Session Four

Chair: Paul Dale

3:30 MinEx CRC - a collaboration between surveys, industry and research organisations
Andrew Bailey, MinEx CRC

3:55 Australia’s decadal plan for geoscience and what it means for industry
Steve Beresford, Independence Group

4:20 Supporting Australian exploration industry research impact through AuScope
investment in the downward looking telescope
Tim Rawling, AuScope

4:45 Panel discussion

5:15 Close

5:30 Bus departs for Exploration Managers Conference (Rothbury)
MinEx CRC Overview

Andrew Bailey
Chief Executive Officer
MinEx CRC
A future for exploration or mining?

“Stop mining the earth altogether.”

Apple promises to stop mining the earth, build all products from recycled materials (April, 2017)
A future for mining?

Apple promises to stop mining the earth, build all products from recycled materials (April, 2017)
A future for exploration or mining?

“Stop mining the earth altogether.”

- There is about 340g/t gold in phones
- Can process 1.2 million units pa, but with 1 billion iPhones made to date

Source: Apple
It’s not as simple as that...
Electric Cars: more complicated

Car body and chassis made from strengthened steel and aluminium alloys

- Fe (Iron)
- Mn (Manganese)
- V (Vanadium)
- Mo (Molybdenum)
- Al (Aluminium)
- Mg (Magnesium)

EV batteries

- Li (Lithium)
- Co (Cobalt)
- Ni (Nickel)
- C (Carbon)

Magnets in EV motors

- Dy (Dysprosium)
- Nd (Neodymium)

Source: Minerals Council of Australia, Australian Mining, 30 Things
Copper in Electric Vehicles

Source: Copper.org
Global Cu Production

increasing at ~3.2% pa
doubling every ~22 years

produced as much copper 1995-2016 as in prior history

Source: US Geological Survey (1900-2016)
Prospective rocks continue under cover

..and where to find it

Outcrop and geophysical images
We have only explored the exposed provinces.

Open file drilling
Coloured for proximity to nearest neighbour
Where we drill we discover

Drilling under cover required

Known mineral deposits
By size and commodity
Cooperative Research
Broad base, significant size

36 Participants contributing:

- $41M cash
- $49M non-staff in-kind
- 311 FTE ($78M equivalent)
- $50.0M CRC Program funding
10-Year Goals

- Australia re-established as the preferred destination for mineral exploration investment, resulting in discoveries
- METS sector thriving taking uncover exploration tools and techniques to the world
- Next generation of professionals and drilling experts trained
Industry Led Agenda

• More efficient drilling technologies to drill more holes
• Safety and environmental factors
• Collect and interrogate data while drilling to inform decisions
• Drilling deployments to optimise technologies and uncover new mineral provinces through National Drilling Initiative (NDI)
• Training and Education vital
Majors, METS and Survey Participants (16)
Programs and Projects

Program 1: Drilling Technologies
  - P 1: Drilling Optimisation
  - P 2: Coiled Tubing Drilling for Definition of Mineral Deposits

Program 2: Data from Drilling
  - P 3: Real-time Downhole Assay
  - P 4: Petrophysical Logging While Drilling (LWD)
  - P 5: Seismic in the Drilling Workflow
  - P 6: Automated 3D Modelling

Program 3: National Drilling Initiative
  - P 7: Maximising the Value of Data and Drilling Through Cover
  - P 8: Geological Architecture and Evolution
  - P 9: Targeting Mineral Systems in Covered Terranes

Mining/METS Companies

Education and Training Program

Opportunity Fund

Geological Surveys
Conclusions

- Demand and range of minerals required increasing
- Mining is required - Exploration is required – Surveys are required
- Exploration under cover is required in Australia
- Exploration innovation requires a cooperative approach and sustained but directed research
**Structure**

- **MinEx CRC Board**
  - **Science Advisory Committee**
    - Program 1
      - Participants
        - 1
        - 2
    - Program 2
      - Participants
        - 3
        - 4
        - 5
        - 6
    - Program 3
      - Participants
        - 7
        - 8
        - 9
  - **Executive Management Committee**
  - **Program Review Panel (PRP)**
  - **Australian Government Participants**
  - **Education and Training**
Program 1: Drilling Technologies
Program Leader: Soren Soe (UniSA)

Project 1: Drilling Optimisation and Automation
Project Leader: Masood Mostofi (Curtin)

To improve average drilling performance of rotary and percussive drilling by 50% using real-time and post-mortem optimization and drilling automation by increasing productivity and consistency.

Focused on tackling the barriers of drilling optimization and automation by:
(a) engineering modelling of various processes involved in drilling operation,
(b) systematic and reliable recording of drilling data, used for optimization,
(c) developing engineering algorithms that can be used for optimization of the drilling operation and autonomous analysis of drilling data, and,
(d) developing a modular autonomous optimization system that can pave the way towards complete automation.
Program 1: Drilling Technologies
Program Leader: Soren Soe (UniSA)

Project 2: Coiled Tubing Drilling for definition of Mineral Deposits
Project Leader: Soren Soe (UniSA)

To improve the sample integrity of CT drilling to that of diamond drilling, then develop the ability to drill multiple deviated holes, up to 1000 m reach, from a single pad, to within 10 m of target and surveyed within 1 m, whilst maintaining the cost, rapidity, safety and environmental benefits of a greenfield CT rig.
Project 3: Real-time Downhole Assay
Project Leader: Yulia Uvarova (CSIRO)

A real-time downhole quantitative analytical technique that provides a broad suite of chemical elements for targeting in greenfield environments at detection limits that allow robust and reliable real-time decisions, including a downhole sensor for Au assay whilst drilling and enable reliable decisions without further analytical work.

CSIRO has previously identified laser-induced breakdown spectroscopy (LIBS) as a potential candidate. LIBS requires little to no sample preparation and has high potential to deliver elemental concentrations in real-time measurements downhole, but the challenge is to adapt this technique to measurements on a moving, uneven, and wet surface.
Program 2: Data from Drilling
Program Leader: Yulia Uvarova (CSIRO)

Project 4: Petrophysical Logging While Drilling (LWD)
Project Leader: Brett Harris (Curtin)

Achieve real time subsurface sensing during CT drilling to depths of 1000m and to provide real time imaging to assist geo-steering to within 30 m of a lithological target.

New LWD sensors and real time subsurface reconstruction algorithms will be designed to integrate within exploration or mining workflows. This research has two linked components; (i) development of new sensors for real time multi-parameter logging while drilling with a Coil Tubing drill rig and (ii) automatic subsurface reconstruction for steering based on geophysical sensing while drilling.
Program 2: Data from Drilling

Program Leader: Yulia Uvarova (CSIRO)

Project 5: Seismic in the Drilling Workflow
Project Leader: Andrej Bona (Curtin)

Aims are for a:

• Reduction of borehole seismic survey costs by 50% from current.
• Reduction of need for brownfields exploration drilling by 50% due to application of seismic methods.

Seismic sensor technologies are aimed to be deployed in boreholes, underground workings and on the surface, to deliver data for continuous updating of a subsurface geological model.
Program 2: Data from Drilling

Program Leader: Yulia Uvarova (CSIRO)

Project 6: Automated 3D Modelling
Project Leader: Mark Jessell (UWA)

Diverse geological data - collected from drilling, from surface exposure, or derived from geophysical data – are to be incorporated into probabilistic 3D models within 1 week of data being available in appropriately formatted and accessible databases.

The models will be explicitly designed to deal with uncertainty and facilitate exploration and resource development decisions, rather than portray one or more geological models of “subjective reality”.
Program 3: National Drilling Initiative

Program Leader: TBC

Project 7: Maximising the Value of Data and Drilling Through Cover
Project Leader: Simon Van Der Wielen (Geoscience Australia)

To develop software solutions that will maximize the value of NDI data by:
1. Delivering the tools and data infrastructure to facilitate upload and management of legacy data and NDI drilling data and information, delivered to stakeholders, researchers and the wider geoscience community.
2. Develop and incorporate advanced geospatial data analytics so that the maximum amount of geoscientific information can be extracted from legacy data.
3. Maximise the efficiency and value of drilling for optimising drill program design and providing drill target rankings relative to end-user defined questions.
Program 3: National Drilling Initiative
Program Leader: TBC

Project 8: Geological Architecture and Evolution
Project Leader: Alan Collins (UoA)

To provide new geoscience data and knowledge of the geology in NDI case study regions via integration of geophysics and petrophysics, regolith and hydrogeology, alteration signatures, basin analysis, and igneous and metamorphic analysis.

These new geoscience data and knowledge are aimed to inform the 3D geology and 4D geological evolution of the case study areas and aid in the identification of known and potential mineral systems within.
Program 3: National Drilling Initiative

Program Leader: TBC

Project 9: Targeting Mineral Systems in Covered Terranes
Project Leader: Alex Otto (CSIRO)

• To create a new generation of multi-scale exploration targeting models for selected mineral systems within the NDI case study areas, that represent and quantify the geological characteristics of each mineral system type.
• To integrate temporal and spatial geoscientific data for specified regions with existing understanding of mineral systems to create maps of mineral potential.
• To provide advice on the most valuable data types, sampling media and sampling densities to map footprints of relevant mineral systems.
• To test and refine exploration targeting models and mineral potential maps by utilizing MinEx CRC drilling technology and research.
AIM: To

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Program 3: National Drilling Initiative
Program Leader: TBC

P 7: Maximising the Value of Data and Drilling Through Cover
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P 9: Targeting Mineral Systems in Covered Terranes
Project Leader: Alex Otto (CSIRO)

Education and Training Program

Opportunity Fund
Australia’s decadal plan for Geoscience: what it means for industry

decadal Plan for Australian Geoscience 2018-2027
Science fiction as an expression of the future of exploration

Portable detection – Star Trek

Direct imagery - Avatar
What can we learn from our past?

We must not forget the lessons we have already learnt

The CRAESTAR

www.explorationradio.com

Available on iTunes
What is this document?
Who are the Australian Academy of Science?

Supports science in discipline areas through national committees including:

- **National Committee for Earth Sciences (NCES)**

**International engagement**
- International Union for Quaternary Research (IUQR)
- International Union for Geodesy and Geophysics (IUGG)
- International Union for Geological Sciences (IUGS)

**National engagement**
- University, Government and Industry Earth Scientists

[www.science.org.au](http://www.science.org.au)
Our National initiatives

1. **UNCOVER** + AMIRA UNDERCOVER Roadmap

2. Infrastructure Reviews and strategy
   - NCRIS AuScope future strategy
   - Chief Scientist national infrastructure review

3. NCES Decadal Plan
Decadal Plan - purpose

This document is intended to inform:

- the Australian Government,
- government and funding agencies
- supporting education and research relevant to the geosciences,
- other stakeholders—
  - geoscientists,
  - universities, education institutions,
  - professional associations,
  - industry
  - associated peak bodies.
What did the last Strategic Plan do?

‘Geoscience – unearthing our future’

• Blue water research ship: RV Investigator
• Continent-wide transects (e.g. reflection seismic)
• NCRIS AuScope funding
• UNCOVER initiative

• > $500m extra funding to Earth Sciences through implementation
Decadal Plan in a nutshell

Evolution from the reductionist approach of last century to

a complex system science approach

Integration across sub-discipline boundaries in a digitalised environment
A decade of transition
The state of our Planet

Next decade will be a critical period in human history as we continue to place the planet under increasing pressure

New understanding of, and innovative approaches to, sustainability
Overarching challenge to develop accurate **predictive power** about:

- **how** our planet will behave,
- how it will respond to our actions, and
- **where** to explore for critical resources.
Decadal Plan process

Financial support from:
- GA and State Surveys
- ~10 Australian Earth Science university departments
- IAG, GSA
- ARC
- Australian Academy of Science

Online Survey
Town hall presentations
Exposure Draft circulated 9/2017 for comments
Who have we talked to?

- On-line survey (575)
- Committee is cross section across earth sciences
- Solicited comments

### Employment Type

- Education/Teaching
- Academia
- Government research body
- Geological Survey
- Other research
- Minerals industry
- Coal
- Oil and gas
- Engineering and...
- Environment

### Career Stage

- Early
- Mid
- Late
- Other
We asked you for your opinion on past innovation in the Earth Sciences?

We have a proud history BUT we are asking for more
Grand Challenges

Australia’s Evolution: the deep interior and deep time
The Earth Science downward-looking telescope

Real-time dynamism of Earth’s crust
Earth today: neotectonics and surface stress states - earthquake prediction; current processes; sedimentary basin resources; real time monitoring; satellite and remote sensing

Earth history contained within the geological record
How has life on Earth driven/impacted upon the planet’s evolution?
How has Earth’s climate changed through time and how best can we predict and plan for the impacts of our own actions upon the planet?

Transforming Earth Science
A bigger picture view: developing whole-Earth capabilities
Investing in education and training

Advocacy: engaging the community at all levels
Over the past decade instruments, methodologies and techniques have been developed to image and determine the composition of crust and mantle materials at the atomic to micro-scale. ‘Learn the macro from the micro’
The Mineral Exploration burning platform

- Australia’s share of resources will dwindle
- Easy deposits already found
- Need new exploration methods and predictive framework for ore systems.
- Giant deposits needed

Minerals + oil/gas = 75% of Australia’s foreign exchange earnings
UNCOVER has permeated Australian geoscience

**Scale Reduction Goals**

<table>
<thead>
<tr>
<th>Theme</th>
<th>Terrane to Regional</th>
<th>Regional to Camp</th>
<th>Camp to Deposit</th>
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</thead>
<tbody>
<tr>
<td>Characterising the Cover</td>
<td></td>
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<tr>
<td>Whole lithospheric architecture</td>
<td></td>
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<tr>
<td>4D Geodynamic evolution and metallogenesis</td>
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<tr>
<td>Distal mineral footprints</td>
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<tr>
<td>Risk/reward for covered economic resources</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Research education and training</td>
<td></td>
<td></td>
<td>Research, education and training is an underpinning and high priority focus area. As it maps across all scales it was not mapped in the Scale Dependency Matrix</td>
</tr>
</tbody>
</table>
Roadmap – Stage 1 Results
Dependency Mapping

AMIRA Road map
Rowe et al 2017
The federal and state survey response to the plan has been impressive.
Where are you on the adoption curve?

...and who/what are you waiting for
What roadblocks are in our way?

More expertise in physics, maths!

3. Find $x$.

Here it is

Education
Training
New types of exploration scientist
We **MUST** cross disciplines. All search sciences have a lot in common.

Rare objects are hard to find and easy to overlook.

**Search space**

**Bayes Law**

**Prediction**

**Base rate**

Wolfe et al 2005

We are/will employ non geology scientists
We can learn from other sciences and industries?

At present we can’t predict or image melanoma early enough

The biological system is at present too complex

The footprint is too restricted

Come at the problem from both ends

We cant just talk to ourselves
We over simplify the ‘analogous’ petroleum transition

**Evolution of ‘3D Seismic’**

- Five Supporting Innovations Build to One Radical Outcome

- 3D seismic took 20 years to impact
- Required the development of sequence stratigraphy
- Two orders of magnitude cost reduction which came from adopters
- Hindsight bias paints an easier picture

Exploration Geoscience includes fundamental science
What does it mean for industry?

• Geologists will become better (and need to)
• Augmentation of your skills (not replacement)
• Interpretation (integration) skills
• Automation of ‘manual’ tasks WILL occur
• All this will happen faster than we think

• We will interpret ‘hidden data’
• We will change sampling strategies
• Exploration Geoscience will grow (separately from Economic Geology)
- Companion document online contains more detail
- Committee and direct contributors listed in printed and online Plan

Supporting Australian exploration industry research impact through AuScope investment in the downward looking telescope

Tim Rawling, AuScope CEO
Australian context

- Old, cold and cratonised
- Search space is becoming mature and exploration is being forced deeper and under transported cover
Australian context

- Large, fast moving plate
- Complex active plate boundaries and geoid geometries
- Highly stressed crust (mostly in compression) and underestimated seismic hazard
- AuScope was established in 2006 to implement an Earth and Geospatial science infrastructure program
- National Collaborative Research Infrastructure Strategy (NCRIS) Program – “Structure and Evolution of the Australian Continent”
- Education Investment Fund (EIF) Program – AGOS
- $110M Commonwealth investment and $17M cash & $154M in-kind co-investment from partners
– AuScope’s purpose is:
– To create widely available access to earth and geospatial science research infrastructure (equipment, data and analytics) to drive front edge Australian scientific research and support scientific investigations in government and industry.
Geodesy
Earth Imaging
Composition & Evolution
Subsurface Observatory
Materials & Properties

National Geospatial Reference Framework
AuScope National Geo Transect Program

AuScope Grid Storage Management Access Interoperability → AuScope Simulator Modelling, Data, Inversion → Earth Model

Industry Portal
Research Portal
Policy Portal
Education Portal
Infrastructure Programs
The AuScope Geospatial Program is responsible for the acquisition and deployment of VLBI telescopes, GNSS sites, absolute gravity measurement, GPS calibration robots and satellite laser ranging sites throughout Australia.

Provides data that underpins Australia’s dynamic geodetic framework in which to observe movement, change and deformation in the Australian Plate.
The AuScope **Earth Imaging** program works with partners at Geoscience Australia and State GSO's to support the deployment of the AusArray Passive Seismic and AusLAMP MT Arrays in addition to the management of an OBS research fleet and supporting the national reflection seismic transect program.
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Earth Imaging - Magnetotellurics

- Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) program
- Collaboration between University of Adelaide, GA and AuScope
- National long-period MT data at approximately 2800 sites across Australia to map the electrical conductivity of the continent in three dimensions
Earth Imaging - Magnetotellurics

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Materials and Properties
The AuScope National Virtual Core Library facilitates the collection, storage and discovery of high quality, semi-quantitative hyperspectral mineralogical data from drill core collected across the Australian Continent.

Each year around $600 million is spent on drilling in Australia but too often the core is only partially logged and then discarded. This program addresses this massive underutilisation of that potential resource for the benefit of Australian Researchers.

Collaboration with MinEX CRC National Drilling Initiative (NDI)
The AuScope Earth Composition and Evolution component provides operational support for a world-class suite of analytical infrastructure.

- Facilities at Curtin, Macquarie and Melbourne Universities.
- National Geochemistry Network
- This system provides Australian Earth Scientists with critical geochronological and geochemical data necessary to understand the formation mechanisms and geological evolution of the Australian continent.
Paradigm change for NGN

- Analytical innovation is producing multi-dimensional data sets at higher rates and in greater volumes (e.g., Split-stream LA-ICP-MS/MC-ICP-MS; U-Th/Pb + Hf + 32 elements - 30X more productive than ion probe); Geoscience Atom Probe with 250 million atoms!)
- ARC grant applications require data management, storage, access and re-use plans (descriptive now, prescriptive later). Australian governments taking a greater interest in creating open data environments for publicly-funded data.
- Federal and state geological surveys interested in creating nationally significant isotope geochemistry maps.
- Structural transition from scholarly metrics based on citing of publications to citing of publications and/or data (DataCite.org).
- Need to improve performance in converting data to publication (estimated that only 15-30% of data generated makes publication).
IGSN and LIMS

- IGSN is a unique alphanumeric code assigned to specimens and related sampling features to ensure their unique identification.
- GA, CSIRO and Curtin/AuScope
IGSN is a unique alphanumeric code assigned to specimens and related sampling features to ensure their unique identification.

IGSN and LIMS

Curtin University

Researcher

Sample & analysis metadata

Analysis data

Instruments

Analysis data & metadata

Analysis metadata with IGSN

RDA

DOI request

Cite My Data

Data & metadata storage

DOI

AuScope Portal

OGC compliant data

Analysis metadata with IGSN & DOI

Standardised data

AuScope

Research Community

IGSN International

Virtual Geochemistry Lab

Researchers, industry, public

Sample metadata

Processed data

Analysis data

IGSN

Analysis data & metadata

AuScope

Sample & analysis metadata

Analysis data
The Simulation Analysis and Modelling or SAM program delivers a digital toolkit for 3D and 4D modelling, simulation analysis and data mining for Australian Geoscientists.

New data assimilation workflows ensure these models are constrained by observational data collected using other AuScope research infrastructure.
– The AuScope Portal, the Virtual Geophysical Laboratory and the new Data Enhanced Virtual Laboratory provide access to data collected or generated by the AuScope National Infrastructure or in collaboration partner organisations.

– This data is freely accessible, findable and interoperable. New development related to the DEVL program will endure all data meets the requirements of the FAIR principles.

– “Data lakes” and E2SIP
Virtual Laboratories

- Initially just linking data to computation
- VLs now instrumental in orchestrating workflows
- Scientific Software Solution Centre (SSSC) provides a registry for workflows that can be human and machine discoverable and more importantly executable on the fly
- Collaboration
AuScope Data Enhanced Virtual Research Environment

Acquisition
- Satellite Data (INSAR + Hyper)
- Airborne Data (Mag, Rad, AEM)
- Field observation data (Geology)
- Borehole Data (NVCL)
- Field Instrument data (MT, Passive Seismic)
- Laboratory Instrument data (Geochem, Geochron)

Data Access
- Government Data Portals (ga.gov.au data.gov., Nat Map)
- Industry Data Portals (AusGIN, NOPIMS)

Tools/Tool Boxes
- Research Data, Tools & Workflow Portals (RDA, NCI, AuScope)
- AuScope Codes
  - iEarth
  - Gplates
  - eScript
  - Underworld

Processing Environments
- EO Industry
- ANVGL Industry
- VGL Research
- VGCL Research
- VHRL Public Sec.

Services Compliant Australian Geoscience Data Stores (NCI, Govt, CSIRO)

Policy Portal

Education Data Portal (AuScope)

Areas of Focus for DEVL

Existing Components

AuScope Scientific Software Solutions Center

AuScope Workflows
- Geophys
- Mantle Inversion
- Modelling

Other Workflows
Outreach – Seismometers in Schools

- The AuSIS Seismometers in Schools and GPS in Schools programs place research quality instrumentation in secondary school classrooms across the country.

- Provided resources engage students in the geosciences and data is QC’ed and included in National research collections.
AuScope 2.0 - Opportunities
National Innovation and Science Agenda

- $1.5B NISA commitment over 10 years
- Highlighted 9 research infrastructure focus areas
- 2018 Budget provides 5 years of operational funding security (~$40M) plus $1.5M new capital
- Significant new capital investment currently deferred beyond forward estimates
- Inward focused Earth monitoring and exploration
- Explore establishment of next generation Earth monitoring and potential development of inward looking “telescopes”
- “generational shift in technology resources and interconnectivity of all facilities”...including the establishment of a virtual laboratory network to enable sharing of large data (including digitised collections) and improved real time communication.
Key science challenges

- Food and water sustainability
- Australia’s mineral resource future
- Australia’s energy future
- Geohazards

We must develop a predictive geoscience capability

- Research
- Infrastructure
  - Enhanced observational capability
  - Data
  - Computational capability
  - International collaboration
  - Cross-sector collaboration
  - Education
  - Advocacy
The AuScope AEOS Strategy is to link field and laboratory infrastructure across Australia to form a sensor array focusing on the Solid Earth. “The AEOS will be our communities SQA – a distributed telescope that looks into the earth rather than away from it.”

Providing unprecedented imaging fidelity of our crust to fundamental and applied researchers in the earth, environmental and geospatial sciences.

Collaboration with UNCOVER and MinExCRC.

Supported by NCES Decadal Plan.
Future Focus

- NISA and the NRIR provides an enormous opportunity for AuScope and the geoscience community as a whole
- Possibility for significant new investment in national programs in support of research initiatives such as UNCOVER
- Building a *Downward looking earth telescope*
- AuScope is seeking community feedback regarding investment priorities over the coming decade
Thank you

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