The current investment landscape for mining, exploration & mineral sands

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How do we make sense of this?
From the world to mining & exploration to mineral sands

The themes

1. Globalisation and sustainable development
2. The ‘tech boom’ and disruptive innovation
3. Climate change and the energy transition

The insight

How does each theme affect the mineral sands industry?

Source: Ramirez & Wilkinson (2016)
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GLOBALISATION & SUSTAINABLE DEVELOPMENT
Nearly a decade of economic & financial growth...

World Annual Real GDP Growth (%)

Dow Jones Year-end Industrial Index

2017 estimate & 2018-20 forecasts made by the World Bank

2018-20 forecasts based on annual average growth rate 2008-2017

Data: World Bank, Statista
...but concerns about inequality, China & the environment

`Elephant’ curve of global inequality and growth, 1980-2016

- Bottom 50% captured 12% of total growth
- Top 1% captured 27% of total growth
- Prosperity of the global 1%
- Rise of emerging countries
- Squeezed bottom 90% in the US & Western Europe

Atmospheric CO2 Levels (ppm)

Data: World Inequality Report 2018; NOAA
...make for ‘interesting times’
...with implications (good and bad) for mining

- Less green & red tape
- Government support
- Lower taxes (?)
- Strong coal, uranium (?), steel & base metals demand
- Focus on health and safety (?)
- Strong economic growth (?)

- Less access to foreign talent & projects
- Weak economic growth (?)
- Resource nationalism & harder social licence
- Weaker demand for uranium (?), renewable and battery metals

Source: Sykes et al., 2017
It was simple in the binary politics of the Cold War...

Mid-20th Century ‘Western’ politics

- ‘Left wing’
  - Australian Labor,
  - UK Labour,
  - US Democrats

- ‘Right wing’
  - Australian Liberals,
  - UK Conservatives,
  - US Republicans

Source: Sykes et al., 2017
...then the ‘left’ was joined by a range of ‘progressives’
...and then many ‘progressives’ went ‘global’...

Post-Cold War ‘Western’ politics

Progressive

Blairite Labour

‘New Left’

Rudd & Gillard Labor

Clinton Democrats

Globalist

Localist

Source: Sykes et al., 2017
...before a return to localism, on both the left and right

Contemporary ‘Western’ politics

Progressive

‘Old left’
(now renewed)

Localist

Globalist

Conservative

‘New left’
(now old)

‘Alt-right’
(Corn Law Tories)

‘The Right’
(not-so-neocon)

Source: Sykes et al., 2017
How do we interpret these many contradictory views?

Contemporary ‘Western’ politics

Progressive

Localist

Globalist

Conservative

‘Old left’ (now renewed)

Labor

‘New left’ (now old)

SNP

En Marche!

‘Alt-right’ (Corn Law Tories)

‘The Right’ (not-so-neocon)

Source: Sykes et al., 2017
Politics is like a playground...

**Swings**
- The normal ‘back and forth’ of democratic politics;
- In a long-term industry to not to react to every ‘swing’ as can be wasteful and isolating;
- The mining industry generally over-reacts to the short-term.

**Roundabouts**
- Longer term structural shifts that re-shape all sides of politics;
- These are important to adapt to as they will only reverse over the long-term;
- The mining industry generally misses these shifts.

**Climbing frames**
- Pre-determined elements of the future that are yet to play out;
- You cannot avoid tackling these issues, even if you want to;
- Often are recognised by the industry, but nonetheless are difficult to act upon.

Source: Sykes et al., 2017
...but we’re on the roundabout and the climbing frame!

Is the shift against ‘sustainable development’ a swing, roundabout, or climbing frame?
- **A climbing frame**: difficult to envision a developed society paying less attention to environmental and social conditions e.g. rise of environmentalism in Chinese middle class.

Is the shift against ‘globalisation’ a swing, roundabout, or climbing frame?
- **A roundabout (maybe)**: a key aspect of ‘globalisation’ is ‘glocalism’ i.e. the strengthening of local identity and rights as everything is placed in global context – the franchise ‘McDonaldisation’ of the world.

Images: Environmental protests in China, Local style McDonald’s fish burger in Singapore

Images: South China Morning Post, Wikipedia; Sources: Steger, 2013; The Economist, 2016; Sykes et al., 2017
...and mineral sands may be about to fall off!

Mineral sands exploration expenditure in Australia

Global mineral sands discoveries by year

Data: Australian Bureau of Statistics; MinEx Consulting © 21 March 2018
The next wave of exploration should be under cover...

- But mineral sand deposits are mainly surficial...
- They will likely not benefit from this wave of innovation.
...but the mineral sands industry will have to go abroad

- It may be difficult to find major new mineral sands discoveries in Australia;
- Mineral sand explorers may be forced to abroad to areas of increased political risk;
- This may make ‘social licence to operate’ even more important than elsewhere in the minerals industry.

Global mineral sands discoveries, 1997-2017

Data: MinEx Consulting © 21 March 2018
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THE ‘TECH BOOM’ & DISRUPTIVE INNOVATION
Chinese growth is normalising & US growth is strong...

**USA & China Real GDP Growth (%)**

2017 estimate & 2018-20 forecasts made by the World Bank

**Global share of Gross Domestic Product (GDP) 2016 (current US$)**

- USA: 24%
- China: 15%
- ROW: 61%

Total: US$75.8 trillion

Data: World Bank
But, titanium dioxide’s China story may not be over...*

Steel Use Intensity

Ratio ~ 1.0 : 1.8

Copper Use Intensity

Ratio ~ 1.0 : 1.8

Titanium Use Intensity

Ratio ~ 2.5 : 1.0

*Ask an expert – this is one of the things I’ll be asking them at this conference!

Data: World Steel Association; International Copper Study Group; World Bank; Iluka
But this is the return of post-industrial ‘weightless’ economy

Data: Yahoo Finance; Images: Shutterstock
The mining industry is currently experiencing FOMO

**ASX sector 5-year performance**

- **Healthcare**: +21.9%
- **Consumer Discretionary**: +12.9%
- **Industrials**: +12.6%
- **I.T.**: +10.8%
- **Real estate**: +8.9%
- **Finance**: +5.8%
- **Consumer Staples**: 2.3%
- **Utilities**: 2.3%
- **Materials**: 0.8%
- **Mining & Metals**: -1.4%
- **Telecoms**: -2.9%
- **Energy**: -3.5%

Data: [ASX](https://www.asx.com.au); NB: Indices are for ASX200, apart from ‘Mining & Metals’ which is based on ASX300. Materials, based on ASX200, includes Mining & Metals constituents of ASX200. Real estate based on REITS. Finance excludes A-REITs.
...our margins will now come from better operation

In theory...

In actuality...

Index of US Open Pit Mine Costs vs Nominal Copper Prices

Source: Trench & Sykes, 2014; Data: Costmine
Will the ‘tech boom’ make us more innovative?

Traditionally miners appear to be “sustainers”...

Bigger, Bigger, Bigger...

...and now automated!

...whilst the oil industry seems a bit more disruptive?

Based on: Christensen, 1997; Images: minature-construction-world.co.uk; The Telegraph; Shutterstock; mining-technology.com; stanford.edu; lancs.ac.uk
e.g. the future of the past is still the future!

...by 2135... there will hardly be any miners underground. Minerals will be won either by robotized machinery or by in situ extraction of the valuable ingredients. ...biotechnology will be increasingly employed in situ to convert metals into a readily soluble form. Mineral processing would then become largely a matter of handling solutions, thus obviating the need for crushing and grinding.”

- Arvi Parbo, former BHP Chairman, in 1986

The radically different view of the future of mining has been the same for a long time. Why?

Source: Strauss, 1986
...as is the current mining industry innovation package

The ‘fringe’

Remote mining

Drones

Driverless trucks

Big data

Diagram: Iluka; Images: Steele, 2003; Concurso Paleontologia; OZ Treasure; Miners Museum Cape Breton
Mining is already behind the digital curve...
...the fringe is where radical innovation is occurring...

• Four key areas of science, technology and innovation:
  - Biotechnology & genetics
  - Computer science & IT*
  - Nanotechnology
  - Neurology & psychology

*Computer science, IT, data science, machine learning, AI etc., are proximal industries to mining so we are already aware of their potential – what about the others?

Sources: Turney, 2010; Imperial Tech Foresight
...but it can be hard to see the links and the reality
...and we have abandoned our own innovation engine

Total Exploration Expenditure (Australia)

Total Exploration Expenditure (Australia)

Unit Exploration Cost (Australia)

Source: Australian Bureau of Statistics
But before we get carried away, society has a view too…

Remember:

- Drones are militarily technology used for spying on & killing people!
- Big data is military technology used to spy on people…
- A.I. is the stuff of Hollywood dystopia…
- Remote ‘lairs’ are what the villains have!

Scenarios for the adoption of remote exploration technologies

- Robinson Crusoe
- Attack of the Drones
- The Lone Ranger
- Local Hero
...so we have to be careful not to create problems

- Which seems the most plausible skill set to recruit in the future?
- Compare it to the previous slide...

Capabilities required for each of the remote exploration technology scenarios

- Remote exploration
  - Yes
  - No

- Local engagement
  - Yes
  - No

- Social science & data science
  - Yes
  - No

- Field geology
  - Yes
  - No

Data science

Social science & field geology

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We are already seeing a technology backlash (‘techlash’)

**Elon Musk:** ‘Mark my words – A.I. is far more dangerous than nukes’
- **CNBC**, 13 Mar 2018

**Facebook** says it can't guarantee social media is good for democracy
- **Reuters**, 22 Jan 2018

**The techlash against Amazon, Facebook and Google—and what they can do**
- **The Economist**, 20 Jan 2018

**Facebook braces for new E.U. privacy law**
- **The Washington Post**, 29 Jan 2018

**EU gives Facebook and Google three months to tackle extremist content**
- **The Guardian**, 1 Mar 2018

**James Damore**, Google engineer fired for writing manifesto on women’s ‘neuroticism,’ sues company
- **NBC**, 8 Jan 2018
Beware disruptive innovation in a concentrated industry!

• Mining may be about to undergo a rapid period of technological innovation, especially digital;
• However, in general highly consolidated industries can be slow adopters leaving them open to disruption;
• Especially if there are diversified players in the sector which may be exposed to more competitive parts of the mining industry…

Data: [USGS](https://www.usgs.gov); Source: Christensen (1997)
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CLIMATE CHANGE & THE ENERGY TRANSITION
What about the fifth technological driver?

Source: Imperial Tech Foresight
The world is entering the ‘energy transition’...

**RENEWABLES**
- Theoretically infinite
- Non-carbon emission generating (at source)
- Distributed sources

**BATTERIES**
- Power storage / averaging
- Portable energy
- Rechargeable (reduced waste & energy efficient)

**Increased energy demand**

**Increased environmental focus**

**Increased transport & mobility**
...creating new opportunities for some metals, but not all...

RENEWABLES METALS

- Silicon & germanium;
- Gallium-arsenide;
- Copper-indium-gallium-selenide (CIGS);
- Cadmium-telluride

Uranium

Rare earths (neodymium, praseodymium & dysprosium) – in the generator magnet

BATTERY METALS

- Lead-acid
- Nickel-cadmium / zinc
- Alkaline (zinc-manganese)
- Nickel metal (lanthanum-rare earth) hydride
- Lithium-ion (graphite, manganese & cobalt)
- Vanadium redox

Note absence of titanium & zirconium!

Images: Shutterstock; Wikipedia; solarchoice

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However, the energy transition will also affect supply...
...maybe helping drive mining underground

- Volkswagen NOX & SOX emission scandal
- Focus on greenhouse gas reduction
- Improved battery technology
- Movement towards all electric underground mines
- Movement towards underground mines
- Focus on social & environmental footprint of surface mining
- Fewer surface mineral deposits awaiting discovery
- Improved automation and remote technology
- Safer underground mines
- MOVEMENT TOWARDS ALL RENEWABLE ELECTRIC UNDERGROUND MINING?
- ...but not mineral sands
- Surface mining of mineral sands means may miss out on the underground transition
- May leave it vulnerable to environmental and socio-political issues
Titanium metal demand is not what it should be...

- Titanium metal is not widely used, despite it being light and useful because it is expensive;
- Aerospace is the main end-use for metal, but it is CO₂ intensive;
- In theory, aerospace biofuel developments may stimulate the air industry and titanium metal demand;
- But cheaper, greener titanium would be even better, as it could then be used across multiple sectors where ‘lightness’ is an asset, e.g. transport, infrastructure, energy…

Titanium minerals demand (2012)

- Pigment (TiO₂) 7%
- Metal 86%
- Other 7%

Titanium metal demand (2012)

- Industrial 8%
- Aerospace 29%
- Military 55%
- Other 8%

Data: Iluka
...and we have seen metal markets transform before...

Growth in market size indices of copper and aluminium 1900-2014
(1900 = 1)

Growth in market size indices of copper and nickel 1900-2013
(1900 = 1)

Growth in market size indices of copper and uranium 1950-2013
(1950 = 1)

Source: Sykes et al., 2016; Data: USGS
...but only when it all comes together!

Aluminium
- Transportation demand
- Bayer and Hall-Heroult processes
- Bulk open pit mining
- Bauxite discoveries in North America

Nickel
- Demand for armour
- Flotation & smelting advances
- Bulk open pit mining
- Discoveries in Sudbury & New Caledonia

Uranium
- Demand for nuclear weapons
- Demand for nuclear power
- Ability to handle radiation
- Bulk mining for very low grade radium
- Radium-uranium discoveries in the Congo

Source: Sykes et al., 2016; Images: Shutterstock
Titanium metal is too energy intensive, i.e. expensive

- Titanium has a very high strength & stiffness-to-weight ratio in comparison to steel making it far more useful… in theory;
- However, it is very expensive due to the energy consumed during production drastically affecting its price-performance ratio in comparison to steel;
- The industry has long waited for a breakthrough replacement to the Kroll process that is less energy intensive;
- Unfortunately, we’re still waiting…

Data: Norgate et al., 2006; Gao et al., 2018
...and too polluting! But is a solution appearing?

- Renewable energy would resolve CO₂ intensity issues;
- Would this alone stimulate titanium metal demand?
- However, ‘super’ cheap renewable energy (e.g. near-free solar) would resolve both cost and environmental issues and could be the market growth trigger…
- …thus an alternative to the Kroll process may not be required.

CO₂ emissions during metals production

Electricity consumption during titanium production

Data: Norgate et al., 2006; Gao et al., 2018
Thank You!

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Copies of this and other similar presentations can be downloaded from our website.
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