The key drivers behind resource growth: an analysis of the copper industry over the last 100 years

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Overview

1. What are the key drivers?
2. How much copper has been found and mined
3. Trends in declining ore grade – is it good news or bad?
4. Untangling the effects of discovery, technology, costs and prices
Key drivers for resource growth

• Exploration success
  – Trends in copper discovery rates over last century
  – Growth in world reserves & resources

• Changes in costs
  – Impact on what we define “economic” ore
  – R&D and Engineers can grow the resource

• Changes in prices
  – Higher prices will expand the pool of economic projects
Discovery: Most of the metal found is tied up in a handful of deposits

Amount of copper found in deposits >0.1 Mt Cu in the World: 1900-2009

Note: Chart include minor adjustment for deposits missing from the database

Source: MinEx Consulting Feb 2010
Until recently, we have been finding it faster than we mine it
Amount of copper mined vs copper found in deposits >0.1 Mt Cu in the World: 1900-2009

CAUTION: Not all discoveries turn into mines, and not all resources get recovered

Note: Chart include minor adjustment for deposits missing from the database

Source: MinEx Consulting Feb 2010
Copper reserves continue to grow

World Copper Reserves: 1900-2010

Sources: Various
Copper reserves continue to grow

World Copper Reserves: 1900-2010

Sources: Various
MinEx Consulting March 2010
Over the last Century copper endowment has grown 25 fold

World Pre-mined Copper Reserves: 1900-2010

Note: Assumess  20mt in cumulative historic production pre-1900
Mining recovers 85% of copper contained in ore

Sources: Production data from USGS
MinEx Consulting March 2010
Over the last Century copper endowment has grown 25 fold

World Pre-mined Copper Reserves: 1900-2010

- Estimated Reserves
- Est Cumulative Mine Losses
- Cumulative Production

Note: Assumes 20mt in cumulative historic production pre-1900
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Sources: Production data from USGS
MinEx Consulting March 2010
Reserve life has slowly declined over the last 60 years

Ratio of Reserves/Production - World: 1900-2010

Assuming continued discoveries, the world isn’t going to run out of copper soon

Sources: Production data from USGS
Reserve data MinEx Consulting March 2010

Note: Chart based on “Estimated Reserves”
Peaks in 1921 and 1932 due to sudden drop in production
Ore grades mined have declined over time

Copper ore grade for World and selected countries: 1900-2008

Note: Rise in ore grade in Australia from 1972 onwards is due to startup of the high-grade Olympic Dam mine

Sources: USGS, Mudd (2009)
Brook Hunt, UBS
The average grade for copper discoveries has remained relatively constant. This is dragging down the average ore grade mined.

Copper ore grade discovered and mined in the World: 1900-2008

WARNING: The definition of what is economic ore has changed over time. The estimated discovery grade is based on the latest available resource figures – which is much larger (but often lower grade) than that originally reported at the time of discovery.

Sources: USGS, Mudd (2009) Brook Hunt, UBS
QUESTION:

Is a declining ore grade bad news or good news?
There is a trade-off between tonnes and grade

Rio Blanco copper deposit

![Graph showing the relationship between grade and resource (tonnes) with data points at 65 million tonnes @ 1.26% Cu = 0.82 million tonnes Cu and 1100 million tonnes @ 0.58% Cu = 6.38 million tonnes Cu.]

... lower grades could signify “good” news as...

Lowering the cut-off grade grows the resource = MORE METAL

Source: MinEx Consulting March 2010
There is a trade-off between tonnes and grade
Tonnes-Grade data for 48 copper deposits

Source: MinEx Consulting March 2010
There is a trade-off between tonnes and grade

NORMALISED Tonnes-Grade data for 48 copper deposits

On average, by adjusting the cut-off grade, it is possible to double or triple the head grade of the ore body, but at the expense of shrinking the ore tonnes by a factor of 10

Base Case defined as the maximum reported resource size for a given deposit

Source: MinEx Consulting March 2010
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Source: MinEx Consulting March 2010

Base Case defined as the maximum reported resource size for a given deposit.
Most of the huge growth in known resources in the last 70 years can be attributed to a reduction in cut-off grades.

Change in pre-mined resources for 12 giant porphyry deposits: 1929-2008

In 1929 these 12 mines accounted for 55% of the world’s Cu reserves. In 2008 they still accounted for 10% of world resources.

Including “speculative” resources increases this to 67 mt Cu.

Sources: Parsons (1933)  MinEx Consulting
Over the last 100 years, the real price and cost of copper has halved

Copper price and (estimated) average operating costs for Western World: 1900-2009

QUESTION:
Is price an input or an output?

... Prices are set by supply & demand

Includes, transportation, smelting & refining and marketing costs

Sources: USGS, Brook Hunt, CRU
MinEx Consulting estimates (for 1900-1974)
Over the same period, unit mining costs have dropped four-fold.

Estimated average operating costs for copper mines in Western World: 1900-2009

The lower cost per tonne has more than offset the lower grades mined - leading to lower unit price per lb of copper produced.

Key Challenge – In the future will costs continue to fall faster than the grade?

Includes, transportation, smelting & refining and marketing costs

Sources: Brook Hunt, CRU, Historical reports
MinEx Consulting estimates (for 1900-1974)
Key Technical Innovations

Estimated average operating costs for copper mines in Western World: 1900-2009

Includes, transportation, smelting & refining and marketing costs

Sources: Brook Hunt, CRU, Historical reports
MinEx Consulting estimates (for 1900-1974)
Economies of scale and new technology helped drive down costs

Cash operating costs for selected open pit mines in USA and Chile

Operating costs include transportation, smelting & refining charges
# Bingham Canyon, Ray, Chino, Morenci, Robinson, Toprerillos, Chuquicamata and El Teniente

Source: MinEx Consulting March 2010
SUMMARY

• World’s copper resource base grew by x25 over last 100 years

• Much of this was through discovery

• Technical innovations enabled giant “disseminated” Porphyries to be mined, and then later Cu-oxide deposits

• Costs reduced through economies of scale and new technologies

• As costs went down, so too did cut-off grades ... thereby further growing the resource

• Prices are a output – not an input. They are driven by supply & demand
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