Science in the Surveys 2019

Tuesday 26 March 2019
Session Two

Chair: Kevin Ruming

11:00 Exploration research towards Australia’s future mineral production
Sandi Occhipinti, CSIRO

11:25 20 years of precompetitive geoscience data in the Capricorn Orogen: the link between mineral systems and crustal evolution
Simon Johnson, Geological Survey of Western Australia

11:50 Enabling data-driven exploration in north west Queensland
Helen Degeling, Geological Survey of Queensland

12:15 Shoring up the framework – Tasmanian geology and mineralisation
Andrew McNeill, Mineral Resources Tasmania

12:40 Lunch
Exploration research towards Australia’s future mineral production

Sandra Occhipinti, CSIRO
2017–2022
NATIONAL MINERAL EXPLORATION STRATEGY

Vision
A sustainable economy, future for national and local mineral wealth

Gcelas
Drive ongoing investment in mineral exploration, generate new opportunities, stimulate economic development and grow the productivity and legitimacy of Australia’s resource sector. Inducive to the success of the mining sector.

BENEFITS OF MINERALS TO THE NATIONAL ECONOMY

The mineral resources sector plays a vital role in Australia’s ongoing economic prosperity. The sector supports the nation’s export earnings, provides substantial direct and indirect employment and investment in regional and Indigenous communities, supports downstream and service industries and delivers scientific and technical innovation.

In 2015–16, minerals contributed 6% of Australia’s GDP, employed 1 in 230,000 people and generated 10% of the nation’s export revenue.

Further mineral exploration is expected to result in increased revenue to Australia’s economy, of $5.58 billion in 2015–16. Social benefits for the nation include:

- The combined direct and indirect contributions of $565 million to GDP, which is 0.5% of the national economy, and 1.5 million jobs, comprising 1% of the nation’s employment.

SCOPING THE STRATEGY

The National Mineral Exploration Strategy will identify the potential for, and technology in, mineral exploration, and is to be published in stages.

An initial national mineral exploration strategy identified $250 million in new opportunities.

The strategy will be refined through collaboration with other state and territory governments, as well as with the Minerals Exploration Incentive Program and other initiatives.

The strategy will act as a catalyst to drive new opportunities in mineral exploration and encourage investment in the sector, leading to increased jobs and economic growth.

NATURAL MINERAL RESOURCES

Increasing mineral discovery success

March 2016

Investment in low-impact, cost-effective technologies will assist in addressing the urgent need to increase the success rate of discovering new, internationally competitive Australian mineral deposits in increasingly challenging geological, environmental and social conditions.
Exploration Undercover

• Defining new search space/s
• Using a mineral systems approach
• Eliminating – spurious elements from analyses
• Using data analytics/machine learning
• Interdisciplinary & multidisciplinary approach to teams
• Collaborating
• Listening
• Taking risks
Base line, cover thickness & uncertainty mapping?

Geophysical Data:
Ground Gravity
Seismic lines
VTEM (EM) survey lines
AGG (airborne gravity gradiometry grids & other data.....

Distribution of cover thickness (sediments)
Faults displayed, where observed in field
In some areas faults control thickness distribution

Standard deviation of combined thickness estimate from distribution of cover thickness. Measures uncertainty of results
Useful for ground-truthing

Jelena Markov & Gerhard Visser
Deep Earth Imaging, FSP
Ore deposits – McArthur River (HYC)

Stripping back through paradigms of ore deposit models and getting to the real story

<table>
<thead>
<tr>
<th>Observation</th>
<th>Syndepositional Model</th>
<th>Diagenetic-epigenetic model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laminated ore textures</td>
<td>Consistent with deposition from water column</td>
<td>Can be produced by replacement of sedimentary (carbonate) layering</td>
</tr>
<tr>
<td>Timing of sphalerite and galena mineralization</td>
<td>Not consistent</td>
<td>Deposition of base metal sulfides after latest diagenetic pyrite indicate diagenetic-epigenetic model</td>
</tr>
<tr>
<td>Lithgeochemical haloes (Tl)</td>
<td>Enrichment of Tl up to 200 m above ore zone could result from low-T fluid after main-stage mineralization</td>
<td>Enrichment of Tl up to 200 m above ore zone indicate fluid flow well after deposition of ore-hosting sediments low-T fluid after main-stage mineralization</td>
</tr>
</tbody>
</table>

After Huston et al. 2006; Econ. Geol.
McArthur River (HYC)- Carbonate Replacement

Sam Spinks et al., AGES
McArthur River (HYC)-Carbonate & Zinc & Thalium relationship
McArthur Basin: Geophysical interpretation and modelling

Teagan Blaikie et al., AGES

Architecture & time

Solid geology and fault event interpretation

Geophysical modelling of basin architecture
Integrating structural interpretation with Basin analysis to develop region-specific targeting concepts for sediment-hosted mineral systems – Marcus Kunzmann

- Facies analysis, sequence stratigraphy, chemostratigraphy, tectonostratigraphy

Fertility & Architecture

E.g., Kunzmann et al., 2019, Ore Geology Reviews
Numerical model – testing what we think is going on

Processes: Fluid flow, heat transport (convection), deformation
**Stratigraphic interpretation**

**Diagenetic scenario:**
- Black shale = seal, diverting fluids into BCF

**Syngenetic scenario:**
- Black shale = chemical trap on seafloor

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**Mineralisation**

**Mineralising fluid**

- Black shale
- Dolomitic siltstone

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*Kunzmann et al. 2019*

**Barney Creek Formation**

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*Spinks et al. 2019*

**Syngenetic: Fluid flows up Emu Fault to seafloor**

**Diagenetic: Fluid diverts out of Emu Fault into BCF**
Results: Thermal convection, diagenetic scenario

Aquifer and faults

Barney Creek Fm (vertical exaggeration x10)

Integrated fluid flux

11 km$^3$ fluid

Note, no deformation
Next steps

- Apply more realistic geometry/architecture to assist in exploration targeting (Sheldon, Schaub, Blaikie)
- Application to another area (Sheldon, Schaub, Blaikie, Schmid)
- Introduction of salinity into models – investigating relative importance of salinity & temperature in driving fluid flow (Sheldon, Schaub, Poulet)
- Update permeability with deformation (Poulet, Sheldon, Schaub)
- Introduce reactive transport into the models, testing ideas about geochemistry & reactions that take place in the system (Mei, Lui, Spinks, Schmid, Sheldon, Poulet et al)

MRIWA Project xxxx with companies: For more information, contact Peter Schaub: peter.Schaubs@csiro.au

R+ postdoc applications, May 2019
Strategic Projects – Discovery, CSIRO
Characterising breccia-hosted mineral systems – an exploration to resource calculation & mine operations project.... In development

Understand the role of breccia in mineral systems:
• establish criteria for recognising distal fringes of breccia-hosted systems
• develop optimal strategies for imaging and chemically analysing breccia ores at multiple-scales
• establish protocols for meaningful geostatistical evaluation and delineation of mineral resources in breccia-dominated systems
• Determine ore deportment, hardness, metallurgical constraints (partnering with Mining & Processing)

Maia mapper image, breccia ore

Barnes, Poulet, Pearce, Vernon et al
Innovation in the **SAMPLING** approach

- SMART SAMPLING... how many samples are needed and where do you collect them
- In this example we could have done 50% less, big economic savings
- This is a rough example – it could be much better, we should achieve the same with 80% less samples, using the algorithm to guide next sample selection
Exploration through cover

- M462 - Multi-scaled near surface exploration using ultrafine soils

Benefits of fine fraction concentration
- Enhance concentrations from dune sands to 10s ppb
- More reproducible/reliable
- Big upside for detection, reproducibility and exploring through cover for subtle Au, Cu, Zn signatures

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Diameter (µm)</th>
<th>Surface/exchange area (m²/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>50-2000</td>
<td>0.04</td>
</tr>
<tr>
<td>Silt</td>
<td>2-50</td>
<td>0.1</td>
</tr>
<tr>
<td>Clays</td>
<td>&lt; 2</td>
<td>5 - 800</td>
</tr>
</tbody>
</table>

Why are we mainly sampling this?

Average total gold by size in dune sands n=14
soils commercialised workflow

A) Original sampling and analysis by GSWA (2000)
- $< 180 \mu m/80$ mesh, milled. 18 of 300 with Au

B) Same samples using UltraFine+
Additional spectral and physical properties

*Future will be Machine learning/uncertainty maps for industry at a click of a button to come*
Hydrogeochemistry of scale

Continental scale can provide major lithological information
Deposit scale can identify anomalies linked to weathering sulfides
Hydrogeochemistry to ‘see’ and detect through cover

- New targets

Reid, Thorne, Roy, Gray et al

Capricorn DISTAL FOOTPRINTS
Ta in Fe pisoliths

Li in Fe pisoliths over Greenbushes

Old samples, new targets/opportunities?

Petalite abundance
Drillcore, Hylogger

LeGras, Laukamp, Anand

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>SWIR 1200 - 2500 nm</th>
<th>TIR 6000 – 14500 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambygonite</td>
<td>LiAl((PO_4)_2)F</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Elbaite</td>
<td>Na((Al_{1.3}Li_{1.5})Al_2(Si_6O_{18}))(BO_3)_3(OH)_3(OH)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Eucryptite</td>
<td>LiAl(^{2+})O_4</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Hectorite</td>
<td>Na(<em>{0.3}(Mg, Li)</em>{3.7}Si_4O_{10}(F, OH)<em>{2-n}H</em>{2}O)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lepidolite</td>
<td>K((Li, Al)<em>{3}(Si, Al)</em>{3}O_{10}(F, OH))</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lithiophilite</td>
<td>Li(^{2+})Mn(^{2+})(PO_4)</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Neptunite</td>
<td>K(_{2}Na_3LiFe^{2+}_2Ti_2Si_4O_4)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Petalite</td>
<td>LiAl(^{2+})Si_{10}O_{16}</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Polythionite</td>
<td>K(<em>{2}LiAlSi</em>{10}O_{16}F_2)</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Spodumene</td>
<td>LiAl(^{2+})SiO_6</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Zinnwaldite</td>
<td>K((Al, Fe, Li)<em>{3}(Si, Al)</em>{3}O_{10}(OH))F</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Data assimilation and value of information

Talebi: Joint geostat + ML for gold prospectivity

Castellazzi: GDE identification from SAR

Jiang: ML to identify paleochannels from AEM
Rosetta – Predictive analytics

- **Outcome:** From hyperspectral images, we can probabilistically predict lithological labels, *modal* chemistry and mineralogy
Probabilistic inversion for a basement conductor

Inverting multiple survey lines for a single basement conductor

Cross-section through the probability to intersect the target

- Geologically plausible target is to the south of the fault
- Identification of a shallow drillable target
- Quantifying the possibility of a larger target

Legacy GEOTEM data from Walford Creek, Queensland, Australia

Contact: Juerg.Hauser@csiro.au
Objective target ranking for greenfield exploration using AEM data

Which conductivity anomalies are potentially economic basement conductors?

Focus the exploration program on anomalies that are likely to be caused by basement conductors.

Apply Bayesian model selection concepts to quantify the likelihood.

No "economic" basement conductor

An "economic" basement conductor

Evidence a basement conductor
barely worth mentioning
strong
very strong

Evidence a basement conductor

very strong
positive
positive
very strong

Contact: Juerg.Hauser@csiro.au
Construction of basement surface from high quality magnetic source depth estimates

Coompana basement surface
Predicting geochemistry/prospectivity using ML

Cole et al.

Random forest regressor used to model geochemistry across the Quamby region based on subsurface covariates.

2 models were tested:

a. using magnetics & gravity covariates;

b. addition of wavelet transformations

Figure 9.1.: Geochemistry model training points (showing Cu values) over larger east succession and Quamby region outline.

Figure 9.7.: Quamby Cu prediction/uncertainty (magnetics and gravity covariates with wavelet features masked by covariate shift).
AuScope

Virtual Research Environment (AVRE) — Data, Visualisation & Analytics

Welcome to the AuScope Virtual Research Environment (AVRE), Australia’s home of geoscience data and tools that help scientists place the next pieces of our giant, continental puzzle.

The AVRE is a rich ecosystem of Findable, Accessible, Interoperable and Reusable (FAIR) data and tools contributed to by a diverse range of Australian research organisations, government geological surveys and the

- NVCL
- Mobile Petrophysical Laboratory (Infrastructure)
- Thermodynamic Infrastructure
- FAIMS – adaptable field mission planning templates

Impact

AVRE has improved the availability and accessibility of comprehensive geoscientific data in Australia. Key impacts include $912M of realised value to mineral exploration, as well as $458M in gold discoveries and $35M per annum in mining efficiencies.

Aside from the key findings by Lateral Economics and CSIRO, the AVRE has been recognised by BOM in the Information Platform for Bioregional Assessments Phase One Information Architecture report (20-12-2012).

1 — Lateral Economics, 2016
2 — CSIRO, 2014
Industry Led Agenda

• Opening up new search spaces
• Working with Universities, GA, State Surveys & Industry
Discovery

Thinking outside the box, to provide solutions for Exploration, Mining, Remediation
20 years of precompetitive geoscience data in the Capricorn Orogen: the link between mineral systems and crustal evolution

Presented by
Simon Johnson
Precompetitive geoscience data and geological surveys

Reduce financial risk to explorers – better use of exploration expenditure – target smaller, more prospective regions for investigation

Free and FAIR (findability, accessibility, interoperability, and reusability) geoscience data

**State geological surveys:**
Mapping, geophysics, geochemistry, geochronology

**Next step to link data to exploration strategy:**
Craton to province-scale drivers of mineral systems – crustal architecture, geodynamic and tectonic processes, timing of mineralization
20 years of mapping in the Capricorn Orogen

1st edition mapping of the State at 1:250k scale complete by late 1970s

Invention of the SHRIMP (high-precision geochronology) drove State remapping at 1:100k scale in the late 1980s

1:100k scale mapping in the Capricorn Orogen started in 1998 – finished exactly 20 years later (55 map sheets)

analytical advances during mapping led to an ‘Enhanced Geochronology’ program

geophysical advances – vibroseis seismic reflection, passive seismic, ASTER, LANDSAT

Maps in more detail but the real value is the revolution in understanding!
Capricorn Orogen

Proterozoic orogen between the Archean Pilbara and Yilgarn Cratons and Glenburgh Terrane

Sutures the cratons to form the West Australian Craton

Well endowed with multiple commodities
Geological history and geodynamic setting

Defined by all mapped components

Geochemistry

Geochronology

Whole rock and mineral isotopes

Structure
Geodynamic setting - collision
Assembly of the West Australian Craton

Punctuated two-stage assembly

Collision/accretion of the Glenburgh Terrane to the Pilbara Craton during the 2400–2145 Ma Ophthalmia Orogeny

Cryptic Ophthalmian-aged magmatic arc – defined by Hf and O isotopes in inherited zircons
Geodynamic setting - collision

Assembly of the West Australian Craton

Collision of the Glenburgh Terrane—Pilbara Craton with the Yilgarn Craton during the 2005–1950 Ma Glenburgh Orogeny to form the WAC

continental margin magmatic arc
Geodynamic setting – reworking

Over 1 billion years of coaxial intracratonic crustal reworking
Deformation, metamorphism, magmatism, sedimentation
Over 1 billion years of coaxial intracratonic crustal reworking
Deformation, metamorphism, magmatism, sedimentation

Change in crust to cold and brittle
Formation of intracontinental basins
Shear zone and fault reactivation
Lithospheric architecture

In 2010 – 581 km vibroseis-source reflection seismic
Well-known (mapped) surface geology – interpreted at depth
Define four crustal blocks and three suture zones
Passive seismic array (COPA)

Two complementary broadband passive source surveys 2014–2017

COPA (black dots) – orogen-scale structure, 88 stations deployed over 3 years

HPS (red dots) – high density array, 25 stations over 200 km along the 10GA–CP2 seismic line (2–8 km spacing) – compare passive and active source data
Lithospheric architecture (HPS array)

The HPS array helped re-interpret parts of 10GA-CP2
Ambient noise shear wave velocity structure highlights compositional contrasts in the crust – reflected in bulk crustal Vp/Vs ratio

Imaged the buried Ophthalmian Arc
Lithosphere–asthenosphere architecture

Base crust
Base lithosphere
Ambient noise bodywave tomography (COPA)

Red – hydrated, altered mantle
Blue – refractory mantle

Critical for understanding mantle–crust interactions
Craton–Province scale
Mineral system defined by two critical elements: Pathway – architecture Energy – geodynamic throttle
The majority of gold and base metal deposits lie on major mantle-tapping shear zones or their secondary structures. Nanjilgardy Fault the most endowed.
Geodynamic throttle (energy=timing)

Link crustal architecture and known tectonic evolution to fluid flow events

Precise timing of mineralization
  xenotome YPO$_4$ and monazite (La,Ce)PO$_4$
  common in hydrothermal systems
  resilient to isotopic resetting
dissolution-reprecipitation reactions
in situ SIMS (SHRIMP) dating
  preserve the textures
  small analysis spot
Precisely dated the timing of gold mineralization at four deposits

Precisely date the timing of shear zone movement and hydrothermal fluid flow
Timing of gold mineralization – northern Capricorn

C xenotime

[Image of map and mineral samples]

Orogenic gold

- Paulsens gold mine: 2403 ± 5 kmB, n = 26, MSWD = 1.09
- Mount Olympus gold mine: 1679 ± 10 kmB, n = 40, MSWD = 2.0
- Belvedere gold mine: 1769 ± 4 kmB, n = 33, MSWD = 1.02
- Star of the West gold mine: 1681 ± 9 kmB, n = 25, MSWD = 0.96

Reworked gold

- Glenelg Orogeny: 1672 ± 18 kmB, n = 8, MSWD = 1.2
Gold mineral system – northern Capricorn

**PATHWAY** - Gold is hosted on the major crustal (mantle-tapping) structures or their 1\textsuperscript{st}/2\textsuperscript{nd} order splay

**ENERGY** - Driven by orogenic events in the mid/deep crust

- link between regional metamorphism and deformation, and hydrothermal fluid flow/mineralization
- barren and mineralized hydrothermal fluids flux during faulting

One large orogenic gold deposit (Paulsens) during accretionary orogenesis

reworked during successive events into smaller deposits

One large deposit and minor secondary gold events
20 years of geological and geophysical ‘mapping’ in the Capricorn – unique understanding of the crustal evolution and architecture through time.

Critical pre-competitive data can be used to directly inform the craton to province-scale drivers of mineral systems.

Where to go from here?
Summary

20 years of geological and geophysical ‘mapping’ in the Capricorn – unique understanding of the crustal evolution and architecture through time

Critical pre-competitive data can be used to directly inform the craton to province-scale drivers of mineral systems

Where to go from here?

National Drilling Initiative (NDI) – apply it to the ‘Gap’ – Proterozoic margins under shallow cover
GSQ’s New Discovery Program

Enabling data-driven exploration in NW Queensland

Science in the Surveys
26th March 2019
Focus on NW Qld

- NW Mineral Province: highest value mineral province in Qld
- Significant exploration investment from major international companies
- Key focus area for Qld Govt and GSQ:
  - NW Minerals Province Strategic Blueprint
  - Qld Mineral and Coal Exploration Guideline
  - GSQ’s Strategic Resources Exploration Program, and
  - GSQ’s New Discovery Program
GSQ Projects and Funding

Strategic Resources Exploration Program

- New Discovery Program
  - Geophysics
  - Geochemistry
  - Synthesis
  - Collaboration
  - 2017-2021
  - $11.6M

- Collaborative Exploration Initiative
  - 2017-2021
  - $3.6M

- Industry Engagement
  - $1.2M

- Frontier Basin Gas Exploration
  - $3.6M

- Geoscience Data Modernisation
  - $7.125M

- New geophysical surveys
- Surveys, case studies, research
- Compilations, research
- Collaborative contributions
New Discovery Program

- New data and research – support exploration and discovery
- Strategic collaborative partnerships with key public geoscience agencies – BRC, CODES, EGRU, CSIRO, Geoscience Australia
- Individual projects (>20) – aiming to maximise synergies and collaboration
Coverage of the New Discovery Program
Recently Completed Geophysics

- $4.3M under New Discovery Program
- Airborne EM (≤ 2.5 km)
- Magnetotelluric (≤ 2.5 km)
- 1 km ground gravity
- High resolution magnetics (≤100 m)
- Deep crustal seismic

All released data available at QDEX Data  http://qdexdata.dnrm.qld.gov.au
High Resolution Mag

- Expanding 100m airborne magnetics and radiometrics
  - Cloncurry South – 2017
  - Cloncurry North – 2018
  - Central Isa – 2019
Central Isa Survey

- Approximately 85,000 line km
- Start date mid-April
- 3 surveys combined to create a large high resolution merge of region
- ~28,000km² covered by 3 surveys
Airborne AEM

- GSQ AEM – VTEM, acquired in 2016-17
- Future targeting AEM planned for FY 2019-2020
  - Targeting Western Succession
  - AusAEM results to drive area selection
Magnetotellurics (MT)

- MT grid surveys – S of Mt Isa and N of Cloncurry (incl Ernest Henry)
- Planning new survey area for collection in 2019
Geochemistry

- Geochemical Toolkit for explorers
  - Adelaide Uni - GeoChem Pacific-GSQ – released 2018
- Hydrogeochemistry of the Mt Isa Province - GSQ-CSIRO
- Mineral chemistry vectoring
  - CODES
  - Footprints of major IOCG and sediment-hosted Cu, Zn, Pb, Ag deposits
Geochemistry

• **Fingerprinting mineral deposits - CSIRO**
  - Geophysical, structural and mineralogical signatures of the Cloncurry Mineral System

Monakoff Cu-Au
E1 Cu-Au
Canteen Cu-Au
Starra Cu-Au

Osborne Cu-Au
Ernest Henry Cu-Au
Ernest Henry Cu-Au
SWAN Cu-Au

Combining.....
- Paleomagnetics
- Mineralogy
- Geochemistry
- Hyperspectral
- Conductivity
- Density
- Mag susceptibility
- Mag remanence
- Radiometrics

TIMA images
Geology/Mineral Synthesis

- Compilation of historic research (BRC/UQ-GSQ completed)
- Machine Learning pilot (DATA61/CSIRO completed)
- Co & HREE mineral systems (Ken Collerson completed)
- Tick Hill gold deposit (PhD, EGRU)
- Mary Kathleen Domain magma fertility (EGRU)
Mary Kathleen Domain Geology

- Important mineral deposits:
  - Mary Kathleen, Little Eva, Dugald River, Tick Hill

- Test association of mineralisation with felsic and mafic magmatism
  - 1540-1500 Ma (similar to IOCGs in Eastern Succession)

- Poorly constrained in the MKD
Deposit Atlas

- Deposit atlas of NW Qld
- UQ collaboration, Rick Valenta
- Compilation of all open file data for major or significant deposits in the NW Minerals Province
Reference Collection

- Digital core library for key deposits in the NW
- Complements Deposit Atlas
- Compile and enhance drill hole data
Geoscience Data Modernisation

• Data “Integration”
• Entering a new era of data-driven “science”, but
• Huge problems with data integration in geoscience
• Differing datasets that were never designed to be integrated
• Geoscientific data is different from most other data:
In Qld, real problems with data storage and data quality

These affect:
- Data discoverability
- Data useability

Ultimately hampering exploration success
Data-Driven Exploration

**Data Input**
- Geoscience Data Reporting Guidelines*

**Data Curation**
- Geoscience Data Modernisation Project

**Value-Add**
- Analytics Insights Intelligence

**Industry Enablement**
- Skills Collaboration Capacity

Effective and efficient use of knowledge to enable industry success
(discovery, cost, time, resources, waste)

* Draft Mineral & Coal Reporting Guidelines available for Industry feedback after 29th March 2019
<table>
<thead>
<tr>
<th>Unsupported technology</th>
<th>MERLIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Borehole, Surface Geology, EDC</td>
</tr>
<tr>
<td>Unsupported technology</td>
<td>QDEX Reports</td>
</tr>
<tr>
<td>Duplicative system, expensive data storage</td>
<td>QDEX Data</td>
</tr>
<tr>
<td>Duplicative system</td>
<td>GEM</td>
</tr>
<tr>
<td>Unsupported technology</td>
<td>Discoverer BI</td>
</tr>
<tr>
<td>Redundant</td>
<td>Mines DB</td>
</tr>
<tr>
<td>Significant cost savings from reduced data volume</td>
<td>GSQ Data (NAS)</td>
</tr>
</tbody>
</table>

GSQ Data Lake
**Data Lake**

- **Find insights in data**
- **DATA VISUALISATION**
  - Interact with the data via spatial, textual, graph, 3D

- **DATA PROCESSING**
  - Optimise, enhance, cleanse & curate data

- **DATA CATALOGUE**
  - Index all digital & physical data

- **DATA OBJECT STORE**
  - Store every piece of data as an object

- **MACHINE LEARNING**
  - AI that learns from data, and identifies patterns & insights

- **DATA ACCESS**
  - Human, computer & cloud data access
Pilot Progress to Date

**RECEIVE/GENERATE**
- EPM report form prototype

**VALIDATE**
- LAS file validator

**STORE**
- Pilot data lake

**CATALOGUE**
- CKAN data catalogue
- Vocabulary manager

**DISCOVER**

**EXTRACT/ANALYSE**
- File transfer test
Summary

• **New Discovery Program**
  - Collaborative research projects from 2017-2021
  - Geophysics, geochemistry, geology, data integration
  - Aiming to boost exploration discovery in NW Qld

• **Geoscience Data Modernisation Project**
  - Takes a wholistic approach to geoscience data
  - Aiming to make ‘data driven exploration’ a reality
Shoring up the framework:
Tasmanian geology, mineralization, and hazards
• One of MRTs main roles is to reduce investment and land use risk by developing a robust geological framework for the State

• “Removing” the vegetation – LiDAR and new DEMs
• Establishing the geological framework – mapping
• Establishing the geological framework – magnetics, gravity, MT, passive seismic – will only discuss gravity
• Shoring up the framework 1 - geochronology
• The third dimension – geophysically corroborated 3D modelling
• Shoring up the framework 2 – natural hazards
  • Landslip
  • Debris flow
  • Tsunami
Removing the vegetation

- 54% of state covered by LiDAR (of varying quality); coverage of north and east to be completed in 2019
- 25m state-wide DEM >20 years old – not being revised by State mapping
- Have produced state-wide 10m and 10+2m DEMs
Establishing the framework - mapping

• Digital seamless 1:250K geology complete and being maintained
• Digital seamless 1:25K geology >54% complete (>88% in highly mineralised areas)

• Program:
  o Complete 1st generation 1:25k coverage in NW Tasmania
  o Developing improved data model
  o Updating existing mapping as opportunities arise
  o Integrating LiDAR into workflow (where possible)
Establishing the framework - geophysics

- Terrain correction update for all gravity data
  - On- and off-shore topography significant
  - Previously corrections done manually to 22 km
  - Replaced by automatic correction from 2-167 km
  - Use improved quality DEMs (including bathymetry)
  - Earth curvature correction now used (significant effect)
  - Add continental slope effect (minor effect only)
  - Highest correction now 40.6 mGal (11.6 mGal greater than in previous corrections).
  - Updated dataset available on-line
Shoring up the framework 1 - geochronology

- Joint projects with GA, UTas, UMelb, Boise State U, UBC, U Sth Florida
- Supports regional mapping and addresses specific problems
- Direct dating of mineralisation (Re-Os on molybdenite and U-Pb in cassiterite)
- How robust are our geochemically and petrographically based correlations?

Detrital zircon reference database
Detrital zircons in Neoproterozoic to early Cambrian sequences

Project with UTas and UMelb.

Fault bounded sequences of varying metamorphic grade – how do they correlate?

In this example the Success Creek Group and Bird Phyllite share similar DZ provenance to the lower parts of Togari Group (Forest Conglomerate), supporting correlations through the Smithton and Dundas Troughs and the Arthur Metamorphic Complex.
Geochronology - Neoproterozoic

Zeehan area:
Sediments mapped as either Neoproterozoic (prospective) or Middle Cambrian (un-prospective) by MRT
LA-ICPMS dating of detrital zircons suggests correlation with the Neoproterozoic Crimson Creek Formation
Geochronology – Mount Read Volcanics (MRV)

• What is the age of the VHMS mineralisation – is there a holy Host?
• Can we use our current volcanological and lithochemical correlations to define prospective horizons?
• Project with UTas and UBC:
  o acquired 49 zircon ages
  o CA-TIMS, errors of <1.0 Ma
  o Couldn’t obtain good dates for all samples
  o Age range is 506.8 – 492.6 Ma
## Geochronology – Mount Read Volcanics (MRV)

<table>
<thead>
<tr>
<th>Deposit</th>
<th>Ore</th>
<th>Method</th>
<th>Footwall</th>
<th>Hangingwall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wart Hill</td>
<td>?</td>
<td></td>
<td>498.5±0.6 Ma</td>
<td>496.5±0.8 Ma</td>
</tr>
<tr>
<td>Thomas Creek</td>
<td>?</td>
<td></td>
<td>500.7±1.2 Ma</td>
<td>?</td>
</tr>
<tr>
<td>Prince Lyell</td>
<td>500.4±2.3 Ma</td>
<td>Re-Os (moly)</td>
<td>500.4±0.6 Ma</td>
<td>?</td>
</tr>
<tr>
<td>Crown Lyell</td>
<td>491.2±2.5 Ma</td>
<td>Re-Os (moly)</td>
<td>500.4±0.6 Ma</td>
<td>?</td>
</tr>
<tr>
<td>Newton clasts</td>
<td>?</td>
<td></td>
<td>502.2±0.9 Ma</td>
<td>502.1±1.0 Ma</td>
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<tr>
<td>Henty</td>
<td>?</td>
<td></td>
<td>~497 Ma</td>
<td></td>
</tr>
<tr>
<td>Red Hills</td>
<td>?</td>
<td></td>
<td>498.5±0.6 Ma</td>
<td></td>
</tr>
<tr>
<td>Rosebery</td>
<td>?</td>
<td></td>
<td>502.8±0.7 Ma</td>
<td>499.4±0.6 Ma</td>
</tr>
<tr>
<td>Hellyer</td>
<td>500±23 Ma</td>
<td>Re-Os (WR)</td>
<td>500.4±0.7 Ma</td>
<td>499.3±0.5 Ma</td>
</tr>
</tbody>
</table>

Geochronology – Mount Read Volcanics (MRV)

- Major Pb-Zn mineralisation at ca 500 Ma; sub-economic mineralisation both older and younger
- Cu-Au Mineralisation starts at ca 500 Ma and may occur over period of several million years (not just at Lyell)
- Issues with previous lithological/geochemical correlations:
  - Lynchford Tuff equivalents span 2.2 Ma – implies not just one eruption; CVC at Red Hills has Tyndall Group age; Elliott Point Porphyry (496.3 Ma) vs Bonds Range Porphyry (500.4 Ma)
The Third dimension - geophysically corroborated 3D modelling

- Semi-regional scale
- Based 1:25,000 mapping and x-sections constructed using geology and drilling data.
- Gravity and magnetic datasets curated by MRT
- Physical properties database curated by MRT
The Third dimension - geophysically corroborated 3D modelling

• With probabilistic interpretation using Geomodeller
• Reference model constructed – inversions of both gravity and magnetics.
• Iteratively vary individual voxels until error is minimised (burn-in)
• For this model required 200 million iterations for gravity and approx. 1 billion for magnetics.
Natural hazards – landslip

C Mazengarb, M Stevenson, N Roberts

- MRTs role is to provide advice to other agencies.
- Since 1960s more than $12 million paid in compensation for damage to dwellings; cost to repair other infrastructure not recorded.
- Re-activation of landslides after 2016 rain event – currently 4 houses severely damaged Tamar Valley.
- Can be cryptic in landscape – use LiDAR to locate and catalogue
- Use identified slips, underlying geology and topography to define Hazard banding
- Currently:
  - Identifying landslips re-activated after 2016 event
  - Updating state-wide hazard banding.
  - Investigating use of InSAR (RADAR interferometry) to measure movement rates.
Natural hazards – debris flow
C Mazengarb, C Kain, M Stevenson

- Rare, locally high impact events after high rainfall
- 2011 and 2016 Caveside flows
- Model using RiverFlow 2D
Natural hazards – debris flow

C Mazengarb, C Kain, M Stevenson

- Glenorchy 1872 event
- Historic research
- Much of Mt Wellington area, above Hobart, shows evidence of historic debris flows
- Flo-2D modelling of 1872 event gives good agreement – can use elsewhere?
Natural hazards – tsunami risk

C Kain and C Mazengarb

Why:
- Travel time < 2 hours, warning time even less
- Tsunami is a hazard with low probability but high, poorly understood consequence
- SES requested for management and evacuation planning

Method:
- Worst case: 8.7 Mw earthquake off SW New Zealand, high astronomical tide (HAT)
- Elevation model with surface roughness and land cover
- Use ANUGA hydrodynamic model
- Won State level Natural Disaster Resilience Grant Programme (NDRGP) award
- Funded to extend modelling to remainder of eastern Tasmania
Natural hazards – Tsunami Risk

Results:

• Significant inundation in exposed eastern locations:
  o Tasman Peninsula
  o Bruny Island
  o Kingston Beach
  o Orford (70 houses)
• Moderate inundation in other places along shores of Derwent Estuary
• Hobart Airport is protected by the dune line, even with the recent lowering
• Evacuation of vessels from ports not likely to be feasible with a tsunami arrival time of 1.5-3 hours post-earthquake
• Need to re-examine potential effects on RHH - include buried Hobart rivulet (not in current model)
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