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PREVIEW

AUSTRALIAN SOCIETY OF EXPLORATION GEOPHYSICISTS

NEWS AND COMMENTARY

FEATURE ARTICLES

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Surface EM and MMR Surveys

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PREVIEW

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FRONT COVER

Geothermal drilling rig at St Hilda's Anglican School for Girls, Perth, WA (image courtesy of the WA Department of Mines and Petroleum).

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Ann-Marie Anderson-Mayes

Welcome to a special issue of *Preview* focussed on geothermal energy. This issue developed out of the inaugural West Australian Geothermal Energy Symposium (WAGES) held in Perth in March of this year. The ASEG was a major sponsor for the symposium, and thus we decided to put together this issue to give all members a taste of the topics covered. I would particularly like to thank three members of the WAGES Organising Committee who helped me with this issue: Mike Middleton (WA Department of Mines and Petroleum), Associate Professor Klaus Gessner (University of Western Australia) and Mark Ballesteros (Conference Chairman).

WAGES has a fairly broad remit with conference topics ranging from geothermal exploration right through to geothermal applications. It is designed to bring together people from all sectors of the geothermal industry, and to increase public awareness of the opportunities to use geothermal energy, particularly in Western Australia. The articles in this issue include a Guest Editorial from John Lund, keynote speaker at WAGES, and a conference summary from Mark Ballesteros, the Conference Chairman. There are then four short feature articles. Klaus Regenauer-Lieb *et al.* discuss the ARRC/Pawsey Centre Geothermal Project in WA; Alison Kirkby describes the ground source heat pump system, which operates at Geoscience Australia; Ameed Ghori describes prospective basins for geothermal energy exploration in WA; and Supri Soengkono *et al.* describe some case studies of geophysical exploration of shallow warm water systems in New Zealand.

Some of these articles contain no geophysical content at all, but I hope after reading them that you have a little more information about geothermal exploration, some of the ways that geophysics is being applied in geothermal studies, and the exciting developments in direct use geothermal applications. It is perhaps these developments that will drive interest in geothermal exploration into the future.

Among all this geothermal content you will find all the usual news and contributions. In particular, there is lots of news in Geophysics in the Surveys, and the Data Trends column makes for fun and interesting reading. Also, on p. 9 you will find details on the nomination process for the ASEG Honours and Awards for 2012. Nominations close on 15 December 2011.

Finally, if you take notice of the fine print on the first page you will have noticed that *Preview* has a new Production Editor. Helena Clements was Production Editor for Preview from Issue 138 to Issue 151, and I would like to offer her my warmest thanks for doing a great job with *Preview*. On the last issue, Helena handed over to new Production Editor, Helen Pavlatos. Welcome Helen to the *Preview* team!

John W. Lund
Emeritus Director of the Geo-Heat Center
Oregon Institute of Technology, Klamath Falls, Oregon, USA

Geothermal energy has many facets and many applications. As the industry develops and expands into new countries it will be beneficial for governments to be aware of what has (and what has not) been effective elsewhere so that any barriers associated with the regulatory and legislative environment can be minimized.

Geothermal projects have certain characteristics that must be addressed in order to be successful. The project development depends on the type and characteristics of the geothermal resource. The higher temperature resources are best used for power generation, the intermediate temperatures ones for direct-use, and the normal ground or groundwater temperatures for geothermal heat pumps. Certain barriers need to be overcome for each project including: determining the resource characteristics, land ownership, permitting, environmental requirements, financing, obtaining the necessary expertise and equipment, having a market for the products, having access to transmission lines or pipelines, and obtaining public acceptance. For a project to be successful it is necessary to have a dedicated leader ('hero') who can provide the time and energy, often unpaid, to coordinate the activities.

Geothermal policy and development in the United States

Geothermal policy in the United States and in the various states, define a geothermal resource as either mineral, water or *sui generis*. The Federal Steam Act of 1970 set leasing requirement and royalty payments for developments on federal lands. Subsequent federal programs such as the Public Utilities Regulatory Policy Act, the Production Tax Credit, the Geothermal Loan Guarantee Program, the User Coupled Confirmation Drilling Program, the Program Research and Development Announcement, the Program Opportunity Notice, and the American Recovery and Reinvestment Act (ARRA) have helped to reduce the risk of project development and assisted with project financing. State programs such as the Renewable Portfolio Standards and the Renewable Energy Credits ('Green Tag') have helped local projects with financing and costs. Task Ordering Agreements and Technical Assistance by the Geo-Heat Center have helped implement direct-use projects. However, variations in funding from the US Department of Energy and changes in policy with the Department of Energy, along with leasing problems on federal lands have somewhat hindered development of geothermal power generation projects in the United States.

At present, the installed capacity for power generation in the United States is 3048 MWe with a total running capacity of 2024 MWe producing approximately 16 603 GWh per year for a 0.62 gross capacity factor and a 0.94 net capacity factor. The majority of the difference between the installed capacity and the running capacity is due to the loss of steam pressure in The Geysers. Geothermal electric power plants are located in California, Nevada, Utah and Hawaii with recent installations in Alaska, Idaho, New Mexico, Oregon and Wyoming. The two largest concentrations of plants are in The Geysers in northern California and the Imperial Valley in southern California. The Geysers continues to receive waste water from Clear Lake and Santa Rosa, California that is injected into the field and has resulted in the recovery of approximately 200 MWe of power generation. The lowest temperature installed plant is at Chena Hot Springs in Alaska, where binary cycle plants use 74°C geothermal fluids to run three units for a total of 730 kWe (gross). With the recent passing of the production tax credit by the federal government (US 2.0 cents/kWh) and renewable portfolio standards requiring investments in renewable energy, the annual growth rate for electric power generation over the past five years is 3.7 percent.

The direct utilization of geothermal energy includes the heating of pools and spas, greenhouses and aquaculture facilities, space heating and district heating, snow melting, agricultural drying, industrial applications and ground-source heat pumps. The installed capacity is 12 611 MWt and the annual energy use is 56 552 TJ or 15 709 GWh. The largest application is ground-source (geothermal) heat pumps (84% of the energy use), and the next largest direct-use is fish farming and swimming/spa heating. Direct utilization (without heat pumps) remained static over the past five years with gains balancing losses; however, ground-source heat pumps are being installed at a 13% annual growth rate with one million units (12 kW size)in operation.

The energy savings from all geothermal energy use in the United States is about 7.3 million tonnes of equivalent fuel oil per years (48.5 million barrels) and reduces pollution by almost 6.6 million tonnes of carbon and 18.8 million tonnes of carbon dioxide annually (compared to fuel oil).

Status of worldwide geothermal direct-use development

Direct utilization of geothermal energy consists of various forms for heating and cooling instead of converting the energy for electric power generation. Direct utilization of geothermal energy has been documented in 78 countries, and the estimated installed thermal power is 48 500 MWt producing 423 800 TJ/year (117 700 GWh/year) of thermal energy with an annual compound growth rate over the past five years of 9.2%. The largest growth has been in space and district heating, and in pool and spa heating. The equivalent annual savings in fuel oil (compared to electricity), amounts to 131 million barrels (19.8 million tonnes) and 17.5 million tonnes in carbon emissions to the atmosphere. Equipment types used in geothermal direct-use projects include well and circulation pumps, transmission and distribution pipelines, heat exchangers and space heating convectors, peaking or back-up plants, and fluid disposal systems. Combined heat and power systems can maximize the benefits and economics from using a geothermal resource. The eight leading countries with direct-use development are China (75 348 TJ/year), United States (56 552 TJ/year), Sweden (45 301 TJ/year), Turkey (36 886 TJ/year), Japan (25 698 TJ/year), Iceland (24 361 TJ/year), France (12 929 TJ/year), and Germany (12 764 TJ/year). Worldwide geothermal heat utilisation is 47% for geothermal heat pumps, 26% for bathing and swimming, 15% for space heating (including district heating), 5% for greenhouse heating, 3% for aquaculture pond heating, 3% for industrial applications, and 1% for others.

Geothermal (ground-source) heat pumps (GHP) are one of the fastest growing applications of renewable energy in the world, growing at a rate of 17% annually over the past five years. They can provide both heating and cooling by using normal ground or ground-water temperatures between 5°C and 30°C. Most of the growth has occurred in the United States, Canada, China, and Europe, but use has been documented in 43 countries. GHP installations can either be closed loop in a vertical or horizontal configuration, or open loop using groundwater or pond water. The coefficient of performance (COP) of GHPs, which is the ratio between thermal energy output to electrical energy input, is usually 4.0 or better. The present worldwide installed capacity is estimated at almost 33 100 MWt with an annual energy use of 55 600 GWh in the heating mode from an equivalent 3 000 000 installed 12 kW units. The estimated saving considering both heating and cooling modes from electricity production is 118 million barrels of oil annually (17.7 million tonnes), and 15.7 million tonnes of carbon and 50.5 million tonnes of CO_2 annually.

Summary

At present, the cost of crude oil is around US$100/barrel and probably will continue to rise along with the price of natural gas. Thus, with geothermal energy becoming increasingly more competitive with fossil fuels and the environmental benefits associated with renewable energy resources better understood, development of this natural 'heat from the earth' should accelerate in the future. An important task for all of us in the geothermal community is to spread the word on geothermal energy, its various applications, and the many environmental benefits that can accrue from its use.

About the author

John W. Lund is the principal engineer for the Low Temperature Geothermal program at the US National Renewable Energy Laboratory. He recently retired from the position of Director of the Geo-Heat Center at the Oregon Institute of Technology (OIT) and has worked in the direct utilization of geothermal energy for over 32 years. He has a PhD in Civil Engineering from the University of Colorado and is an emeritus Professor of Civil Engineering at OIT.

The material for this Guest Editorial is based on John's presentations at the WAGES 2011 Conference.

Climate change: let's not confuse likelihood with consequence – or why I reluctantly support the carbon tax

The specifics of Australia's carbon tax were recently released. Many Australians will now need to answer some tough questions. For example, what is the probability that climate change is real? What is the economic impact of the carbon tax on Australia, my family and me? What are the long-term consequences of not doing CO_2 abatement? At the next election should I vote for a party that wants to reverse the carbon tax?

Let me share with you my view of the climate debate and the carbon tax. Many geoscientists – myself included – are 'grumpy' with climate models that predict climate change due to anthropogenic CO_2. There are emotional and rational parts to this grumpiness. The emotional part is that we feel ignored. The climate modeling community – and the public in general – have tended to ignore the very relevant input geoscientists could and should have to the climate debate. Climate modelers are predicting global warming and sea level rise in the mid-term (5–100 years). Geoscientists have an intellectual ownership of long-term climate and sea-level data that should be included in any discussion and validation of climate models. But the climate modelers and public ignore us.

What is the rational part of the geoscientists' grumpiness? We know that over the long-term (geologic time scale) our planet has had many swings in CO_2, temperature and sea level far larger than changes predicted by mid-term climate models – and those swings occurred without anthropogenic influences. We also know that because of Milankovitch cycles, our climate is nearing the end of a warm period and will soon (in geologic time) return to its normal colder state. And we know that mid-term geologic and climate processes are very complex and therefore difficult to model accurately. For these reasons the *likelihood* that the warming climate models are correct is – in my opinion – at best 50%.

But the *likelihood* of climate change should not be confused with the *consequences* of climate change. The predicted consequences are more extreme weather like the recent floods, tornadoes, heat waves and fires seen in Australia, Europe and North America ... but if the climate is warming, these severe weather events will increase in frequency and severity. The consequences of climate change include loss of crop land, food shortages and population relocations (more boat people). As mentioned above, I think the likelihood of these events becoming worse is less than 50% – but due to the severity of these consequences, I am willing to pay a price to protect against them. And this is why I support the carbon tax.

Above, I have discussed likelihood and consequence of climate change. But there is another issue: the cost associated with achieving CO_2 abatements. The carbon tax kicks off with a cost of $23/tonne in 2012, but the plan is to switch over to an emissions trading system (ETS) in 2015. Under the ETS the total permitted amount of CO_2 Australia can emit is lowered each year and polluting companies will need to purchase ever more limited CO_2 emission permits at government-run auctions. ETS plans rely on technical innovation and financial investment by third parties to curb CO_2 emissions. ETS plans would seem to have a very uncertain cost – for example, can we safely assume that our ETS scheme will foster new technologies that economically lower CO_2 emissions? Below I discuss some reasons why there is optimism on the ETS cost front.

Peak Oil: petroleum geologists have been predicting since the 1950s that the world will run out of oil. Oil production in certain parts of the world – most notably North America and Europe – has already 'peaked' and is now in decline. Over the next 20–100 years, the world will suffer from decreasing oil supplies and from increasing demand due to growing third world economies. The world will need to develop alternatives to petrol and diesel fuelled transportation. The most likely alternatives are electric or hydrogen or compressed natural gas powered vehicles – all of which emit less CO_2 than petrol. This search for alternatives to oil will certainly have a cost, but because of peak oil, this cost is inevitable. We will pay for this cost with or without a carbon tax and ETS.

Coal and the shale gas 'revolution': natural gas-fueled electricity plants generate about half as much CO_2 as coal-fired electricity plants. Why aren't all power plants powered by natural gas? Consider the dilemma of an electricity provider in North America that needs to build a new power plant (and Australian operators have faced similar issues). Electricity companies and regulators prefer to build gas-fired plants because they are cheaper to build and cleaner to operate than coal-powered plants. But the price of gas in North America over the past 10 years has had wild swings between $2/MMBTU and $13/MMBTU – so coal has been the chosen fuel. But now the shale gas revolution in North America has added 200 years of additional gas supply to the North American market and stabilized the price at $3–4/MMBTU. Similarly, in Eastern Australia, coal seam gas supplies have grown by a tremendous amount in the past five years and a recent well in the Cooper Basin by Beach Energy hints that Australia's shale gas supplies could also expand like North America's. This expansion of Australia's natural gas supplies – combined with an ETS scheme – can minimize the cost of CO_2 abatement.

My guess is that most of the politicians in Canberra are very aware that the fastest and least expensive path to significantly reducing our CO_2 emissions is to switch from coal to natural gas. They wish to drive us in that direction but are reluctant to publically emphasise that gas should or will replace coal because that statement would alienate key constituencies, i.e. organized labor associated with coal mines and environmentalists that want coal to be entirely replaced with solar and/or wind power.

So Australia's coal industry is likely to suffer the most under the carbon tax. But the coal industry and coal workers have some room for optimism: the emerging technology of CO_2 capture and sequestration (CCS). Australia is one of the world leaders in studying CCS and has a demonstration project underway in the Otway basin. There are some estimates that CCS will cost between $25 and $50/tonne of coal (see the most recent AAPG Explorer). With a carbon cost starting at $23/tonne and increasing under an ETS plan, within a few years it becomes cheaper for coal-powered utilities to pay for CCS than to pay the carbon tax.

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In summary, I – like many geoscientists – have concerns about the accuracy of climate models. Despite these concerns I support the carbon tax. I do so because the consequences of global warming are severe, and because the cost of CO_2 abatement is not that high.

My reluctant support of the carbon tax does not mean that the ASEG, or its other officers or its members support the carbon tax. Additionally, my support of the carbon tax should not be interpreted as support for any political party.

Dennis Cooke
Email: dennis.a.cooke@gmail.com

New Members

The ASEG extends a warm welcome to 10 new members to the Society (see table). These memberships were approved at the Federal Executive meetings held on 29 May and 30 June 2011.

Name	Organisation	State	Member grade
Drew Allan Breen	Moultrie Database and Modelling	QLD	Active
Richard Barnwell	Terrex Seismic	QLD	Active
Fargana Exton	Schlumberger Oilfield Services	WA	Active
Andrew McMahon	Geodynamics	QLD	Active
Alison Carol Langsford	University of Adelaide	SA	Student
Timothy Jones	Geoscience Australia	ACT	Active
Romney Rayner	Coffey Geotechnics	NSW	Active
Roger Miller	Fugro Airborne Surveys	WA	Active
Jonathan Fairlie Ross	Heathgate	SA	Associate
David Ronald Tassone	University of Adelaide	SA	Student

We would also like to welcome **Terrex Seismic** as a new corporate member of the ASEG. The Terrex group provide onshore 2D and 3D seismic acquisition, contracting and spatial services. With over 30 years of domestic and international experience, Terrex utilise a variety of acquisition techniques including vibroseis and dynamite shot-hole operations to provide geophysical exploration and data capture on behalf of oil and gas companies, CSG, shale gas, coal and mineral exploration companies and government agencies.

Terrex Seismic is supported by two additional business units to address industry demand for a 'one stop shop' of seismic acquisition services. These are Terrex Contracting (TC), which completes seismic line preparation and restoration and Terrex Spatial (TSp), their surveying branch administering requirements for their 2D and 3D seismic programs. Terrex Spatial also offers a full range of surveying services to mining, local council and engineering clients including LiDAR aerial surveillance, GIS Applications, Geodetic Control Surveys, Gravity Surveys, Pipeline Routing, DCDB (Digital Cadastral Database) Updates and As-built Surveys.

Terrex Seismic have completed more than 600 programs, investing in the latest equipment and most experienced people to produce quality, high resolution seismic and subsurface information across all geological formations for the following applications:

- Oil, Gas, Coal Seam Gas, Coal and Minerals Exploration
- Groundwater Mapping
- Underground Carbon Storage Projects
- Vertical Seismic Profile
- Microseismic Monitoring
- Research Seismic including Regional and Deep Crustal Mapping

Terrex HQ is located in Perth, with operations administered from Brisbane. The Terrex fleet of seismic vibroseis equipment ranges from low environmental impact 15 000 lb Peak Force 4x4 Buggy 'EnviroVibes' through to 62 000 lb Peak Force 4 × 4 Buggy Vibrators. They complete programs in tough and diverse terrain, with heliportable and shot-hole dynamite operations, six Terrex seismic crews, two Terrex contracting crews and nine Terrex (TBC) spatial surveying crews, complete with full support vehicles and on-site camp accommodation.

For more information, go to http://www.terrexseismic.com.

Release of journal Impact Factors

Exploration Geophysics' editorial board and authors can be very pleased with the latest international rating.

International recognition for academic journals is difficult to achieve and is measured by an Impact Factor (IF). The ASEG joined a fortunate group when the journal received its first rating last year. In late June of this year the journal received a rating of 0.619. This is a major boost, a rise in IF of 53% in only one year.

The journal citation report is calculated by Thomson Reuters and is based on the average number of times published papers are cited in academic literature for a period after publication. Impact Factors have a huge influence on the way published scientific research is perceived and evaluated.

The number of papers submitted to *Exploration Geophysics* is also steadily increasing, with submissions in the first half of 2011 numerically two-thirds of the submission for 2010. *Exploration Geophysics* shows every indication that it is entering into a virtuous cycle, in which improving citation rates lead to more submissions, which lead to a better publication, which leads to improving citation rates.

Preliminary calculations suggest *Exploration Geophysics* will track higher still next year. The journal is now sitting ahead of *Applied Geophysics* (IF 0.38), while *Marine Geophysical Research* (IF 0.76) and the *Journal of Environmental and Engineering Geophysics* (IF 0.84) are not far ahead in the ratings.

The Editor-in-Chief of *Exploration Geophysics*, Mark Lackie, said, 'We are delighted that the successes of *Exploration Geophysics* have been acknowledged in this way. This result will further endorse the journal as a worthy place for quality research in applied geophysics, and ensure that we will attract high quality authors and reviewers'.

Richard Hecker

Nominate a colleague for an ASEG Honour or Award for 2012

An important role of the ASEG is to acknowledge the outstanding contributions of its individual members both to the profession of geophysics and to the ASEG. The society has a number of different Honours and Awards across a range of categories. The next Awards are scheduled to be presented at the ASEG Brisbane Conference from 26–29 February 2012.

The ASEG awards are made through nominations of the membership at large, as well as through State and Federal executives. A list of the various available awards is set out below and all members are therefore invited to submit nominations for the next round according to the 'Nomination Procedure' set out below. Some of the awards carry considerable prestige in the eyes of the ASEG and therefore require detailed documentation to support the nomination. Please contact the Committee Chairman, Andrew Mutton, if you require further guidelines on what is required.

Recipients selected from these nominations will be presented with their award at the forthcoming Brisbane conference.

ASEG Gold Medal

For exceptional and highly significant distinguished contributions to the science and practice of geophysics, resulting in wide recognition within the geoscientific community. The nominee must be a member of the ASEG.

Honorary Membership

For distinguished contributions by a member to the profession of exploration geophysics and to the ASEG over many years. Requires at least 20 years as a member of the ASEG.

Grahame Sands Award

For innovation in applied geophysics through a significant practical development of benefit to Australian exploration geophysics in the field of instrumentation, data acquisition, interpretation or theory. The nominee does not need to be a member of the ASEG.

Lindsay Ingall Memorial Award

For the promotion of geophysics to the wider community. This award is intended for an Australian resident or former resident for the promotion of geophysics (including but not necessarily limited to applications, technologies or education), within the non-geophysical community, including geologists, geochemists, engineers, managers, politicians, the media or the general public. The nominee does not need to be a geophysicist or a member of the ASEG.

Early Achievement Award

For significant contributions to the profession by way of publications in *Exploration Geophysics* or similar reputable journals by a member under 36 years of age. The nominee must be a member of the ASEG and have graduated for at least 3 years.

ASEG Service Awards

For distinguished service by a member to the ASEG, through involvement in and contribution to State Branch committees, Federal Committees, Publications, or Conferences over many years. The nominee will have been a member of the ASEG for a sustained period of time. All nominations will be considered for the award of an ASEG Service Certificate. Where the nomination details outstanding contributions to the shaping and the sustaining of the Society and the conduct of its affairs over many years, consideration will be given to the award of the ASEG Service Medal to the nominee. Honorary Members are not eligible for nomination.

Nomination procedure

Any member of the Society may nominate applicants. These nominations are to be supported by a seconder, and in the case of the Lindsay Ingall Memorial Award by at least four geoscientists who are members of an Australian geoscience body (e.g. GSA, AusIMM, AIG, IAH, ASEG or similar).

Nominations must be specific to a particular award and all aspects of the defined criteria should be addressed. To gain some idea of the standard of nomination expected, nominees are advised to read past citations for awards as published in *Preview*. If required, proforma nomination forms are available from the Chairman, Andrew Mutton.

Nominations including digital copies of all relevant supporting documentation are to be sent electronically to:

Andrew Mutton
Chairman, ASEG Honours and Awards Committee
Email: andrew.mutton@bigpond.com.au

The deadline for applications is 15 December 2011.

ASEG News

New South Wales

In May, Julian Vrbancich, from the DSTO, gave a talk on marine seismic profiling and marine sand resistivity investigations in Broken Bay and Jervis Bay (NSW) and how that data assists the interpretation of airborne electromagnetic data for bathymetric studies. Julian explained how airborne electromagnetic (AEM) methods are being investigated as a means to determine water depths in shallow coastal waters, but that instrument calibration errors and EM noise will affect the bathymetric accuracy. In order to support this work, a marine continuous seismic (CSP) profiling study and a resistivity study of vibrocore samples of shallow marine sands were undertaken in both Broken Bay and Jervis Bay (NSW) to characterise the seabed.

In June, Clive Foss from the CSIRO gave a presentation on an Australian Database of Remanent Magnetization Anomalies – a new web-based resource for mineral exploration. Clive explained that they have started to populate the database, and are planning the facilities required to make the database available as an interactive, web-based resource. Clive explained that the key objectives are to facilitate interpretation of magnetic field data, increase reliability in developing deep drilling targets from magnetic field interpretation, and to better establish the spatial range of magnetizations related to igneous, metamorphic, thermal, alteration and mineralization events. Many questions were directed at Clive.

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.

The speaker for September will be Bruce Dickson who will be speaking on geophysical indicators of global climate changes.

Mark Lackie

South Australia/Northern Territory

The South Australian and Northern Territory branch has held several successful events over the last few months. On 31 May we held a networking night, inviting students to meet with industry, government and consulting geophysicists. The event was a great success, with everybody making the most of the opportunity to meet some new people.

On 14 June we welcomed the SEG Distinguished Lecturer, Andrey Bakulin. Andrey presented the talk ‘Virtual Source Method for Imaging and Monitoring Below Complex Overburden’. An enthusiastic audience received his talk and many stayed afterwards to ask questions. Unfortunately due to the volcanic ash cloud from the Puyehue volcano in Chile, Andrey’s flights from Adelaide were delayed and his scheduled talks in Perth were cancelled. As it was his first trip to Australia, he was lucky enough to visit Kangaroo Island and went sightseeing in Adelaide.

On 12 July, Tim Keeping from the Geological Survey of South Australia presented 'Geophysics of the Tallaringa Trough, Officer Basin'. A crowd of 25 people attended to hear Tim present his geophysics honours work. Enthusiastic discussion followed late into the evening.

Future events include the SEG/EAGE Distinguished Instructor Short Course (DISC) in August, a talk on magnetotellurics in September, our annual industry night in October and student night in November. Look out for the new wine offer adverts in this – and future – editions of *Preview*.

The SA branch holds technical meetings monthly, usually on a Tuesday or Thursday night at the Coopers Alehouse beginning at 5:30 pm. New members and interested persons are always welcome. Please contact Philip Heath (philip.heath@sa.gov.au) for further details. If you are an ASEG member and are not receiving emails please ensure your contact details are up to date by contacting aseg@casm.com.au.

Philip Heath

Victoria

On Friday 20 May, Richard Lane from Geoscience Australia provided an impressive encore of the ASEG Distinguished Lecture 'Building on 3D Geological Knowledge through Gravity and Magnetic Modeling Workflows at Regional to Local Scales' to the geoscience staff and student body at Monash University.

On Tuesday 24 May the ASEG Victorian Branch hosted the technical presentation 'Potential Field Searchlights' by Mark Dransfield, Chief Geophysicist and AGG Manager, Fugro Airborne Surveys. Drawing parallels to seismic wavefronts and TEM smoke ring diffusion Mark convincingly introduced the audience to the mental framework in which a potential field measurement is imagined to illuminate the earth in a manner analogous to a light beam. The presentation was well received and sparked a series of questions and discussions.

On Wednesday 22 June, Tim Rawling, Associate Professor at The University of Melbourne, presented 'Development of Complex Basin Management Systems from 3D Geology and Geophysics' to a large member turn-out at the Kelvin Club. With great visuals Tim showed how 3D geological models assist when managing multiple uses of Victorian basins for CO_2 sequestration, petroleum production and geothermal energy extraction. Tim also demonstrated how 3D geological models can be used, not only in basin management, but also to help explore for gold resources in Victoria.

We are looking forward to seeing many ASEG Victorian branch members at the upcoming technical meetings, social functions and short courses.

Asbjorn Christensen

Western Australia

In essence the Western Australian committee has identified the need to better our services to WA members and as a result we came up with an action plan to help us fulfill this commitment. Some of the initiatives put forward include a combination of one-day workshops/symposia and a number of field trips per year to nearby mines. We also recognized the importance of continuous interaction between academic institutions, service providers in the industry, smaller businesses and those who are employed by these parties. As a result we would like to offer our members the opportunity to meet other scientists and engineers, interact with other professionals and experience not only the workplace of others but also technologies, techniques and applications.

Furthermore we want to encourage scientists from across Australia and overseas to participate in our technical talks and workshops. We therefore extend our warmest welcome to those people who are interested to contact us as soon as possible. Our intention is to tackle this task by getting ASEG members, businesses and institutions involved and through this involvement we hope to accomplish our goals.

On an administrative level, feedback was given on the re-development of the ASEG webpage and we are looking forward to the modernised version. We understand that some of the new attributes will include functionalities to help link professionals as well as making the process of registration and updating personal information more convenient.

We would also like to remind our students of upcoming events including the student careers evening, student night and a soon-to-be social event – all of which are places where they can meet scientists or if you like 'likeminded' people. Details on ASEG's scholarship program will soon be circulated and expressions of interest from our students at this early stage are welcomed.

Riaan Mouton

Website Update: www.aseg.org.au

Have you visited our website lately?

The current website has been undergoing some improvements and much needed maintenance:

- All members should now be able to login, update their details and pay their fees online.
- Branches are now entering content about upcoming workshops and meetings.
- Job advertisements can be found under the employment section.

Corporate members can advertise for free. Other companies can advertise for a fee.

THE NEW WEBSITE is coming…

The ASEG Federal Executive has been working hard, in collaboration with PESA, to bring its members a new, exciting, state of the art website. The website is currently in the planning stages and is due to go online in early 2012. The website will be officially launched at the 22nd International Geophysical Conference and Exhibition in Brisbane and will bring to the members a powerful tool for information about the society and its events but also tools for networking, education and resources.

Contact the new webmaster, Carina Kemp, for more information on the current or planned website.
Email: c.kemp@geomole.com.

International Geological Congress comes to Australia after 36 years

International Geological Congresses are arguably the most comprehensive geoscience meetings on the planet and the next one, the 34th, will be held in Brisbane in less than 12 months time, from 5 to 10 August 2012. The size and complexity of this Congress is a far cry from the first, held in Paris in 1878, only two years after the IGC was formed in Buffalo, New York in August 1876. Australia's only previous IGC was held in Sydney in 1976, when more than 3500 delegates attended.

Recent IGCs have attracted over 6000 delegates and we are hoping to attract almost this number of attendees from all over the world, particularly Asia, to Brisbane for the 34th IGC.

The Congress will include a wide ranging scientific program comprising 218 Symposia under 37 Themes; many magnificent field trips throughout Australia, New Zealand and the southwest Pacific; a major exhibition; workshops and many other attractions.

The Australian bid for the 34th IGC goes back to 2003 when Ian Lambert and Neil Williams teamed up to prepare a formal bid to host the meeting on behalf of the Australian Geoscience Council. Against keen opposition from other countries, Australia's proposal was accepted at Florence in 2004 during the 32nd IGC.

A special issue of *Episodes*, the International Union of Geological Sciences journal, will promote the 34th IGC through feature papers and a series of articles on the geology of the field trip regions. In addition, a full colour hard cover book 'a Geology of Australia' is being produced by Geoscience Australia for the Congress, along with various updated products from the state geological surveys.

This Congress will place more emphasis on the resource industries than previous meetings, but the the scientific program covers all the geosciences. For the practising exploration geophysicist some of the relevant themes and symposia include:

Geoscience information

- Geoscience Spatial Data Infrastructure
- Information Management – Interoperability and Standards
- Delivery, dissemination and exploitation of geoscience data and information
- Tools – software, hardware, open source
- Model fusion, visualisation, exploration and 3D and 4D modelling.

Energy in a carbon constrained world

- CO_2 Geosequestration
- Geothermal resources
- Nuclear energy and waste disposal
- Clean energy: options and limitations

Mineral resources and mining

- Geology and genesis of ores for a changing economy and a carbon constrained world
- Future sources of industrial minerals and construction materials
- Resource and reserve reporting, and the valuation of mineral assets
- Resource modelling, estimation and visualisation for project and mine development
- Mining geology, technology, geophysics and geometallurgy
- The future mine and geoscience
- Methods of assessing undiscovered mineral resources.

Mineral Exploration Geoscience

- Footprints of mineralised systems: new concepts and data for exploration
- The science of exploration targeting
- Probing the Earth from near-surface to the mantle – techniques, modelling and case histories to aid mineral exploration
- Advances in geochemical exploration
- Exploration and discovery: diagnosis, prognosis, are we in need of cure?

Mineral deposits and ore forming processes

- Orogen to district scale structural and tectonic controls on porphyry and epithermal deposits
- Volcanic and basin-hosted ores (Fe, Zn-Pb, Cu, U)
- Dating of ore deposits
- Iron Oxide Copper Gold deposits
- Sediment and/or greenstone-hosted gold
- Global sulphur cycle and impact on metallogenesis
- Mineral deposits: episodes, accumulation of metals in China and adjacent regions
- Giant and super giant ore bodies.

Coal – a Myriad of resources

- Finding resources, making reserves
- Coal – a record of change
- Clean coal – what is the global reality?

Petroleum systems and exploration

- Petroleum prospectivity of passive margin basins of North and South Atlantic, Arctic, India and Australasia
- Pacific Rim petroleum system architecture
- Petroleum system modelling; geochemistry, basins and source rock
- Petroleum reservoir modelling, seals and enhanced oil recovery
- Petroleum exploration in frontier basins
- Putting the geo into geophysics – adding clout through better datasets and joint interpretation.

Unconventional hydrocarbons – emerging fuels

- Coal Seam Gas
- Shale and Tight Gas
- Gas hydrates
- Heavy oil.

And if you would like to stray from your core business, how about some Geohazards, Remote Sensing, Ground Water/Hydrology, Antarctic Geoscience, Planetary Science, the Deep and Dynamic Earth or even Climate Change and Archaeology?

It's all there, so have a look at the Scientific Program, what's on offer for the Field Trips, the 2nd circular at www.34igc.org, and register now to take advantage of the Super-Early Bird Registration Offer before September 2011.

David Denham

ASEG 2012 22nd ASEG International Conference and Exhibition News Update (06)

The conference is hotting up! Maybe it's the new financial year but suddenly the conference feels real and the milestones are flashing by as the juggernaut continues. To date over 250 expressions of interest have been received and 20 keynote speakers have been identified. Over half the exhibition booths have been sold and 13 workshops planned. For me the quality and variety of keynote speakers alone will make this conference worth attending. They will be highlighted in our upcoming Eblasts and their biographies are on our website.

It's not too late to submit an expression of interest. The deadline has been extended to 2 September but please, you must submit your expression of interest before you submit your paper. The earlier submissions mean that we will have a preliminary program in August with early bird registration to follow shortly after.

A big thank you to our sponsors. Their early engagement has made it possible for us to proceed with our conference plans safe in the knowledge that we will run a successful conference.

Gold Sponsors: Anglo American Exploration (Australia), Origin.

Silver Sponsors: Beach Energy, CGGVeritas, Carpentaria Exploration, Geosoft, Pitney Bowes Business Insight, Talisman Energy, Velseis (our silver sponsorships are all sold).

Bronze: Planetary Geophysics Pty Ltd, Quantec.

If you have not done so already, please visit our website (www.aseg2012.com.au). This is the site for registration, paper submission, preliminary program, keynote speakers, social program: how can anyone not want to come! There is also a downloadable poster for you to display in your office.

Co-Chairs: Wayne Mogg and Andrea Rutley
Technical: Binzhong Zhou
Sponsorship: Ron Palmer
Exhibition: John Donohue
Finance: Noll Moriarty
Workshops: Koya Suto
Publicity: Henk van Paridon
Students: Shaun Strong
Social: Janelle Kuter

Anyone able to help (we still urgently need people to help with papers) should contact Binzhong. You don't need to be in Brisbane.

Henk van Paridon

News

West Australian Geothermal Energy Symposium – WAGES 2012

Date: 2–3 April 2012
Venue: Perth Convention and Exhibition Centre, Perth, Western Australia.
Website: www.wageothermalsymposium.com.au

Geothermal energy offers a wide range of opportunities to reduce our reliance on fossil fuels and associated greenhouse gas emissions. Building on the success of the inaugural WAGES in March 2011, the symposium will bring together technical experts, policy makers and potential end-users to promote and expand the understanding and utilisation of geothermal energy in Western Australia at all levels. The event will provide a forum to examine the technical and regulatory issues critical to the success of the industry and increase public awareness of the opportunities to use geothermal energy.

Call for papers

The **West Australian Geothermal Energy Symposium** is seeking research papers and case studies on the following subjects:

- Exploration for Geothermal Resources
- Direct use of Geothermal Energy: district heating/cooling, ground-sourced heat pumps, sorption chillers, air conditioning and desalination for residential and industrial projects
- Electricity generation concepts and technologies
- Business development, funding and economic analysis.

The West Australian Geothermal Energy Symposium provides the opportunity to publish short one-page abstracts in a conference volume. Arrangements to publish extended abstracts or conference proceedings are currently under consideration, and will be announced on the website in due course.

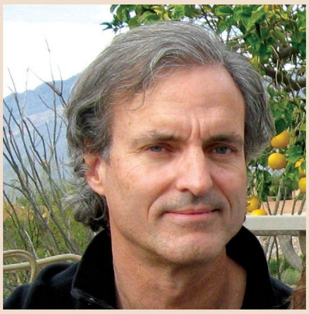
Abstracts

Expressions of interest close 15 December, and the abstracts must be submitted by 31 January 2012. Detailed instructions for the preparation of abstracts will be posted on the conference website (www.wageothermalsymposium.com.au).

Organising committee

Jenny Archibald, Managing Director, GT Power Pty Ltd
Mark Ballesteros, Director, EarthConnect (chairman)
Grant Bolton, Principal Consultant, Rockwater Pty Ltd
Klaus Gessner, Associate Professor, University of Western Australia
Adrian Larking, Director of Operations, GreenRock Energy Ltd
John Libby, Managing Director, New World Energy Limited
Mike Middleton, W.A. Department of Mines and Petroleum
Klaus Regenaur-Lieb, Director, W.A. Geothermal Centre of Excellence
Sean Webb, Business Manager, W.A. Geothermal Centre of Excellence

WAGES highlights geothermal potential



Mark Ballesteros

Mark Ballesteros

Chairman, WAGES Organising Committee.
Email: mark@earthconnect.com.au

The inaugural West Australian Geothermal Energy Symposium (WAGES) was held 21–22 March 2011 and was attended by over 125 delegates representing industry, academia, government and potential users of geothermal technology. Participants hailed from all states except Queensland and the Northern Territory, as well as international delegates from New Zealand, Papua New Guinea, Indonesia and Malaysia. The event touched on the full spectrum of geothermal topics from ground source heat pumps to large-scale electricity generation, with the major focus on direct use applications.

The symposium examined geotechnical, engineering, commercial and regulatory issues. The program was consciously designed to appeal to the diverse backgrounds of the delegates, which included researchers, hydrogeologists, engineers, consultants, tradesmen, contractors, architects, planners and government representatives. We recognise that one of the barriers to the widespread use of geothermal energy is lack of public awareness of the possibilities. Our objective was to provide more than a technical conference, but a forum that would provide an opportunity to raise awareness and understanding of how geothermal energy can become an integral part of Western Australia's long-term energy planning.

Keynote speakers included US-based John Lund, former director of the Geo-Heat Centre and internationally recognised authority on ground source heat pumps and direct use geothermal applications, and Alex Smillie, head of Geothermal Operations at Star Energy, which is currently operating a successful geothermal power station in Indonesia. John Lund shared some of his experiences from the United States as to what it takes to get a geothermal project going and some of the government programs and policies that have helped and hindered the process (see Guest Editorial in this issue, p. 3). Alex Smillie discussed the challenges of developing and operating a geothermal electricity project in Indonesia. Both provided interesting insights into issues likely to arise as the industry develops in Western Australia.

Day 1 included a review of current activities by geothermal permit holders in WA and a broad overview of the geothermal industry in WA, culminating with a panel discussion on how to effectively incorporate geothermal technology into our overall energy solution. The panel included both keynote speakers as well as Klaus Regenauer-Lieb (WA Geothermal Centre of Excellence), Bev Bower (WA Department of Mines and Petroleum) and Alannah McTiernan (Sustainable Energy Association of Australia) and was moderated by ABC Radio's James Lush. The discussion concluded that, in addition to the long term potential for large-scale base load electricity generation, economically attractive opportunities currently exist in WA for direct use geothermal and ground source heat pump projects that can and should be encouraged and pursued.

Day 2 featured two parallel sessions, one covering geotechnical issues and the second focused on case studies and applications. These presentations revealed the depth and variety of sub-surface research currently underway, as well as highlighting some exciting engineering developments and interesting case studies. They also ensured that there was always something of interest to all delegates – although it did result in some hard choices as to which session to attend! Abstracts along with a number of the presentations are available on the conference website (www. wageothermalsymposium.com.au).

And of course, no event is without a couple of logistical challenges. Perhaps foremost among these was the 24-hour delay of John Lund's arrival in Perth due to bad weather in the USA. John put in a spectacular effort, however, driving all night through a snow storm from his home in Oregon to San Francisco after his flight was cancelled and then enduring additional delays before arriving in Perth at 1:00 pm on Monday afternoon (3 hours after his scheduled key note address). He was whisked from the airport directly to the conference centre where he quickly changed clothes and proceeded to dazzle the audience with his quickly re-scheduled presentation without showing the slightest signs of jet lag. Impressive.

The response from delegates was very positive. In particular, Alex Smillie commented, '*I found the conference most interesting – it was refreshing after the many conferences in Asia that are run by event organisers focussed on profit and with no enthusiasm or understanding of the subject matter. It was great to see the level of enthusiasm and commitment in the Aussie geothermal crowd.*'

We look forward to building on this strong foundation to make WAGES 2012 bigger and better. We hope to see you there!

Award of 10 new offshore exploration permits

Six companies have been given a total of 10 permits to explore for oil and gas in Australian waters off the Western Australia and South Australian coasts in areas open for bidding under the 2010 offshore petroleum acreage release. The exploration work that follows will have a combined value of nearly $137 million over three years, with further investment up to $368 million possible depending on initial findings. With the price of oil hovering around US$100/bl, it is not surprising that there was keen interest in bidding for these areas. Figures 1–3 show the locations of these permits and Table 1 summarises details for each permit.

On 8 July 2011, the Minister for Resources and Energy, Martin Ferguson AM MP, said broadening our geological frontiers stood to make Australia less reliant on fuel imports which, in turn, enhances energy security.

‘Australia has a $16 billion trade deficit in crude oil, refined products and LPG. That figure may double within four years. So everyone who fills up at the bowser has a stake in future discoveries’, Minister Ferguson said.

‘But we must meet our energy security requirements in a way that also ensures the safety of workers and the environment. By integrating the lessons of what happened at Montara, we are making sure our oil and gas industry continues to be among the best and safest in the world.’

Minister Ferguson concluded, ‘The exploration activities to be undertaken in the Bight region will also be subject to special conditions, recognising the region’s importance in terms of tourism, agriculture and the marine environment’.

Further information on these areas and application requirements can be found by visiting this website: www.ret.gov.au/petexp or by sending an email to: petroleum.exploration@ret.gov.au.

David Denham

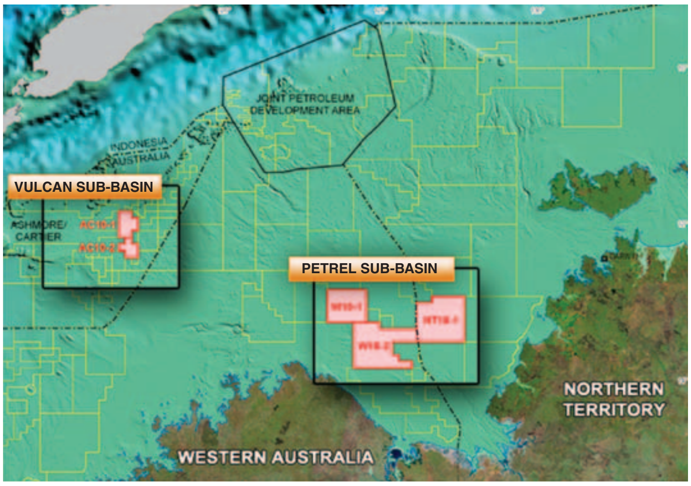


Fig. 1. *Locations of permits AC10-1, AC10-2 and W10-2, which were granted in July 2011.*

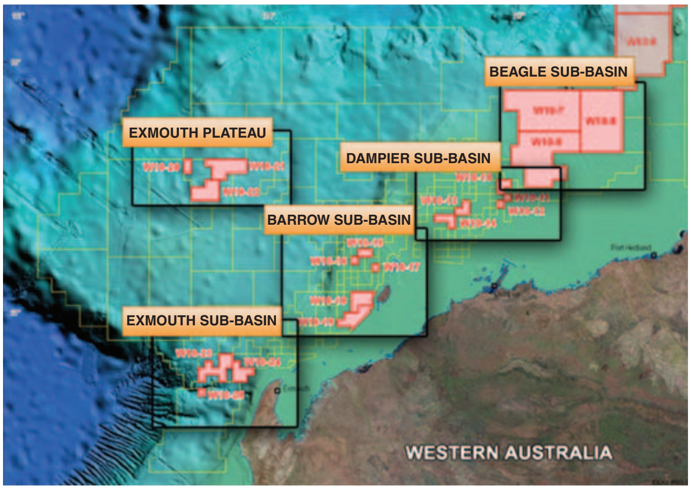


Fig. 2. *Locations of permits W10-10, W10-14, W10-16, W10-18 and W10-19, which were granted in July 2011.*

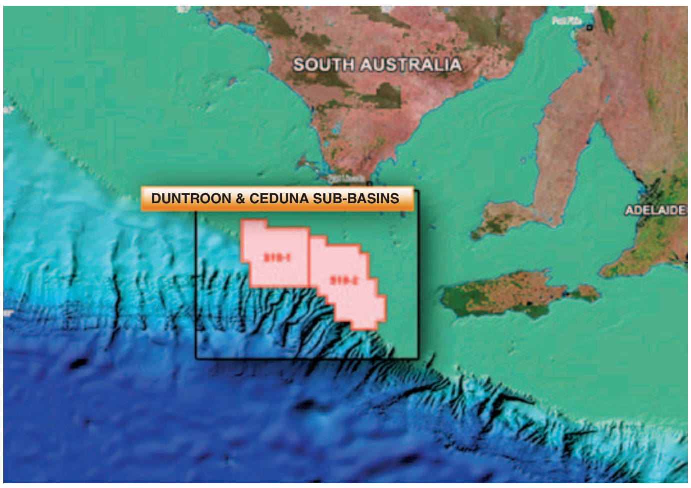


Fig. 3. *Locations of permits S10-1 and S10-2, which were granted in July 2011.*

Table 1. Details of permit area, operating companies, and exploration programs for 10 new offshore exploration permits

Permit area and number of bids	Operating companies	Exploration program
Vulcan Sub-basin of the Bonaparte Basin off Western Australia AC/P54 (released as AC10-1 – see Figure 1). One other bid.	PTTEP Australasia (Ashmore Cartier) Pty Ltd	A guaranteed work program of 300 km^2 of new 3D seismic surveying, an exploration well and geotechnical studies to an estimated value of A$40.3 m. The secondary work program consists of an exploration well, 300 km^2 3D seismic reprocessing and geotechnical studies to an estimated value of A$35.7 m.
Vulcan Sub-basin of the Bonaparte Basin off Western Australia, AC/P53 (released as AC10-2 – see Figure 1). No other bids.	MEO Australia Limited	A guaranteed work program of 150 km of new 2D seismic surveying, 500 km^2 3D seismic reprocessing and geotechnical studies to an estimated value of A$0.85 m. The secondary work program consists of an exploration well and geotechnical studies to an estimated value of A$25.5 m.
Joseph Bonaparte Gulf off Western Australia, WA-454-P (released as W10-2 – see Figure 1). One other bid.	MEO Australia Limited	Guaranteed work program of 300 km of new 2D seismic surveying, 750 km of 2D seismic data reprocessing, 400 km^2 of new 3D seismic surveying and geotechnical studies to an estimated value of A$4.55 m. The secondary work program consists of an exploration well and geotechnical studies to an estimated value of A$20.5 m.
Barrow Sub-basin of the Northern Carnarvon Basin off Western Australia, WA-453-P (released as W10-16 – see Figure 2). No other bids for this area.	Apache Northwest Pty Ltd	A guaranteed work program of 80 km^2 3D seismic reprocessing and geotechnical studies to an estimated value of A$0.7 m. The secondary work program consists of an exploration well and geotechnical studies to an estimated value of A$25.4 m.
Barrow Sub-basin of the Northern Carnarvon basin off Western Australia WA-455-P (released as W10-18 – see Figure 2). Three other bids.	Chevron Barcoo Pty Ltd.	A guaranteed work program of 600 km of new 2D seismic surveying, one exploration well and geotechnical studies to an estimated value of A$6.5 m. The secondary work program consists of an exploration well and geotechnical studies to an estimated value of A$4.5 m.
Barrow Sub-basin of the Northern Carnarvon Basin off Western Australia WA-456-P (released as W10-19 – see Figure 2). Two other bids.	Chevron Barcoo Pty Ltd.	A guaranteed work program of two exploration wells and geotechnical studies to an estimated value of A$8.5 m. The secondary work program consists of an exploration well and geotechnical studies to an estimated value of A$4.5 m.
Dampier Sub-basin of the Northern Carnarvon Basin off Western Australia, WA-457-P (released as W10-14 – see Figure 2). Two other bids.	Flow Energy Limited	A guaranteed work program of 322 km^2 of new 3D seismic surveying, 403 km^2 3D seismic reprocessing, 200 km 2D seismic reprocessing and geotechnical studies to an estimated value of A$4.3 m. The secondary work program consists of one exploration well and geotechnical studies to an estimated value of A$22.8 m.
Dampier Sub-basin of the Northern Carnarvon Basin off Western Australia WA-458-P (released as W10-10 – see Figure 2). Three other bids.	Flow Energy Limited	A guaranteed work program of 242 km^2 of new 3D seismic surveying, 335 km^2 3D seismic reprocessing, 50 km 2D seismic reprocessing and geotechnical studies to an estimated value of A$3.45 m. The secondary work program consists of one exploration well and geotechnical studies to an estimated value of A$22.8 m.
Straddling the Duntroon and Ceduna Sub-basins of the Bight Basin off South Australia EPP41 (released as S10-1 – see Figure 3). One other bid.	Bight Petroleum Corp	A guaranteed work program of 768 km^2 of new 3D seismic surveying, bathymetry survey, geochemical sampling survey, an exploration well and geotechnical studies to an estimated value of A$63.625 m. The secondary work program consists of 1969 km^2 of new 3D seismic surveying, two exploration wells and geotechnical studies to an estimated value of A$156.2 m.
Straddling the Duntroon and Ceduna Sub-basins of the Bight Basin off South Australia EPP42 (released as S10-2 – see Figure 3). No other bids.	Bight Petroleum Corp	A guaranteed work program of 235 km of new 2D swath seismic surveying, bathymetry surveying, geochemical sampling surveying and geotechnical studies at an estimated value of A$3.975 m. The secondary work program consists of an exploration well, 405 km of new 2D swath seismic surveying and geotechnical studies to an estimated value of A$49.9 m.

News

Update on Geophysical Survey Progress from the Geological Surveys of Queensland, Western Australia, New South Wales, Tasmania and Geoscience Australia (information current at 13 July 2011)

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

This issue reports two new gravity surveys in Western Australia. Figure 1 shows the boundary for the Peak Hill–Collier survey. 9100 stations will be collected on a regular 2.5 km grid to cover a total survey area of 56 140 km^2. The second survey will be run along gazetted roads in the Kimberley region (see Figure 2). Station spacing will be 400 m along a total road length of approximately 2700 km.

Airborne electromagnetic data and inversion models for the VTEM™ AEM Kombolgie Survey area, Northern Territory

New airborne electromagnetic (AEM) data and inversion products have been released for the Kombolgie VTEM™ AEM survey area in the Northern Territory. Data have been inverted using the layered earth inversion algorithm software developed at Geoscience Australia.

The Pine Creek AEM Kombolgie survey covered a total of 8800 line km and an area of 32 000 km^2 and included mapping of subsurface geological features that are associated with unconformity-related, sandstone-hosted Westmoreland-type and Vein-type uranium mineralisation. The data are also capable of interpretation for other commodities including metals and potable water as well as for landscape evolution studies. The improved understanding of the regional geology to greater than 1500 m resulting from the inversion results will be of considerable benefit to mining and mineral exploration companies.

The Phase 2 Kombolgie VTEM AEM survey final inversion data and conductivity models are now available for free download from the GA website: http://www.ga.gov.au/energy/projects/airborne-electromagnetics.html. For further information, email ross.brodie@ga.gov.au or phone +61 2 6249 9607.

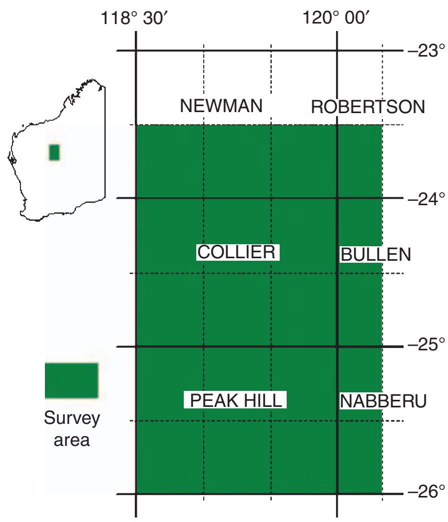


Fig. 1. *Peak Hill–Collier gravity survey area.*

Table 1. Airborne magnetic and radiometric surveys

Survey name	Client	Contractor	Start flying	Line (km)	Spacing AGL Dir	Area (km^2)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
South Officer 1 (Jubilee)	GSWA	Thomson	1 Jun 10	180 000	200 m 50 m N–S	32 380	100% complete @ 22 Jun 11	TBA	148 – Oct 10 p23	TBA
South Officer 2 (Waigen–Mason)	GSWA	Thomson	28 Jun 10	113 000	400 m 60 m N–S	39 890	100% complete @ 5 Jan 11	TBA	148 – Oct 10 p24	QA/QC of final data in progress
East Canning 3 (Stansmore)	GSWA	Thomson	14 Jul 10	114 000	200 m (east) 400 m (west) 50 m N–S	25 934	100% complete @ 2 Nov 10	TBA	148 – Oct 10 p24	Data released via GADDS on 23 June
Eucla Basin 2 (Loongana)	GSWA	Fugro	20 Jun 10	113 000	200 m 50 m N–S	20 320	100% complete @ 3 Dec 10	TBA	148 – Oct 10 p24	Data released via GADDS on 26 May
Eucla Basin 4 (Madura)	GSWA	Fugro	1 Jul 10	102 000	200 m 50 m N–S	18 220	100% complete @ 22 Nov 10	TBA	148 – Oct 10 p24	Data released via GADDS on 2 June
South Canning 2 (Morris–Herbert)	GSWA	Aeroquest	1 Jul 10	125 000	400 m 60 m N–S	45 850	100% complete @ 11 Jan 11	TBA	148 – Oct 10 p25	Data released via GADDS on 9 June
North Canning 4 (Lagrange–Munro)	GSWA	Aeroquest	20 Sep 10	103 000	400 m 60 m N–S	36 680	100% complete @ 23 Jun 11	TBA	148 – Oct 10 p26	TBA
Southeast Lachlan	GSNSW	Fugro	1 Mar 10	107 533	250 m (NSW) 500 m (ACT) E–W	24 660	100% on 9 Sep 10	TBA	144 – Feb 10 p15	Data released via GADDS on 9 June

Table 1. *Continued*

Survey name	Client	Contractor	Start flying	Line (km)	Spacing AGL Dir	Area (km²)	End flying	Final data to GA	Locality diagram (*Preview*)	GADDS release
Grafton–Tenterfield	GSNSW	GPX	16 Jun 11	100 000	250 m 60 m E–W	23 000	20.9% complete @ 10 Jul 11	TBA	151 – Apr 11 p16	TBA
West Kimberley	GSWA	Aeroquest	29 Jun 11	134 000	800 m 60 m N–S. Charnley: 200 m 50 m N–S	42 000	TBA	TBA	150 – Feb 11 p20	TBA
Perth Basin North (Perth Basin 1)	GSWA	Fugro	11 Jun 11	96 000	400 m 60 m E–W	30 000	5.4% complete @ 10 Jul 11	TBA	150 – Feb 11 p20	TBA
Perth Basin South (Perth Basin 2)	GSWA	Fugro	22 Mar 11	88 000	400 m 60 m E–W	27 500	56.8% on 10 Jul 11	TBA	150 – Feb 11 p20	TBA
Murgoo (Murchison 1)	GSWA	Thomson	28 Feb 11	128 000	200 m 50 m E–W	21 250	20.9% complete @ 19 Jun 11	TBA	150 – Feb 11 p20	TBA
Perenjori (Murchison 2)	GSWA	GPX	TBA	120 000	200 m 50 m E–W	20 000	TBA	TBA	150 – Feb 11 p21	Expected to commence September 2011
South Pilbara	GSWA	GPX	TBA	136 000	400 m 60 m N–S	42 500	TBA	TBA	150 – Feb 11 p21	Expected to commence 20 July 2011
Carnarvon Basin North (Carnarvon Basin 1)	GSWA	GPX	TBA	104 000	400 m 60 m E–W	32 500	TBA	TBA	150 – Feb 11 p21	Expected to commence 24 July 2011
Carnarvon Basin South (Carnarvon Basin 2)	GSWA	GPX	TBA	128 000	400 m 60 m E–W	40 000	TBA	TBA	150 – Feb 11 p21	Expected to commence February 2012
Moora (South West 1)	GSWA	Aeroquest	13 Jun 11	128 000	200 m 50 m E–W	21 250	5.8% complete @ 10 Jul 11	TBA	150 – Feb 11 p22	TBA
Corrigin (South West 2)	GSWA	GPX	TBA	120 000	200 m 50 m E–W	20 000	TBA	TBA	150 – Feb 11 p22	Expected to commence September 2011
Cape Leeuwin–Collie (South West 3)	GSWA	Fugro	25 Mar 11	105 000	200/400 m 50/60 m E–W	25 000	70.2% complete @ 10 Jul 11	TBA	150 – Feb 11 p22	TBA
Mt Barker (South West 4)	GSWA	GPX	24 Apr 11	120 000	200 m 50 m N–S	20 000	12.7% complete @ 29 May 11	TBA	150 – Feb 11 p22	Survey on-hold until later in the year
Offshore East Coast Tasmania	MRT	Fugro	28 Feb 11	30 895	800 m 90 m E–W	19 570	100% complete @ 21 Apr 11	TBA	150 – Feb 11 p23	TBA
Galilee	GSQ	Aeroquest	TBA	125 959	400 m 80 m E–W	44 530	TBA	TBA	151 – Apr 11 p15	Anticipated start date late August 2011
Thomson West	GSQ	Thomson	14 May 11	146 000	400 m 80 m E–W	52 170	10.9% complete @ 4 Jul 11	TBA	151 – Apr 11 p15	TBA
Thomson East	GSQ	Thomson	14 May 11	131 100	400 m 80 m E–W	46 730	10.9% complete @ 4 Jul 11	TBA	151 – Apr 11 p16	TBA
Thomson Extension	GSQ	Aeroquest	22 Jun 11	47 777	400 m 80 m E–W	16 400	0.8% complete @ 29 Jun 11	TBA	151 – Apr 11 p16	TBA

TBA, to be advised.

News

Table 2. Gravity surveys

Survey name	Client	Contractor	Start survey	No. of stations	Station spacing (km)	Area (km^2)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Galilee	GSQ	IMT	3 May 11	6400	2.5 km regular	TBA	100% complete @ 10 Jul 11	TBA	151 – Apr 11 p15	TBA
Thomson	GSQ	Daishsat	1 Apr 11	7670	2.5 km regular	TBA	100% complete @ 30 Jun 11	TBA	151 – Apr 11 p15	TBA
Peak Hill–Collier	GSWA	Daishsat	29 Jul 11	9100	2.5 km regular	56 140	TBA	TBA	This issue (Figure 1)	TBA
Kimberley Road Traverses	GSWA	Daishsat	1 Sep 11	7560	400 m station spacing along 2700 km of gazetted roads	TBA	TBA	TBA	This issue (Figure 2)	TBA

TBA, to be advised.

Table 3. Airborne electromagnetic surveys

Survey name	Client	Contractor	Start survey	Line (km)	Spacing AGL Dir	Area (km^2)	End survey	Final data to GA	Locality diagram (*Preview*)	GADDS release
Central Australian Palaeovalley	GA	Aeroquest	15 Jul 11	5000	1000 m and tie lines at 30 km	4113	TBA	TBA	152 – Jun 11 p24	TBA

TBA, to be advised.

Airborne electromagnetic data and inversion models for the Frome Embayment region, South Australia

New airborne electromagnetic (AEM) data and inversion products have been released for the Frome Embayment area in South Australia. The data were acquired using the TEMPEST™ AEM system during 2010 and cover 95 450 km^2 in 32 317 line km. The survey primarily targeted potential uranium-bearing mineral systems in the Callabonna Sub-basin of the Frome Embayment and the Lake Eyre Basin on the flanks of the northern Flinders Ranges, continuing to Marree and Cameron Corner, and included portions of the Curnamona Province and the northwest Murray Basin.

This data release includes new inversions using the Geoscience Australia layered earth inversion (GA-LEI) algorithm and data products, including point-located ASCII data and geo-located grids, sections and images.

The Phase 2 Frome Embayment TEMPEST™ AEM survey final inversion data and conductivity models are available for free download from the GA website: http://www.ga.gov.au/energy/projects/airborne-electromagnetics.html. For further information, email Ian.Roach@ga.gov.au; or phone +61 2 6249 9683.

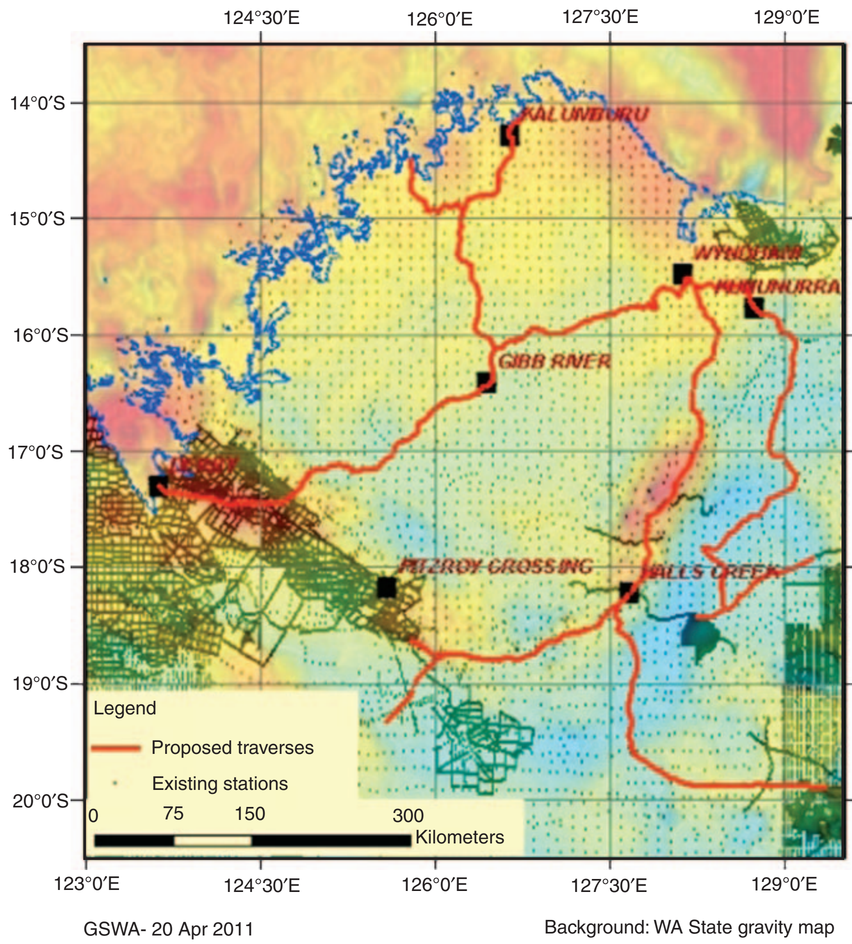


Fig. 2. *Proposed gravity traverses–Kimberley 2011.*

Survey update for Queensland

Gravity surveys

Daishsat Pty Ltd completed a precision GPS-gravity survey in the Thomson Orogen area of southern Queensland on 30 June 2011. Over 7000 new gravity stations on a regular 4 km by 4 km square grid were surveyed in the area between St George and Cunnamulla, adjacent to the New South Wales border.

Integrated Mapping Technologies has also completed a precision GPS-gravity survey over the Galilee Basin in central Queensland. This survey was completed on 12 July 2011 and extended from Winton in the west to Capella in the east. Over 6000 new gravity stations on a regular 4 km by 4 km grid were surveyed.

Both surveys were completed under the National Geoscience Agreement with Geoscience Australia. Preliminary data indicate a vast improvement on the older regional 11 km spaced data.

Once post-survey processing and quality-control procedures have been finalised, the data from both surveys will be included in the National Gravity Database. Data are expected to be available in early August 2011.

Magnetic and radiometric surveys

Thomson Aviation has commenced an airborne magnetic and radiometric survey over the Thomson Orogen area in south-western Queensland. Adverse weather conditions delayed the start of the survey; however, approximately 11 per cent has now been completed. The survey will cover over 270 000 line km at a 400 m flight line interval.

Aeroquest (Aust) Pty Ltd has commenced the Thomson Extension airborne magnetic and radiometric survey immediately to the north of the Thomson survey. After the Thomson Extension survey is completed, Aeroquest will undertake a 400 m flight line survey over the Galilee Basin around Longreach. This will complete the final airborne magnetic and radiometric coverage in central Queensland.

Bernie Stockill

News

Levelled marine gravity and magnetic data for Australia's southwest margin

To facilitate structural interpretation and studies of basement architecture in the basins off southwestern Australia, new ship-track gravity and magnetic data collected as part of the Australian Government's Offshore Energy Security Program have been levelled with existing marine data and merged with onshore datasets (Figure 3). The two marine surveys conducted in late 2008 and early 2009 (surveys GA-310 and GA-2476) acquired about 43 000 line km of new data that improves the coverage of gravity and magnetic data over a large portion of Australia's southwestern margin.

The new data were merged and levelled with an existing Australia-wide dataset of levelled marine data (Petkovic *et al.*, 2001) and combined with onshore data from the 5th Edition of the Magnetic Map of Australia (Milligan *et al.*, 2010) and the 2010 release of the Australian National Gravity Database (http://www.ga.gov.au/minerals/projects/current-projects/continental-geophysics/gravity.html#afgn). Levelling ship-track gravity data is necessary because it minimises the often substantial mismatches at line cross-overs that are caused by positioning errors, instrument drift and variations in the quality of data and data processing. Without these corrections, artefacts and distortions at line cross-overs can render gridded data uninterpretable.

The final compilations of gravity and magnetic data provide a consistent dataset that covers the southwestern margin of Australia in the area bound by 106–120°E and 19–37°S. This area includes the Mentelle, Perth and southern Carnarvon basins, as well as the Wallaby Plateau. It also covers the Australian Government's 2011 release of offshore petroleum exploration acreage in the Perth and southern Carnarvon basins. The data are available for download from the Geophysical Archive Data Delivery System (http://www.geoscience.gov.au/gadds/). Further information can be obtained by contacting Ron Hackney (ron.hackney@ga.gov.au).

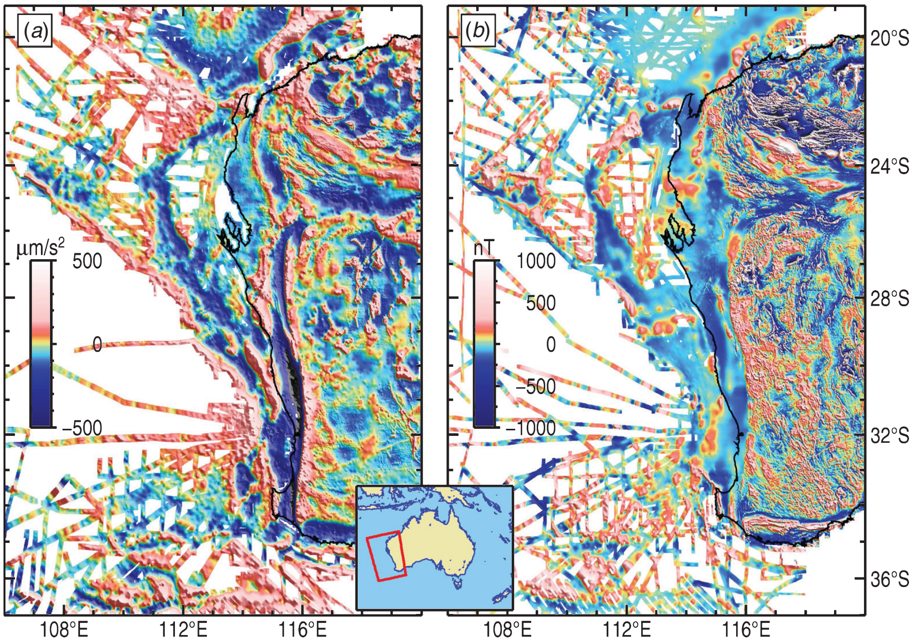


Fig. 3. *Maps of levelled and merged magnetic and gravity datasets for the southwest margin of Australia. (a) Residual gravity image computed from the Bouguer anomaly by subtracting its upward continuation to 25 km. (b) Variable-latitude reduced-to-pole magnetic data.*

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Data update – South Australia

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Email: Tim.Keeping@sa.gov.au

To coincide with the 2011 South Australian Resources and Energy Investment Conference (SAREIC) the Geological Survey of South Australia (GSSA) has published two updated state wide geophysical grids, two new state wide vector datasets and a major data package release. All were made available as of 1 May 2011 through the Primary Industries and Resources South Australia (PIRSA) Minerals website (http://www.pir.sa.gov.au/minerals/) and PIRSA content delivery website South Australian Resources Information

Geoserver (SARIG) (http://sarig.pir.sa.gov.au/).

The SARIG website provides all state grids for download as GeoTiff, ERS Grid and where applicable, the ASCII data used for their derivation is also available. The latest state wide 2.67g/cc Bouguer gravity grid is available. Gravity stations were divided into multiple layers defined by discernable survey qualities, gridded separately and merged into the final product. For further details see Philip Heath's presentation from SAREIC 2011 online (http://www.pir.sa.gov.au/__data/assets/pdf_file/0011/154775/Phil_Heath.pdf).

The new release of the radiometric grids of South Australia were created using techniques recently developed at Geoscience Australia. Over 150 different airborne radiometric surveys were levelled and merged using AWAGS 2 (Australia Wide Airborne Geophysical tie line Survey) and vehicle-borne streaming radiometric tie-lines. The datasets were gridded at 100 m for the following products: K, Th, U, Total Count, KThU ternary, DOSE and Uranium to Thorium ratio.

Gradient Strings (multi-scale edges/worms) for South Australia were derived from Geoscience Australia's nationwide TMI and gravity datasets. Gradient strings have been created using the Intrepid[tm] WormE tool for upward continuation levels from 100 up to 25 000 m. This vector dataset is available in ESRI shape file format for download through the PIRSA Minerals website (http://www.pir.sa.gov.au/minerals/data/gradient_strings_of_sa).

The GSSA's data package release of its 18-month unconformity-related uranium project in collaboration with the Saskatchewan Geological Survey contains the final data and inversion (prepared by Geoscience Australia) for the Cariewerloo Basin AEM survey, basement modelling, gradient strings and interpretations tied to geological and geochemical analysis (Figure 4). The datasets are available for order from PIRSA or for download on the PIRSA Minerals website (http://www.pir.sa.gov.au/minerals/data/cariewerloo_basin).

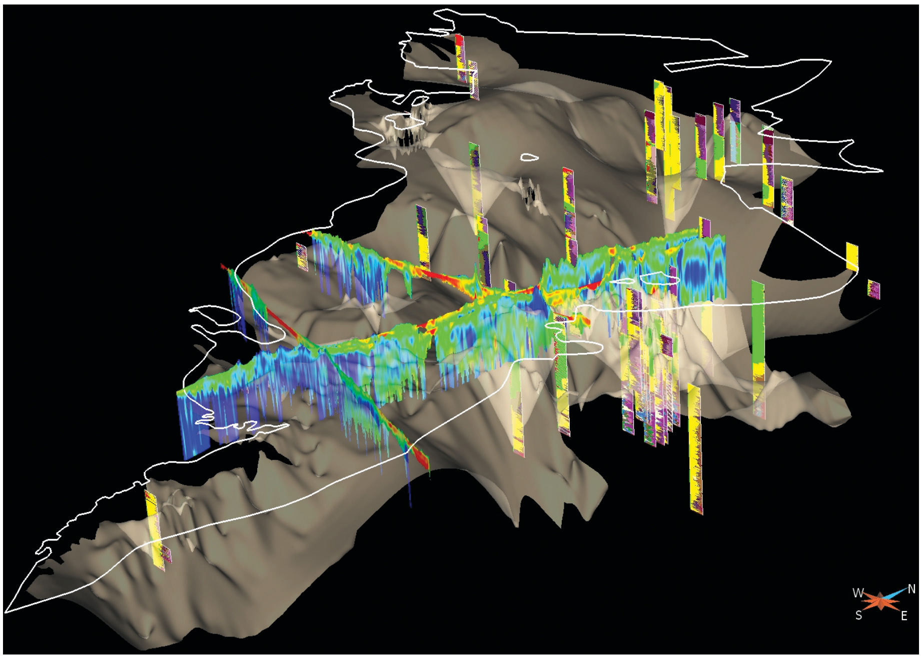

Fig. 4. *Model of the Pandurra Formation combining the estimated extent of the Cariewerloo Basin and depth to basement with georeferenced AEM survey lines and Hylogger analysis of drill holes superimposed.*

Geothermal cities

Klaus Regenauer-Lieb

government buildings with cooling capacities ranging from 300 kW to several MW. The proposed technology does not occupy a substantial aboveground footprint, thereby making it amenable to existing building retrofit. The standard and existing chillers in buildings simply need to be replaced by adsorption chillers. Installing or retrofitting this technology on to only 300 buildings in the Perth metropolitan area with a required cooling capacity of 1 MW each would lead to 724 000 tonnes of CO2e abatement per annum. The same technology can also be applied in new townships, such as Alkimos with 20 000 dwellings and the township in Pilbara, with 50 000 dwellings being planned. The adoption of the first demonstrator (Figure 1) alone, can in both the Perth metropolitan area and in new Western Australian townships, abate 82 million tonnes of CO2e over 20 years.

Klaus Regenauer-Lieb[1,2,4] and Western Australian Geothermal Centre Team[1,2,3]

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This article is based on a presentation to be made at the Australian Geothermal Energy Conference in Melbourne, November 2011. Preview *would like to thank the conference organisers for permission to publish this article.*

The US Geothermal Energy Association has identified Perth as one of the top 10 ‘Geothermal Cities’ on the grounds of ‘entering the geothermal community with a new twist – as the first geothermally cooled city with commercially powered heating and air-conditioning units.’ This announcement reports on the proposal of the WA Geothermal Centre of Excellence (WAGCoE) for CSIRO to cool and heat the Australian Resources Research Centre (ARRC) and the adjacent Pawsey Centre with heat from a deep aquifer below the building. This Education Investment Fund supported project is the first demonstration of a novel WAGCoE developed, patented geothermal cooling technology that has the potential to displace 60 per cent of the electricity needed for conventional heating, ventilation and air conditioning for modern cities by a clean geothermal solution. By working with CSIRO on this project, WAGCoE aims to take the first step towards providing geothermal desalinated water, air conditioning and power to our cities with zero emissions. The Centre will achieve this by supporting a series of geothermal demonstration projects demonstrating exploitation of convective geothermal fields in sedimentary aquifers. Successful completion of the ARRC/Pawsey Centre Geothermal Project is expected to lead to adoption of this technology by the wider community, notably in industrial and commercial buildings, schools, shopping centres and

Keywords: Geothermal cities, direct heat, power generation, zero emission.

Dual heat abstraction – heat rejection solution

The first innovative component of the ARRC/Pawsey Centre geothermal demonstration project is the novel coupling of adsorption chiller technology to a geothermal heat source. This part of the demonstration hinges on the abstraction of heat from a deep aquifer. Wherever water in excess of 60°C is available (not only from a geothermal but also from another waste heat source), its widespread use in this way can displace a significant amount of electricity use in modern cities.

The second innovation is the new concept of a coupled heat rejection into the shallow aquifer using the method of chaotic mixing. This component is often overlooked but probably the most relevant for broadening the footprint of geothermal worldwide and not only for direct heat use. All geothermal implementations, including so-called high temperature resources, have to tackle the problem that they provide temperatures that are still lower than those obtained from burning fossil fuels. Therefore, the lack of efficiency of geothermal energy is always compounded by the need to reject large amounts of energy as heat. Since most geothermal applications are water-cooled it implies in practical terms that the cooling towers have to often waste twice the amount of water produced by the geothermal system or more. Our below ground heat rejection solution solves this problem.

The proposed ARRC/Pawsey Centre geothermal demonstration project shown in Figure 1 will introduce a tight-knit combination of three components:

(i) deep geothermal abstraction;
(ii) shallow geothermal heat rejection; and
(iii) adsorption chiller as an end-user of this novel concept.

For the geothermal city concept we see the adsorption chiller as interchangeable with any of the cascaded heat solutions from electric power production, to HVAC (heating, ventilation and air conditioning), to desalination and city farming.

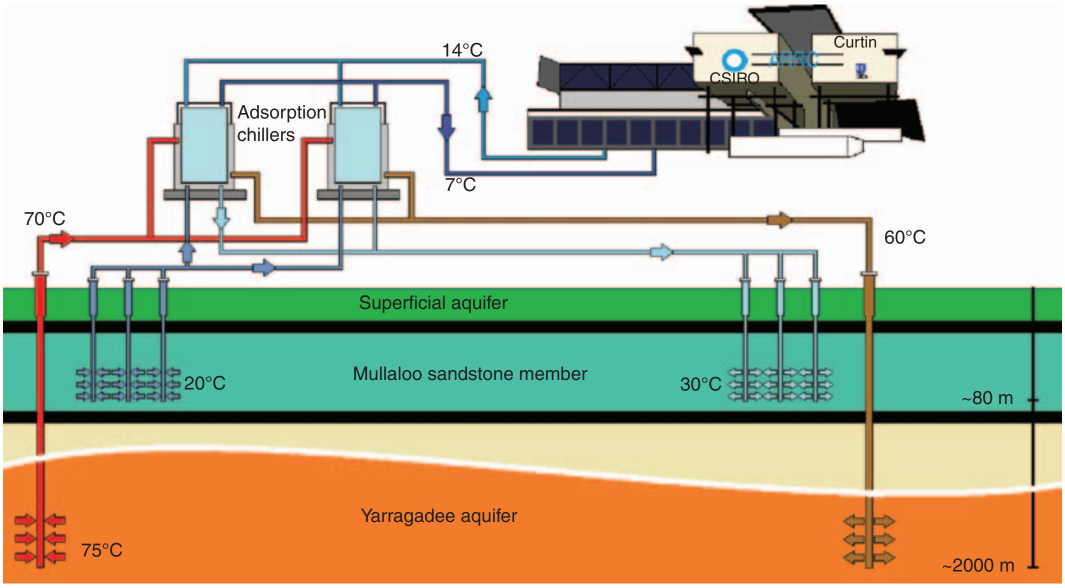

Fig. 1. *Proposed geothermal heating and cooling solution for the Australian Resource Research Centre. Geothermal heat is being harvested from the deeper Yarragadee aquifer to power the adsorption chiller, which provides cooling to the ARRC building, and all the heat is then rejected into the shallower Mullaloo aquifer.*

Heat abstraction

The activities of the WAGCoE in this field have been reported on in previous conferences (e.g. Regenauer-Lieb *et al.*, 2008) and are summarized here in brief. We are focussing particularly on the overlooked potential of hot sedimentary basins, which provide typically lower temperature than the hot rock or volcanic plays. The two key challenges involve geological targeting of the heat sources; and combating the engineering challenges of using the low-grade heat directly. This has been accomplished by:

- assessing the geological and geophysical data from the Perth Basin to identify geothermal targets and thereby construct digital geological models of the basin;
- delivering two patents for utilising heat directly from low temperature geothermal sources and establishing a geothermal desalination facility and a geothermally powered adsorption cooling device (described in more detail later);
- developing a complex system design that combines surface engineering and the underground heat exchanger for optimal tradeoffs and for infrastructure sustainability.

WAGCoE also has a fundamental research program that pushes for hotter and deeper resources. We investigate deeper below the sedimentary cover and address the challenges of extracting heat from the granitic basement. Novel multiscale methods for data assimilation in geosciences have been developed from 4D-synchrotron tomography to large-scale geophysical, geological and geochemical data sets which are reported in one of the premier science journals *Nature* (Regenauer-Lieb *et al.*, 2006; Fusseis *et al.*, 2009; Schrank *et al.*, 2011).

Heat rejection

Recently, a patented technology for efficient heat rejection has been developed based on a controlled laboratory experiment performed in CSIRO's Division of Material and Engineering Science in the Highett labs, Melbourne (Metcalfe *et al.*, 2010a; Metcalfe *et al.*, 2010b). A numerical approach has been developed that allows optimisation of subsurface chaotic mixing which has many potential applications, e.g. for treating contaminant sites, for in-situ leaching, in the petroleum industry, CO_2 sequestration, nuclear waste disposal and geothermal energy extraction and heat rejection.

Heat rejection installations into shallow aquifers are also sometimes known as 'aquifer thermal storage' or 'open loop

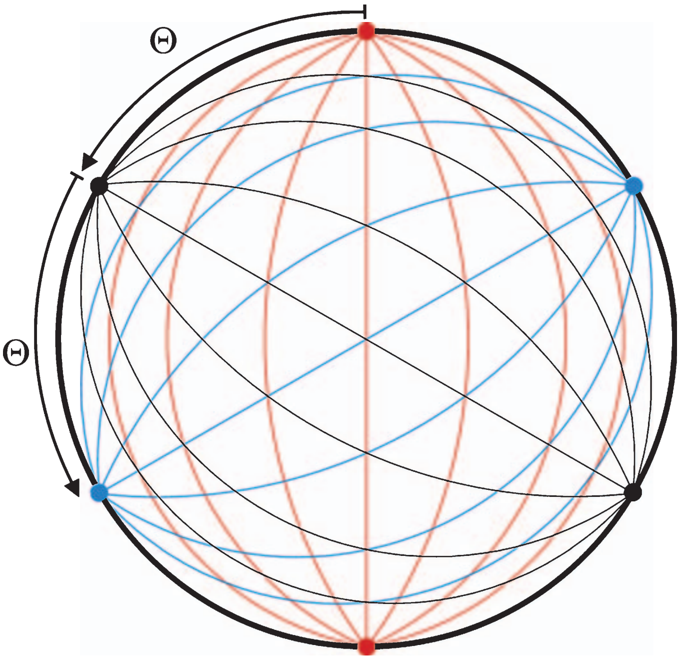

Fig. 2. *Example programmed dipole sequence for a chaotic switching protocol (rotated potential mixing). The red streamlines show the flow regime induced by one well dipole, then, after some programmed duration t, this dipole is deactivated and another dipole at jump angle Θ is activated (black streamlines), then deactivated at time 2t and a third dipole is immediately activated (blue streamlines), and so on.*

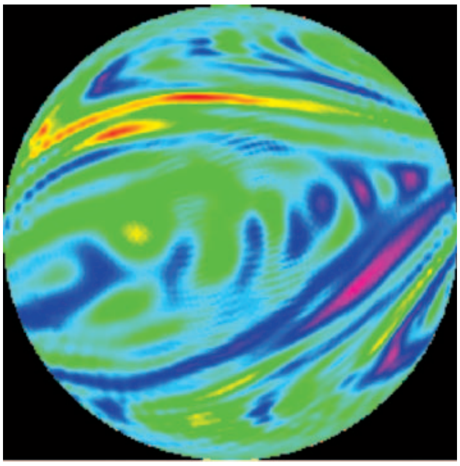

Fig. 3. *Example of optimal mixing eigenmode (Lester* et al.*, 2010).*

groundwater systems'. They classically consist of a pair or several pairs of extraction/injection well dipoles. These are often designed and operated in a loop, where the extraction well and the injection well are considered to be fixed for the lifetime of the operation. Thermal breakthrough, where disposed hot water from the injector reaches the extraction well, poses a serious risk for these operations. This risk limits the optimal design life of the pair. The design life and the maximum amount of heat that can be rejected can be increased significantly through a simple switching protocol that efficiently mixes the water between the dipoles. An example is shown in Figure 2 (Trefry *et al.*, 2011) for an arrangement of injection-extraction pairs verified in laboratory and numerical experiments as shown in Figure 3 (Lester *et al.*, 2010).

This technology is particularly useful for the heat rejection side since, owing to thermodynamic efficiencies, more heat must be rejected than is extracted. The desire would be to operate such a geothermal well field beyond the classical engineering lifetime of 20 years. The lifetime requirement arises because of the substantial capital investment for drilling the wells and the above ground infrastructure. A significant problem on this time scale is the problem of chemical precipitation around the injection boreholes. This is because the deep aqueous chemistry often can be saline/acidic with dissolved gases. The mixing protocol also has the potential to address this problem since the chemical potentials are switched.

Adsorption chillers

Adsorption chillers form a relatively new class of heat driven chillers first patented in the 1980s. Compared with absorption chillers, which are the conventional alternative, adsorption chillers rely on a solid rather than a liquid phase to drive the heat exchange. The solid adsorbent can be either silica gel or zeolite. The key virtues of adsorption chillers are that they can be powered by heat sources with temperatures as low as 65°C and there is no risk of solution crystallization. Compared with absorption chillers, which typically require a heat source temperature of 90°C, adsorption chillers are viable with geothermal resources at shallower depths. This drastically reduces the risk and cost of drilling and improves reservoir performance, which translates to a lower ongoing pumping cost for extraction of the groundwater. There is a trade-off between reservoir accessibility and required flow rate. Being a relatively new technology with a smaller consequent market penetration, the unit costs of an adsorption chiller (currently twice that of an absorption chiller) are expected to reduce significantly over time. However, in terms of net project capital costs they are already competitive because of the below ground advantages.

For installations where space is an issue, the adoption of zeolite-water as the working pair provides a far more compact option than the standard silica gel-water technology, which therefore requires a smaller aboveground footprint. To the best of our knowledge this technology has not been deployed in Australia, but has been tried and tested commercially chiefly in Japan and Europe since the late 1980s in the paint industry, iron refineries and process industry where low grade heat is abundant. WAGCoE's manager of the above ground engineering program, Professor Hui Tong Chua, is an international leader in this technology, and holds an adsorption chiller patent granted in Singapore, US and Europe which has been successfully licensed to the industry since 2003. His adsorption chiller design model is used by Mayekawa, the world-leading manufacturer for adsorption chillers, in its in-house product prototyping. He is currently developing a new generation of compact adsorption chiller which can operate at temperatures as low as 55°C. This will conceivably boost the viability and uptake of geothermal adsorption chiller technology.

Heat driven chillers, absorption and adsorption regardless, reject significantly more heat to the environment than standard electricity driven chillers. In standard engineering design, cooling towers are used for heat rejection to the atmosphere. They consume a significant amount of fresh water, discharge a considerable amount of spent water to the sewerage which produce significant emissions and require ongoing chemical treatment. A key innovation of our proposed ARRC/Pawsey Centre geothermal demonstration project is that we replace this standard design protocol with the novel ground-source heat rejection design described above. So instead of rejecting heat to the atmosphere, the same amount of heat is rejected to a shallow aquifer at a depth of about 80 m. This innovative scenario consumes essentially the same amount of electricity as the standard cooling tower design, but it does not consume any fresh water, nor does it require any ongoing chemical treatment. In addition, the perennially cool groundwater offers 2°C and 6°C temperature drop on top of what cooling towers can offer, in winter and summer, respectively, thereby further improving chiller efficiency.

Research partners

CSIRO, Curtin University, The University of Western Australia.

Industry Collaborators: GTPower, Green Rock Energy Ltd, New World Energy, Geodynamics, BHP, Newcrest, Geowatt (Switzerland).

The Geothermal Research Initiative (GRI): A collaborative network of the Australian geothermal energy research community involving CSIRO, Western Australian Geothermal Centre of Excellence, Queensland Geothermal Energy Centre of Excellence, South Australian Centre for Geothermal Energy Research, Melbourne Energy Institute, Priority Research Centre for Energy at University of Newcastle, Geoscience Australia, The Institute of Earth Science Engineering at the University of Auckland (NZ).

Institutional Collaborators: Geological Survey of WA, WA Department of Water, Institute for Geothermal Resource Management (Germany), Sustainable Energy Association Australia (SEA), Australia–US–Switzerland–Iceland International Partnership for Geothermal Technology (IPGT).

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The ground source heat pump at Geoscience Australia

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Introduction

Ground source heat pumps (GSHP) are one of the fastest growing applications of renewable energy in the world, with increases in installed capacity of over 10% per annum between 1995 and 2005 (Rybach, 2005). GSHP systems are widespread overseas, particularly in the USA and Europe, with a total installed capacity of 7.2 GWth (47% of world total) in the USA, and 3.84 GWth (25%) in Sweden. In comparison, Australia lags behind with a total installed capacity of 5.5 MWth, (0.036% of the world total) (Rybach, 2005).

GSHP systems utilise the stable nature of the earth's temperature at depth to provide cooling during the hot summer months and heating in the colder winter. They do not need elevated ground temperatures to operate, rather the constant ground temperature acts as a heat sink, or source, to augment the air conditioning system. GSHPs circulate a working fluid, usually water, through the ground and then through the building to distribute or absorb heat. They can be open or closed loop with a range of possible loop configurations (Figure 1). The loops are buried anywhere from several metres to over 100 m in the ground.

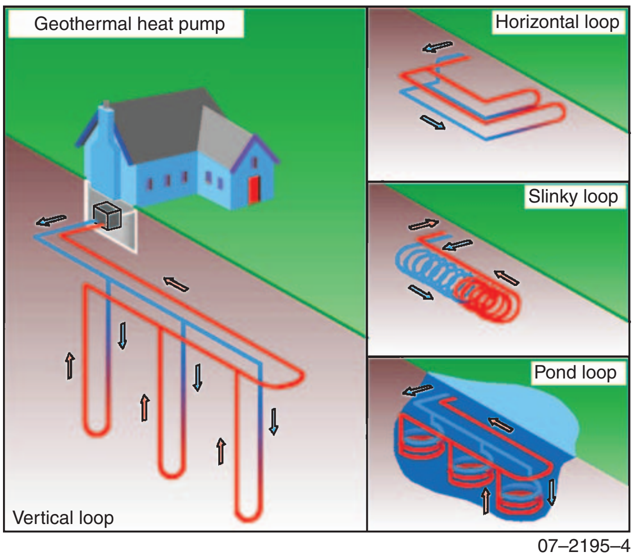

Fig. 1. *Examples of loop configurations that can be used for ground source heat pump systems.*

GSHP systems use electricity to circulate, not generate, heat, so they can provide considerable electricity savings over the life of a building. GSHPs are ideally suited to climates where extremes in both high and low temperatures are experienced. In this way, the systems are sustainable because the GSHP causes minimal net annual change in ground temperature – the ground is cooled by the GSHP due to the cool air temperature in winter and heated in summer. However, systems do exist where there is an imbalance between heating and cooling demand (e.g., open loop systems installed in the London Chalk aquifer (Etheridge, 2010)).

The Geoscience Australia ground source heat pump system

The Geoscience Australia (GA) building located in Symonston, ACT, accommodating 700 staff, utilises one of the largest GSHP systems in the southern hemisphere (Dickinson *et al*., 2007; Figure 2). The system was installed in 1997 when the Geoscience Australia building was constructed (Dickinson *et al*., 2007), and has an installed capacity of 2.5 MWth.

In the Canberra region, the ground temperature at about 100 m depth is fairly constant throughout the year at 17°C. This is a valuable resource considering the large range in surface air temperatures experienced in Canberra with lows well below 0°C and maximum temperatures in excess of 35°C (Figure 3). The constant ground temperature is used as a source of heating or cooling depending on the seasonal requirements of the building.

Fig. 2. *View from underneath the Geoscience Australia building showing pipes circulating water between the pump room and the underground bore field.*

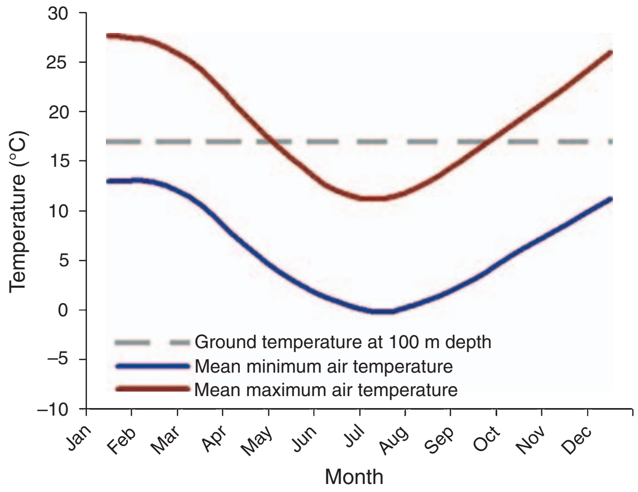

Fig. 3. *Seasonal air temperature variations in Canberra compared to ground temperature at 100 m depth (climate data courtesy of http://www.worldweather.org/185/c00302.htm).*

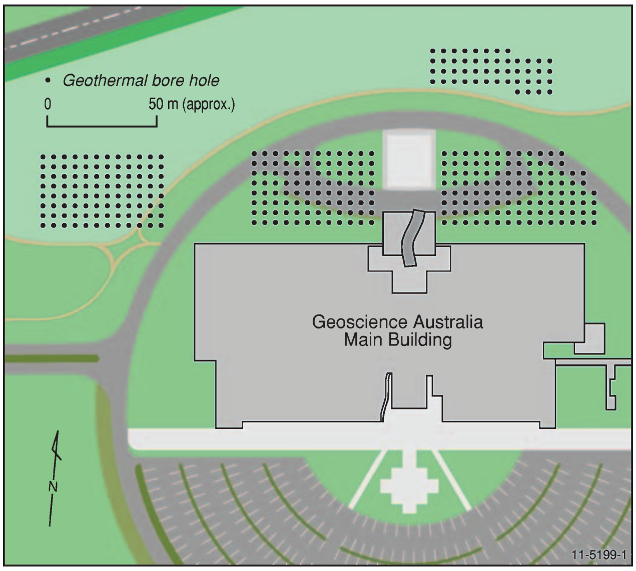

Fig. 4. *Distribution of boreholes associated with the ground source heat pump system at Geoscience Australia.*

The GSHP system at GA is a closed loop system consisting of three components: an underground bore field, which comprises 352 bore holes grouped into four fields located in front of the GA building (Figure 4). Each borehole is 20 cm in diameter, and contains a loop of 80 mm poly pipe through which water is circulated. The water is heated by up to 3°C in winter and cooled by up to 3°C in summer. The water is then aggregated to control and pump room. Here, if necessary, the fluid is further heated or cooled to bring its temperature to about 22°C. The fluid is then distributed via pumps to 210 individual heat exchangers located throughout the general office area of the building. The heat exchangers work in a similar way to conventional split system air conditioning units, with heat being transferred between the water and the air via a refrigerant.

The temperature of the returning fluid is measured in the control room before being sent out through the bore field. In spring and autumn when outside temperatures are mild, it is sometimes more efficient to bypass the ground loop. If this is the case the control centre will automatically recirculate the fluid through the building.

System performance

The GA system is one of the longest operating of its type in Australia, providing an opportunity to examine the long term performance of a GSHP system. A 10-year building review conducted in 2007 (Dickinson *et al.*, 2007) estimated that the system had saved a total of about $400 000 in electricity costs. Energy performance comparisons made with the 2007–2008 'Energy Use in the Australian Government Operations' reports show that the GA building has maintained energy performance close to targets set for general office administration buildings. This is significant given the requirements to provide separate air conditioning to laboratories and special storage areas. The energy savings can be attributed to the GSHP system and other energy efficient design principles used in the building.

Conclusion

The uptake of ground source heat pump systems in Australia has been limited to date, especially when compared to the USA and Europe. The Geoscience Australia building is an example of a large scale GSHP system that can provide significant savings in both heating and cooling costs and CO_2 emissions.

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Temperature and heat flow information for geothermal energy exploration in Western Australia

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The Geological Survey of Western Australia (GSWA) is continuing its studies in subsurface temperatures and heat-flow modelling to assess prospective areas and encourage geothermal energy exploration in Western Australia. Estimated temperatures and heat-flow modelling identified high temperatures on the Broome Platform and in areas north of Onslow within the Canning and Carnarvon basins, respectively. In the Perth Basin, 3D modelling calculated temperatures above 150°C at 4 km below sea level within the Bookara Shelf, Coomallo and Beermullah troughs. These areas have temperatures up to 100°C within a depth of 3 km for hot sedimentary aquifer (HSA) resources, and up to 200°C within a depth of 5 km for hot rock (HR) resources. The northern Perth Basin is the most attractive target for geothermal energy development, with its favourable temperatures, geology, well-developed infrastructure and commercial markets.

Keywords: geothermal gradients, heat flow, modelling geothermal energy, Western Australia.

Introduction

Exploration for geothermal energy in Western Australia was formalized in January 2008, with the first geothermal acreage released in the Perth Basin. Presently, seven companies are exploring for geothermal energy in 41 Geothermal Exploration Permits (GEPs) in the State. The University of Western Australia (UWA) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) are developing new technologies for geothermal energy exploration, exploitation, and utilization.

The Geological Survey of Western Australia (GSWA) is continuing its studies in subsurface temperatures and heat-flow modelling to identify prospective areas for geothermal energy exploration in Western Australia. Nine specific geothermal reports can be downloaded free of charge from http://www.dmp.wa.gov.au/801.aspx; http://geodocs.doir.wa.gov.au/document/documentSearch.do.

New data include estimated equilibrium temperatures in 579 wells, measured thermal conductivity on 302 cores, one-dimensional (1D) heat-flow modelling in 329 wells, and three-dimensional (3D) geological and heat-flow modelling of the northern Perth Basin, and available stress and basement heat generating data for the study areas. These data include all available temperatures recorded in onshore petroleum wells, drilled within the Bonaparte, Carnarvon, Canning, Officer, and Perth basins, including two offshore Browse Basin wells.

The aim is to identify areas with temperatures up to 100°C within a depth of 3 km for hot sedimentary aquifer (HSA) resources, and up to 200°C within a depth of 5 km for hot rock (HR) resources, which can be developed using Enhanced Geothermal System (EGS).

Bonaparte and Browse Basins

The larger part of the Bonaparte Basin lies offshore whereas the Browse Basin is entirely offshore. Thermal conductivities were measured in 13 cores from four wells, Bonaparte 1A, Bonaparte 2, Laminaria East 1, and Turtle 1, within the Bonaparte Basin. The lowest measured conductivity is 1.24 W/m°C for the Jurassic Frigate Shale in Laminaria East 1, and the highest is 5.09 W/m°C for the Devonian Cockatoo Group in Bonaparte 1A (Hot Dry Rocks Pty Ltd, 2010a). Within the Browse Basin, conductivities were measured in four cores from Brecknock 2 and Calliance 1, with minimum values of 2.29 W/m°C for the Triassic Nome Formation, and maximum values of 4.51 W/m°C for the Jurassic Plover Formation (Hot Dry Rocks Pty Ltd, 2010b).

Based on 1D heat flow modelling of nine wells (Hot Dry Rocks Pty Ltd, 2010a) the apparent surface heat flow ranges 60–103 mW/m² with a median value of 76 mW/m² for the Bonaparte Basin. Within the Browse Basin, the modelled heat flow values for the Adele Island 1 and Browse Island 1 sites are 30 mW/m² and 51 mW/m², respectively (Hot Dry Rocks Pty Ltd, 2010b).

Presently, these basins are not suitable for geothermal energy development and no company has applied for Geothermal Exploration Permits.

Canning Basin

The Canning Basin is the largest basin of Western Australia. Estimated equilibrium temperatures in 274 wells, measured thermal conductivity on 50 core samples from 22 wells, and 1D heat flow modelling in 101 wells identified regions of high temperature (up to 200°C) at depths of less than 5 km, which is presently considered economic for development of hot rock resources using EGS.

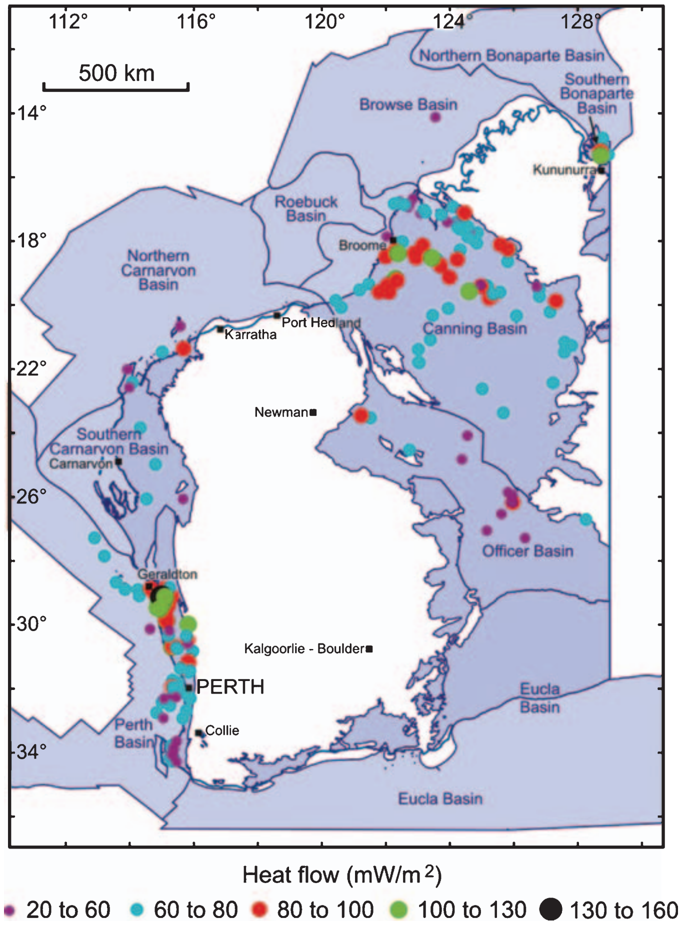

Fig. 1. *1D heat-flow values modelled in wells of Western Australian basins.*

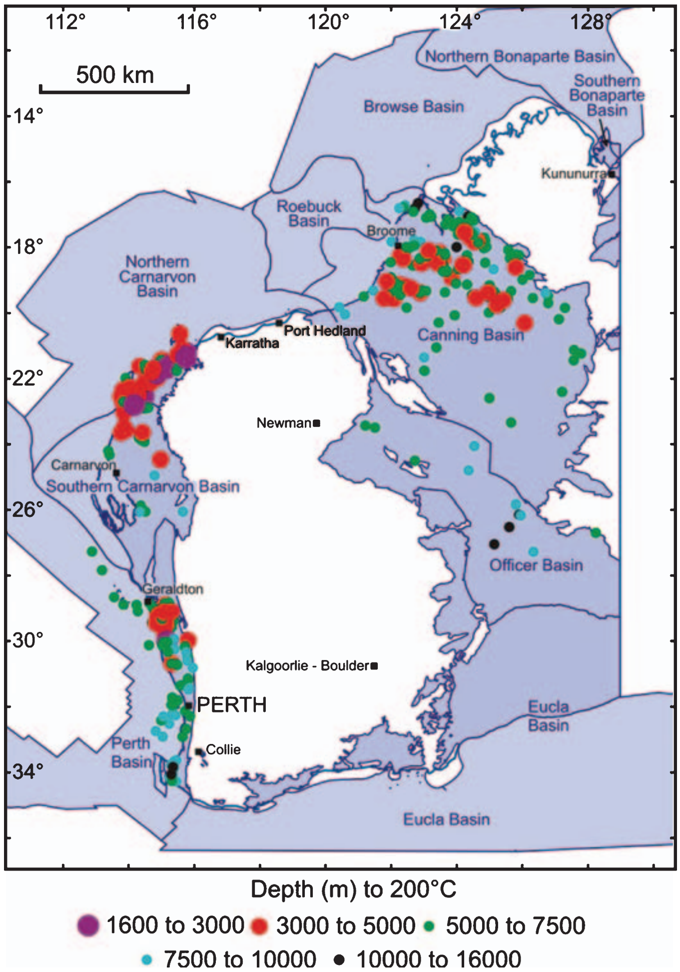

Fig. 2. *Calculated depth (m) to 200°C in wells of Western Australian basins.*

Measured thermal conductivity ranges from 1.06 to 5.83 W/m°C and modelled surface heat flow ranges 20–160 mW/m². The lowest measured thermal conductivity (1.06 ± 0.28 W/m°C) is within the Ordovician Goldwyer Formation, and the highest values (5.83 ± 0.22 W/m°C) were detected within the Upper Carboniferous Reeves Formation (Driscoll *et al*., 2009).

Estimated heat flow values are lower (less than 65 mW/m²) in locations where thick sedimentary deposits are present such as the Fitzroy Trough, Lennard Shelf, and Kidson Sub-basin. The heat flow values increase to over 80 mW/m² on the Broome Platform and Jurgurra, Mowla and Barbwire Terraces. Higher heat flow values have been modelled for Goodenia 1, Lovells Pocket 1, Kanak 1, Cudalgarra North 1, and Cudalgarra 1, where heat flow values exceed 100 mW/m² (Figure 1). These new data indicate that the Broome Platform has the highest temperatures (Figure 2). Given its shallow basement the Broome Platform has a high potential for geothermal energy development, provided other factors are also found favourable for developing HR and HSA (Chopra and Holgate, 2007; Driscoll *et al*., 2009; Ghori, 2009; Ghori, 2010).

Geothermal energy exploration in the Canning Basin began with an acreage release in September 2009, and applications for GEPs are under consideration.

Carnarvon Basin

The Northern Carnarvon Basin is the main oil and gas producing basin of Western Australia, with over 984 petroleum wells providing a huge amount of subsurface data up to a drilled depth of 9 km. Subsurface data for the Southern Carnarvon Basin is limited to 258 wells, mostly onshore.

Estimated equilibrium subsurface temperatures in 138 onshore petroleum wells, measured thermal conductivity on 61 core samples from 10 wells, and 1D heat-flow modelling of 21 wells identified regions of high temperature (up to 200°C) at depths of less than 5 km (Chopra and Holgate, 2007; Ghori, 2008; Hot Dry Rocks Pty Ltd, 2010c).

The measured thermal conductivity ranges, from 0.64 to 4.97 W/m°C and modelled surface heat flow ranges from 24 to 95 mW/m². The lowest measured thermal conductivity (0.646 W/m°C) is within the Devonian Gneudna Formation, and the highest values (4.97 ± 0.24 W/m°C) are within the Carboniferous Quail Formation (Hot Dry Rocks Pty Ltd, 2010c).

Estimated heat flow values increase from south to north within the onshore parts of the Carnarvon Basin. Values are lowest (<60 mW/m²) in the Barrow and Exmouth sub-basins and increase to up to 95 mW/m² toward the onshore Peedamullah Shelf (Figure 1). Although these observations are based on a limited number of wells it indicates that the area north of Onslow has the highest temperatures (Figure 2). Given its shallow high-temperature areas the Carnarvon Basin has a high potential for geothermal energy development, provided other factors are also found favourable for developing HR and HSA

(Chopra and Holgate, 2007; Driscoll *et al*., 2009; Ghori, 2009; Ghori, 2010).

Presently, two companies are investigating geothermal resources in eight GEPs, awarded in February 2010 (Middleton and Bruce, 2010).

Officer Basin

The Officer Basin contains over 8 km of Neoproterozoic strata and has been explored sporadically for petroleum since the late 1960s. Yowalga 3 is the deepest (4197 m) of 16 wells within the basin.

Estimated equilibrium temperatures in 16 petroleum wells, measured thermal conductivity on 40 core samples from six wells, and 1D heat-flow modelling in 14 wells indicate regions of low temperature (up to 150°C) at depths of greater than 5 km (Hot Dry Rocks Pty Ltd, 2010d).

The measured thermal conductivity ranges from 1.25–5.54 W/m°C and modelled surface heat flow values from 33 to 95 mW/m². The lowest measured thermal conductivity is within the Cretaceous Samuel Formation (1.25 ± 0.03 W/m°C) from BMR Browne 1, and the highest values are within the Neoproterozoic Hussar Formation (5.54 ± 0.11 W/m°C) in GSWA Empress 1A (Hot Dry Rocks Pty Ltd, 2010d).

Generally the estimated heat flow values increase from the deep basin centre to the basin margins. The lowest value (<60 mW/m²) is observed in the eastern Gibson, Yowalga, and northern Lennis areas (Figure 1). These data indicate that in most of these locations temperatures are lower, i.e. 150°C at depths greater than 5 km (Figure 2; Hot Dry Rocks Pty Ltd, 2010d).

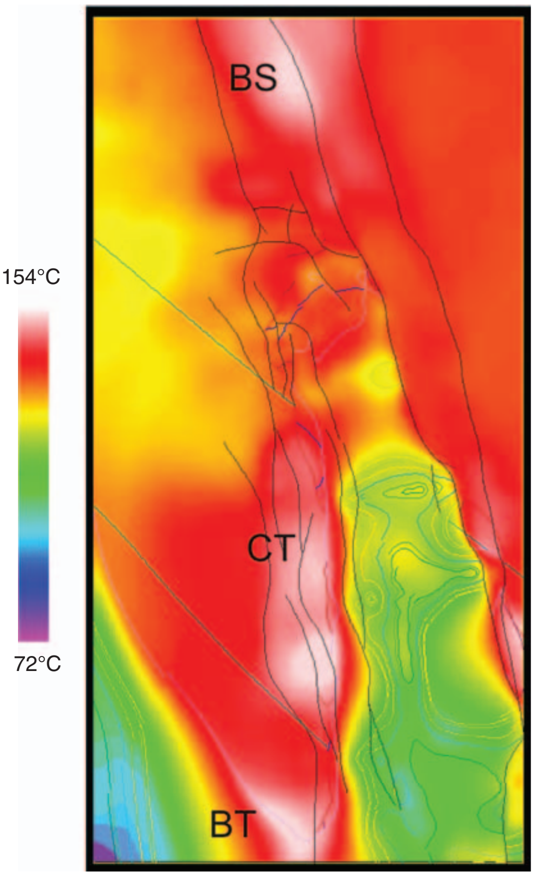

Fig. 3. *Temperatures at 4 km below sea level, computed from 3D heat-flow modelling. Highest temperatures are computed in the vicinity of BS (Bookara Shelf), CT (Coomallo Trough), and BT (Beermullah Trough), after Gibson* et al. *(2010).*

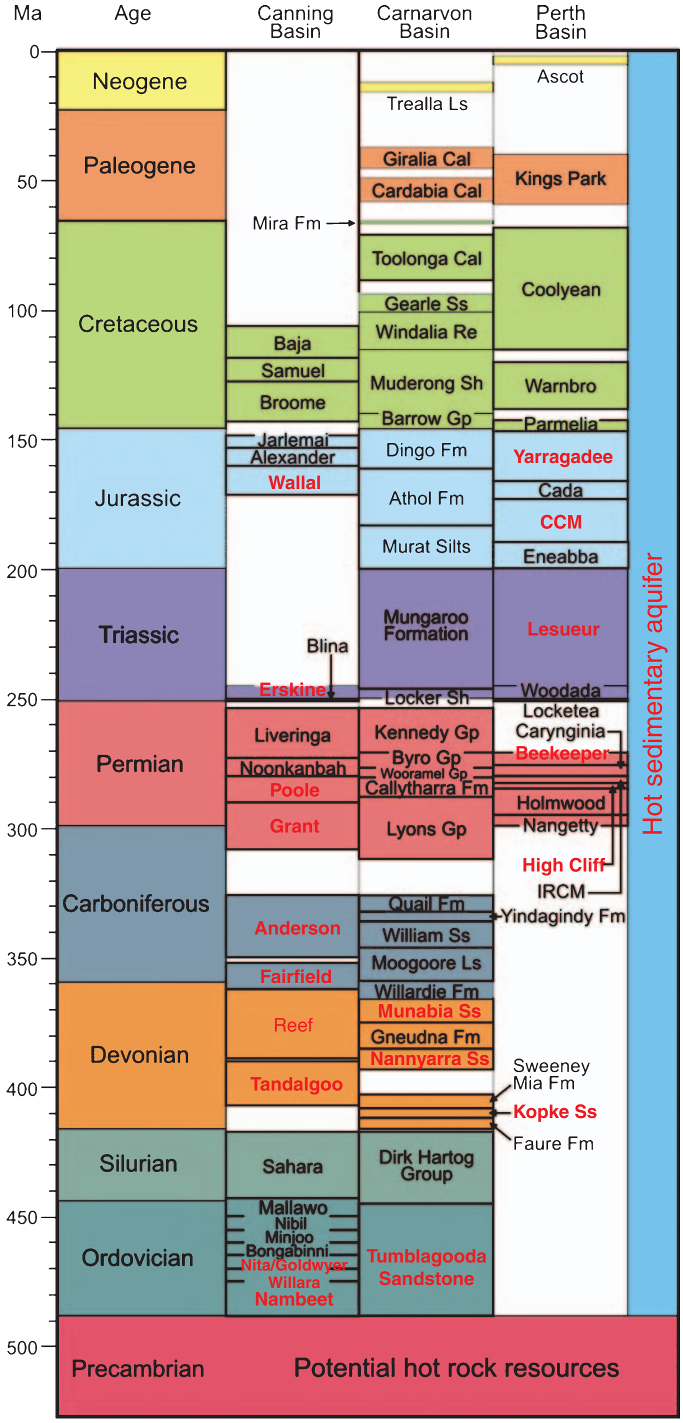

Fig. 4. *Generalised time-stratigraphy of the Carnarvon, Canning, and Perth basins, and potential geothermal resources (after Ghori, 2009).*

Perth Basin

GSWA initiated the search for geothermal energy in the early 1980s and recognised the potential of low temperature hydrothermal resources of up to 85°C at depths of less than 2 km

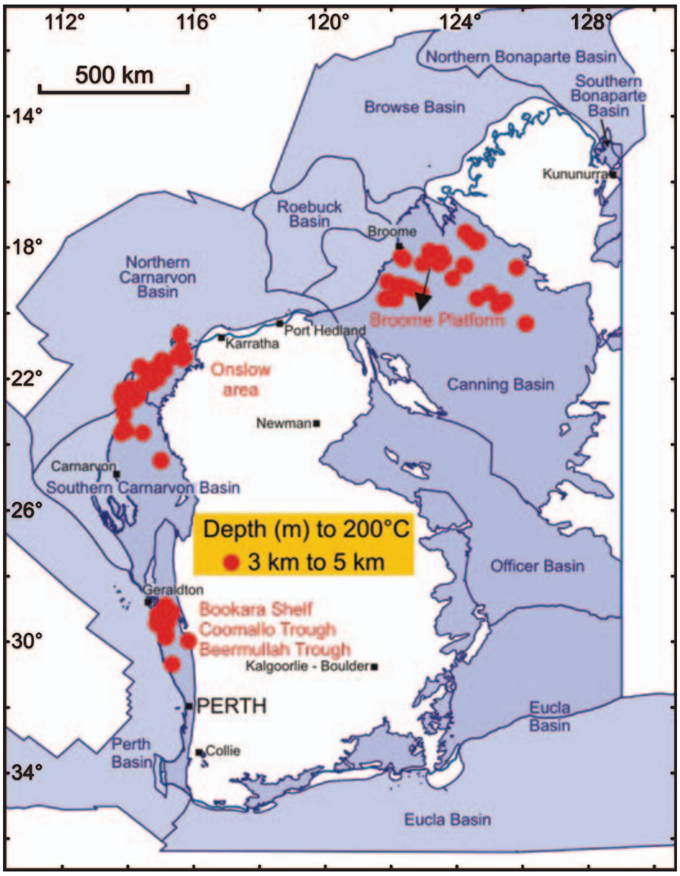

Fig. 5. *Location of wells with 200°C within depths between 3 km and 5 km, within the Carnarvon, Canning, and Perth basins.*

(Bestow, 1982). Geothermal exploration and exploitation was formalized in 2008, after a two-decade long break (Ghori, 2009). Presently, the Perth Basin is the most attractive target for geothermal energy research, exploration and development with six companies and two research institutions exploring in 31 GEPs (Middleton and Bruce, 2010).

Estimated equilibrium temperatures in 289 petroleum wells, measured thermal conductivity on 36 core samples from 14 wells, 1D heat flow modelling of 162 wells, and 3D geological and heat flow modelling of the northern Perth Basin identified regions of high temperature (>150°C) at depths of less than 4 km (Chopra and Holgate, 2007; Hot Dry Rocks Pty Ltd, 2008; Ghori, 2008; Gibson *et al.*, 2010).

The measured thermal conductivity ranges from 1.33 to 7.01 W/m°C and modelled surface heat-flow ranges from 30 to 140 mW/m². The lowest measured thermal conductivity (1.30 ± 0.11 W/m°C) is within the Permian Rosa Brook Coal Measures in Sue 1 and the highest values are within the Jurassic Cadda Formation (4.55 ± 0.86 W/m°C) in Gingin 1 (Hot Dry Rocks Pty Ltd, 2008).

The estimated heat flow values are lower in the south (Bunbury Trough) and increase up to 90 mW/m² north of Eneabba. The highest heat flow values have been modelled at Dongara 26 (116 mW/m²), and lowest (30 mW/m²) at Narkarino 1 (Figure 1). Calculated high temperatures from 3D heat-flow modelling are recognised at the vicinity of Coomallo and Beermullah troughs, Bookara Shelf, and north of Moora (Figure 3).

New temperature and heat flow data indicate that northern parts of the Perth Basin have the highest temperatures and shallow basement, within 5 km depth (Figure 2 and 3), provided other factors are also found favourable for developing HR and HSA (Hot Dry Rocks Pty Ltd, 2008; Ghori, 2008; Gibson *et al.*, 2010).

Stratigraphy and potential geothermal resources of the Carnarvon, Canning, and Perth Basins are summarised in Figure 4, and location of wells where depth to 200°C is between 3 km and 5 km in Figure 5.

Conclusions

The Coomallo and Beermullah troughs, Bookara Shelf, and the area north of Moora in the Perth Basin; the Broome Platform in the Canning Basin, and areas north of Onslow in the Carnarvon Basin have favourable temperatures with shallow basement for geothermal exploration. The estimated temperatures in many wells of the Canning, Carnarvon, and Perth basins are up to 100°C within a depth of 3 km for hot sedimentary aquifers (HSA) resources and up to 200°C within a depth of 5 km for hot rock (HR) resources. The Perth Basin is the most attractive target with its well-developed infrastructure and commercial markets.

Acknowledgments

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Geophysical techniques for low enthalpy geothermal exploration in New Zealand

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Introduction

Shallow warm water resources associated with low enthalpy geothermal systems are usually difficult to explore using geophysical techniques, mainly because the warm water creates insufficient physical changes to the host rocks to be detectable. In addition, often the system also has a limited or narrow size.

This paper presents case studies of geophysical exploration of shallow warm water systems over a variety of settings in New Zealand (mostly over the North Island), with a variable degree of success. Locations of study areas are shown in Figure 1.

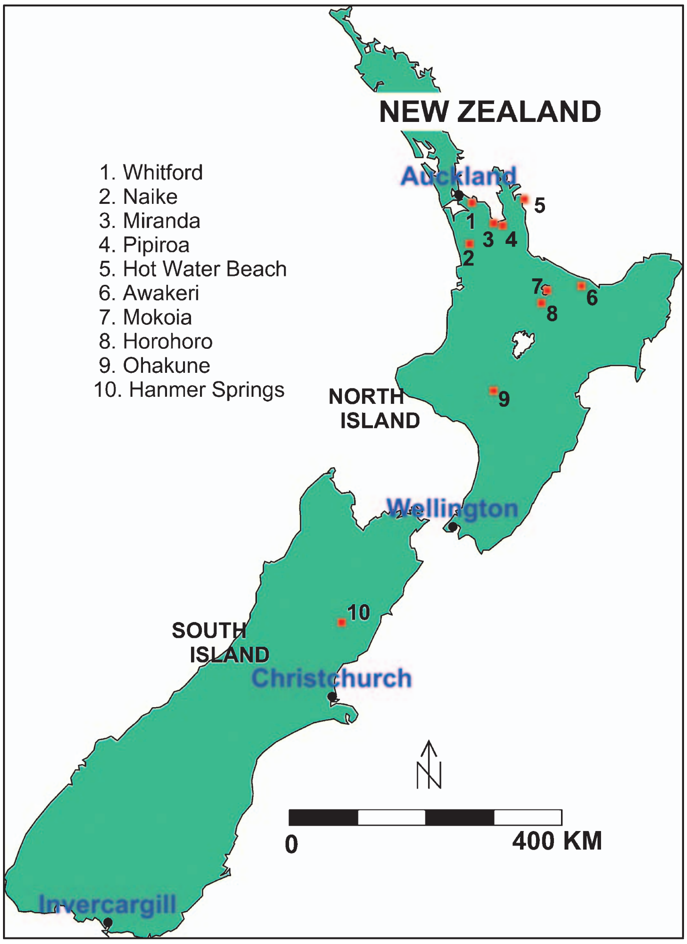

Fig. 1. *Location map of the study areas.*

Shallow temperature measurements

A simple and direct method for the exploration of warm water systems is shallow ground temperature measurements. Ground temperature variation over the Naike hot springs (Figure 1) is shown in Figure 2*a*. It suggests a relationship between the ground temperature and Faults II and III which were mapped by Siswojo *et al.* (1985) from an examination of aerial photographs.

The occurrence of thermal water near Whitford (Figure 1) at South Auckland was revealed during the drilling of a few shallow wells (<80 m) for a farm water supply. The existence of this thermal water was also shown by subsequent ground temperature measurement across the area.

At Pipiroa (Figure 1) temperatures at 1 m depth did not vary by more than 0.5°C from 15°C reflecting normal ambient temperatures. Slightly warmer temperatures (up to 19°C) were measured beneath several nearby drains where warmer surface waters (22–26°C) or gas discharges had been noted.

At least five hot springs occur along the south-eastern shore of Mokoika Island (Figure 1) in Lake Rotorua. Results of shallow ground temperature measurements clearly indicate two favoured sites for accessible shallow hot water resources.

Gravity method

The gravity method is often used as a structural technique for the exploration of New Zealand warm water systems.

At Naike, residual gravity data (Kasonta, 1984) appear to indicate the deepening of greywacke basement under the overlying Tertiary rocks (see Figure 2*c*), but show no obvious correlation with the thermal springs. A correlation between residual gravity anomaly and faults II and III seems to occur close to the greywacke basement outcrop, but this is questionable because of the limited number of measurement sites.

Detailed gravity measurements over the Whitford warm water prospect (Chen, 1990) did not show any obvious relationship with the inferred fracture zone in this area as suggested by various DC resistivity surveys (Mohamed, 1988; Yang, 1989; El-Shariff, 1990).

At Awakeri (Figure 1) the gravity data were useful because they showed evidence of displacement of formations of different density along a cross fault that appeared to intersect the main graben-bounding fault (Bromley *et al.*, 2003).

Direct current (DC) resistivity survey

Direct-current (DC) resistivity measurements using a variety of electrode arrays have been the most common method for the exploration of low enthalpy geothermal resources in New Zealand.

At Naike, Schlumberger DC apparent resistivity data appear to indicate the deepening of greywacke basement under the overlying Tertiary rocks (consistent with the gravity data), but show no obvious correlation with the thermal springs (see Figure 2*b*).

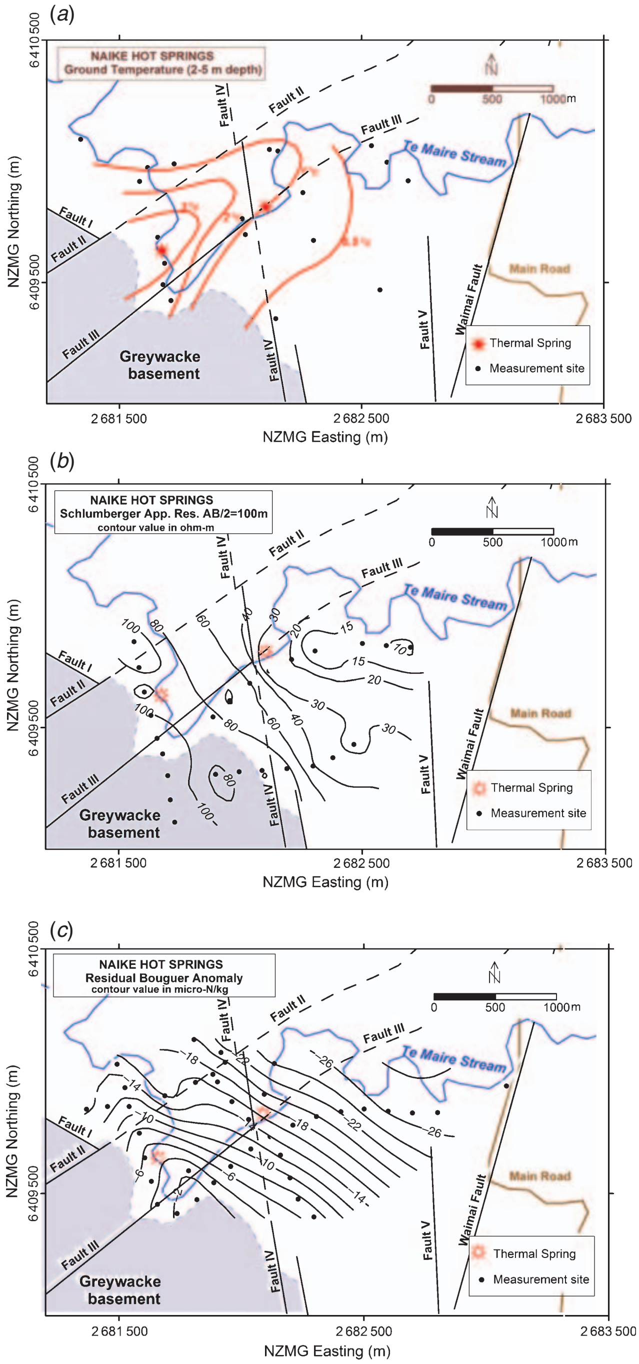

Fig. 2. *Ground temperatures (a), Schlumberger app. resistivity (b) and residual Bouguer anomaly (c) of the Naike hot springs (from Simandjuntak, 1983; Kasonta, 1984; Siswojo* et al.*, 1985).*

Apparent resistivity tensor measurements, together with ground temperature survey and borehole temperature data suggest the presence of a zone of NNW oriented basement fractures associated with the warm water at Whitford (Boedihardi and Hochstein, 1990). The existence of such a fracture zone is also supported by a circular Schlumberger electrical sounding (CES) carried out by Yang (1989).

DC resistivity measurements using Schlumberger array were carried out across the Miranda hot springs (Figure 1) by Sudarman (1982). Figure 3 shows that the group of hot springs at Miranda is associated with a small area (~0.3 km^2) of low apparent resistivity (AB/2 = 300 m). The further decrease of apparent resistivity to the east may indicate the influence of seawater. 2D interpretation of the Schlumberger traversing data, combined with 1D interpretation of the vertical electrical soundings (VES), suggest a deepening of a resistive sub-stratum towards the north and east. An E–W oriented displacement of the resistive sub-stratum (see Figure 3) was interpreted by Sudarman (1982) as a possible deep structural scarp that may be associated with the Miranda hot springs.

At Hot Water Beach (Figure 1) on the eastern coast of Coromandel Peninsula, Schlumberger resistivity traversing (AB/2 = 500 m) indicated low apparent resistivity values of 5–19 ohm-m (relative to background values of 50–60 ohm-m)

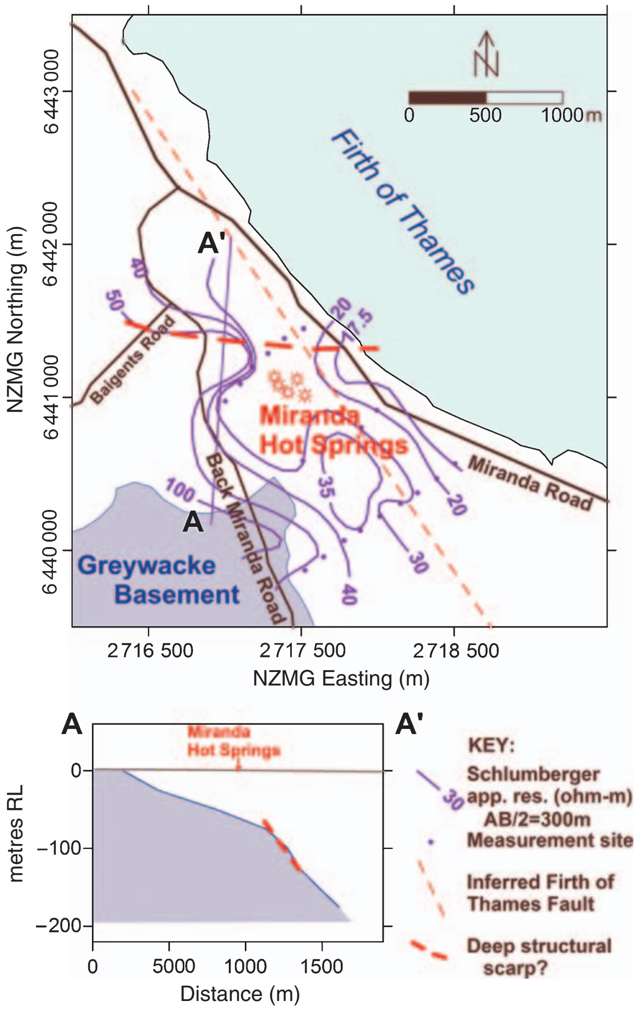

Fig. 3. *Results of a DC resistivity survey over the Miranda hot springs (from Sudarman, 1982).*

associated with local extent of hydrothermally altered rock. The lowest values were recorded along the fracture zone and closest to the hot springs. The sounding suggested a vertical extent of about 500 m for the thermal alteration anomaly.

Tensor resistivity gradient data, using an adaptation of the multiple-source tensor bipole-dipole method, with effective probing depths of 50–150 m, revealed anomalously low resistivities (about 15 ohm-m) in the vicinity of the spring and the productive bores at Awakeri (Bromley *et al.*, 2003).

In the South Island, hot springs at Hanmer (Figure 1) occur in an alluvium-filled depression (about 60 m thick) between greywacke ranges. As with all South Island hot springs, the origin of the hot water is tectonic, resulting from convective circulation of meteoric water along active faults, to about 3–4 km depth, where temperatures are 100–120°C. Resistivity gradient array and VES soundings (Bennie and Graham, 2001a) were interpreted to indicate the presence of a shallow low resistivity layer (20–40 m thick of 30 ohm-m). The resistivity of the spring water itself is 5 ohm-m while that of background cold water is 200 ohm-m. The low resistivity layer could therefore represent porous sediments saturated with the thermal fluid and/or an associated clay-rich unit.

Electromagnetic (EM) survey

More recently, resistivity investigations using shallow magnetotellurics (MT), controlled source audio magnetotellurics (CSAMT) and transient electromagnetic (TEM) methods have also been used to explore the shallow warm water systems in New Zealand.

MT soundings were made near Miranda hot springs (Bennie and Graham, 2001b). Resistive (300–500 ohm-m) greywacke basement was modelled at depths of 100–200 m, deepening to the north. The resistivity of the overlying Waitemata sediments is 20–40 ohm-m. Shallow resistivities of about 10 ohm-m indicate areas where clay-rich sediments are saturated with thermal fluids, particularly in the immediate vicinity of the hot springs.

At Pipiroa (between Miranda and Thames, see Figure 1), GNS undertook a TEM resistivity sounding during September 2005 in the vicinity of a capsicum producing greenhouse to search for evidence of a hot water resource. The result showed that resistivity would probably be ineffective at targeting hot water in this area because of the pervasive deposits of puggy blue/grey marine clays, which have very low resistivities.

Along the south-east shoreline of Mokoia Island (Lake Rotorua), shallow scalar MT resistivity soundings and a TEM sounding were recorded (by GNS) in order to determine the local subsurface resistivity structure and to assist with planning possible direct use of hot water. The TEM sounding showed a low resistivity layer of 5–10 ohm-m, presumably caused by geothermal fluid or clay, within the upper 50–100 m depth. The shallow MT soundings recorded at frequencies from 8 kHz to 4 Hhz, showed a consistent pattern of low resistivities near the surface (10–30 ohm-m) underlain by a higher resistivity layer (100–300 ohm-m).

CSAMT measurements along a NW profile were conducted through the 11 hectare Horohoro property of Plenty Flora Ltd (see Figure 1 for location), with the purpose of testing the

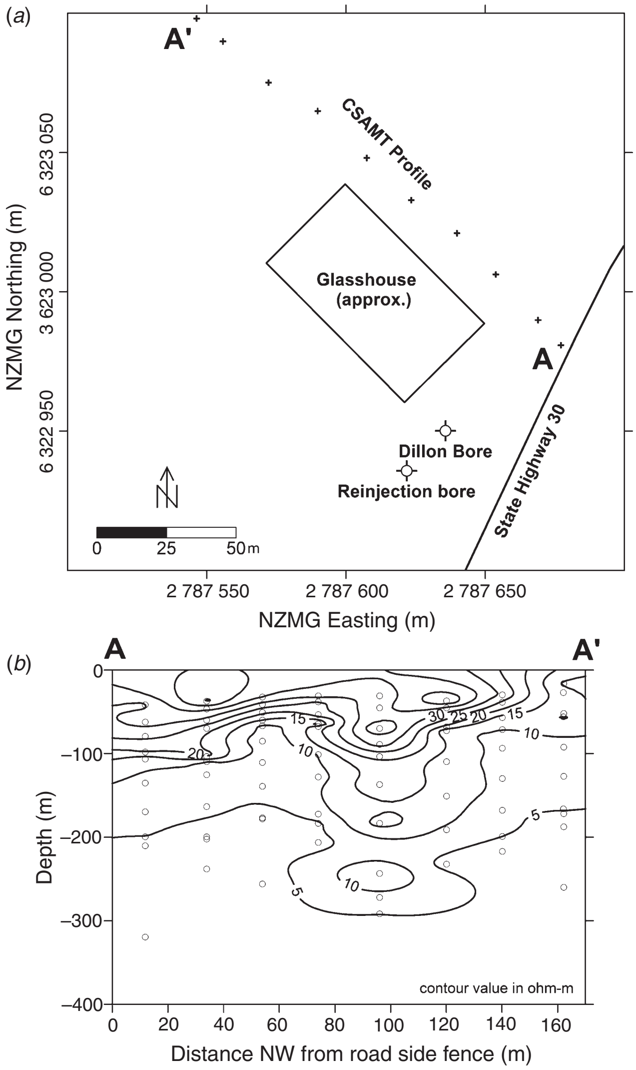

Fig. 4. *Map of CSAMT resistivity profile line location and boreholes (a) and CSAMT resistivity cross-section along line A-A' (b), Plenty Flora Ltd, Horohoro.*

resistivity method for targeting hot water resources in the depth range of up to 300 m. The CSAMT resistivity cross-section along the profile is shown in the lower part of Figure 4. The profile shows a low resistivity layer below about 100 m depth near the road (SH30), sloping up to about 50 m depth near the NW end. This low resistivity layer (less than 10 ohm-m) can be attributed to geothermal fluids and/or hydrothermal clay alteration occurring within and beneath a conductive, clay-rich mudstone layer. The 5th dipole (centred at 96 m) has anomalous high resistivities at depths from about 50 m to 270 m. This is possibly caused by silicification of the fractured mudstone and ignimbrite formations. It may indicate the presence of higher permeability. Therefore, greater fluid flow may naturally pass through the rock in this vicinity.

Given that the existing well at the Plenty Flora area proves the presence of a lateral subsurface flow of hot geothermal water, centred at about 200 m depth, then the presence of an isolated more resistive anomaly within an otherwise low resistivity layer throughout this site suggests that the best place to drill a new investigation borehole would be at this local anomaly, near the centre of the 5th dipole (96 m from the road). The target depth would be 200–250 m. If drilling is undertaken, cuttings from the hole should be studied for evidence of silicification and fracturing.

Conclusions

The works described in this paper have provided us with several conclusions. Shallow temperature methods are useful where the hot water resource is close to the surface and is not masked by overlying aquifers of cold groundwater.

Gravity anomalies can be interpreted in terms of subsurface structure, where formations of different density have different thickness, but the gravity method is generally ineffective at identifying the actual warm water reservoir.

DC resistivity methods provide a practical means of locating warm water resources or associated hydrothermal clay alteration, but they are usually less efficient at resolving narrow target structures.

CSAMT, TEM and shallow MT have advantages in terms of efficiency of 3D data collection and improved resolution of subsurface resistivity structure (to about 300 m depth). However, it should be noted that such EM methods are always highly susceptible to local electrical noise sources.

Highly conductive clays of thermal or non-thermal origin create penetration depth limitations and interpretation difficulties for the resistivity methods. Interpretation of resistivity anomalies needs to be treated in a site specific manner.

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How valuable can stuff be?

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My 10-year-old daughter is a bit of a writer and avidly read my last column. She firmly disagrees with my use of the word 'stuff' when I described a company's valuable data assets. She claimed that I used the word far too many times and also that for such a serious matter that I should have chosen and used a more appropriate word such as 'bits and pieces' or 'things'.

To be honest her opinion is a little jaded. I promised her a kitten the week before and then reneged on the deal citing a new baby in the house and a busy work load as reasons not to get one – until she is 21. Later that night I found one of my business cards attached to the whiteboard in my study with my title firmly scribbled out replaced with 'Guy C. Holmes – Promise Breaker'.

With hindsight, I think that my daughter probably was right. 'Stuff' is a bit of a weak word, and it certainly doesn't relay the importance or value that can be placed against a data holding. So let's be serious for a little while and think about just that – the value of data.

What exactly is 'valuable data' anyway?

From my years in the industry, data is usually only treated as valuable if someone wants to use it. If no one needs the data today, it is virtually useless and has no value. But tomorrow it might suddenly become valuable when someone wants it, and it will then be the end of the world if it can't be found. It is this very interesting juxtaposition that can be held accountable for the lack of pro-activity in ensuring that 'valuable data' is preserved and secured for the future.

There is very rarely one person in a company who is both responsible for and who understands the value of the data. You have to be completely impartial to estimate its value – no sentimental thoughts and definitely no personal pride or connection to the project the data refers to. Simply, what did it cost to create the data then and what will it cost to re-create it now? If the company does not have the data when it needs it, what will the lost time to the company cost due to the data not being available at the right time?

As an example, let's take a 3D seismic survey from 2001. It cost \$7M to acquire, \$750k to process, \$250k to interpret – a total of \$8M all up. This was followed by a \$12M drilling program based on the results of the processing and interpretation. How much is that data worth? To many, the data is not worth the \$5K offsite storage bill per annum. To others, like the bean counters, the data is worth the \$20M it took to acquire it and use it for drilling. Yet others, like us pure preservationists and glass totally full type guys, may value the data at \$300M because that drilling programme resulted in a producing well on a 100 million barrel field.

The reality is that data changes value as time goes on. It does not always decrease in value, but it can have a roller coaster ride of value during its lifetime. Worthless one minute and priceless five years later. I have seen well log data and seismic data deemed worthless, followed by desperate companies searching for that data that cannot easily be reacquired. In fact, in these cases the value of the data becomes 'whatever is less than re-acquiring it'. Geophysical data is indeed a rare 'data' with access to these data required sometimes regularly over a 40 to 50 year period. Most other industries have a 'get and forget' usage.

So, if someone could somehow put a value on this stuff (oops, there I go again), valuable data, then it would certainly make my life easier. In fact it would help companies justify a budget to protect the investment they have in their data assets. Imagine that, a budget to preserve the very data that a miner or oil and gas company uses to estimate its own worth on the stock exchange – that would be novel. Wait a minute, did I just figure out the worth of the data? I think I did.

Anyway, enough for now – I have to go buy a kitten.

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