preview and can request paper printed or electronic addition of Exploration Geophysics.
Overseas Members including New Zealand may request a paper printed or electronic of both Preview and Exploration Geophysics.

Exploration Geophysics

❑ Paper/printed (Australia) – Additional $38.50
❑ Paper/printed (New Zealand) – Additional $35.00
❑ Paper/printed (Rest of the World) – Additional $55.00
❑ Electronic – (Australia, New Zealand and Rest of the World) No additional fee

Preview

❑ Paper/printed (New Zealand) – Additional $10.00
❑ Paper/printed (Rest of the World) – Additional $30.00

Amount Payable: Section 7 + Section 8 + Research Foundation Donation (optional) = $ _____ ❑ Tick if you require a receipt

❑ MasterCard ❑ Visa ❑ AMEX

Name of Card Holder: _____ Card No. __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

Expiry Date: _____/_____ Signature: _____

(Note: Keep a copy for your record. A receipt will not be issued unless specifically requested.)

The above information is required for our records, but if you do not wish to be included in the ASEG directory or Internet search facility, please indicate by ticking appropriate box below:

❑ I ***do not*** wish to be included in the ASEG Directory. ❑ I ***do not*** wish to be included in the ASEG member search facility on the Web site.

Section 8. Promotional Opportunities

The ASEG provides opportunities for special category listings (eg. Consultants, Contractors) in the Directory and a link from the ASEG Internet Web Page.

❑ I (or my business) would like to be included in a special category listing in the Directory.

❑ I (or my business) am interested in having a link from the ASEG Internet page. Rates will be advised when links are implemented. (Corporate and Corporate Plus Members get a complimentary link.)

❑ I (or my business) am interested in advertising in the Directory, or other ASEG's publications. Rate details will be forwarded by our Publisher, CSIRO Publishing, doug.walters@csiro.au or Ph +61 3 9545 8505 (Discounts available for Corporate Members and volume advertising)

Section 9. Declaration

I, _____ (name), agree for the Australian Society of Exploration Geophysicists to make all necessary enquiries concerning my application and suitability to become a Member. By lodging this Application and upon being accepted in my membership, I agree to be bound by the Constitution of the Australian Society of Exploration Geophysicists, including its ethical and professional standards.

*Signature:*_____ *Date:*_____

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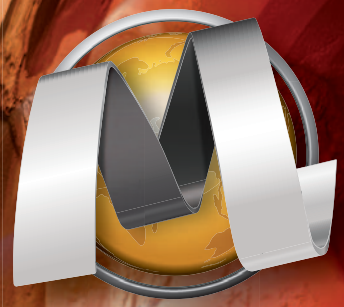

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February	**2015**		
15–18	ASEG–PESA 2015: Geophysics and Geology together for Discovery 24th International Geophysical Conference and Exhibition http://www.conference.aseg.org.au/	Perth	Australia
March	**2015**		
18–21	PACRIM 2015 http://www.pacrim2015.ausimm.com.au	Hong Kong	China
22–26	SAGEEP 2015 http://www.eegs.org/Annual-Meeting-SAGEEP/SAGEEP-2015	Austin, Texas	USA
April	**2015**		
19–22	SEG/CGS Workshop: GEM Chengdu 2015 Gravity, Electrical and Magnetic Methods and their Applications http://www.seg.org/events/upcoming-seg-meetings/gem-chengdu-2015	Chengdu	China
May	**2015**		
15	2nd Great Basin and Western Cordillera Mining Geophysics Symposium being held in association with the Geological Society of Nevada Symposium http://gsnv.org/2015-symposium/	Reno, Nevada	USA
17–22	20th Caribbean Geological Conference http://www.thegstt.com	Port-of-Spain	Trinidad & Tobago
June	**2015**		
1–4	77th EAGE Conference and Exhibition 2015 http://eage.org	Madrid	Spain
July	**2015**		
7–10	2nd Near-Surface Geophysics Asia-Pacific conference (NSGAP) http://www.seg.org/events/upcoming-seg-meetings/2015/ns-asia-pacific-2015	Hawaii	USA
September	**2015**		
6–10	1st European Airborne Electromagnetics Conference and 21st European Meeting of Environmental and Engineering Geophysics – Near Surface Geoscience 2015 http://eage.org/event/index.php?eventid=1325&Opendivs=s3	Turin	Italy
October	**2015**		
5–8	8th Congress of Balkan Geophysical Society http://www.eage.org/event/index.php?eventid=1313&Opendivs=s3	Chania	Greece
18–23	SEG International Exhibition and 85th Annual Meeting http://www.seg.org	New Orleans	USA
November	**2015**		
18–20	12th SEGJ International Symposium http://www.segj.org/is/12th/	Tokyo	Japan
December	**2015**		
7–9	9th International Petroleum Technology Conference http://www.iptcnet.org	Doha	Qatar
May	**2016**		
30 May–2 June	78th EAGE Conference & Exhibition http://www.eage.org/	Vienna	Austria
October	**2016**		
16–21	SEG International Exhibition and 86th Annual Meeting http://www.seg.org	Dallas	USA
June	**2017**		
12–15	79th EAGE Conference & Exhibition 2017 http://www.eage.org/	Paris	France
July	**2017**		
2–17 (TBC)	3rd Near-Surface Geophysics Asia-Pacific conference (website TBA)	TBA	Australia

Preview is published for the Australian Society of Exploration Geophysicists. It contains news of advances in geophysical techniques, news and comments on the exploration industry, easy-to-read reviews and case histories, opinions of members, book reviews, and matters of general interest.

For style considerations, please refer to the For Authors section of the *Preview* website at: www.publish.csiro.au/journals/pv.

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