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Gas and Coal Outburst Committee Seminar
11/11/09 – Illawarra Master Builders Club
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Investment Group

Pintail Laboratories
- Biogeneration & Remediation

Lateral Technologies International
- Lonestar Lateral Drilling (Zero Radius Drilling)

Apex Energy NL
- Australian CBM Leases
CSM & CMM

Illawarra and Burragorang
Areas

<table>
<thead>
<tr>
<th>Area</th>
<th>km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEL444</td>
<td>32</td>
</tr>
<tr>
<td>PEL442</td>
<td>172</td>
</tr>
<tr>
<td>Metropolitan</td>
<td>58</td>
</tr>
<tr>
<td>Huntley CCL700</td>
<td>19</td>
</tr>
<tr>
<td>PEL454</td>
<td>168</td>
</tr>
<tr>
<td>BVC CCL740</td>
<td>36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>485</strong></td>
</tr>
</tbody>
</table>

Reserves/Resource

- $2P = 58\, PJ$
- $3P = 210\, PJ$
- $C = 1360\, PJ$

*MHA Petroleum Consultants*

Coal – Circa 9 billion tonnes

GIP – Circa 2.5 TCF
Ilawarra

- Multiple Coal Seams
- Abandoned Mines
- Goafs
  - 4 x Active mines
  - >20 Abandoned mines
  - Multiple gassy goafs
Burrarorang

- Multiple Coal Seams
- Abandoned Mines
- Goafs
  - 8 x Abandoned mines
Apex Energy Activity

Resource Evaluation
- Digital Magnetotelluric Survey (DMT)
- Goaf System Contact Study

Drilling project
- Pt 3A –Proj 07013 – Approval Granted 24/9/09
- Fund Raising
- Contractor Engagement

DF #1 Well – Production Ready
DMT Survey

Digital Magnetotelluric (DMT) survey
Seam Isopachs

Woonona Seam
Goaf system
Significance
Why are goafs and abandoned mine workings important to Apex Energy?

- Readily accessible gas reserves
- Localised increased permeability
  - Lower seam gas transmission
- Gas storage potential
South Clifton Mine Plan
Goaf Behaviour - Relaxation Zones

Pre-extraction strata – shows an inactive gas borehole

Post-extraction strata – shows gas borehole now flowing
Strata Relaxation Modelling
Lunargas Pty Ltd

130m wide face – 75m behind face
Goaf Gas Migration Model
Goaf System Contact Theory

Section X - X
Drilling Program
Stage 1 & 2
15 Well Drilling Program

Stage 1
- 10 wells (5 goaf & 5 core)

Stage 2
- 5 goaf wells
Sydney Basin
Coalbed Methane
Sources of Gas

EM3

Hawkesbury Sandstone
Gosford Formation
Bald Hill Claystone
Bulgo Sandstone
Stanwell Park Claystone
Scarborough Sandstone
Wombarra Shale
Coalcliff Sandstone
Bulli Seam
Balgownie Seam
Woronora Seam
Wongawilli Seam
American Creek Seam - Upper
American Creek Seam - Lower
Tongarra Seam
Woonona Seam

N.B. Seam correlations are provisional, particularly the Woronora - Wongawilli - American Creek interval

18.00m coal
Source: *Minarco

Circa 30m coal

12.41m coal
Source: *ERA
Impermeable clay and ash layers preventing flow of gas from all gaseous coal seams
Too many wells below the line

Sub economic wells

Sydney Basin Av

Sydney Gas Overview
Average Well Rates in Stage II

Average Production of Stage-II Wells in Camden for the Month of March-07

• Previously Had Identified Too Many Low Rate Wells
• Approved SIS wells – 2 of the top 10 performers, while still dewatering. GL15 highest in field.
• Will propose many more SIS for next FY program
Bacteria, introduced through influx of meteoric waters, is responsible for bio-enhancement of mylonitised coals, leading to higher gas production fairways being created on Sydney Gas Limited/AGL Limited joint venture (Source - Faiz, 2007 CSIRO).
Darkes Forest #1 Well

轻松产水
CSIRO Carbon Isotope Tests at Darkes Forest #1 Well – March 2005

<table>
<thead>
<tr>
<th>Carbon Dioxide $\delta^{13}$C</th>
<th>VPDB = Vienna Standard Pee Dee Belemnite</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% VPDB</td>
<td>Indicative of marine carbonate source</td>
</tr>
<tr>
<td>-60% VPDB</td>
<td>Biogenic source</td>
</tr>
<tr>
<td>-25% to -40% VPDB</td>
<td>Terrestrially sourced thermogenic gas</td>
</tr>
<tr>
<td>-35% to -50% VPDB</td>
<td>Thermogenic gas from marine organic matter</td>
</tr>
</tbody>
</table>

The carbon isotope data for the gas from the Darkes Forest-1 well appears most likely to be a mixture of biogenic and thermogenic gas, with biogenic gas being the major component.

Biogenic $\rightarrow$ MIX $\rightarrow$ Thermogenic

$\delta^{13}$C -56.1‰ average at Darkes Forrest
Origin of Methane & Carbon Dioxide - Darkes Forest #1

After Scott & Tyler, Figure 19, (1998)
Pressure Trends
Sydney Basin Coals

- Natural fracture system removed by tectonic action
- Coal lacks a well-developed fracture or cleat system for gas delivery
- Coals are generally high gas content.
Exploration, gas exploitation and enhancement

- Multiple coal seams
  - Low permeability
  - High gas content
- Extensive abandoned mines and goafs
THE PROBLEM:

THE SOLUTION:
Cutting-edge Technology to Increase Oil & Gas Recovery

**Perforating Assembly**

- Production Casing
- Rods
- Production Tubing
- Weight Bars
- Guide Shoe
- Milling Assembly
- Producing Formation
- Anchoring Device
Ultra-Short Radius Lateral Jet-Drilling System

Lateral Jet Drilling Assembly

- Production Casing
- Production Tubing
- High Pressure Tubing
- Flexible Hose
- Shoe
- Rotating Jet Nozzle

Production Formation
Anchoring Device
Jet-Drilling Nozzle & Square Spring Drill-string

Lance comprises square spring steel
High Pressure Hose Wrapped with Square Spring to Facilitate Pushing Nozzle into Formation

With cross-section of Guide-Shoe
Lonestar Cutting Tool Demonstration
Pintail Biotechnologies

Technology Development and Opportunity

Coalbed Methane, Shale Gas Production and Petroleum Bioremediation
Pintail Introduction

Company founded in 1987
## Mine Projects (partial list)

<table>
<thead>
<tr>
<th>Client</th>
<th>Client</th>
<th>Heap Tons</th>
<th>Contaminants</th>
<th>Gold Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Pine</td>
<td>Hecla</td>
<td>1.3 million</td>
<td>Cyanide, nitrates</td>
<td>Yes</td>
</tr>
<tr>
<td>Copperstone</td>
<td>Cyprus</td>
<td>2.1 million</td>
<td>Cyanide, copper</td>
<td>Yes</td>
</tr>
<tr>
<td>Cripple Creek</td>
<td>CC&amp;V</td>
<td>5 million</td>
<td>Cyanide, nitrates</td>
<td>Yes</td>
</tr>
<tr>
<td>Summitville</td>
<td>EPA</td>
<td>10 million</td>
<td>Cyanide, copper</td>
<td>Yes</td>
</tr>
<tr>
<td>McCoy Cove</td>
<td>EPA SITE &amp; MWTPP</td>
<td>Process solution</td>
<td>Cyanide, nitrates, metals</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Hayden Hill</td>
<td>Kinross Gold</td>
<td>30 million</td>
<td>Enhanced gold recovery</td>
<td>Project cancelled</td>
</tr>
</tbody>
</table>

All remediation/mine closure projects were successfully completed to client and regulatory satisfaction.
## TPH Bioremediation Projects

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Starting conc., mg/kg</th>
<th>End conc., mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boise Road Maintenance Yard</td>
<td>Heavy oil, asphaltenes</td>
<td>23,000 – 43,000 mg/kg</td>
</tr>
<tr>
<td>Oregon Diesel Spill</td>
<td>Diesel</td>
<td>8,300</td>
</tr>
<tr>
<td>Denver Federal Center</td>
<td>Cutting oil</td>
<td>12,500</td>
</tr>
<tr>
<td>Getchell Mine</td>
<td>Heavy oil, diesel, hydraulic fluid in arsenic sediment</td>
<td>3,000 – 5,000</td>
</tr>
<tr>
<td>McCoy Cove Mine</td>
<td>Diesel, heavy oil</td>
<td>&gt;3,000</td>
</tr>
<tr>
<td>Scotland Land Development</td>
<td>Diesel, and oil</td>
<td>&gt;5,000</td>
</tr>
<tr>
<td>Fallon Naval Air Station</td>
<td>Jet fuel, heavy oil, diesel</td>
<td>1,300 – 1,900</td>
</tr>
</tbody>
</table>
Significance of Biotech Approach to Gas Extraction Enhancement

- Delivery of gas-in-place by:
  - Mineral/coal bio-fracturing
    - Alteration of fouling minerals
    - Clay Stabilization
    - Clay Removal
    - Calcite Degradation
    - Etc.
  - Bio-refining of kerogens
Geology, Engineering and Geomicrobiology

- We need to think beyond porosity, permeability and fractures
- We need to understand gas diffusion and adsorption in coal
- We need to understand the reservoir at the molecular level
Methanogenesis

- Methane produced by coalification process
  - Release can be assisted by
    - Alteration of fouling minerals (Calcification etc)
    - Bio-refining of Kerogens in coal/shale

Biogenesis

- Production of Methane by bacterial action
  - Occurs naturals
  - Becoming better understood
  - Gas produced is young relative to coalification gas
  - Identified by Carbon Isotope testing (Carbon dating)
Methane Storage in Coal

- Methane in coal is:
  - Adsorbed on the surfaces and organic matter of the coal
  - Stored as free gas in cleats and open pores

- Adsorption types between gas phase and coal:
  - Physical Adsorption
    - Gas trapped in micropore matrix (5-500 angstroms)
  - Chemical Adsorption
    - Stored in molecular structure of kerogen in coal
    - Sorbed on internal surfaces of coal, sorbed to minerals and within micropore matrix
Adsorption Capacity and Coal Rank

An adsorption isotherm curve defines the holding capacity of gas as a function of pressure.

<table>
<thead>
<tr>
<th>Pressure (psi)</th>
<th>Adsorption (scf/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>500</td>
<td>200</td>
</tr>
<tr>
<td>1000</td>
<td>400</td>
</tr>
<tr>
<td>1500</td>
<td>600</td>
</tr>
<tr>
<td>2000</td>
<td>800</td>
</tr>
<tr>
<td>2500</td>
<td>1000</td>
</tr>
<tr>
<td>3000</td>
<td>1200</td>
</tr>
</tbody>
</table>

Adsorption vs coal rank

- Anthracite
- Bituminous
- Sub-Bituminous
Macerals

- Organic units of coal or oil shale composition
- The term 'maceral' in reference to coal is analogous to the use of the term “mineral” in reference rocks.

Types of Macerals

- Vitrinite – cellular material - roots, bark, plant stems and tree trunks
- Inertinite - equivalent of charcoal and degraded plant material
- Liptinite - decayed leaf matter, spores, pollen and algal matter
Kerogen

- Kerogen is a mixture of organic chemical compounds that make up a portion of the total organic content.
- Some types of kerogen release crude oil or gas (hydrocarbons).
- Methane adsorbs to kerogen.
- Hydrocarbons can be released by microbial digestion/refining processes.
- Most kerogens are type 2/3.
Sorption Capacity of Different Kerogen Types

![Sorption Capacity Bar Chart]

- **I**: 50 mg HC/g TOC
- **II**: 60 mg HC/g TOC
- **III**: 90 mg HC/g TOC
Microbiological Action

- It is critical to look at the microporosity system, kerogen content and macerals for storage and/or generation sites for methane.

- Gas generation will come from contact of methane-producing bacteria with organic material.

- Produced gases will generate fractures in coal which will produce more surface area contact and more gas generation.
Bacterial Biofracturing of Oil Shale

Bacteria generated macroscopic fractures to aid gas flow within 2 months after injection.

Bacteria generated microscopic fractures by removing organic material (kerogens) and producing further methane within 2 months.
Changes in Gas Composition with the Application of Methanogenic Bacteria

1. Samples from the New Albany Shale, Indiana, USA

2. Crushed gas analysis of the core established methane at about 94%

3. Treatment with distilled water as control did not change the high methane composition

4. Treatment with bacteria resulted in breakdown of the kerogens which act as gas movement inhibitors and % methane dropped

5. Result is now higher gas flow from shale

6. Result is higher calorific value from heavier gas ends
Coal Sample Collection

- Gujarat NRE 50kg – Raw Coal Stock Pile

- Taiyuan Coal samples
  - Henan Provincial CSG Development & Utilisation Ltd

- Zhengzhou Coal Samples
  - Shanxi Energies Industrial Group Ltd
Feasibility Process

**Phase 1**
- Microbe Isolation
- Match to chemically-defined nutrient formulae

**Phase 2**
- 100mL serum cultures
- Nutritional Microbe/Archaea ID
- Preliminary Gas Generation Studies

**Phase 3**
- 2.5 L Bioreactor Studies
- Coal Mineral Alteration
- Gas Generation (methane, C2-C6, H₂, CO₂)
1st stage - Isolating correct bacteria

2nd stage - culture ready to up scale

3rd stage - up scaled to medium tanks

To application

4th stage – up scaled to tanks or ponds

Pintail Bio-remediation and bio-extraction
up scaling bacteria to heap leach capabilities
RESULTS SO FAR
Coal Gas Release and Generation
Chinese Anthracite Samples

Headspace Gas Analysis – Primary Isolation Cultures

Percent Gas Generated

CO2  H2  CH4

- Shanxi 1C H10
- Shanxi 1B H10
- Shanxi 1B X70
- Henan 1 H10
- Shanxi 1B X702
- Henan 2 H10
- Shanxi 1B S40
Gas Analysis by Media & Methanogen Media Sequential Analysis – Gujarat NRE Sample (Wongawilli Seam)

Headspace Gas Analysis, All Media

H-10 Headspace Reactor Methanogen Media
Hydrogen and Methane Observations

Hypothesis: Hydrogen will be produced first and then methane in carbon dioxide reduction pathways.

As hydrogen is converted to methane, hydrogen drops in headspace gases and methane increases.

Sequential headspace gas analysis will confirm reaction sequence and by-products.
Feasibility Summary

- Tests to-date have generated positive data using microbial processes to enhance methane release/generation in Bulli and Chinese coals.
- Up to 72% methane has been generated in serum bottle reactor headspace.
- Up to 6% hydrogen has been generated in serum bottle reactor headspace.
- Best methane generation is in H10 methanogenic media.
- Best hydrogen generation is in X70 chemolithotrophic media and S10 halophilic media.
- Methane production via release of chemically-bound methane from coal appears to account for about 50-60% of methane and other methane generation appears to account for about 40-50% of the methane in preliminary tests.
Technology Application

Illawarra Scenario
IMPROVING GAS FLOW THROUGH USE OF LONE STAR MULTIPLE LATERALS IN OPEN HOLE CONFIGURATION

Impermeable clay and ash layers preventing flow of gas from all gaseous coal seams

High pressure laterals drilled into every coal seam and sub seam to improve gas flow – between 40-60 laterals in 2 days
IMPROVING GAS FLOW THROUGH USE OF LONE STAR MULTIPLE LATERALS IN OPEN HOLE CONFIGURATION
IMPROVING GAS FLOW THROUGH USE OF LONE STAR MULTIPLE LATERALS IN OPEN HOLE CONFIGURATION
FURTHER GAS FLOW ENHANCEMENT THROUGH THE APPLICATION OF BACTERIA VIA MULTIPLE LATERALS

Improved Gas flow using Bio Solution which removes contaminates