Minerals Down Under:
A new National Research Flagship

Presentation to SMEDG
29/11/2007
Graham Carr
Content of talk

1. Mineral exploration research landscape in Australia
   • Including the roles of the Federal Government, State Surveys, Universities, CSIRO, exploration companies large and small, contractors and consultants.

2. The National Flagship Program
   • Vision, scope, collaboration and funding

   • Exploration, mining, processing, licence to operate
In a buoyant industry, government funding is at risk because of the argument:

“If the industry is doing so well, why should government fund research?”

The argument must be made that international companies can invest exploration dollars around the globe and that there needs to be government intervention to guarantee investment in Australia.

This argument has been carried and won over the past few years by State and Federal Geological Surveys and most recently by CSIRO.
The Message

1. The Value of the Industry to Our Nation – demand for commodities will continue.

2. The Risk that this value will diminish significantly over the next decades.

3. Research and the provision of fundamental new forms of geological knowledge of Australia can significantly reduce this risk.
What cars are made of
(after Bo Hedberg)

- 1000 kg steel/iron
- 11 kg copper
- 19 kg lead
- 8 kg zinc
- 38 kg glass
- 53 kg aluminium
- 232 kg rubber
- 63 kg plastic / other
- **1425 kg Total**

- 2250 kg iron ore
- 1180 kg copper ore
- 435 kg lead ore
- 326 kg zinc ore
- 75 kg quartz
- 254 kg bauxite
- 444 kg crude oil
- 113 kg various
- **5077 kg Total**
Australian mineral production

Mudd, 2005
Driver: Australian ore grade

Mudd, 2005
Driver: Australian waste rock and tailings production

Mudd, 2005
Driver: Australian workforce

Source: Access Economics

Net entrants to the workforce vs. Year

CSIRO  Minerals Down Under: a new national research flagship
Driver: Australian workforce

However, between 2005 and 2015 the workforce will need to increase by 50% (70,000 people) to sustain the sector (MCA 2007-08 pre-budget submission, December 2006)
Driver: Exploration expenditure trends

Global Exploration Spend (non-ferrous)

- Worldwide
- Australia
- Australia's Share
Driver: Who’s exploring?

Exploration Spend by Company Type

- **Majors**
- **Juniors**
- **Mid-tiers**
CSIRO’s research is delivered in three major areas:

1. Priority-driven core research
   - Science outcomes for industry and community
   - Generally single Divisions, but includes a number of major cross-Divisional activities

2. National Research Flagships
   - Strategic initiatives that aim to make a sustained contribution to national economic and social growth and sustainability
   - Multi-divisional and with major external partners

3. The Emerging Science Initiative
   - Developing new science capabilities e.g. nano science, complex systems
Flagships – 2004 to 2007

• Flagships
  • In Australia research funding is becoming ever more focussed on major National Challenges
  • 6 such Challenges were defined in 2004:

  - Energy Transformed
  - Food Futures
  - Light Metals
  - Preventative Health
  - Wealth From Oceans
  - Water for a Healthy Country
Additional Flagships in 2007

• In 2007 Budget, 3 more Flagships were announced:
  • Climate Adaptation
  • Niche Manufacturing
  • Minerals Down Under
The Minerals Down Under Flagship will assist the Australian minerals industry to exploit new resources with an in-situ value of A$1 trillion by the year 2030, and more than double the size of the associated services and technology sector to A$10 billion per year by 2015.
## Recent Federally Funded Exploration Research Initiatives in Australia

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Funding Source</th>
<th>Scope</th>
<th>Period</th>
<th>Investment (Total after leverage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODES ARC CoE</td>
<td>DEST</td>
<td>Ore Systems Studies, Geometallurgy</td>
<td>2005-2010</td>
<td>$15 ($30)</td>
</tr>
<tr>
<td>NCRIS AuScope</td>
<td>DEST</td>
<td>Research Infrastructure</td>
<td>2007-2011</td>
<td>$34 ($130)</td>
</tr>
<tr>
<td>Minerals Down Under</td>
<td>CSIRO</td>
<td>Exploration Technologies</td>
<td>2007-2011</td>
<td>$35 ($58) new $150 ($250) redirected</td>
</tr>
<tr>
<td>CRC DET (proposal)</td>
<td>DEST</td>
<td>Drilling &amp; targeting technologies</td>
<td>2009-2016</td>
<td>$30- 40 ($75 - $100)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td><strong>2005-2016</strong></td>
<td><strong>~$160 ($350)</strong></td>
</tr>
</tbody>
</table>
Flagships are different because……..

1. Larger scale projects
2. More multi-disciplinary
   • Cross Divisional KPI
3. More collaborative
   • Collaboration Fund ($114 million over 4 years)
   • Flagship Clusters – collaboration between CSIRO, Unis and other Govt agencies
4. Greater external oversight
   • Each Flagship has an Advisory Committee
5. Structured Engagement Strategy
   • Close relationship with Geological Surveys
   • Focus on improving engagement with SME Explorers and contractors
   • Strategic relationships with the big end of town
6. Increase the skilled workforce – education and training
The Core Components of Minerals Down Under

Discovering Australia’s Mineral Resources
- Mineral system lifecycles and targeting
- Terrane-scale technology applications
- 3D mapping technologies

Transforming the future mine
- Enhancing knowledge from drilling
- Geologically intelligent surface mining
- Non entry underground mining

Securing Australia’s future Ore Reserves
- Systems geometallurgy for next generation Australian ores
- Intelligent heap leaching – from empirical process to controlled system
- Towards the “invisible” mine – transforming future Australian mineral extraction

Driving sustainable processing through system innovation
- Transforming waste to wealth through industrial ecology
- Systemic innovation to manage precious resources
- Scoping mineral futures
Discovery Theme Goal

To facilitate discovery of $250 billion* of new mineral resources in Australia by 2025

* Estimated by value of contained metals within the discovered resources based on long term commodity prices
“3D-4D” becomes standard practice in Australian mineral exploration

Streams:

1. Mineral System Life Cycles and Targeting

2. Terrane-scale Technology Applications

3. 3D Mapping Technologies
The Core Components of Minerals Down Under

Minerals Down Under Flagship

- Discovering Australia’s Mineral Resources
  - Mineral system lifecycles and targeting
  - Terrane-scale technology applications
  - 3D mapping technologies

- Transforming the future mine
  - Enhancing knowledge from drilling
  - Geologically intelligent surface mining
  - Non entry underground mining

- Securing Australia’s future Ore Reserves
  - Systems geometallurgy for next generation Australian ores
  - Intelligent heap leaching – from empirical process to controlled system
  - Towards the “invisible” mine – transforming future Australian mineral extraction

- Driving sustainable processing through system innovation
  - Transforming waste to wealth through industrial ecology
  - Systemic innovation to manage precious resources
  - Scoping mineral futures
Stream Goal
Reduce mineral discovery cost in Australia through development and application of new technologies and understanding for area and target selection

Transformational Science
- "Computational Laboratory" for testing conceptual models and understanding processes of ore body formation and evolution
- Impact of biota on all geochemical behaviours in plants and the near-surface

Capability Growth
- Advanced numerical modelling system for all processes in earth’s crust
- Biogeochemical capability for regolith materials
- Synchrotron science for extreme chemistry and mineral mapping

Present Partners
Auslope, pmd*CRC, CRCLEME, GA, iVEC

Prospective Partners
Australian Universities, State Geological Surveys, AMIRA, NASA, BGS

Leverage existing work
- Build on success and capabilities of CRCLEME and pmd*CRC
- Ore system understanding for new types of ore deposits (e.g. Ni)
- Thermochronology for new targeting tools (e.g. diamonds)

Deliverables
- New technologies and techniques to increase targeting successes
- Toolkit of advanced computational modelling capabilities able to simulate ore-related processes at all scales
Mechanisms of geochemical dispersion through transported overburden

- Biota: vegetation, microbes, bioturbation
- Electrochemical cell
- Hydrogeochemical
- Gaseous
Micro PIXE quantitative element mapping of a phyllode

Highest Concentration
Zn 0.199%
Cu 859 ppm
Fe 1.04%
Ca 22.5%
Mn 0.517%

Low
High
Stream Goal
Contribute to an increase in Australia’s share of global mineral exploration expenditure through provision of data infrastructure and new types of data and expertise to government agencies.

Transformational Science
- Full interoperability leading to efficient pre-competitive geospatial data exchange for exploration
- Hyperspectral technologies provide understanding of large scale mineral alteration in terranes

Australia leads the world in geoscience data delivery, data standards and interoperability

Leverage existing work
- SEEGrid initiative is progenitor of Auscope Grid (a large part of Auscope investment plan)
- GeoSciML - delivery of complex geospatial data in common XML format
- Current HyLogger™ for Auscope Virtual Core Library

Capability Growth
- Improvements in hyperspectral instruments
- Advanced systems for data delivery
- Disseminating capabilities through embedded researchers

Present Partners
Auscope, Open GIS Consortium, GA, State & Territory Geological Surveys

Prospective Partners

Deliverables
- Auscope infrastructure delivery
- New improved data delivery systems, methods, protocols and universal data standards
- Next generation mineral maps
National Virtual Core Library

- **Outcome of AuScope (NCRIS)**
- **Deliverables are:**
  - An automated hyperspectral core logger (HyLogger™) in every state core library – delivered progressively from mid 2008 onwards.
  - Algorithms and software to interpret mineralogy from spectra
  - Data storage and knowledge access capabilities for research (& industry) users.
NCRIS - National Virtual Core Library

An automated hyperspectral core logger in every State Geological Survey core library
The HyLogger™

- Semi-automatic, robotically-sampled, visible & infrared, oxide carbonate and hydroxide spectrometers
- Spectrometer: ~8mm resolution. Continuously-scanning
- Digital imagery ~0.1 mm resolution
- Measurement: ~700 – 800 m per day
- Laser profilometer for core quality & breaks
- Outputs with TSG software
  - Mineralogical identification & abundance indices in various formats exportable to mine planning packages
  - Linescan & virtual core tray images, drill hole mosaics
- Models
  - HyLogger - I 2001-2005
  - HyLogger - II 2006 (new technology)
  - HyLogger - III 2008 (integrated with TIR)

CSIRO  Minerals Down Under: a new national research flagship
HyChips™

- Comprises: Automated ASD spectrometer, small robotic table, lighting, custom telescope and step remover, control computer, digital camera.
- ~10 mm samples collected in step-and-measure mode Can be used for core but slower
- 1-6 chip trays per pass
- 20-120 samples per pass
- 4 minutes for 3 trays
- Up to 2500-3000 samples / day
- Replicate measurements per bin
- Outputs as for The HyLogger
  - Optional digital photography & profilometer
  - Multiple holes per file
- Models
  - HyChips-1
  - HyChips-3
  - HyChips-6
The TIR-Logger

- Robotically-sampled, Fourier Transform Thermal IR (FTIR) reflectance framework-silicate spectrometer
  - 5000 - 14000 nm range. Average spectral resolution ~40 nm
- Spectrometer
  - ~14mm spatial resolution sampled every 4 mm
- Digital imagery
  - ~0.1 mm resolution
- Measurement rate
  - ~700m per day
- Laser profilometer for core quality & breaks
- Outputs with TSG software
  - Spectral parameters and relative mineral abundance indices in various formats
  - Linescan images, virtual core tray images, drill hole mosaics
  - One drill hole per file
- Prototype completed late 2005 with MERIWA support

CSIRO Minerals Down Under: a new national research flagship
HyLogging Systems - 2

As new HyChips 6-2 2006

Turnkey HyLogging Facility April 2007

Containerised HyChips 6-2 2007

Operational Set-up
Demostrator (NVCL.CSIRO.au)
CSIRO
Minerals Down Under: a new national research flagship
### Drill-hole Details:

<table>
<thead>
<tr>
<th>WTB5</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hole name</td>
<td>WTB5</td>
</tr>
<tr>
<td>Project</td>
<td>Teutonic Bore</td>
</tr>
<tr>
<td>Owner</td>
<td>GSWA</td>
</tr>
<tr>
<td>Machine</td>
<td>HyLogger-1</td>
</tr>
<tr>
<td>Drilled date</td>
<td>5/17/2004</td>
</tr>
<tr>
<td>Scanned date</td>
<td>5/17/2007</td>
</tr>
<tr>
<td>DB entry date</td>
<td>5/17/2007</td>
</tr>
<tr>
<td>Depth</td>
<td>186.94m to 248.8m</td>
</tr>
<tr>
<td>Trays</td>
<td>19</td>
</tr>
<tr>
<td>Sections</td>
<td>150</td>
</tr>
<tr>
<td>Samples</td>
<td>21695</td>
</tr>
<tr>
<td>Latitude</td>
<td>28°24'50&quot; S</td>
</tr>
<tr>
<td>Longitude</td>
<td>121°8'30&quot; E</td>
</tr>
<tr>
<td>UTM</td>
<td>E: 3179979 29m</td>
</tr>
<tr>
<td></td>
<td>N: 6055542.86m</td>
</tr>
<tr>
<td></td>
<td>Zone: 51 S WGS 84</td>
</tr>
<tr>
<td>RL</td>
<td>0</td>
</tr>
<tr>
<td>Azimuth</td>
<td>0</td>
</tr>
<tr>
<td>Inclination</td>
<td>0</td>
</tr>
<tr>
<td>Reports</td>
<td>upload new report view reports</td>
</tr>
<tr>
<td>Analyst</td>
<td>Jon Huntington</td>
</tr>
</tbody>
</table>

**Mosaic**

Trays increment left to right & top downwards. Click any individual tray for enlargement.
Mineral Map of Australia

- “Next Generation Mineral Mapping Initiative”
- “Big Footprints” alteration
- Over 150 1:250 000 scale mapsheets covering brownfields and greenfields exploration areas across Western Australia alone.
- With current available airborne capabilities it would take >30 years to generate an Australian mineral map
- Gap filled by satellite systems?
“Regional” Retrograde Alteration: Broken Hill (HyMap)

- 40 flight lines
- 3 m pixels
- 250 Gbytes

Geological Survey of NSW HyMap 2002

(Mg,Fe)_{oct} Si_{tet} = Al_{oct} Al_{tet}

R^III (mol)

Standard 1:25 000 scale map sheets

R^III = Al_{oct} + V + Cr

Wavelength nm)
Broken Hill Published Geology

From Geoscience Australia
HyMap: White Mica Composition

\[ R^2 = 0.4981 \]
CSIRO

Minerals Down Under: a new national research flagship

Broken Hill style syngenetic base metal
Thakaringa-style epigenetic base metal
Retrograde hear zones

HyMap: White Mica Composition, Published Shear Zones and Mineral Deposits

Fluid composition and plumbing
Interoperability

Drive for interoperability has led to SEEGrid

DOIR
PIRSA
GA

XML - GML\XMML

Web Feature Services (OGC)

Slides courtesy Stuart Girvan - Geoscience Australia
Stream Goal
Enable Australian geoscientists to operate consistently in 3D by 2025 through development of new software for efficient interpretation of existing data types & new geophysical tools for defining 3D subsurface geology

Transformational Science
- Development of SQUID airborne tensor magnetometer (GETMAG II)
- Joint geophysical inversion for all geophysical data types

Capability Growth
- Geophysical equipment and inversion techniques
- Multi-scale lithological, mineralogical and structural interpretation and visualisation in 3D
- New hyperspectral algorithms

Deliverables
- Toolkit of computational techniques for fast production of 3D geological maps
- GETMAG II and other geophysical imaging techniques, including inversion methods

Leverage existing work
- Mineralogical and chemical core logging (Hylogger and LIBS)
- Current generation 2D and 3D geoscience data modelling tools
- Developmental work on next generation SQUIDs

Present Partners
Auscope, pmd*CRC, CRCLEME, DSTO

Prospective Partners
Intrepid Geophysics, BRGM, Australian universities, UBC, State & Territory Geological Surveys
Computer Aided Geological Interpretation (CAGI)

• **VISION:** To enable geoscientists to rapidly integrate all geophysical data into a 3D geological interpretation.
• Based on GeoModeller and UBC-GIF codes and CSIRO EM Inversion Codes
• **Components of the project are:**
  • Workflow analysis
  • Inversion research
  • Physical properties research
  • Linking the codes

• **Proposed collaboration between CSIRO, BRGM, Intrepid Geophysics and UBC_GIF software**
SQUID Technologies

• Current Applications in land EM and airborne Magnetics
• Potential applications in down hole sensors
Tallawang magnetite mine

Location, plan and section showing
Drill hole intersections
Plan and section with total magnetic intensity map

CSIRO Minerals Down Under: a new national research flagship
TMI vs tensor deconvolution (performed on the TMI)
The Concept of Additional Value From Drilling

- **Enhanced automated core logging:**
  - Full Mineralogy
  - Geochemistry – XRF, LIBS, NAA
  - Petrophysical Properties
  - Structure
  - Geometallurgical Information

- **Strategies for using chips**
- **Strategies for down hole**
- **Strategies for measurement while drilling**
Proposed New CRC “Deep Exploration Technologies”

Proposal
An Industry-led Bid for a New Cooperative Research Centre for Deep Exploration Technologies

August 2007

AMIRA International
CSIRO Exploration and Mining

For internal use by recipient only. Disclosure to others prohibited. Intellectual property rights vested in Researcher(s) not to be used without licence.
The mission:
*Deliver innovative geological insights and technologies that will have a positive impact on discovery rates for economic deposits under cover in greenfield and brownfield environments. Possible Goals Include:*

- **Goal 1** Develop better, safer, higher value drilling technologies
- **Goal 2** Develop innovative data fusion and inversion methodologies that can be used in data-poor or sparse data areas
- **Goal 3** Develop new deep targeting geophysical methods
- **Goal 4** Develop new deep-probing geochemical technologies
- **Goal 5** Deliver top-class graduates

Focus to be defined by industry
Why a new CRC?

- Address big, difficult science issues around enhancing discovery rates in Australia.
- Maintain Government Investment in Exploration R&D - the two existing exploration-focused CRCs (CRC LEME & *pmd*CRC) will cease to exist as from 1 July 2008.
- Leverage University, CSIRO and Industry funds to provide a critical mass of research capacity in Australia.
- Provide resources and a focus for training the next generation of exploration professionals
Transforming the Future Mine
Enhancing Knowledge from Drilling

Stream Goal
To significantly reduce the cost of drilling and enhance the quality and quantity of information obtained from boreholes through the design, testing and delivery of effective drilling and down-hole data acquisition.

Transformational Science
- A high frequency percussive/rotary action hard rock mole exploiting tensile stresses and based on a detailed understanding of the physics of rock-bit interaction & adaptive drill control.
- New sensor development to allow measurements while drilling & advanced next generation down hole logging systems.

Delivering world-class scientific and engineering solutions to transform the drilling process.

Capability Growth
- Development of component technologies to be integrated into novel drilling tools.
- Application in mining and exploration of technologies derived from oil & gas industries.

Leverage existing work
- Smartcut – advanced abrasive resistant cutting tools comprising thermally stable diamond composite bits.
- Sweetspot - intelligent control system to optimise drilling efficiency.
- Smartrods – fibre composite drill rods.

Present Partners
- Curtin University and other research organisations.

Prospective Partners
- Concept design for enhanced resonance hard rock drilling mole.
- New logging technology to cost-effectively measure geological and mining rock mass characteristics.
- Fibre composite coiled tubing.

Deliverables
- Concept design for enhanced resonance hard rock drilling mole.
- New logging technology to cost-effectively measure geological and mining rock mass characteristics.
- Fibre composite coiled tubing.