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PREVIEW

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

NEWS AND COMMENTARY

Natural gas – a strategic national asset

AGM news and reports

Research Foundation updates

EIS – $80 million for WA

Commodity prices in 2008

FEATURE ARTICLES

Coal seam gas in eastern Australia

TerraWulf II: Cluster-computing facility

The search for cosmic magnetism

PREVIEW

ADVERTISERS INDEX

2009 ASEG CORPORATE MEMBERS

CORPORATE PLUS MEMBERS

Elliott Geophysics International Pty Ltd
Vale Exploration Pty Ltd
Velseis Pty Ltd

CORPORATE MEMBERS

Archimedes Financial Planning
Beach Petroleum Ltd
CGG Veritas
Chevron Australia Pty Ltd
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Fugro Airborne Surveys
Geoscience Australia
Geosensor Pty Ltd
Geosoft Australia Pty Ltd
Haines Surveys Pty Ltd
Newmont Australia Pty Ltd
Origin Energy Resources Ltd
Outer-Rim Exploration Services Pty Ltd
Papuan Oil Search Ltd
Petrosys Pty Ltd
PGS Australia Pty Ltd
Pitney Bowes Business Insight
Rio Tinto Exploration Pty Ltd
Santos Ltd
Seismic Asia Pacific Pty Ltd
UTS Geophysics Pty Ltd
Woodside Energy Ltd
Zonge Engineering & Research Organisation

CONTENTS

FRONT COVER

Tipton West Coal Seam Gas Field. Photos courtesy of Arrow Energy. *(See p. 26 for details.)*

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Ann-Marie Anderson-Mayes

As your new editor, I would like to begin with an enormous thankyou to my predecessor, David Denham. David guided *Preview* through 58 issues from October 1999 (Issue 82) to April 2009 (Issue 139). He put in an enormous amount of work to ensure that *Preview* delivered a high quality mix of news, comments, technical articles, reviews and matters of interest to ASEG members. I am sure all our members will join me in recording here our sincere appreciation for all his efforts. To ensure a smooth transition from the old to the new, David will continue as Associate Editor with *Preview*. His support and advice are invaluable. He is also the new Secretary of the ASEG following the AGM in April. David continues to play a pivotal role at the ASEG.

A second vote of thanks needs to be recorded for all those people who contribute pieces to *Preview* magazine. FedEx and ASEG Committee members, State Branch representatives, employees of the various national and state survey bodies and a small cohort of regular contributors receive a reminder email from the *Preview* Editor once every two months. Most of these contributors write a few paragraphs or more for most issues of *Preview*. They have to endure reminder emails as we approach our publishing deadline, whilst they are no doubt very busy doing their 'real' work. But it is their regular contributions combined with the excellent feature articles which ensure that *Preview* continues to appear on your desk every two months.

My role as Editor is to ensure that *Preview* continues to reflect, as far as possible, the mix of news, views and articles that are likely to be of interest to the full spectrum of ASEG members. This means trying to achieve a balance of material that will be of interest to geophysicists working in minerals, petroleum, environmental and geotechnical arenas; members who span the spectrum from students to highly experienced practitioners; and employees who may be in academic, research, large corporate, small corporate, consultancy or solo practitioner roles.

As a geophysicist with a background in research and consultancy on environmental and minerals projects, I only have direct experience of one part of the ASEG spectrum described above. So, I need your help. For *Preview* to adequately reflect the news and views of its members, those members must contribute. Here are a few examples of what I mean.

- If you have seen an interesting talk or presentation at your local ASEG Branch, either write a short report or contact me so that I can track down the presenter for a potential article.
- Perhaps you have been chatting to colleagues or thinking about an issue that is important to the geophysical community. If so, write me a Letter to the Editor. This only need be a few paragraphs and it enables the wider ASEG community to participate in the discussion. Of course, if you are really passionate about your topic and feel the need to write more, submit it as an Opinion Piece!
- If you and/or your colleagues have been doing some interesting research or have worked on a really interesting case study, then offer to submit an article to *Preview*. This is not a rigorous research article as appears in *Exploration Geophysics*, but rather technical information that might be of use or interest to other geophysicists.
- Perhaps you have been reading a book or text related to exploration geophysics or the geosciences which could be included in our Book Review section. Contact me to either write a few paragraphs yourself or add it to the list of texts for our Book Review Editor to consider.
- Finally, don't forget the fun and interesting side of being a geophysicist. Perhaps you are able to contribute photos and a couple of paragraphs about an amazing field trip, or something that went horribly wrong, or an experience that changed your perspective on life as a geophysicist. Geophysicists, like many other geoscientists, are often privileged to see a variety of cultures and natural environments around the world. Sometimes, we work in extraordinary conditions. For some of us, it is those experiences that add richness and depth to our careers.

And if none of the above has stimulated you to put fingers to keyboards, then please take the time to send me feedback about *Preview*. Is there something you would like to see more of or less of? I can't promise to meet everyone's interests all the time, but I would like to meet most of them at least some of the time.

And so to the content of my first issue. In April, we had the ASEG AGM in Perth. Consequently, this issue's ASEG News is packed full of reports and updates. In March, Belinda Robinson, CEO of APPEA, gave an address to the National Press Club. By all accounts her presentation regarding Australia's natural gas resources was excellent. We are grateful for her Guest Editorial which summarises the exciting potential of the natural gas industry in Australia. This is complemented by a comprehensively detailed Feature Article by Robert Day reviewing Australia's coal seam gas (CSG) industry. Research News in this issue features an article by Malcolm Sambridge on the extraordinary computational power of TerraWulf II. Finally, Roger Henderson spotted the article on the magnetism of the wider universe in January's edition of *Australasian Science* magazine (www.australasianscience.com.au) and suggested we republish it in *Preview*. The author, Bryan Gaensler, made a few changes for us, in particular adding a list of further reading. Whilst the article is not going to help you find the next great ore deposit, I hope you find it interesting to read about magnetic fields on a much larger scale than we are generally accustomed to examining.

Natural gas – a strategic national asset

Belinda Robinson
Chief Executive
Australian Petroleum Production
& Exploration Association Limited (APPEA)

Can you think of an Australian industry, in the current economic climate, that has the potential to reduce global emissions by 180 million tonnes each year on what it would otherwise be; generate $10 billion each year in government revenue and create more than 50 000 jobs over the next 10–15 years?

In these challenging times, Australia's natural gas industry is good news.

The need for urgent greenhouse action, concerns over domestic and regional energy security, and our region's growing appetite for energy have brought into stark relief the strategic value of Australia's natural gas resources.

The world's demand for energy is growing, largely as a consequence of population growth and developing countries' determination to attain the standard of living that most of us take for granted. Australia is well-positioned to meet a substantial portion of that need. In Australia our need for secure and reliable energy is also increasing.

Australia is in an enviable if not unique position to address this challenge. In particular, natural gas is available here and now and is the key to assisting Australia and the world make a smooth transition to the substantially lower or no emissions future that must lie ahead.

Around 60% of the natural gas that we produce today is used domestically – piped around the country to service households, businesses and, of course, for electricity generation. The other 40% is exported in the form of Liquefied Natural Gas or LNG – gas that is refrigerated to minus 161 degrees so that it may be transported long distances.

So what is it about natural gas that makes it so special?

In a domestic energy context:

- depending on the technology used, natural gas emits between 50 and 70% less carbon dioxide than is produced by an existing conventional coal-fired power station;
- gas-fired power generation uses very little water; and
- it has a very small environmental footprint – 15 hectares for an average 1000 MW plant, (compared to about 6 to 8 thousand hectares for solar and 8 to 14 thousand hectares for wind) and low impact and low visibility infrastructure requirements.

The case for LNG is equally compelling. For every tonne of greenhouse gas emissions associated with the production of LNG in Australia, between 4.5 and 9 tonnes are avoided in the Asia-Pacific region when this gas is substituted for coal in generating electricity.

Australia consumes about 1 trillion cubic feet of gas (Tcf) each year. We export almost as much as that again. To put that in perspective, all up, Australia produces enough gas in a year to keep Adelaide going for 40 years. If you add up all of Australia's resources, we have 400 Tcf of natural gas, more than 250 years worth at current rates of production. A large proportion of these are Coal Seam Gas (CSG) resources. CSG is here to stay in supplying clean energy to Queensland, eastern Australia and the world through the export of LNG. The proposed CSG-LNG projects in Queensland are well positioned to deliver significant economic and environmental benefits to the local communities and to Queensland.

Australia has $200 billion worth of gas projects on the drawing boards. Add to those projects the potential for domestic natural gas projects and we have a game-changing shift in the Australian resource sector.

While our resource base is more than capable of realising this ambition, it won't happen without commitment – by the industry to invest and governments to do all they can to encourage, and remove impediments to, that investment.

Climate change policy is a case in point. By putting a price on carbon, a well-designed emissions trading scheme should result in less carbon intensive products being cheaper than their higher carbon intensive competitors. This encourages the market to move towards more carbon-efficient, and less greenhouse gas emitting, sources of energy. The Australian natural gas industry supports an international price on carbon.

The proposed Australian scheme, however, will constrain the growth prospects of Australia's LNG industry by imposing a cost on the emissions associated with the production of LNG while ignoring the substantial net greenhouse benefits that accrue to the world as a consequence of natural gas being used instead of higher emitting alternatives in countries that have not introduced a price on carbon.

Australia will be better off every year in terms of GDP, taxation income, employment and greenhouse gas abatement if the upstream gas industry is able to compete on its merits and within an internationally competitive investment framework. Some of our most important neighbours will also be better off economically and environmentally if our gas export potential is fully realised, and Australia's ability to strengthen its relationship with these countries, through the energy umbilical cord, presents other positive opportunities.

Hats off to the past, coats off to the future

We cannot predict our future over the next year with any greater degree of success than your average economist (and face it, they are all looking very average). We can however maintain some control of our future by building on past successes and taking well-judged initiatives.

Firstly I wish to thank the outgoing President Peter Elliot for his hard work over the year past. We have made positive steps in reviewing our governance and future leadership. We have held a very successful Conference. We are building links with the Indonesian geophysics society HAGI which is part of an important process of internationalizing our society. Thank you Peter for your leadership in these matters.

Secondly I wish to thank Joe Cucuzza who steps down from the FedEx after three years as President Elect, President 2007–2008, and Past President. Joe initiated the review of governance and leadership and has actively assisted in the evaluation of future options. He has also contributed markedly to our international links via his extensive AMIRA and business contacts.

In looking to the next year I see three areas where the Society can serve its members interests.

Professionalism in the ASEG

We are a professional and technical society and advancing the professional interests of our members must always be our primary goal. We have an excellent record in our Conferences and we must ensure that this continues.

We have a strong record in our publications from an industry standpoint, but our standing in academia (as evidenced in recent Australian Research Council ERA rankings of journals, which will play a major part in the academic directions and rewards available for geophysicists in universities) is poor. This is an area where I expect to work with FedEx and other societies with efforts to achieve improved recognition of our publications.

We are justifiably proud of our conferences both in terms of their technical content (all now available online) and their financial success. There are nine national earth science societies representing geoscientists in Australia, four representing geophysicists in the west Pacific, and two major international societies. We have a strong record of past collaboration in online indexing of publications (with SEG), journal publications (with SEGJ and KSEG) and joint conferences (with PESA and GSA). We must continue to develop synergies in order to face challenges of the 21st century while retaining the identity that has been our strength in the past.

An area we have not previously been involved in is provision of professional credentials. Industry recognition of expertise is available in Australia through both the AusIMM and the AIG – but ASEG has no part of the process. Should we? How can we interface with the existing routes in a way which best advances the interests of our members?

Education

The ASEG under Joe Cucuzza played a part in the initiation of a Survey of Geophysics capability in Australian universities, and discussion continues (see the article by Richard Lane in April 2009 *Preview*). It is clear that geophysics teaching and research in Australian universities is not sufficient to maintain current skills in the profession. How can we engage with industry and academia to improve this? Should we increase the number of specialist lectures and seminars offered by ASEG and SEG, and if so, which topics are priorities for up-skilling our membership?

Education of the public including school students is a vital role for science generally, and as geophysicists we have an interest in being part of the process. Education at the secondary school level is an important tool for inspiring the upcoming generation in science, and in particular our branch of science. We have several members who have been active in giving talks to local schools (Dr Michael Roach in Tasmania is one example) but a structured program aimed Australia-wide, for education of science teachers (and hence their students) has been developed by our sister society PESA. We have agreed to join the PESA program as a platinum sponsor of TESEP (Teacher Earth Science Education Program) and have three of our members who are now science teachers contributing to this course. It is my hope that our contribution to course material will grow with time.

Organisation of the ASEG

Apart from the Federal Executive, ASEG has nine committees and six State Branches. Its strength lies in the energy provided by its members. If you have an idea for betterment of our outcomes in the areas listed above, your involvement will be welcomed.

It has been evident in this last year that communication between FedEx, Committees and Branches has room for improvement, hence we plan for more direct involvement in and support of Committees by members of the FedEx. Communication with Branches is also a 'needs improvement' item, as evidenced by the concerns raised during recent discussion of the proposal to create a CEO position for the ASEG.

I look forward to visiting each State Branch at least once over his next year. Your suggestions and feedback are always welcome.

Michael Asten
President
michael.asten@flagstaff-geoconsultants.com.au

Outgoing President's report: ASEG AGM April 2009

Firstly, I wish to thank the Members of the Australian Society of Exploration Geophysicists for having faith and trust in me to lead the society through another successful and interesting year. I also wish to thank certain Members of the Federal Executive Committee who put in much effort during the year to ensure the smooth running of the society's affairs. On the Fedex Committee, I wish to thank David Cockshell our Treasurer, who has done a sterling job during his first year as Treasurer. David replaced John Watt in May last year and John has assisted with the changeover to ease David into the Treasurer's seat. John also continued on the committee as an ex officio member and helped a great deal with the Business Review that was completed last year and the financial models that have been developed since.

Mike Asten, as President Elect, has been a great deal of help and is more than ready to take over the reins as the incoming President. Koya Suto as Vice President has been our liaison with the SEG and is on the SEG International Affairs Committee. Koya has also assisted in liaising with other sister societies of the ASEG and has been invaluable as the unofficial keeper of ASEG corporate knowledge over the last 17 years. Koya has been a continuous member of the Fedex Committee since 1992 and deserves a standing ovation for his dedication and service to the society. Andrea Rutley, also our Vice President has been chairing the Conference Advisory Committee and has helped greatly with organising the last conference in Adelaide and the ensuing conferences to be run in Sydney and Brisbane.

Troy Herbert has done his best as Honorary Secretary but has had great constraints put on his time by changes in the Mining Industry. David Denham, our Editor for *Preview*, and Lindsay Thomas, our Editor for *Exploration Geophysics*, both finished a marvellous period in driving those publications. Mark Lackie is our new editor for *Exploration Geophysics* and Ann-Marie Anderson-Mayes is our new editor for *Preview*. I welcome both our new editors and hope they enjoy these roles for the foreseeable future. Our Webmaster, Wayne Stazinowsky, has made great strides over the last 12 months in restructuring our website and turning it into a practical data base for membership and publications. This will be the foundation on which major advances will be made in communication and access for our members.

Emma Brand has done an excellent job as the Membership Committee Chair, working at arm's length from Canada with local backup from Cameron Hamilton. Although, our total membership number appears to have dropped slightly over the last 12 months this was mainly due to recognizing that we still had some lost and nonfinancial members listed in our directories. This has now been remedied with the help of CASM. Thanks are also due to Reece Foster who is the State Branch's Representative on the Fedex and who has given the committee a lot of useful feed back as well as liaising with the various State committees.

The Research Foundation Committee was chaired again this year by Phil Harman who is also our nominated President Elect for 2009–2010. I refer you to the RFC report for more information. This year we renamed the Technical Committee as the Education Committee, in the hope that this 'new' committee will generate more contact with undergraduate and secondary school students and thereby encourage interest in geophysics from this next generation of potential geophysicists. Milovan Urosevich is Chairing the Education Committee until someone else can be found to relieve him.

I also wish to thank CASM and, in particular, Louise Middleton who has put in an enormous effort this year to ensure the smooth running of all events during the year. Louise has helped enormously in reminding various Fedex Committee members, including myself, when official requirements of the society need to be executed.

In February, we had a very successful 20th Conference and Exhibition in Adelaide which attracted some 800 delegates from Australia and overseas. The conference had a well rounded

Fig. 1. *David Cockshell and Michael Asten watch as Peter Elliott presides over the ASEG AGM on 29 April 2009.*

Fig. 2. *Peter Elliott hands over the presidential gavel to Michael Asten.*

selection of papers from most areas of geophysics but with the majority of papers coming from the oil and minerals industries. I congratulate the Chairman of the Conference Organizing Committee, Andrew Shearer, and the PESA Co-Chair Tony Hill, as well as members of the COC for a well organized and well run conference.

During the previous 12 months we have followed through on an innovation introduced by Joe Cucuzza during his term as President, which is a full business review of the ASEG, where it is at, and where we expect it to be in 5 years from now. During this process we critically looked at how to best serve our members and provide future guidance to succeeding Fedex committees. The world is changing and the ASEG has to change with it but this must be done in a healthy and sustainable fashion. The Business Review highlighted the strengths and weaknesses of the ASEG and as a result there have been additional management tools utilized to improve the administration and management of the society.

A possibility that will be considered during the coming months will be the employment of a full time Executive Officer. An Executive Officer would be responsible for the day to day running of the society and provide continuity between Federal Executive Committees. At present the ASEG depends largely on volunteers to run the society, and this has been adequate up until recent years. However, the ASEG has grown and the environment we operate in has become more complex and demanding on individuals. With increased legal responsibilities and an increasing number of activities it is essential that the ASEG moves towards a more professional style of management.

As a growing society, the ASEG has many opportunities in front of it. These include running a conference every 12 months; improving our professional education facilities along the lines of a DISC; running workshops more frequently; and generally providing better service to our members. The ASEG can also look at itself in a global context and increase its services to overseas members.

Due to robust membership renewals and a successful 20th Conference and Exhibition in Adelaide, the ASEG carries on into 2009 in a strong financial position.

Peter Elliott
Immediate Past President

Treasurer's annual report for 2009 AGM

Audited financial statements for the year ended 31 December 2008 for the Australian Society of Exploration Geophysicists are presented.

The financial statements refer to the consolidated funds held by the society as a whole, including the State branches. An audited version of the profit and loss statement and end of year balance sheet will be placed on the ASEG web site.

The society's funds are used to promote, throughout Australia, the science and profession of geophysics. In 2008 this was achieved by:

- funding the publications: *Exploration Geophysics*, *Preview*, and the *Membership Directory*;
- supporting the functions of State Branches;
- funding the national administration of the society;
- funding continuing education programs;
- provision of loans and grants for conventions;
- provision of subsidies for student members; and
- support for the ASEG Research Foundation.

The income statement for the year shows a loss of $74 901 after tax. The end of year balance shows a total equity of $726 414 as of 31 December 2008, compared to $801 315 to the end of 2007. The result is in line with the budgeted loss of $73 742 before tax. A budget loss is normal for a calendar year in which there is no conference.

The society's revenue source continues to be derived from:

- conferences and functions – $156 000 (93% of budget);
- membership subscriptions – $114 000 (97% of budget);
- publications advertising – $53 000 (67% of budget);
- interest from accumulated investments – $55 000 (121% of budget); and
- other income, including sponsorship and wine sales – $55 000 (168% of budget).

Some of the apparent publications low revenue may be related to the allocation of payments into 'other revenue' budget lines where no remittance advice was provided with payments. Overall the actual income for the year was 98% of the budget figure.

The major expenses for the society include:

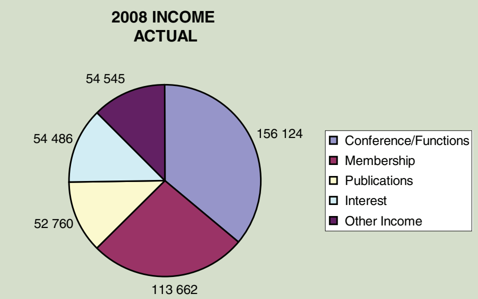
- publications – $215 000 (81% of budget);
- operational expenses of $110 000 (on budget);
- conferences and functions – $95 000 (140% of budget);
- secretariat fees – $57 000 (on budget excluding secretariat expenses); and
- other expenses – $6000 (near budget).

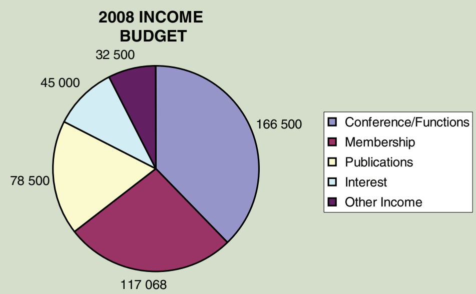
Publications expenses were significantly below budget figures largely due to no commission fees being taken as expenses (these being taken out of income prior to payment to ASEG) and web costs being $25 000 lower than expected (and included in operational expenses). Functions were under budget due to costs for the Distinguished Instructor Short Course being $11 000 less than expected. Conference costs exceeded budget by $13 000 due largely to higher than anticipated venue costs. However, there was significant inter-allocation of various expenses between conference lines and operational expense lines that made it difficult to reconcile with budget figures. Secretariat expenses were aggregated into operational expenses. There was no specific identification of wine offer expenses in the 2008 budget.

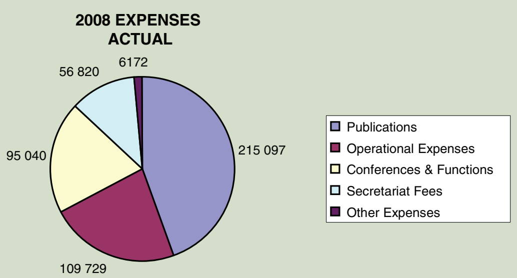
Even so, the overall expenditure was 94% of the budgeted figure.

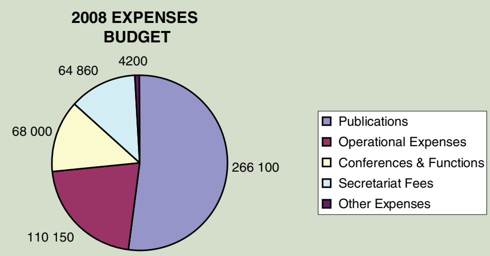
This difficulty of reconciliation of income and expenditure to budget lines was identified in the Wyndam Price review of the society, undertaken in 2008. A complete restructure of the 2009 budget and Chart of Accounts has been done to facilitate a better reconciliation of portfolio allocation and reporting. In addition, a cashflow has been developed for the 2009 budget. This should facilitate better financial management and reporting, also in line with recommendations in the Wyndham Price review.

Considerable effort was expended by the FEDEX committee in compiling a strategic financial model for the society









for a five-year period. This included two scenarios – one with an executive officer employed by the society and one with status quo. This modelling aimed at providing insight to potential for employing an executive officer for the society, in line with recommendations in the Wyndham Price review. The modelling has been most informative for consideration of the long-term viability and vitality of the society and key strategic issues that need attention.

At the AGM on 29 April there was a question about the security of the society's invested cash and the interest rate in light of the current economic environment. In response to this, the bulk of the society's cash is deposited in an investment trust that provides consistently higher rates of return than bank term deposits but with better access arrangements. The trust primarily deals with secured loans. Our secretariat advises that a number of similar societies also have cash reserves invested in this trust, and a continuous watch is kept of the trust's financial position in light of the interests of all these societies.

The society is in a sound financial position going into 2009. Continuous improvement in financial management is being undertaken to maintain/enhance this position for the benefit of the society and its members.

C. David Cockshell
Treasurer
29 April 2009

Adelaide conference a successful outing for the Research Foundation in a milestone year

In a year when the Research Foundation passed a milestone of over $500 000 in total outlays, we had a successful fund raising campaign at the recent Adelaide conference. The main activity was a raffle which raised $2099.85 and was drawn at the conference dinner. Congratulations to the winners who were as follows:

Prize		Winner
1st prize	Bottle of grange	John Perrella
2nd prize	Navman	Mike Hatch
3rd prize	1995 Penfolds	Jim Dirstein
4th prize	6 bottles Cockatoo Ridge wine	Steve Petrie
5th prize	6 bottles Cockatoo Ridge wine	Luke Gardner
6th prize	USANA nutritional supplements	Peter Elliott

There seemed to be a rather strong emphasis on the fruit of the vine in the prizes so I trust they were all suitably imbibed and enjoyed. Thanks to those who donated the prizes including the ASEG Federal Executive, Cockatoo Ridge Wines and John Waites for the USANA nutritional supplements which I am told are used by high performance athletes.

Once again this year I am grateful to Chris Nind of Scintrex for kick starting further fund raising at the conference dinner with $800. This led to further coercion and arm twisting by dinner hosts Barry Long and Nick Sheard helping to bring the total raised to $11 849.85.

Companies and individuals that contributed were:

Scintrex
Geotech
Velseis
Terex Seismic
Western
Geco
Carpentaria Exploration Limited
Geosoft Australia Pty Ltd
David Tucker
Kenmore Geophysical Consultancy
Beach Petroleum
Electro Magnetic Imaging Technology
Search Exploration Services Pty Ltd
Origin Energy
CG Anderson & Associates
Rio Tinto

The Research Foundation was established in 1989 by the ASEG for the specific purpose of providing financial support for field and laboratory work associated with research projects carried out as part of honours or post graduate studies. Since 1991 the Research Foundation has supported over 80 student projects in various universities in Australia with outlays totaling more than $500 000.

The Research Foundation can only carry out this work through the on-going generosity of the ASEG membership, both individual and corporate, the ASEG Federal Executive and other industry based donations. The importance of the funds raised at the conference should not be under estimated.

I would like to express my sincere appreciation to everyone that participated by buying tickets in the raffle and to the companies and individuals who showed additional generosity at the dinner. I would also like to thank Louise Middleton for her enthusiasm and commitment to the cause along with my fellow Research Foundation members.

Phil Harman, ASEG RF Chairman

Melbourne Mining Club to become a major supporter of the Research Foundation

The Melbourne Mining Club is to become a major sponsor of the ASEG Research Foundation by donating $20 000 per annum. The Foundation will support at least one project in a Victorian institution and the award will be co-branded between the Foundation and the Melbourne Mining Club. The prioritisation of projects and allocation of funding will be carried out through the Foundation technical committees.

The Melbourne Mining Club was founded in 2001 under the patronage of Sir Arvi Parbo to create a forum where industry participants, investors and related support sectors meet to discuss important contemporary issues. In particular it organises regular lunches where invited speakers are drawn from leaders of the mining industry. It also holds regular meetings, known as the Cutting Edge series, where junior mining and exploration companies have an opportunity to present an overview of their activities.

The Mining Club is a not for profit organisation that attracts financial support from a wide range of industry participants. Surplus funds are distributed to a variety of industry education foundations in Victoria.

The Melbourne Mining Club has been attracted to the ASEG Research Foundation because of its track record in supporting worthwhile activities and the disciplined process by which we assess and prioritise projects.

I am excited to welcome the Melbourne Mining Club as a major new sponsor.

Phil Harman, ASEG RF Chairman

For the record

With apologies to the ASEG Research Foundation, an error appeared on p. 14 of April's *Preview* (Issue 139). Since 1991 the Research Foundation has spent a total of $500 000 (not $50 000) supporting 80 research projects. For more information on the Research Foundation's activities, please read Phillip Harman's report in the Research News section of this issue.

News from the AGM

The Annual General Meeting of the ASEG held on Wednesday 29 April installed the new Federal office holders unopposed.

Michael Asten, President and Director
Phil Harman, President Elect and Chairman of the ASEG Research Foundation
David Denham, Secretary, Public Officer and Director
David Cockshell, Treasurer and Director
Koya Suto, Vice President and Chairman of International Affairs Committee

The full listing of the current Federal Executive is in the table below.

Under the Constitution, all State Branch Presidents also have right of attendance at Federal Executive Meetings as Observers.

Proposal for appointment of a CEO for the ASEG – adjourned

The motion

> *'That the Federal Executive Committee be given approval to proceed with the contracting of a full time or part time Executive Officer for the effective running of the Society's affairs.'*

attracted significant debate both before and during the meeting. Incoming President Michael Asten referred to an explanatory note emailed to all members prior to the meeting stating that while it was the recommendation of the Federal Executive to pursue the objective of appointing a CEO no appointment would be made without further discussion and consultation with State Branches.

After discussion from members on the merits and the timing of the proposal, by motion from the floor of the AGM the motion was adjourned. In consequence the Federal Executive will continue to consider options regarding such a position, with a view to bringing a new recommendation to the AGM in 2010.

Michael Asten
President

ASEG Federal Executive 2009–2010

President: Michael Asten
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New Members

The ASEG welcomes the following 42 members to the Society. Their Membership was approved at the Federal Executive meeting held on 26 March 2009.

Name	Affiliation	State	Membership Category
Michael Archer	QUT	QLD	Student
Katerina Baglay	BHP Billiton	WA	Associate
Paul Belfrage	Beach Petroleum	SA	Active
Volmer Berens	Department of Water Land and Biodiversity Conservation	SA	Associate
Andres Bona	Curtin University	WA	Active
Darren Braley	Adelaide University	SA	Student
Matthew Browne	Adelaide University	SA	Student
Michelle Byett	Curtin University	WA	Student
Luke Chadwick	Adelaide University	SA	Student
Mark Di Bacco	Santos Ltd	QLD	Active
Michael Edwin Glinsky	BHP Billiton	WA	Active
Benjamin Gluszkowski	Adelaide University	SA	Student
Jonathan Gorham	Curtin University	WA	Student
Benjamin Harrison	University of Melbourne	VIC	Student
Allen John Hundley	GeoSonics	NSW	Active
Anthony Hunt	Adelaide University	SA	Student
Ivor Hikuepi Kahimise	Ministry of Mines and Energy (Namibia)	Namibia	Associate
Jye Kluske	Adelaide University	SA	Student
Roy Lansley	Sercel Inc.	USA	Active
Maxim Lebedev	Curtin University	WA	Active
Jaime Lovell	Macquarie University	NSW	Student
Randy Luckiw	Conquest Seismic Services Inc.	USA	Associate
Patrick Lyons	Lincoln Minerals Limited	SA	Active
Daniel Marsh	Rio Tinto Ltd	UK	Associate
Martin Novak	Santos Ltd	SA	Active
Jacob Paggi	Lightning Nickel	WA	Associate
Stephane Perrouty	Toulouse University	France	Student
David Rowe	Western Geco	SA	Active
Malcolm Sambridge	Australian National University	ACT	Active
Harriet Schuyler	Adelaide University	SA	Student
John K Sinnott	Xstrata Nickel Australia	WA	Associate
Richard Fraser Smith	Technical Images Pty Ltd	SA	Active
Adrian Spizzo	Adelaide University	SA	Student
Antoinette Stryk	Monash University	VIC	Student
David Tassone	Adelaide University	SA	Student
Benjamin Turner	Dayboro Geophysical	QLD	Active
Rameshbabu Veldi	Dept of Atomic Energy	India	Active
Xubzn Wang	Chengdu University of Technology of China	China	Associate
Wendy Watkins	Origin Energy	QLD	Active
Nicole Amanda Williams	Energy Executives Pty Ltd	QLD	Active
James Wood	Resource Potentials	WA	Associate
Zhaofang (Jennifer) Zhu Zhu	De Beers Canada Inc.	Canada	Active

The ASEG congratulates the following four members whose Membership was upgraded to the status of Emeritus at the meeting of the Federal Executive held on 26 March 2009.

Name	Affiliation	State	Membership Category
Frank Lindeman	Retired		Emeritus
Markku Peltoniemi	Retired	OS	Emeritus
Keith Potts	Retired	SA	Emeritus
Chris Swain	Retired	WA	Emeritus

Phillip (Phil) Harman – President Elect

Phil Harman

I graduated from the University of Sydney, having completed my BSc Honours degree in 1971 majoring in geology and geophysics. The majority of my career has been with BHP (now BHP Billiton) in the minerals exploration group where I worked in many different roles, geological and geophysical, and locations. Since 2001 I have been involved with a number of small companies, most of which were founded to apply the FALCON airborne gravity gradiometer system in Australia. I have truly enjoyed every experience that I have had in this challenging industry, most particularly the colleagues I have worked with and friends I have made all over the world.

The early part of my geophysical career was dominated by an interest in the application of geophysics in coal mining, in particular the use of high resolution seismic reflection techniques for locating faulting ahead of underground mine workings. In the 1980s I was appointed (a tender-aged) Chief Geophysicist of BHP Minerals. This was the time when the development of computing power was gathering pace through the availability of relatively inexpensive (now very expensive) minicomputers and image processing systems.

In the late 1980s I moved to Perth as Exploration Manager for Western Australia. Then from 1992 to 1997 I was Manager Exploration for South America based in Santiago, Chile. These were exciting times working in a large globally integrated exploration group with high class professionals from every corner of the world. In the late 1990s the successful development of the FALCON system saw me involved in creating a business plan for its deployment and then leave BHP Billiton in late 2001 to set up Gravity Capital Limited to apply the technology in Australia.

I have been a member of the ASEG since its very beginning in Sydney when I was a student and Don Emerson said 'if you want to become a geophysicist join this'. I have always maintained a strong affinity with the organisation and with the life-long friends and colleagues that I have made though belonging to such an applied and industry oriented group of professionals. I have been Chairman of the Research Foundation for some years now and see it as a relatively low key but vital part of the ASEG's activities.

My career has spanned a time when exploration geophysics has grown up. In minerals the mistakes made during the 1960s nickel boom with techniques developed for application in completely different environments to Australia, saw the spawning of industry and government supported research programmes which have led to a greater understanding of the Australian regolith and the development of broad band geophysical methods designed to cope with these conditions. We have seen the results of this work truly come of age during the recent nickel boom where time domain EM was at the forefront of a host of new discoveries, twenty plus years after the first research projects were started. I doubt though whether standard discounted cash flow economics could justify the investment over the thirty years from research to success.

In the oil patch, the advancement of the industry to thousands of acquisition channels and the imaging capabilities of 3-D seismic has been nothing short of miraculous. This will need to continue if we are to meet the energy demands of the emerging world.

Nevertheless, although we have seen major strides made in the development of geophysical technology during the last 30–40 years, we now face new challenges. The world mining industry has been consolidated into a few major corporations with portfolios of projects made up from the fruits of the successful and long forgotten past explorers. The consequence is that the number of exploration groups with long term and committed backing has diminished. This affects the potential career prospects for young people entering our industry and also begs the question of who will be able to afford the commitment needed to make the more challenging discoveries of the future.

When I started in this business, geophysics was seen as the way of the future under cover. This remains the case but unless we challenge ourselves to see beyond our technology and place our anomalies in their geological context, and then effectively communicate the risk of exploring where there are no rocks to map at the surface and target rock sequences are below considerable thicknesses of cover, the investors whom we all rely on to back our efforts will be severely challenged and the future will be unrealised.

I look forward to my expanded role with the ASEG over the next three years.

Jack Bouska, SEG's Distinguished Lecturer for Spring 2009 visits Australia

Jack Bouska is the SEG's Distinguished Lecturer, Spring 2009. His itinerary runs from January to July and includes at least 34 official lectures in countries including India, UAE, Korea, Malyasia, Indonesia, USA, Bahrain, Saudi Arabia, Canada, Australia, South Africa, Japan and China. In Australia, the ASEG was fortunate to host presentations by Jack in Brisbane, Canberra, Adelaide and Perth.

Bouska speaks with a clear passion for seismic data. In fact, he declared at the opening of his presentation in Perth, 'Who here loves seismic? I love seismic!' As a geophysicist hailing from a minerals and environmental background I could not claim to love seismic, but I learnt a lot from Bouska's presentation. Part of the abstract for his talk states the following:

> *Years of seismic specialization among practicing geophysicists have segregated acquisition, processing, and interpretation into separate functions, which makes it difficult for any individual to treat the whole seismic process as a single integrated system.*
>
> *From experience, I have developed a sometimes elegant, occasionally cumbersome, but always effective methodology which assimilates the tasks of acquisition design, seismic processing, and interpretation into one coordinated procedure. Decisions regarding acquisition parameters, survey geometry, and processing flow must be driven by interpretation requirements. These choices are guided by analysis of acquisition and processing tests applied to existing data sets rather than the more common practice of simply replicating the parameters used on previous surveys.*

Fig. 1. *Jack Bouska presenting to the ACT Branch on 11 May 2009.*

Whilst the lecture was clearly about seismic data and directed to an audience literate in the art of seismic processing, some of the core messages have wider relevance. Bouska consistently comes back to the message that seismic surveys should always be about the geology. His presentation demonstrates that the spectrum of noise sources and the equivalent range of noise rejection techniques in seismic has resulted in a situation where surveys are often very good at measuring noise at the expense of the geology. He advocates an integrated seismic survey and interpretation methodology that ensures the mapping of the target geology remains paramount.

As geophysicists of any specialisation, it is sometimes easy to get caught up in the fine details and minute problems of a given survey technique. For the non-seismic geophysicists, Bouska's talk is a reminder to step back and look at the big picture. For the seismic geophysicists, it is packed full of detailed discussions about survey design and noise removal, some of it challenging standard seismic survey practices.

And why does Bouska love seismic? In his own words...

> *Early in each lecture, I pose a question: 'Who here likes seismic?' As you might expect, I invariably receive a flurry of raised hands in response. Naturally, I like seismic too, and for a variety of reasons: I enjoy hypothesizing about the reservoir geology, and I'm equally passionate about designing the best and most cost-effective acquisition experiment to image the subsurface. I'm also fascinated by working the data-processing and analyzing the images – for comparison against, and then revision of my original beliefs about the reservoir. In those two sentences, I'm really just describing a practical implementation of 'the scientific method' for seismic surveying. But those brief comments also succinctly illustrate my view on how acquisition, processing, and interpretation might be integrated in a single system to produce better seismic images within realistic budgets.*

If you were unable to attend one of Bouska's presentations, then the following key references might be of interest.

Bouska, J., 1997, Sparse 3D, What's in a Name?: http://www.cseg.ca/publications/recorder/1997/09sep/sep97-sparse-3d.pdf

Bouska, J., 2008, Advantages of wide-patch, wide-azimuth ocean-bottom seismic reservoir surveillance: *The Leading Edge* **27**(12), 1662–1681.

Bouska, J., 2009, Integrating seismic acquisition and processing: http://tinyurl.com/c6hr62 (SEG web feature focus article advertising the DL)

Bouska, J. and Johnston, R., 2005, The first 3D/4-C ocean bottom seismic surveys in the Caspian Sea: Acquisition design and processing strategy: *The Leading Edge* **24**(9), 910–921.

Information on the SEG Distinguished Lecturer program, Bouska's current tour, as well as past lecturers can be found at:

http://www.seg.org/SEGportalWEBproject/portals/SEG_Online.portal?_nfpb=true&_pageLabel=pg_gen_content&Doc_Url=prod/SEG-Education/Ed-Distinguish-Lect-Program/dlprogram.htm

The above link also has a download for the slide set from Bouska's lecture:

http://www.seg.org/SEGportalWEBproject/prod/SEG-Education/Ed-Distinguish-Lect-Program/Documents/Bouska_slides.pdf

Ann-Marie Anderson-Mayes

Australian Capital Territory

On 11 May, the ACT Branch, together with the local PESA branch, hosted the SEG Distinguished Lecturer for 2009, Jack Bouska. The talk was attended by around 35 people, several of whom travelled to Canberra from Sydney. After coffee and elaborate cakes, Jack presented his talk on 'Integrated seismic acquisition and processing'. His ideas on using processing strategy as a guide to the planning of seismic surveys certainly provided incentive to think beyond entrenched 'industry standards' in an effort to obtain better seismic reflection data at vastly reduced cost. After lunch in Manuka, Jack spent some time with members of Geoscience Australia's onshore seismic acquisition and processing team before being delivered to the airport for his flight to Adelaide and the 18th presentation of his DL tour.

Upcoming events for the ACT Branch include a student evening on 21 May, a talk on 17 June by Denis Shephard (former curator of a collection of geophysical instruments at the National Museum) and a possible talk on marine EM for gas hydrate characterisation by Karen Weitemeyer (Scripps Institution of Oceanography) on 24 June (subject to ship schedules). Our next SEG Lecturer, Andrew Long (South Pacific Lecturer), will be presenting at Geoscience Australia on 9 July.

Ron Hackney

New South Wales

In March, David Denham spoke about the four main parameters that govern life on Earth by humans. These are population, energy, food (including water) and climate. David spelt out that by the end of this century we will have too many people living on planet earth; we will have depleted much of our non-renewable energy resources; food and water shortages are likely to persist and the climate will change so that several of our main food growing areas will be less productive. There was a great deal of discussion throughout and after the talk, with the thought provoking presentation enjoyed by all.

In April, Peter Hatherly from the University of Sydney spoke about the Crandall Canyon Coal Mine collapse in Utah in 2007. Peter took us through the events that occurred before, during and after the collapse. Peter showed seismic monitoring results from the collapse that showed that the main Crandall Canyon seismic event and others that occurred during this time were indeed due to mine collapses. Peter also discussed the role for this technology in deep coal mining.

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 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 website.

Mark Lackie

Queensland

The Queensland branch held their April meeting at the Irish Club with Eric Battig presenting his Adelaide ASEG conference paper entitled '3D IP and Resistivity For Nickel Exploration: Case Study From Western Australia'. This was a great opportunity for those who couldn't get to the conference or missed the talk while in another session.

In early May we co-hosted the SEG Spring DL, Jack Bouska, with PESA. Jack presented both a three hour extended lecture and an hour long luncheon talk on techniques for integrating seismic acquisition and processing. Both events were extremely well attended with over 40 participants. Jack did a fantastic job and his willingness to also give the extended lecture was much appreciated.

Wayne Mogg

South Australia

The SA Branch held its AGM later than normal, giving the local members (and committee) a chance to recover from the ASEG 09 conference. At our AGM in early April, a new committee was voted in, with a healthy mix of new faces and old hands. The committee wishes to thank those moving on, especially Graham Heinson, for his long-standing role on the committee and amongst others, his efforts in rounding up students for local meetings over the years. Andrew Shearer is also taking a deserved break after his efforts as Co-Chair for ASEG 09 to make the conference as successful as it was. Jenni Clifford is replaced as Treasurer by Philip Heath, but we may see her back on the committee once her new arrival is settled.

Immediately afterwards Edyta Frankowicz from the Royal Holloway University of London presented 'Fault and Fracture Characterisation Using 3D Seismic Data' with interesting examples from the North Sea, Bass and Canterbury Basins.

In May the local committee hosted the 2009 SEG Distinguished Lecturer Jack Bouska for 'Integrating Seismic Acquisition and Processing', which was very well attended by petroleum geophysicists of all disciplines from the local exploration companies, regulatory body, service companies and consultants.

The SA Branch holds technical meetings monthly, usually on a Thursday night at the Historian Hotel, from 5:50 pm. New members and interested persons are always welcome. Please contact Luke Gardiner (luke.gardiner@beachpetroleum.com.au) for further details.

Luke Gardiner

News

Update on geophysical survey progress from the geological surveys of Queensland, Western Australia, Northern Territory and Tasmania and Geoscience Australia (information current at 15 May 2009)

Tables 1–3 show the continuing acquisition by the States, the Northern Territory and Geoscience Australia of new gravity, airborne magnetics and radiometrics, and airborne EM data over the Australian continent. All surveys are being managed by Geoscience Australia.

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Contractor	Start flying	Line (km)	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Cooper Basin North	GSQ	GPX	29 Sep 08	166 373	400 m, 80 m E/W	59 480	100% complete @ 12 Feb 09	Mar 09	134 – Jun 08, p. 22	15 Apr 09
Offshore NE Tas	MRT	Fugro	8 Dec 08	29 262	800 m, 90 m E/W	18 750	100% complete @ 29 Jan 09	Mar 09	137 – Dec 08, p. 23	26 Mar 09
Balladonia	GSWA	UTS	2 Dec 08 est.	43 449	400 m, 60 m E/W	14 960	100% complete @ 12 Jan 09	Feb 09	134 – Jun 08, p. 22	26 Mar 09
Esperance	GSWA	Thomson Aviation	19 Sep 08	82 674	400 m, 60 m E/W	29 200	100% complete @ 18 Dec 08	Feb 09	134 – Jun 08, p. 22	26 Mar 09
Cape York	GSQ	GPX	23 Apr 09	239 180	400 m, 60 m E/W	59 480	8% complete @ 10 May 09	TBA	139 – Apr 09, p. 21	TBA

TBA: to be advised

Table 2. Airborne electromagnetic surveys

Survey name	Client	Contractor	Start flying	Line (km)	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Paterson	GA	Fugro	8 Sep 07	28 367	1000 & 2000 m for GA 200 m–666 m company infill; 120 m; E/W & SW/NE North & South respectively of the Rudall River NP	33 950	100% complete @ 14 Sep 08 Recommence 27 May 08 after demobilising on 30 Nov 07	South Paterson, Jan 09. North Paterson Mar 09	130 – Oct 07 p. 30	Data for South Paterson released on DVD on 4 March 2009. Data for North Paterson released in DVD 17 April. All requests to the GA Sales Centre
South-West Catchment Council: Darkan – Wagin	GSWA DAFWA and SWCC	Geoforce	10 Jun 08	1127	300 m N-S	288.6	21 Jun 08	TBA	133 – Apr 08 p. 20	TBA
Pine Creek (Kombolgie)	GA	Geotech Airborne	21 Aug 08	9350	1666 & 5000 m for GA; 200 m–1000 m company infill; E/W flight lines; Flying height 30 m	30 710	100% complete @ 16 Oct 08	TBA	133 – Apr 08 p. 21	TBA
Pine Creek (Woolner & Rum Jungle)	GA	Fugro	11 Oct 08	20 825	1666 & 5000 m for GA; 200 m–1000 m company infill; E/W flight lines; Flying height 120 m	44 689	75.0% complete @ 10 May 09	Data acquisition resumed 15 April for completion by June 09	133 – Apr 08 p. 21	TBA

TBA: to be advised

Table 3. Gravity surveys

Survey name	Client	Contractor	Start survey	No. of stations	Station spacing (km)	Area (km²)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Westmoreland – Normanton	GSQ	Integrated Mapping Technologies	TBA	5977	4 regular	95 620	100% complete @ 17 Aug 08	Nov 08	133 – Apr 08 p. 21	Dec 08
Central Arunta	NT	Atlas Geophysics	6 May 08	9958 in Area A & a possible 1128 in Area B	4 regular with selected areas for infill at 500 m to 2 km	97 600	100% complete @ 7 Aug 08	Nov 08	133 – Apr 08 p. 21	Jan 09
Windimurra	GSWA	Atlas Geophysics	30 Jul 08	6066	2.5 km regular	~30 000	100% complete @ 17 Sep 08	Nov 08	135 – Aug 08 p. 16	Nov 08
Cunderdin	GSWA	Daishsat	28 Jan 09	10 744	50–250 m, 500 m, 2 km	22 500	100% complete @ 16 Apr 09	TBA	139 – Apr 09 p. 22	TBA
Cape York	GSQ	Daishsat	12 May 09	10 315	4 km regular	171 900	TBA	TBA	139 – Apr 09 p. 21	TBA
Barkly	NT	TBA	TBA	7268 in Area A & a possible 3875 in Area B	4 km regular	178 230	TBA	TBA	This issue	TBA
South Yilgarn Margin	WA	TBA	TBA	6500	2.5 km regular	39 240	TBA	TBA	This issue	TBA

TBA: to be advised

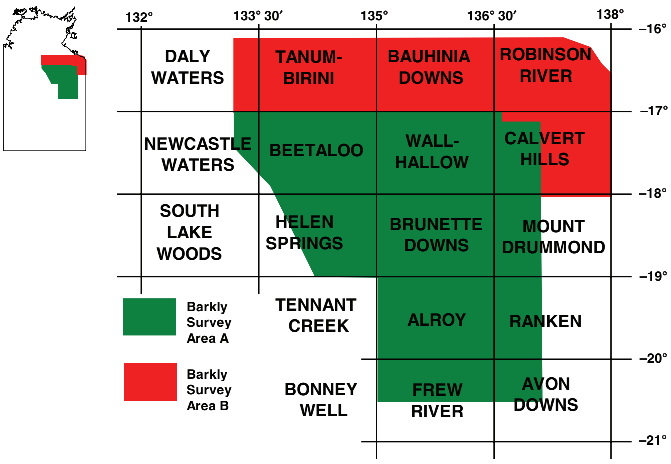

Fig. 1. *Location of the Barkly Gravity Survey (see Table 3 for details).*

There are two new surveys listed in this issue. The Barkly gravity survey (Figure 1) covers an area of ~178 000 km² with a regular 4 km grid, and the South Yilgarn Margin gravity survey (Figure 2) covers a smaller area of ~39 000 km² with a finer grid of 2.5 km. The latter survey is the first gravity survey funded under Western Australia's new Exploration Incentive Scheme, reported on p. 18 of this issue.

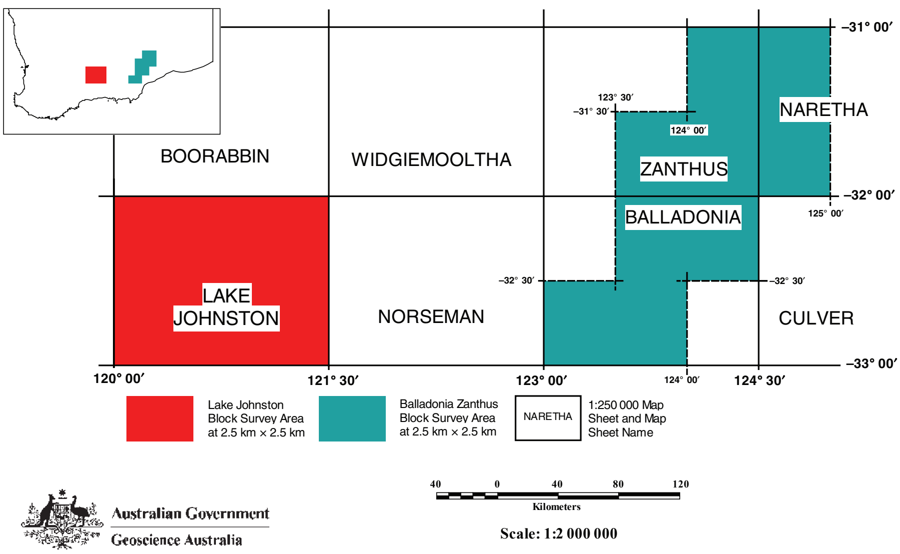

Fig. 2. *Location of the South Yilgarn Margin Gravity Survey (see Table 3 for details).*

$80 million over five years for Western Australia

The Exploration Incentive Scheme (EIS) is an $80 million initiative of the State Government of Western Australia, funded by Royalties for Regions over five years. Most of the activities in the EIS are focused in under-explored greenfield regions with the goal of encouraging continued exploration in Western Australia.

The EIS is made up of the following six programs:

- Exploration and Environmental Coordination ($1.5 million)
- Innovative Drilling including the Co-funded Drilling Program ($26.9 million)
- Geophysical and Geochemical Surveys ($32.5 million)
- 3D Geological Mapping ($13.8 million)
- Promoting Strategic Research with Industry ($2.3 million)
- Sustainable Working Relations with Indigenous Communities ($3 million)

It will be managed by the Department of Mines and Petroleum (DMP).

The geophysical and geochemical component of the programme is substantial and is divided into three areas.

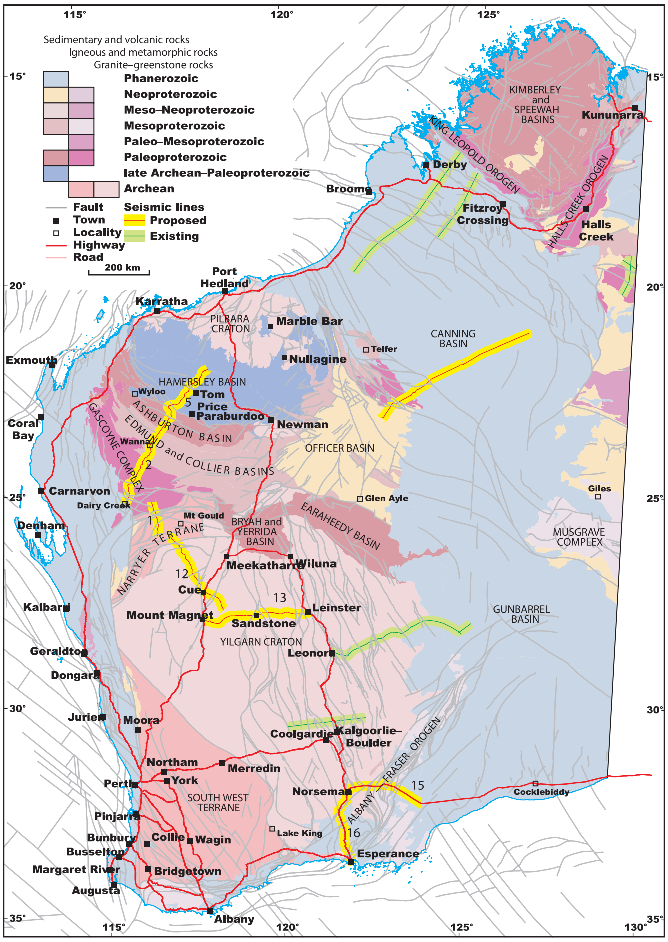

Fig. 4. *Planned deep crustal seismic traverses.*

Airborne magnetic and radiometric surveys

Prior to implementing the EIS, only 70% of the State was covered by medium resolution airborne magnetic and radiometric surveys. New airborne magnetic and radiometric surveys undertaken under the EIS will complete medium resolution airborne magnetics and radiometrics coverage of the State. Figure 3 shows the planned aerial survey coverage.

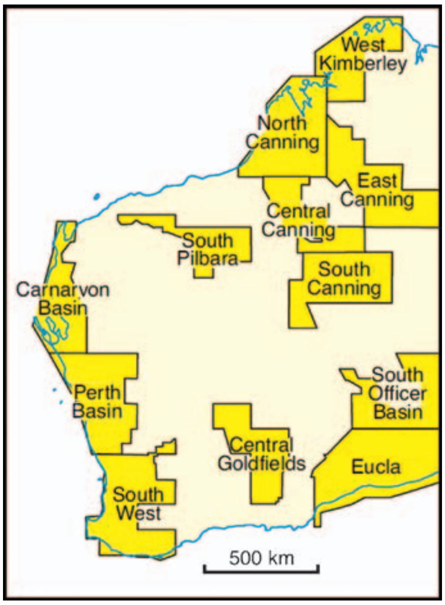

Fig. 3. *Planned airborne magnetics and radiometrics surveys.*

Deep crustal seismic traverses

Figure 4 shows the location of planned deep crustal seismic traverses. This activity, adding to a network of deep seismic traverses, will improve the understanding of the crustal structure of Western Australia. Integrated geophysical and geological transects across the West Australian, North Australian and South Australian cratons and their margins in Western Australia, as well as the intervening Neoproterozoic and Phanerozoic Basins, will provide a key to the geological evolution of the Australian lithosphere over the Earth's past 4 billion years. They will also provide an understanding of the crustal infrastructure hosting large mineral systems.

Regional gravity and geochemical surveys

The objective of implementing regional gravity surveys is to provide 3D geological information to complement GSWA's geological mapping programs in selected greenfield exploration areas. Regional geochemical surveys will provide multi-element geochemical coverage of under-explored parts of the Yilgarn Craton to stimulate mineral exploration. Data collected from the surveys will then be incorporated into GSWA's web-based geochemical database. Regional ground gravity surveys and regional geochemical surveys will be completed simultaneously when they cover the same geographic area. The first of the regional gravity surveys is in this program is the South Yilgarn Margin Survey shown in Figure 2.

More information about EIS can be found at www.dmp.wa.gov.au/EIS.

3D geological model management system for Geoscience Victoria

In an Australian first, Geoscience Victoria (GSV) and mining software and services company, Runge, have developed and implemented a new 3D geological model management system to seamlessly build, manage and distribute high-quality 3D models. The vision was to create a system that was the 'first point of call' for anyone building or requesting a model within GSV. The model would then be available for use both within and outside GSV, with appropriate security for confidential models that will only be accessible by authorised individuals.

GSV Director, Kathy Hill, said that GSV managed a huge amount of geological data collected by government and industry. Existing information management systems were simply not suitable for 3D data. Runge's Mining Dynamics software provided GSV with the appropriate suite of tools to manage 3D model data. Glen Kunz, Mining Dynamics Manager for Runge, said, 'We are pleased to support GeoScience Victoria's long-term strategy to represent the state's geology in 3D and to provide users, such as exploration companies, timely and visual access to geosciences information.'

GSV's long-term strategy, under the project title '3D Victoria', includes a plan to develop a sophisticated state-of-the-art 3D model of Victoria's onshore and offshore geology at a scale of 1:250 000 or better by 2012. Users are able to integrate and compare private project data with the '3D Victoria' data and then generate new images or numerical interpretations to download and take away. Add this to the 3D visualisation facility described in *Preview* 134 (June 2008) and GSV's 3D capabilities are looking very impressive.

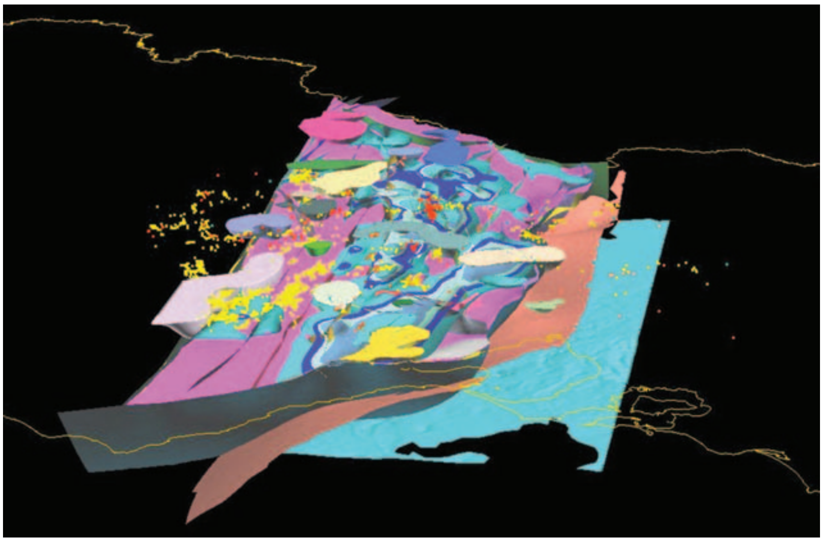

Fig. 5. *1:250 000 scale geology model of the Bendigo structural zone. This model shows the basement geology model including all known mineral deposits in the region (red dots = alluvial gold and gold dots = hard rock gold). The view is to the NNW. Image courtesy of Geoscience Victoria.*

The Bendigo Zone model (Figure 5) represents the first instalment in the '3D Victoria' program. The model is based on 1:250 000 scale serial cross-sections, and includes representations of topography, stratigraphy, fault geometries, cover thickness and the distribution of known ore deposits. The model is bounded by the Avoca Fault to the west and the Mount William fault to the east. It extends north under Murray Basin sediments to the Governor Fault and south to the Bambra Fault on the margin of the Otway Basin. The model was created using Intrepid Geophysics' 3D GeoModeller. The 3D GeoModeller software uses primary geological observations, stratigraphic relationships and a sophisticated 3D interpolation to build the 3D model.

For more information visit www.3dvictoria.dpi.vic.gov.au.

News from PIRSA

In May 2009 the annual South Australian Resources and Energy Investment Conference was again held at the Hilton Hotel in Adelaide. This conference coincided with 5 years of PACE – The Plan for Accelerating Exploration. Since the commencement of PACE in 2004 a number of geophysical surveys have been undertaken resulting in over 54 000 new gravity stations (from the Northern Olympic Domain, Stuart Shelf and Gawler Craton and Curnamona surveys) and over 70 000 line km of airborne magnetic and radiometric data (from the Tallaringa and One Tree surveys). Due to the success of this program PACE has been extended until 2011.

In late May to early June a ground streaming radiometric survey is being undertaken. It is anticipated that approximately 4000 line km of ground data will be acquired that will be used for improved levelling of airborne radiometric datasets in the Curnamona region. Currently there is over 20 000 line km of radiometric streaming data within South Australia and this data has greatly enhanced our ability to level the various radiometric datasets across the State.

Since 2008 over 500 km of seismic reflection data has been collected across the state in collaboration with Geoscience Australia, as part of their Onshore Energy Security Program, PIRSA and Auscope. Throughout the next 12 months these data will undergo extensive interpretation to improve our geological understanding and improve prospectivity in these regions. Parts of the Gawler-Officer-Musgrave-Amadeus line 08GA-OM1 will also be subject to drill-testing and petrophysical analysis.

Research towards 3D geology within the State is ongoing. Currently a petrophysical database is being compiled that will be used to feed into these modelling projects. Various techniques for incorporating magnetically derived depth to basement estimates with known drillhole depth values are being trialled to create better depth to basement maps for the State. New gradient string maps are also being created and investigated.

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TerraWulf II: Many hands make light work of data analysis

M. Sambridge, P. Tregoning, T. Bodin, H. McQueen, C. Watson and S. Bonnefoy

For more than 30 years geophysicists at the Research School of Earth Sciences (Australian National University) have been making use of large computers to analyse data recovered from seismic and other instruments deployed across the Australian continent. This began in the mid-1970s when then Director of the Research School of Earth Sciences (RSES), Prof. Anton Hales, was one of the first to recognise the potential of using computational power to perform the necessary calculations required to build the first depth varying seismic wave speed models of the Australian Lithosphere. In the days before the advent of national or even campus computing facilities, Prof. Hales established an in-house programme of building, running, repairing, patching, and ultimately coaxing the valve driven machines of the day into action. Since that time computational power and demand has grown exponentially, as has the diversity of applications (even within geophysics) that have made use of it.

In 2008, RSES launched the latest in a long line of dedicated computing facilities, TerraWulf II. As the name suggests, this is the second of its particular species. The first, built in 2003, capitalised on a worldwide trend of combining off the shelf PC computers to form a highly cost effective (BeoWulf) supercomputer. The second, TerraWulf II (or TII as it is known to users) has 10 times the compute power of TI (~1.5 Teraflops) and occupies one quarter of the room space. Its construction was a joint venture between ANU (through RSES) and AuScope Ltd (The Earth Science infrastructure initiative funded through the Federal Government's National Collaborative Research Infrastructure Strategy program). TII was designed primarily for use in earth imaging and geospatial applications however scientists are constantly finding new and innovative ways to exploit its power and convenience. For the technically minded the specifications of TII are summarised as follows: a cluster of 96 IBM x3455 compute nodes and one IBM x3655 head node. There are two AMD Opteron Dual-core 2.8 GHz processors per node, each with 160 GB SATA Hard Disk and 9 GB (or 17 GB for 24 nodes) DDR2 Memory. The communication network consists of Gigabit Ethernet with 48 nodes, also connected through higher speed Voltaire infiniband switches.

A key difference between modern computational clusters like TII and the earlier machines at RSES is the focus on parallelism. The increase in processing power of each generation of micro-processors has begun to slow down, however computational gains can still be made by combining multiple processors together to perform complex calculations. Hence the rise of parallel based clusters like TI and TII. The initial uses of parallel computers (more than 10 years ago) were largely in areas involving highly advanced simulations of physical phenomena, e.g. weather prediction, ocean modelling, mantle convection and seismic wavefield simulation through complex media. As a consequence, parallel computing facilities gained a reputation for being highly exotic and only for the specialised user. In recent times, this situation has begun to change, as the power of parallel computing has become accessible to a much wider range of scientists, even those without the interest in or need for advanced computational methods. A prime driver is the need to analyse data from large spatial arrays of instruments being used to build earth observing datasets, a task which is often particularly suited to parallelism. TII is increasingly being used for this type of 'loosely coupled' calculation.

An example is the geospatial scientist who has to perform the same processing tasks on many separate subsets of data independently (e.g. one analysis for

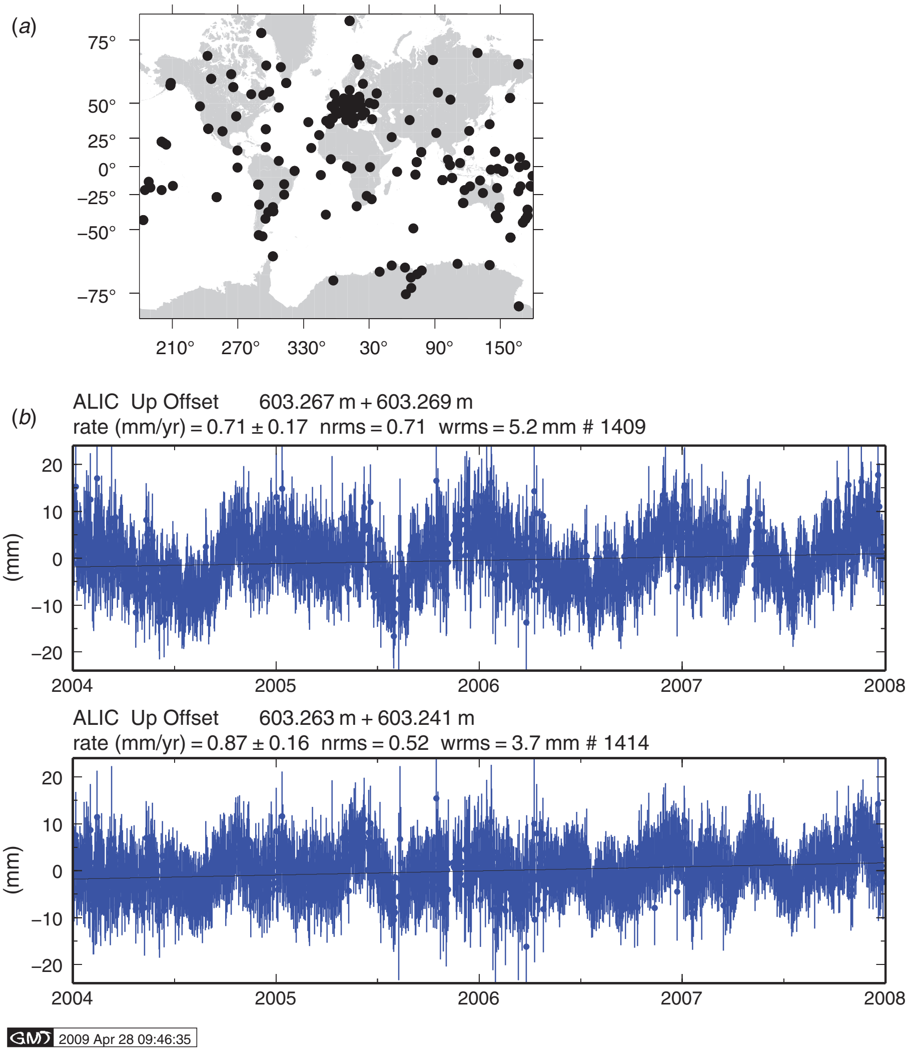

Fig. 1. *(a) Map of GPS site locations used in the analysis (left). The time series of the height estimate of the site at Alice Springs, NT, (b) from the original analysis (upper right) and (c) the refined analysis (lower right). The weighted root-mean-square of the daily height estimates has been reduced from 5.2 to 3.7 mm.*

each day of recorded observations). This is illustrated in the first example below. With a cluster of computers, each independent job is performed simultaneously in parallel meaning that the whole task can be achieved in a fraction of the time that it would normally take with single processor workstations. Another example is in the use of Monte Carlo based data inference (inversion) methods where many independent potential solutions to a problem need to be tested against the data, e.g. seismic models of the Earth interior fitting observed travel times or waveforms. This is illustrated in the second example below. TII has been used for both types of calculation, as well as the more traditional simulation of geophysical phenomena using advanced computational techniques. In its short life it has already racked up over seven hundred thousand cpu-core hours of use across applications ranging from earth imaging, geospatial analysis as well as simulation of geophysical processes from the Earth's surface to its core. In addition it has been used as a test bed to develop a new generation of data inference tools. We present two examples below of recent applications.

Assessing processing strategies in GPS analyses

The ability to estimate position using the Global Positioning System (GPS) has decreased from ~0.2 m in the 1980s to around 1–2 mm today. Recent improvements have resulted not only from an enhanced global tracking network but also from improvements in modelling of the propagation of the GPS signals through the atmosphere, deformation of the surface from atmospheric pressure loading and ocean tide loading (the increase/decrease in ocean and atmosphere mass causes elastic deformation of the surface of the Earth that can be detected in high-accuracy GPS analyses).

In a recent study utilising the TII, Tregoning and Watson (2009) analysed GPS observations on a global network of over 80 sites (Figure 1*a*). The analysis was performed using several different mathematical functions to represent

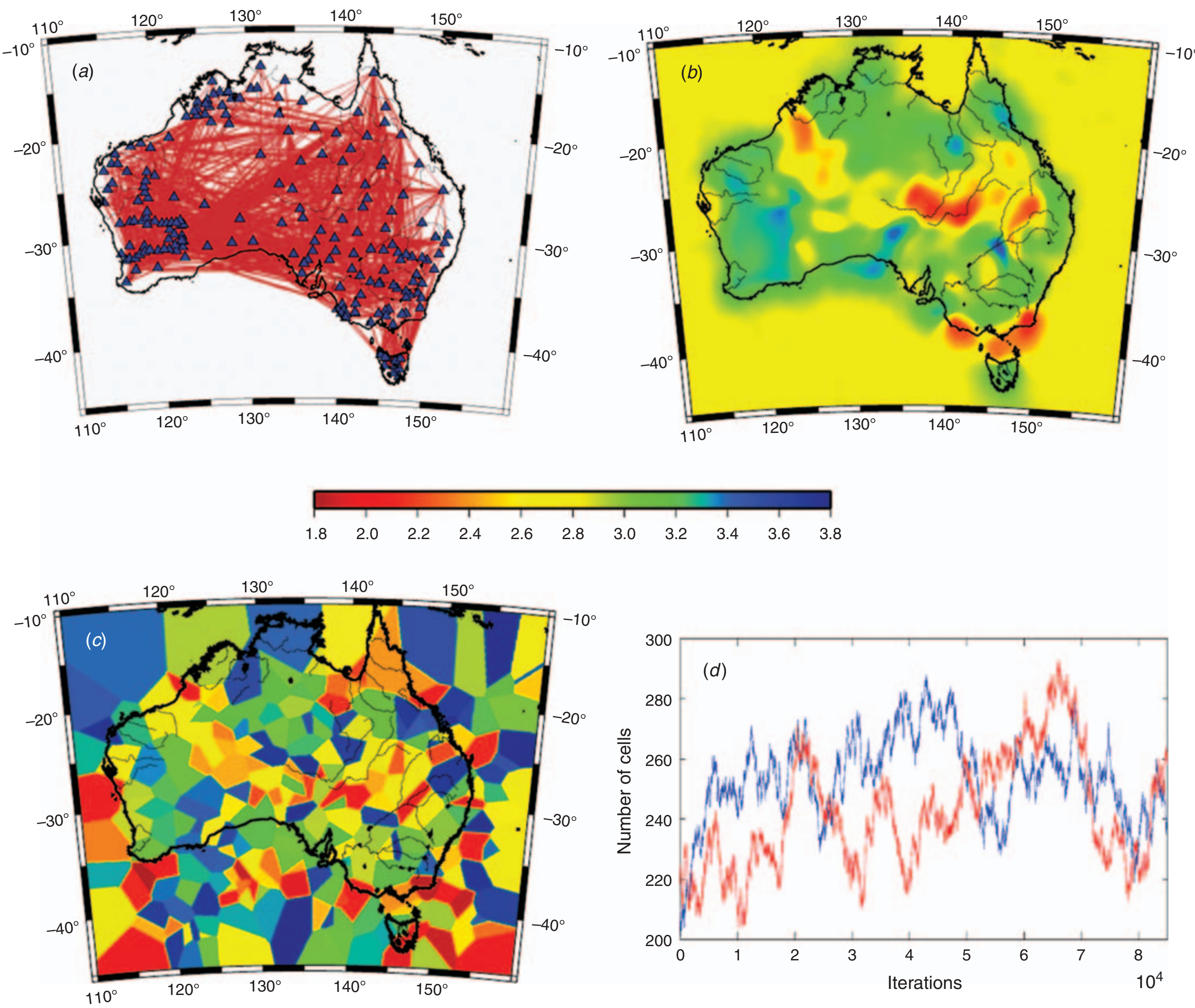

Fig. 2. *(a) Ray path density for 1158 rays in ambient noise dataset of Saygin and Kennett (2009). (b) Shear wave speed model produced by averaging 8000 models generated by the Bayesian Monte Carlo procedure, (c) best fit model obtained, (d) number of cells in the model as a function of iteration. Red and blue lines represent results from two of the 200 independent random walks through the model space.*

- the atmospheric delay at any angle,
- the *a priori* hydrostatic delays in the vertical direction, and
- different models for the atmospheric pressure deformation, including the once/day and twice/day atmospheric tides (which cause periodic deformation of up to 1.5 mm in height).

Eight years of data were analysed and the resulting time series of positions for each site were assessed in the time and frequency domains to ascertain which suite of models yielded the 'best' solutions. On a single CPU, the analysis undertaken in this study would have taken over 23 years to complete. Only the efficient power of the TII could enable such a study be contemplated seriously.

Figure 1*b* shows time series of height estimates at the GPS site near Alice Springs, NT, using processing strategies typical of the 1990s as well as those considered to be the most accurate today (Figure 1*c*). There is a clear decrease in coordinate variation, demonstrating that the new modelling techniques yield more accurate estimates.

Imaging the seismic structure of the Australian continent

Figure 2 shows results from a new Bayesian Monte Carlo seismic imaging procedure developed on TerraWulf II. Unlike standard approaches that gradually refine a single image of the Earth's interior, this new approach reported by Bodin *et al*. (2009) refines an ensemble of many potential solutions. Here ambient noise seismic data from Saygin and Kennett (2009) are used to generate an image of the Rayleigh wave group wave speed of the Australian upper crust. A unique feature of the process is that both the surface wave velocity and the underlying cellular parametrization are solved for simultaneously. Figure 2*c* shows the best data fit model, which is relatively crude, but the average of 8000 final Earth models (Figure 2*b*) shows detailed features that correlate well with surface geology. In this example 17 million different Earth models were tested against the data, a feat that is only practical when the computation is spread across 200 cores of TerraWulf II.

These examples show how cluster-computing facilities like TerraWulf II are becoming an invaluable tool to the geophysicist. Clusters have been proliferating in research institutions, business and industry in recent years and as more applications evolve we can expect demand for such facilities to increase in the future.

Acknowledgments

We thank Erdinc Saygin, Brian Kennett and Nick Rawlinson. Calculations were performed on the TerraWulf II cluster, a computational facility supported through the AuScope initiative. AuScope Ltd is funded under the National Collaborative Research Infrastructure Strategy, an Australian Commonwealth Government Programme. Use of TII is open to all members of the AuScope community. See http://rses.anu.edu.au/terrawulf for further details. Part of this project was supported through ARC Discovery grants DP0986750 and DP0665111.

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Saygin, E., and Kennett, B. L. N., 2009, Ambient seismic noise tomography of Australian continent: Tectonophysics, doi: 10.1016/j.tecto.2008.11.013.

Tregoning, P., and Watson, C., 2009, Atmospheric effects and spurious signals in GPS analyses: *Journal of Geophysical Research*, in press.

Research Foundation supports seven new projects in 2009

This year the Research Foundation received a total of thirteen applications to support new projects. Of these the Research Foundation committees have recommended seven. The following projects have been made offers:

In Petroleum:

- University of Queensland – BSc (Hons) – $4900
  'Optimization of sweep parameters and pre-correlation processing for Envirovibe seismic sources'
- University of Queensland – BSc (Hons) – $4900
  'Understanding very-shallow seismic reflection using acquisition modeling'
- University of Adelaide – David Tasson – PhD – $24 100 over three years
  'Uplift of the Otway Basin and implications for hydrocarbon exploration: integrating seismic with palaeoburial proxies'

In Minerals:

- Monash University – Brenton Crawford – PhD – $30 000 over three years
  'Defining the margins of Australia's ancient geological cratons from gravity and magnetic fields'
- University of Western Australia – Roger Clifton – PhD – $3000 over three years
  'Geophysical studies of the Kalkarindji flood basalts of the Northern Territory'
- RMIT University – Lachlan Hennessy – BSc (Hons) – $4900
  'Transform of coincident loop EM data to equivalent potential field responses'

In Engineering:

- Macquarie University – Jaime Lovell – BSc (Hons) – $4000
  'The usefulness of MASW in delineating soils'

Congratulations to the recipients and I wish them every success with their projects. We all look forward to hearing about the results at future ASEG conferences.

The work of the Foundation is only made possible through the generous support of the members of the ASEG, corporate memberships and donations, and the financial support of the ASEG Federal Executive.

Phil Harman
Chairman, ASEG RF Committee

Commodity prices volatile in 2008

Oil peaks, then drops like stone –

2008 will be a year to remember for the resource industries. Oil prices had a particularly interesting year. Figure 1 shows how rapidly the oil price rose to a maximum of ~$140/bl in July 2008 – doubling in about one year; and how the fall was even more dramatic. It took just five months to drop to US$41 by December 2008. By the beginning of 2009 the price had stabilised in the US$40–60 range but this is not encouraging in the short term given the increased costs in finding new oil.

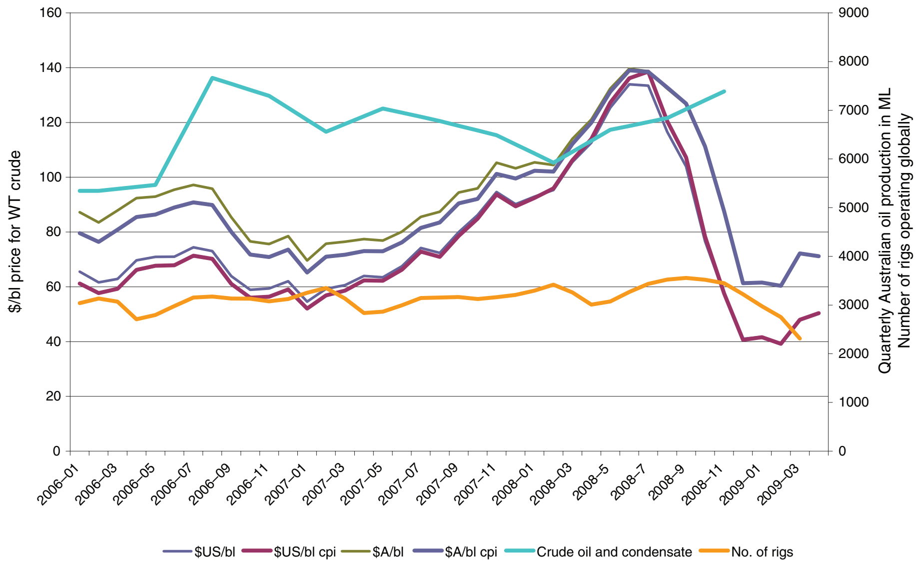

Fig. 1. *West Texas oil price in US$/bl and A$/bl, in both actual and CPI adjusted dollars (to March 2009); Australian oil and condensate quarterly production in millions litres and number of globally operated oil exploration and production rigs. The sources are: Oil prices: http://www.economagic.com/em-cgi/data.exe/var/west-texas-crude-long; Australian Oil production: http://www.abare.gov.au/publications_html/acs/acs_08/acs_08.html; Baker Hughes Rig Counts: http://investor.shareholder.com/bhi/rig_counts/rc_index.cfm.*

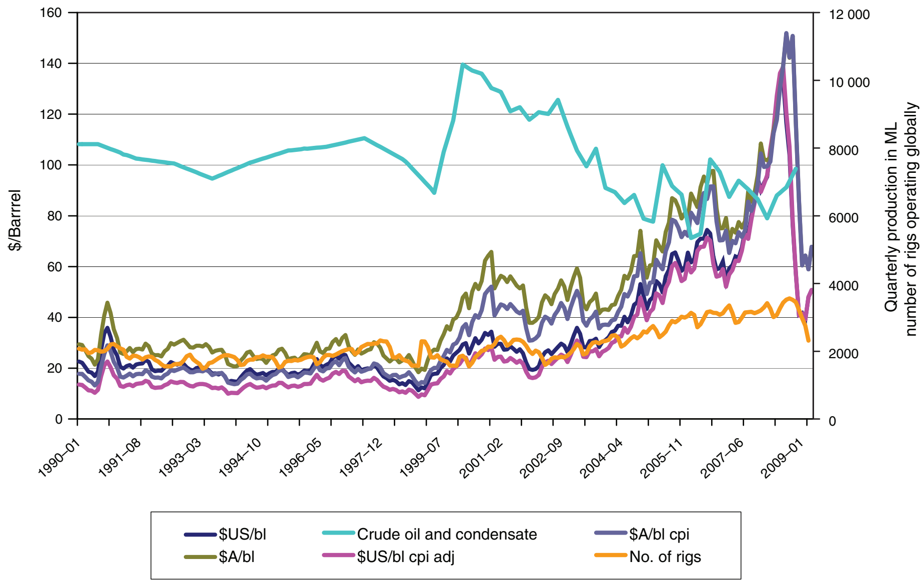

Fig. 2. *West Texas oil price in US$/bl and A$/bl, in both actual and CPI adjusted dollars (to March 2009); Australian oil and condensate quarterly production in millions litres and number of globally operated oil exploration and production rigs. The sources are: Monthly Oil prices: http://www.economagic.com/em-cgi/data.exe/var/west-texas-crude-long; Quarterly Australian Oil production: http://www.abare.gov.au/publications_html/acs/acs_08/acs_08.html; Monthly Baker Hughes Rig Counts: http://investor.shareholder.com/bhi/rig_counts/rc_index.cfm.*

One of the best indicators of the health of the petroleum exploration industry is the number of drilling rigs being used. According to the Baker Hughes Rig Count (http://investor.shareholder.com/bhi/rig_counts/rc_index.cfm) this reached an all time global record of 3417 in February 2008, only to fall to about 3000 at the end of the year. In March 2009 the number has dropped to 2313, which is the lowest since 2004.

The good news for 2008 was that Australian oil production increased by about 20% to over 7000 ML in the December quarter. This is still a long way from the peak of more than 10 000 ML produced in 2000 but at least the steady decline in oil production appears to have been arrested.

– but longer term trends are encouraging

The longer term trends on the same set of parameters provide a better picture of what has happened and what the future may hold in store. The oil price (in CPI adjusted terms) started to rise steadily in 1999; it had doubled in price by 2004 and by 2008 it had increased by a factor of six. At the same time the number of operating drilling rigs had increased from about 1800 to 3300. It is clear, just by looking at Figure 2, that the price rises were unsustainable and that a major correction would take place.

The number of rigs tracks the price very well but the Australian oil production is still down on the 2000 peak and is unlikely to climb to those levels again.

I think we can conclude from the longer term trends that the oil price will stabilize in the US$40–60 price range during 2009, before the inevitable gradual rise in the second half of 2010, as demand picks up. A major concern is how much the level of investment in exploration will be cut before the oil price increases significantly. We do not want to lose the human capital that has been invested recently into the service companies and major oil explorers.

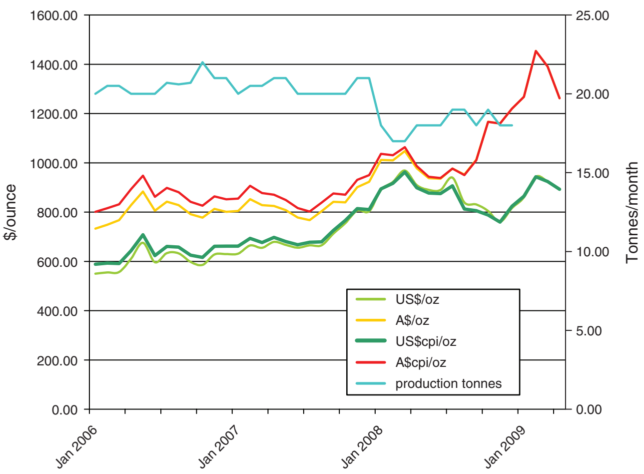

Fig. 3. *Gold prices in Australian and US dollars per ounce, both actual and CPI adjusted to 2009 dollars. Note how Australian and US dollar curves diverge in the second half of 2008. Also plotted is the estimated monthly gold production, interpolated from the quarterly published ABARE figures. The downward trend in Australian gold production continued throughout the year. Data obtained from the ABS, the RBA and the website: http://www.economagic.com/em-cgi/data.exe/blscu/CUUR0000AA0.*

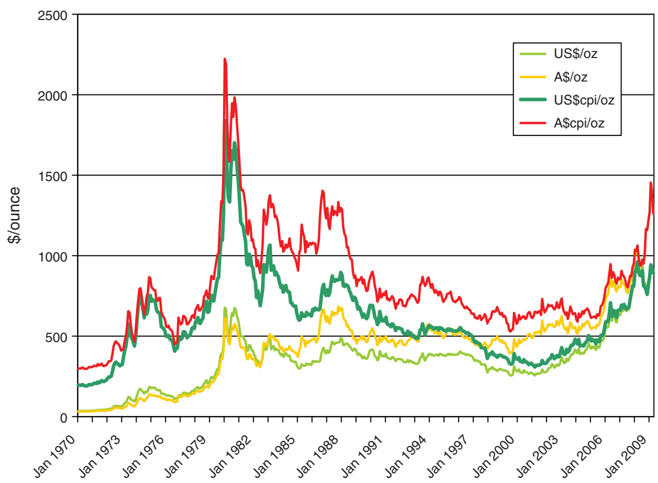

Fig. 4. *Gold prices in Australian and US dollars per ounce, both actual and CPI adjusted to 2009 dollars. Note how the price (in real terms) is well short of the values reached in the early 1980s. Data obtained from the ABS, the RBA and the website: http://www.economagic.com/em-cgi/data.exe/blscu/CUUR0000AA0.*

Gold prices hold firm but production falls

Gold prices remained strong during 2008 at an average price of about US$860/ounce (CPI adjusted to 2009 dollars). This was well above the 2007 average price of US$710/ounce, and as can be seen from Figure 3 the price has been comparatively stable over the past few years.

The main problem for Australian gold companies is that they have not been able to produce enough gold to capitalise on the market's strength. Annual production for 2008 was only 217 tonnes, compared to 245 tonnes in 2007 and the maximum of 313 tonnes in 1997.

There are therefore considerable rewards to be had for the discovery and development of new gold deposits and hopefully the gold explorers will keep investing in exploration. We've just got to find it! Figure 4 shows the longer term trends and indicates that in real terms the prices are well below the peaks in January 1980, when the price rose to US$1840 in March 2009 dollars.

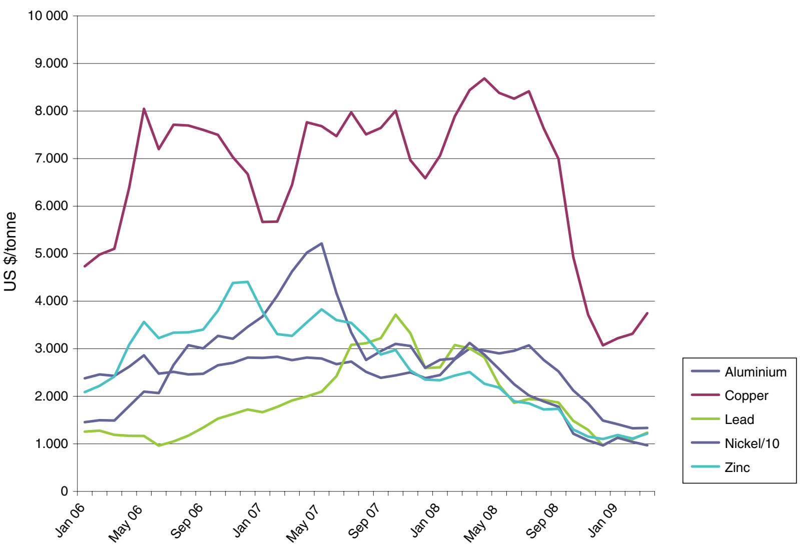

Fig. 5. *Metal prices for aluminium, copper, lead, nickel and zinc, in US$/tonne except for nickel, where the price is ten times the plotted value. Notice how the prices do not peak at the same time. Data obtained from the London Metal Exchange and ABARE.*

Prices fall for main non-ferrous metals

Figure 5 shows the recent price variations for five of the main non-ferrous metals. Interestingly the prices for each commodity peaked at different times. Aluminium peaked in July 08, copper in April 08, lead in October 07, zinc in December 06 and nickel in May 07.

By the beginning of 2009 the price of aluminium had fallen to 43% of its maximum value, copper to 38%, lead to 30%, zinc to 25% and nickel to only 19%. Fortunately prices appear to have stabilised but the nickel, zinc and lead producers are doing it tough. It looks like the troubles of the car manufacturers made ripples throughout the mineral exploration sector.

Let's hope that 2009 leads to recovery.

David Denham

Coal seam gas booms in eastern Australia

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Introduction

A decade ago a significant shortfall in gas supply was forecast in eastern Australia, herein defined as including Queensland, New South Wales, Victoria, Tasmania and South Australia. The rationale for this forecast was that producing conventional gas fields in the Cooper Basin of northeast South Australia and southwest Queensland, which supplied Adelaide, Brisbane and Sydney, had reached maturity, were in decline and would be unable to meet predicted demand. It was anticipated that the shortfall would be met by gas piped from existing fields in Bass Strait and by new production from gas fields discovered in the highlands of Papua New Guinea (PNG), delivered via a pipeline across Torres Strait. In the intervening period, gas for the Sydney market was delivered from Bass Strait. However, the advent of a new coal seam gas (CSG) industry in Queensland eliminated the predicted shortfall and obviated the need for supplies imported from PNG (Baker and Slater 2008). The main eastern Australian sedimentary basins targeted for CSG are shown in Figure 1, together with existing and planned gas transmission pipelines. At the end of 2008, certified 2P (Proven and Probable) reserves of CSG comprised 28 253 pentajoules (PJ) representing 60.2% of the known natural gas reserves in eastern Australia (Baker and Slater in press; Figures 2 and 3). This is a spectacular increase given that estimates of 2P reserves of CSG in the region were less than 5 PJ in 1996 (Figure 4). By December 2008, CSG production had risen from approximately 1 PJ per annum to 167 PJ a year (RLMS 2009). CSG now provides the major source of gas for the Queensland markets, increasing quantities are being piped to South Australia, with supplies to the Newcastle and Sydney market planned. Most importantly for the burgeoning CSG industry, significant exports as liquefied natural gas (LNG) are envisaged from the Central Queensland port of Gladstone. In this paper the history of the CSG industry in the region is reviewed, exploration and production methodology outlined, together with current production and reserves and future envisaged development.

History of the Australian coal seam gas industry

CSG, also known as mine gas, coal bed methane and coal mine methane, is methane that is adsorbed on to coal. It is simply natural gas produced from a non-conventional reservoir. Reduction of pressure causes methane to be released and gassy mines have been the scourge of coal miners since coal mining began. Initial attempts to utilise CSG were small in scale and focused on pre-mining drainage, with the methane produced used to power surface plants. In the USA energy shortages, substantial tax concessions and the proximity to gas distribution pipeline networks fostered the commencement of commercial production in 1982. By 1994 CSG production had become a major industry with production growing exponentially and reaching an annual production of 1800 PJ by 2004 (Davies and Day 2006). In Australia, notwithstanding differences in geology, drilling and completion techniques, pipeline infrastructure, market size and market maturity, the pattern of CSG industry development has been remarkably similar. This is particularly the case when the first five pioneering years of commercial production in the USA and Queensland is compared (Davies and Day 2006).

In Australia, the Bowen and Sydney Basins were the initial targets for CSG exploration, beginning with Houston Oil and Minerals Australia Limited's unsuccessful exploration drilling in the Bowen Basin in 1976. During the 1980s and early 1990s considerable effort and expense was incurred by major companies such as Conoco Australia Pty Ltd, MIM Holdings Ltd and Mitsubishi Gas Chemicals (Australia) Pty Ltd operating in the Bowen Basin; by Enron Corporation in the Galilee Basin; and by Amoco Exploration in the Sydney Basin. Limited exploration of the Clarence-Moreton Basin was also undertaken by Conoco and Seamgas Pty Ltd (a BHP Australia Coal Pty Ltd subsidiary). BHP also endeavoured to produce CSG commercially in both the Bowen and Sydney Basins, though their driver was primarily mine gas drainage to improve mine safety. None of their activities met with success, with several factors, including a poor appreciation of the local and regional geology, effect of stress regimes on coal permeability, inappropriate well completion methods, as well as cost contributing to the failure. This early unsuccessful phase is well documented by Riley (2004).

The first commercial production in Australia was achieved by BHP in February 1996 from within the Moura Mine Leases covering the Late Permian Baralaba Coal Measures of the eastern part of the Bowen Basin. Production averaged 4 terajoules (TJ) per day and was piped to Gladstone. This project is now operated by Anglo Coal (Moura) Ltd. Commercial production in the Sydney Basin began in April 2001, when Sydney Gas Ltd, which had been exploring Permian coals of that Basin since 1998, supplied CSG to the Sydney market.

During the 1990s, Oil Company of Australia (OCA) (now a subsidiary of Origin Energy Ltd) acquired Conoco's interests in the Moura-Dawson Valley area of the eastern Bowen Basin. The Baralaba Coal Measures in this area contain an aggregate of 30 m seams of coal with gas contents of 9–25 m^3/tonne on a dry ash free basis at depths of 300 m to 1000 m. However, permeability is adversely impacted by high compressive stress and mineralisation in cleats and fractures. Conoco's experience had demonstrated that concepts applicable under these conditions in the Black Warrior Basin in the USA were not valid here. OCA's focus on understanding the local geological setting and stress regime together with improvements in drilling and well completion and better cost control resulted in modest success with current estimated production of 5.5 PJ per year (Baker and Slater in press). Factors that reduce and/or destroy permeability in the Moura-Dawson Valley region continue to inhibit CSG production in the Gunnedah and Sydney Basins in New South Wales. The Moura-Dawson Valley operations are now owned by Anglo Coal (Moura) Ltd in joint venture with Mitsui Moura Investments Pty Ltd, with Molopo Australia Ltd holding a 50% interest in some areas.

Western areas of the Bowen Basin have proven to be more favourable for commercial CSG production. In 1989 at Fairview, Tri-Star Petroleum Pty Ltd identified the potential of the

Fig. 1. *Eastern Australian sedimentary basins showing gas transmission pipelines (after Baker and Slater 2008, fig. 1).*

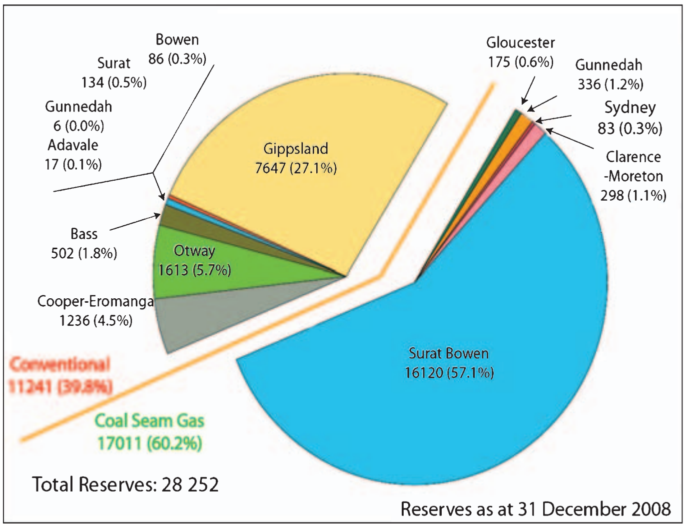

Fig. 2. *Eastern Australian gas reserves by sedimentary basin (source RLMS 2009).*

Comet Ridge which is characterised by low structural stress. At Fairview, the Bandanna Formation (a correlative of the Baralaba Coal Measures) has 5 m to 11 m of coal with high gas content (10–15 m^3 per tonne) at depths ranging from 500 m to 800 m and permeabilities exceeding 50 millidarcies. Production of the first sales gas occurred in 1996 when an estimated 1 PJ was produced that year. Fairview CSG Field has large reserves and is now jointly owned by Origin Energy Ltd (23.93%), Santos Ltd (36.07%) and PETRONAS (Petroliam Nasional Berhad) of Malaysia. The field was producing at an annualised rate of just over 26 PJ in 2008. Spring Gully Gas Field is a similarly large field that occupies the southern portion of the

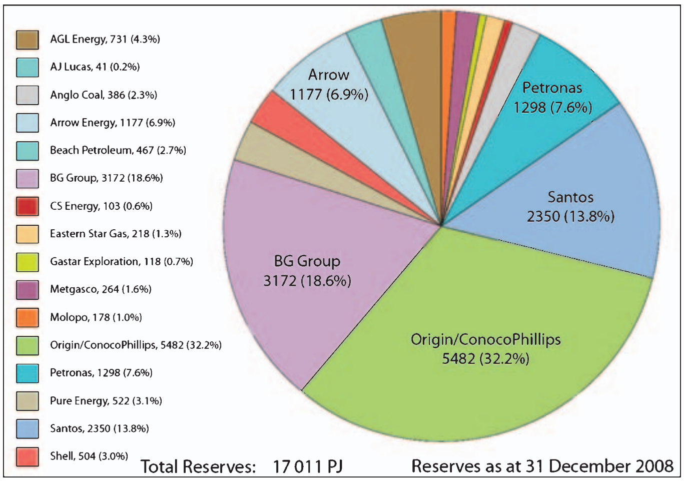

Fig. 3. *Eastern Australian coal seam gas reserves by company (source RLMS 2009).*

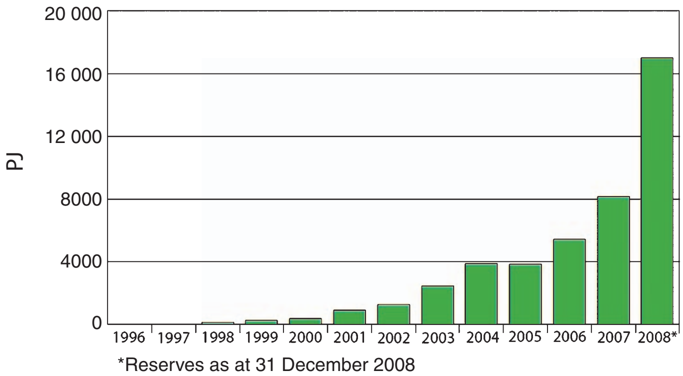

Fig. 4. *Coal seam gas reserves at 31 December 2008 (source RLMS 2009).*

Comet Ridge Anticline and shares the geological setting of Fairview. Origin is the operator and production from the field began in June 2005. To the east, coals of the Baralaba Coal Measures of Burunga Anticline are highly fractured and display good permeability. The Burunga Anticline hosts two large fields. Scotia in the north is owned by Santos and began production in May 2002. Peat CSG Field, to the south of Scotia, is operated by Origin and commenced delivering CSG to markets in February 2001.

In the northern Bowen Basin, the Late Permian Rangal Coal Measures (a correlative of the Baralaba Coal Measures and the Bandanna Formation) and the older Moranbah Coal Measures, German Creek Formation, Collinsville Coal Measures and more recently, the Fort Cooper Coal Measures have been explored for CSG. The main target has been the Moranbah Coal Measures which have 2 to 4 m seams with a net aggregate average thickness of 15 m of coal and good gas content at shallow depths around 300 m, although permeability is low to moderate. Initial exploration undertaken by North Queensland Energy Pty Ltd at Broadmeadow in the 1980s was unsuccessful, mainly due to low permeability. Like the eastern part of the Bowen Basin further south, the northern region is characterised by high stress and compressional faulting. Success was achieved at Moranbah by a joint venture comprising BHP Coal Pty Ltd and CH_4 Ltd, which adopted an innovative combination of in-seam horizontal and vertical drilling. Production began in 2005 with delivery to customers in Townsville via a 373 km pipeline built by the Queensland Government owned corporation Enertrade. The Moranbah project is now owned by AGL Energy Ltd and Arrow Energy Ltd, each with a 50% interest and the pipeline by the Victorian Funds Management Corporation.

The focus of the early CSG exploration in Eastern Australia was on the higher rank thermal and coking Permian coals of the Bowen and Sydney Basins which exhibited good gas contents. In this, companies were following the USA experience and insufficient attention was given to factors that impacted permeability, local geology, drilling methods and costs. However, by 2000 the local industry had addressed earlier shortcomings in their exploration strategy and methodology and significant CSG production was firmly established in the Bowen Basin. Attention then turned to the Middle Jurassic Walloon Coal Measures of the Surat Basin. Demonstrated success in CSG development in the Bowen Basin was partially responsible, but the major reason was the success of CSG production from low rank coals of the Powder River Basin in the USA, with the projected shortfall in supplies of gas for eastern Australia also a factor contributing to the initiation of CSG exploration in the Surat Basin. The first CSG well in the Surat Basin was drilled in 1995 (Day *et al.* 2006), but further exploration did not occur until 2000 when Origin Energy Ltd and two new public companies, Arrow Energy NL and Queensland Gas Company Ltd (QGC) took up permits. Success was achieved rapidly. CSG productive coals were found to have adequate gas contents ranging from 5 to 10 m^3 per tonne, at shallow depths (150 m to 600 m) and occurred in multiple seams aggregating up to 20 m in thickness (Day *et al.* 2006). Arrow Energy's Kogan North Field achieved the first commercial CSG production in January 2006, followed soon after by QGC's Berwyndale South Field, which delivered its first sales gas in May 2006 (Baker and Slater 2008). Exploration of the Surat Basin outlined a fairway favourable for CSG production from the Walloon Coal Measures. The fairway was defined by depth and gas content and extended from northwest of Roma in the west to south of Dalby (Day *et al.* 2006). Numerous CSG fields have been discovered within this fairway by Arrow Energy Ltd, Origin Energy Ltd, Santos Ltd, Bow Energy Ltd, and the companies recently acquired by the BG Group plc through its wholly owned subsidiary BG International (AUS) Pty Ltd (QGC Ltd, Sunshine Gas Ltd and Pure Energy Resources Ltd).

In the USA, the CSG industry in its formative years was reliant on substantial tax concessions. A similar, though more modest, assistance to the local CSG industry flowed from a Queensland Government greenhouse gas reduction strategy, which mandated that 13% of electricity sold in the State be generated by gas rather than coal (Queensland Government 2000). The policy led to new opportunities for gas sales in the dominantly coal-fired electricity generation sector. In southeast Queensland, CS Energy, a government owned generating corporation, entered into long-term contracts to buy CSG and assisted in funding the development of some CSG fields in the Surat Basin. In North Queensland, Enertrade, built the 393 km pipeline that enabled the Moranbah Project to deliver gas as a substitute fuel for diesel in power stations in Townsville. Without the stimulus provided by the Queensland Government policy, the projected shortfall in gas supply in eastern Australia would have been insufficient to give birth to a new industry. Other factors also contributed to the acceptance of CSG and its remarkably rapid growth in Queensland. These include the large size of the coal resources of the Bowen and Surat Basins, the optimum depth and gas content of the coal seams, and their proximity to existing natural gas pipelines. In addition to these attributes, the State's strong economic growth with its attendant energy demands resulted in the construction of a number of gas fueled peak-load power stations which were able to benefit from the curtailment of electricity generation by large coal-fired power stations reliant on water cooling, resulting from the prolonged drought in eastern Australia (Baker and Slater in press).

Exploration methodology

Draper and Boreham (2006) have documented the six geological controls that determine the suitability of Queensland Bowen and Surat Basin coals for CSG production. The key factors are:

- depositional environment,
- tectonic and structural setting,
- rank and gas generation,
- gas content,
- permeability, and
- hydrogeology.

These parameters vary reflecting the coals varied geological histories. Permian coal seams in the Bowen Basin are higher in rank, more laterally continuous and have greater gas contents than Jurassic coals of the Surat and Clarence-Moreton Basins. In the former, rank varies from vitrinite reflectance of 0.55% to above 1.1% Rv and from 0.35% to 0.6% Rv in the latter. CSG productive coals have high vitrinite contents usually exceeding 60% and are well cleated.

Exploration for CSG involves a combination of the methodologies of coal and petroleum exploration and in the Surat Basin, ground water production. As in all successful exploration, diligent preparation of a data base compiled from previous investigations is an essential prerequisite. Open-file results of previous exploration now available online are the starting point. Regional geological and geophysical studies, especially closely spaced airborne magnetic data, provide a good guide to structural and inferred stress regimes and faulting. Existing seismic survey data from petroleum exploration is invaluable, but specially commissioned seismic surveys for CSG are not a first option, because of cost in relation to the low prices received for gas. Compilation of a data base of relevant information from previous coal, petroleum and groundwater drilling is an important prerequisite.

Exploration drilling is the preferred initial stage because of the shallow depths of the targets involved. Anticlinal features or plunging noses are favourable sites for initial drilling as these are most likely areas of tensional stress, fracturing and attendant enhanced permeability. Seismic and magnetic data may prove useful in identifying pressure shadows associated with faulting. Drilling procedures are those adopted in coal exploration and indeed, the same slim-hole rigs are frequently used. If necessary, chip holes are drilled first to establish the presence, approximate thickness and extent of target coals, with core holes spaced as required to obtain coal cores for determination of coal properties, as is the case in coal exploration. To minimise formation damage, drilling of coal bearing sequences with air or water is preferred. Coals intersected are frequently drill stem tested to determine water production potential and estimate permeability. Flow injection tests may also be made to gauge permeability. A simple suite of wireline logs is run, including gamma ray and electric logs, although a wider range of logs such as acoustic scanning logs, which indicate fractures and stress, may be utilised. Selected coals intersected during coring are placed in sealed canisters on retrieval and their gas content and desorption rates recorded.

Once coal thickness, areal extent and gas content are ascertained, a volumetric calculation of estimated gas resource in place is possible. CSG pilot projects with 3 to 30 wells are necessary to evaluate the most prospective locations. These allow establishment of the feasibility of production, well spacing, appropriate well completion procedures, what measures may be needed to stimulate gas production and to obtain data for independent reserve certification. Vertical wells provide the cheapest option. Pilot and production wells are spaced 0.5 km to 1 km apart, are cased to just above the coal bearing production zone, and the well bore usually enlarged by under-reaming, before perforated or slotted production casing and down-hole pumping equipment are installed. Fracture stimulation or cavitation may be undertaken in areas of low permeability. An innovative combination of horizontal in-seam wells intersecting a vertical well was developed in the Moranbah Project (Matthew and Hogarth 2003) and is likely to have wider application elsewhere in regions with gassy but tight coals as in the Gunnedah, Sydney and Clarence-Moreton Basins.

CSG has more than 95% methane and requires little processing other than removal of minor inert gases (mainly carbon dioxide) and water. Isotopic studies show that CSG can have biogenic, thermogenic or metamorphic sources (Draper and Boreham 2006). In some cases, as in the Sydney Basin, CSG contains contributions from all three sources (Pinetown *et al.* 2008). Metamorphic methane is generated during coal formation. Biogenic gas is formed by methanogenic bacteria and occurs at depths down to 1 km. In the Surat Basin biogenic processes have enriched the gas content of coals in the Jurassic Walloon Coal Measures. Thermogenic gas is derived from volcanic activity and is prevalent in parts of the Sydney Basin.

Methane adsorbed onto coal requires a reduction in pressure to allow gas to flow. Gas production is achieved by pumping

Fig. 5. *Aerial view of Tipton West CSG Field showing dam for by-product water and compressors (Arrow Energy photo).*

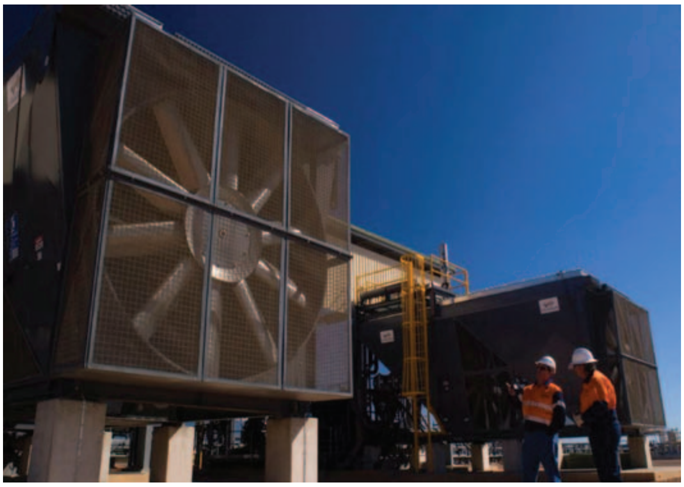

Fig. 6. *Compressors at Tipton West CSG Field (Arrow Energy photo).*

Fig. 7. *Well head at Tipton West CSG Field in sorghum field.*

water contained in the coal seams, although free gas in cleats and fractures is not uncommon. Some CSG fields produce little water while the Permian Scotia Field has no water production. In the Surat Basin, the coals act as aquifers and water production is substantial. CSG pilot wells need to achieve a certain level of gas production to be considered commercial and to enable reserve certification. By-product water must be contained in purpose built dams (Figure 5) as its salt content is too high for discharge into streams. Disposal of by-product water has become a significant issue (Baker and Slater in press). CSG is produced at low pressures and large compressors (see Figure 6) are needed to bring the gas to pressures needed for pipeline transmission. All gas and water production gathering lines are buried and the well heads have a minor ‘footprint’ (Figure 7). Untreated by-product water is brackish and has been used in coal-washery plants and some cattle feedlots and a range of aquaculture studies have been conducted (Day *et al.* 2006). Potable water can be produced by reverse osmosis and may be used for irrigation and to supplement town water supplies. In Queensland, by-product water production, storage and disposal is tightly regulated by the Environmental Protection Authority (Queensland Government 2008). Water production reaches a peak and declines as gas production increases, so the water resource has a finite life estimated to be 10–20 years. Additional production wells must be drilled to maintain gas production throughout the life of the field and this will prolong water production.

Current activities

Queensland is the centre of current CSG activities as existing fields expand and new projects are brought into production. At the end of 2008 the State was providing over 95% of the CSG output in eastern Australia (Baker and Slater in press). The major producing fields in the Bowen Basin are Moranbah, Fairview, Spring Gully, Peat, Scotia and the Dawson Valley near Moura. In the Surat Basin, Berwyndale South, Argyle-Kenya, Kogan North, Daandine and Tipton West are in production, while the Camden area is the producer in the Sydney Basin.

Moranbah CSG Project is a 50/50 joint venture between Arrow Energy Ltd and AGL Energy Ltd and is operated by Arrow Energy. Gas production began in February 2005 and currently stands at approximately 16.8 PJ per year from the Moranbah Coal Measures. Gas is piped to Townsville where it is used in power generation and by nickel and copper refineries. AGL also uses CSG in a small power station at Moranbah. Local gas consumption will rise when the Incitec Pivot ammonium nitrate plant is built there. Arrow Energy is actively exploring Permian coal measures in this northern region of the Bowen Basin in addition to those of the Moranbah Coal Measures. Present 2P reserves of 947 PJ of the Moranbah Project will increase significantly as a result. Arrow's future reserves will largely be dedicated to their Gladstone LNG project. A pipeline 450 km in length is planned to carry gas from Moranbah to Gladstone.

In the Dawson Valley where production from the Baralaba Coal Measures first began in 1996, the Anglo Coal/Mitsui Moura Investments/Molopo operations supply gas to the ammonia/ammonium nitrate plant of Queensland Nitrates Pty Ltd and to markets in Gladstone. Present 2P reserves are reported to be 386 PJ.

On the Comet Ridge, the Fairview CSG Field now operated by Santos Ltd on behalf of Origin Energy Ltd and PETRONAS began production in 1996. The Field now produces from the Bandanna Formation at an annual rate of almost 27 PJ (Baker and Slater in press). Fairview is linked to the Wallumbilla to Gladstone pipeline and separately to Wallumbilla. CSG production to date is mainly used in electricity generation. Production will increase substantially as new processing capacity is installed. Reserves are large but have not been reported separately by the operator. Fairview is likely to be a key CSG supplier to the proposed Santos-PETRONAS LNG plant in Gladstone. By-product water from these two fields is treated by reverse osmosis.

Further south on the Comet Ridge, the Spring Gully CSG Field, which is operated by Origin Energy, began production in 2005 and by 2008 production had reached 39 PJ per year. The field is undergoing expansion and production will increase substantially in future. CSG from Spring Gully is piped to Wallumbilla where the gas can be shipped eastwards to Brisbane or Gladstone or via southwest Queensland to Mount Isa and South Australia. A gas-fired power station is also planned at Spring Gully. As at Fairview, reserves are large but have not been reported separately. Conoco-Phillips has acquired a 50% interest in this and other Origin Energy CSG projects and an LNG export project in Gladstone is planned.

Origin Energy also has the Peat CSG Field on the Burunga Anticline which commenced production in 2001 from the Baralaba Coal Measures. Wells at Peat and Scotia CSG Field on the northern part of the Anticline produce little or no water. Current production is at the rate of 5.5 PJ per year and 2P reserves are estimated to be 38 PJ (RLMS 2009). A lateral line links Peat and the Scotia CSG Field to Wallumbilla to Brisbane pipeline. Gas-fired power stations provide the main market for their production.

CSG has been produced from the Middle Jurassic Coal Measures of the Surat Basin since 2006. The most productive fields are associated with the Undulla Nose where Origin Energy and the BG Group (which bought QGC) have interests. QGC's Berwyndale South Field, with daily production at the rate of 70 TJ per day is the most productive in the Surat Basin. This field supplies gas to the Swanbank Power Station near Brisbane and the Braemar Power Station near Dalby. At 30 June 2007 2P reserves stood at 385 PJ; they have since been upgraded but not reported separately. The Argyle-Kenya CSG Field discovered and developed by QGC, is now jointly owned by Origin Energy and the BG Group. As with Berwyndale South, upgraded 2P reserves have not been reported separately, but were 831 PJ (RLMS 2009). Gas from this field is contracted to supply the Incitec Pivot ammonia plant in Brisbane. Other QGC fields, Bellevue, Lauren and Codie near Berwyndale South are in the development stage. Additional exploration and appraisal work will be undertaken in connection with BG's planned LNG export facility in Gladstone.

Arrow Energy has three CSG fields in production – Kogan North, Daandine and Tipton West – with all production dedicated to electricity production. Kogan North is a 50/50 joint venture with the government owned corporation CS Energy, while the Shell Group has a 30% interest in all of Arrow's projects through the Shell–Arrow alliance. At 31 December 2008, Daandine, Kogan North and Tipton West have 2P reserves of 148 PJ, 84 PJ and 565 PJ respectively (RLMS 2009). Arrow has several additional projects in development, including Dundee, Stratheden, Longswamp and Meenawarra.

Elsewhere within the 'Walloon Fairway', more development will occur as projects are undertaken by Santos (Coxen Creek), Origin (Talinga) and the BG Group through their takeovers of Sunshine Gas Ltd (Lacerta and Polaris) and Pure Energy Resources Ltd (Cameron).

Other sedimentary basins in Queensland have attracted CSG exploration. They include the Permian-Triassic Galilee Basin, the Mesozoic Eromanga, Ipswich, Clarence-Moreton, Maryborough, Styx and the coastal Tertiary Coastal Basins. None have achieved commercial success to date.

In New South Wales, the Gloucester, Gunnedah, Sydney and Clarence-Moreton Basins are being actively explored for CSG. Commercial production has only been achieved in the Sydney Basin although there are projects with certified reserves in the remaining basins. In Victoria, results of CSG exploration have been disappointing, while in Tasmania, coals with promising permeability have so far had gas contents deemed insufficient for pilot production. In South Australia, coals of the Arckaringa Basin are being investigated for their underground coal gasification potential.

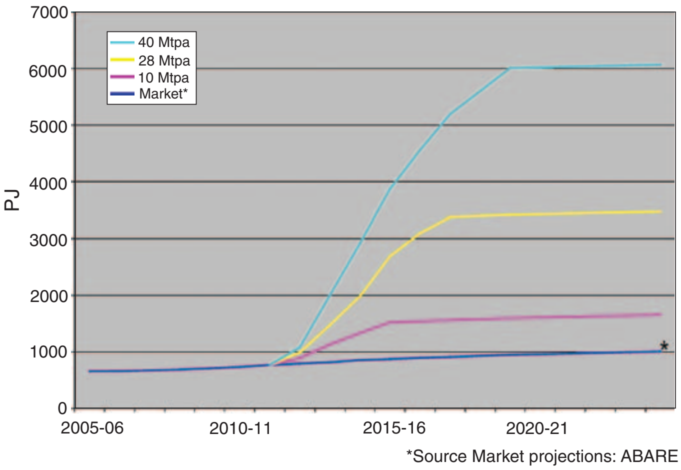

Fig. 8 *Forecast CSG growth projections to service a LNG industry (source RLMS 2009).*

Production and reserves

CSG production in eastern Australia began 13 years ago and has increased rapidly since 2000, with production doubling in 2008 (Figure 8). The eastern Australian market for gas at the end of 2008 is estimated to be 670 PJ per year (RLMS 2009) with CSG accounting for about 25% of gas sold in this market. In eastern Queensland, production is estimated at 164 PJ per year, with an additional 27 PJ piped to the Mount Isa region from the southwest of the State (RLMS 2009). Estimated daily CSG production from all Queensland fields during 2008 is 443 TJ, with 15 TJ per day produced by the Camden Project southwest of Sydney (RLMS 2009).

Figure 2 shows the size and distribution of independently audited proven (1P) and probable reserves (2P). These totaled 28 251 PJ at 31 December 2008, with CSG comprising 17 011 PJ or 60.2% of that total (RLMS 2009). Currently reported reserves of individual CSG fields have been presented previously. Five groups, Origin/Conoco Phillips, Santos/Petronas, Arrow/Shell and the BG Group held over 80% of the certified 2P reserves (Figure 3) at the end of 2008. Since that date further industry consolidation has seen Pure Energy Resources Ltd acquired by the BG Group and Beach Petroleum Ltd's interests bought by Arrow Energy. RLMS (2009) estimates that 2P reserves will exceed 25 000 PJ by the end of 2010 as 3P (proven, probable and possible) now estimated at 40 490 PJ, are converted to 2P. Four groups, Origin/Conoco Phillips, Santos/Petronas, Arrow/LNG/Shell and the BG Group through their wholly owned subsidiary QGC LNG Pty Ltd have proposals to produce LNG for export via the Central Queensland port of Gladstone. All of these may not proceed in their current form for a variety of reasons. Already LNG projects proposed by Sunshine Gas and Sojiitz and the Impel LNG are uncertain. However, drilling and development activities undertaken in connection with LNG projects will substantially increase CSG reserves.

Future developments

The pace of CSG development is accelerating and in the next year new Queensland production is anticipated from the Bellevue, Coxen Creek, Lacerta, Stratheden and Talinga CSG fields in the Surat Basin. In New South Wales, the Casino project in the Clarence-Moreton Basin and the Narrabri project in the Gunnedah Basin could be in production. New pipelines are planned to link Wallumbilla with Newcastle and Casino to Brisbane, thereby opening greater opportunities for CSG development in New South Wales.

Recognition of the size of the CSG resources in Queensland has attracted the attention of major international oil and gas industry companies such as Conoco Phillips, PETRONAS and Shell as well as the BG Group. Prior to that local companies were examining the feasibility of LNG production with a view to obtaining prices for gas that were more aligned to the prevailing world oil price. The price of gas used for electric generation is low by world standards as CSG in eastern Australia is in competition with coal as a fuel source and only gained market entry as a result of the introduction of greenhouse gas reduction initiatives in Queensland.

Proposals for export of LNG have gained momentum with the entry of the major companies mentioned above. CSG has not been utilised on such a scale and significant challenges lie ahead. Approximately 65 PJ of raw CSG has to be produced to provide 1 million tones of LNG for export (Baker and Slater in press). The smallest proposal, that of the Arrow led group, envisages an LNG plant at Gladstone producing 1.5 million (MM) tonnes per year. Origin-Phillips, Santos-PETRONAS and the BG Group all plan separate, larger, notional 3.5 million tonne per year processing trains in Gladstone. Baker and Slater (in press) estimate that LNG production of 40 MM tonnes per year would require the drilling of about 20 000 wells per year over a 20 year period. Not all LNG projects will proceed as planned for commercial and logistic reasons. Also governmental approval and environmental requirements will have to be addressed. Notwithstanding these issues, the CSG industry stands to grow enormously in the coming few years.

Acknowledgements

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The author has been an active participant in the development of the CSG industry. He became a Director of Arrow Energy NL in 1998 soon after the formation of that company and saw it move from fledgling explorer to significant player in the industry. In 2006 he resigned from Arrow and became Chairman of Pure Energy Resources Ltd until this company's success led to its acquisition by the BG group in March 2009.

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The search for cosmic magnetism

Bryan Gaensler

Magnets are everywhere, but we don't know how they got here

The Earth's magnetic field is not just a curiosity or a handy navigation aid but is vital for the existence of life. The Sun continually generates a stream of high-energy charged particles that flow out in all directions as part of the solar wind. Exposure to this particle stream can cause serious damage to living tissue; any humans who one day travel to Mars will need heavy shielding around their spacecraft to protect them from this onslaught. However, we experience no such ill effects on Earth because these particles are deflected and diverted by the Earth's magnetic field. The only place these particles approach anywhere near the Earth's surface is near the north and south poles where they fluoresce in the atmosphere and generate the aurorae.

Several other planets in the solar system (most notably Jupiter and Saturn) are also magnetic, as is the Sun itself. The Sun's magnetism is responsible for a whole range of phenomena, such as sunspots, solar flares and coronal mass ejections. On average the Sun's magnetism has about the same strength as the Earth's, but in sunspots the magnetic field is about 1000 times higher.

Ingenious techniques have allowed astronomers to also study magnetism in other, much more distant stars. In some cases the presence of strong magnetic fields is inferred indirectly, by observing 'star spots', 'stellar flares' and other energetic activity analogous to what we see up close for our own Sun. For other stars we can detect and study magnetic fields directly because the light travelling to us from the star is slightly distorted as it passes through the magnetism on the star's surface. Just in the last ten years, a new class of stars, 'magnetars', has been discovered – these bizarre beasts are only about 25 km across and appear to be the most magnetic objects in the Universe, with magnetic fields up to a quadrillion (1 000 000 000 000 000) times stronger than the Earth's![1]

Magnets in space

The sky seems full of magnets. Where does this magnetism come from?

Although the rotation of a star can amplify an existing magnetic field in the object's interior, this can only work if one starts with some weak initial magnetism. This presumably was present when the star first formed. Since we know that stars form out of collapsing gas clouds, this means that the gas in interstellar space must be magnetic also.

This was spectacularly verified in 1949, when two American astronomers, John Hall and Albert Hiltner, independently discovered that the light from some stars was linearly polarised. This was unexpected, because starlight, like most naturally occurring light sources, was expected to be unpolarised. Hiltner and Hall clearly showed that this was not the case: if starlight is supposed to be unpolarised, then something must be polarising the light on its journey from the star to our telescope.

It was quickly realised that this must be the result of interstellar magnetism. Space turns out to be quite dusty, and most dust particles in space are not tiny spheres, but are elongated, like tiny grains of rice. In the presence of magnetism, these dust grains act like tiny compasses, and line up with the direction of the magnetic field. When starlight then passes through a region filled with these aligned dust particles, most polarisation angles are absorbed or scattered, and the light that emerges is polarised at the angle that the dust lets through. Detecting polarised starlight therefore tells us that there must be invisible magnetic fields between the star and us. And what's more, the angle of polarisation tells us the orientation of the aligned dust grains, and hence the direction of the field. Although this explanation seems a little contrived, it has been confirmed by the fact that the more dust is in front of a star, the larger fraction of that star's light is seen to be polarised.

Hiltner and Hall's pioneering measurements have now been repeated for more than 10 000 stars all over the sky. In the same way that sprinkling iron filings over a magnet on a bench top reveals the pattern of its magnetic field, starlight polarisation has allowed us to build up a picture of the magnetic field in our Milky Way. If we could somehow step outside our Galaxy and look down on it from above, the Galactic magnetic field might look something like what is shown in Figure 1: each spiral arm can be thought of as a curved bar magnet, with one pole near the centre of the Galaxy and the other pole at the outer tip. This beautifully ordered pattern seems to be the form that magnetism takes in many other spiral galaxies too. These magnetic fields are very weak – about one millionth the strength of the Earth's. But because of the vast volume they encompass, a massive amount of energy is required to create and sustain them. Standard theories suggest that, just like for the Earth's magnetic field, this galactic magnetism is the result of a rotating dynamo, and that it has taken billions of years for these magnetic fields to gradually take shape.

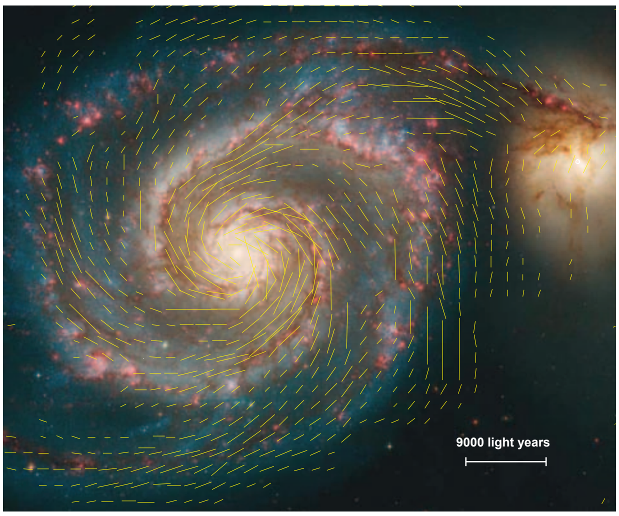

Fig. 1. *Hubble Space Telescope image of the spiral galaxy Messier 51, with the direction of the magnetic field superimposed. Viewed from above, the magnetic field of the Milky Way probably has a similar appearance. Credit: Hubble Heritage/NASA/STSci, Rainer Beck/MPIfR. Graphics: Sterne und Weltraum.*

[1]In comparison, the most powerful magnet ever constructed in the laboratory produces a field that is a mere million times stronger than the Earth's.

A magnetic mystery

It is remarkable that magnetism is so pervasive in the Universe. If you drop a fridge magnet on the floor a few times, it quickly loses its magnetism. Similarly, all the dramatic explosions and collisions that galaxies experience as they evolve should serve to quickly tangle and destroy their magnetism before it can accumulate appreciably. And yet galaxies like the Milky Way are clearly magnetic. What is going on?

The first thing to examine is whether violent episodes indeed destroy a galaxy's magnetism. We set out to test this by looking for magnetism in the Large Magellanic Cloud (LMC), a small galaxy in orbit around our Milky Way, at a distance from Earth of about 170 000 light years. As shown in Figure 2, the LMC and its companion, the Small Magellanic Cloud, are slowly being torn apart by the gravity of the Milky Way. The violent battering that the LMC is experiencing should ensure that even if it had a magnetic field at some point in the past, it probably doesn't have one now.

To study the magnetism of the LMC, we utilised an obscure effect discovered by English physicist Michael Faraday over 150 years ago. Faraday discovered that under certain conditions, polarised light will have its angle of polarisation rotated as it passes through a region in which magnetism is present. And the stronger the magnetic field, the more rotation is produced.

If we study the polarised radio signals produced by distant galaxies, we can see this 'Faraday rotation' effect, produced as the signals pass through clouds of foreground magnetised gas as shown in Figure 3. To study the magnetism of the LMC, we took this phenomenon to its extreme: we found about 300 very distant galaxies behind the LMC, and measured the polarisation and Faraday rotation of each. This allowed us to map out what magnetism might be present in this nearby galaxy. To our surprise, we found that the LMC has quite a strong magnetic field, and that this field is beautifully ordered into a spiral pattern, just like in our own Galaxy. This simply should not be the case – any magnetism that the LMC might have been able to build up over billions of years should have been destroyed as our Galaxy gradually tears its companion apart. The implication is that magnetism in galaxies must be generated very rapidly: at the same time as the Milky Way disrupts the magnetism of the LMC, the LMC must be regenerating new magnetism to replace it. Since most galaxies throughout the Universe are undergoing some sort of violent interaction (and indeed our own Milky Way has had many such encounters in the past), the conclusion is that magnetism is something that galaxies can create very quickly (relatively speaking!), in 100 million years or less.

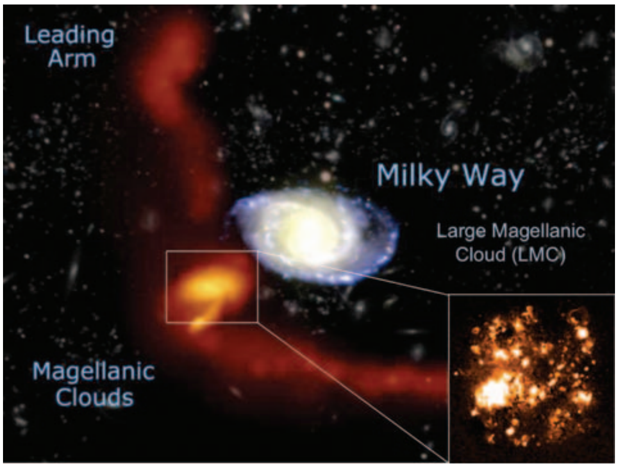

Fig. 2. *Simulation of the Large and Small Magellanic Clouds in orbit around the Milky Way. The Milky Way's gravity has stripped long streams of gas from the two smaller galaxies. Inset: detailed map of hot gas in the Large Magellanic Cloud. Credit: Main image: Daisuke Kawata, Chris Fluke, Sarah Maddison and Brad Gibson, Swinburne University of Technology, Australia. Inset: The Southern H-Alpha Sky Survey Atlas, supported by the National Science Foundation.*

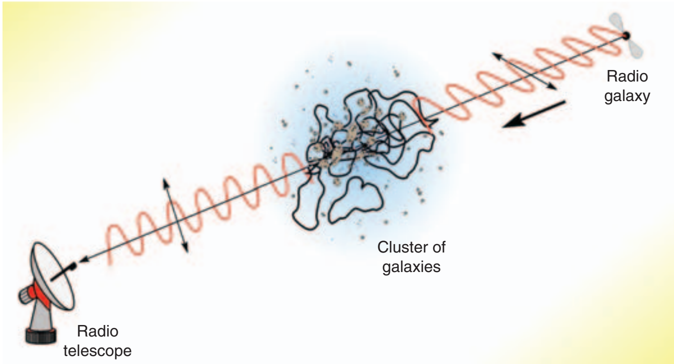

Fig. 3. *When the polarised radio emission from a background galaxy passes through a foreground cloud of magnetic gas, the emission undergoes Faraday rotation. This effect can be detected with a radio telescope and can be used to measure the strength of cosmic magnetic fields. Reprinted with permission from 'Intergalactic Magnetic Fields' by Philipp P. Kronberg,* Physics Today, *December 2002, p. 40. © 2002, American Institute of Physics.*

This supposition has recently been confirmed by a different set of experiments in which Swiss and American teams have measured the magnetism in galaxies that are billions of light years away. As the speed of light is finite, looking out into space is also looking back into time. These distant galaxies are thus much younger than our Milky Way and we can use them to see how magnetism in galaxies has changed over time. Measurements of background polarisation for these younger galaxies has shown that they too are magnetic, and that this magnetism is just as strong, billions of years ago, as we see in our neighbourhood. Once again, this contradicts the simple idea that the magnetism we see in galaxies today has grown slowly to its present strength over billions of years. Some as yet unidentified process allows magnetism in galaxies to grow very quickly.

Cosmic magnetism with the Square Kilometre Array

There is clearly something fundamental that we are not understanding about where magnetism comes from, and how it evolves as galaxies evolve. The problem in making further progress is that measuring these weak magnetic fields is difficult and time-consuming – the 300 measurements of Faraday rotation that we carried out through the LMC took about 1000 h of observations with one of the world's most powerful radio telescopes.

Motivated by this puzzle of cosmic magnetism, along with several other fundamental unsolved problems, a new generation of radio telescopes is now taking shape, culminating in the largest telescope ever conceived, the Square Kilometre Array (SKA).[2] The SKA will have such exquisite sensitivity that

[2]For more information, see www.skatelescope.org and www.ska.gov.au.

every inch of the sky will be filled with distant polarised radio sources. Thus for any galaxy at all, in any direction and at any distance, we will always be able to measure the effects of Faraday rotation as this background polarised light passes through it. This will give us a spectacular census of magnetism in galaxies of all types and of all ages, with which we hope we can finally determine how magnetic fields emerge, evolve, and perhaps are also destroyed.

While we eagerly await the results of the SKA, it is important to realise that the great leaps forward in the study of magnetism will not come simply from collecting magnetic galaxies, like stamps in an album. We know from studying the magnetic field of the Earth and the Sun that when viewed in detail, magnetism can be unbelievably complicated and dynamic. Or to quote the astronomer Lo Woltjer, 'The larger one's ignorance, the stronger the magnetic field!' We are only now beginning to appreciate the major role that magnetism plays in many of the most complicated and perplexing processes in astrophysics and cosmology. So when we begin to open the window to the 'Magnetic Universe' with the SKA, it is virtually certain that we will find many remarkable and unexpected phenomena. These new discoveries will undoubtedly provide the answers to many long-standing problems, but at the same time they will raise a new set of magnetic mysteries for the next generation of astronomers to puzzle over.

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Does magnetism matter?

The discovery that interstellar space is magnetic was unexpected and remarkable. But is this just a piece of cosmic trivia, or is magnetism an important part of the big picture?

It turns out that many previously unsolved problems in astronomy suddenly make sense once one includes the effects of interstellar magnetism. As far as life on earth is concerned, probably the most crucial role magnets play in space is in the formation of new stars. The Sun and our solar system formed 5 billion years ago in a dark cloud of interstellar gas, which gradually became hotter and denser as it collapsed under its own gravity. But under the influence of gravity alone such clouds would collapse too rapidly to form stars like the Sun. However, we now realise that the strong magnetic fields present in these clouds resist the force of gravity and slow down the collapse enough that stars can form in the way we expect. If it were not for cosmic magnetism, our Sun and its planets would never have come into existence.

A similar problem applies to the entire Milky Way Galaxy. Viewed from the side, the stars and gas in our Galaxy form a circular disk that is about 100 000 light years across, and a few thousand light years thick. If we calculate the gravity of all the material in this disk, we find that the disk should collapse down on itself until it is paper-thin. However, this doesn't happen – something is holding up the gas and keeping it floating thousands of light years above the centre. We now believe that this is the result of magnetic pressure, which provides the buoyancy needed to keep the Galaxy 'inflated'.

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August			**2009**
16–19 Aug	AAPG/SEG/SPE Hedberg Research Conference http://www.aapg.org/education/hedberg/vancouver/index.cfm	Vancouver	Canada
24–28 Aug	11th International Congress of the Brazilian Geophysical Society http://congresso.sbgf.org.br	Salvador	Brazil
September			**2009**
7–9 Sep	EAGE: Near Surface 2009 http://www.eage.org	Dublin	Ireland
13–18 Sep	2009 SAGA Biennial Technical Meeting and Exhibition http://www.sagaonline.co.za/2009Conference/index.htm	Mbabane	Swaziland
15–16 Sep	3rd Faroe Islands Exploration Conference 2009 http://fiec.jf.fo/	Tórshavn	Faroe Islands
October			**2009**
12–14 Oct	9th SEGJ International Symposium http://www.segj.org/is/9th	Sapporo	Japan
25–30 Oct	SEG International Exposition and 79th Annual Meeting http://seg.org/meetings	Houston	USA
November			**2009**
15–18 Nov	EAGE: Subsalt Imaging Workshop http://www.eage.org	Cairo	Egypt
December			**2009**
14–18 Dec	American Geophysical Union, Fall Meeting http://www.agu.org/meetings	San Francisco	USA
February			**2010**
1–3 Feb	8th International Conference and Exposition on Petroleum Geophysics http://www.spgindia.org	Hyderabad	India
March			**2010**
7–10 Mar	GEO 2010: 9th Middle East Geoscience Conference and Exhibition http://www.eage.org	Manama	Bahrain
April			**2010**
5–8 Apr	EAGE: Saint Petersburg 2010 http://www.eage.org	St Petersburg	Russia
11–15 Apr	SAGEEP 2010 http://www.eegs.org	Keystone	Colorado
June			**2010**
14–17 Jun	72nd EAGE Conference and Exhibition incorporating SPE EUROPEC 2010 http://www.eage.org	Barcelona	Spain
August			**2010**
8–13 Aug	2010 Meeting of the Americas http://www.agu.org/meetings	Iguassu Falls	Brazil
22–26 Aug	ASEG–PESA: 21st Conference and Exhibition http://www.aseg.org.au/Events/Conference	Sydney	Australia

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