Innovation in Exploration

F. Robert
Outline

• Exploration challenges
• Industry response
• Exploration Innovation Consortium
  – Historical background
  – Footprint project
  – Now and Future
• Lessons & recommendations
Need discoveries to sustain healthy mining industry. But…

• Mining camps maturing
• Discoveries getting deeper
• Global discovery rates down
  – Only 45% become producers
  – 12.4 years to production!
• Costs increasing

Also need quality discoveries

• 80% metal in top 20% mines
• Need Tier 1 discoveries

From Schodde (2015)

Canadian discoveries: only 3 “Tier 1” / decade
Industry response

• Becoming more engaged & proactive
• Driving development of relevant R&D Programs
  – Facilitated by groups like AMIRA or CMIC
• Two examples:
  – Deep Exploration Technology CRC (Australia)
  – CMIC “Footprint” Project (Canada)
• 2 aspects of innovation: technology and concept
Deep Exploration Technology CRC

• AU $61M cash and $93M in-kind (2010-2018)
  – $28M cash from Australian Gov’t

• Sponsors: Industry, Service Providers, Research Organizations, Gov’t agencies
  – 13 Core partners ($450K/y)
  – 24 Affiliate Sponsors ($10K/y)

• ~90 researchers in 10 organizations
  – 52 graduate students

• Incorporated entity with independent board
Deep Exploration Technology CRC

- **Industry-driven program**
  - Reduce time & cost of drilling
  - Improve value from drilling

- **Step-change technologies for “deep” exploration**
  - Coiled tubing drilling
  - Down-hole sensing
  - Top-of-hole sensing: Lab-at-Rig

Cheaper, faster, safer drilling
- 50m/h, 500m depth, $50/m
- <10 tonnes & small footprint
DET-CRC: Lab-at-Rig

- Portable semi-automated lab
- Quantitative mineralogy & chemistry from drill muds
- Data back in <12h: ~real-time
CMIC Exploration Innovation Consortium

- Created 2010 under CMIC
  - Industry-driven

- Vision:
  - Improve discovery rates through step-changing innovation and targeted R&D

- Objectives:
  - Define exploration challenges
  - Develop R&D roadmap
  - Catalyst for R&D projects

- ~35 Partners
  - Exploration companies
  - Service providers
  - Institutions

- How was it done?
  - Extensive consultation
  - Part-time consultant (Tosdal)
  - Full time CMIC person (Galley)
  - Dedicated Industry champions
## Critical Research Areas

<table>
<thead>
<tr>
<th>Themes</th>
<th>Discovery Criteria</th>
<th>Discovery Technology</th>
<th>Data to Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Focus</strong></td>
<td>Knowledge and models</td>
<td>Detection &amp; Delineation</td>
<td>Interpretation</td>
</tr>
<tr>
<td><strong>Key Questions</strong></td>
<td>• Where to look?</td>
<td>• How to best detect?</td>
<td>• What do the data mean?</td>
</tr>
<tr>
<td></td>
<td>• What to look for?</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Exploration Challenges</strong></td>
<td>• Terrane selection</td>
<td>• Mapping and detection tools</td>
<td>• Visualization and integration</td>
</tr>
<tr>
<td></td>
<td>• Area selection</td>
<td>• Cheaper drilling</td>
<td>• Physical property models</td>
</tr>
<tr>
<td></td>
<td>• Vectoring to ore</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Education & Technology Transfer**
# 10 year Exploration R&D Program

<table>
<thead>
<tr>
<th>Deep Mature Camps</th>
<th>Remote &amp; Covered Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Multi-parameter footprints and 3D vectoring</strong></td>
<td>1. Characteristics of fertile terranes and districts</td>
</tr>
<tr>
<td>• <em>Detecting edges and vectoring to ore</em></td>
<td>• <em>How to identify most fertile areas?</em></td>
</tr>
<tr>
<td>2. Techniques to unravel deep 3D geology</td>
<td>2. Techniques to map sub-surface geology</td>
</tr>
<tr>
<td>• <em>Deep penetrating detection and mapping techniques</em></td>
<td>• <em>Drilling, data integration</em></td>
</tr>
<tr>
<td>• <em>Data density for detection</em></td>
<td>• <em>Data density for detection</em></td>
</tr>
<tr>
<td>• <em>Real-time decision</em></td>
<td>• <em>Understand mechanisms</em></td>
</tr>
<tr>
<td></td>
<td>• <em>Develop techniques</em></td>
</tr>
</tbody>
</table>
Footprint Project

- Objective: develop new approach for subtle distal footprints detection + vectors to ore = discovery of concealed deposits
- 5-year program, $13M budget (now in Y4)
  - Largest CRD granted by NSERC
- 28 company sponsors, 45 researchers, 24 Canadian universities, and Gov’t partners
- Silo-breaking collaborative effort between Industry, Researchers and Service Providers
Footprints Project

• Concept
  – Multiple parameters on same sample suites, same deposits
  – Integration: big data analytics
  – Better response

• 3 study sites, 3 commodities
Footprints Project: Key results

Increased footprint size

Data integrated in “Common Earth” model
Other R&D projects considered (2012-15)

- **Exploration-focused**
  - Permafrost drilling
  - Lightweight heli-portable drill
  - Muon technology
  - Exploration Simulator

- **Impact across LOM stages**
  - Real-time portable analyzer
  - Mine-based rock mass characterization
  - Iron Ore R&D Consortium

But no success!
EIC Next Steps: Footprints II

Remote & Covered Areas

1. Characteristics of fertile terranes and districts
   - How to identify most fertile areas?

2. Techniques to map sub-surface geology
   - Drilling, data integration
   - Data density for detection

3. Secondary dispersion
   - Understand mechanisms
   - Develop techniques

- Exploring through cover
  - Focus: surficial geochemistry.
  - Industry expert group formed
  - Project scope being defined
**EIC Next Steps: contribute to TZWM**

- Innovation portfolios impacting multiple business areas

<table>
<thead>
<tr>
<th>CMIC Portfolios</th>
<th>Increasing Mining Intensity</th>
<th>Decreasing Energy Intensity</th>
<th>Increasing Labour Productivity</th>
<th>Decreasing Capital Intensity</th>
<th>Safety, CSR &amp; Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underground Mining</td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy / Processing</td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Management</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>
Lessons learned

• Focus on relevant problems
• Industry-driven focus, research-driven delivery
• 3 year projects better
• Need strong champions
  – From Industry & Research
• Proactive communication

Keys to successful RDI

• Catalyzing Vehicle - CMIC
• Vision & unifying initiative
  – TZWM proposal
• Support from Senior Industry Leaders
• Adequate Gov’t funding
• …and timing!