Geology 4.0: The final bow?

Mark Burnett: Principal Geologist
## The Four Industrial Revolutions

<table>
<thead>
<tr>
<th>Industrial Revolution</th>
<th>Timespan</th>
<th>Trigger</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>1760 - 1840</td>
<td>Steam engine and railways</td>
<td>Mechanical Production</td>
</tr>
<tr>
<td>Second</td>
<td>Late 1800’s to early 1900’s</td>
<td>Electricity and the assembly line</td>
<td>Mass Production</td>
</tr>
<tr>
<td>Third</td>
<td>1960’s to early 2000’s</td>
<td>Semiconductors, computers, internet</td>
<td>Automation</td>
</tr>
<tr>
<td>Fourth</td>
<td>Mid 2000’s onwards</td>
<td>Internet of Things (IOT) 4D Printing Hyper connectivity Virtual Reality (VR) Artificial Intelligence (AI) Intelligence Augmentation (IA)</td>
<td>“Everything”</td>
</tr>
</tbody>
</table>

[https://www.nicva.org/sites/default/files/d7content/attachments/articles/the_impact_of_the_4th_industrial_revolution_on_jobs_and_the_sector.pdf](https://www.nicva.org/sites/default/files/d7content/attachments/articles/the_impact_of_the_4th_industrial_revolution_on_jobs_and_the_sector.pdf)
## New core skills (From WEF)

<table>
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<th>2020</th>
<th>2015</th>
</tr>
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<tbody>
<tr>
<td>Complex problem solving</td>
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</tr>
<tr>
<td>Critical thinking</td>
<td>Coordinating with others</td>
</tr>
<tr>
<td>Creativity</td>
<td>People management</td>
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<td>Coordinating with others</td>
<td>Negotiation</td>
</tr>
<tr>
<td>Emotional intelligence</td>
<td>Quality control</td>
</tr>
<tr>
<td>Judgement and decision making</td>
<td>Service orientation</td>
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<td>Negotiation</td>
<td>Active listening</td>
</tr>
<tr>
<td>Cognitive flexibility</td>
<td>Creativity</td>
</tr>
</tbody>
</table>

[https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/](https://www.weforum.org/agenda/2016/01/the-10-skills-you-need-to-thrive-in-the-fourth-industrial-revolution/)
Impact on jobs

Vulnerable to automation
- Physical
- Repetitive

- Mine Surveyors (100%)
- Telemarketers (99%)
- Geologists (63%)
- Mining Engineers (13%)
- Recreational Therapists (0.3%)
Aspects that will impact geoscientists

- Robotics
- Virtual reality (VR)
- Artificial intelligence (AI)
- Intelligence augmentation (IA)
- Cross-disciplinary sciences (systems thinking)
The Geologist that was
Already adapting

https://www.researchgate.net/figure/Portable-XRF-analysers-can-be-used-in-mineral-exploration-due-to-its-easy-and-fast_fig1_283641425
Drones: old news, new applications?
Interactive geologic maps
Real-time 3D modelling
Real geology

Red Limonite

Saprolite
Implicit modelling: real models?
Coiled tube drilling

### Pros and cons

<table>
<thead>
<tr>
<th>Known technology</th>
<th>No core</th>
</tr>
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<td>Continuous drilling</td>
<td>Chips recovered from a fluid</td>
</tr>
<tr>
<td>Increased rate of penetration</td>
<td>Sample representativity</td>
</tr>
<tr>
<td>Safer (fewer people)</td>
<td>Not designed for metal exploration</td>
</tr>
<tr>
<td>Lower environmental impact</td>
<td>Cost-effective prospecting tool</td>
</tr>
</tbody>
</table>


Top-of-hole geochemistry

- Uses diamond drillhole cuttings, i.e. chips.
- Laser-induced breakdown spectroscopy (LIBS) (DET Deep Exploration Technologies).
- X-ray (Olympus).
- Uses self-organizing maps.
Rich data sets in real time
But what about my core?

- Repetitive task (80% capture, 20% processing)
- Inconsistencies between geologists
- Relogging expensive and time consuming
Case study

- Major company required all exploration core to be logged and validated in a very short space of time.
- Historical inconsistencies in database.
- Apparently complex geology.
- Automated core scan + machine learning algorithm.


https://pdfs.semanticscholar.org/7486/2ac7ad0a4f56f18a6f1bd695e38d3f3ebd9a75.pdf
Case study

- All core logged on time and under-budget.
- Average logging rate of 1,000 m/day (one machine).
- Included first-pass geotechnical and structural logging.
- Machine classified lithology 91% accurate.
- Consistent, electronic database available for analysis and modelling.
The Machine
Big data

Watson is learning to think like a geologist
IBM Watson & Goldcorp

#IBMIndustrial
Large data—case study

GLOBAL SEARCH CHALLENGE

The Global Search Challenge is designed to recognize, reward and promote exploration excellence. We encourage you to Show Us Your Best exploration ideas and properties. Cash prizes will be awarded every 4 months. Selected submissions will be featured in our showcase. In addition we are prepared to offer financing to the winning proposals.

The Global Search is building on Goldcorp’s very successful internet goldrush, “The Challenge”, launched in March 2006. Our objective is to identify, assist and promote the individuals, teams and organizations with the Best probability of discovering important mineral deposits of the 21st century.

REGISTER TODAY! SHOW US YOUR BEST!

www.goldcorp.com
The challenge

• In March 2000, Goldcorp Inc. invited contestants from all over the world to submit exploration proposals for its Red Lake Mine Property.

• The contest was named “The Challenge”.

• Each proposal had to be: concise, identify specific targets, be supported by appropriate geological reasoning, and be submitted by e-mail in the English language.

• Proposals could be submitted by individuals or by teams.

• Geological information about the Property was available by CD-Rom and supplemented with additional information on the web site (http://www.goldcorpchallenge.com/ challenge.homepagesatic.html).
The results

- More than 110 sites were identified.
- Half of these were previously unknown to the company.
- Of these new targets, more than 80% yielded significant gold reserves.
- The then CEO, was of the opinion that process cut two to three years off the company’s exploration timeline.
- The estimated value of the targets was estimated at being worth than USD6 billion in value.
- The prize money was only a little over half-a-million dollars.
The new tools – in summary

- Automated drill rigs.
- Real-time monitoring.
- Real-time downhole geophysics.
- Real-time sample analysis and systems.
- Hyperspectral analysis.
- Big data integration and analysis.

Education and training
The field in the classroom
Virtual outcrop mapping

http://gigapan.com/galleries/10319/gigapans/12322
Virtual outcrop mapping

http://gigapan.com/galleries/10310/gigapans/123221

www.amcconsultants.com
Analogue underground mapping
Virtually underground
Full immersion deposit modeling
The next step?

Unmanned unattended mineral exploration drilling and sample return system
Dave Lowell’s 9 rules

- Ore is rock which can be mined at a profit.
- Mines are found in the field, not the office.
- Mines are found by drilling holes.
- Exploration is a cost-benefit business.
- High-tech devices and geophysical surveys are very rarely of value in mine discovery.

Dave Lowell’s 9 rules

- It is important to have a good understanding of the target you are looking for, including understanding some mining engineering, metallurgy, mine finance, and mineral economics.
- Mineral exploration has a very low probability of success.
- Finding mines is a high-risk business.
- Plan your own exploration project.
What does it mean for me?

- Geological understanding will always be the most important skill in building valid geological models.
- Implicit modelling will provide maximum benefit from the flood of real-time geoscience data.
- Geoscientists must develop multi-discipline skill sets.
- Understand the requirements of all downstream customers of resource models.


www.amcconsultants.com
Thank you