Innovation in Mineral Processing: 
*Distinguished Past and Uncertain Future*

*The AusIMM Delprat Lecture, 2016*

Tim Napier-Munn

JKMRC/JKTech
Delprat Lecturers

• **Mike Nelson** – Innovation in flotation technology
• **Alban Lynch** – Mineral processing in the 20th cent.
• **Graeme Jameson** – Size matters: coarse & quick flotation can reduce costs
• **John Ralston** – 21st cent. challenges in the chemistry of mineral processing
• **Bill Johnson** – Future mineral processing challenges
• **Tim Napier-Munn** – Innovation in mineral processing
Thanks to …..

- **Rob Dunne** (formerly Group Exec. Fellow, Metallurgy, Newmont)
- **Neil Jagger** (formerly CEO, Outotec Asia Pacific)
- **Graeme Jameson** (Laureate Prof, Uni of Newcastle)
- **John McGagh** (formerly Head T&I, Rio Tinto)
- **Joe Pease** (formerly CEO, Glencore Technology)
- **Neville Plint** (Former Head, BI Projects (CEL), Anglo American. Now Director, SMI, UQ)
Innovation

• Invention vs innovation

• Many kinds of innovation:
  - IR, WH&S, finance, procurement, management, environmental, social, exploration, mining, minproc, extraction met.

• Innovation is not optional
Guillaume Delprat – Innovator
BHP General Manager, 1899-1921

From ‘History of Flotation’ by Lynch, Harbort, Nelson (AusIMM)
Why did Delprat succeed?

1. A **crisis** – difficulty in processing the Broken Hill sulfides.
2. Competition between the BH mines.
3. Collaboration with others.
4. A skilled technologist.
5. An entrepreneurial nature.
6. A GM’s power.
The need for innovation
Mining Multifactor Productivity, Australia

ABS, 2015
Miners bracing for ‘doomsday’

SCOTT PATTERSON

Mining executives, welcome to your worst-case scenarios.

Glencore chief executive Ivan Glasenberg rejected predictions that copper would fall below $US4000 a tonne, dubbing it a "doomsday" price. Rio Tinto chief executive Sam Walsh last year said the idea that iron-ore prices would fall to $US30 a tonne was from "fantasy land."

Since Mr. Glasenberg's comments in September, copper prices have tumbled nearly 20 per cent, falling close to $US4300 a tonne. It has risen in recent days, but was down 13 per cent at $US4530 in London on Thursday and an increasing number of analysts are now saying prices will go below $US4000 soon.

Iron ore was changing hands for more than $US60 a tonne when Mr. Walsh made his remarks last February, but it plummeted to below $US40 a tonne in recent weeks, and now $US30 a tonne appears within reach. It fell 1 per cent on Tuesday to $US40.80, and some analysts think it could fall into the $US20s this year.

Spokesmen for Glencore and Rio Tinto declined to comment.

The vicious fall in commodity prices is upending the forecasts of the leaders of the world's top commodities companies and scrambling their plans to cope with the worst rout in decades. Some of the high-stakes strategies are being torn apart.

"We all know China is bad. The question is how bad, and the lack of transparency is causing a lot of uncertainty."

SCOTT STEWART, BLACK-HAWK RESOURCES
Tarnished and tattered: metals, and mining stocks
After a boom of historic proportions prices among some metals are alarmingly low, and the resulting collapse in mining stocks rivals two other epic stock-sector busts

Change since January 1980 in the prices of a weighted basket of metals, monthly data*

Copper prices
Kerb prices on the London Metal Exchange
$US per tonne

How each sector failed in the four-plus years after a peak
Global metals and mining stocks**
Peak: Feb 5, 2012
Global financial company stocks***
Peak: May 23, 2007
Pre-Lehman Brothers collapse
Nasdaq 100, post dom.com bubble Peak: March 24, 2000

Iron ore spot price
$US dry tonne

*Calculated from IMF price indexes for copper, aluminium, iron ore, tin, nickel, lead, zinc, and uranium until December 2015 **MSCI Word indexes, in US dollar terms; metals and mining stock are up to Jan 28
Source: WSI

ces slid following years of booming demand from Japan. Investors said recently. Price declines since
from the year before, their third straight year of decline. In monetary terms, they fell 19 per cent to...
Mining bust driving innovation: Stokes

MINING: Rio Tinto believes it can maintain its position as a leader in innovation despite weakness in the commodities sector.

Rio’s chief executive of iron ore, Andrew Harding, said encouraging investment in innovation over the longer term was “not insurmountable”.

The miner could accelerate its basis, and that’s what will keep us in front,” Mr Harding told a business lunch in Perth.

The Mine of the Future project involves driverless trucks and trains, and a central control centre in Perth.

Mr Harding said investors did not want to be significantly exposed to innovation when they
“A key focus of our government is innovation. We need to be more innovative, we need to be more technologically sophisticated”.

Malcolm Turnbull, Nov. 2015
No more innovation necessary!
No more innovation necessary

Mineral processing’s crocodile

1932

2016
Some MinProc Innovations Since 1948

- Increases in scale
- Dense medium cyclone
- CIP/CIL
- Knelson, Falcon, InLine Pressure Jig
- High pressure grinding rolls
- High intensity flotation (eg Jameson cell)
- AG/SAG mills
- Fine grinding (eg IsaMill, Vertimill)
- Hi-rate thickeners
- High intensity mag seps
- Selective flotn. & flocc. reagents
- Analytical chemistry
- Automated quantitative mineralogy
- Process simulation
- OSA & other instrumentation
- Process control & DCS
Some Case Studies of Innovation

- Increases in scale
- High pressure grinding rolls
- Jameson flotation cell
- Automated quantitative mineralogy
- The MIM Pb/Zn story
- Process simulators
Innovation in SCALE

Is it running out of puff?
Mills 1970s

2.7 x 2.4 m mills
Mufulira

Picture courtesy Elaine Wightman
Mills 2016

12.3 x 10.0m 28 MW (Sino Iron, WA)
Flotation 1959

1.3 m³ cells

Picture courtesy Elaine Wightman
Flotation 2016  600 m$^3$ cell
Flotation 2016  630 m$^3$ cell
Lessons from the story of Scale

- Almost all scale development is done by vendors.
- Main drivers are opex/capex, and competition.
- Enabling technologies important (eg materials, CAD).
- Can we increase scale indefinitely? Or are we running out of options?
The High Pressure Grinding Rolls

Prof. Klaus Schonert

Tim Napier-Munn, JKMRC/JKTech
Lessons from the HPGR story

• Began in academia, in an industrial context.
• Innovation came from another industry (cement).
• First application driven by perceived special benefit (diamond liberation).
• Over 25 years to maturity.
• Roll wear problem solved by manufacturers.
• Patent protection, defence and licensing key.
The Jameson Flotation Cell

Prof. Graeme Jameson
Lessons from the Jameson Cell story

• Began in academia, in an industrial context.
• Patent protection, defence and licensing key.
• Commercialisation route: TUNRA & MIM Tech.
• Link to industry (MIM).
• Over 20 years to maturity.
The Mount Isa Pb/Zn story
Sphalerite Liberation in Recalculated Feed vs Zinc Recovery

Smoothed Data: 3 Period Rolling Average

% Liberated Sphalerite RF
Zn Rec to Zn Con
Comb Zn Rec

PERIOD/YEAR

LGM Production from P8 85/86
Fine Grinding from P4 92/93
GF Stage 2 P4 00/01
Pb Regrind Mill P7 94/95
Hilton Study P7 96/97
LGM Production Ceased P4 96/97

Johnson, Pease, Young, Munro (1997)
The IsaMill
Lessons from the Mount Isa Pb/Zn Story

- Crisis drove the innovation.
- Skilled, experienced metallurgical team.
- Regular mineralogy measurements (point counting).
- Commercialisation route for IsaMill (MIM Technology).
- 10 year story; long-term commitment.
- Support from the board.

The Automated Quant. Mineralogy Story

QEMSCAN

MLA
Lessons from the Automated Mineralogy Story

• Began in government research and academia.
• Links to industry.
• Over 20 years to maturity.
• Commercialisation was essential (Intellection & JKTech).
• Industry launch customers key.
• Q*S/MLA competition drove advances.
Simulation software (JKMRC)

Pictures courtesy JKTech
...and Limn – the Flowsheet Processor

Tim Napier-Munn, JKMRC/JKTech

Picture courtesy Dave Wiseman
Lessons from simulation software development (JKMRC)

- Developed in academia.
- Close collaboration with industry.
- Continuity of support >25 years (P9 project).
- Commercialisation through start-up (JKTech).
- Enabling technology key: PC
- Experience developed through consulting.
Some lessons from these (and other) innovations

- Innovation is hard and takes a long time.
- It is increasingly multi-disciplinary.
- Skilled people are essential for success.
- A commercialisation path is necessary.
- Strong links between innovators and users are key.
Sources of Innovation

- Universities and public research
- Vendors and engineering companies
- The lone inventor
- Production staff
- Other industries
Drivers for innovation: *the 7 Cs*

- Cash (revenue)
- Costs
- Competition
- Compliance
- Community
- Culture
- Crisis
Some barriers to innovation

- Loss of skills and experience
- FIFO
- Decline in industry-innovation links
- Short-termism – inconsistent strategies
- Obsession with unimportant IP
- The silo mentality
Barriers to Innovation

1. Loss of skills and experience
Barriers to Innovation

Loss of skills and experience
- the retirement tsunami

- 39% of mining executives expect to retire in the next 5 years.
- 25% classified themselves as unemployed.
- 21% classified themselves as underemployed.
- 31% said they were thinking of leaving the industry permanently.

Survey by The Mining Recruitment Group, Vancouver, 2015
Bars to Innovation - Loss of skills and experience


Data courtesy Prof. Peter Hayes, UQ
This has happened before, in 1998........
Barriers to Innovation - Loss of skills and experience

The graduate production cycle

No. graduates

Time
Barriers to Innovation - Loss of skills and experience

Would this be possible to-day?
Barriers to Innovation

2. FIFO
Barriers to Innovation


An independent review of existing, predominantly fly-in-fly-out resource projects in Queensland
Barriers to Innovation

3. Industry-Innovation links

Australia *close to last* in OECD survey of business-university collaboration in 33 countries

The Australian
November 12\textsuperscript{th}, 2015
But the mining industry has a good track record of supporting research and innovation.
JKMRC students working in concentrators
“….. there would be value in building a national industry placement scheme of significant scale and scope”

McGagh review
March 2016
### Australian exports 2013-14 ($ billions)

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<th>Category</th>
<th>Value</th>
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<td>2</td>
<td>Coal</td>
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<tr>
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Barriers to Innovation

Industry-Innovation links – the METS sector

Tim Napier-Munn, JKMRC/JKTech
Barriers to Innovation

4. Short-termism

Average innovation time constant: 15 years

Average tenure of world top-40 mining company CEOs = 5.3 years.

Australian mining company CEOs = 2.7 years

Swann Global, Nov. 2012
Barriers to Innovation

Short-termism – confused company T&I strategies

We must invest in technology

No we mustn’t
Short-term thinking the enemy of inspiration and innovation

cornerstones of great thinking. After all, Isaac Newton spent considerable time pondering under finding it harder and harder to think beyond the next business quarter. Driven by shareholder toxicity of short-term corporate thinking, including increased chief executive turnover and broadkill off a leader’s desire to develop 21st-century skills required for success, such as contextual aware-short. It also means leaders to become more comfortable taking risks and making mistakes.

Heavy hitters take aim at short-term investors

effects of short-termism”. It says short-termism and activism are significant contributors to economic decline.

• Paul Muller (MD, Consolidated Minerals)  
  “Short termism is the biggest problem and is more so in difficult times. How do you encourage the ability to think medium to long term? It comes down to quality of leadership..”

• Andrew Harding (formerly Rio Tinto CEO Iron Ore)  
  “It becomes harder to find support to do something big [in innovation] when the sector is at the bottom of the investment cycle”

• VCI Report “Innovation State of Play” 2016  
  “Investor perspectives of mining need to shift from innovation being associated with risk to lack of innovation being associated with risk to sustainable returns. CEOs acknowledged that miners need to better educate investors...”
Barriers to Innovation

Short-termism → confused company T&I strategies
Barriers to Innovation

5. Unnecessary protection of IP
“The way industry deals with IP is seen as a key barrier, as IP ‘hoarding’ directly impedes the advance of innovative practices”

CEEC Industry Workshop, 2012
Barriers to Innovation
Unnecessary protection of IP

The prize goes to those who use the technology the best, not to those who own the IP
Barriers to Innovation

6. The silo mentality

Tim Napier-Munn, JKMRC/JKTech
Barriers to Innovation

Silo mentality – the solution
Coalition for Energy-Efficient Comminution

- Workshops, conference presentations
- The CEEC Innovation Roadmap
- Website with technical material
- The CEEC Medal
- Energy curves
- LinkedIn technical discussions
- Media activities, newsletter

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- MMG
- AngloAmerican
- TOMS
- OZ Minerals
We need to, and can, innovate better

- Preserve the corporate memory
- Manage FIFO rosters to improve continuity
- Strengthen the innovation links
- Take a longer view; less short-termism
- Rational, long-term management strategies for dealing with technology
- Be more relaxed about some IP
- Tear down the silos
A glorious failure

Large-scale innovation in mining and comminution
“He that will not apply new remedies must expect new evils, for time is the greatest innovator”

Sir Francis Bacon
1561-1626