



# Perspectives on the Sustainable Development of Mineral Resources

Stanford University

December 9 2017

# Key Distinctions for Understanding Human Behavior in Resource Investment

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- Short term greed trumps most longer terms common sense outcomes
- Unintended consequences always show up
- Loss of containment is almost certain, Sometimes catastrophically, sometime slowly.
- Everybody involved has a personal, self-interested point of view - often with very different time frames.
- Change is hard
- Leading change requires a compelling vision with a demonstrated ability to deliver results

# Greed Verses Fear

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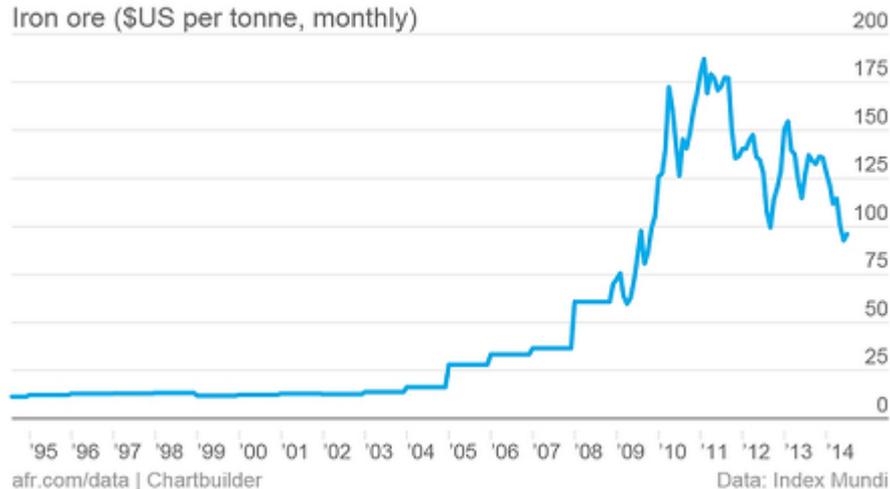
- Investing in Natural Resources is a tug of war between greed and fear.
- Long term GDP demand growth, or rapid changes in demand in thin markets due to technological changes drives commodity prices higher and presents the appearances of excess returns, at least in the short term - thus greed, **but.....**
- Prices are volatile and may fall, technology shifts can undermine demand, countries change their taxes, laws and permit conditions, local communities can become restive or obstruction or outright extortionist. Macro economic shock can crash markets. Environmental laws changes. Unions can change the cost profile – thus fear. **So....**

Greed leads to a rush to produce, perhaps a few corners are cut which leads to .....

**COBALT PRICE**  
31.75 USD/LB  
7 DEC '17



Iron ore (\$US per tonne, monthly)



# Unintended consequences....

[#COMMODITIES](#)

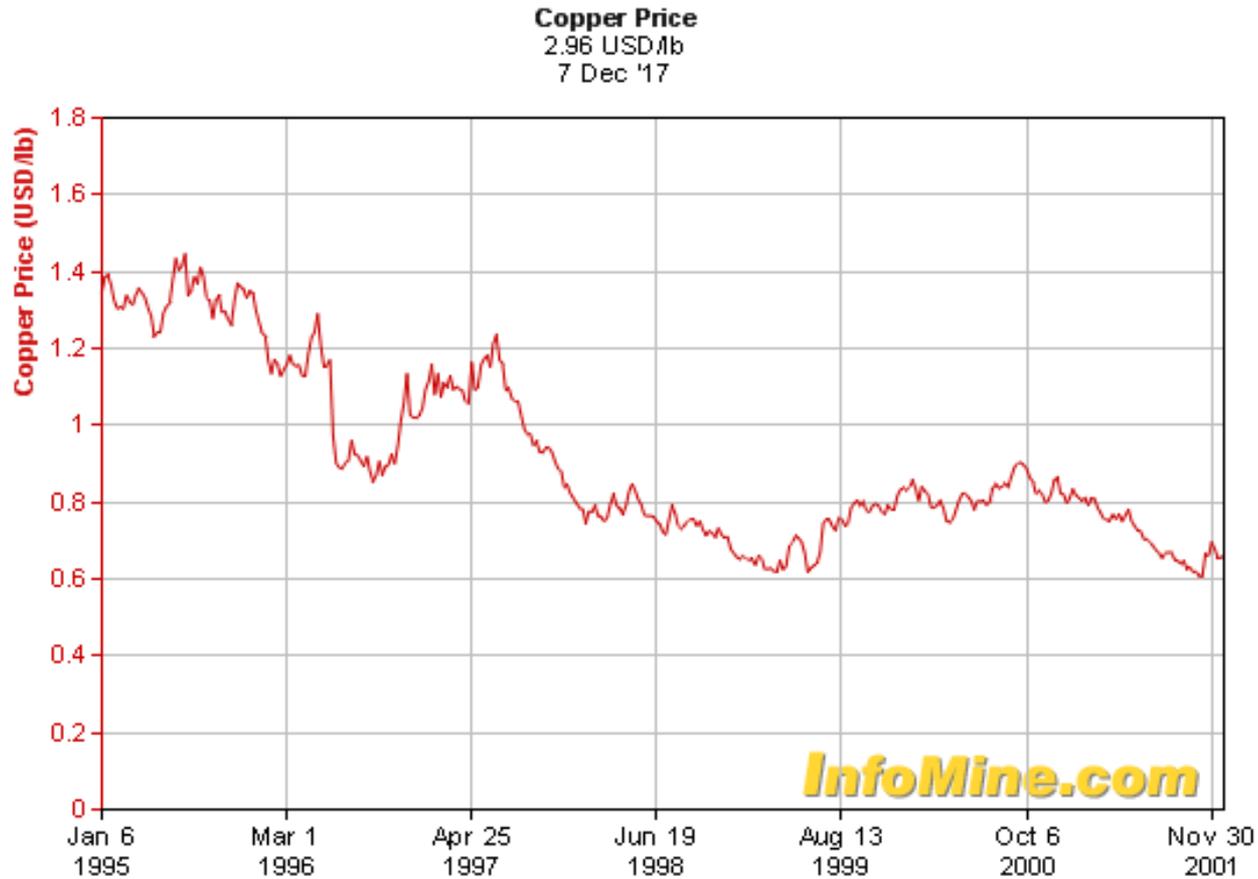
JUNE 29, 2017 / 11:56 PM / 5 MONTHS AGO

## Court gives BHP, Vale until October 30 to settle \$47 billion Samarco claim

Reuters Staff



# Fear leads to production cuts, closures etc .....



## Copper Macro Industry Behavioral Data 2016 -2017

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Glencore implements closure of Katanga and Mopani Mines, 200,000 tonnes of annual production lost.

Freeport closes Sierrita Mine, 75,000 tonnes copper lost. Annual dividend cut to zero

Anglo Sells high cost Chile Norte Division, Copper production drops 15% yoy

Chilean heavy rain causes 10 day suspension of El Teniente

China announces it wants to buy more offshore copper assets. Sees supply at risk.

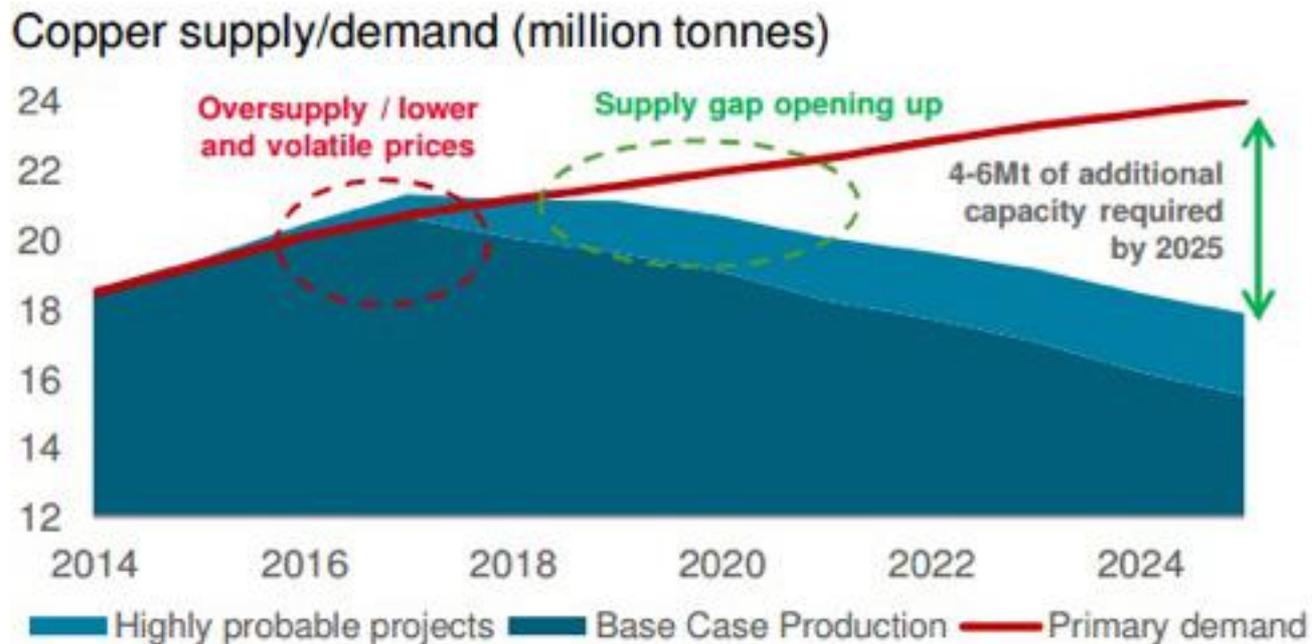
Minmetal's Los Bombas mines commences shipments.

Escondida and Freeport Indonesia suffer significant production losses at they fail to reach agreements with unions and governments

BCL goes into liquidation

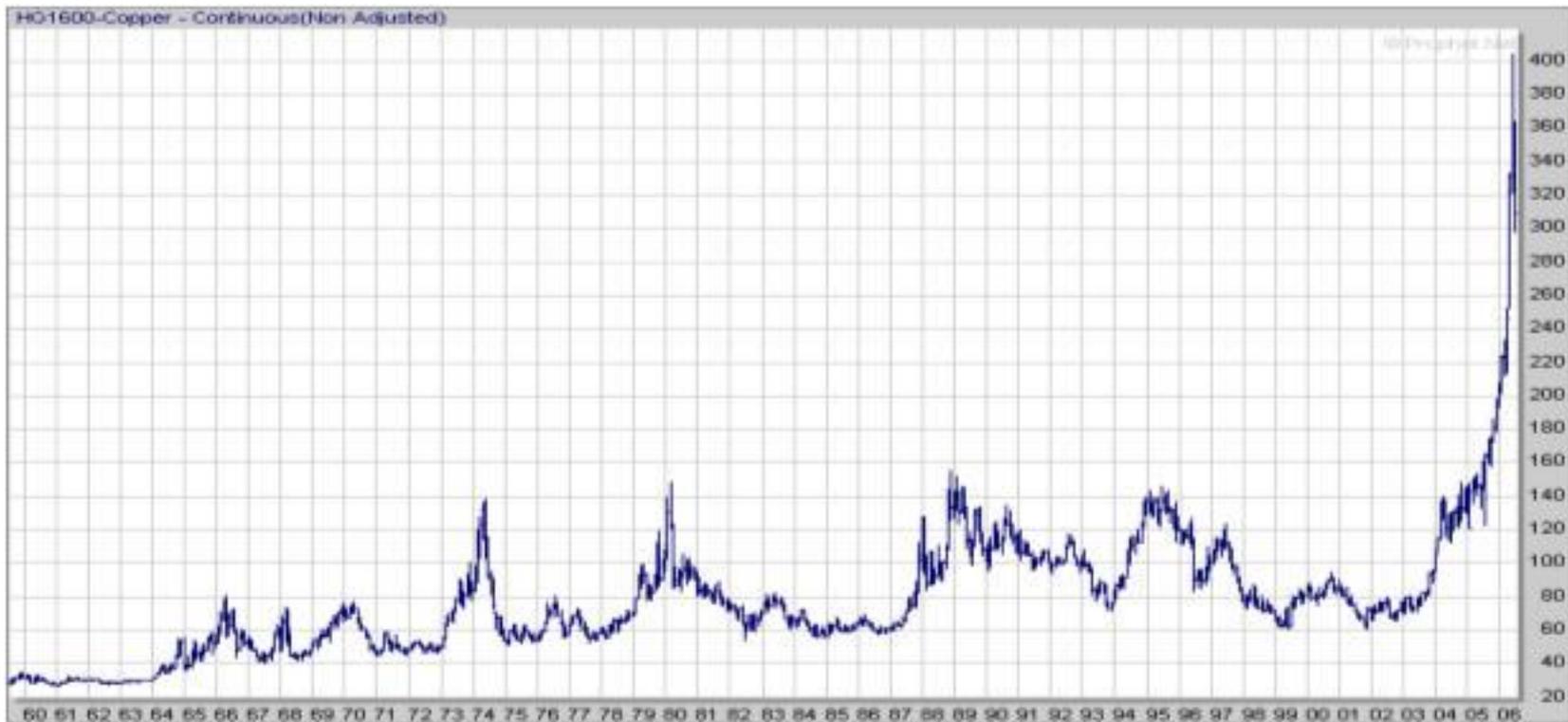
Last large new mine being built – Cobre Panama comes on stream in 2018.

And results in future supply shortages ..... Which starts the cycle over ..

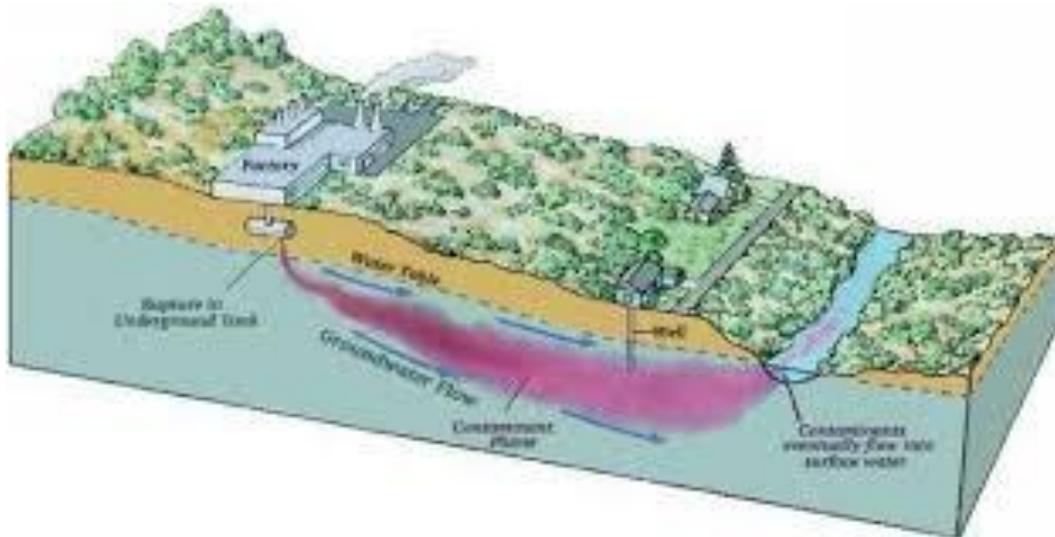


# So in a cyclical industry how do we manage risk to prevent ...

Average copper peak to peak cycle length 6 years with 3x peak to trough volatility since 1970.



# Loss of containment ... Inevitable or controllable?



# There are innovative solutions – Island Copper but...



FIGURE 2. Aerial Photograph of Island Copper During Operation, Looking Southwest.

Everybody involved has a personal, self-interested point of view – No Conflict – No Interest. Resolution of conflict is increasingly political ....

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Pebble is the largest known undeveloped copper ore body in the world, measured by either the amount of contained metal or the amount of ore. Northern Dynasty estimated that Pebble contains over **\$300 billion** worth of recoverable metals at early 2010 prices.

[Pebble Mine - Wikipedia](https://en.wikipedia.org/wiki/Pebble_Mine)

[https://en.wikipedia.org/wiki/Pebble\\_Mine](https://en.wikipedia.org/wiki/Pebble_Mine)

## Pebble Mine is a poison pill for Alaska's wild salmon

By CARL SAFINA JOEL REYNOLDS

NOV 09, 2017 | 4:00 AM



# Change is Hard... but often hugely worthwhile

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People exist in a “current knowledge” paradigm. New information that challenges the accepted truth or paradigm is inherently threatening –

We can live with all kinds of known threats and stress – it is literally what we don't know we don't know that kills us – or at least results in some really bad days – but new knowledge can result in incredible breakthroughs.

*Ferrobacillus ferrooxidans* is the bacteria that eats sulphides and creates acid mine drainage and liberates heavy metal toxins to the environment from sulphide mine wastes, dumps and mines - well that sucks – but wait a minute! – if bacteria can eat sulphides, can we control them?

Today sulphide copper heap leaching produces hundreds of millions of lbs of copper/yr from low grade copper ores without milling, no tailings, no smelter and 1/5 of the energy of traditional copper production. All created by using acid mine generating bacterial to eat the copper sulphide minerals and the acid to dissolve the copper the bacteria don't want. We are learning how to grow them fast on purpose and keep them happy. These projects are the lowest cost copper producers on the planet. There are obvious applications to in-situ leaching – if we can maintain containments???

# One of the lowest cost cleanest sources of copper in the world

## Escondida Sulphide Leach: Chile

### Bioleaching (mesophiles)

- Low-grade, run-of-mine (ROM) ore with SX / EW
- Designed to produce 180 000 tpa copper cathode
- Project cost: US \$ 870m (includes desalination plant at Coloso)
- Production at plant began in 2007



# So what does Private Equity need to invest in the development of natural resource?

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1. Clear economic rule and conditions. Political, tax and fiscal stability is critical in a highly cyclical business where investments take time to mature.
2. A clear sustainability framework where you can demonstrate to your investors that you are a socially responsible investors.
3. Excellent and sophisticated modelling that can test multiple scenarios to determine the likely outcomes and the worst case outcomes.
4. Risk models and risk management systems that anticipate (hopefully) most of the possible outcomes and defines those that can be managed and those that cant.
5. An ability to see opportunity where others only see risk and invest where the risks can be overcome (hopefully).

## Finally, Leading Change can make a huge difference ....

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Leading change requires a compelling vision of what is possible with a demonstrated capability of delivering results.

This is what is required of today's geoscientists. We are uniquely positioned to foresee future consequence. We can often more accurately model risk and the unintended consequences of action, benign or otherwise. We have a unique ability to lead debate and dialog on change that can lead all of us into a better more sustainable future.

Knowledge is not enough. Telling the truth about what is so is useful to get the debate going, however providing compelling ideas, solutions, technologic possibilities and powerful engagement forums to bring together all points of view on what is necessary to solve the complex system problems that are emerging as the world's physical systems become more and more intimately entangled with its human systems.

# So what does the Geoscience community need to do?

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1. Better more easily understood predictive models that build confidence in society by their accuracy – no right/ wrong agendas, no socialism vs capitalism bias just what so without change and with it– We need to take into account human responses to information.
2. Point toward the better future – we are in a hundred year move from fossil solar energy to real time solar with fully distributed energy and fully self contained largely solar electric housing with or without fuel cells, wind power etc. which will replace the large static grid systems with their huge capital costs. In the same way that cell phones leapfrogged fixed line phone systems in the third world - distributed electrified housing this will lead to rapid equalization of life styles across the world and possibly reverses the drive to urbanization.
  - What is required is better batteries and better solar cell conversion – on the way.
  - We need to help lead the debate on where research \$ are spent and align ourselves with research that solves the key intractable issues we can solve with our current knowledge and practices.
  - Nothing works better than seeing – we should build sustainable rural communities as teaching models.
  - We need to integrate full cycle economics and human behavior into our complex system models to help policy makers make better choices and influence more intelligent political dialog.
3. Scarcity and peak capacity is an illusion – high price breads innovation, substitution and breakthroughs in materials, resource utilization and recycling.
4. Finally we need a long term vision of human stewardship of our planet – we are painfully becoming one world and we need to meet the needs and aspirations of the humans while preserving our ecosystem or the outcome is clear.....

Join the dinosaurs ... and who better understands dinosaurs than us?

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