

The Economic and Social Benefits of Mining and Metallurgical in Canada

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**THE ECONOMIC BENEFITS OF
RESEARCH AND DEVELOPMENT
IN THE CANADIAN MINING
AND METALLURGY SECTOR**

Peter Warran, PhD



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Canada



Analytical Framework

- Economic Agent: Vertically Integrated Mining Corporation
- Research and Development are the primary driver of value in the Corporation in Primary Metals companies



Four Economic Arguments

1. Metallurgy has made significant contributions to the Canadian economy and society.
2. R&D is the fundamental value creator of the corporation.
3. The downward “tipping point” for Canadian mining and metallurgy happened earlier than is widely believed.
4. Canadian expertise and potential for innovation in metallurgy still exist, but in a different form.



Economic & Social Benefits

- Benefits that flow to the economy and society from mining and metallurgy.
 - Benefits to the Firm: Operating companies seek improvements in efficiency, yield, and estimated reserves.
 - Social Benefits: Employment, safety, health, and environment.
 - Benefits to the Economy: Technology innovation and movement to Industry 4.0.

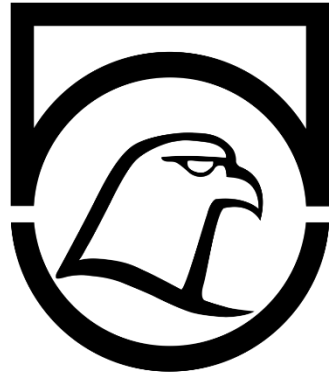


Outline

- Canada in the Golden Age
 - Stelco
 - Inco
- New Mining Age
 - Hatch
- Current Mining Economic Debates
- Future of Mining
- Policy Implications



INCO



Great Canadian Metallurgy Centres

- WW2-Postwar Economy: Base Metals surpass Precious Metals
- In the Day: Golden Age of Canadian Metallurgy 1950-1990
 - Corporate R&D Centres
 - Inco, Falconbridge, Alcan, Noranda, Cominco, Stelco
 - Universities: Schools of Mines
 - Government: Federal Ministry of National Resources:
- Canada as World Metallurgy Leaders
 - Patents, technology transfer around the world
- Sheridan Park, Ontario: Link Mining & Manufacturing



Paradise Lost

- Diffusion of talent from Corporate Centres
 - Consultancy
 - Universities
 - Government Labs
- Inter-Disciplinary Knowledge
 - Role of Geo Science, Engineering, Data Science
 - Global Knowledge Flows



Margaret B. W. Graham
Bettye H. Pruitt

R&D for Industry

A Century of Technical Innovation at Alcoa

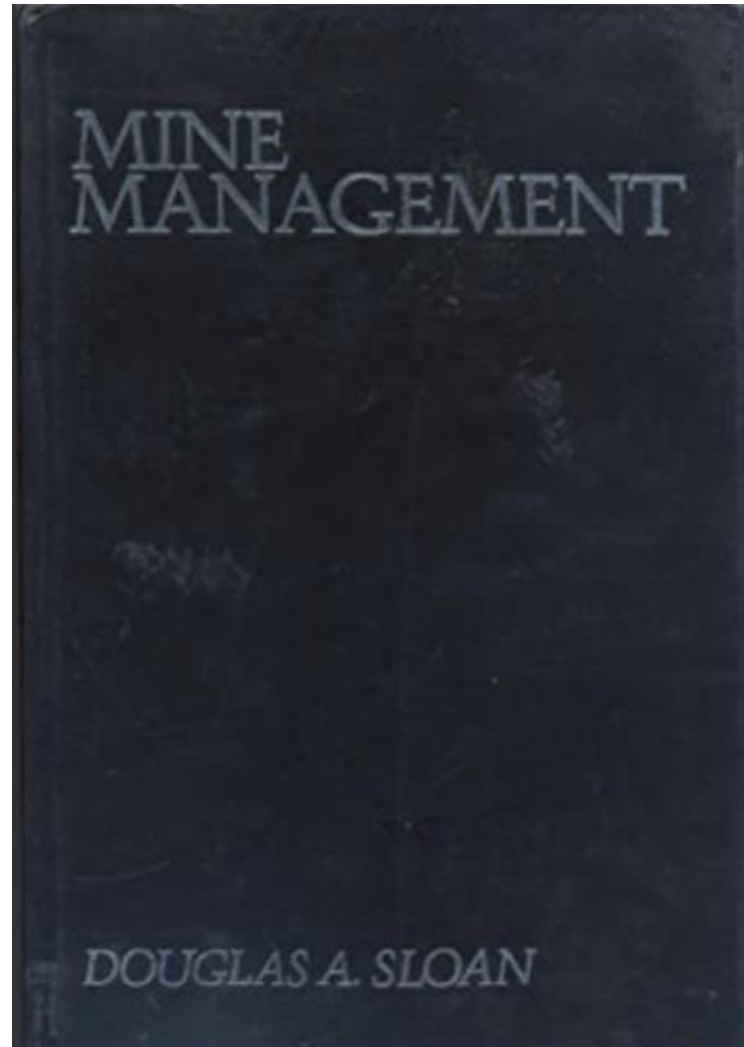


Graham: R&D in Process-Based Industries

- Base Metals Industry: R&D creates the Fundamental Value of the Corporation. Alcoa example, postwar consumer household products, aluminum beverage can.
- Inherently Hi Cost, Complex and Risky: Scale-Up from Bench to Plant
 - Production Interruptions, organizational conflicts, old procedures.
- Inherently Multi-Disciplinary: Science, Engineering, Shop Floor Knowhow
- Managerial & Organizational Cohesion. Change Management.



D.A Sloane, **Mine Management**. (New York, Chapman & Hall 1983)



DA Sloane, Mine Management (1983)

- New formal management system to replace traditional tacit knowledge: Blacksmith' Culture in underground mining.
- Systematic measurement and procedures for comprehensive planning and Management by Objectives
- Unintended Consequence: System of incentive and Bonus plans for supervisors undermined movement to robotics and tele-operating in underground mining when Inco was the global leader in the 1990s.



Two Tales of Mining & Metallurgy

- The transformation in mining and metallurgy can be summarized in two narrative threads.
- The Downside Inco Story, we encounter a Golden Age followed by corporate decline and marginalization of metallurgy.
- The Upside Hatch Story, we see the dramatic growth of a small engineering consulting firm from, in the period of Inco's decline, a 600-person to a 6,000-person operation, and eventually to what we have today: a global mining and metallurgy consultancy encompassing the expertise of 9,000 staff.





The Steel Company of Canada



Stelco Case

- Steel in puts (iron ore & met coal) by volume amount to most of the physical activity in global mining.
- Steel companies used to own their own mines. Cliffs-Arcelor NA.
- Example of the critical links of mining to manufacturing. Major concern of Canadian governments.
- Critical lesson: how product development is embedded in process improvements.



Auto Materials to Manufacturing Value Chain

Exploration & Extraction



Mineral Processing



Product Development



Stelco Research

- 1940s-60s. On site “Works” laboratory. Special Projects.
- 1960s-80s. R&D Centre. Role as hub for technical knowledge diffusion across the corporation. Led the steel industry.
- 1980s-2000. Loss of pricing oligopoly. No longer ‘affordable’. Reduced to technical services to operating departments.
- Sold off its IP. The Stelco Coil Box was sold to Hatch.



inco



Inco

- In its heyday, Inco was one of the world's largest operating companies in the mining industry and was a global leader in metallurgy.
- Most of that technical capacity is now lost.
- Across the industry, the relative marginalization and decline of metallurgy has been most associated with widespread downsizing related to the global consolidation of mining companies in the first decade of the new century.



Primary Research



Drilling
Extraction
Mineral Processing

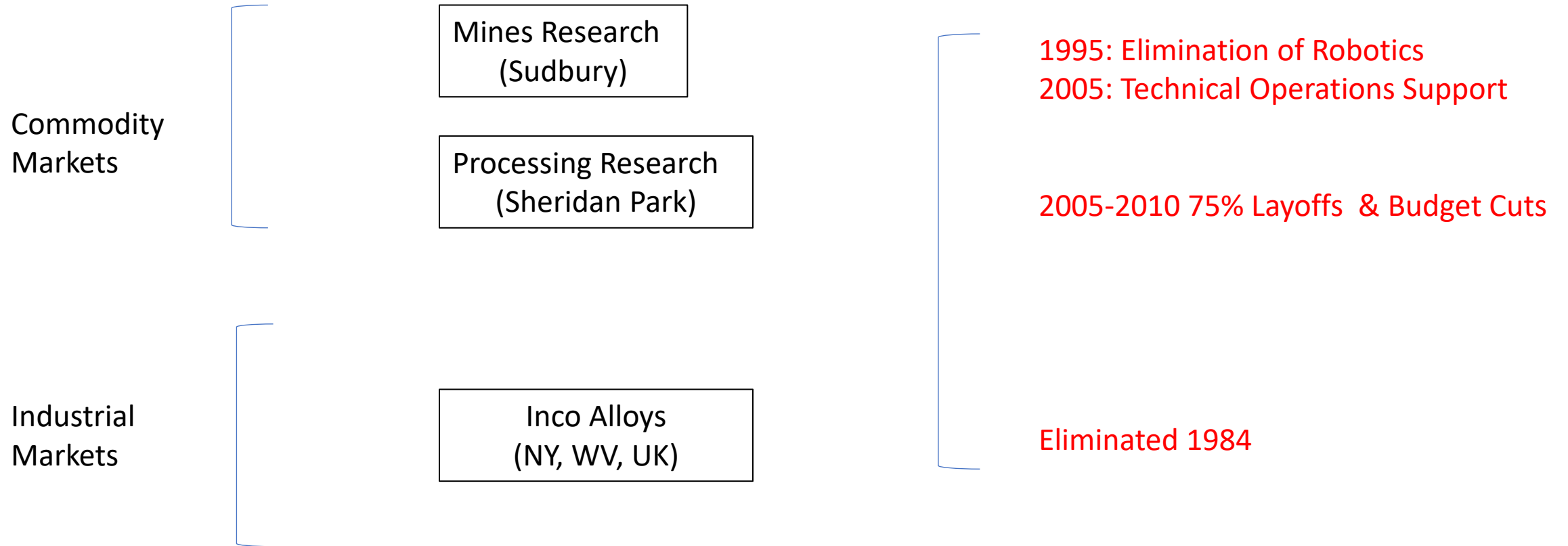
Product Development



Alloys
Powders
Stainless



Inco R&D Cuts



HATCH

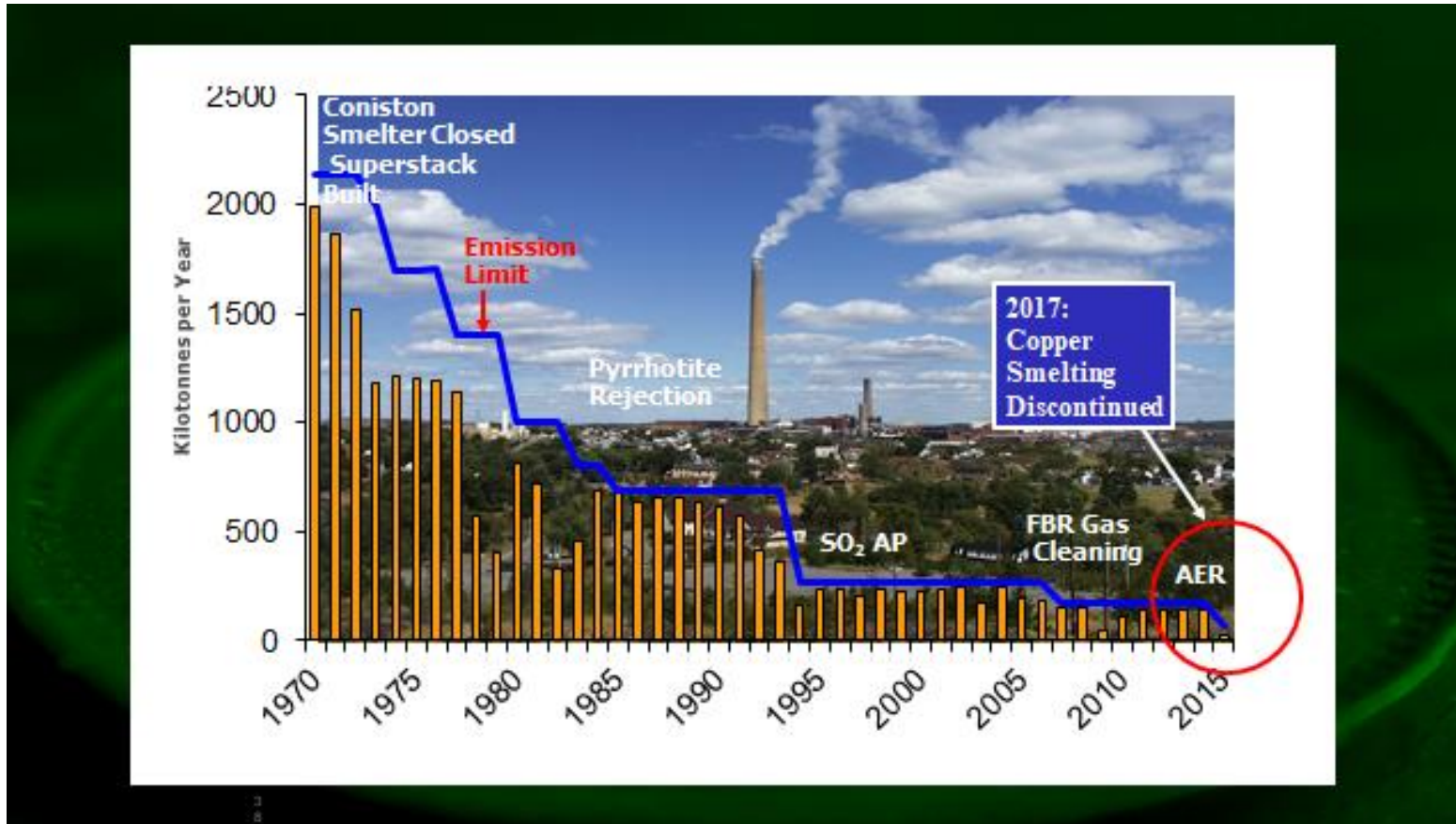


Rise of Hatch Engineering

- From 1995 to 2005, while Inco was declining from 40,000 to 10,000 people, Hatch was growing from 600 to 6000 people.
- Reflects the changes in the relations between mining operating companies and supply and service providers. Also the circulation, recruitment and retention of met talent in the industry.
- Hatch moves from engineering services to technology development and IP.
- Hatch Hall of Fame technology cases: Furnace Cooling, The Coilbox, Tube Digestion, IAS Industrial Automation. Three of these involved the purchase of technologies from metals companies.



Inco SO₂ Abatement



Lessons from the Inco-Hatch SO₂ Case

- Great example of joint efforts to deal with Canadian mining and environmental improvements. Circulation of met talent over time.
- Very different expertise brought from each side. Hatch technical innovation developments always needed parameter adjustments and 'fit' that only operators have.
- Policy implication: If Canada does not remain active in primary metallurgy research and development at the producer level, then a purely IP market strategy by itself will be self-limited and how sub-optimal benefits to the economy.



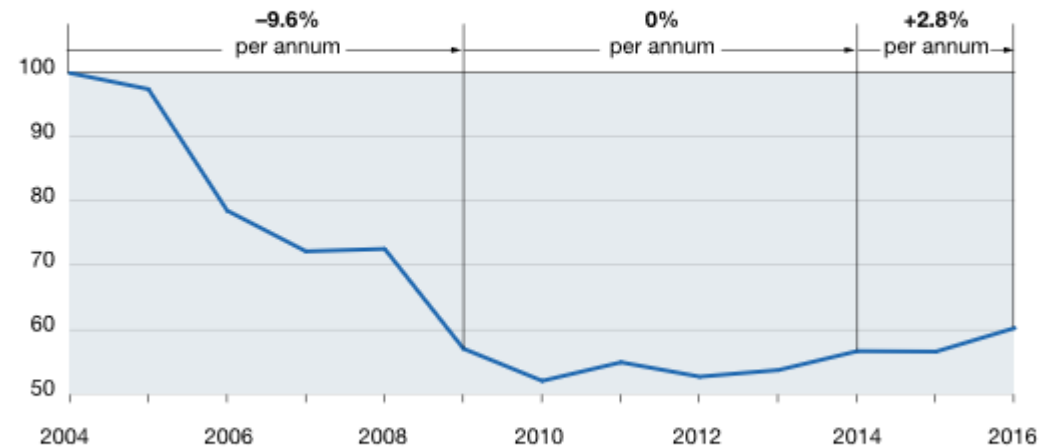
Current Debates in Mining Economics



Mine Productivity Trend (Final Product Output per Person Employed)

Since 2014, mining productivity has begun to reverse course with a gradual increase.

MineLens Productivity Index (MPI), index (2004 = 100)



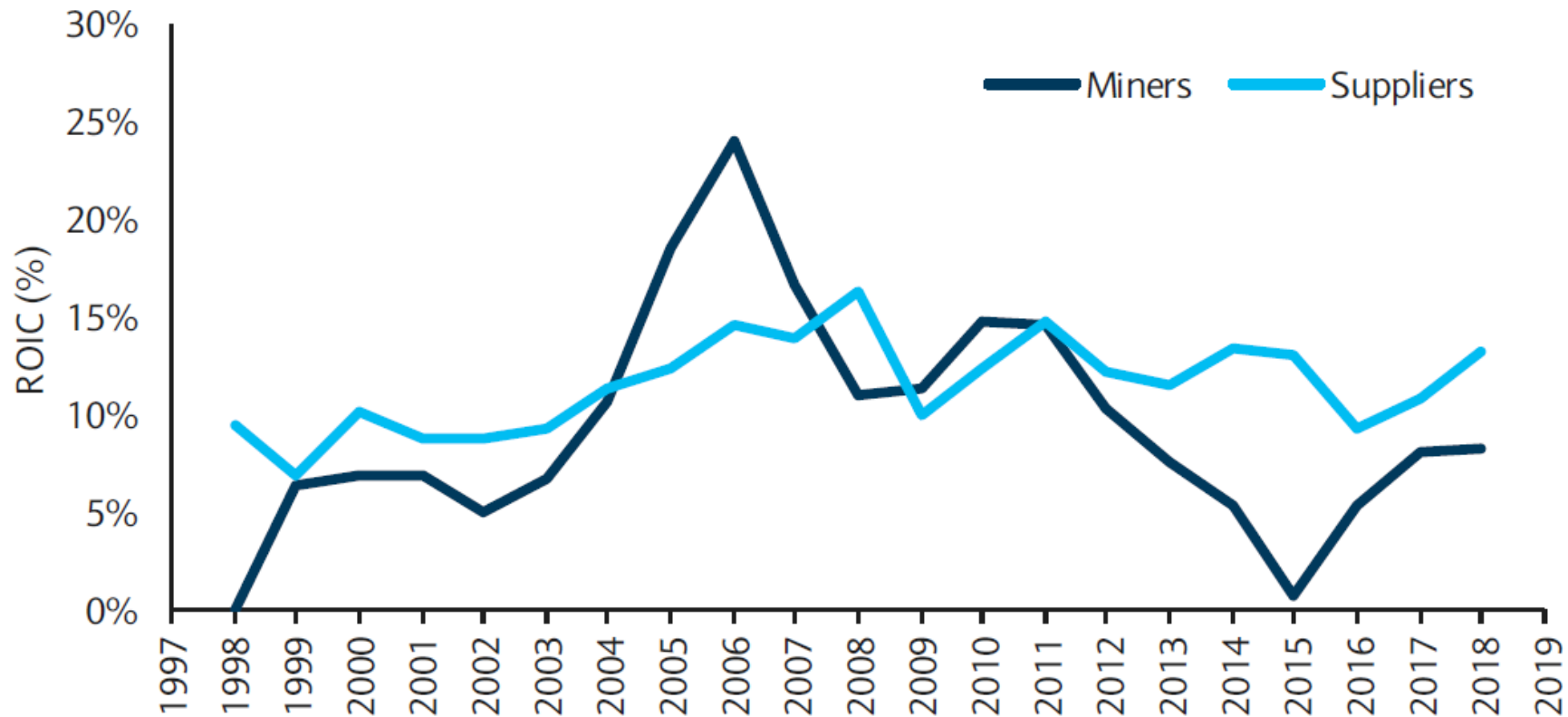
McKinsey&Company | Source: Company reports and websites; MineLens by McKinsey; McKinsey analysis

Source: (McKinsey 2018)



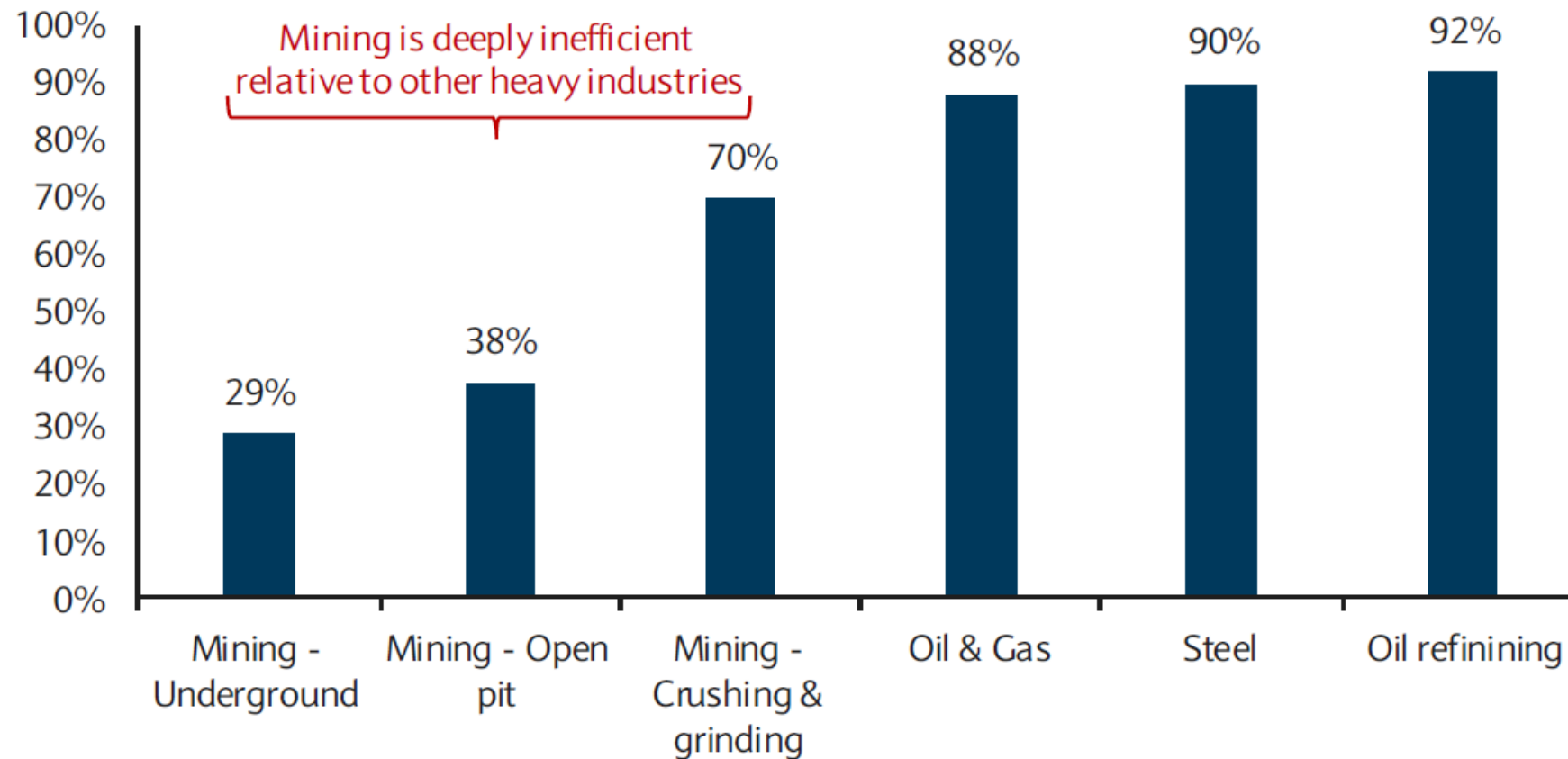
ROI Miners vs Suppliers

Return on invested capital – suppliers capturing more value than usual



Equipment Utilization Rates

The mining industry has very low equipment utilization rates, notably in underground



Future of Underground Mining

- Growing need for underground mining solutions.
- UG mining as a percentage of total contribution to mining market value will grow from 37% in 2017 to 43% in 2040.
- Hard-rock mining will grow from 36% of UG mining to 46% of UG mining.
- Growth estimates provide a strong market opportunity for continuous mining solutions.



Future Scenarios

- Humphreys economic scenario
 - The industry as a whole will never be able to overcome the productivity lag of the early 2000s. It will take a fundamental shift in typical mining business models, to a circular economy rental model, to add value to the underlying resource. Producers would be able to received revenues on multiple product cycles instead of one-and-done.
- Barclays Scenario
 - Technical innovation can overcome market surplus and a reduced hurdle rate. Some producers will make it and some won't. Multi-site operators with the ability to scale will succeed, providing that they have the resources to make the investments and have near-term implementable technologies.

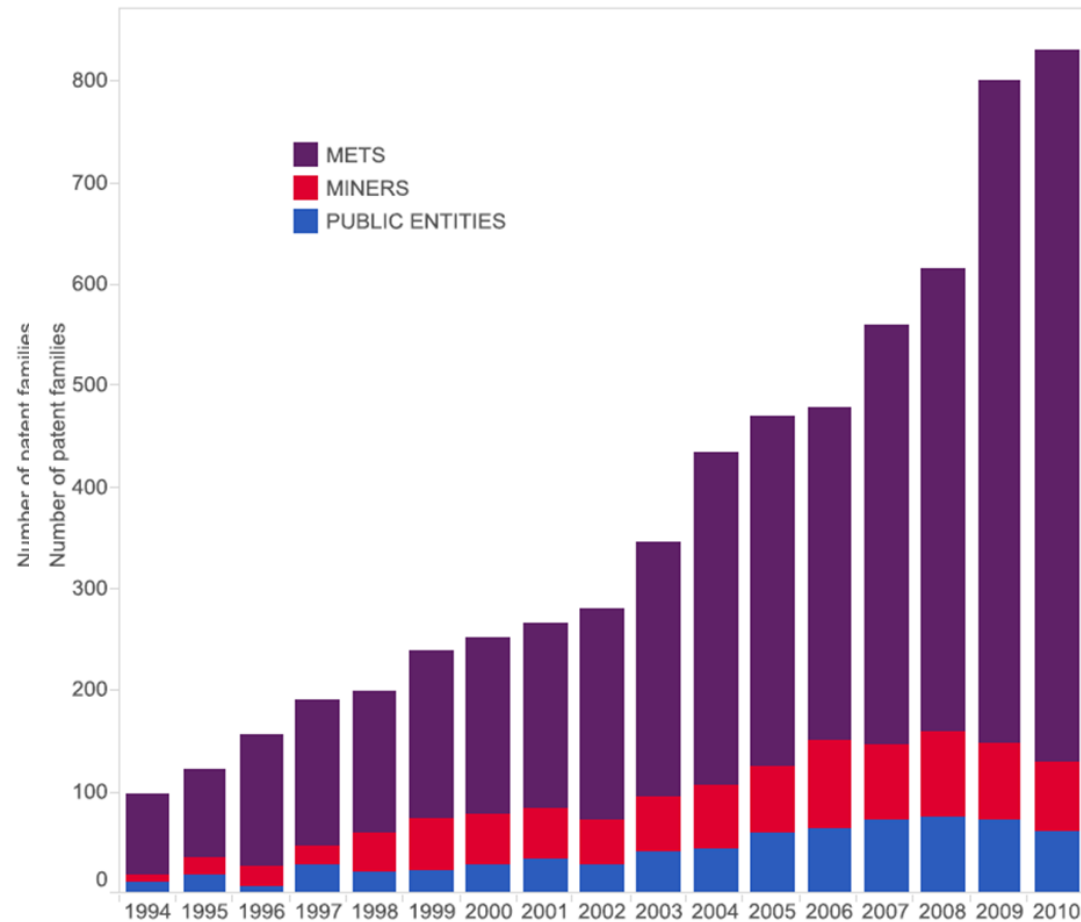


What's Next: Drivers of Change



Innovation, Patents & Mining Supply Chain

METS: Mining Equipment,
Technology & Services Firms



Source: PATSTAT April 2013



Two Speed Mining 1

- Tech Scenario 1:
 - Digital Technologies lead in Precious Metals Exploration and Development
 - Base metals incrementalism dominated by OEMs.
 - Tech SMEs at the Margin
- Tech Scenario 2:
 - Precious Metals driven by crisis in Reserves.
 - Base Metals: Discovery Rate and Scale crisis of productivity



Two Speed Mining 2

- Economic Scenario 1:
 - (Humphreys 2019): The Industry will never overcome the productivity lag
 - Change Business Model in Mining to a Circular Economy rental model to add value to the underlying resource
- Economic Scenario 2:
 - (Barclays 2019): Technical innovation can overcome market surplus and reduced Hurdle Price to sustain 15% ROI.
 - Some will some won't. Multi-Site operators with ability to scale. And resources and implementable technologies.



Innovation Dynamics of the Extractive Industries

- Extractive Industries:
 - Highly Cyclical Commodity Markets
 - Dominance Global Operating Companies
 - Unique Properties of Local Knowledge and Technology
 - Reserves: Harsh Environments: NL Ice
 - Sudbury Ore Bodies: Deep Mining
- Changing Dynamics of Innovation in Supply Chains
 - Traditional Equipment Suppliers: Incrementalism
 - New Role of Service Companies in Supply Chains
 - Increased Role of Public Research Infrastructure



Sudbury Mining Supply Chain

- 1890-1980s
 - Canadian-Based Vertically Integrated Mining Companies. Inco, Falconbridge
 - Small local & domestic suppliers
 - Operators drive innovation. Lot of international knowledge transfer
- 1990-2010
 - Global Mining Consolidation
 - Scaling down of In-house Technical Expertise
 - Innovation: Equipment OEMs
- 2010 - Present.
 - Collaborative Innovation networks CMIC, CEMI
 - Emergence of Tier 1 Service Firms. Deloitte, Hatch, Stantec

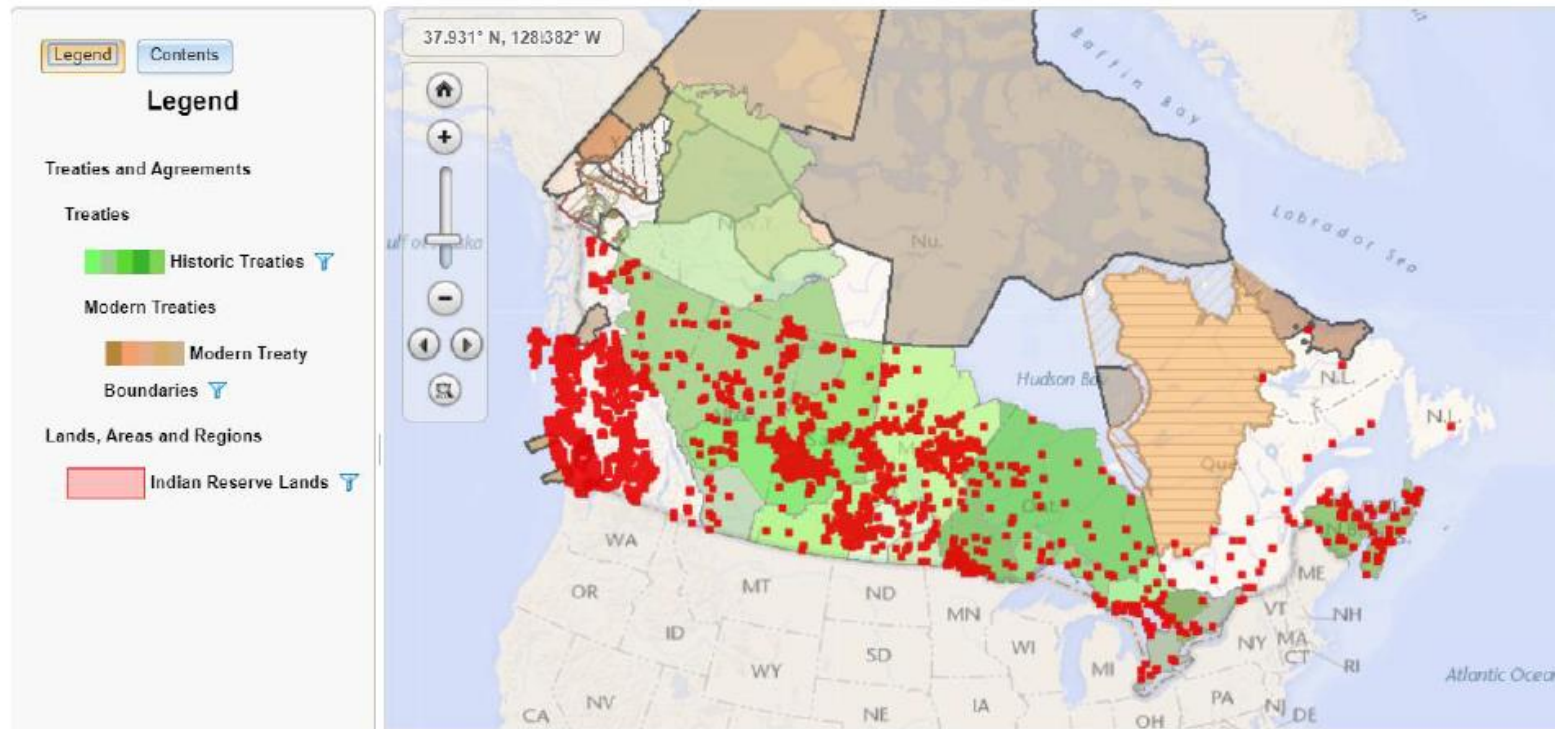


Shifting Boundaries of the Firm

- The innovations literature point to the impact of digital technologies on established forms of industrial organization. Specifically it changes that boundaries of the firm.
- Boundaries:
 - Between the Vertically Integrated Firm and the Supply Chain of materials, equipment and service Providers.
 - Extractive Industries are converging with the Advanced Manufacturing Model.
- Indigenous Communities
 - Boundaries of the Firm align with the Watersheds of Local Communities
 - Econometrics: Benefit Agreements Increase Enterprise Value of the Firm



Indigenous People's Property Rights



Conclusion

- Can the Canadian mining industry of today contribute what the world-leading mining and metallurgy companies of the past did in the Golden Age?
- The answer is “No”. But that may not be the right question.



Different Question, Different Answer

- Even before the foreign takeovers and consolidations of the 2000–2010 period, the system of innovation in mining was changing from an individual corporate function to a networked system of innovation.
- The industry in future may be able to make a broader contribution to the economy and society than in the past, when the economic benefits of innovations flowed mainly to individual firms.

