Minerals Down Under:
A new National Research Flagship

Presentation to SMEDG

29/11/2007

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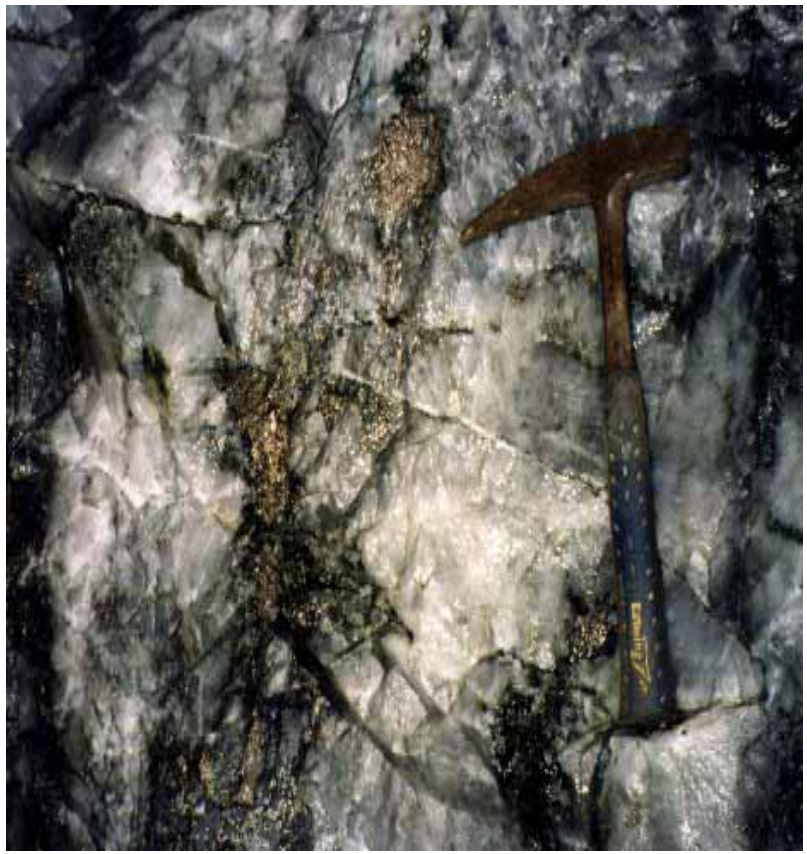
CSIRO

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

3. **Minerals Down Under – The Science**
   - **Exploration**, mining, processing, licence to operate



Mineral Exploration Research Landscape

- **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.**

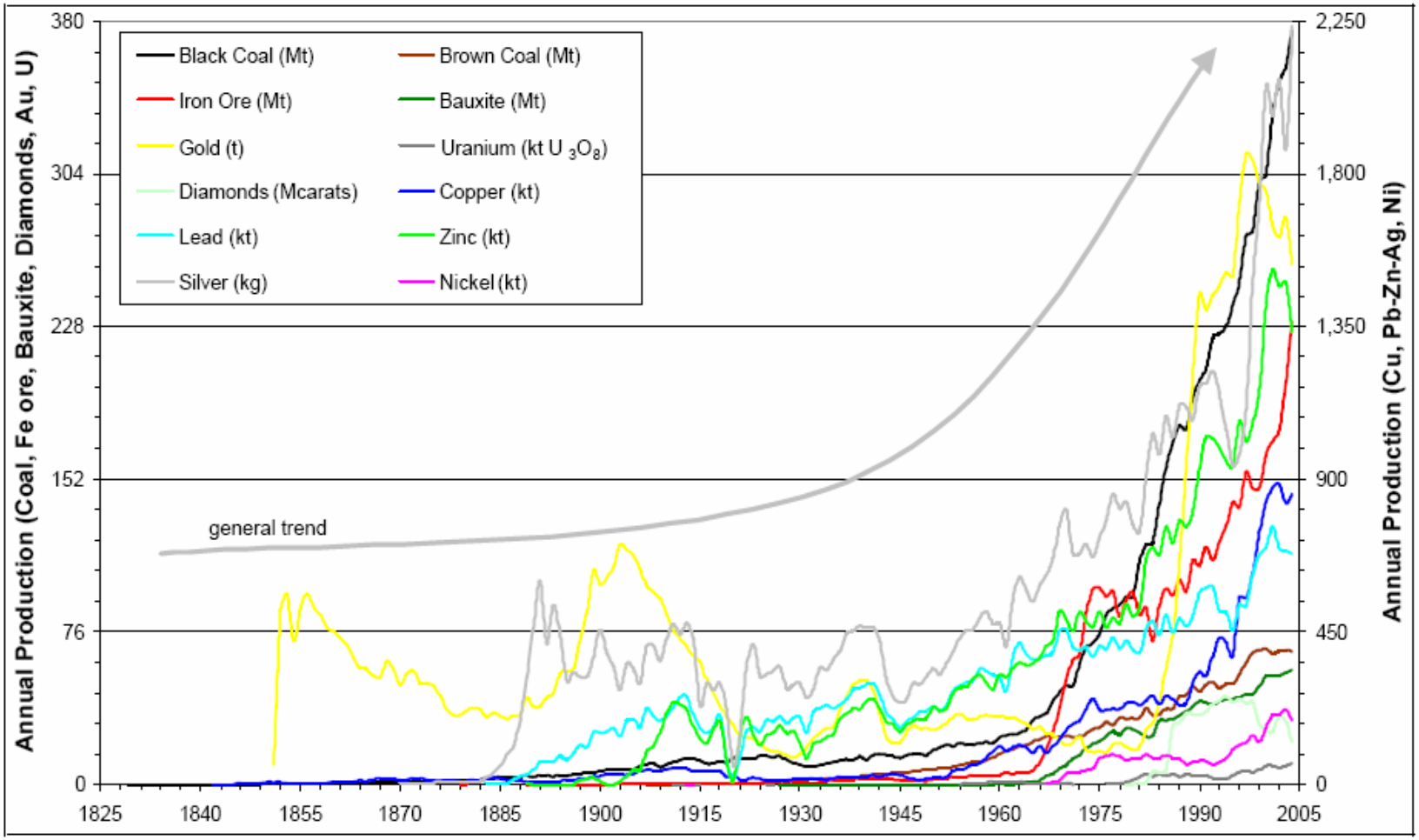
What cars are made of

(after Bo Hedberg)

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

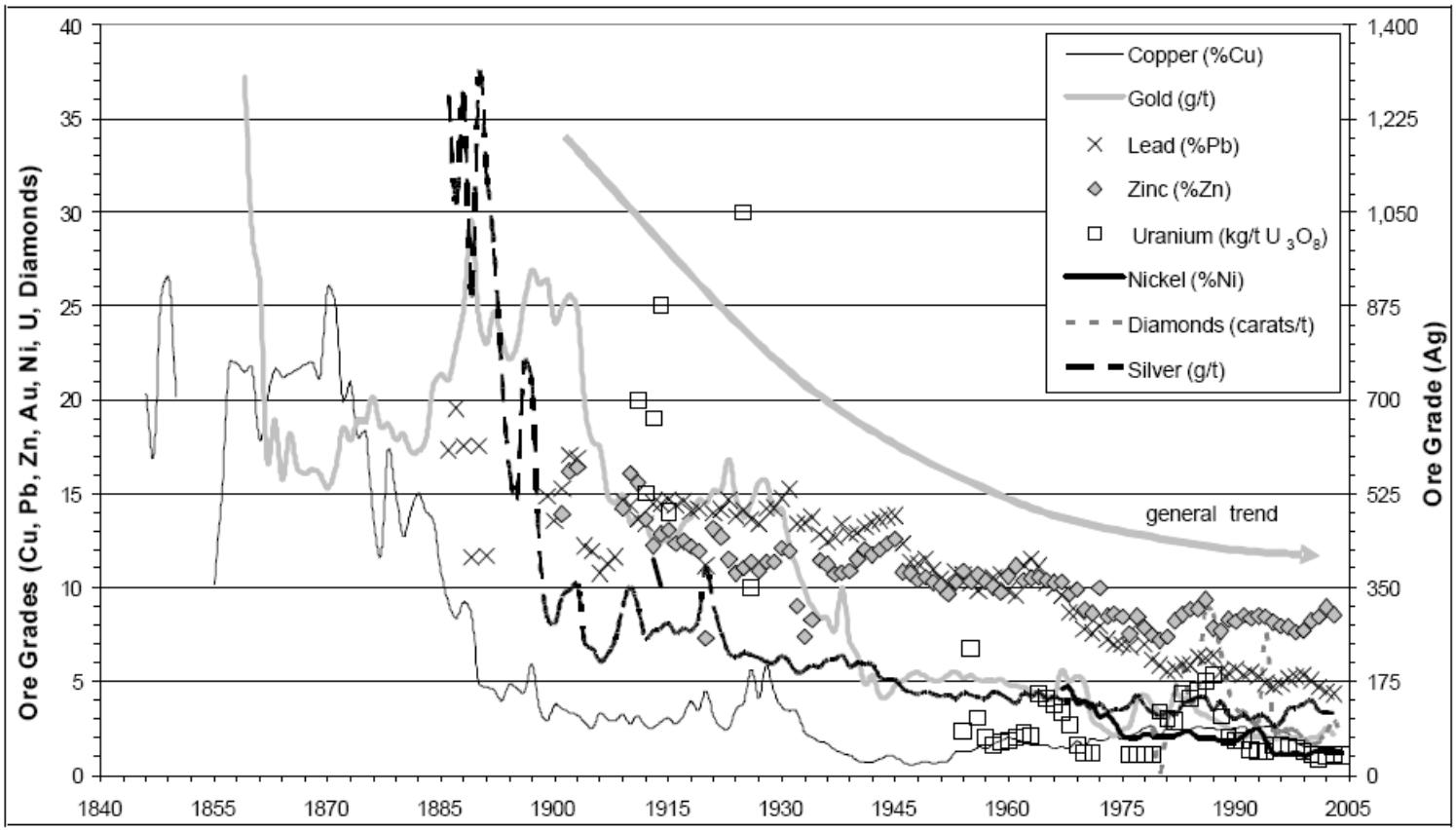
- 2250 kg iron ore
- 1180kg copper ore
- 435 kg lead ore
- 326kg zinc ore
- 75 kg quartz
- 254 kg bauxite
- 444 kg crude oil
- 113 kg various
- **5077 kg Total**

Australian mineral production



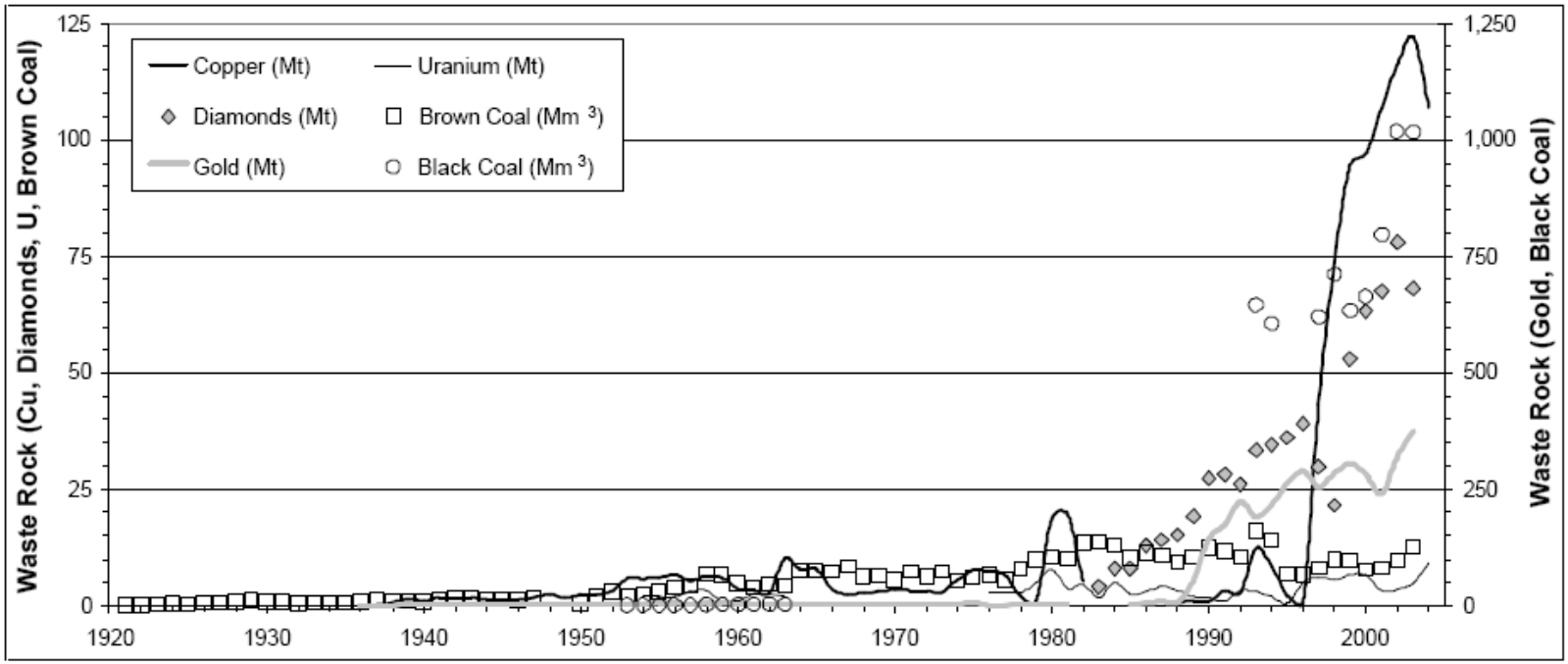
Mudd, 2005

Driver: Australian ore grade



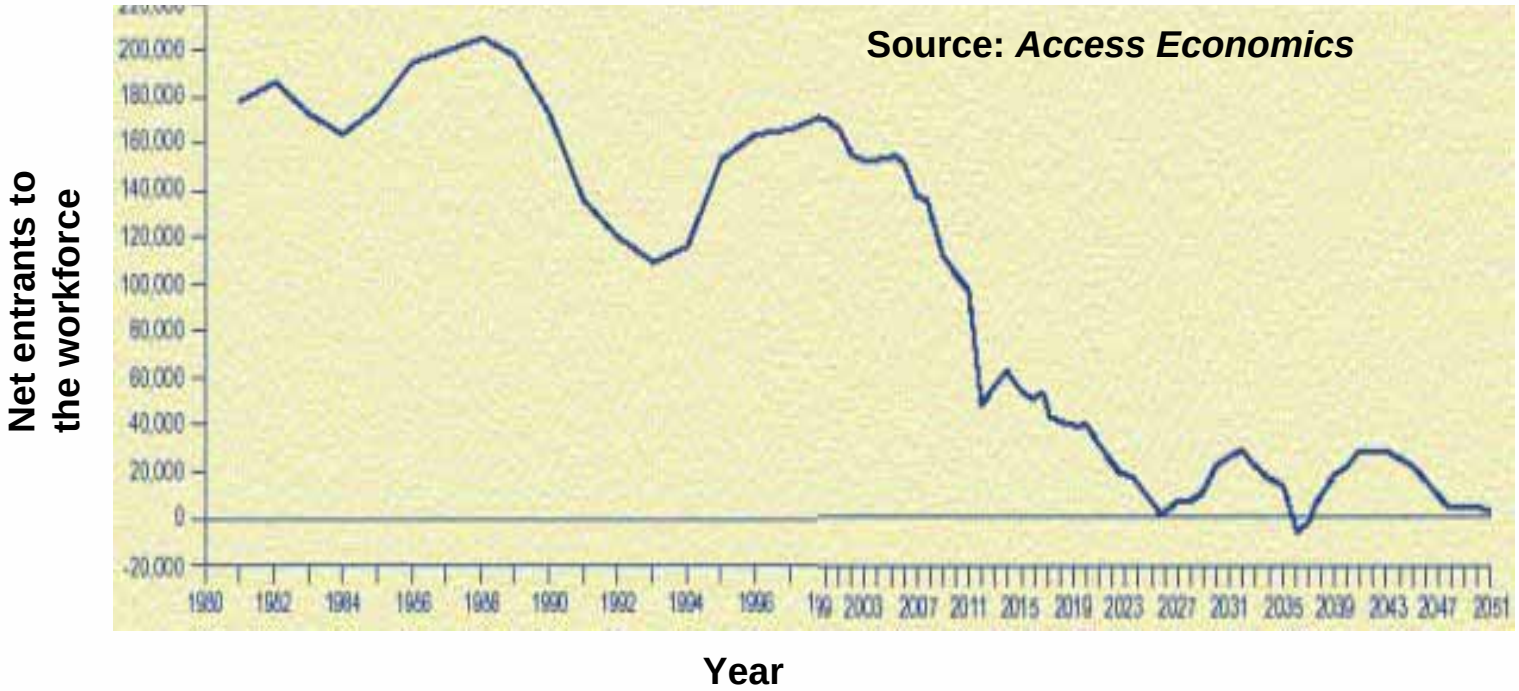
Mudd, 2005

Driver: Australian waste rock and tailings production

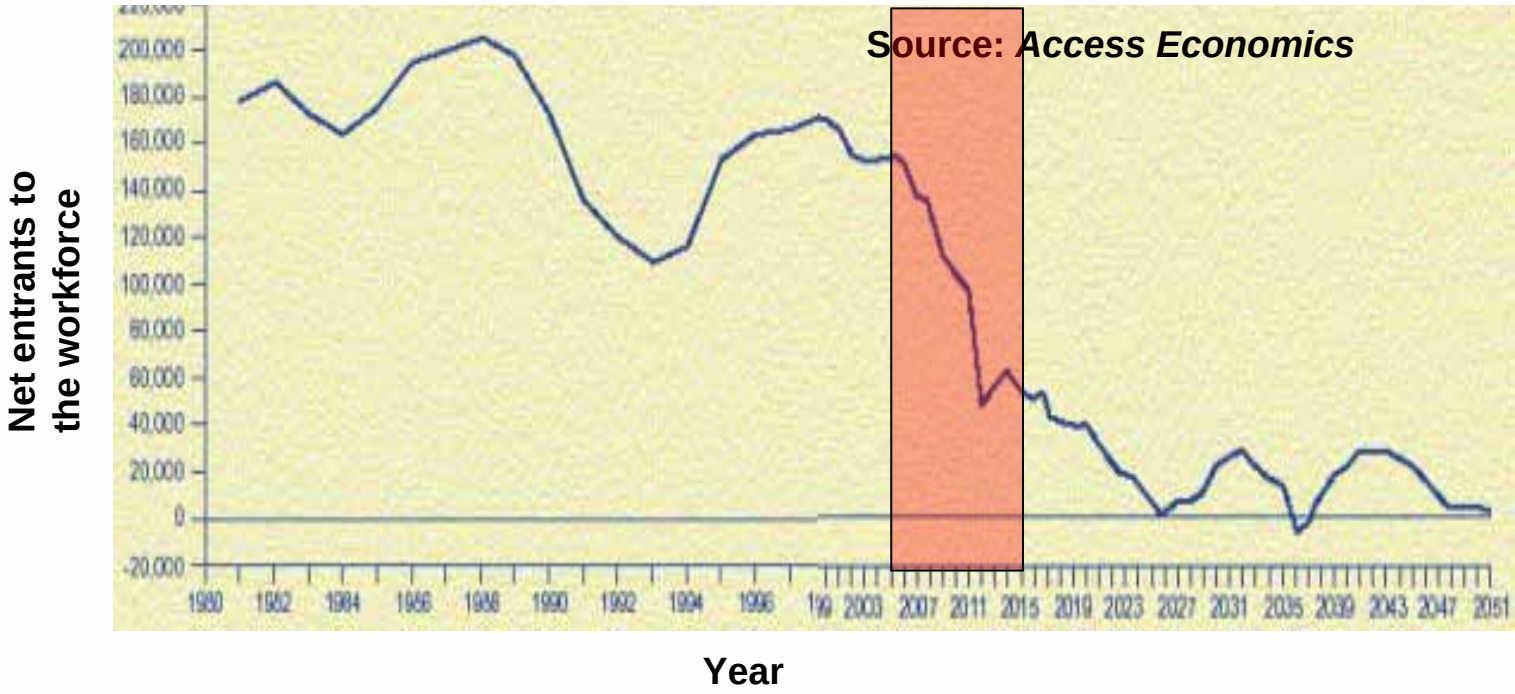


Mudd, 2005

Driver: Australian workforce

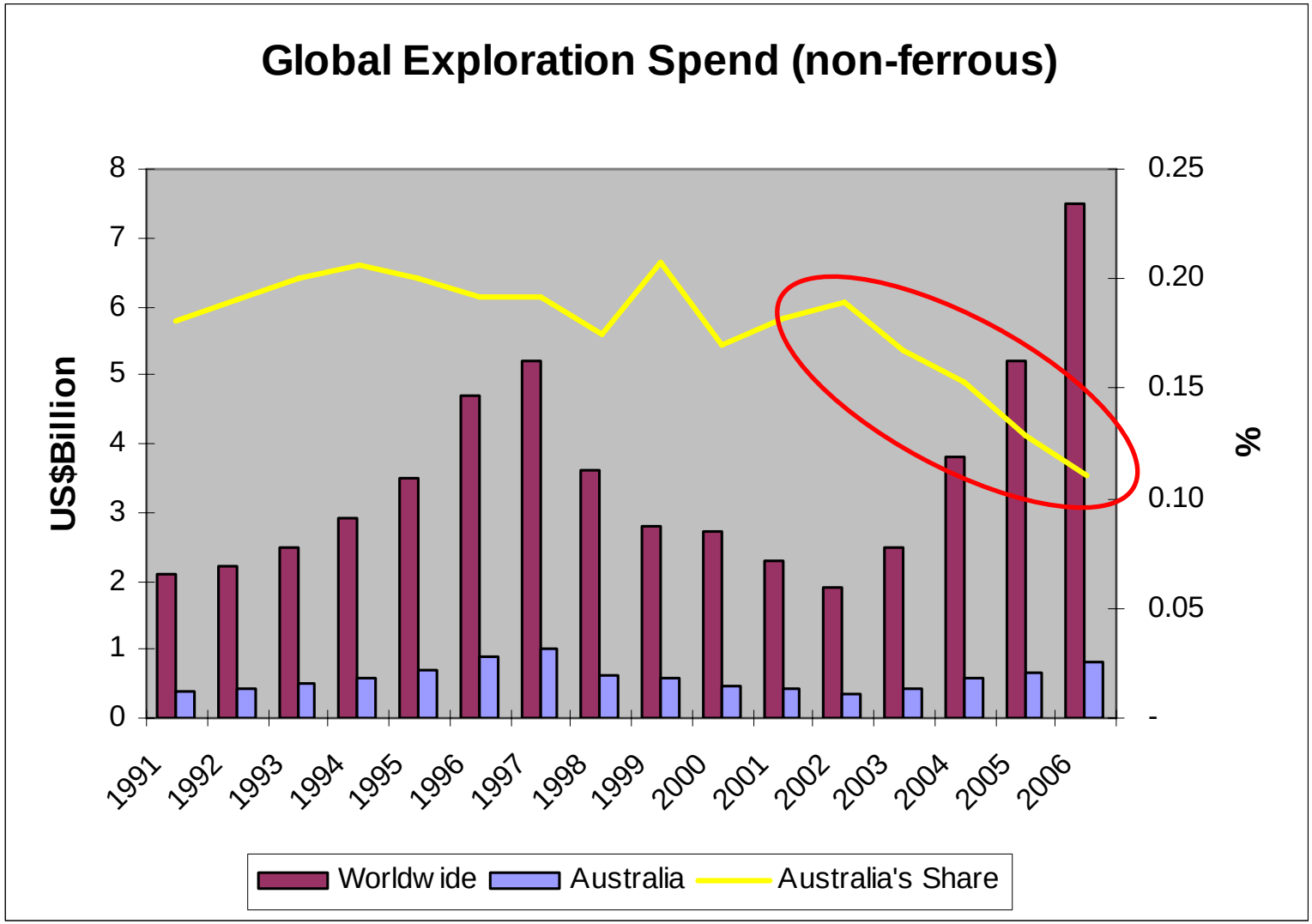


Driver: Australian workforce

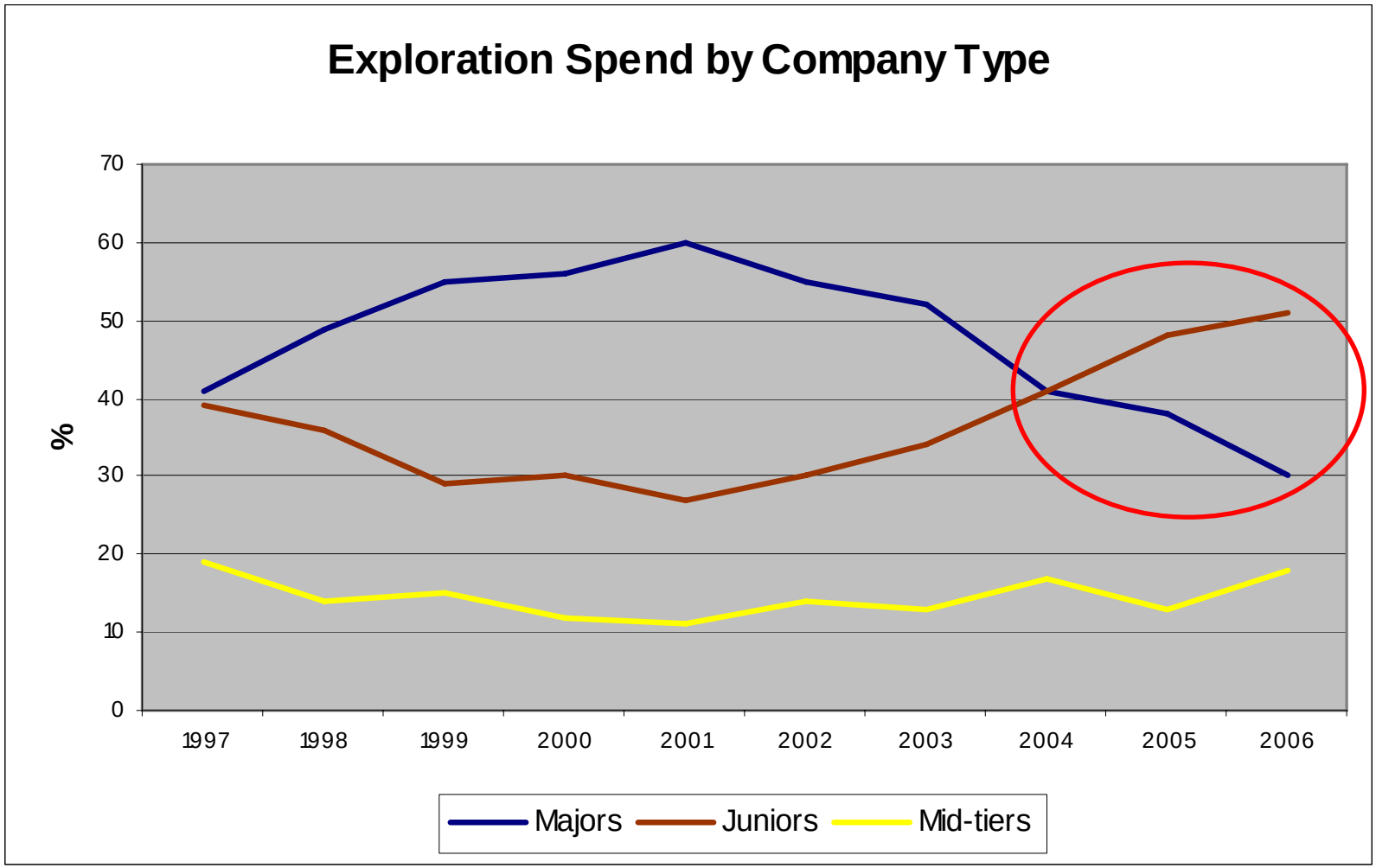


However, between 2005 and 2015 the workforce will need to increase by 50% (70,000 people) to sustain the sector (MCA 2007-08 pre-budget submission, December 2006)

Driver: Exploration expenditure trends



Driver: Who's exploring?



National Flagship Program

- **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

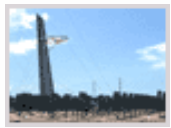
2. National Research Flagships

   - ***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

Light Metals

Wealth From Oceans

Food Futures

Preventative Health

Water for a Healthy Country

Additional Flagships in 2007

- **In 2007 Budget, 3 more Flagships were announced:**
  - Climate Adaptation
  - Niche Manufacturing
  - ***Minerals Down Under***

Vision

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.

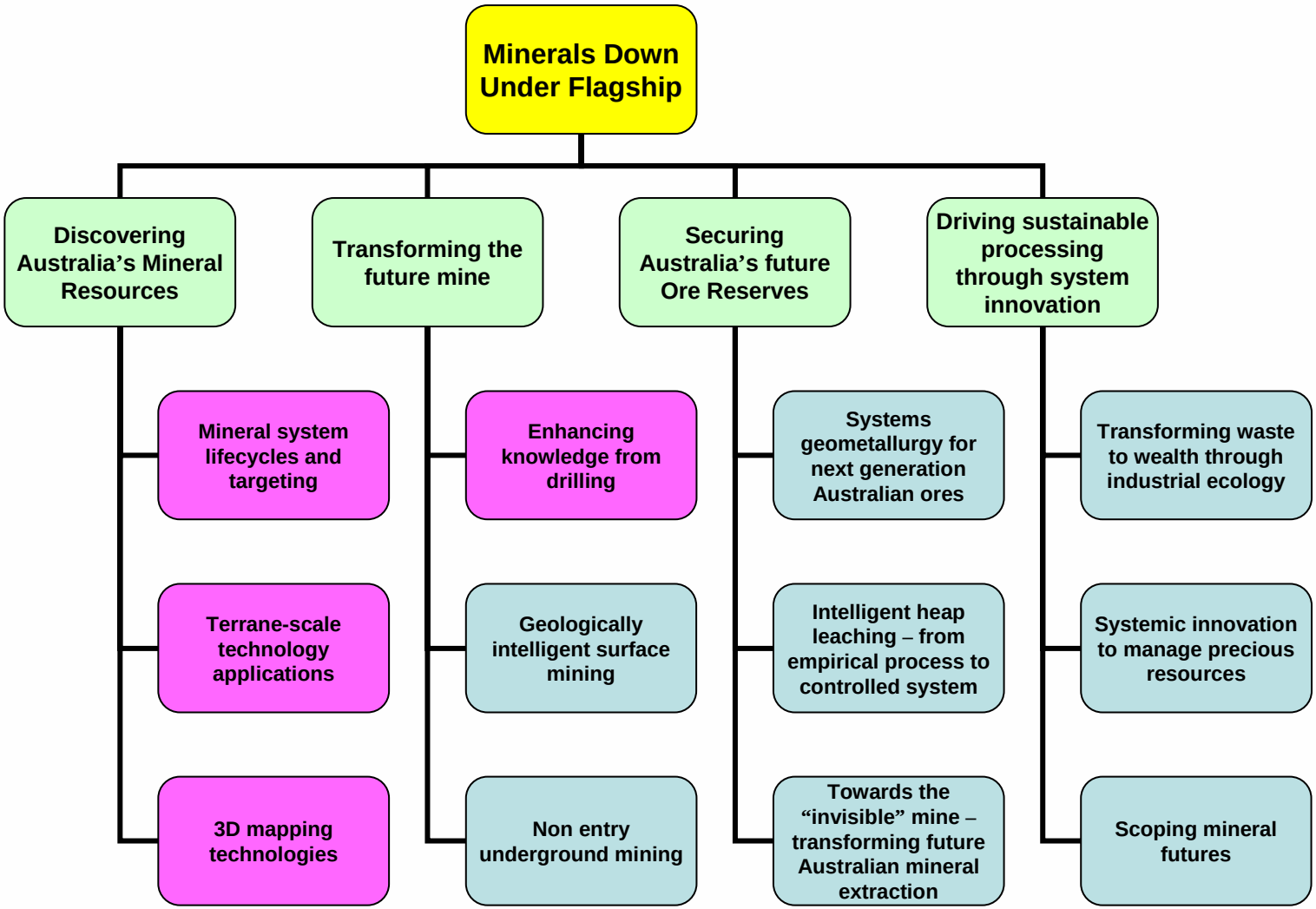
Recent Federally Funded Exploration Research Initiatives in Australia

Initiative	Funding Source	Scope	Period	Investment (Total after leverage)
GA Energy Security Package	DITR	Integrated Crustal Scale Knowledge	2006-2011	$59 ($59)
CODES ARC CoE	DEST	Ore Systems Studies, Geometallurgy	2005-2010	$15 ($30)
NCRIS AuScope	DEST	Research Infrastructure	2007-2011	$34 ($130)
Minerals Down Under	CSIRO	Exploration Technologies	2007-2011	$35 ($58) new *$150 ($250) redirected*
CRC DET (proposal)	DEST	Drilling & targeting technologies	2009-2016	$30- 40 ($75 - $100)
TOTAL			2005-2016	~$160 ($350)

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



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

Overall goal & streams

“3D-4D” becomes standard practice in Australian mineral exploration

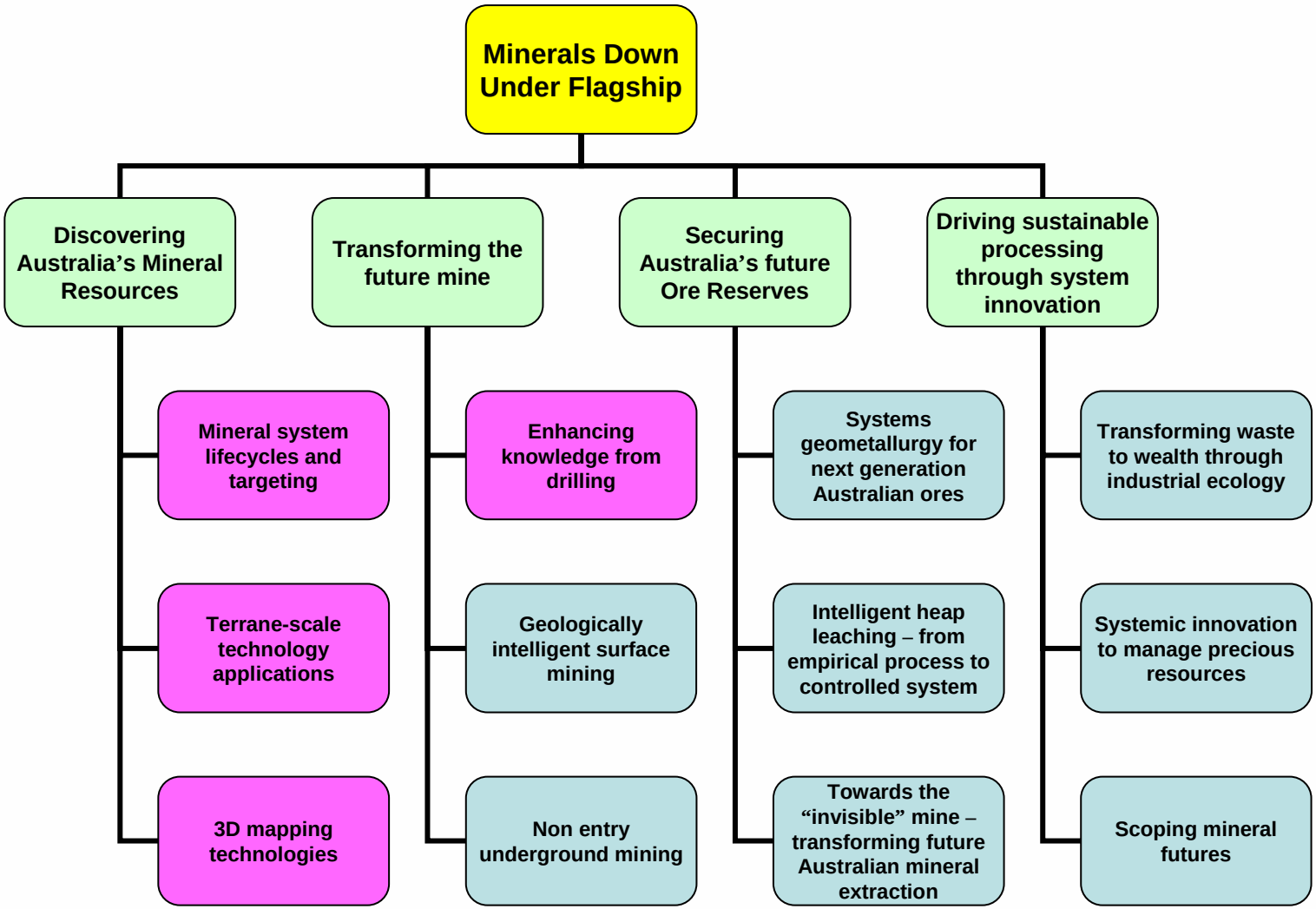
Streams:

1 Mineral System Life Cycles and Targeting

2 Terrane-scale Technology Applications

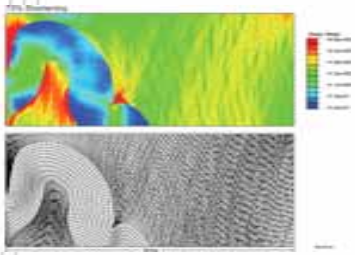
3 3D Mapping Technologies

The Core Components of Minerals Down Under



Discovery

THEME 1 Discovering Australia's Mineral Resources
STREAM 1.1 Mineral System Life Cycles and Targeting



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

Applying new targeting technologies for all mineral deposit types

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)

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

Auscope, pmd*CRC, CRCLEME, GA, iVEC

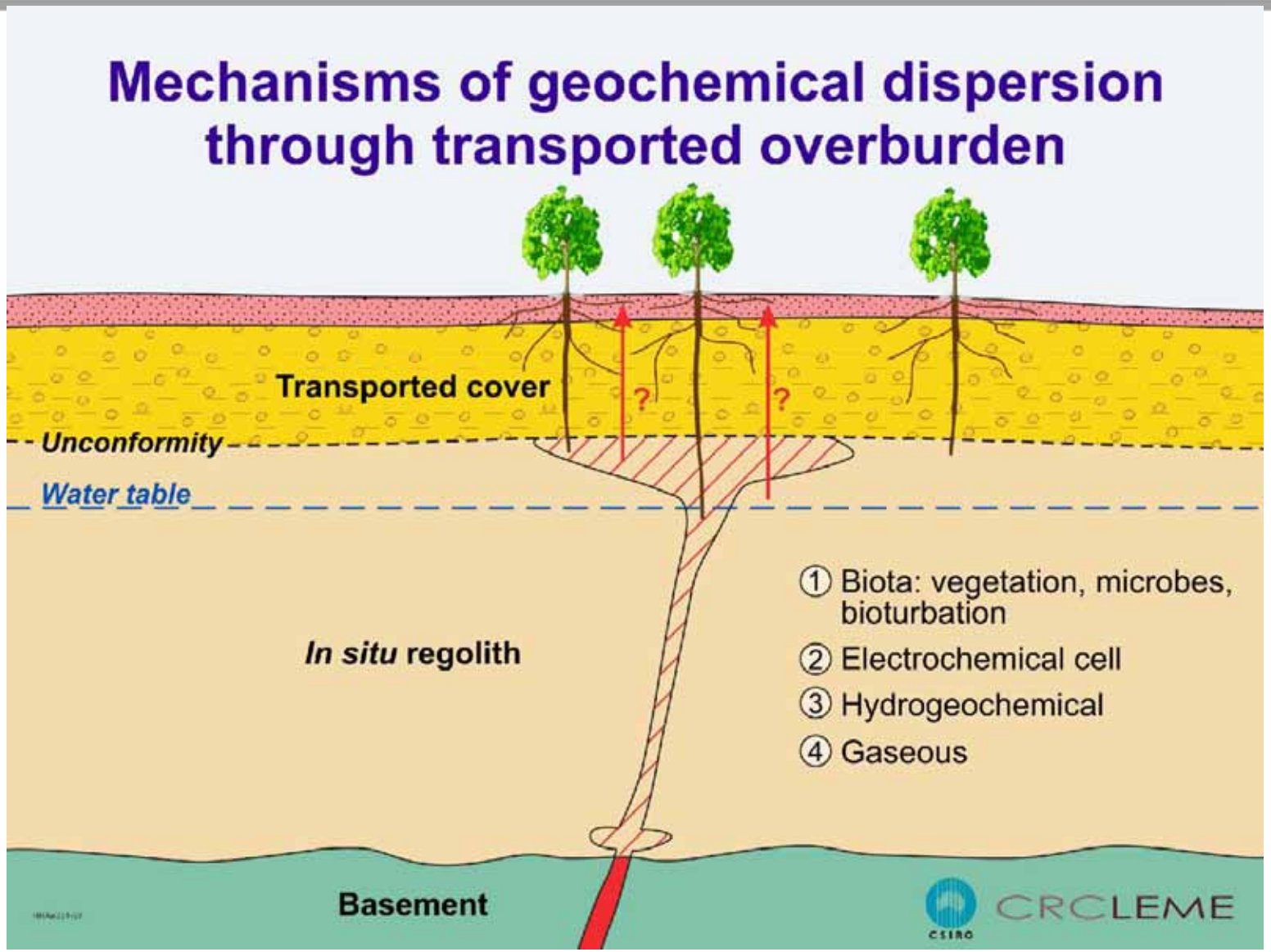
Prospective Partners

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

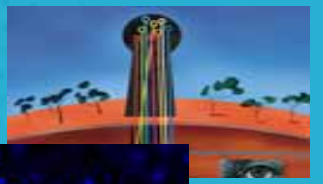
Deliverables

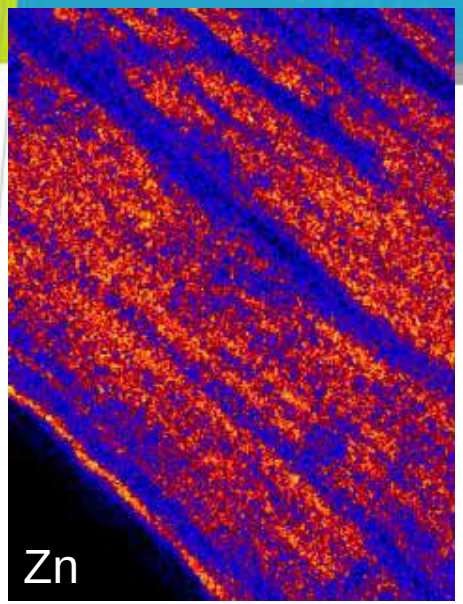
- New technologies and techniques to increase targeting successes
- Toolkit of advanced computational modelling capabilities able to simulate ore-related processes at all scales

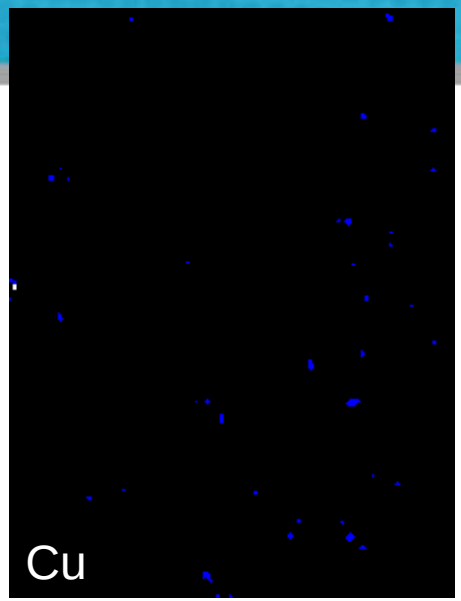
Biogeochemistry

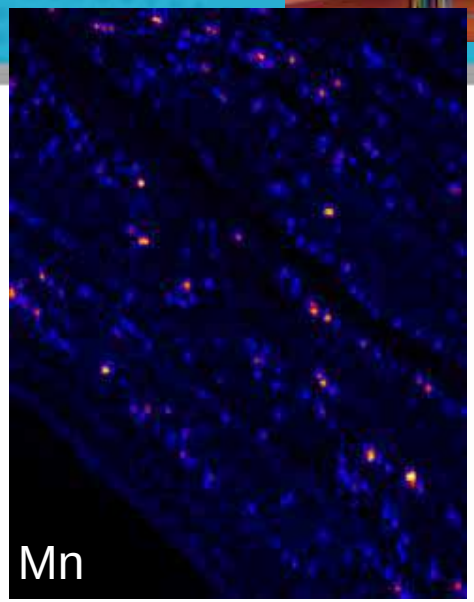


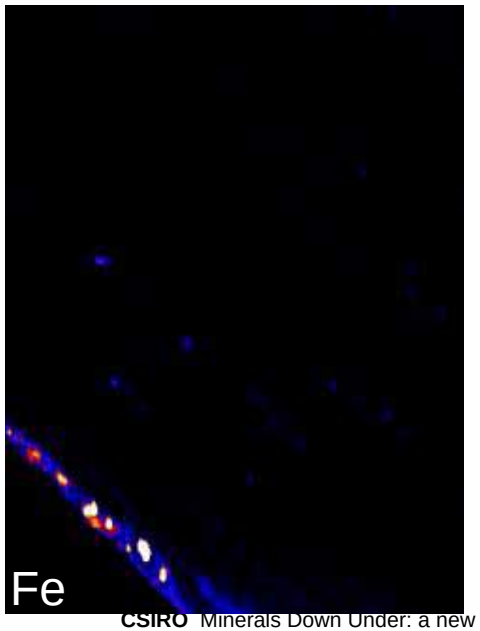
Micro PIXE quantitative element mapping of a phyllode

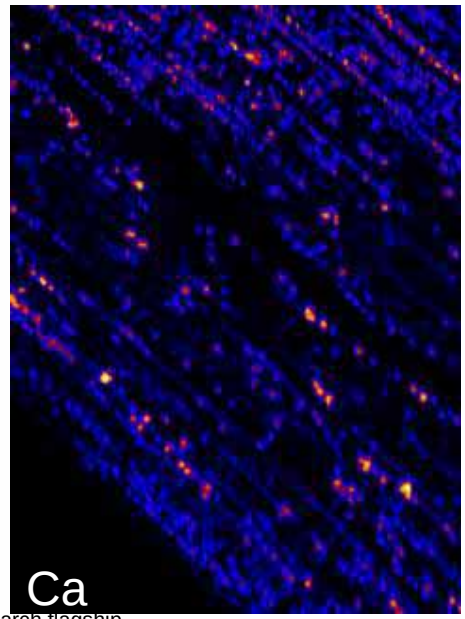








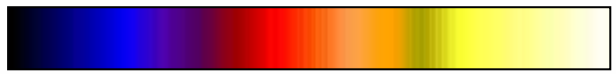




Highest Concentration

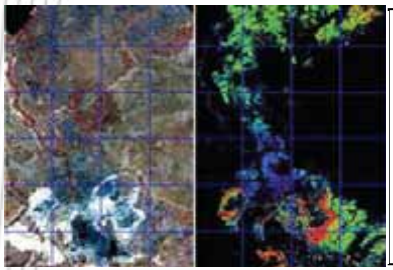
Zn 0.199%
Cu 859 ppm
Fe 1.04%
Ca 22.5 %
Mn 0.517%

Low High



Discovery

THEME 1 Discovering Australia's Mineral Resources
STREAM 1.2 Terrane Scale Technology Applications



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

British Geological Survey, US Geological Survey, BRGM, Geological Survey of Canada etc.

Deliverables

- Auscope infrastructure delivery
- New improved data delivery systems, methods, protocols and universal data standards
- Next generation mineral maps

National Virtual Core Library

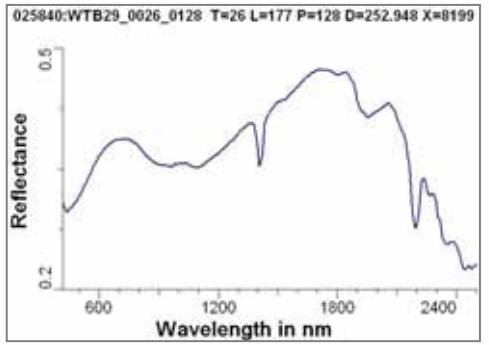
- **Outcome of AuScope (NCRIS)**
- **Deliverables are:**
  - An automated hyperspectral core logger (HyLogger™) in every state core library – delivered progressively from mid 2008 onwards.
  - Algorithms and software to interpret mineralogy from spectra
  - Data storage and knowledge access capabilities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

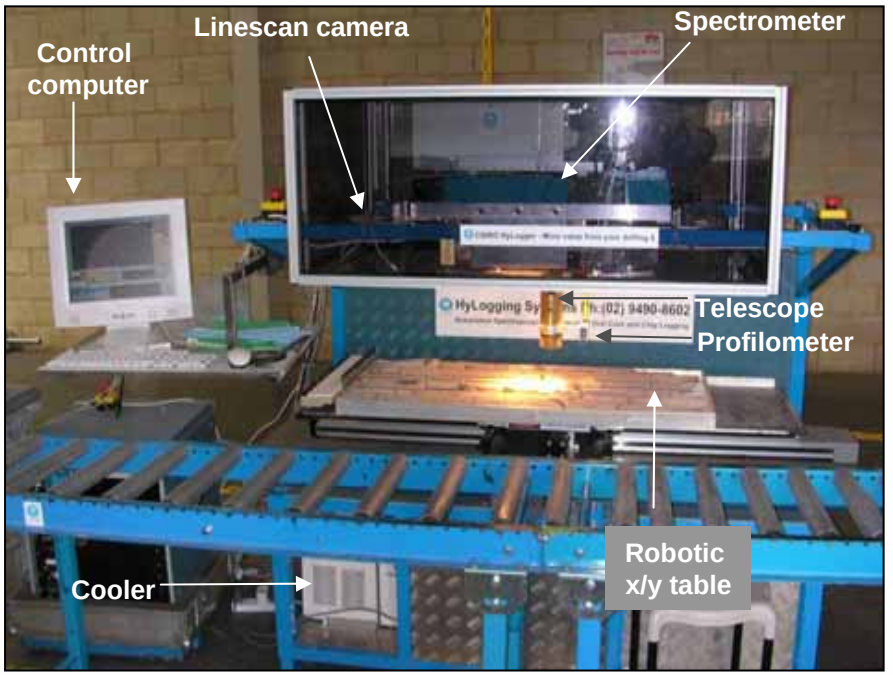
NCRIS - National Virtual Core Library

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)





HyLogger-I in the Kalgoorlie Core Library in 2004

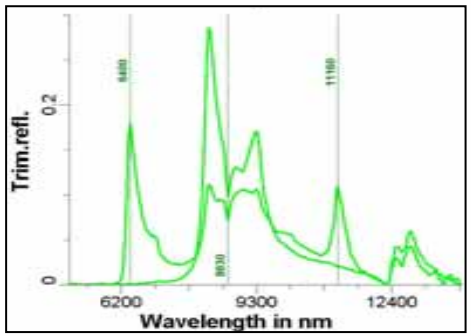
HyChips™

- **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

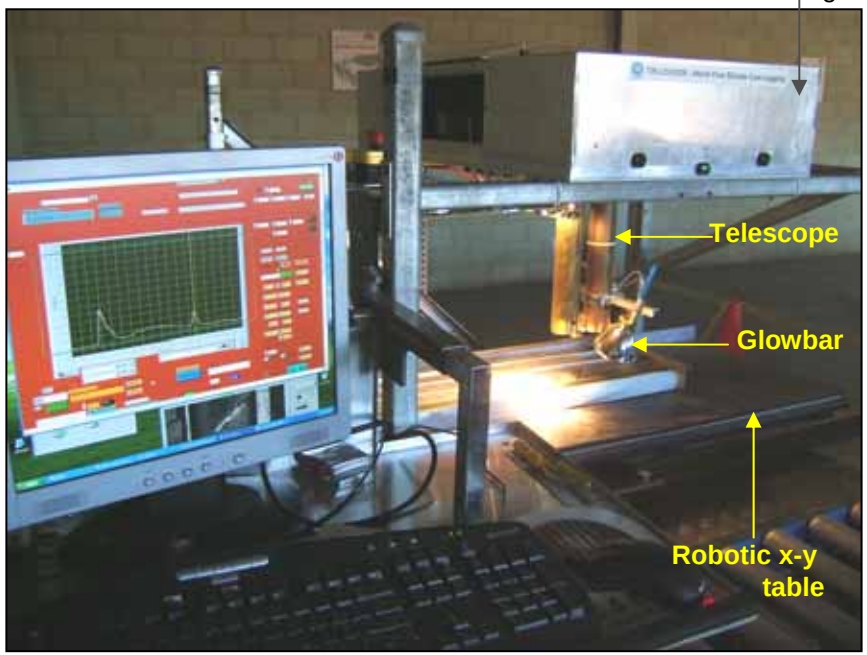
The TIR-Logger

- **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**



Spectrometer & linescan camera housing



The TIR-Logger in the Kalgoorlie Core Library in 2005

HyLogging Systems - 2

As new HyChips 6-2 2006

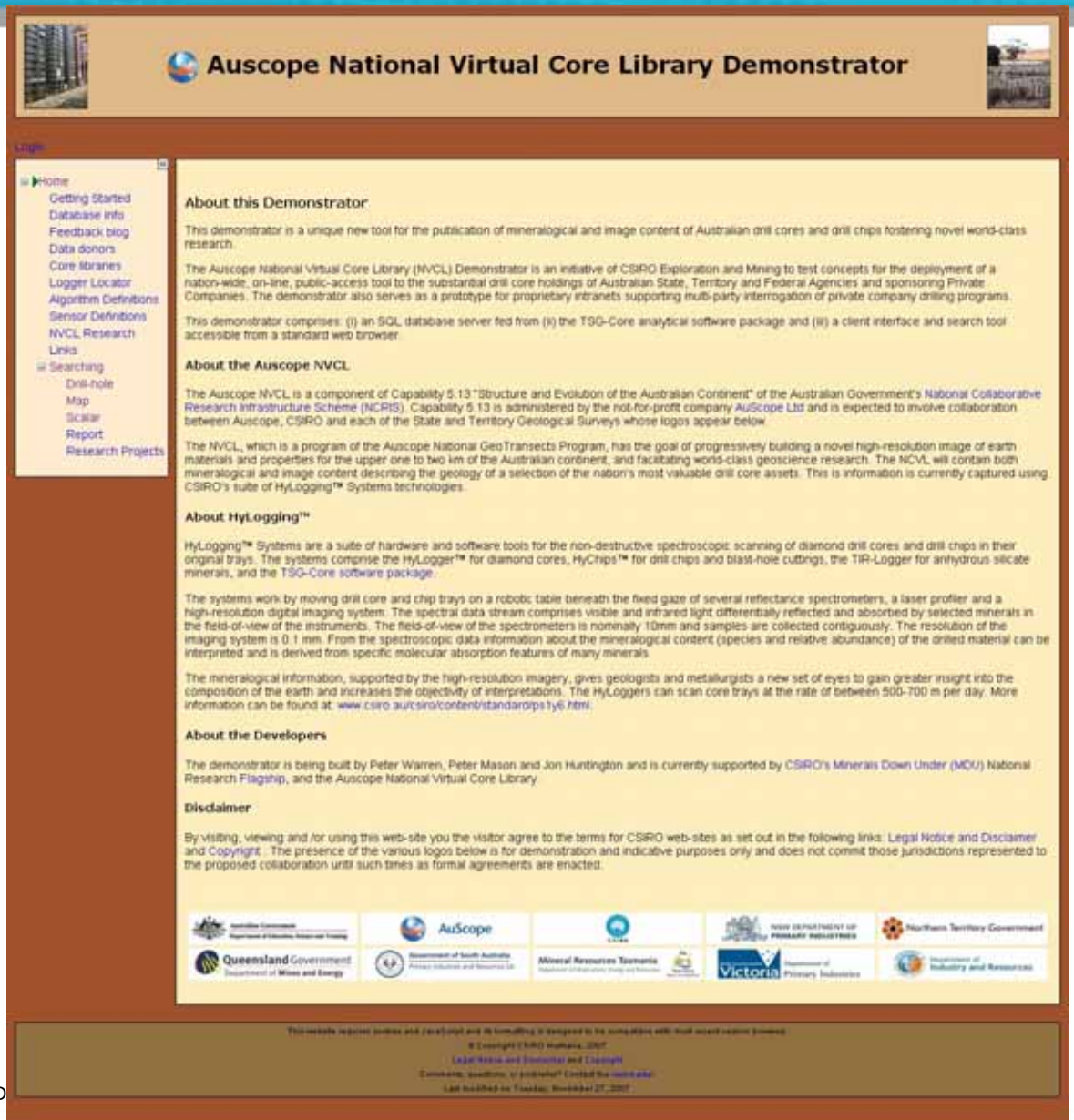
On Site 2006

Turnkey HyLogging Facility April 2007

Containerised HyChips 6-2 2007

Operational Set-up

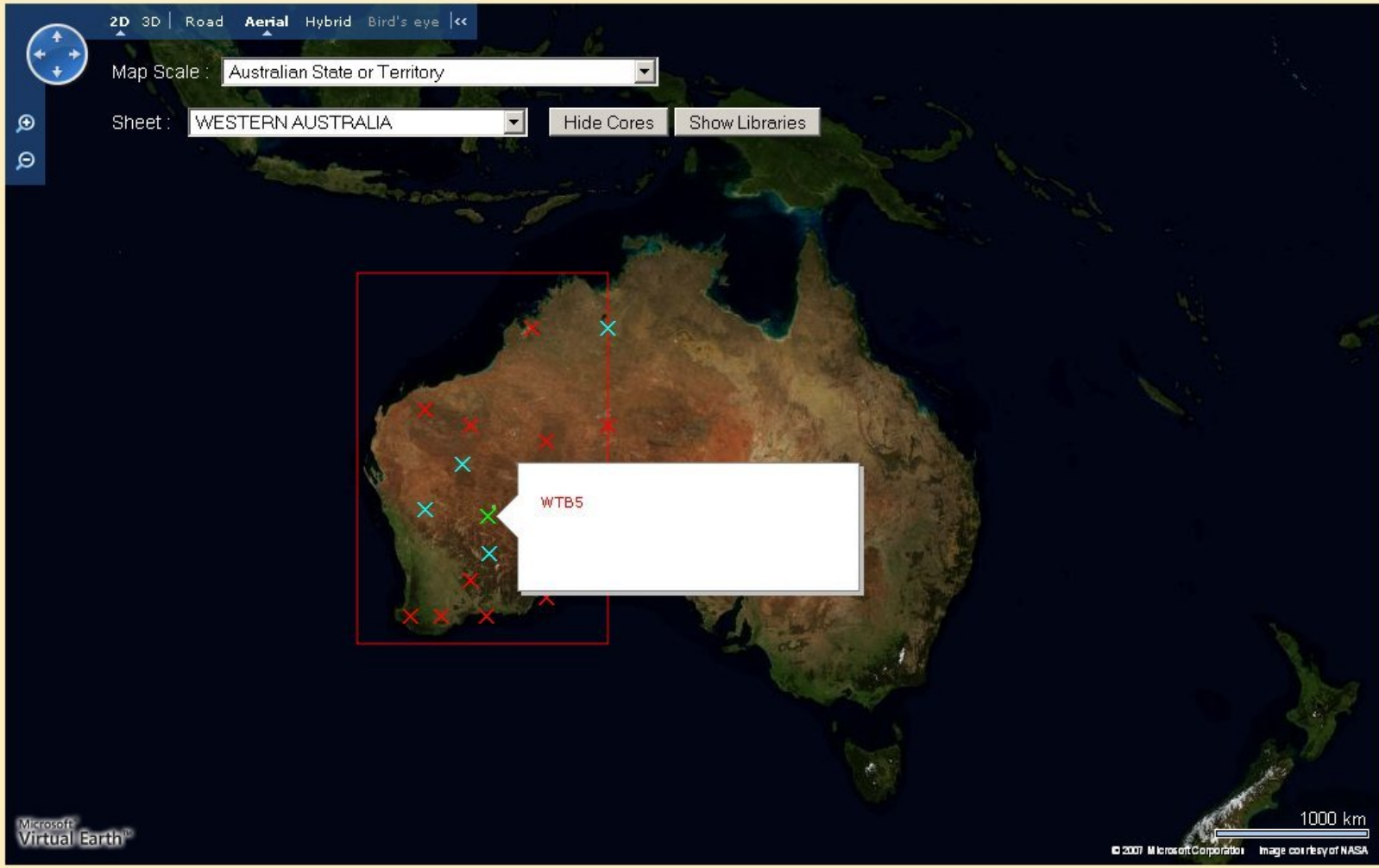
Demostrator (NVCL.CSIRO.au)



Auscope National Virtual Core Library Demonstrator

Login

- Home
  - Getting Started
  - Database info
  - Feedback blog
  - Data donors
  - Core libraries
  - Logger Locator
  - Algorithm Definitions
  - Sensor Definitions
  - NVCL Research
  - Links
  - Searching
    - Drill-hole
    - Map
    - Scalar
    - Report
    - Research Projects



Auscope National Virtual Core Library Demonstrator

Login

Selected hole = WTB5

- Home
  - Getting Started
  - Database info
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  - Links
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    - Drill-hole
    - Map
    - Scalar
    - Report
    - Research Projects
  - Hole : WTB5
    - Location
    - Scalars
    - TSA Results
    - tray 2
    - tray 3
    - tray 4
    - tray 5
    - tray 6
    - tray 7
    - tray 8
    - tray 10
    - tray 11
    - tray 12
    - tray 13

Drill-hole Details:

WTB5	
Hole name	WTB5
Project	Teutonic Bore
Owner	GSWA
Machine	HyLogger-1
Drilled date	
Scanned date	9/17/2004
DB entry date	5/17/2007
Depth	106.94m to 249.9m
Trays	19
Sections	150
Samples	21695
Latitude	28°24'50" S
Longitude	121°8'30" E
UTM	E : 317969.28 m N : 6855542.66 m Zone : 51 S WGS 84
RL	0
Azimuth	0
Inclination	0
Reports	upload new report view reports
Analyst	Jon Huntington

Mosaic

Trays increment left to right & top downwards. Click any individual tray for enlargement.

Auscope National Virtual Core Library Demonstrator

Login

Selected hole = WTB5

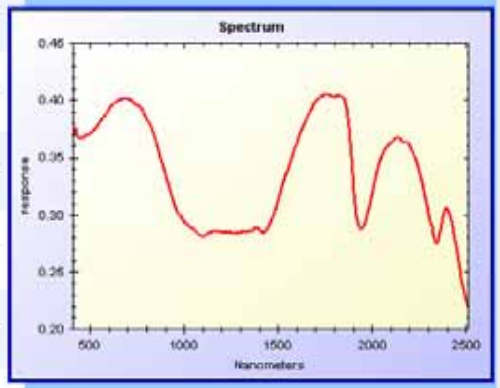
Section

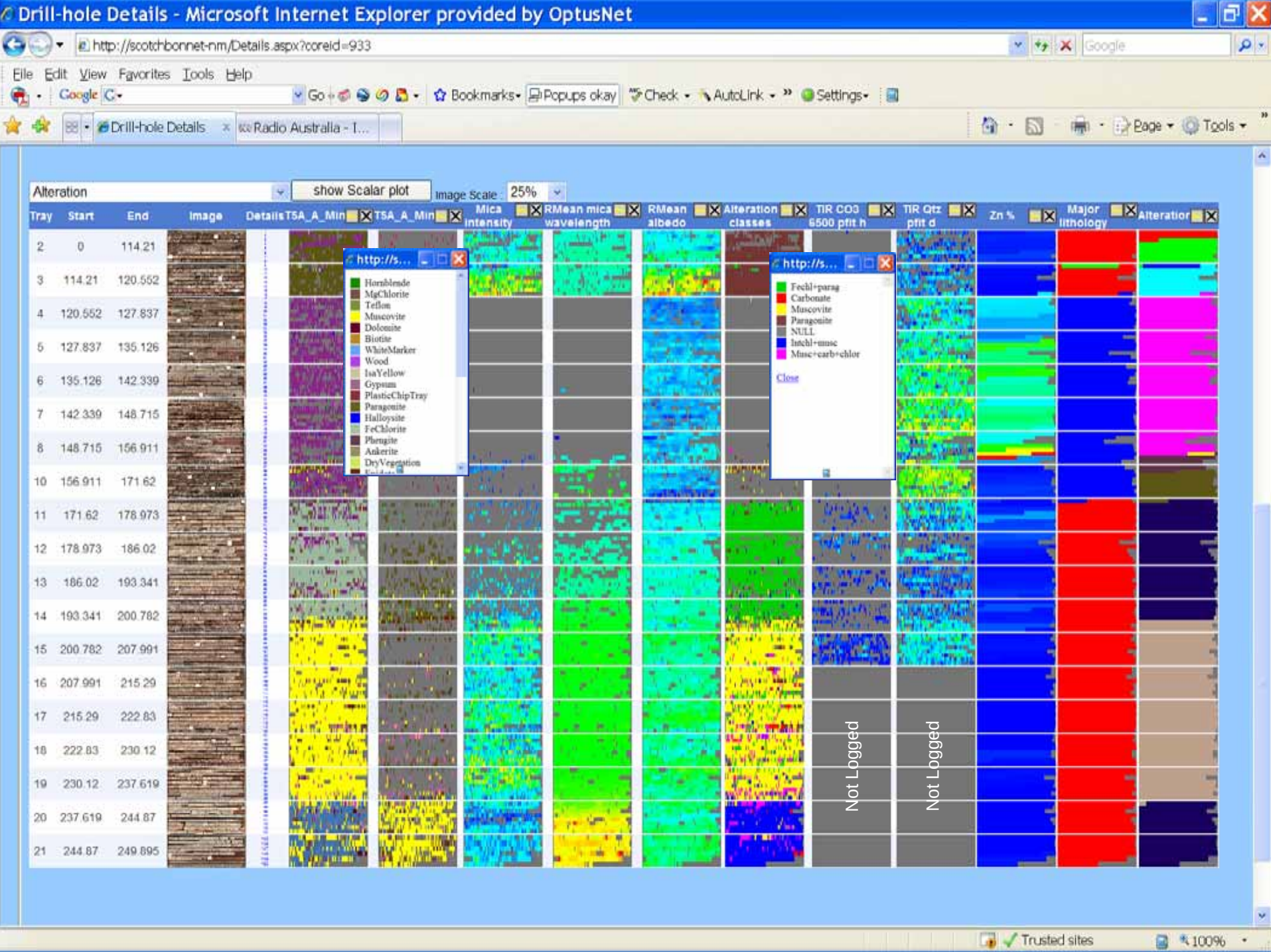
Show Spectra on mouse over Scalars TSA_A_Mineral1 Add Samples Per Page : 25 Image Scale : 75%

Show Spectral Image

Depth	Image	TSA_A_Mineral1
219.09		NULL
219.096		Muscovite
219.102		Muscovite
219.109		Muscovite
219.115		Muscovite
219.121		Muscovite
219.128		Muscovite
219.134		Muscovite
219.14		Muscovite
219.147		Muscovite
219.153		Muscovite
219.159		Muscovite
219.166		Muscovite

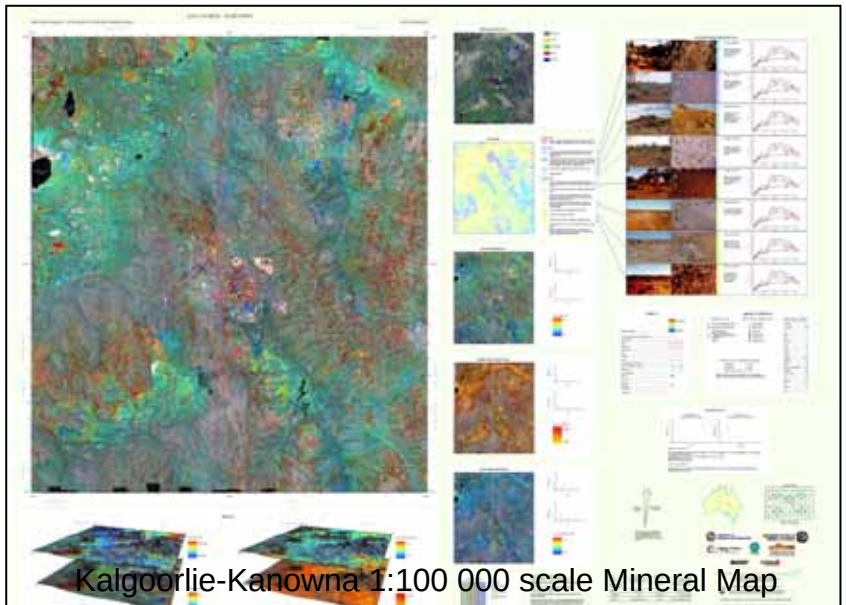
38.799	Carbonate
38.806	Carbonate
38.812	Carbonate
38.818	Carbonate
38.824	Carbonate
38.831	Carbonate
38.837	Carbonate
38.843	Carbonate
38.849	Carbonate
38.856	Carbonate
38.862	Carbonate
38.868	Carbonate
38.874	Carbonate
38.881	Carbonate
38.887	Carbonate



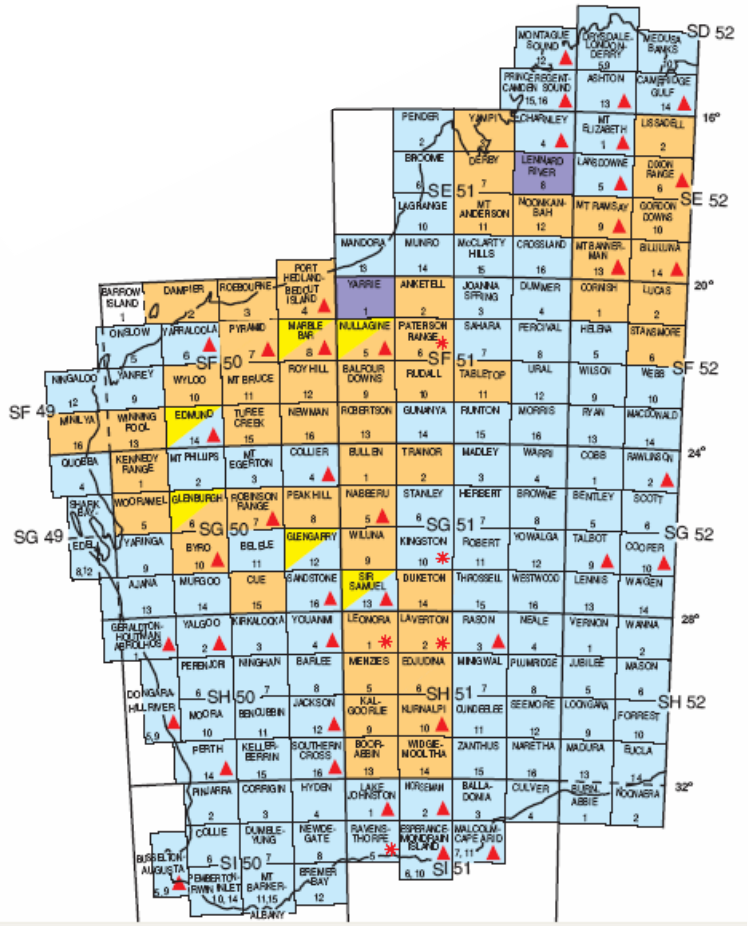

Drill-hole Details - Microsoft Internet Explorer provided by OptusNet
http://scotchbonnet-nm/Details.aspx?coreid=933
File Edit View Favorites Tools Help
Drill-hole Details
Radio Australia - T...
Alteration
show Scalar plot
Image Scale : 25%
Tray Start End Image Details T5A_A_Min T5A_A_Min Mica intensity RMean mica wavelength RMean albedo Alteration classes TIR CO3 6500 pfit h TIR Qtz pfit d Zn % Major lithology Alteration
2 0 114.21
3 114.21 120.552
4 120.552 127.837
5 127.837 135.126
6 135.126 142.339
7 142.339 148.715
8 148.715 156.911
10 156.911 171.62
11 171.62 178.973
12 178.973 186.02
13 186.02 193.341
14 193.341 200.782
15 200.782 207.991
16 207.991 215.29
17 215.29 222.83
18 222.83 230.12
19 230.12 237.619
20 237.619 244.87
21 244.87 249.895
http://s...
Hornblende
MgChlorite
Teflon
Muscovite
Dolomite
Biotite
WhiteMarker
Wood
IsaYellow
Gypsum
PlasticChipTray
Paragonite
Halloysite
FeChlorite
Phengite
Ankerite
DryVegetation
http://s...
Fechl+parag
Carbonate
Muscovite
Paragonite
NULL
Inchl+musc
Musc+carb+chlor
Close
Not Logged
Not Logged
Trusted sites
100%

Mineral Map of Australia

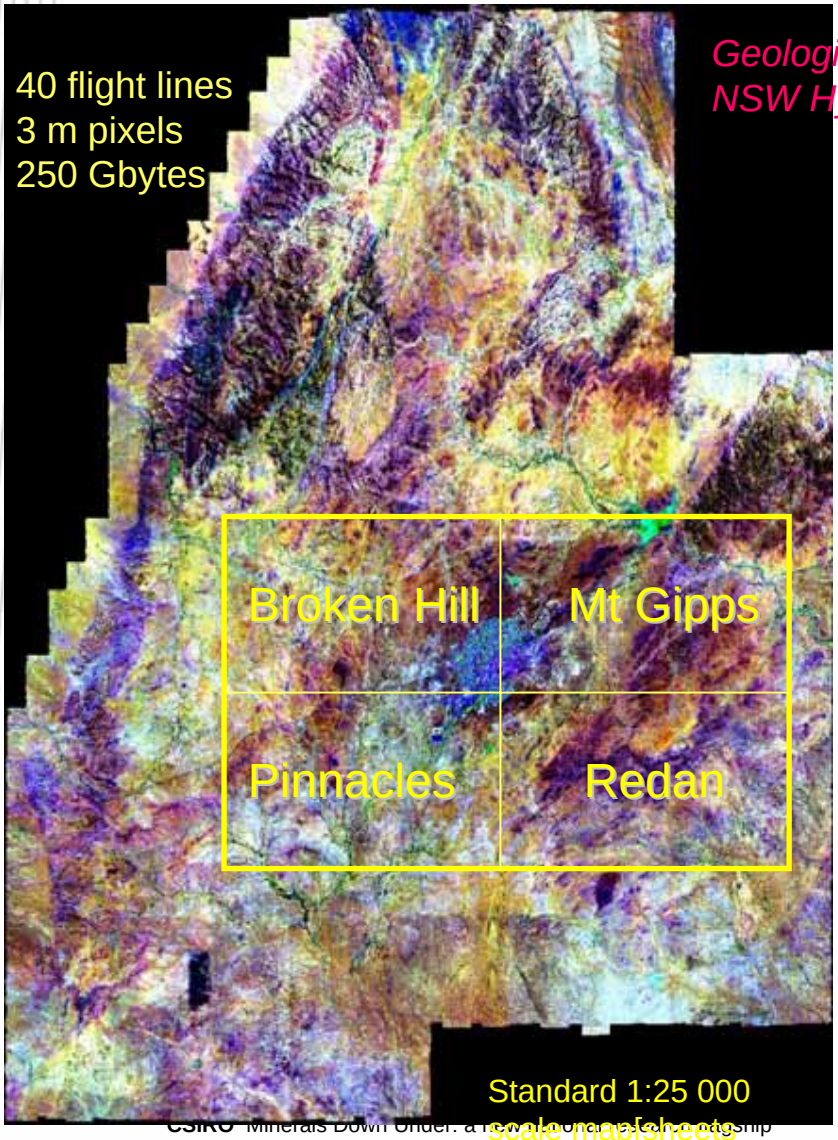
- **“Next Generation Mineral Mapping Initiative”**
- “Big Footprints” alteration
- Over 150 1:250 000 scale mapsheets covering brownfields and greenfields exploration areas across Western Australia alone.
- With current available airborne capabilities it would take >30 years to generate an Australian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

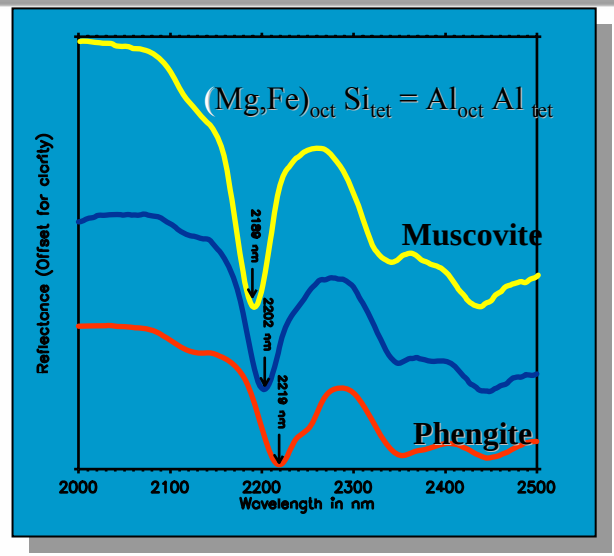


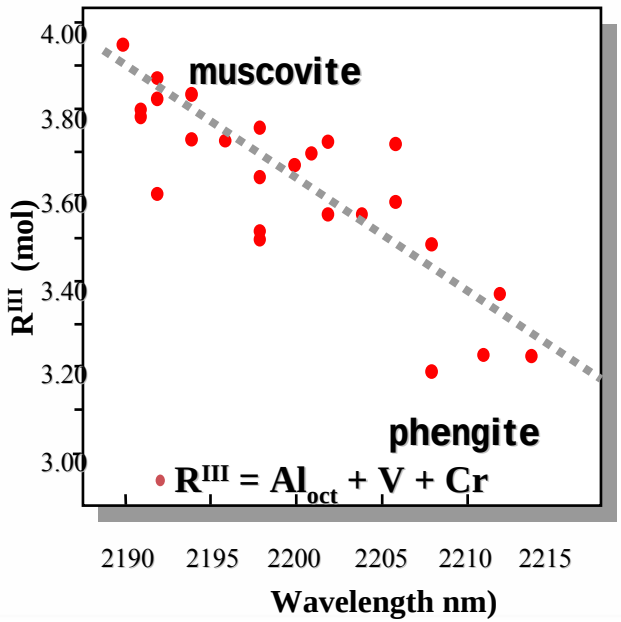
Kalgoorlie-Kanowna 1:100 000 scale Mineral Map



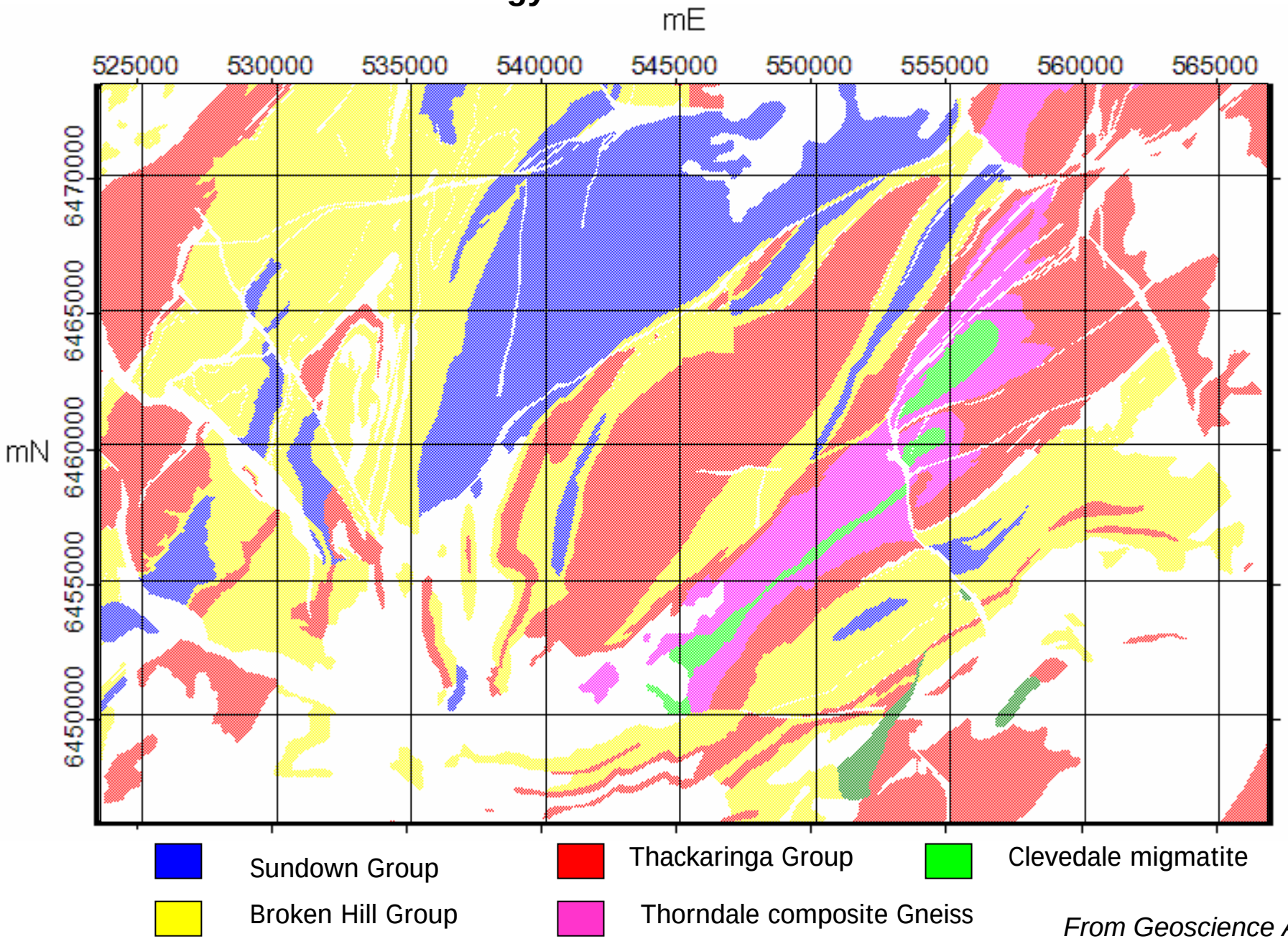
“Regional” Retrograde Alteration : Broken Hill *(HyMap)*





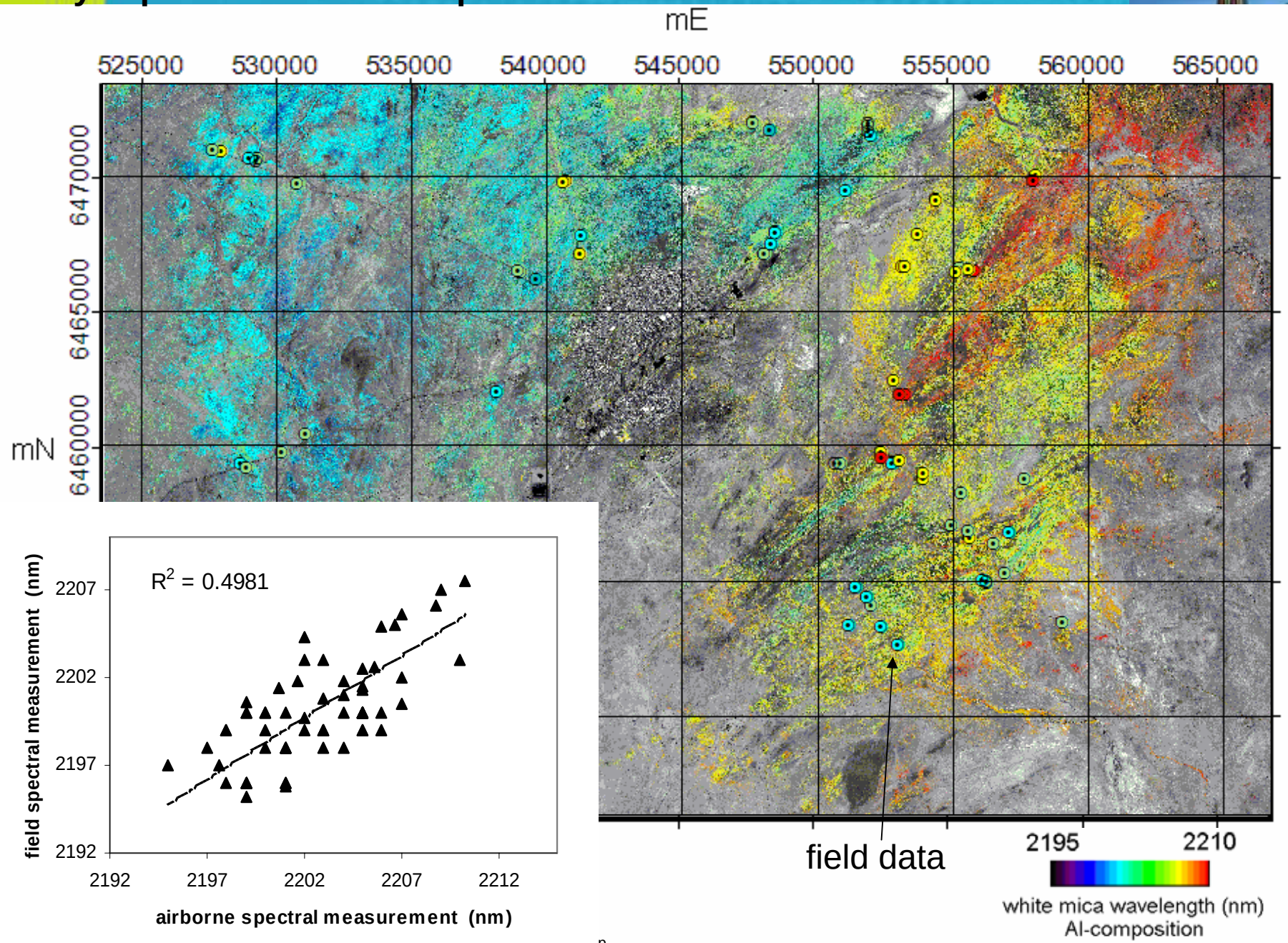


Broken Hill Published Geology



From Geoscience Austra

HyMap : White Mica Composition



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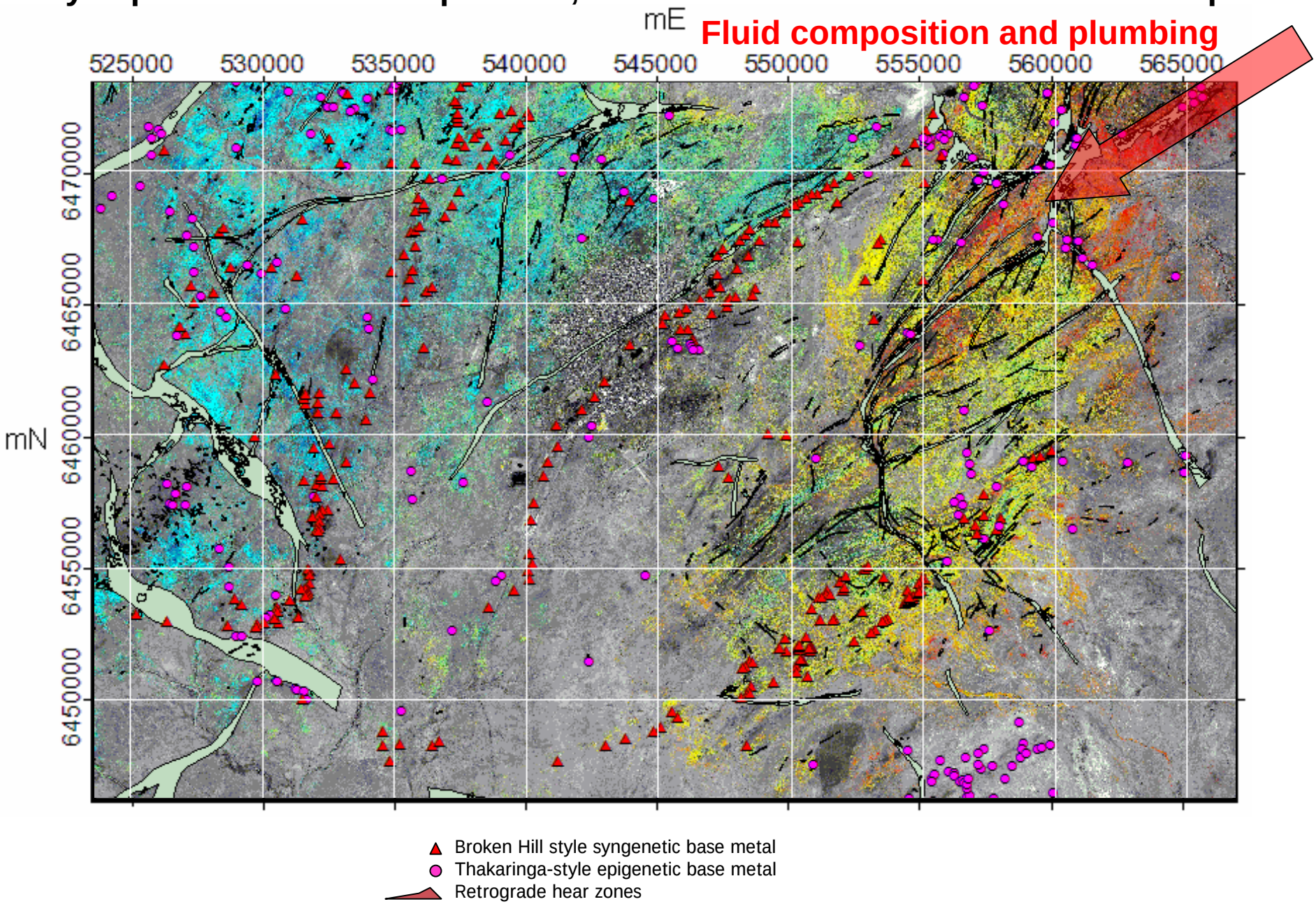
HyMap : White Mica Composition, Published Shear Zones and Mineral Deposits

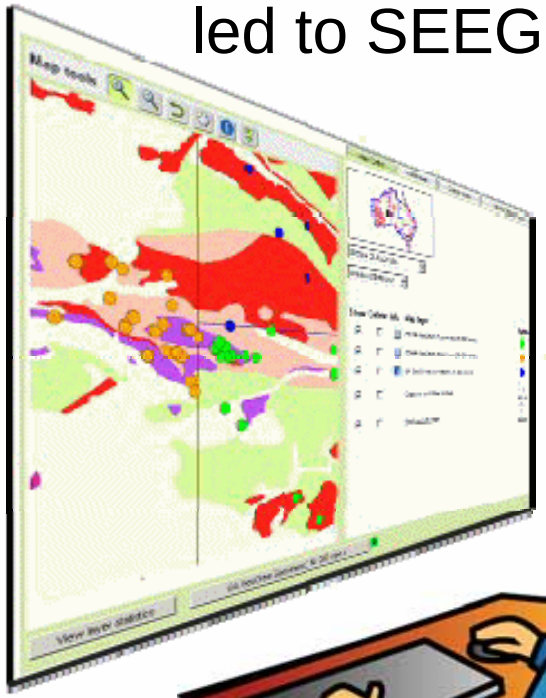


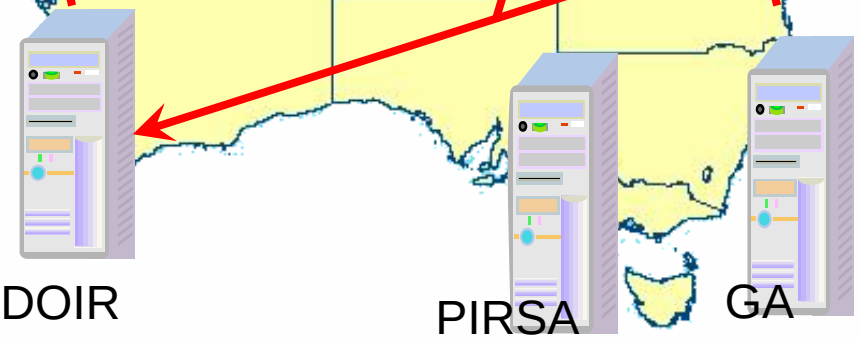
Interoperability

Web Feature Services (OGC)

Drive for interoperability has led to SEEGrid

XML - GML\XMML





DOIR

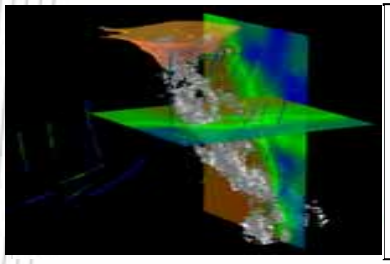
PIRSA

GA

Slides courtesy Stuart Girvan - Geoscience Australia

Discovery

THEME 1 Discovering Australia's Mineral Resources
STREAM 1.3 3D Mapping Technologies



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

Developing advanced geophysical tools and enabling technologies for 3D interpretation

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

Capability Growth

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

Present Partners

Auscope, pmd*CRC, CRCLEME, DSTO

Prospective Partners

Intrepid Geophysics, BRGM, Australian universities, UBC, State & Territory Geological Surveys

Deliverables

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

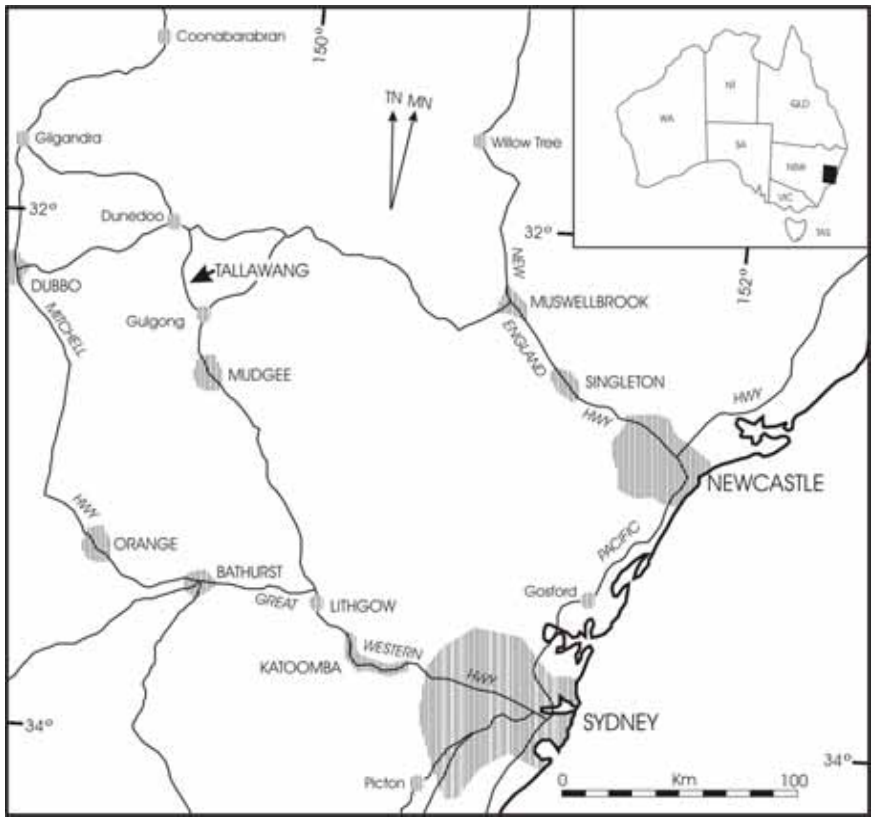
Computer Aided Geological Interpretation (CAGI)

- **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

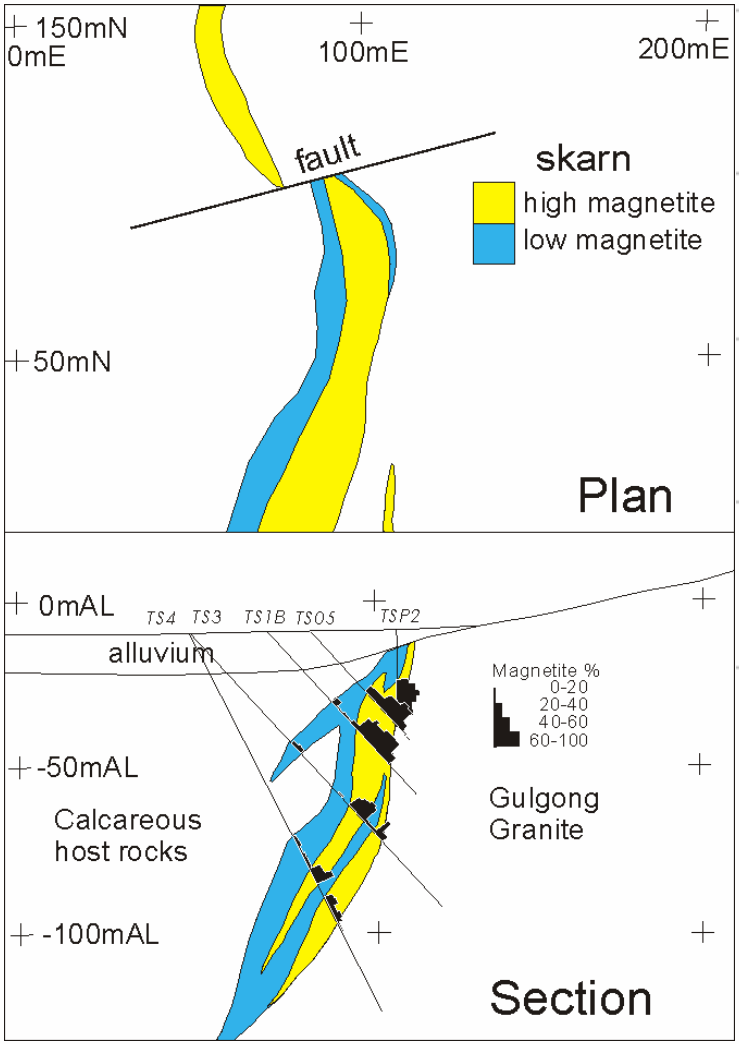
- **Current Applications in land EM and airborne Magnetics**
- **Potential applications in down hole sensors**

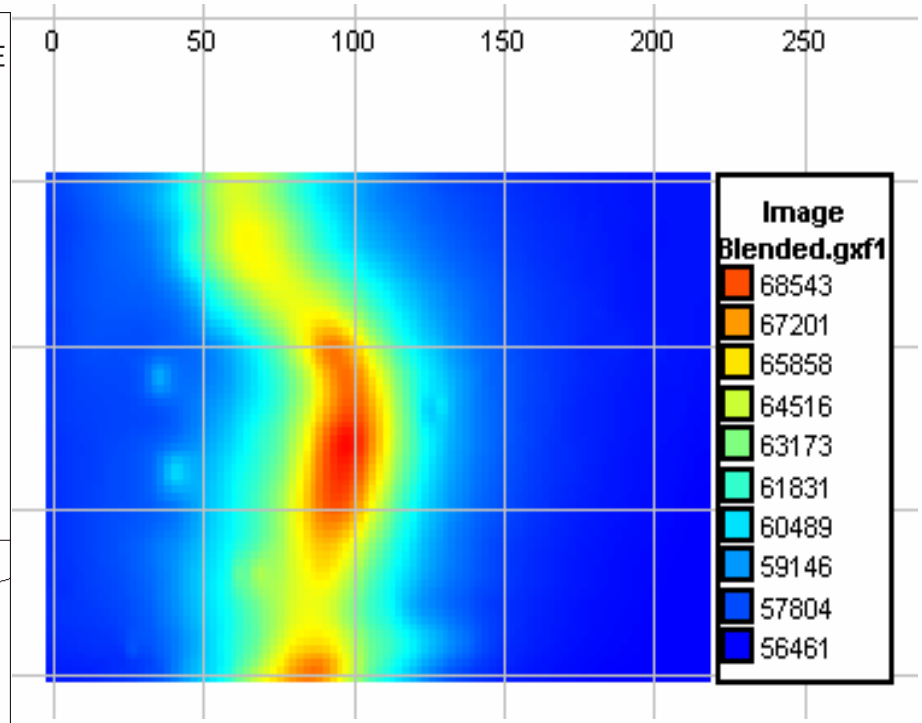
Tallawang magnetite mine



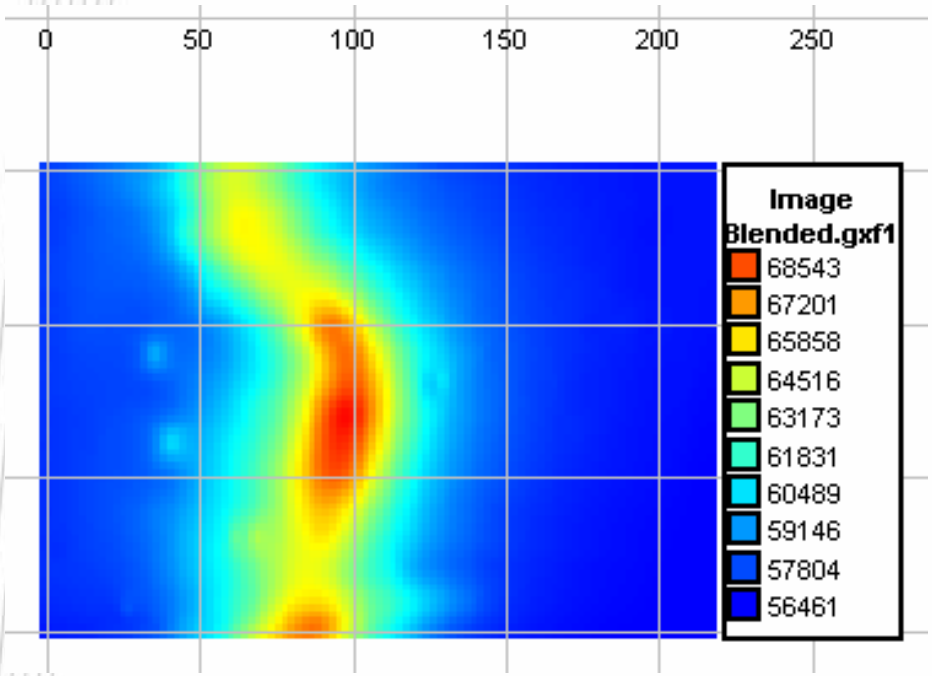
Location, plan and section showing Drill hole intersections

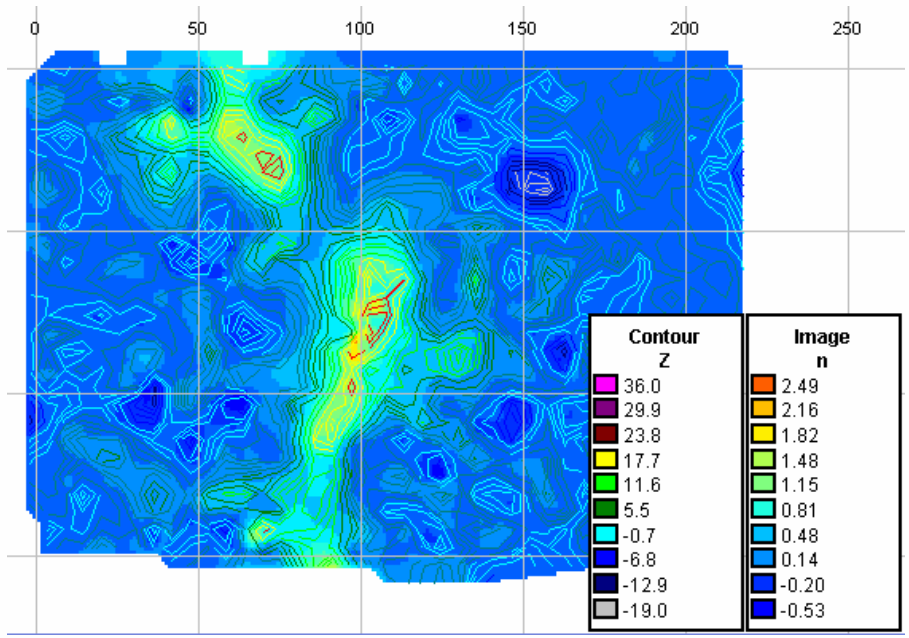
Plan and section with total magnetic intensity map





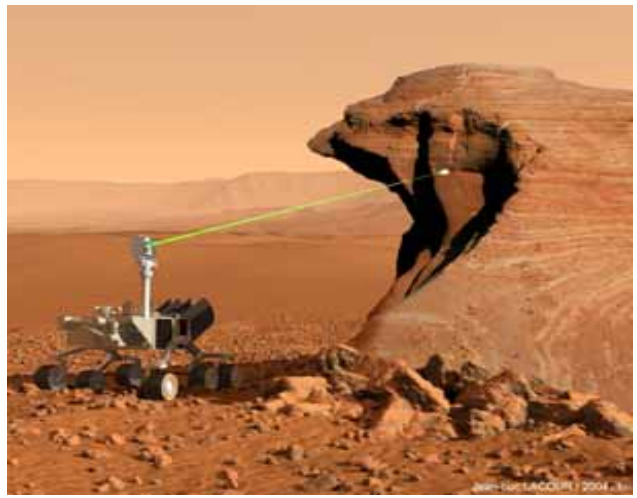
TMI vs tensor deconvolution (performed on the TMI)





The Concept of Additional Value From Drilling

- **Enhanced automated core logging:**
  - Full Mineralogy
  - Geochemistry – XRF, LIBS, NAA
  - Petrophyscal Properties
  - Structure
  - Geometallurgical Information
- **Strategies for using chips**
- **Strategies for down hole**
- **Strategies for measurement while drilling**



Proposed New CRC “Deep Exploration Technologies”

AMIRA INTERNATIONAL

Proposal

Confidential

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

August 2007

AMIRA International
CSIRO Exploration and Mining

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Level 2 271 William St Melbourne VIC 3000 Australia Phone: +61 3 8636 9000 Facsimile: +61 3 8636 9999

Possible Mission and Goals of the New CRC

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

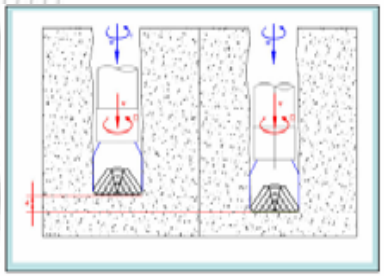
Focus to be defined by industry

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

Future Mine

THEME 2 Transforming the Future Mine
STREAM 2.1 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

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

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

Present Partners

Nat. Inst. Adv. Industrial Sci. & Tech. - Japan

Prospective Partners

Strategic partnering with AMIRA, industry (drilling manufacturers and mining houses), academia (Curtin University) and other research organisations

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