The Future of Mineral Exploration Drilling and Sampling

Exploration '17
Thursday 26 October
Toronto, Ontario
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<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker</th>
<th>Institution</th>
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<td>1.00 PM</td>
<td>Introduction</td>
<td>David Giles</td>
<td>University of South Australia/DET CRC</td>
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<td>1.05 PM</td>
<td>Coiled Tubing Drilling in Mineral Exploration</td>
<td>David Giles</td>
<td>University of South Australia/DET CRC</td>
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<td>1.30 PM</td>
<td>Logging-While-Drilling in Mineral Exploration: State-of-the-Research</td>
<td>Anton Kepic</td>
<td>Curtin University/DET CRC</td>
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<td>1:50 PM</td>
<td>Sampling for Coiled Tubing Drilling</td>
<td>Ben van der Hoek</td>
<td>University of South Australia/DET CRC</td>
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<td>2.00 PM</td>
<td>Top-of-Hole Geochemistry and Mineralogy: State-of-the-Research</td>
<td>Yulia Uvarova</td>
<td>CSIRO/DET CRC</td>
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<td>2.20 PM</td>
<td>Coffee</td>
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<td>2.40 PM</td>
<td>Seismic Pre-Drilling and Sampling: State-of-the-Research</td>
<td>Milovan Urosevic</td>
<td>Curtin University/DET CRC</td>
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<td>3.00 PM</td>
<td>Assay-While-Drilling: State-of-the-Products</td>
<td>James Cleverley</td>
<td>Imex</td>
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<td>3.20 PM</td>
<td>Geological Logging with X-ray Vision</td>
<td>Aaron Baensch</td>
<td>Olympus</td>
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<td>3.40 PM</td>
<td>The Future of Geological Survey Drilling</td>
<td>Steve Hill</td>
<td>Geological Survey of South Australia</td>
</tr>
<tr>
<td>4.00 PM</td>
<td>Close</td>
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</table>
YOUR SPEAKERS
DAVID GILES
Program 3 Leader
University of South Australia/DET CRC

Prof David Giles is Strand Leader and John Ralston Chair of Minerals and Resources Engineering at the Future Industries Institute, University of South Australia. Prof Giles has over 20 years’ experience in minerals exploration spanning the boundaries of industry and academia. He is Leader of Program 3 (Targeting) within the Deep Exploration Technologies CRC.

BEN VAN DER HOEK
Researcher,
University of South Australia/DET CRC

Ben van der Hoek is a key researcher in DET CRC Project 3.2 Lab-At-Rig® Futures at the University of South Australia. Ben completed his PhD at the University of Adelaide with DET CRC in 2013 in the field of regolith geochemistry and has since pursued his interests in geochemistry and engineering as a researcher within the Lab-At-Rig® team.

ANTON KEPIC
Project 2.2 Leader,
Curtin University/DET CRC

Currently the Boart Longyear Chair in Geophysical Instrumentation in Curtin University, Anton has been with Curtin University since 1999. Anton previously held positions within WMC in Exploration and Technology group, and holds degrees from University of Western Australia (BSc. Hon) and a PhD in Geophysics from the University of British Columbia.

YULIA UVAROVA
Project 3.2 Leader
CSIRO/DET CRC

Yulia is a Principal Research Scientist, Research Group Leader and Project Leader at CSIRO Mineral Resources. Currently, Yulia is leading Project 3.2 Lab-at-Rig® Futures, which will lay the foundations of future Lab-at-Rig® platforms that will take advantage of new sensor technologies and develop the application beyond current deployment in greenfields exploration.
Milovan Urosevic received BSc (Hons) in geophysics from the University of Belgrade in 1980, MSc in geophysics from the University of Houston in 1985 and PhD in geophysics from the Curtin University of Technology in 2000. He acquired over ten years of industry experience working in areas of seismic data processing, AVO, inversion, multi-component seismology and seismic anisotropy.

After joining Curtin University in 1991 he has taken part in various industry projects related to the oil, coal and mineral exploration. His main interest is in the utilisation of new technologies to advance exploration of natural resources.

He is currently involved in two major Australian corporative research centres (CO2CRC and DET CRC). He is also leading a large ANLEC R&D (Australian National Low Emissions Coal Research and Development) project that is investigating and evaluating the applicability of novel, alternative seismic methodologies for rock characterisation. Milovan is associate editor of the Exploration Geophysics Journal.

James Cleverley is currently Global Product Manager – Geosciences for REFLEX, a leading brand of ASX-listed Imdex Ltd, (Perth, Australia). James has been involved in two industry-led research cooperatives dating back to his second post-doc at James Cook University with the Predictive Mineral Discovery CRC and then heading up projects in phase 1 of the Deep Exploration Technologies CRC as Research Group Leader in CSIRO, before moving to Imdex in mid-2014.

James was the project lead for the DET CRC Lab-at-Rig® project, a collaboration between REFLEX, Olympus and CSIRO, which was commercialised by Imdex in September 2015. More recently James has taken over product management of technologies designed to provide near real-time decision support in the geosciences in the Imdex In-Field Geoanalysis solution. He is passionate about the use of geochemical data, data analytics, sensor and real-time technology, and the understanding of hydrothermal systems for exploration targeting and mine optimisation, but has been lucky enough to work on everything from large gold deposits to chondritic meteorites.
Aaron is the Principal Geologist – International Mining Group (IMG) for Olympus Scientific Solutions Americas (OSSA) headquartered in Boston, MA, USA. He is also an embedded researcher & project manager at the Deep Exploration Technologies – Commonwealth Research Cooperative (DET CRC) based in Adelaide, Australia & co-inventor of the recently commercialized Lab-At-Rig® product.

Aaron has been working with Olympus (formerly Innov-X Systems) since 2008 and has become an Industry Specialist in the application of field portable x-ray fluorescence, x-ray diffraction and microscopy for mineral exploration, mining, mineral processing, environmental and petroleum applications. He is currently focused on the research & development and business development of real-time mineral analysis technologies, including the adaption of systems used by NASA on the Mars Curiosity Rover for terrestrial mineral analysis.

Dr Steve Hill is Chief Government Geologist and Director of the Geological Survey of South Australia, where his role is to oversee and coordinate the Geological Survey’s research and generation and delivery of pre-competitive geoscience data. Before joining the Public Service in 2013, Dr Hill spent more than 20 years in academia at the University of Adelaide, University of Canberra and Australian National University.
Coiled Tubing Drilling for Mineral Exploration

David Giles
DET CRC Program 3 Leader
Future Industries Institute, UniSA

The Future of Mineral Exploration Drilling and Sampling
Exploration '17, Toronto
26 October 2017

Why Coiled Tubing Drilling?

Magnetics (TM)

Mt Isa
How do we characterise and explore within this search space?
How is your sense of scale?

457 holes
Unsorted distributed
Source: DEEP depth-to-basement study
Previous Drilling

UK
How do we characterise and explore within this search space?
How is your sense of scale?

We need more drill holes!!
Why Coiled Tubing Drilling?

- Coiled Tubing Drilling (CTD) achieves 2x ~1,000m Alberta gas wells per day in soft, predictable sedimentary rocks.
- 2-3 hours move in and rig up time.
- Penetration rates: up to 100m/hr.
- No drill rod connections.
- Safer, more time drilling, rapid tripping, maintain hole balance.
- Small footprint, contained fluids.
- CTD offers improved cost, safety, and environmental impact in mineral exploration.

= More drill holes

DET CRC Coiled Tubing Strategy

- Key challenges for CT drilling in mineral exploration:
  - Coil durability
  - Ground up rig design
  - ROP with low weight-on-bit drilling
  - Hole integrity / fluid loss
  - Sample representivity

- DET CRC’s target:
  - Greenfields rig to 500m, weight less than 10 tonnes and $50/m.

Challenge: Coil durability

Challenge: Ground up design and build a new rig

Challenge: Rate of Penetration

Challenge: Clean Fluid

- Dam water pumped and trucked to the drill site, cleaned, treated, and recycled - again and again.
- Up to 240L/min recycled and cleaned during drilling – system volume 7700 litres (2000 gallons).
- Managing salinity, pH and additives while cleaning.
- Reliable water cleaning in the field proven to work in very dusty conditions.
Challenge: Hole Integrity / Fluid Loss

- Axxon Rig, Brukunga Nov 2014 Water drilling, no intervention, 100% loss
- RoXplorer® Stavely trials May 2017 Water loss improved from 40-100% to ~5% using DET CRC mitigation strategies

Challenge: Cuttings Return / Representative Sampling

RoXplorer® Field Trials Selected KPI’s

- Drill 20m in 1 hour
- Drill 400m in 4 consecutive 12 hour shifts
- Ensure borehole stability and condition during drilling process
- Fluid and sample return >70% over 200 m of drilling
- Representative samples at 1m resolution, able to identify key lithological boundaries
- Chip samples at 1m resolution for entire drill hole

Port Augusta Field Trial
Feb-March 2017

- Twinned drill holes
- MSDP02 Diamond
- MSDP15 Coiled Tubing

- 400m of flat lying, consolidated, Proterozoic sedimentary cover, overlying basalt

Stavely Field Trial
May-June 2017

- Twinned holes
- Stavely12 Sonic
- Stavely21 Coiled Tubing

- 136m of flat lying, unconsolidated (running sands, swelling clays)
- Cainozoic sedimentary cover, overlying mafic and intermediate volcanics

MSDP15 Selected Results

- First 20m below casing drilled in 56 mins (357mm/min)
- 367m in first 4 shifts, average ROP 245mm/min (cf. 14.5 shifts to drill 376 with Diamond)
- Stable and clean borehole
- Fluid and sample return maintained at >98% below casing
- 110m of continuous sampling at <1m depth resolution and average depth resolution of 34 cm
- Chip samples at 1m resolution for 90% of drill hole
- Consistent deviation of ~2.6° (kicked from bottom of casing and then straight)
Stavely21 Selected Results

Rotary drilling to 42m and installation of PQ steel casing
Drilled to 140m (base of unconsolidated) using CT with blade bit and installed HQ steel casing in three 12 hour shifts
Drilled a further 267m of basement using CT with percussion bit in three 12 hour shifts
Water loss improved from 40-100% to ~5% using DET CRC mitigation strategies
Chip samples at 1m resolution for entire basement interval
Total deviation of 10m in 425m (average 1.35°)

RoXplorer® Capability

<table>
<thead>
<tr>
<th>Setting Type</th>
<th>Diameter Tubing/Rod</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary Drilling</td>
<td>114.3mm</td>
<td>PQ (Collar)</td>
</tr>
<tr>
<td></td>
<td>76.2mm</td>
<td>PVC</td>
</tr>
<tr>
<td>Coiled Tubing Drilling</td>
<td>76.2mm</td>
<td>3&quot; SFJ LW</td>
</tr>
</tbody>
</table>

Drilling Type
- Soft Rock: Blade bit
- Hard Rock: W70

Chip samples at 1m resolution for entire basement interval
Total deviation of 10m in 425m (average 1.35°)

RoXplorer® Site layout

Experimental site layout 800m²
Commercial site operation:
1 x Driller
2 x Offsider (water truck driver, fitter, fluid management, sampling)
1 x Supervisor

RoXplorer® Where to from here?

Q: What do we do with a rig that is mobile, small footprint, safer, quicker, cheaper

...and returns a sample which is representative, with <1m depth resolution and little smearing and amenable to visual logging, Lab-at-Rig assay, archiving sub-sampling for mineral separates (e.g. for mineral tracers or geochronology)

A: Drill a lot of holes!

Mt Isa

<table>
<thead>
<tr>
<th>Depth to basement</th>
<th>500 m</th>
<th>1000 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of all holes</td>
<td>226</td>
<td>964</td>
</tr>
<tr>
<td>Total meters drilled</td>
<td>132,400</td>
<td>527,800</td>
</tr>
<tr>
<td>Drilling cost @ $75/m</td>
<td>$9.9 M</td>
<td>$39.6 M</td>
</tr>
<tr>
<td>Area covered (km²)</td>
<td>64,900</td>
<td>122,300</td>
</tr>
<tr>
<td>Cost per km²</td>
<td>$152</td>
<td>$324</td>
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In-ground value of current and mined resources from the exposed Mt Isa Inlier is ~$194 B or ~$3.08 M/km². *
Logging-While-Drilling in Mineral Exploration

Anton Kepic
Project Leader of DET CRC Project 2.2
Sensors for Rapid Downhole Characterisation
Exploration 17 Workshop
October 2017

LWD how to do it and what’s out there?

Logging While Tripping Rods
- Inside rods – RC and Percussive
  - EZ Gamma – Reflex
  - Protruding through the bit – Diamond Drilling
- AutoSonde - DET CRC / Thurnrobe - Boart Longyear
- Shuttle - DMT

Measurement While Drilling or LWD
- Measure through outer rods
  - AutoShuttle – DET CRC for Diamond Drilling
  - Incorporated into outer rods/Bottom-Hole-Assembly
  - Geosub – DET CRC for Coiled Tube drilling

Multi-Sensor Sonde – 4 logs for 1 effort

- AutoShuttle is Measurement-While-Drilling by seeing through the outer rods
- AutoSonde is Logging-While-Tripping
- Natural Radioactivity
- Chargeability
- Electrical Conductivity
- Magnetic Properties

Tools are mechanically coupled and synchronized with a single handset

Multi-Sensor AutoSonde
DH88 Brukunga test facility, Australia

Electrical Resistance
Chargeable Sulphides
Natural Radioactivity
Magnetic Formations

Auto-Depth ability with Accuracy – yes we can

MAGSUS
AutoSonde deployed during lab changes + EOH

Thin interval at ~132m
Sharp boundary at ~136m

Magmas (from handheld meter)
Iron concentration (from Lab-at-Rig®)

Rhyolite
Rhyodacite
Thin interval at ~112m
Sharp boundary at ~120m

Galvanic
TC Gamma
Magsusc and TC Gamma AutoSonde – as good as wireline logging?

Resolution Advantages of a New Approach - AutoSonde

AutoShuttle with Spectral Gamma Shuttle

LWD Spectral Gamma Collected over 35m
- Large crystal with 6.5% energy resolution at 662 keV
- Able to clearly extract the usual K, U, Th plus new Heavy Mineral Index
- Logging performed at approx 0.3m/min
- 1024 ch data
- Spatial resolution is about 0.3m
- Reliable and robust during tests

Spectral Gamma – New Capability

New Capabilities: HMI from Spectral Gamma Data vs Core Assay: Brukunga RD01
Coiled Tube LWD - GeoSub in BHA

- GeoSub located between CT and FTP Sub
- Power and comms via existing wireline
- CT rig runs with/without GeoSub

CT Geosub Sensors/Electronics

GeoSub inner

GeoSub outer

Conclusions

Reflex and DMT have commercially available systems for logging while tripping (RC and Diamond)
DET CRC has created two viable petrophysical logging tool types AutoSonde and AutoShuttle that can be deployed on diamond drilling rigs
- A critical element is to have auto-depth capability
- Data quality must be similar to wireline or offer new capabilities
- Replacement of wireline logging for less cost in many applications
- Issues with hole collapse largely eliminated
- New measurements possible with LWD
Geological sampling from coiled tubing drilling

Ben van der Hoek
University of South Australia / DET CRC
Exploration ‘17
The Future of Mineral Exploration Drilling and Sampling Workshop

The challenge

- No core
- ~7.5 kg/m cuttings
  80-150 L/min fluid
- 200-500 mm/min ROP
  300-500 L/m drilling fluid
- Fluid additives
- Broad/coarse cutting size (0-5 mm)

Sub-sampling

Split 1
Conducted wet (i.e., 95% fluid)
12.5% of 7.5 kg
~625 g coarse cuttings (<5 mm)
- Dewater, dry, pulverise 900 g solids

Split 2
Conducted dry
~10% of 900 g
~100 g fine material (<100 µm)
- Lab-At-Rig® XRF/XRD (Olympus)

Sub-sampling equipment

- Designed modified cone splitter
- Sub-sample fluid and cuttings
- DET CRC
  Provisional Patent Application ✔
  Registered Design ✔

CT drilling sample

Representative Sampling
Sample depth

- Depth algorithm
  - Hole depth (rig data)
  - Annulus Area (bit diameter)
  - Flow rate (top-of-hole sensors)
  - Deviation (survey-while-drilling tools)

Identification of features (geochemistry)

- Identification of features (mineralogy)

Identification of features (geochemistry)

- Identification of features (mineralogy)
Acknowledgements

Thank you to the P3.2 team: Fred Blaine, Caroline Tiddy, David Giles, Yulia Uvarova, James Cleverley, Aaron Baensch, Neil Francis.

The work has been supported by the Deep Exploration Technologies CRC whose activities are funded by the Australian Government's CRC Programme.

This is DET CRC Presentation 2017/ ????.
Top-of-Hole Geochemistry and Mineralogy: State-of-the-Research

Yulia Uvarova CSIRO/DET CRC and Project 3.2 Team (CSIRO, InMex, Olympus, DET CRC) Explorations 17 The Future of Mineral Exploration Drilling and Sampling Workshop

pXRF

- Little to no sample preparation
- Fast - min reading time 10s per beam
- Elements from (Mg) to U

Portable X-ray Diffraction (pXRD)

- Portable and robust
- Little sample required (~ 10 mg)
- Very little sample preparation - crushing to <150 μm particle size
- Data collection time ~ 10 mins
- Unique piezo-harmonic vibrating cell eliminates the problem of preferred orientation

SwiftMin® - XRD data processing challenge solved!

Automated batch-processing of powder XRD data, results in seconds
Quality of pXRD data + SwiftMin®

Turning a waste stream to good

Particle size distribution

Diamond drilling cuttings – new sample medium

Proof-of-concept at Brukunga, South Australia

Laser-Induced Breakdown Spectroscopy (LIBS)
Advantages of LIBS

- No sample preparation
- Solids, liquids and gases
- Rapid analysis – both online and offline
- Almost all elements (light elements and elements that are problematic for pXRF!)
- Continuous analysis (kinetics)
- Depth profiling
- Mapping
- Chemometrics
- Portable (on Mars!)

Customised software for processing of LIBS data

Conclusions

- pXRF, pXRD and LIBS sensors available for top-of-hole analysis;
- Algorithms for data processing are being developed;
- Combined XRD-XRF-LIBS analyses offer rapid and low-cost characterization of geologic materials for mineral exploration and mining industry and deliver elemental and mineralogical information of high quality where appropriate QA/QC protocols are followed.

Acknowledgements

I’d like to thank the wonderful and brilliant Project 3.2 Team: Neil Francis, Steve Tassios, Doug Body, Monica LeGras, June Hill, Chris Ryan, Nathan Reid, Aaron Baensch, James Cleverley, Fred Blaine, David Giles and many more.

The work has been supported by the Deep Exploration Technologies CRC whose activities are funded by the Australian Government's CRC Programme.

This is DET CRC Presentation 2017/1060.
Seismic in the window of pre-drilling and sampling: state of the research

Milovan Urosevic on behalf of the team from the Department of Exploration Geophysics, Curtin University and HiSeis, Perth, WA
Andrej Bona, Roman Persyner, Sasha Znamov, Roman Egorov, Konstantin Tetyanychko, Anton Kepic, Sinem Yavuz and others from Curtin Uni & Jai Kinkela and the team from HiSeis P/L

Seismic & mineral exploration

- Many different seismic surveys, investigations and studies conducted over several decades
- Seismic has not been established as the primary exploration method in mineral industry

Why?

- Cost
- Mineral prospecting with seismic methods is not straightforward
- Imaging issues (complex geology)
- Recording difficulties (ground conditions)
- Cumbersome to analyze/interpret
- Nobody likes wiggles
- Other natural and human obstacles...

20th century seismic windows

- 3D seismic acquisition on the rise - brownfields
- 3D – PreStackTimeMigration (PSTM) - standard imaging technique
- Seismic calibration through cores and log correlation
- Borehole imaging on the rise
- Seismic data/image analysis incorporates impedance inversion, cooperative analysis/inversion, volumetric interpretation, immersive environment...

Uptake of seismic surveys for mineral exploration 2010-2017, an example

HiSeis = A small company, dedicated to application of seismic for mineral exploration, span-off by Curtin Geophysics in 2010

High quality 3D seismic image depicting very complex geology: Yilgarn, WA

Beautiful to a geophysicist
But wiggles...

What rock units do we have here? What depth? Where is the target? Need calibration...

Core samples - Rock properties
Formation’s AI and AI vs EI

Targeting VMS from seismic data

AI versus EI can provide close to unique separation of VMS
Need true relative amplitude processing to utilise AI-EI relationship

Log correlation for lithology

Strike and dip – borehole correlation

Well tie - value for seismic to geology correlation

Joint analysis, Inversion, Volumetric interpretation…

Mag and Seismic
Model-based Acoustic Impedance Inversion

Ore shoots

Al inversion to target Uranium ore-shoots

Volumetric Interpretation – from “wiggles” to geology, Cracow 3D

Very promising but can we do better?

21st century seismic windows

- New sensors (DAS, MEMS…)
- Many thousands of surface autonomous sensors
- Instrumented fields
- Full Waveform Inversion (FWI)
- Depth imaging
- No Wiggles – physical properties, lithology, geological models

Data acquisition - New developments

Distributed Acoustic Sensing (DAS)

- Measures along the whole cable length at once (up to ~10km)
- Outperforms hydrophones (and in some cases geophones)
- Cheap (<$5/m) and disposable – could go to every borehole
- Can be used to measure temperature, stress changes
- Embed in coil tubing
- Drill bit vibration sensing,
- Fluid flow/cutting transport monitoring?
- Seismic while drilling?

Why use DAS?

Continuous receivers - borehole or surface
Order of magnitude cheaper than any other seismic sensor

First test in borehole at Curtin (DEG)

Borehole and surface seismic using DAS

A concept - frequent CT boreholes for high resolution imaging

Exceptionally high data density, portability, can record 40,000 plus channels with a single interrogator
DAS technology very attractive for the mineral sector!
First field test in the world - SA

- Fracture zones correspond to core observations
- Reflections agree with lithology
- Order of magnitude faster acquisition

Benefits to mineral industry

DAS is likely to become a key new technology that could revolutionize in the first instance borehole and then surface seismic in mineral exploration

- New technology will greatly increase data density (by an order of magnitude)
- Will provide detailed 3D geological model from single and multi-well VSP surveys yielding improved targeting of extensions of mineralized bodies
- Significant cost cutting of exploration drilling
- Enable permanently instrumented mines at a very low cost (on demand imaging and constant monitoring of mine operations)
- Of particular interest to hypersaline environments where standard recording equipment will be significantly damaged or impossible to implement (mineralisation under salt lakes – widespread in WA)
- Make reflection seismic economical for green fields exploration

Data processing - New developments

Full-waveform inversion (FWI) – iterative matching of the entire recorded wavefield by forward modelling

Most suitable for borehole data due to:
- presence of direct waves (known velocity-initial model)
- high signal to noise ratio
- Broad band signal

FWI for hard rocks: P-wave velocity recovery

Starting model
1 well + fibre optic
16 shots at the surface

Recovered "Geology" that is P wave velocity

Sunrise Dam model

Eganov et al., 2017

Conclusions

General growth in 3D surface seismic and borehole seismic acquisition, advanced processing and interpretation already in practice

And then?

- Next generation seismic = DAS + FWI
- Next generation drilling = CoIL Tubing (CT)
- Next generation logging = Behind the Drill Bit (BDB)
- Next generation sampling = Lab At the Rig (LAR)

21st century exploration: CT + BDB + LAR + DAS + FWI
Progress in delivering Assay-While-Drilling

James Cleverley, Global Product Manager – Geosciences

Industry Challenge

I need to make a decision

What is the Assay?

Tophole and Downhole Integration

Top of Hole Assay - DD

Trial deployment with Barrick as part of Kickstarter partnership

- Manual proof of concept of workflow and sub-systems (TRL3), communications and data integration systems
- Delivered near real-time assay information from diamond drilling with excellent depth fidelity and resolution

Information Products

Self-Organising Map classification of Discriminant Projection of Lithological elements
Top of Hole Assay – CT Drilling
Lab-at-Rig for CT

Proof of concept: demonstrator for sample prep and assay of CT Rig sample

Dewatering, Drying, Comminution, Press and Assay (TRL2/3)

Data delivered to IMDEX HUB-IQ in ~10 mins of drilling

Near real-time Top of Hole Assay
Platform automation

What can we do now?
In-field Sample preparation and Geoanalysis

A portable sample preparation and assay solution
Setup a field lab in 20 mins

What can we do now?
In-field Sample preparation and Geoanalysis

A portable mill and met assay solution

The In-field Geoanalysis Workflow
The End-to-end Solution

Complete End-to-End Solution
The end-to-end solution
IMDEXHUB-IQ™
Delivering confidence in your data wherever you are

IMDEXHUB-IQ QA/QC Approval workflows give you confidence in the data you have collected, wherever in the world you are.

Real-time decisions?
Where should I drill hole number 2 and 3?

Regulatory Processes
People and Skills
Internal Business Processes
Shareholder Value
Geological Logging with X-ray Vision

Olympus X-ray based Sensors & Lab-At-Rig®

Aaron Baensch – Principal Geologist, International Mining Group

Olympus Scientific Solutions Americas (OSSA)

The Future of Mineral Exploration Drilling and Sampling Workshop
26th October 2017 – Toronto, Canada

Thank you to the Sponsors, Researchers & Affiliates (Past & Present)

Olympus Involvement with DET CRC

Coil Tube Drill (500m/day @ $50/m)
Downhole Sensors (Autonomous Sonde)
Lab-At-Rig® - Top-of-Hole Sensing (Real-Time Geochemistry & Mineralogy)

Three Core Research Projects:

Olympus & Olympus Scientific Solutions Americas (OSSA)

Olympus = Long history in Optics, Imaging & Sensor Technology

- 40,000 Employees, Market Cap ~US$12B, Founded Japan 1919
- Core Businesses:
  - Cameras & Audio
  - Medical, Surgical & Life Sciences (End, GI, Gyn, Urol…etc.)
  - Industrial = OSSA (HQ = Boston & Quebec)
    - Non Destructive Testing (NDT)
    - Ultrasonic
    - Phased Array
    - Eddy Current
    - Advanced NDT Solutions & Systems
    - Industrial Borescopes & Videoscopes
    - Microscopy & Optical Metrology
    - Analytical Instruments
      - X-ray Fluorescence (XRF)
      - X-ray Diffraction (XRD)

Combining XRF + XRD + Microscopy = Integrated Geoscience Solution

www.ruby.colorado.edu

Physics 101 - X-ray Fluorescence (XRF) & X-ray Diffraction (XRD)

- XRF => Elemental Chemistry (Energy Dispersive Spectroscopy)
- XRD => Quantitative Mineralogy (Fundamental Crystallography)
**OLYMPUS Scientific Solutions**

**HAND-HELD**
- GoldXpert
- Mesa / Lambda

**PORTABLE / MOBILE**
- REDWAVE
- Sorter
- X-STREAM
- Sorter

**BENCH-TOP / CUSTOM**
- X-50
- Delta Series
- Swift

**AUTOMATED / CONVEYOR**
- Fox-IQ
- Series

**OLYMPUS – XRF Products Overview (Chemistry)**

**Handheld XRF – VANTA (5th Gen Hand-Held)**
- Rugged
  - IP67 Rated – Dust & Water Proof
  - High Temperature Rating ~50C
  - Drop Tested
  - "Eye-Lid" Detector Shutter
- Revolutionary
  - Stable Hardware & Better Resolution
  - More Precise & Accurate
  - No Cal Check – Patented "Pulse"
  - Screw-less Window Change
- Productive
  - New DPP – Fast HCR
  - Wi-Fi – Cloud Enabled
  - Embedded GPS
  - New Software, Methods, Modes & GUI

**OLYMPUS – XRD Systems (Mineralogy)**
- Terra XRD = Worlds Only "Truly Portable" XRD
- BTX II = Worlds Smallest & Lowest Cost Bench-Top XRD

**OLYMPUS – XRF Products Overview (XRF Products Overview)**

**OLYMPUS – XRD Systems (Mineralogy)**
- Terra XRD = Worlds Only "Truly Portable" XRD
- BTX II = Worlds Smallest & Lowest Cost Bench-Top XRD
Mars Rover Link to Olympus

- MSL Curiosity is the 3rd Generation of Mars Rovers
  - Significantly larger Rover, powered by Radioisotope Thermoelectric Generator (RTG) to support Advanced Geo-Scientific payload and sampling tools

Sojourney (1997)
- 11.5 kg

MER (2004)
- 185 kg

MSL Curiosity (2012)
- 900 kg

- Spirit
- Opportunity
- CheMin: XRD/XRF
- APXS: Alpha Particle XRF
- ChemCam: Laser-Induced Breakdown Spectroscopy (LIBS)
- MastCam: Spectral & Optical
- MAHLI: Optical / Hand Lens
- SAM: Gas Chromatography
- Quad Pole Mass-Spec
- Raman Laser Spectrometer

LAB-AT-RIG® - Near Real-Time pXRD & pXRF for Drillhole Logging

Reflex Lab-At-Rig® Platform
- Developed within DET CRC
- Now Commercialised by Imdex (Reflex Division)
- Part of New Assay While Drilling (AWD) Business
  - Includes module for adaption to CT-Drilling (sample handling, preparation & presentation)

Real-Time Cloud Based Data Delivery via REFLEXHUB-IQ
LAB-AT-RIG® - What Can it Achieve? (Results from Brukunga SA)

Data Quality

We know the data can be good, but what can we do with it?

Automated “Geology”

Boundary detection and multiscale spatial domain

LAR Field Trials “Extremely Valuable” for Product Development

Delivered “New, Rich Data Sets” in Real 24/7 Working Environments

Partner Developments – REFLEX: Press & BYOD (ReflexHub-IQ)
What's Next? End-to-End Solutions (Reflex @ PDAC 2017)

The Future? RoXplorer & Lab-At-Rig…?

Further Reading:
Uvarova, Gazley, Cleverley, Baensch, Lawie & leGras; Representative, high spatial resolution geochemistry from diamond drill fines (powders): An example from Brukunga, South Australia; JGE Volume 170, P1-9, August 2016

Further Reading:
Uvarova, Cleverley, Baensch & Verrall, Coupled XRF and XRD analyses for rapid and low-cost characterisation of geological materials in the mineral exploration and mining industry, AAG Explore Vol. 162, March 2014

Further Reading:

Thank you to the Sponsors, Researchers & Affiliates (Past & Present)
Thank you for your attendance & attention...
The Future of Geological Survey Drilling

Dr Steve Hill
South Australia Chief Government Geologist
Geological Survey of South Australia

The role of Government....

1. Just let it happen?
   - “They are big boys and girls ... let competitive nature take care of it ... we don’t pick winners ... good luck, let us know when you are successful ...”

2. Attract, stimulate and partner?
   - “Attracting exploration investment is competitive so what can we do to give us the edge? How can we make a difference? United we stand...”

The Case for Pre-competitive Geoscience...

- **Royalties** on minerals are charged by state and territory governments, as the owners of the minerals in the ground
- Further incentives for state/territory governments to have a strong mining industry also includes employment, community economic benefit, infrastructure development, critical mass, offer best-practice resource recovery etc....
- Pre-competitive geoscience reduces exploration investment risk and provides more informed decision making
- Highlights the state/territory prospectus for mineral exploration opportunities
- Objective to host the best quality and quantity of mineral exploration for the best potential for mineral discovery and thereby sustain a strong mineral industry
- Can we afford not to support this?

Government / Private Drivers of Discovery (a.k.a. “The Magna Carter”)

- **Land Access**
- **Availability of Finance**
- **Human & Intellectual Capital**
- **Precompetitive Geoscientific Data and Information**
- **Capture and Delivery**
- **Value-add Research**
- **Underexplored / Covered Regions**
- **Targeted Programs**

**Discovery**

**Quality of Exploration**

**Quantity of Exploration**

**Greenfields**

The DISCOVERY challenge...

The covered minerals search space across 80% of South Australia!

Decreasing Discovery success

- Poorly constrained geology in covered areas
- Poor integration of geology with exploration targeting
Geoscience initiatives / strategies in support of future mineral discoveries in Australia


Addressing the discovery challenge...
- Pre-competitive surface geology mapping, geophysics, geochemistry, mineralogy, drilling...

We need to....
- Better understand and map geology in covered areas
- Map and test mineral systems under cover
- Retrieve samples from under cover for further analysis
- Develop a degree of confidence for geophysics

Geological Survey Drilling...
1. Stratigraphic Drilling
2. Collaborative Drilling
3. Mineral System Drilling
4. National Drilling Initiative?

Stratigraphic Drilling
- Traditional regional drilling to better characterise lithology and stratigraphic relationships
  - Very often the first drill hole into many rock types or settings
  - Typically become key "type" or representative sections

Example: PACE Copper – Coompana Drilling
Part of Western Gawler Craton / Coompana targeted geoscience program

- $3M collaborative program
- between GSSA and GA
- Targeting different geophysical domains
- Bourt Longyear selected as drilling service provider
- Drilling commenced 9th April 2017 for ~ 5 month program
Example: **PACE Copper – Coompana Drilling**

Part of Western Gawler Craton / Coompana targeted geoscience program

- Eight Drillholes completed
- For a total of 4560 m
- Drilling reports available shortly

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**Collaborative Drilling**

- Co-investment between Government and Industry for drilling
  - Benefit for Government:
    - Exploration investment attraction and activity (1:20 return)
    - Open file drill core and derivative data
    - Encourages bold target assessment
  - Benefit to Industry:
    - Funding support and endorsement
    - Geoscience value-add

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Example: **PACE Discovery Drilling**

7 Completed Rounds of Drilling Collaborations

- 438 drilling proposals
- 237 receiving PACE support
- 154 Complete

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**Mineral System Drilling**

- Attempts to coherently map and show vectors within a mineral system
  - Benefits:
    - More prospective / mapping approach
  - Challenges:
    - Expense
    - Justify drilling distal to main target

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**Example: South Australian Mineral System Drilling Program**

A 1580 Ma crustal section for South Australia?

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**Mapping Mineral Systems**

- Increase the size of the target
- Predict where you are within the mineral system
Key questions for 1590Ma Mineral Systems in South Australia

1. Prospectivity of the Gawler Range Volcanics (GRV)?
2. Depth of cover? (what is cover here?)
3. What was the nature of mineralizing fluid-flow?
4. What are the characteristics of mineralisation trap sites?

Where to from here?

National Drilling Initiative (NDI)

- MSDP set the scene with concept and CT Drilling Rig trials – cheaper and faster drilling...
- Regional mapping (undercover) using a drill rig instead of a geological hammer
- The next major step change for Australian pre-competitive geoscience?

In-ground value of current and mined resources from the exposed Mt Isa Inlier is ~$250 B.*

* Resources from Geoscience Australia OzMin database. In ground value calculated in AUD on commodity prices at 20 May 2016
National Drilling Initiative

- Define NDI workflow and accreditation
- Components / Themes
  1. NDI from our drilling legacy
  2. NDI in new frontiers
  3. From NDI to Knowledge

Summary / Key Points

- Evolution of Geological Survey Drilling has taken place alongside evolution of:
  - drilling and analytical technology
  - Industry requirements as they enter new exploration search space
  - The role of government and competitive investment attraction in the minerals industry

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