Coalfield Geology Council of New South Wales

NSW GOVERNMENT | Industry & Investment

# THIRTY SEVENTH SYMPOSIUM
on the
# GEOLOGY OF THE SYDNEY BASIN

## ABSTRACTS

Edited by


Adrian Hutton, University of Wollongong
Colin Ward, University of New South Wales
Harry Bowman, Harry Bowman Consulting



May 6-7, 2010
POKOLBIN NSW AUSTRALIA

COALFIELD GEOLOGY COUNCIL
OF NEW SOUTH WALES

in conjunction with NSW GOVERNMENT Industry & Investment

# 37th Symposium on the Geology of the Sydney Basin

## 6-7th May 2010

Mercure Resort
Hunter Valley Gardens, Pokolbin

Program

## Program - Day 1

Thursday 6 May 2010

**Registrations 8:15 - 9:00**

### Session One (Open) - Semillon Centre

| | |
|---|---|
| Chair: | **Malcolm Ives** |
| 9:00 | **Welcome & Announcements from the Chair** |
| 9:15 | **Ralf Oppermann**<br>Application of Hi-Res Fault Imaging Technology in the Resource Industries |
| 9:45 | **Kaydy Pinetown**<br>Delineation of Coal Seam Gas Domains in the Hunter Coalfield, Sydney Basin |
| 10:15 | **John Ross and Elizabeth Webb**<br>Groundwater Supplies Across the Southern Sydney Basin - The Importance of Geological Structure |
| 10:45 | **Morning Tea - Semillon Centre** |
| 11:15 | **Brad Mullard**<br>NSW Energy Resources - Now and In the Future; Kenneth Mosher Memorial Lecture |
| 11:45 | **Zach Casley, Oliver Bertoli, Clare Mawdesley, Grenville Davies & Doug Dunn**<br>Benchmarking Estimation Methods for Coal Resource Estimation |
| 12.15 | **Gareth Cooper & Graeme Beardsmore**<br>Geothermal Systems Assessment - Understanding Risks in Geothermal Exploration in the Sydney Basin |
| 12:45 | **Lunch - Shiraz Room** |

### Symposium Dinner - Shiraz Room

| | |
|---|---|
| 6:30 | **Welcome Wine Reception** |
| 7:00 | **3 Course Formal Dinner** |

**Guest Speaker - Michael Creech**
*'Getting the Drift II: Catastropic Continental Drift - The Devil IS in the Detail.'*

### Session Two (A) - Semilon Centre

| | |
|---|---|
| Chair: | **John Edwards** |
| 1:45 | **Peter Hatherly, Terry Medhurst & Binzhong Zhou**<br>The Geological Strata Rating and its Derivation from Geophysical Logs and Seismic Reflection Data |
| 2:15 | **George Poropat**<br>Correlaton of 3D Deformation Measurement and Slope Stability Radar Monitoring |
| 2:45 | **Hamish Guthrie**<br>Whittle Optimisations in Coal |
| 3:15 | **Afternoon Tea - Semillon Centre** |
| 3:45 | **M. Campbell & R. England**<br>Options for Sink/Float Analysis - Economic & Technical Review |
| 4:15 | **Dick Sanders**<br>CSI East Maitland: Coal Science Investigations |
| 4:45 | **Scott Thomson**<br>Reservoir Pressure, Stress and Tectonics |
| 5:15 | **Summing up & Announcements** |
| 5:20 | **Close of Day 1** |

### Session Two (B) - Chardonnay Room

| | |
|---|---|
| Chair: | **Harry Bowman** |
| 1:45 | **Andrew Bray**<br>Tectonic Subsidence of the Sydney Basin |
| 2:15 | **Kevin Ruming, Ron Boyd & Claudia Shröder-Adams**<br>East Australian Sand River |
| 2:45 | **Ray Nolan**<br>Wingecarribee Swamp - Its Rise and Fall in Geological Terms |
| 3:15 | **Afternoon Tea - Semillon Centre** |
| 3:45 | **J.G. Bailey, L. Hugo, & A. Calandra**<br>Char from Tailings - Waste to Fertiliser and Soil Ameliorant: A Win-Win Situation |
| 4:15 | **Phillip Blevin, Bruce Chappell & Heejin Jeon**<br>Heat Generating Potential of Igneous Rocks Within and Underlying the Sydney Basin: Some Preliminary Observations |
| 4:45 | **J.G. Bailey & M. Davis**<br>Mineral Carbonation in Serpentines of the Great Serpentine Belt |
| 5:15 | **Summing up & Announcements** |
| 5:20 | **Close of Day 1** |

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# 37th Symposium on the Geology of the Sydney Basin

## 6-7th May 2010
Mercure Resort
Hunter Valley Gardens, Pokolbin
Program

## Program - Day 2
Friday 7 May 2010

**Registrations 8:30 - 9:00**

### Session One (A) - Semillon Centre

**Chair:** **Marianne Harvey**

9:00 **Welcome to Day 2 & Announcements**

9:15 **Abouna Saghafi**
A Tier 3 Method for Estimating Fugitive Emissions from Open Cut Coal Mining: Application to Hunter Coalfield

9:45 **Scott Thomson**
Gas Layering in the Subsurface: Implications for Greenhouse Gas Emissions

10:15 **James Douglass & Bryce Kelly**
3D Geological Modelling and Carbon Storage Potential in the Sydney basin

10:45 **Morning Tea - Semillon Centre**

11:15 **Saju Menacherry, Alexandra Golab & John Kaldi**
A Regional to Site-specific Assessment for Potential $CO_2$ Geologic Storage in the Sydney Basin, Australia

11:45 **Lila W. Gurba, Alexandra Golab & Szczepan Polak**
$CO_2$ Geological Storage Opportunities in the Gunnedah Basin, and the Southern Bowen Basin, NSW

12:15 **J. G. Bailey & K. A. Hyland**
Geosequestration Potential of the Clare Sandstone, Southern Gunnedah Basin

12:45 **Lunch - Shiraz Room**

### Session One (B) - Chardonnay Room

**Chair:** **Kevin Ruming**

9:00 **Welcome to Day 2 & Announcements**

9:15 **Colin Ward, David French, Maria Dubikova, Ken Riley & Zhongsheng Li**
Mobility of Trace Elements from Fresh and Long-Stored Fly Ashes

9:45 **Colin Ward, Ken Riley, David French, Leanne Stephenson, Owen Farrell & Zhongsheng Li**
Leaching of Trace Elements from Coal Stockpiles in the Sydney and Collie Basins

10:15 **Lei Zhao**
Comparative Study of the Mineralogy of the Bulli and Great Northern Coal Seams, Sydney Basin

10:45 **Morning Tea - Semillon Centre**

11:15 **David Och, Ian Graham, Horst Zwingmann, Robin Offler & Lin Sutherland**
Significance of the Era Beach Dyke and Fault Zone, Royal National Park, NSW

11:45 **Michael Creech**
Reserves, Reserves, and Not a Tonne to Mine

12:15 **Ian Graham, Zoe Hatzopoulos, Lin Sutherland & Horst Zwingmann**
The Age, Geochemical Affinity and Significance of the Maroota Basalt, Hawkesbury, NSW

12:45 **Lunch - Shiraz Room**

### Session Two (Close) - Semillon Centre

**Chair:** **Adrian Hutton**

1:45 **Chairul Nas & Hidarton**
Quality of Kalimantan's Coking Coals Indonesia

2:15 **Jolanta Jaworska, Ricky Mantaring, Andrew Alexander, Alexander Tutt-Branco, Lila W. Gurba & Cindy Barber**
Recent Data from Munmorah-1 and Vales Point-1 Shed New Light to the Geothermal and Petroleum Potential of the Sydney Basin

2:45 **N. Bryant, W. McLean, J. Ross & S. Scarff**
Use of Environmental Isotopes for Aquifer Characterisation and Connectivity Assessment during CSG Exploration in the Hunter Valley, NSW

3:15 **D. Hunt, P. Dundon & J. Van Den Akker**
The Interpretation and Implications of Transient Groundwater Responses to Longwall Mining in NSW

3:45 **Summing up, thanks & farewell**

4:00 **Post-symposium coffee session**

4:30 **Close of Symposium**

*Speakers and titles of papers may be subject to change.*

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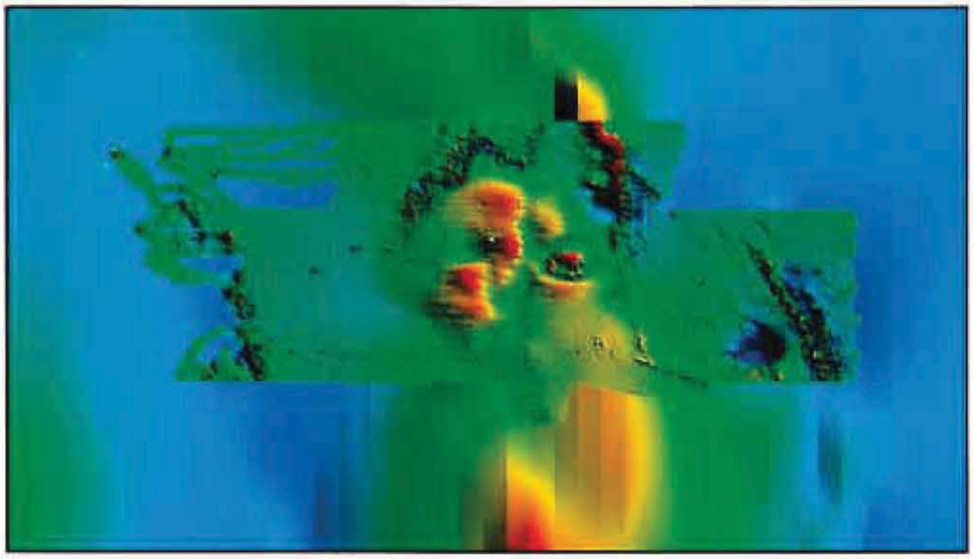

***Ground magnetics data set superimposed on aero magnetic data set.***

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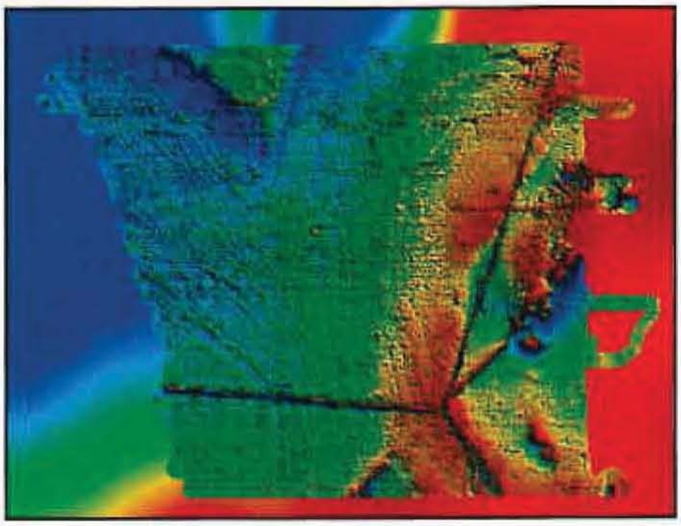

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For more information, please contact

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# PREFACE

Welcome to the 37th Symposium on the Geology of the Sydney Basin. There are 34 presentations for this year's symposium in addition to posters and trade displays. The program covers a number of coal geology topics over the Thursday and Friday sessions. There are social events on the Wednesday and Thursday evenings.

The 37th symposium will be held at Pokolbin, NSW and is run by the Coalfield Geology Council of NSW in conjunction with Industry and Investment NSW (formally the NSW Department of Primary Industries). Malcolm Ives, the chairman of the Coalfield Geology Council of NSW will open the symposium.

The Kenneth George Mosher Memorial Lecture is the keynote address in honour of the former Chief Geologist of the Joint Coal Board. This year it will be given by Brad Mullard, Executive Director of Mineral Resources, Industry and Investment NSW.

I would like to acknowledge the efforts of the Symposium Organisation Committee, John Edwards, Darren Hope and Kevin Ruming. In particular Darren Hope for coordinating papers, posters and presentations and John Edwards for organising the trade displays. Papers were reviewed and edited by the Editorial Committee, Adrian Hutton, Colin Ward and Harry Bowman. Support from Industry and Investment NSW has been provided by Kevin Ruming, Lee Main, Elizabeth Laidlaw and Sarah Jardine through logistics, publications and event management. We are pleased to have support from the University of Newcastle, particularly from Judy Bailey and Richard Bale and from undergraduates, Kevin Allanson, Jessie Cooke, Elodie Burton-Bradley and Sara Petrie who have assisted in the organisation of the symposium.

I welcome you to the 37th Symposium on the Geology of the Sydney Basin and hope that you will have an enjoyable couple of days.

Marianne Harvey
Convener

# INDEX

**01**

# APPLICATION OF HI-RES FAULT IMAGING TECHNOLOGY IN THE RESOURCE INDUSTRIES

**Ralf Oppermann**

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## ABSTRACT

Novel techniques and workflows in automated fault extraction have been developed to visualise faults at extremely high resolution from 3-D seismic data, and to subsequently evaluate how these faults can impact resource activities (drilling & mining), resource recoveries (e.g. oil & gas, coal) and the safety of operations (e.g. gas kicks, outbursts).

Examples from oil & gas projects around the world demonstrate that new methods in fault imaging can deliver groundbreaking insights into the drilling and production of resources. These insights often challenge current perceptions:

- Presently, most 3D surveys in the resource industries are under-utilized with respect to the detailed delineation of faults in the subsurface. The techniques presented push fault resolution down to the true fault resolution of a particular data set, not the perceived fault resolution that is typically established by visual (interpreter) mapping only.
- The increased fault resolution results in a dramatic increase in the number of faults that are identified from seismic.
- There are way more faults penetrated in wells than realised in the oil & gas industry, and these faults are often directly linked with a number of drilling and production problems, or production opportunities, in compartmentalised, tight, fractured and unconventional reservoirs, where faults in the subsurface can form fluid barriers or fluid conduits. Fault penetrations are often linked with drilling problems (e.g. gas kicks, fluid losses, geomechanical issues), as well as production issues (water production along fault planes, compartmentalisation).

An analogy with the coal mining industry is drawn, where faults can pose geotechnical, production and/or safety hazards in underground mines.

A focused application of the new technology workflows can deliver increased recoveries from resources, and can result in cheaper, safer and more successful drilling and mining operations. As such, the techniques are viewed as "best practice" tools for resource development planning and execution.

**02**

# DELINEATION OF COAL SEAM GAS DOMAINS IN THE HUNTER COALFIELD, SYDNEY BASIN

**Kaydy Pinetown**

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## ABSTRACT

The tectonic history of the Sydney Basin, New South Wales, gave rise to the development of complex structures, especially in the northern region of the basin. Geological elements of the Hunter Coalfield, located in the north-eastern part of the basin, display characteristics of a complex burial history, including episodes of igneous activity and a variety of sources of coal seam gas (CSG).

In a preliminary investigation of the origin, distribution and controls on CSG in the Hunter Coalfield, the high degree of variability in gas content and composition, along with the presence of large- and small-scale geological structures, did not allow delineation of regional trends in gas content, composition and origin, coal rank and composition, nor of adsorption properties and permeability. Upon further investigation, five domains having different gas attributes, structural features and local geology were identified, one of which is located in the south, three in the central region, and one in the northern part of the coalfield. Within these domains similar patterns exist for gas content and composition, coal petrology, and other reservoir characteristics. In some cases the boundaries of the domains occur along structural boundaries but in other cases domain boundaries extend across structural boundaries.

For instance, the southern domain is bordered by the Hunter River Cross Fault in the north, and by the coalfield boundary in the south, west and east. Coals of the Newcastle and Wittingham Coal Measures are present in this domain and in situ gas contents are up to ~25m$^3$/t, the highest in the coalfield. $CO_2$ is a major gas component (between ~30% and ~60% of the gas, with the remaining gas consisting primarily of $CH_4$) down to ~150 m depth and between the depths of ~300m and ~800m. At other depths $CH_4$ is the major gas component. By contrast, in the northern domain, located to the west of the Aberdeen Thrust Fault, sections of the Newcastle and Wittingham Coal Measures have been uplifted and eroded. The coals in this domain generally have in situ gas contents of up to ~14m$^3$/t, and $CO_2$ as the dominant gas component (between ~60% and ~90%) from the surface down to ~500m depth.

The patterns of gas distribution are controlled by a variety of factors, including the geological setting and burial history, which control migration of groundwater and therefore biogenic gas production. The study has shown that the Hunter Coalfield is a compartmentalised CSG reservoir and that delineating domains within the coalfield provides improved understanding of the CSG distribution. This has implications for CSG exploration and mine safety, as well as for evaluation of fugitive emissions from open cut coal mines.

**03**

# GROUNDWATER SUPPLIES ACROSS THE SOUTHERN SYDNEY BASIN – THE IMPORTANCE OF GEOLOGICAL STRUCTURE

**John Ross and Elizabeth Webb**
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## ABSTRACT

Groundwater investigations for drought water supply for the Greater Sydney area were initiated in the Sydney Basin in late 2004 as part of the NSW Government's Metropolitan Water Plan (MWP) suite of initiatives. The importance of groundwater was confirmed in the 2006 MWP after several priority areas were drilled and the prospectivity of the Hawkesbury Sandstone aquifers was confirmed at three locations in the Southern Highlands and in Western Sydney. All of these locations had substantial geological structural features which are important in determining the hydrogeological and hydrogeochemical characteristics of each area.

The Kangaloon area (east of Bowral and north of Robertson) in the Southern Highlands targeted the Kangaloon Structural Corridor (KSC) while the Leonay and Wallacia areas in western Sydney targeted the Lapstone Structural Complex (LSC).

The Kangaloon investigations were sited on the northern side of the Mittagong Ranges and the KSC. A number of horst – graben and other faulted structures were identified, together with an early Tertiary intrusion (Mt Butler intrusive) that was previously unknown. This mainly east-west structure is important in defining the high-yield groundwater resources and is also thought to be responsible for some artesian conditions observed across the area. The highest bore yields are associated with the most fractured areas of the Hawkesbury Sandstone, as well as volcanic sills and other intrusions. Hydrochemical studies also provided improved insight into recharge/discharge processes and groundwater flow within fractured aquifers.

The LSC at Leonay is expressed as the Lapstone Monocline, but at Wallacia it is expressed as the Nepean Fault. The large diatremes in the area are also important features. The significance of the difference in expression is fundamental in understanding the hydrogeological characteristics of each area. A detailed study of the geological structure combined with more detailed hydrochemistry sampling and analysis provided a more accurate conceptualisation of how groundwater moves through the sandstone geology at each location, the local and regional recharge/discharge processes and its residence times.

# 04

# NSW ENERGY RESOURCES

**Brad Mullard**

NSW Department of Industry and Investment. PO Box344 Hunter Regional Mail Centre 2310

## ABSTRACT

Access to cheap energy has become essential to the functioning of modern economies. However, in recent years, new threats to energy security have emerged in the form of the increased world competition for energy resources due to the increased pace of industrialization in countries such as India and China.

This strong global demand for energy has resulted in significant growth in Australia's production of energy over the last 10 years.

Australia is a member of an exclusive club being one of less than a dozen countries who are net energy exporters. Australia is the world's ninth largest energy producer, accounting for around 2.4 per cent of world energy production.

The main fuels produced in Australia are coal, uranium and natural gas. Australia's energy production is dominated by coal, which accounted for 54 per cent of total Australian energy production in energy content terms, followed by uranium with a share of 27 per cent and natural gas with a share of 11 per cent. Crude oil and LPG represented 6 per cent of total energy production, and renewables represented only 2 per cent.

Coal is the world's most abundant and widely distributed fossil fuel source, although 85 percent of global coal reserves are concentrated in just six countries (in descending order of reserves): USA, Russia, India, China, Australia and South Africa. Over the past 6 years global demand for coal has resulted in it being the fastest growing primary fuel.

Globally some 23% of primary energy needs are met by coal and 40% of electricity is generated from coal. About 70% of world steel production depends on coal feedstock. In NSW about 90% of our electricity needs are met from coal fired power stations.

The major development in Eastern Australia supply has been the development of Coal Seam Gas (CSG) as an important part of the energy portfolio. The published certified 2P reserves of CSG now exceed conventional natural gas resources in Eastern Australia.

However, unlike virtually all other states which have significant domestic reserves of gas NSW is heavily dependent on gas supplies from interstate, principally South Australia and Victoria.

Currently NSW consumes around 140 PJ of gas per year. Of this amount only a very small percentage (approximately 6%) is supplied locally from coal seam gas operations principally from around the Camden area, southwest of Sydney.

While there is active exploration underway for coal seam methane in NSW, to date identification of 2P reserves of gas has only reached around 2,200 PJ although addition 2P reserves are being added constantly. Queensland has in comparison in excess of 23,000 PJ of 2P coal seam methane reserves and this figure is increasing rapidly. Queensland also has access to substantial additional conventional gas reserves.

Shale gas is increasingly become an important source of natural gas particularly in the United States. Shales have low matrix permeability, so gas production in commercial quantities requires fractures to provide sufficient permeability. While gas has been produced from shales with natural fractures, it is only recently as a result of developments in hydraulic fracturing and horizontal drilling that gas production from non naturally fractured reservoirs have become commercially viable.

Shales with gas potential typically are rich in organic matter (0.5% to 25%) and are usually mature petroleum source rocks. Deep drilling by Mineral Resources Branch of Industry Investment NSW has identified thick organic rich shales with gas potential in the Newcastle region. Recently a number of companies have become interested in evaluating shale gas potential in Australia.

The Sydney basin is currently under evaluation for it's potential for geothermal energy. The coal measures can provide an effective thermal blanket allowing heat to build up within granites 4 to 6 Km below the earth surface from radiogenic decay. While the focus for geothermal resources in Australia has been the Cooper Basin in central Australia, the established infrastructure and markets as well as the potential for suitable granites make the Sydney Basin an attractive exploration target for geothermal resources.

The NSW Government is committed to achieving a 60 per cent cut in greenhouse gas emissions by 2050. Current NSW emissions are about 163 million tonnes $CO_2e$ and as a result this target equates to net NSW greenhouse gas emissions reduction of 61.3 million tonnes $CO_2e$ in 2050.

In addition NSW has committed to achieving a 20 per cent renewable energy consumption by 2020 to take advantage of the Australian Government's expanded Renewable Energy Target.

The Department of Industry and Investment NSW is also undertaking a regional stratigraphic drilling program aimed at identifying high potential reservoirs for long term $CO_2$ storage from power stations. The drilling program will provide information that will allow more accurate modelling and prediction of reservoir characteristics in New South Wales Basins.

The NSW Government is planning a large-scale $150 million post combustion capture and storage demonstration project in NSW. The project should be operational by 2013 capturing more than 50,000 tonnes of $CO_2$ each year and pumping it into deep underground rock formations for permanent disposal. Funding for this project will be jointly shared by the NSW Government, the Australian Coal Association and the Commonwealth Government.

05

# BENCHMARKING ESTIMATION METHODS FOR COAL RESOURCE ESTIMATION

**Zach Casley / Olivier Bertoli / Clare Mawdesley**
MAusIMM and AIG / MAusIMM and GAA/ MAusIMM and AIG
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**Grenville Davies[1] / Doug Dunn**
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**ABSTRACT**
The coal industry in Australia has been actively working in recent years towards the (re-) integration of geostatistical techniques to the process of coal resource estimation. The benefits of using geostatistical techniques, over the current interpolation algorithms in use in coal modeling packages used to generate the grid estimates, need to be illustrated for the methodology to gain a broader acceptance in the coal industry.

This paper focuses on the benefits gained at BHP Billiton Mitsubishi Alliance's Saraji mine for the estimation of the total product yield value at a 9.7% product ash cutoff of a particular seam of the Saraji deposit.

In order to perform this comparison, the results of the alternative estimation methodologies need to be benchmarked, which in most situations is achieved through the reconciliation of the estimates against production and/or process plant reconciliation data. Unfortunately, this benchmarking was not possible as no reconciliation data for the area of interest in the chosen seam was available, as it has not been mined at the time of the study.

Where no reconciliation data is available, an alternative method is to use conditional simulations as the benchmark for comparison. The simulated values can be regarded as 'reality', and the alternative estimation methodologies, based on a sampling of the underlying 'reality', can then be compared using the simulated 'reality' as the benchmark for comparison.

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[1] Now at Snowden, Level 15, 300 Adelaide Street Brisbane QLD 4000 Australia

**06**

# GEOTHERMAL SYSTEMS ASSESSMENT – UNDERSTANDING GEOTHERMAL POTENTIAL IN THE SYDNEY BASIN USING A RISK BASED APPROACH

**Gareth T Cooper[1]* & Graeme R Beardsmore[1]**

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## ABSTRACT

Traditionally geothermal exploration has concentrated on temperature as the principle, if not only, indicator of prospectivity. In reality geothermal systems in the Australian context are defined by four critical geological factors (risk areas) which must be considered when undertaking a holistic Geothermal Systems Assessment (GSA) of an area. The probability of encountering an economic geothermal resource is largely controlled by four geological factors—heat flow (conductive and advective), thermal resistance (insulation), reservoir characteristics (including prevailing stress regime) and access to a working fluid (water or steam).

Temperature risks cannot be accurately assessed without a detailed understanding of rock thermal resistance and heat flow. Based on limited data, the Sydney Basin has a median heat flow of $74mW/m^2$, which is about 16% higher than the global average for rocks of an equivalent age. However this is based on both poorly constrained rock thermal conductivity data and a paucity of quality temperature data suitable for temperature-field modelling.

Like a number of Late Palaeozoic-Mesozoic basins in Australia, the Sydney Basin has significant coal resources which provide thermal resistance for geothermal systems. This may assist in reducing temperature risks, particularly in the northern Sydney Basin where both the Lower and Upper Permian Coal Measures are present in variable thicknesses.

Geothermal reservoir risks are poorly understood in the basin, in particular Hot Sedimentary Aquifer (HSA) geothermal systems at a temperature required for commercial electricity may only be expected where there is preservation of a permeable sequence within the Lower Permian succession. This is largely a consequence of rapid permeability reduction with depth, although this does not preclude the possibility of low-enthalpy and direct use applications for selected reservoir levels. Engineered Geothermal Systems (EGS) may be a more widely viable system in the Sydney Basin, although this cannot be accurately assessed without detailed measurement and modelling of tectonic stresses and rock properties. There is however a level of uncertainty about the nature of deeper rocks in the basin, particularly the Pre-Permian basement. Further regional work on the likely distribution, thermal conductivity, anisotropy, fracture and geomechanical properties of basement rocks would assist in reducing EGS risks within the basin.

**07**

# THE GEOPHYSICAL STRATA RATING AND ITS DERIVATION FROM GEOPHYSICAL LOGS AND SEISMIC REFLECTION DATA

**Peter Hatherly[1], Terry Medhurst[2] and Binzhong Zhou[3]**

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PO Box 883, Kenmore Qld, 4069.

## ABSTRACT

Through a series of ACARP projects we have developed a new geotechnical rating system based on the interpretation of geophysical logging data. Known as the Geophysical Rating System (GSR), this rating system provides continuous rock ratings from an analysis of geophysical logs. GSR data can be modelled to provide hazard plans and 3D geotechnical models of ground conditions. The computational speed and objective nature of the analysis make it an attractive approach to geotechnical studies whenever geophysical logging data are available.

Determination of the GSR is mainly through sonic data but consideration is also made of rock type (coal, carbonaceous material and clastic), the porosity, the clay content, in-situ stress conditions and down-hole variability. GSR values range between about 10 (very weak) and 90 (very strong).

The GSR provides an excellent measure of rock properties because seismic velocity responds to the state of the intact rock and any defects that are present. Through a parameter known as acoustic impedance, seismic reflection surveys also respond to the variations in the seismic velocities and densities of the strata under investigation. In our research, we have also investigated the recovery of acoustic impedances from seismic reflection survey data and shown how they complement borehole studies by directly estimating large scale variations in GSR.

08

# CORRELATION OF 3D DEFORMATION MEASUREMENT AND SLOPE STABILITY RADAR MONITORING

**George Poropat**
CSIRO Earth Science and Resource Engineering
Queensland centre for Advanced Technology

## ABSTRACT

Recent developments in 3D imaging and 3D data processing have shown that structural data obtained using 3D imaging and deformation measurements made using 3D imaging can be correlated with surface monitoring data acquired by slope stability radar (SSR). These developments mean that the movement measured using slope stability radar can be correlated with structural measurements and interpretation obtainable using 3D imaging. Visualisation of the correlations can aid in interpreting deformation observed using slope stability radar and some case examples are presented.

**09**

# WHITTLE OPTIMISATIONS IN COAL

**Hamish Guthrie**

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Level 15, 300 Adelaide Street, Brisbane

ABSTRACT

For a significant period of time open pit optimisation tools have been used in the metalliferous industry to provide information on the potential optimum pit dimensions and economic value based on defined operational parameters, costs and product prices. The optimisation process provides significantly more information than optimum pit dimensions:

- Assessing the economic viability of a deposit;
- Assessing options for capital investment and development strategies; examining effects of mining costs and product price sensitivities;
- Analysing expected return on investment scenarios;
- Determining the strategic direction for the mine, optimal extraction sequence and development for new mines and push backs;
- Re-evaluating mine plans in response to changing conditions.

In the past, optimisation tools have probably been under-utilised by the coal industry. This paper investigates the potential uses of pit optimisation tools for coal mines in determining economic pit outlines and developing strategic mine production schedules. The intent is to enable quick scenario analysis in assessing the optimal economic operational outcome.

Typically within the coal industry margin ranking is the predominant method of evaluating the economic limits and general production sequencing. Pit optimisation tools can assist this process by generating multiple scenarios and sensitivities, to guide further strategic planning and more rigorous mining evaluation. This paper details some of benefits, constraints, and effective uses of these methods.

Snowden have successfully used Whittle pit optimisation software for several coal operations. Many of these have differing input material types, products, cost variables, and production requirements. However, in each of these projects, the pit optimisation software has proved to be sufficiently flexible.

This paper provides some examples of the capabilities of Whittle software in coal.

**10**

# OPTIONS FOR SINK / FLOAT ANALYSIS – ECONOMIC AND TECHNICAL REVIEW

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## ABSTRACT
Float and sink testing is the standard laboratory method for determining, with respect to relative density, the washability characteristics of a wide range of coal samples, from bore core to mine production and coal preparation plant products. The media used to separate particles into their various density fractions are generally mixtures of organic liquids. These organic liquids are toxic, environmentally hazardous and may also interfere with the properties of interest for a coal producer or end user.

Research over the last few decades has identified a number of alternative approaches to organic liquids for float and sink testing. Some of these have had a very short-lived and limited acceptance into commercial laboratories (e.g. hematite). The vast majority, however, has not been trialed on a large scale but may still remain a potential solution to what is a world-wide problem. Safety concerns for operators using organic liquids as a medium have led to improvements in laboratory design, fume extraction and greater policing of personal protective equipment. However, the elimination of organic chemicals from coal laboratories should remain a high priority.

**11**

# NOVEL COAL INTERPRETATION STRATEGIES

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**ABSTRACT**

To drill and analyse a coal deposit entails a huge expense. The full value of the coal quality data base that it provides is not realised until the data base is fully validated and interpreted.

These two processes are iterative. A preliminary validation stage 'cleans up' the data to give better correlations that assist in the interpretation stage. In turn, these correlations establish relationships between key parameters which are fed back into the continuing validation process, enabling actual values to be compared to calculated values, so that extreme data are identified and either deleted, or replaced with calculated values – to the advantage of the geological model. Calculated values may also be entered where no actual values exist.

The interpretive coal quality technologist is like a crime laboratory forensic technician. Big conclusions are often required to be reached based only on very small clues, backed by considerable research and experience.

This paper describes the fundamental properties that 'fingerprint' a given coal, as well as the key tools that are used to interpret the available coal quality data.

Summary descriptions are given of situations where creative interpretations have solved coal quality riddles, and added value to a coal quality data base. Examples include: is the scatter in results due to laboratory variance, or to a rank gradient in the deposit; can we identify a hard coking coal without coking tests, not even a CSN; can we make a pronouncement on likely handleability and boiler slagging issues from M, VM, RD, CV and ash data only; the fluidities are low – is the laboratory to blame or is there a technical explanation; the CSN varies from 0 to 9 – did the laboratory get it wrong, or is the rank range in the deposit responsible?

**12**

# RESERVOIR PRESSURE, STRESS AND TECTONICS: SHAPING THE FUTURE OF INSEAM DRILLING IN UNDERGROUND MINING

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**ABSTRACT**
Inseam drilling and drainage practice has been highly successful in making Australian mines safer and more productive. This cornerstone of this success has been the provision of heavy duty drilling equipment, steering technology and the fundamentally favourable geological conditions enjoyed in Australian underground mining.

The efficiency of current inseam drilling technology will be limited in the future by increasing reservoir pressure, and increasing tectonic stress as mining tends to deeper reserves. The impact of faulting and tectonic history also has a role to play in mitigating drilling efficiency.

This paper explains why inseam drilling and drainage has been successful to date, and identifies the fundamental weaknesses that will need to be addressed if current levels of efficiency are to maintained as underground mining encounters increasingly challenging conditions.

# 13

# TECTONIC SUBSIDENCE OF THE SYDNEY BASIN

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## ABSTRACT

From at least the Late Permian the Sydney Basin evolved as a foreland basin to the tectonic loads of the deforming New England Fold Belt and its hypothesised southern extension, the Currarong Orogen. Some have placed the onset of foreland loading in the Sydney Basin in the Early Permian, however, most agree that it occurred somewhere in the mid to Late Permian. This paper details a preliminary investigation of the processes that controlled subsidence within the Sydney Basin using the method of sediment decompaction and backstripping. The results support the notion that foreland loading began in the mid to Late Permian when a pulse of thrusting in the adjacent orogenic belts caused a sudden and marked increase in the rate of tectonic subsidence within the basin. The results also provide further evidence for the existence of the Currarong Orogen by showing that tectonic subsidence increases not only toward the New England Fold Belt in the northeast but also towards the proposed location of the Currarong Orogen in the southeast.

**14**

# EASTERN AUSTRALIAN SAND RIVER

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**ABSTRACT**
How does sand reach the deep sea? Current models using a sequence stratigraphic approach predict sand delivery by river systems to the edge of the continental shelf during times of low sea level and then by gravity processes to deep water. Here we demonstrate how the east Australian longshore transport system or "sand River" supplies deep water sands at sea level highstand.
The modern coastal sediment dispersal system of eastern Australia operates from sources in the Sydney Basin 1000 km northward to sinks on the coastline of southeast Queensland and the adjacent Tasman Sea abyssal plain. Individual sand reservoirs of over 203 km3 (e.g Fraser Island) have accumulated in less than one million years, from longshore transport rates averaging 500,000 m3 per year. Zircon dating techniques enable the tracing of this entire sediment dispersal system from its original source in Antarctica to its final sink on the floor of the Tasman Sea. Igneous rocks with a characteristic age of around 600 Ma produced zircons and associated source rocks on the current northern margin of Antarctica prior to continental breakup with Australia. Triassic uplift shed sediments and associated zircons 1000 km northward in a braided river before intermediate deposition in the Sydney Basin of eastern Australia. Continental rifting in the late Cretaceous produced the modern Tasman Sea and an uplifted escarpment along eastern Australia, including the Sydney Basin. Escarpment erosion of the 600 Ma zircons and associated quartz sands by river processes feeds the modern Tasman Sea longshore transport system, delivering reservoir quality sand 1000 km north for storage on the SE Queensland shelf. In the Holocene, this "sand river" has intersected the highstand shelf edge and is currently supplying the east Australian longshore transport sands directly to the floor of the Tasman Sea via a network of wave, tide and gravity driven flows through a 4 km-deep network of submarine gullies and canyons.

Presentation based on a paper by
Ron Boyd, Kevin Ruming, Ian Goodwin, Marianne Sandstrom, and Claudia Schröder-Adams, **Highstand transport of coastal sand to the deep ocean: A case study from Fraser Island, southeast Australia**, Geology 2008 v. 36, p. 15-18.

# 15

# WINGECARRIBEE SWAMP – ITS RISE AND FALL IN GEOLOGICAL TERMS.

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**ABSTRACT**

The Wingecarribee Swamp is within the Southern Highlands, NSW. west of Robertson and within the 40 km2 catchment of Caalang Creek. Prior to its collapse, on the night of the 8th. August, 1998, following very heavy rainfall, the swamp comprised about 9 square kilometres of heath-filled wetlands and included peat up to 5 or 6 metres thick. About the western 6 km2 had been "flooded" by the Wingecarribee Storage Reservoir in 1972 and the central portion of the peat-land had been, and was being, extracted from within a dredge-pool at the time of the "collapse".

Prior to the "collapse' and exposure of some of the swamp's bedrock, it had been considered that, like other Upland Swamps on the Hawkesbury Sandstone, it had formed "upon a sandstone base" (Sydney Water, 1995). It was also thought that the 35,000 to 40,000 years old river valley may have been related to "Pleistocene periglacial conditions", with peat accumulation having commenced much later, after "amelioration of the former cold/dry climatic regimes" (Jaunzemis, 1983). This possible glacial origin was also referred to by Kodela and Hope, in their "Statement of Significance, 1992".

Following the "collapse", reported assessments by students at the University of Wollongong (Smith, 2000 and Hales, 2001) and a more recent investigation by Coffey (2004), for the Sydney Catchment Authority, provide new data, which allow for re-assessment of the origin of the swamp. Similarly, it is now possible to re-assess the mode of "collapse" of the swamp and of other possible reasons for its failure.

16

# CHAR FROM TAILINGS - WASTE TO FERTILISER AND SOIL AMELIORANT: A WIN-WIN SITUATION

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## ABSTRACT

Bituminous coal tailings are a waste product of the coal industry currently constituting environmental, land use and economic pressures on the industry. Tailings are generally disposed of in dams on the minesite, which are costly to maintain and rehabilitate, sterilise land for other uses and may constitute long-term risks to the post-mining environment. We report on a study proposing to recover fine tailings for gasification or pyrolysis to char, which will then be nutrient-loaded for use as a fertiliser and soil conditioner. The nutrient-loaded tailings char has tentatively been called "Chailings". In a similar way to the use of biochar from crop waste or algae, "Chailings" show potential to improve soil structure, increase productivity and dramatically reduce the emissions of methane ($CH_4$) and nitrous oxide ($N_2O$) from soils on millennial timescales.

The production of biochar from crops is expensive and therefore unlikely to occur on a scale that will significantly alter emissions from agricultural soil or provide large scale soil enhancement. Production of "chailings" promises to be an order of magnitude less expensive than biochar creation, since it does not require crop growth, but uses "fossil" biochar or coal, as its source, and potentially provides a superior output. "Chailings" promise to reduce tailings volume on mining leases, reduce colliery carbon footprint and produce an abundant and affordable product for agriculture, with the added benefit of recycling of gasification or pyrolysis products for energy generation.

In order to create char from waste coal sources, recovered fine tailings are heated in low oxygen conditions to produce char, as well as pyrolysis tars and gases for recycling. The creation of porous char from bituminous coal, brown coal and biomass by gasification or pyrolysis (heating without oxygen), is well researched, because pyrolysis is the initial phase of coal combustion and gasification. It relies on rapid devolatilisation and resultant creation of high surface area, carbon-rich char, which is then combusted. This research aims to determine the optimum process conditions to generate chars which can adsorb and release nutrients to soil most successfully while improving soil structure.

Bituminous coal char has a complex and irregular pore structure which is difficult to model. The maximum internal surface areas for bituminous coal chars compare favourably with the maximum internal surface areas for brown coal chars or biochars under specific conditions. By varying the gasification pyrolysis conditions of temperature, pressure, heating rate and atmosphere, bituminous coal chars can be produced with a range of internal surface areas (less than ten to hundreds of $m^2/g$), comparable to brown coal and biochar, with a range of pore size distributions. The current challenge is to determine what order of surface area will be most suitable for nutrient adsorption and delivery, since char surface areas have previously been measured using $CO_2$ and $N_2$ adsorption, not nutrients appropriate to fertiliser.

# 17

# HEAT GENERATING POTENTIAL OF IGNEOUS ROCKS WITHIN AND UNDERLYING THE SYDNEY BASIN: SOME PRELIMINARY OBSERVATIONS

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## ABSTRACT

The geothermal energy potential of the Sydney Basin is ultimately governed by the presence of high heat producing rocks as determined by their K, Th and U contents. Heat generating potential can be expressed as *A* in units of $\mu Wm^{-3}$ (microwatts per cubic metre). Granites typically have values of *A* around 2 to 3, while those with *A* greater than 5 are termed high heat producing (HHP). Igneous rocks are the typical candidates for geothermal exploration, but any rock with $A > 5$ can be considered as having heat generating potential. HHP granites in the basement under the Sydney Basin could have potential for hot fractured rock (HFR) or hot sedimentary aquifer geothermal systems.

Little is known about the heat producing potential of igneous units spatially associated with the Sydney Basin. Suites of Palaeozoic granites in the basement rocks provide a model to predict the nature of the rocks underlying the basin. Of the Silurian, Devonian and Carboniferous igneous basement rocks, the Carboniferous granites have the best heat generating potential. About 20% of all analysed Carboniferous samples have $A > 4.0$ and about 10% have $A > 5.0$. The HHP granite in the basement window at Wandandian (*A* values of 5.3 and 6.4) is also tin mineralised. Tin mineralisation hosted in basement rocks also occur at Ettrema and Tolwong and indicates the presence of HHP granites at depth in this region. The granite at Yalwal is also felsic, fractionated and HHP in character. If these granites represent correlatives of the Oberon Supersuite, and/or are typical of granites buried elsewhere under the basin, then HHP granites may be widespread as basement rocks under the southern Sydney Basin.

Permian shoshonites emplaced into the basin typically range in *A* from 0.5 to 1.8, with an elevated value of 3.2. Jurassic intrusions in the southern highlands generally have higher values of *A* in the range 1.7 to 4.8, with a pegmatite having $A = 9.4$. Alkaline syenitic rocks from the Huntley DDH4 borehole however average 6.1 with values of *A* ranging from 3.7 to 9.3. The Jurassic alkaline magmas have high concentrations of Zr, Ta and Nb in addition to elevated K, Th and U. These Jurassic rocks are not felsic and fractionated in the sense of the high silica, calc alkaline granites, but can be similarly regarded as having potential as a HHP igneous rock suite. The limited volume of Jurassic magmatism may however reduce their potential as a heat source. Tertiary basaltic rocks are also present across the basin but have very low heat producing potentials ($A \sim 0.4$ to 1.0).

# 18

# MINERAL CARBONATION TO PRODUCE MAGNESITE: A PRACTICAL SOLUTION FOR LONG-TERM $CO_2$ SEQUESTRATION IN THE GREAT SERPENTINE BELT, NSW, AUSTRALIA

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## ABSTRACT

New South Wales requires a range of sequestration options for its annual stationary emissions of $CO_2$ from energy generation. With inadequate sequestration capacity in depleted hydrocarbon reservoirs or porous aquifers at requisite depths for supercritical injection, mineral carbonation is an additional method of sequestration for carbon dioxide emissions. Mineral carbonation replicates the natural weathering process of magnesium-rich silicate rocks to form principally insoluble magnesite ($MgCO_3$), binding $CO_2$ chemically in a form that is stable over geological time. The reactions are exothermic, and occur naturally over extended periods.

This study assessed the properties of the ultramafic rocks of the Great Serpentine Belt between Bingara and Barraba, NSW, for their mineral carbonation potential. Although dunites have the fastest reaction time and highest conversion rate, the more abundant serpentinites, although hydrated, are attractive targets for mineral carbonation. Serpentinite volumes calculated to a maximum mineable depth of 500 m have the potential to sequester *ex situ* more than 300 years of stationary emissions for NSW at 2007 levels. Geomagnetic modelling indicates serpentinites extend to 2 km depth, which may add significant *in situ* sequestration capacity.

Current research aims to decrease the overall cost of storage of $CO_2$ in serpentinite from $70 to $40 per tonne of net fixed $CO_2$. Costs will be offset with saleable end-products such as magnesite refractories, magnetite separated during processing, chromium in the form of chromite and spinel, nickel as an accessory element in serpentine minerals, as well as silica and exothermic heat. Commercially viable mineral sequestration requires the carbonation reaction rate to be accelerated. Current research focuses on reducing energy penalty by accelerating the aqueous weathering reactions occurring naturally in serpentinites and pursuing biologically-mediated sequestration by microbes.

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# A TIER 3 METHOD FOR ESTIMATING FUGITIVE EMISSIONS FROM OPEN CUT COAL MINING: APPLICATION TO HUNTER COALFIELD

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## ABSTRACT

Fugitive emissions from open cut coal mines arise when coal and associated strata are broken and disturbed as part of the mining process, liberating the gas that is trapped within coal seams. The IPCC (Inter-governmental Panel on Climate Change) recommends using an Emissions Factor (*EF*) approach as the basis for estimating these emissions. The *EF* is the volume of gas ($m^3$) released per tonne of coal produced. There are three levels of accuracy associated with estimation of emissions, namely, Tier 1, 2 and 3 with increasing level of accuracy.

Until recently Australian open cuts used a method, which can be qualified as a Tier 1 method or a Tier 2 method at best. In this method EF values of 3.2 $m^3$/t and 1.2 $m^3$/t are used for NSW and Queensland, respectively. These values are used for all mines in these states irrespective of the level of 'gassiness' of coal seams and strata.

The proposed Tier 3 method considers the coal seams and strata as gas reservoir units and introduces the concept of the 'gas release zone'. This zone consists of the geological strata units (layers) affected by coal extraction operations. The primary data required are the in situ gas content of the coal and carbonaceous rocks contained within the gas release zone, prior to mining. The basic assumption of the method is that this gas is released on mining, with appropriate allowance for emissions from the mine floor and any residual gas remaining with the coal at the point of use. In this methodology, regions of similar gas content and reservoir properties are termed a 'gas zone'. A limited amount of drilling is required in each gas zone to characterise the gas zone and provide inputs to the model. *EF* values from various locations in a given gas zone are expected to be similar. The most important parameters of the model are the in-situ gas content and gas composition.

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# GAS LAYERING IN THE SUBSURFACE: IMPLICATIONS FOR GREENHOUSE GAS EMISSIONS

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**ABSTRACT**
Recent work has established that gas distribution in subsurface layers follows predictable patterns that have proven to be repeatable throughout many Australian basins. This pattern is a response to tectonic history, the coalification process, biogenesis, groundwater flow and magmatic activity.

This paper identifies the drivers behind variability in gas character in the subsurface, and develops a generalised model that can be used to better understand, and predict gas layering for greenhouse gas (GHG) emission accounting purposes.

The implications of this study are important to open cut mining operations because it provides a firm basis for estimating GHG emissions for National Greenhouse Emissions Report (NGER) accounting purposes. The model can also be applied to economic studies of the incremental worth of coal extraction as gas content increases with depth. The model also has implications for underground mining outburst risk analysis.

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# 3D GEOLOGICAL MODELLING AND CARBON STORAGE POTENTIAL OF THE SYDNEY BASIN

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ABSTRACT
The Sydney Basin contains Australia's largest concentration of stationary carbon dioxide emission sources, including power generation, oil refining and other industrial activities. For these emissions to be stored geologically capacity must be found within the geological sequence of the basin, or of adjacent basins.

A 3D conceptual geological model is presented, and used to make a preliminary estimate of carbon storage potential in the Sydney Basin. The model is built using the EarthVision suite of software tools (www.dgi.com). Information used to constrain the conceptual model included historical borehole reports, published geological conceptual basin cross sections, and published horizon top maps. The model seeks to represent the characteristics of the major sedimentary units and structures of the Sydney Basin. Rock properties crucial to fluid injection (porosity, permeability, temperature) are interpolated from the data available and modelled within the 3D geological framework.

A phase state model was calculated, using 3D grids of temperature and pressure values, to determine the location and extent of zones where supercritical conditions for $CO_2$ are met. Estimations of total pore volume within the supercritical zone indicate the theoretical capacity of the deep units is greater than that required to store the projected 20 year emissions from the Sydney Basin. The vast majority of this volume, however, may not be accessible due to low permeability at depth, and the fact that the centre of the Basin sits beneath urban development and National Parks.

As only a small and scattered number of boreholes penetrate to the required depth, the interpretation could change dramatically with the addition of a further small number of boreholes.

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# A REGIONAL TO SITE-SPECIFIC ASSESSMENT FOR POTENTIAL $CO_2$ GEOLOGIC STORAGE IN THE SYDNEY BASIN, AUSTRALIA.

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## ABSTRACT

New South Wales has second largest concentrations of $CO_2$ emissions in Australia. Due to the prevalence of $CO_2$ point sources within the Sydney Basin, it is essential to find suitable locations where $CO_2$ can be stored underground effectively and safely. The Sydney Basin has low to intermediate seismicity and intermediate faulting intensity. Geothermal gradients are also intermediate and formation pressure data indicate that the sedimentary successions are "normally" pressured. Under these conditions, $CO_2$ will remain in a supercritical state at depths greater than ~800 m. The basin contains a number of Permian reservoir-seal pairs in deep saline formations which, at first glance, are potentially suitable for $CO_2$ storage and containment. However, their spatial distribution and the reservoir characterisation are poorly constrained. Therefore, the geosequestration potential of the Sydney Basin is currently being assessed on both the basin and site-specific scales to identify, characterise and prioritise potential $CO_2$ subsurface storage areas.

The study was conducted by reviewing accessible well completion reports for wells that extend to over 800m depth and data on stratigraphy, structure, reservoir parameters, hydrogeology and fluid flow characteristics of the Sydney Basin. The developed datasets were used to construct tectonostratigraphic well correlation map, depositional and static model of the basin. The study has identified several sandstone/mudstone dominated stratigraphic units that could store and retain injected $CO_2$. Some of the potential units have reasonable porosities (up to ~20%) for supercritical $CO_2$ storage, but the permeabilities are generally low (<10 mD), which will affect injectivity. The sandstone units interbedded with the coals might also be worth considering as potential $CO_2$ storage units. The study has identified ten "prospects" for further assessment. There may be potential also to store $CO_2$ in unmineable coal seams within Late Permian Coal Measures in conjunction with enhanced coal bed methane recovery (ECBMR), particularly in depleting coal seam methane reservoirs.
*Key words: emission, geosequestration, $CO_2$, storage, trapping, prospect, reservoir*

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# $CO_2$ GEOLOGICAL STORAGE OPPORTUNITIES IN THE GUNNEDAH BASIN, AND THE SOUTHERN BOWEN BASIN, NSW

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## ABSTRACT

Regional mapping is an essential component to determining the suitability of potential sites for geological storage of carbon dioxide ($CO_2$). As part of a larger project to evaluate the $CO_2$ storage potential of eastern Australian sedimentary basins, the Carbon-Dioxide Geological Storage Atlas of the Gunnedah-Bowen and Surat Basin in New South Wales (NSW), Australia has been developed using the ArcInfo Geographical Information System (GIS) and 3-D visualisation packages. The Atlas provides a graphic and mapping display that can assist in analysing the spatial characteristics of key geologic, physiographic, and anthropogenic factors affecting $CO_2$ storage opportunities in the study area. The aim of the Atlas is to build confidence with the data and to map, visualise and understand uncertainties and the potential risk associated with $CO_2$ geological storage capacity estimates.

The key layers mapped include: $CO_2$ industrial and natural sources, regional geology and depositional environment, hydrogeology, potential $CO_2$ geological storage sites, existing energy resources and the proximity to extractable geological resources, geothermal conditions, the $CO_2$ spatial density profile, infrastructure and socio-economic factors. A series of maps were created to identify those areas where there are social and environmental sensitivities that may affect the approval process for carbon storage projects. Finally, map layers were developed to show areas with potential for chemical reaction of $CO_2$ with minerals in mafic (basalt) and ultramafic (serpentinite) rocks. Mafic and ultramafic volcanic formations are a distinguishing feature of the region's geology, including large basalt flows that form the basement to the sedimentary sequence. However, a systematic and quantitative evaluation of basalts as a potential geologic storage option has not yet been developed in Australia. It is anticipated that the resources, maps, figures and data sets assembled in the Atlas, will assist in the development of both local and NSW state government approaches to land use and sustainable management of energy resources including coal, gas, water and other resources in the Gunnedah region.

Avoidance of high concentrations of carbon dioxide is a priority in delineating petroleum exploration and $CO_2$ storage targets. However, coal seams and natural gas accumulations in conventional reservoirs of the Gunnedah-Bowen Basin contain elevated levels of $CO_2$. The $CO_2$ concentrations are highly variable, ranging from pure methane to pure $CO_2$ over short distances. The high accumulation of $CO_2$ mapped in several exploration well testing in the study area provides some evidence that $CO_2$ has remained in place for thousands to millions of years with no evidence of leakage. The presence of naturally occurring $CO_2$ in the Gunnedah Basin demonstrates the efficacy of this basin for long-term storage of $CO_2$ but also indicates a decrease in the total pore volume of the basin, because some pores are already occupied by $CO_2$.

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# AN ASSESSMENT OF THE GEOSEQUESTRATION POTENTIAL OF THE CLARE SANDSTONE, A HETEROGENEOUS, DEEP, SALINE AQUIFER IN THE SOUTHERN GUNNEDAH BASIN

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## ABSTRACT

This project aimed to assess the potential of the Clare Sandstone, a saline aquifer in the Bando Trough and northern Murrurundi Trough, southern Gunnedah Basin, as a reservoir for sequestration of carbon dioxide emissions from coal-fired power generation. Reservoir characterisation of the unit, including determination of accurate storage volume, depends on thorough knowledge of its porosity and permeability, including petrographic analysis to delineate diagenetic influences. Framework grains are predominantly Lachlan Fold Belt sourced plutonic and metamorphic quartz, lithics and minor feldspar, with sporadic influences from New England Fold Belt volcanics. Kaolinite, illite and illite-smectite are the principal clays, which tend to inhibit porosity by blocking pore spaces and coating pore walls. Diagenetic history from textural relationships among cements indicates quartz overgrowths occurred first, followed by siderite, ankerite and calcite cement, then dawsonite ($NaAlCO_3(OH)_2$) and finally, kaolinite. Dawsonite present in the Bando Trough, likely precipitated from permeating $CO_2$-rich fluids from nearby intrusive activity, and is useful as a natural analogue for geosequestration. SEM observations show the cements and diagenetic clays have acted to inhibit porosity and permeability by blocking pore throats.

The study identifies the Clare Sandstone as a highly variable sedimentary unit with some potential as a geosequestration reservoir. More accurate determination of geosequestration capacity depends upon more detailed knowledge of the unit thickness, porosity, permeability, formation depth and salinity in the depocentre of the Murrurundi Trough.

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# MOBILITY OF TRACE ELEMENTS FROM FRESH AND LONG-STORED FLY ASHES

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## ABSTRACT

A range of trace elements occurs in the fly ashes from Australian power stations, although the overall concentrations are generally low compared to similar ashes from other countries. The potential mobility of environmentally significant trace elements from the ashes in water is, however, a more significant consideration in ash disposal or use than the overall concentration of the elements concerned. This paper examines the mobility of selected trace elements in fly ashes from combustion of a Sydney Basin coal, stored under sub-aqueous conditions for several decades, in relation to the mobility of the same elements from equivalent fresh, dry ash materials. The work provides a basis for assessing the long-term changes in element mobility associated with ash disposal sites, and also when the ash is used in applications involving interaction with water, such as engineering construction, soil conditioning or mine backfill.

Element mobility from fly ashes in most cases is related to the pH of the ash-water system, reflecting combinations of solution/precipitation, ion exchange and adsorption/desorption processes. Changes in natural pH and buffering capacity have been found to occur in ash with sub-aqueous storage, accompanied by changes in the relative mobility of a number of trace elements from the ash materials. Elements such as Al and Cd, that are relatively mobile at low pH levels from fresh dry acid ash, for example, have been found to have lesser degrees of mobility from the same ash stored under water, even if the ash has only been stored for a relatively short period, because of an increase in the natural pH level. Other elements such as Se and Mo, that are inherently more mobile at higher pH values, show increased mobility from water-stored ashes than from equivalent fresh dry ash samples. Although only small fractions of the total trace element content are typically mobilised, these changes, and possibly reverse changes with storage of alkaline ashes, need to be taken into account in design and management of ash disposal systems, and in uses of the ash that may bring the material into contact with water over extended periods of time.

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# LEACHING OF TRACE ELEMENTS FROM COAL STOCKPILES IN THE SYDNEY AND COLLIE BASINS

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## ABSTRACT

Laboratory testing has been carried out on samples from the Sydney and Collie Basins to evaluate the potential for release of environmentally-significant trace elements from Australian coals in exposed stockpiles. Samples of each coal were shaken in sealed polyurethane bottles with demineralised water or a controlled pH (acid) solution for 18-24 hours, after which the concentrations of major and trace elements in the resulting leachates were determined. The natural pH of the Sydney Basin coals in water was shown by the batch tests to be 8.0 to 9.3, while that of the Collie Basin coal was 4.75 to 5.0. The low pH associated with leaching of the Collie coal was due to oxidation of pyrite; the more alkaline pH associated with the Sydney Basin coals reflected the dominance of clay and carbonate minerals in the coals and the absence or near-absence of pyritic material.

Trace elements of environmental concern were mostly released at low concentrations from the coals of both study areas. Some elements, such as Co, Mn, Ni and Zn, were released at slightly higher levels from the Sydney Basin samples when the coals were tested with acid rather than water, suggesting a slight influence of pH on element mobility from the coals concerned. Other elements, such as Mo and Se, were less mobile from the Sydney Basin coals under acid conditions than at natural (alkaline) pH levels. Element release from the Collie coals, which had a naturally acid pH when tested with water, showed a similar pattern to that displayed by the Sydney Basin coals under acid test conditions.

Similar tests were conducted on a sample of the calcareous coastal sand on which the Collie Basin stockpile had been built. These showed that many elements of environmental significance, especially As, Cr, Cu, Mo, Pb, Sb, Th, U, V and Zn, were released in higher concentrations from the sand than from the Collie Basin coal sample. A few elements, such as Mn and possibly Ni, were released in higher concentrations from the coal (although values were still low), while others, such as Cd and Co, were released in low but approximately equal concentrations from both coal and sand samples.

Evaluation of the element concentrations released from the Sydney Basin coals in relation to relevant water quality standards indicates that the run-off waters from coal stockpiles are likely to meet target values, even without further dilution on discharge. Of the elements released at higher concentrations from the coal than the sand in the Collie Basin tests, only Zn appears from some of the test data to exceed current water quality guidelines. However, if the common dilution attenuation factor of 100 is applied, the Zn concentrations would still be below the trigger values set by those guidelines for marine environments, especially in cases where the trace element concentrations in the coal leachate are attenuated by contact with the sand beneath.

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# COMPARATIVE STUDY OF THE MINERALOGY OF THE BULLI AND GREAT NORTHERN COAL SEAMS, SYDNEY BASIN

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## ABSTRACT

The mineralogy of individual coal plies and non-coal intra-seam bands from the Great Northern and Bulli seams of the Sydney Basin have been evaluated using optical microscopy and quantitative X-ray diffraction. Clay mineralogy was determined on oriented aggregates of the clay fraction of the coal mineral matter and inter-seam sediments. Coals from the Great Northern and Bulli seams consist of abundant well-ordered kaolinite, minor quartz and carbonates (dolomite, ankerite and siderite), and in some cases minor anatase. In contrast, the roof and floor materials of these two seams contain abundant quartz, minor and equal proportions of kaolinite, illite and expandable clay minerals. K-feldspar is present in the coals and non-coal bands in the lower metre of the Great Northern seam section and restricted to the non-coal bands in the upper part of the seam. However, it is not present, even in the intra-seam non-coal bands of the Bulli seam, which may reflect deposition of the Great Northern seam at a greater distance from the sediment source in the New England Fold Belt. The silicate mineralogy of the coal and intra-seam bands is different to the floor of these two coal seams, especially with the K-feldspar in the non-coal bands of the Great Northern seam. This suggests that minerals in the coal seam were derived from another source, such as contemporaneous volcanic activity associated with deposition of the peat beds.

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# Significance of the Era Beach Dyke and Fault zone, Royal National Park, NSW

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**ABSTRACT**
A series of basaltic dykes and fault zone occur in the Triassic Stanwell Park Claystone at Era Beach, Royal National Park south of Sydney. Field relationships suggest that the basaltic dykes intruded a NNE striking fault zone and that their margins were brecciated after emplacement as a result of further movement on the fault zone. K-Ar dating of fault gouge indicates an age for movement on the fault zone of 120 Ma that contrasts with crystallisation age of 51 Ma. Major and trace element geochemistry suggest the dykes have compositions transitional between alkali basalts and basanites and have been emplaced in a continental setting. They are similar in chemistry to basaltic dykes found at Bondi (eastern Sydney), Maroota (northwestern Sydney) and North Avoca (Central Coast).

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# RESERVES, RESERVES AND NOT A TONNE TO MINE

**Michael Creech**

## ABSTRACT

Approximately 95 coal mines have closed in New South Wales and Queensland during the last 35 years. This paper outlines research into the reasons for these closures correlated with the reserves reported immediately prior to closure. Reserves are defined in JORC as "that economically mineable part of an indicated or measured resource...that demonstrates at the time of reporting that extraction can be reasonably justified". As such one would expect that the reserves quoted immediately prior to closure should be negligible.

Despite one third of these mine closures being reported as the result of reserve depletion, there are nonetheless large amounts of coal that have been left in the ground. The average reserves reported the year before closure was found to be equivalent to 20-30 years production for the average mine studied. Additionally there have been seven mines that closed within the study period with over 100 million tonnes of reported reserves remaining in the ground.

The average reserves "lost" when a coal mine closes in Australia is unsatisfactorily high and suggestions are made to remedy the situation. These include more frequent independent revisions and reviews as well more active monitoring from regulatory bodies. This paper aims to illuminate some of the darker areas of resource and reserve estimation with the intention of suggesting ways to improve these estimates and reduce the coal "lost" when mines close in future years.

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# THE AGE, GEOCHEMICAL AFFINITY AND SIGNIFICANCE OF THE MAROOTA BASALT, HAWKESBURY REGION, NSW.

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**ABSTRACT**
The Maroota Basalt occurs as a flow remnant which disconformably overlies the Cenozoic Maroota Sand Formation in the Hawkesbury River District, approx.50 km northwest of Sydney. Sand fractions from the Maroota Sand formation are actively exploited for industry and much earlier, the gravels may have been exploited by the indigenous people of the region for stone tool manufacture. The Maroota Sand occupies two former ancient river beds, one flowing north and the other flowing west. The ~ 45 Ma Maroota Basalt disconformably overlies the Maroota Sand and would once have been far more extensive. It may also have played an important role in damming the former west and north flowing stream systems, leading to the east-flowing Hawkesbury-Nepean river system of today. On a more regional scale within the Sydney Basin, the age of the Maroota Basalt lies within error or a few Ma of alkaline basalts from Epping (47 Ma) and Peats Ridge (49 Ma), and within 10 Ma of alkaline basalts from Era Beach (51 Ma) and Kulnurra (54 Ma). Collectively, this suggests a widespread though sporadic alkaline volcanism event within the Sydney Basin from 45 – 55 Ma.

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# QUALITY OF KALIMANTAN COKING COALS, INDONESIA

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## ABSTRACT

Some of high rank coal occurrences in Kalimantan, Indonesia have been identified and documented as coking coal deposits. The occurrence of the coking coal deposits is essentially controlled by the distribution of the bituminous coal. These coking coals generally have low ash and low to high sulfur and a very high fluidity, although the content of inert macerals appears to be very low as represented by the Central Kalimantan coking coals. Petrographically, these coals in general are dominated by vitrinite macerals with minor inertinite and liptinite contents. Vitrinite reflectance (Rv) ranges from 0.7% to 1.1%. With these characteristics, in carbonization process the coals produce high CRI and low CSR cokes. Nevertheless, these clean and high fluidity coking coals might become a good blending material for coke industries.

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# RECENT DATA FROM MUNMORAH-1 AND VALES POINT-1 SHED NEW LIGHT TO THE GEOTHERMAL AND PETROLEUM POTENITAL OF THE SYDNEY BASIN

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## ABSTRACT

RSDP Munmorah–1 and RSDP Vales Point–1 were drilled near the New South Wales (NSW) east coast some 38.5 km southwest of Newcastle inside the Delta Electricity Munmorah and Vales Point Power Station compounds. The wells were fully cored from the surface-casing shoe (~250 m bsl) to total depth (TD) as part of the Regional Stratigraphic Drilling Program of NSW Industry & Investment's state-wide assessment of potential carbon dioxide geological storage. This was in response to the government's initiative to reduce greenhouse gas emissions. A four-well drilling program was designed to test the potential of the Sydney Basin sedimentary sequence for geological storage of carbon dioxide gas (to be injected at a supercritical state). The initial two-well program was drilled in 2009 to investigate the presence of reservoir sands from 800 m and deeper. To penetrate this target total depth was reached at around 2000 m. Apart from getting important data on reservoir characteristics for $CO_2$ storage, the drilling program provided valuable new information on organic geochemistry and temperature regimes in this northeastern region of the Sydney Basin.

RSDP Munmorah–1 and RSDP Vales Point–1 are located within the Newcastle Coalfield in the area defined by Harrington et al. (1989) as the Lake Macquarie Trough. Both wells penetrated through thick Triassic sediments and Late Permian coal measures and terminated probably near the top of the Maitland Group sequence. Continuous temperature logging was conducted in both RSDP Munmorah–1 and RSDP Vales Point–1 with the results indicating anomalously elevated geothermal gradients of over 35 deg C per 1000 m.

Several core samples were taken from both wells and analysed for vitrinite reflectance and total organic carbon, as well as organic matter typing through Rock-Eval pyrolysis. Additional samples from RSDP Munmorah–1 were tested for hydrocarbon composition via solvent extraction, from sections where hydrocarbons were identified from wireline logs. The results of the analyses suggest the presence of source rocks with organic content mostly of terrestrial origin. These sediments are moderately rich in kerogens which are primarily gas prone (humic). The organic matter in the analysed section is late mature (gas) for hydrocarbon generation.

Basin modelling based on these data indicates that hydrocarbon generation commenced in the Late Permian as a result of rapid sedimentation in the Sydney Basin combined with elevated heat flow possibly retained from a Late Carboniferous rifting phase. Additional hydrocarbon generation coincided with deeper burial of the source rock during Triassic and Jurassic sedimentation, as well as an increased heat event related to the Tasman Sea rifting.

Based on the uncorrected average geothermal gradient of about 36 deg C per 1000 m in RSDP Munmorah–1, the projected temperature at 5 km is approximately 198 deg C (surface ambient at 18 deg C). The average geothermal gradient of above 35 deg C per 1000 m in RSDP Vales Point–1 indicates that a temperature of 194 deg C can be expected at 5 km depth. Further conductivity measurements and heat flow analysis are required to quantify this geothermal potential.

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# USE OF ENVIRONMENTAL ISOTOPES FOR AQUIFER CHARACTERSIATION AND CONNECTIVITY ASSESSMENT DURING CSG EXPLORATION IN THE HUNTER VALLEY, NSW

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## ABSTRACT

Coal seam gas (CSG) exploration is currently under way in the Hunter Valley, New South Wales. In 2009, AGL Energy initiated a baseline groundwater study and pumping trial at one exploration well close to the township of Broke, in order to understand the potential longer term impacts that their CSG exploration and production would have on aquifers overlying target exploration seams.

In the study area, the shallow alluvial aquifer is less than 12 m deep, extending across the valley floor of Wollombi Brook. This aquifer is drawn upon by local farmers and residents through licensed stock and domestic bores. The Wollombi Coal Measures underlie the alluvium and comprise inter-bedded conglomerate, sandstone, coal seams, mudstone and shale. Water bearing zones are present in the coal seams and within some of the more brittle rocks located at shallow depth. The current coal seam of interest is the Blakefield seam, which occurs at a depth of 323 mbgl.

A network of monitoring boreholes was installed around the gas exploration well to monitor the overlying aquifers during the exploration phase of the project. The main aquifers targeted were: the shallow and deep alluvium, shallow bedrock coal seams and the Wybrow coal seam. Baseline monitoring was undertaken prior to a 12-day pumping test on the deep gas exploration well. Hydrochemistry and isotope (oxygen-18, deuterium, carbon-14, and tritium) studies were undertaken confirm the origin and connectivity of waters under natural baseline conditions, and to establish connectivity or changes in connectivity between aquifers as a result of pumping.

There was no evidence in the water level monitoring data at any of the monitoring bore sites to suggest there is any drainage or connectivity between the shallow aquifers and deep (coal seam) aquifers proposed for CSG exploration. This finding was verified by the chemical and isotopic results, which showed no significant changes from baseline conditions due to pumping from the Blakefield seam. The environmental isotope (radiocarbon and tritium) data confirmed that groundwater in the alluvial aquifers is modern (<50 yrs BP), while groundwater in the coal seams ranges between 3,000 yrs BP for the shallow coal seams to more than 20,000 yrs BP for the deep Blakefield seam.

Based on this investigation, CSG activities are considered to have negligible effect on the local productive alluvial and shallow bedrock groundwater supplies.

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# THE INTERPRETATION AND IMPLICATIONS OF TRANSIENT GROUNDWATER RESPONSES TO LONGWALL MINING IN NSW

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## ABSTRACT

Subsidence and strata relaxation affect the bulk hydraulic properties of the rock mass above and around a longwall mine in a number of different ways. In Australia, assessments of hydrogeological impacts during operational mining have concentrated on characterising and modelling the increase in bulk permeability that results from the connective fracturing and bed separation that occurs as a result of subsidence. Hydrogeological assessments concentrate on these 'headline' changes in bulk permeability because they increase the rate at which groundwater drains into the underground workings, and therefore represent the main mechanism through which the mine can affect surrounding groundwater resources. However, these changes are not constant, and fracture pathways that are opened during mining can often close again due to strata settlement, swelling of mudrocks and clogging due to the movement of fines. Such effects tend to reduce inflows and hence hydrogeological impacts over time.

Longwall mining can also result in a number of transient, stress-related effects that affect local hydrogeology, but are not associated with connected fracture pathways or inflows to the underground workings. These effects can have a significant impact on pressure heads within hard rock strata, and can even produce noticeable monitoring responses within the weathered overburden. Although they are unlikely to affect surrounding water resources, such stress-related effects can have significant implications for observed groundwater level fluctuations.

Understanding the hydrogeological response to transient changes in rock mass properties and stress regimes is therefore important when interpreting groundwater monitoring data associated with longwall mines. It is particularly important if highly confined strata or low storage regolith materials are being monitored to give advance warning of potential impacts on aquifers or surface water sources. This paper uses examples from extensive, multi-level groundwater monitoring data to examine the nature and magnitude of the various types of groundwater response around a multi-panel longwall mine. It also discusses the implications for the design and interpretation of groundwater monitoring programmes associated with water resource protection around longwall mines within a NSW context.