

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

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Overview

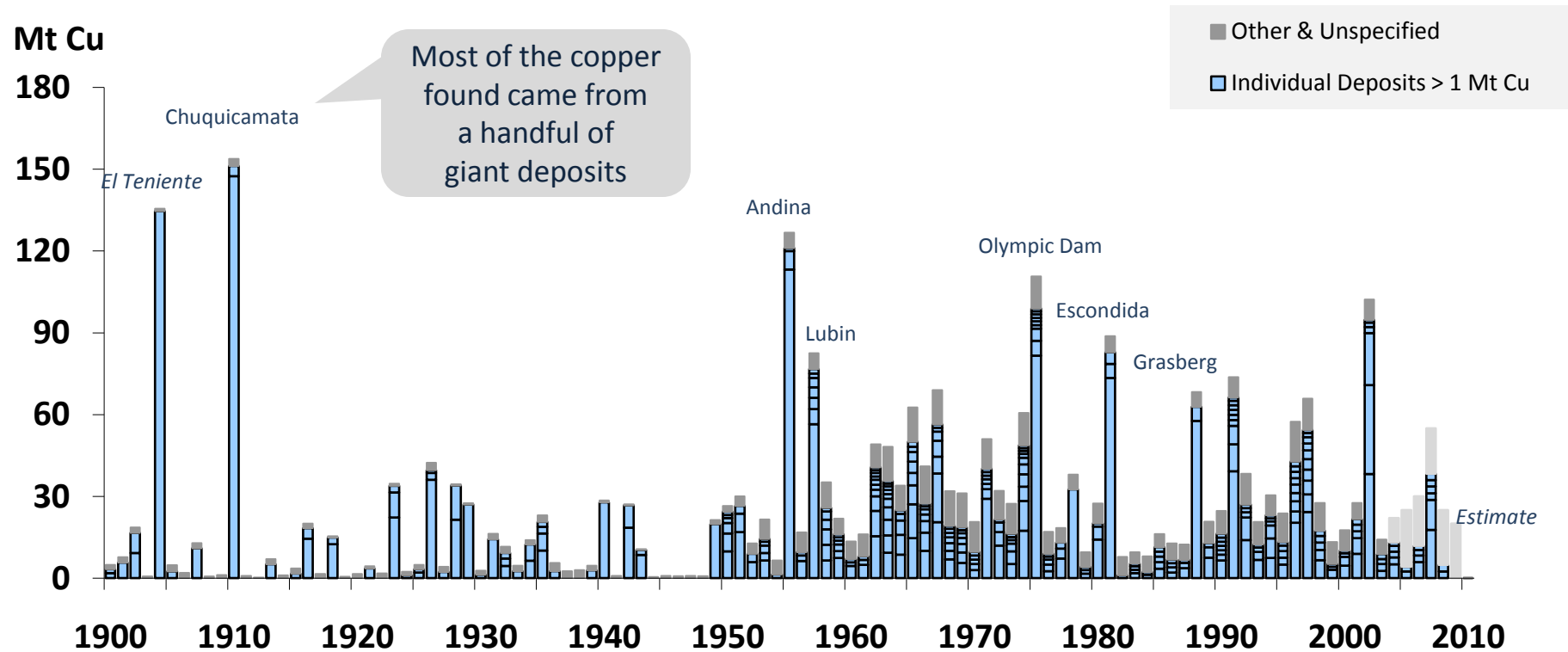
1. What are the key drivers?
2. How much copper has been found and mined
3. Trends in declining ore grade
 - is it good news or bad?
4. Untangling the effects of discovery, technology, costs and prices

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

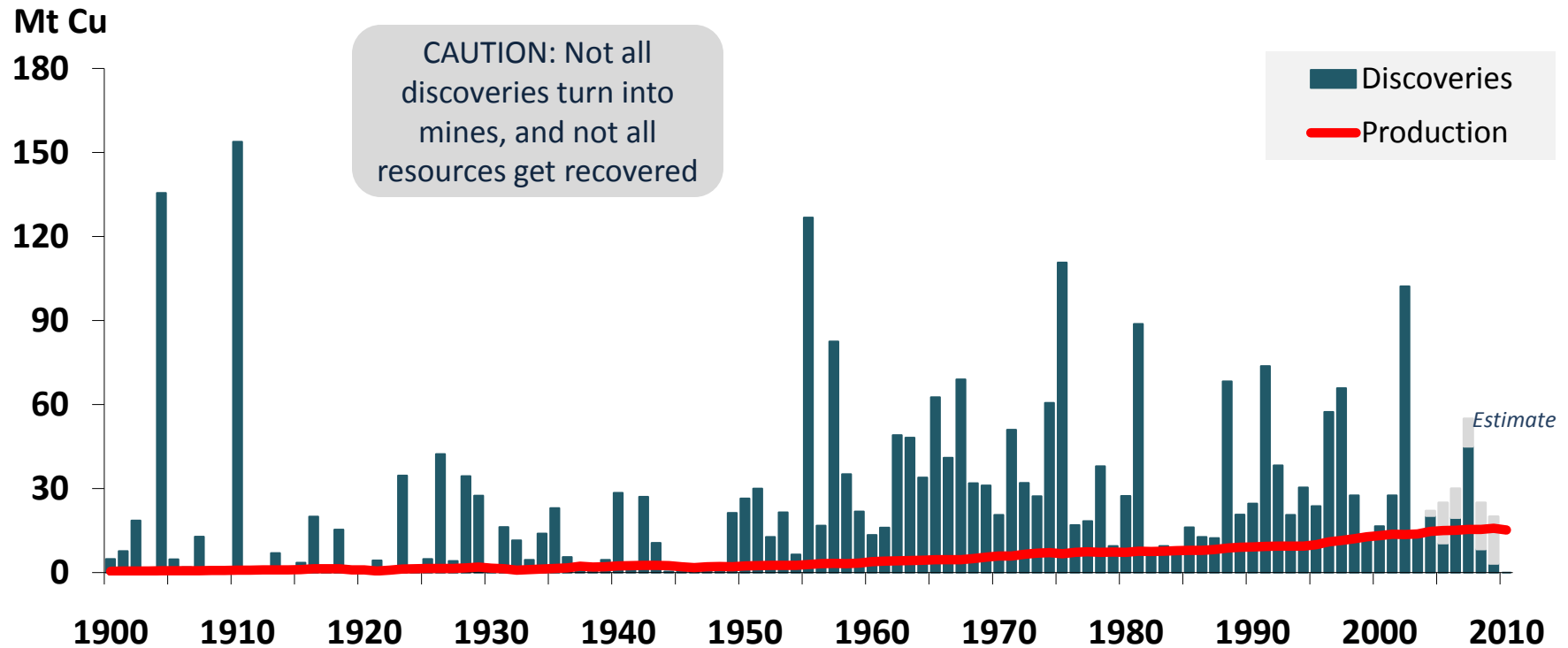


Source: MinEx Consulting Feb 2010

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

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

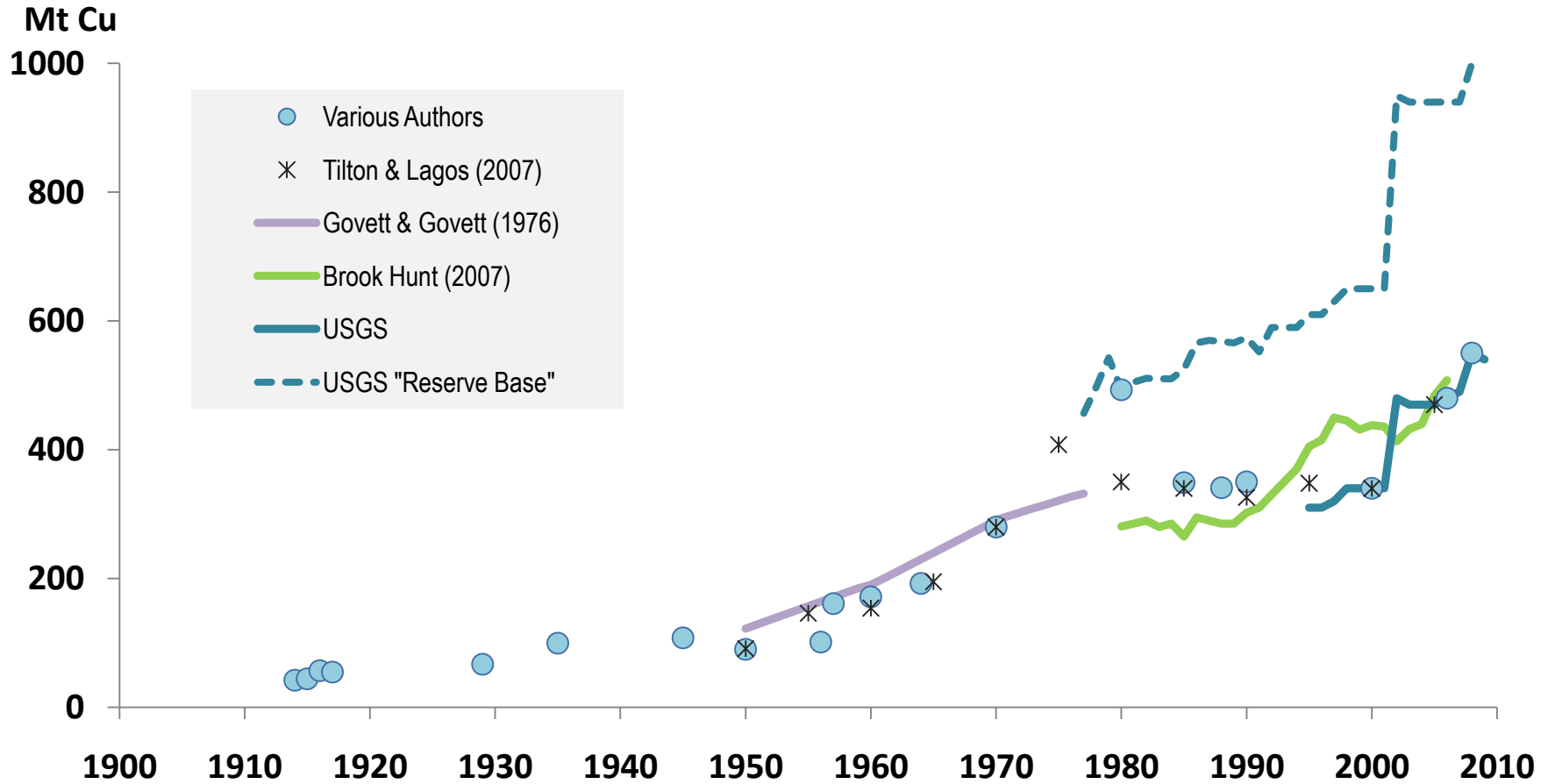


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Copper reserves continue to grow

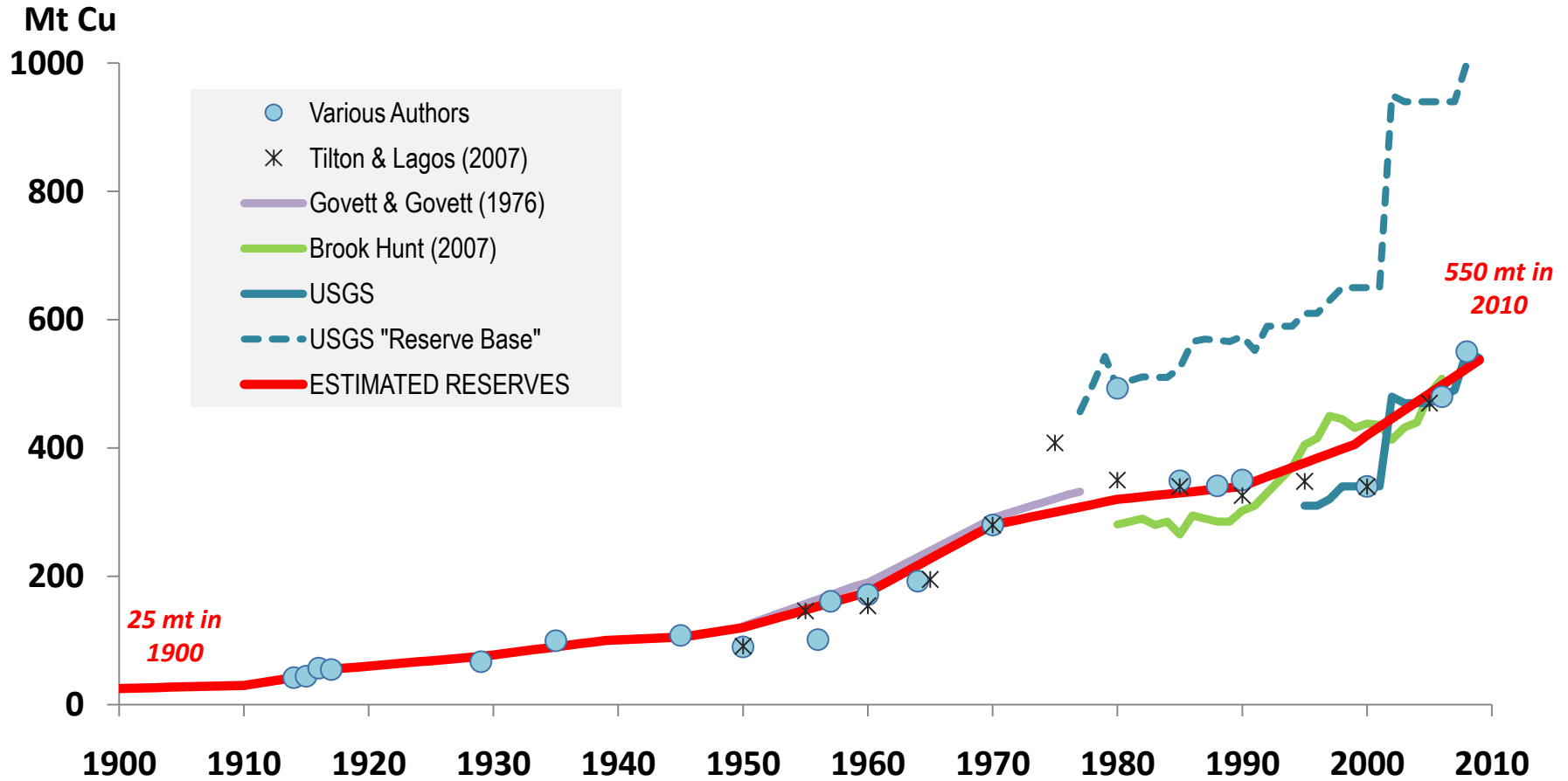
World Copper Reserves: 1900-2010



Sources: Various

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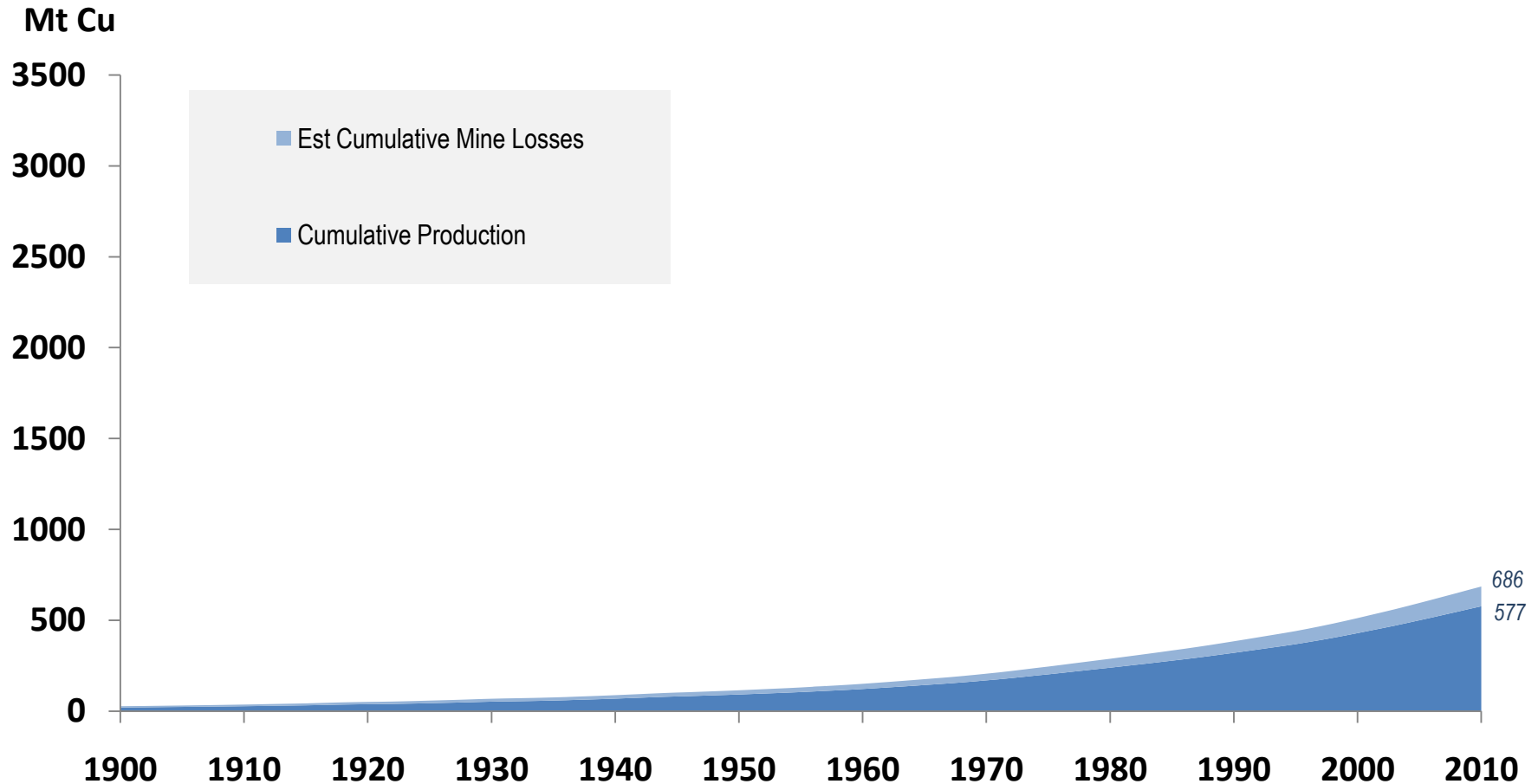
World Copper Reserves: 1900-2010



Sources: Various
MinEx Consulting March 2010

Over the last Century copper endowment has grown 25 fold

World Pre-mined Copper Reserves: 1900-2010

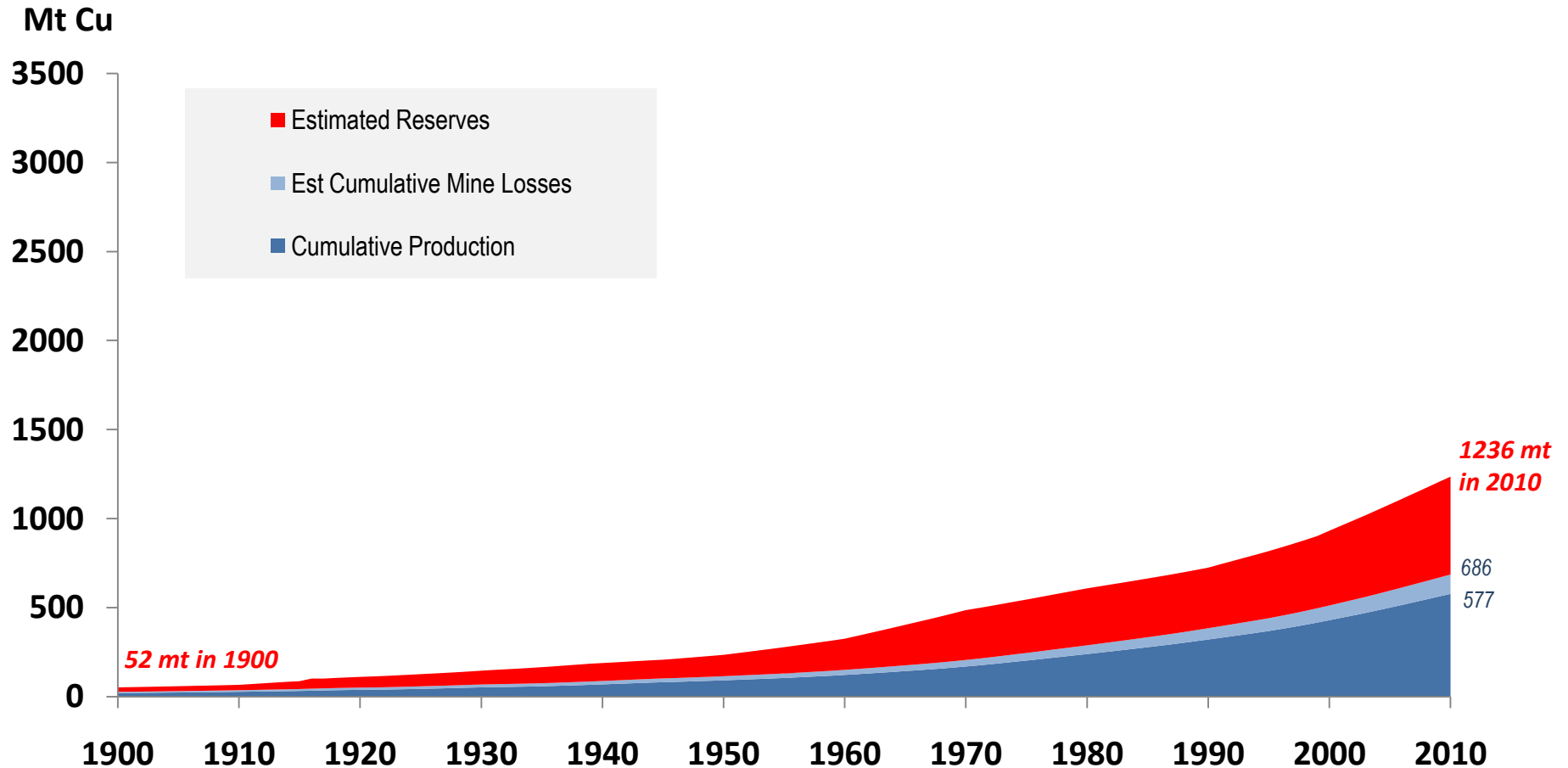


Sources: Production data from USGS
MinEx Consulting March 2010

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

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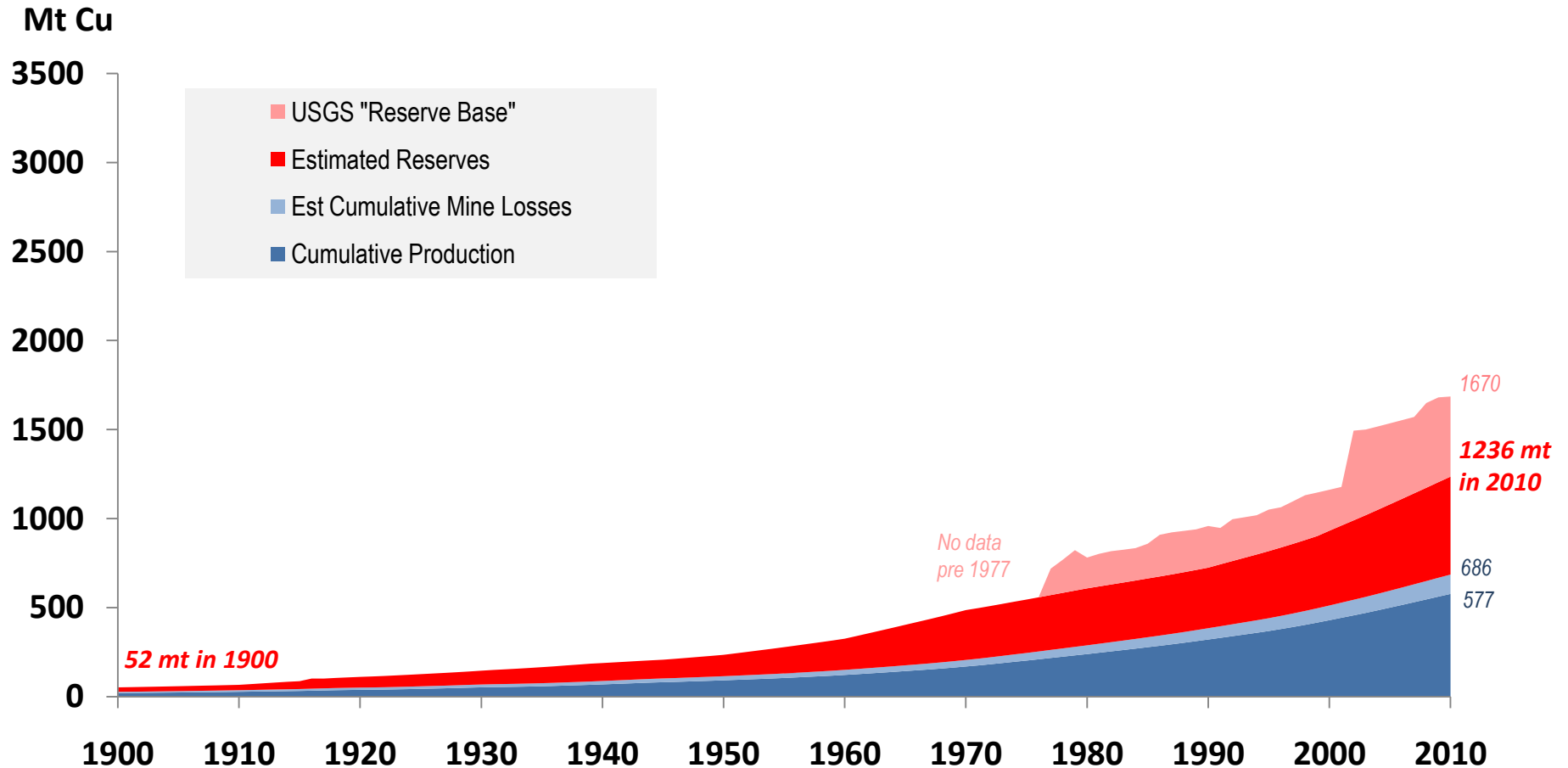


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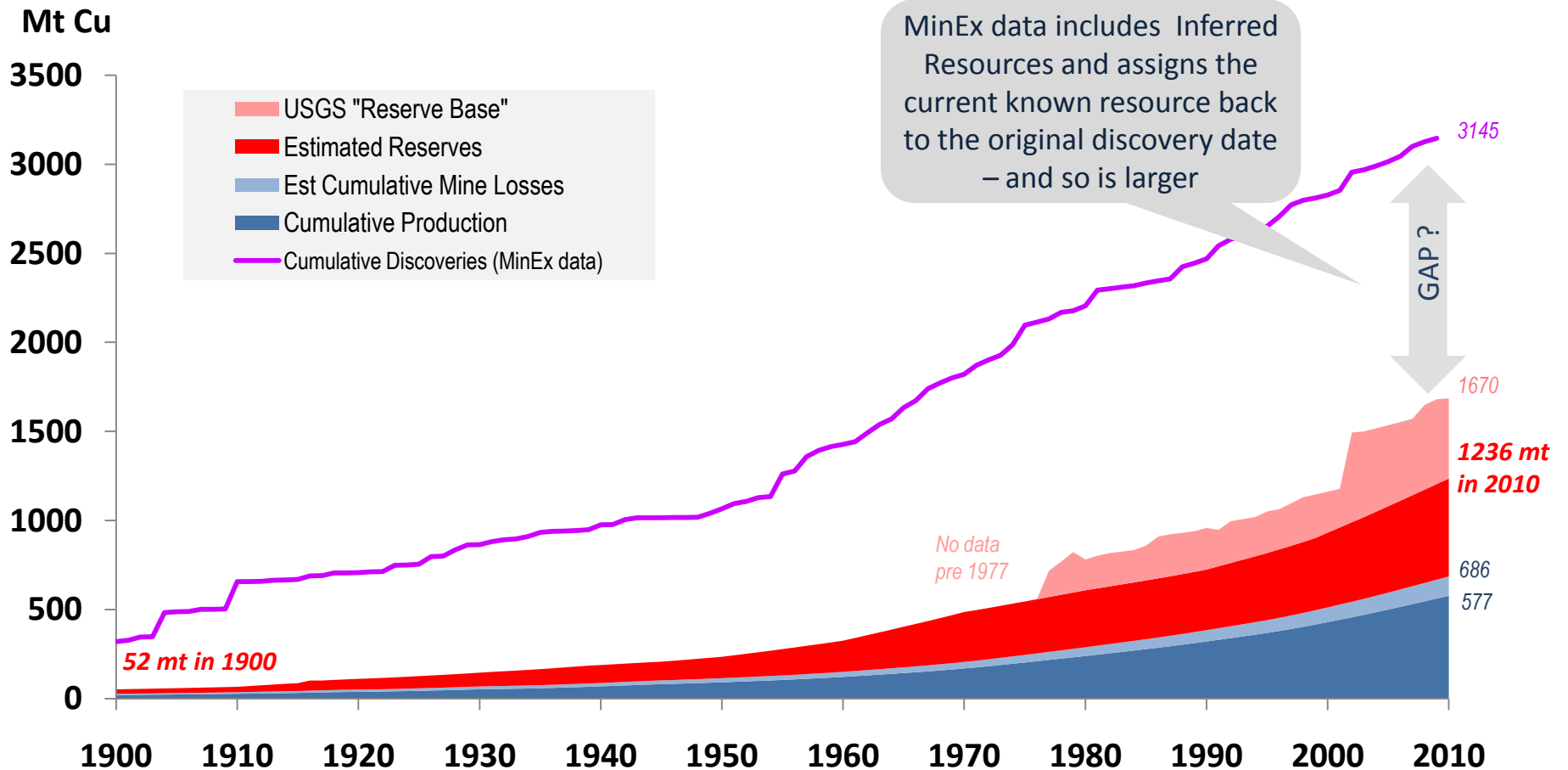


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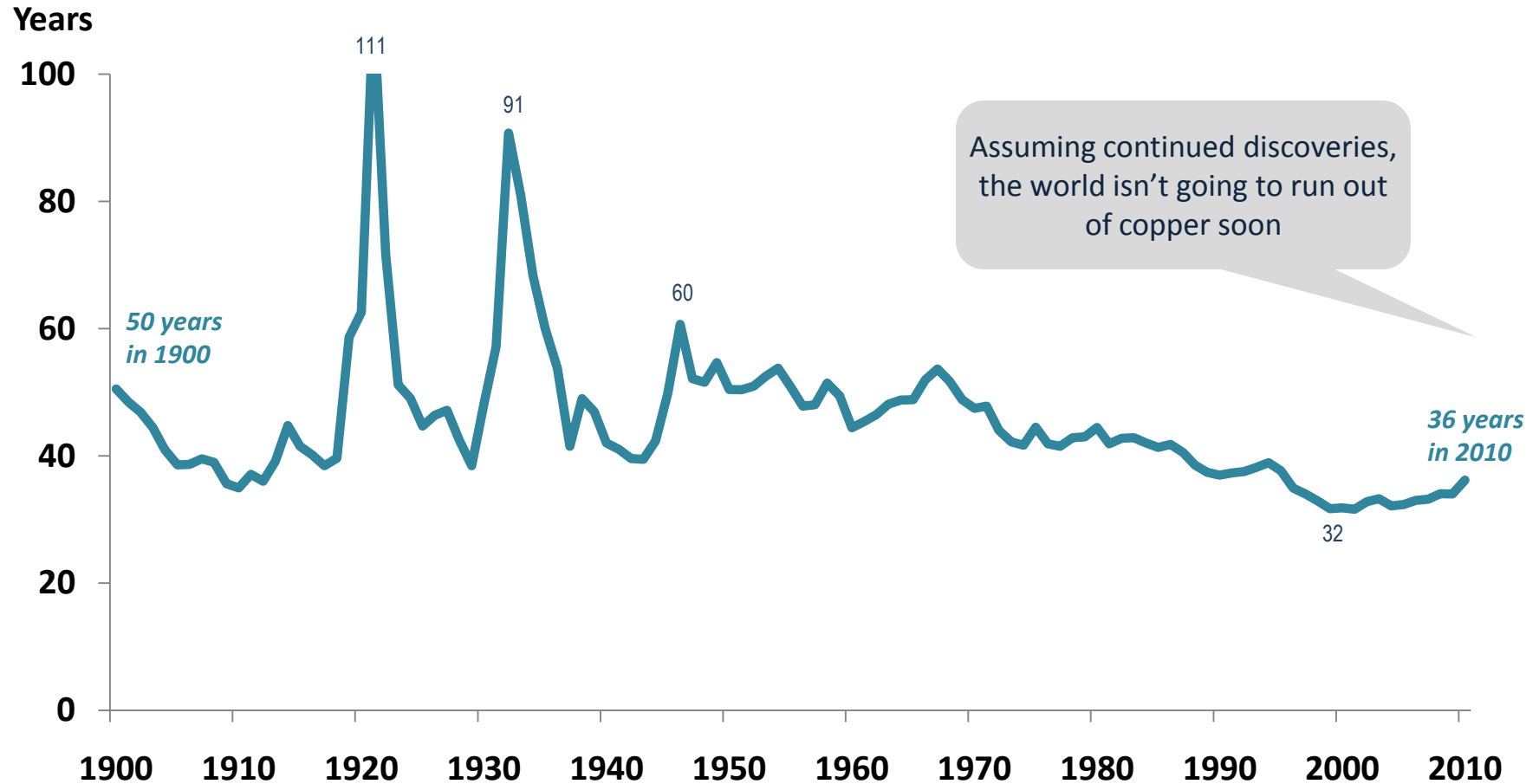


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Reserve life has slowly declined over the last 60 years

Ratio of Reserves/Production - World: 1900-2010

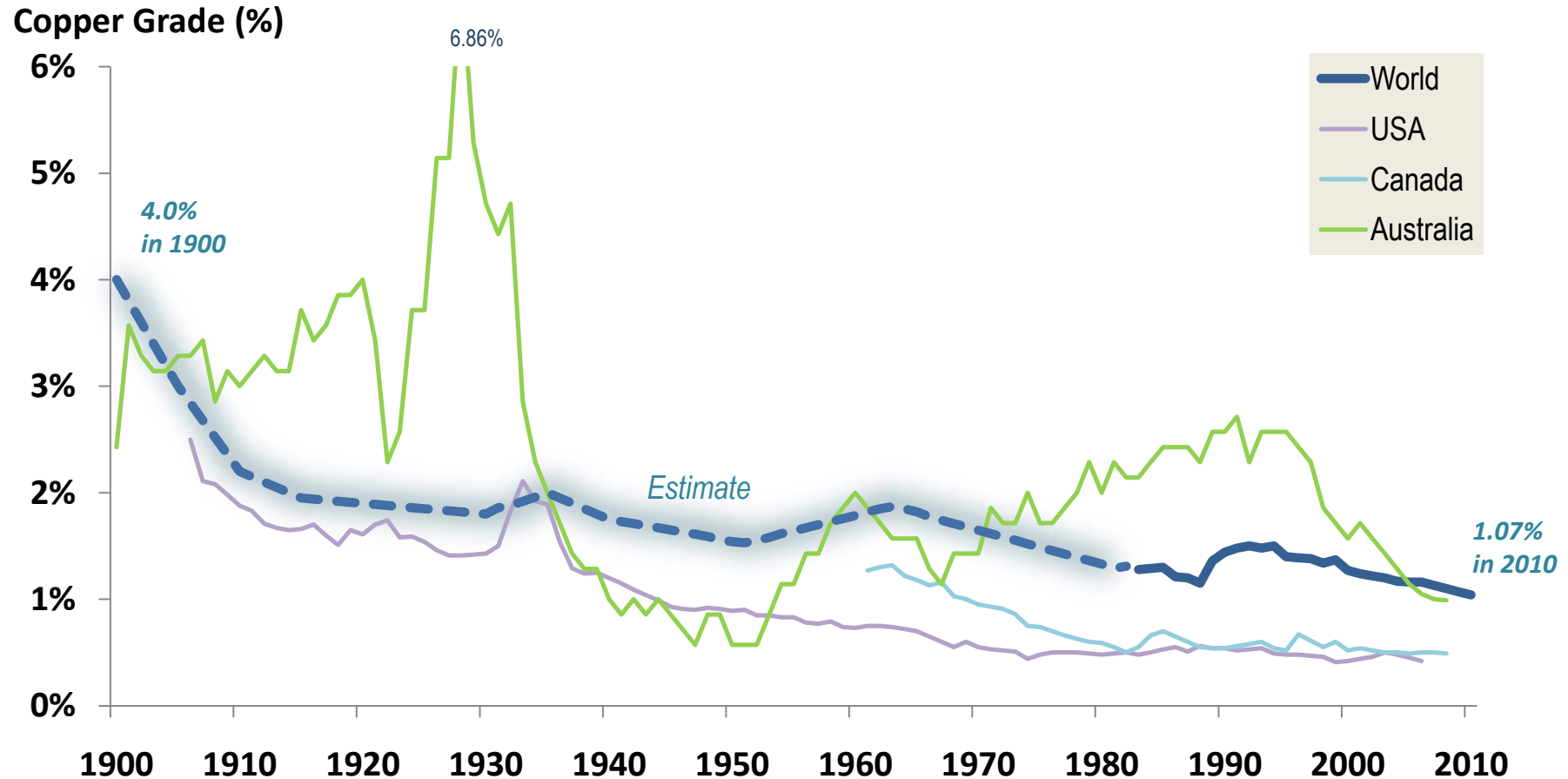


Sources: Production data from USGS
Reserve data MinEx Consulting March 2010

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

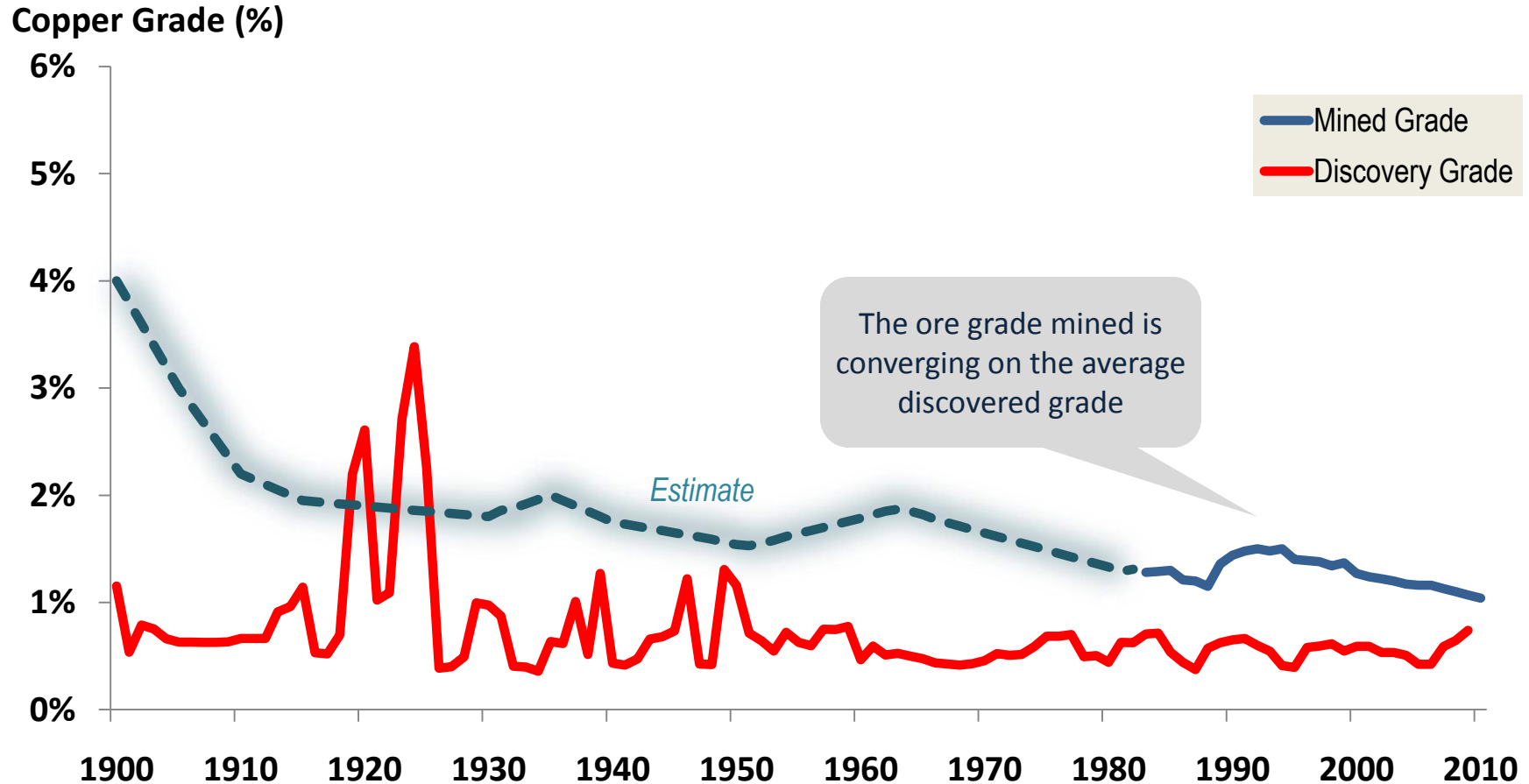


Sources: USGS, Mudd (2009)
Brook Hunt, UBS

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

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

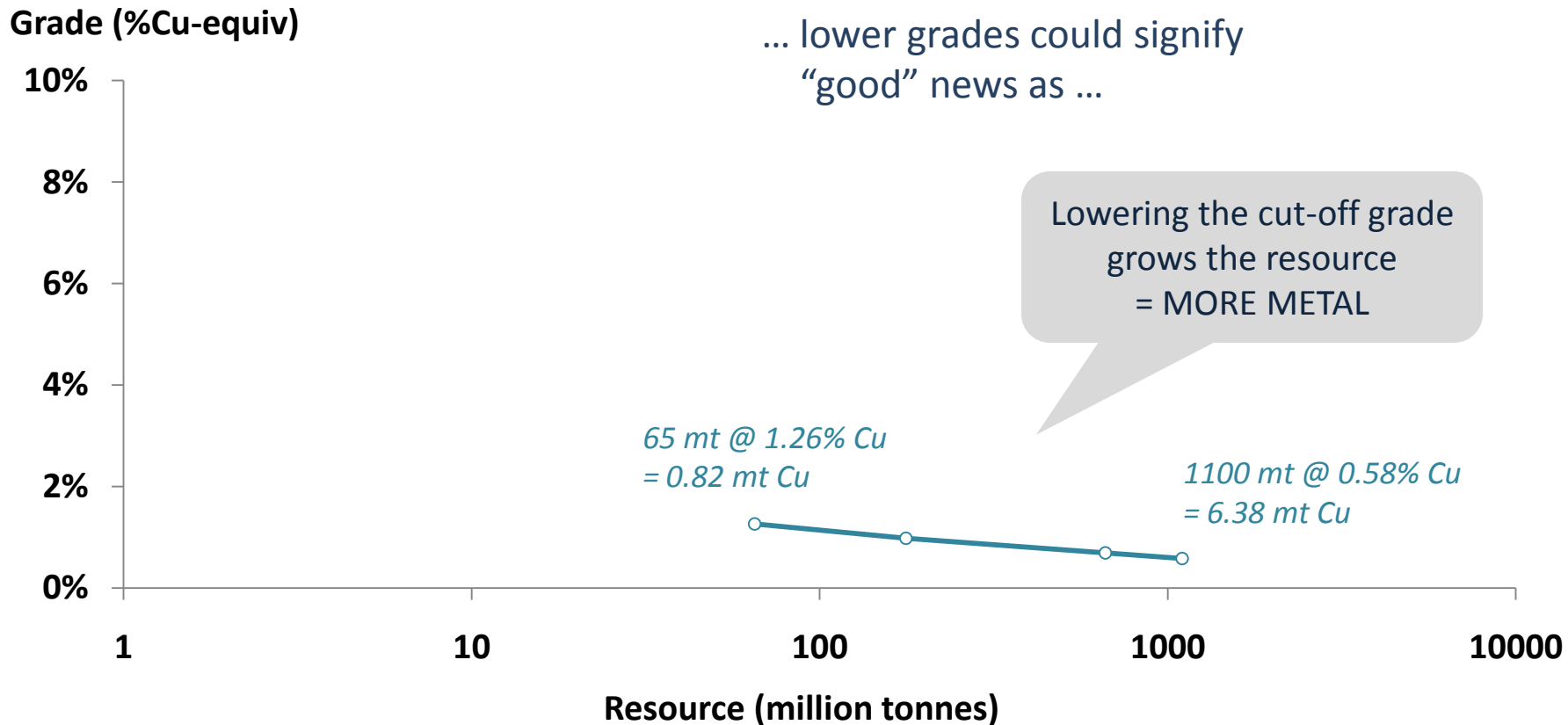
Sources: USGS, Mudd (2009)
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QUESTION:

Is a declining ore grade bad news or good news ?

There is a trade-off between tonnes and grade

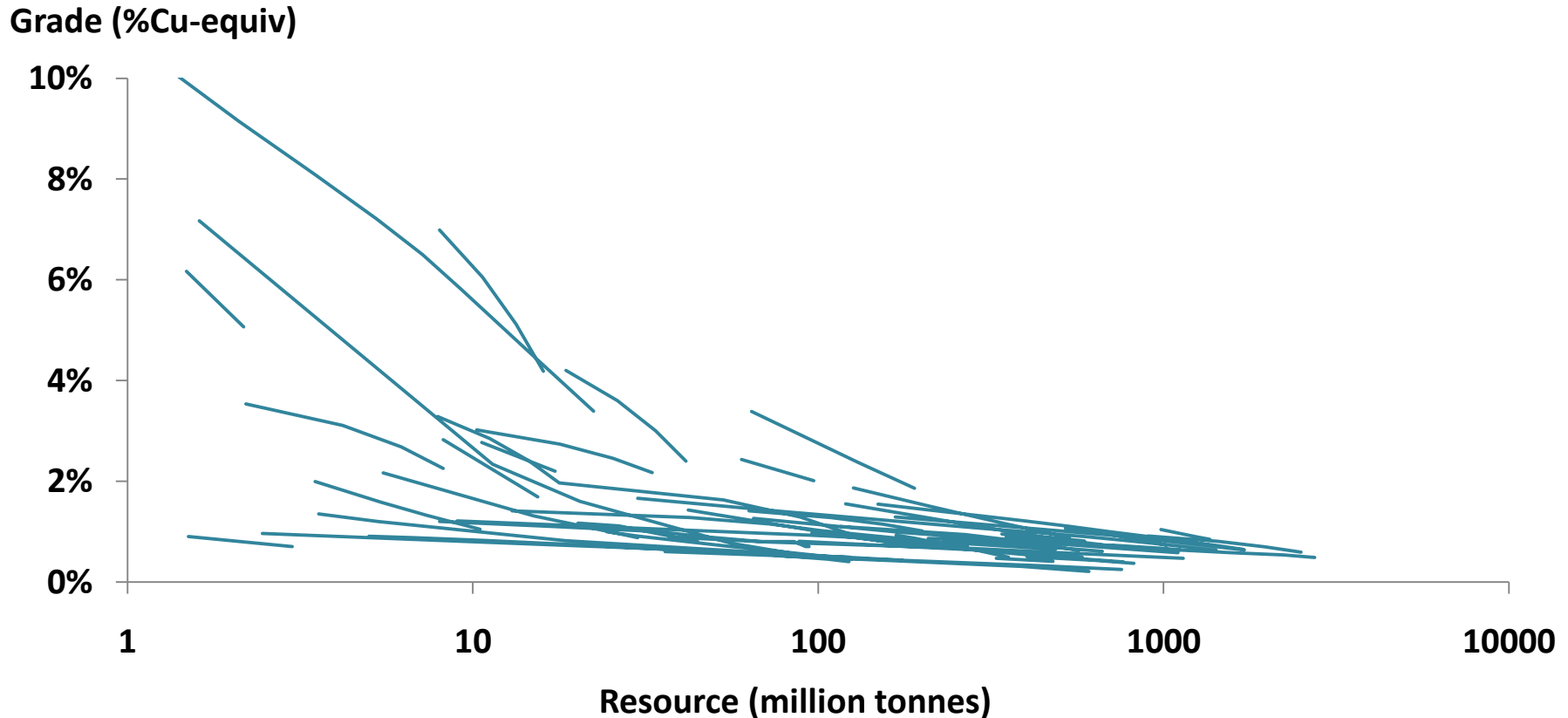
Rio Blanco copper deposit



Source: MinEx Consulting March 2010

There is a trade-off between tonnes and grade

Tonnes-Grade data for 48 copper deposits

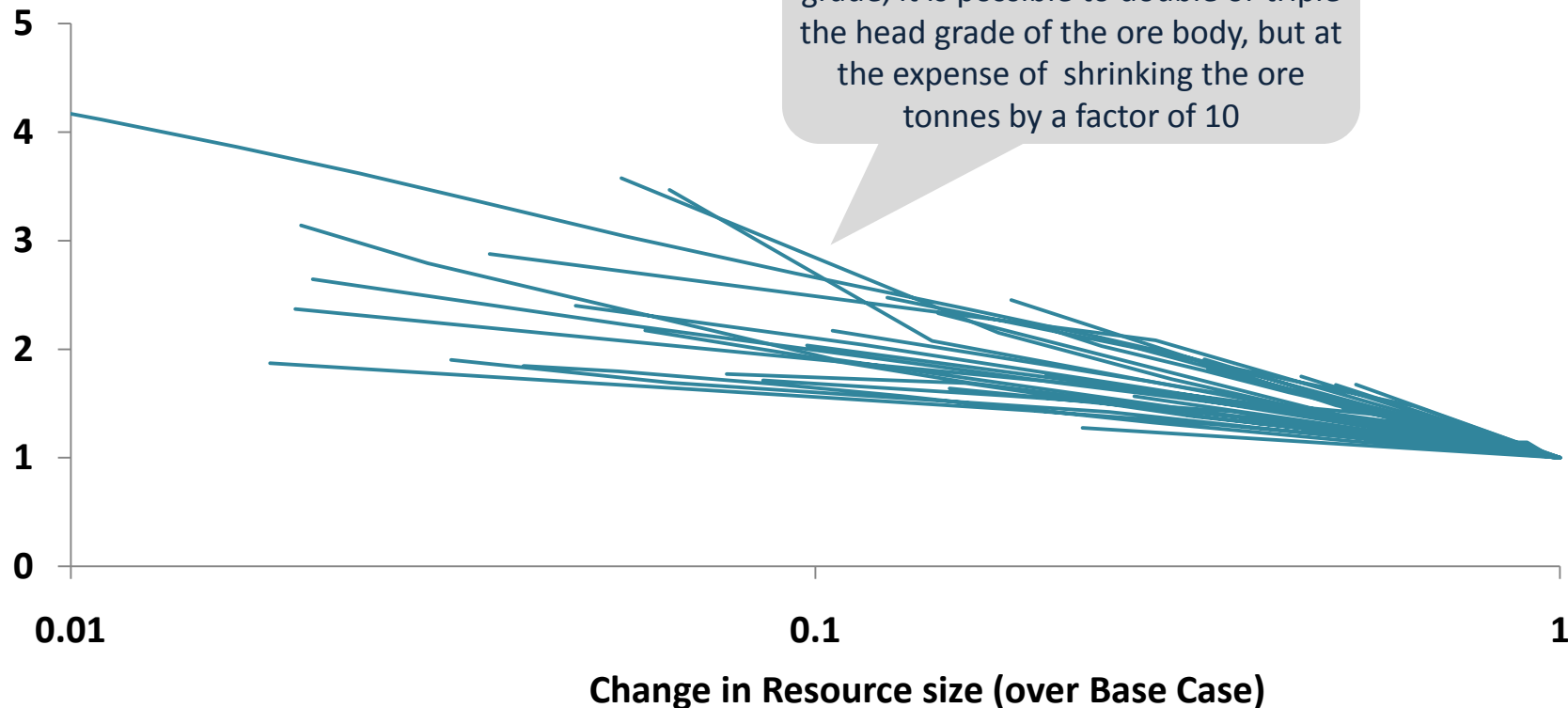


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NORMALISED Tonnes-Grade data for 48 copper deposits

Change in Grade (over Base Case)



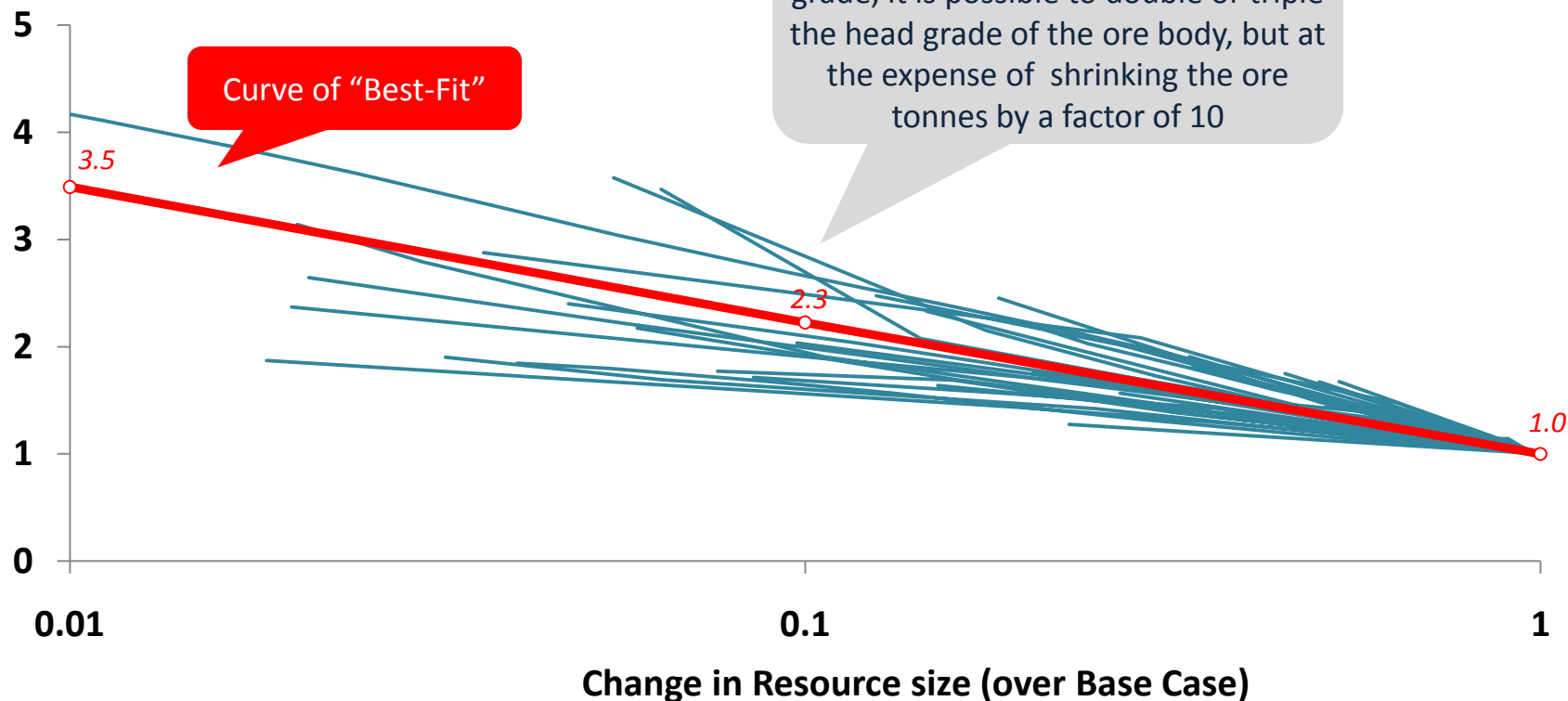
Base Case defined as the maximum reported resource size for a given deposit

Source: MinEx Consulting March 2010

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NORMALISED Tonnes-Grade data for 48 copper deposits

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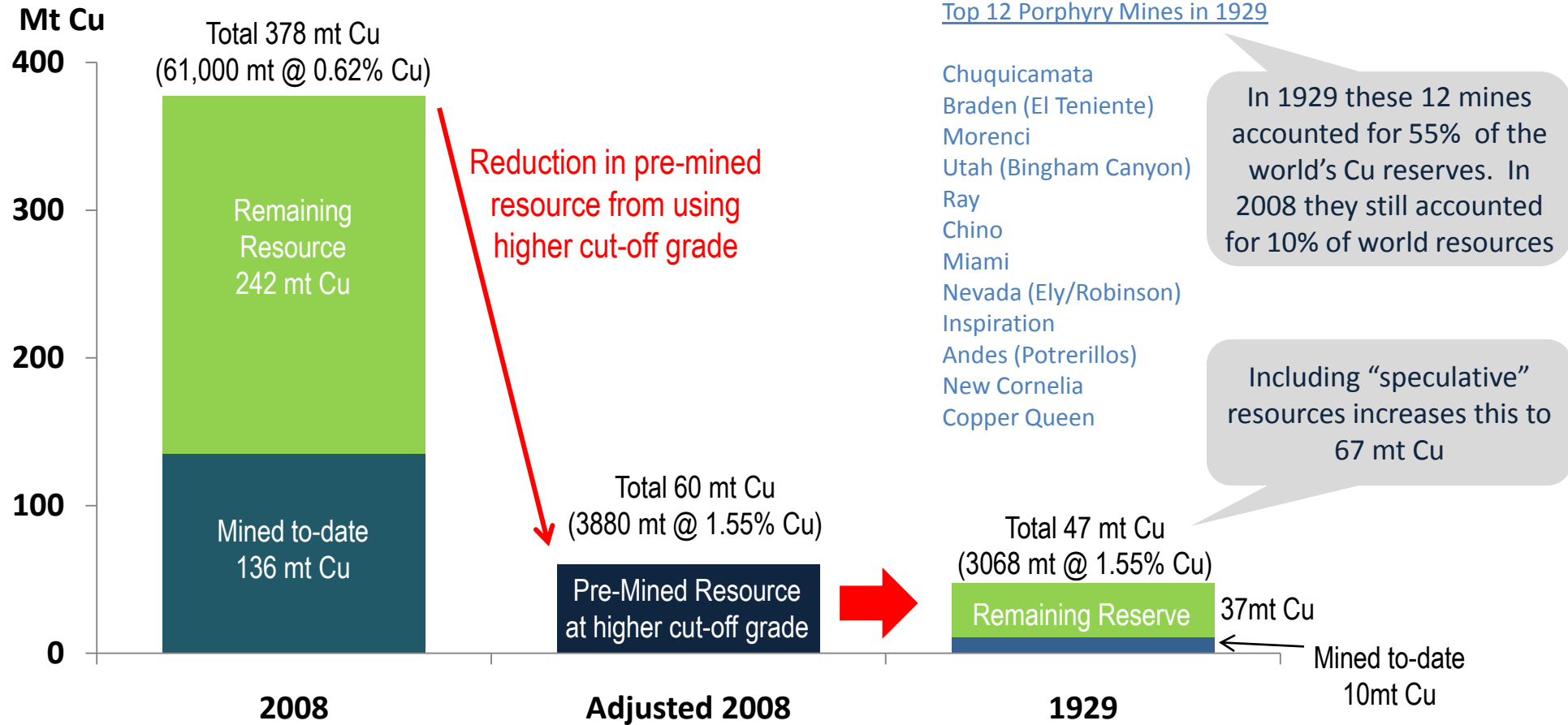


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Source: MinEx Consulting March 2010

Most of the huge growth in known resources in the last 70 years can be attributed to a reduction in cut-off grades

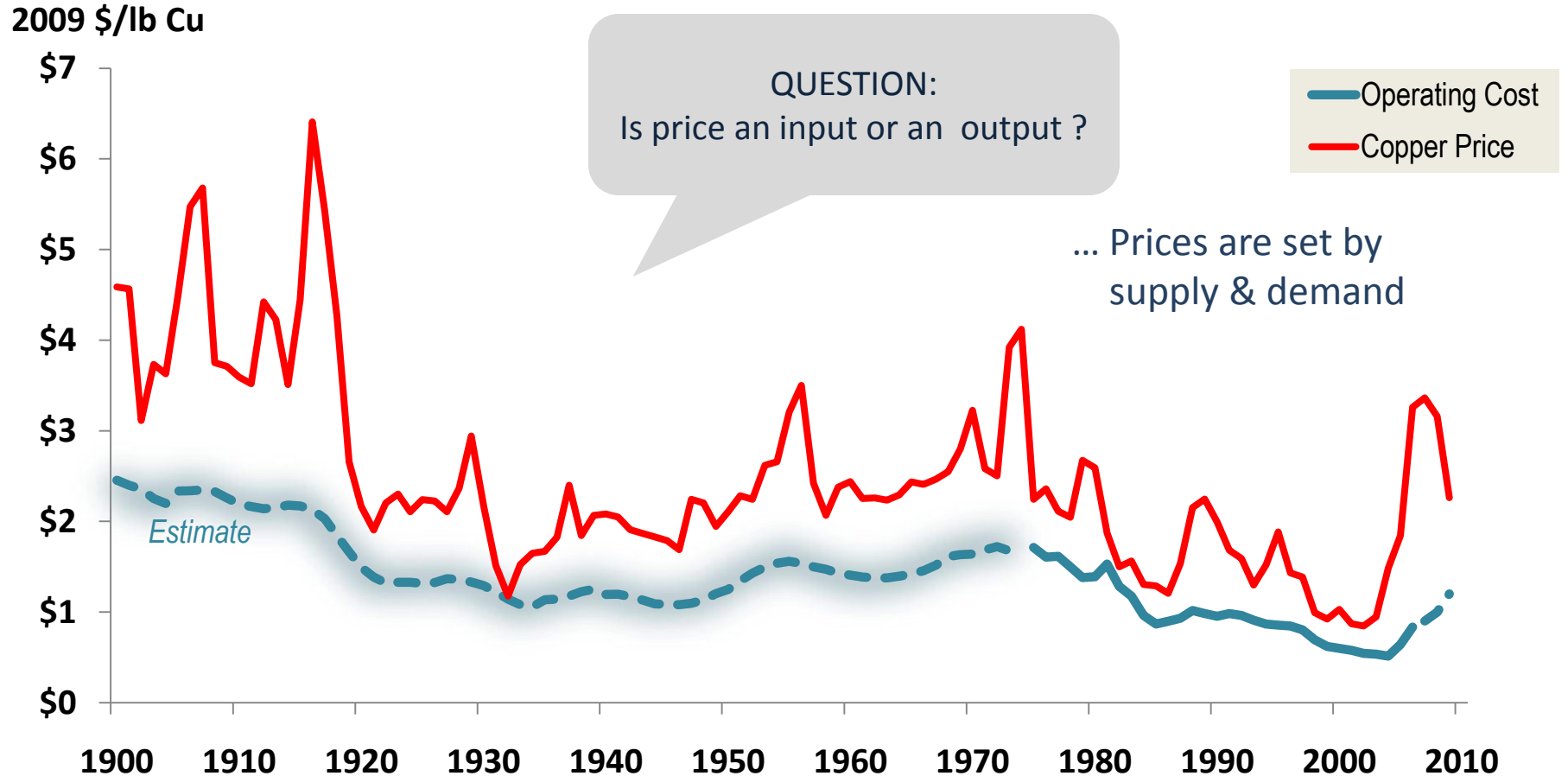
Change in pre-mined resources for 12 giant porphyry deposits: 1929-2008



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

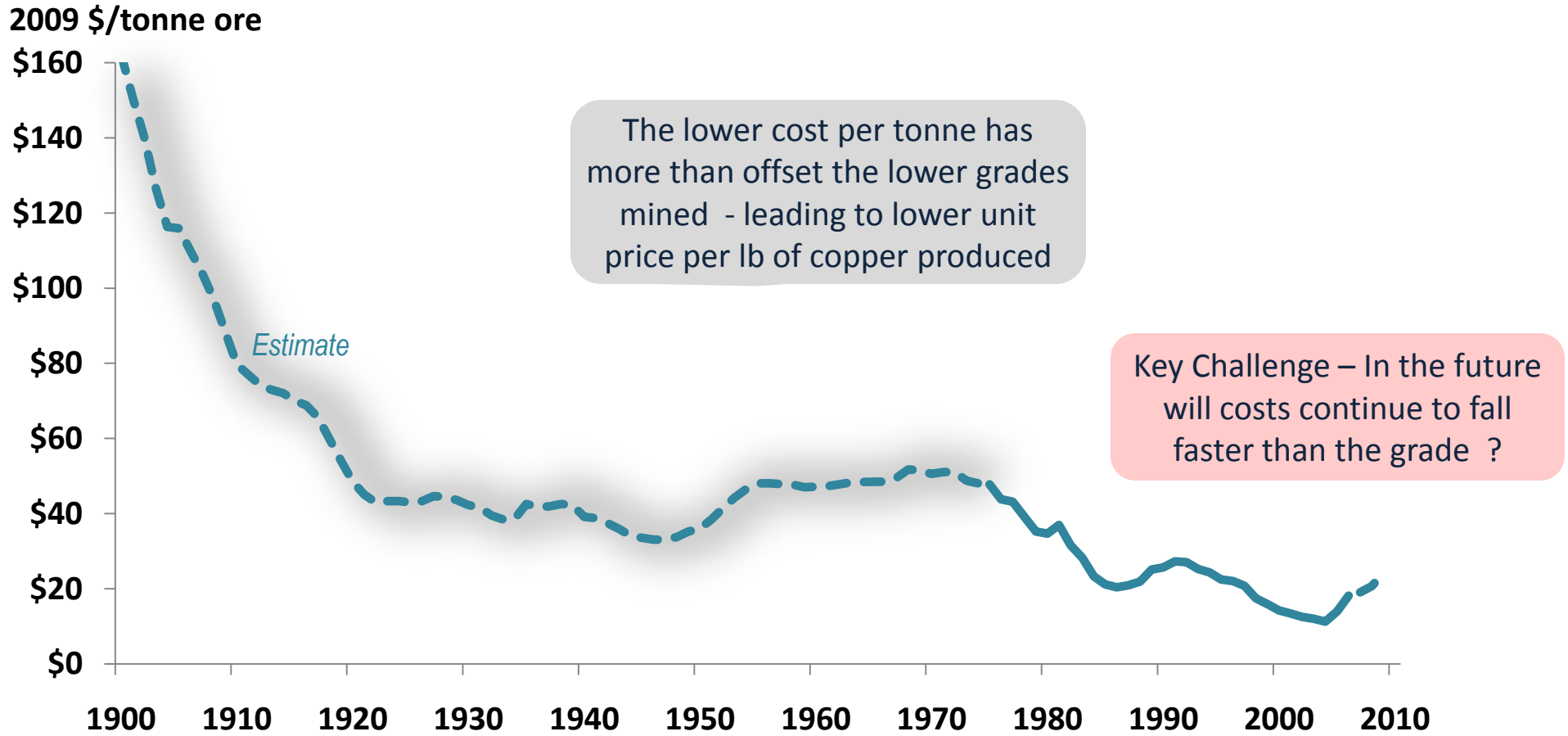


Sources: USGS, Brook Hunt, CRU
MinEx Consulting estimates (for 1900-1974)

Includes, transportation, smelting & refining and marketing costs

Over the same period, unit mining costs have dropped four-fold

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

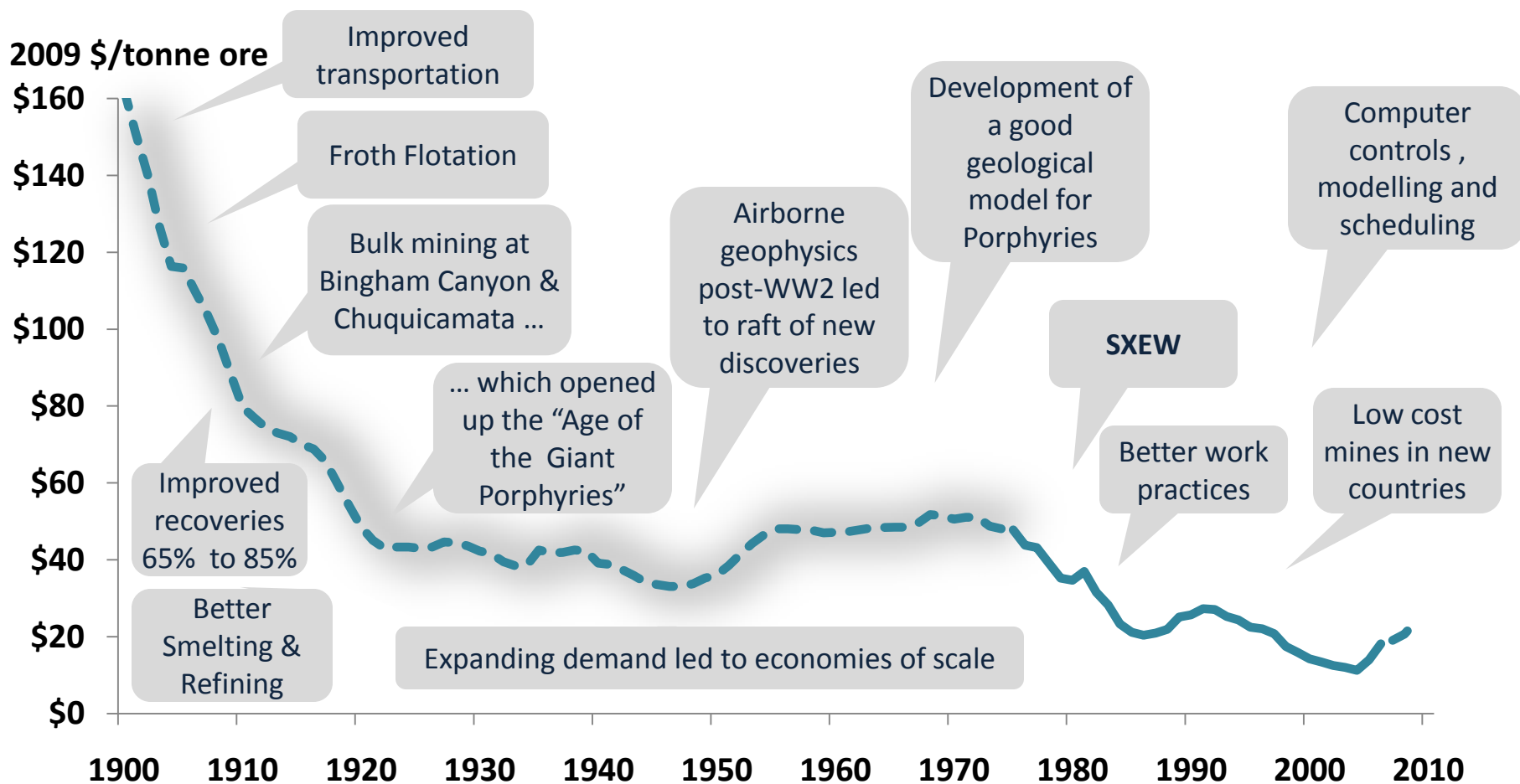


Sources: Brook Hunt, CRU , Historical reports
MinEx Consulting estimates (for 1900-1974)

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Key Technical Innovations

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

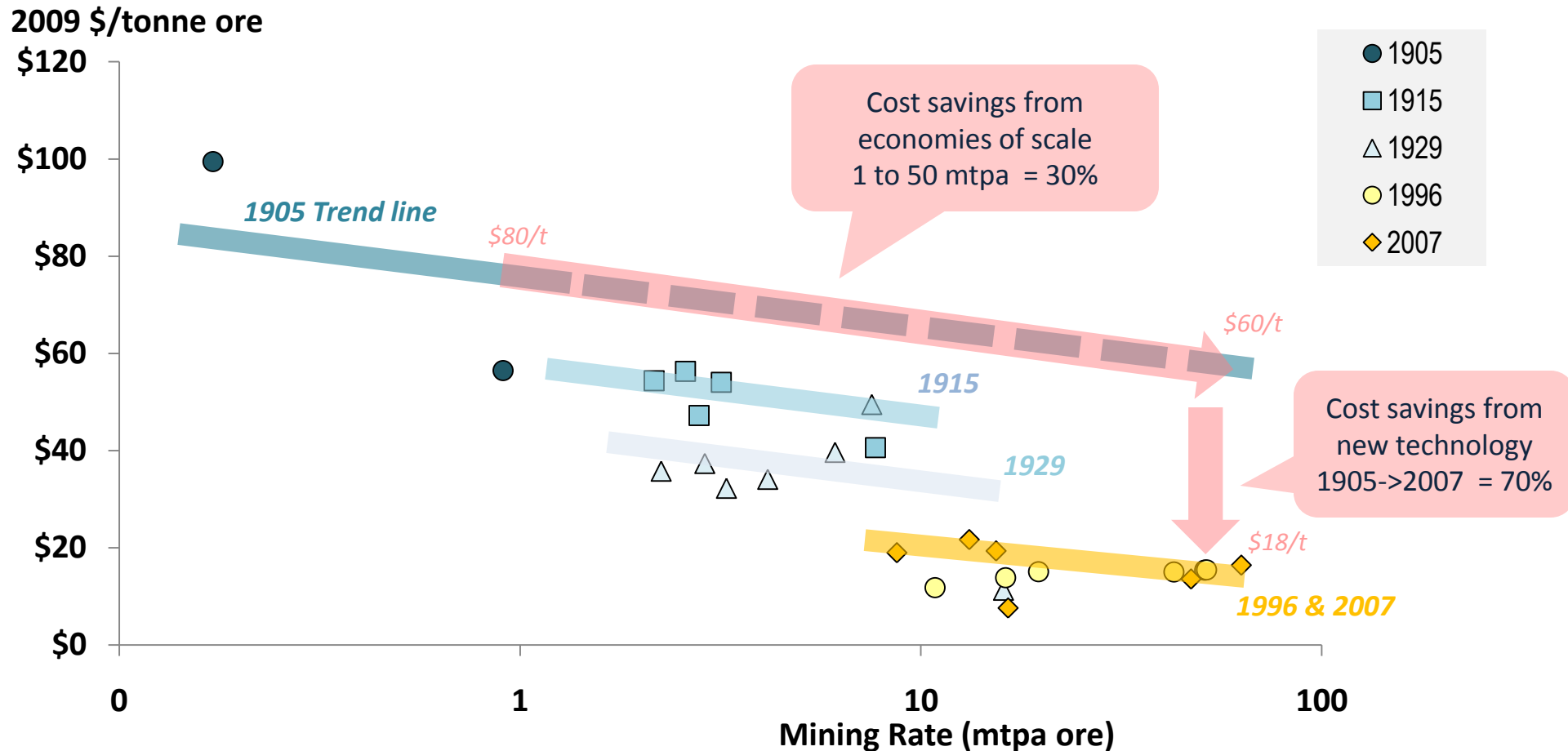


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Economies of scale and new technology helped drive down costs

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
 - Hard to untangle the partnership between geologists & engineers ... say 50: 50
- Technical innovations enabled giant “disseminated” Porphyries to be mined, and then later Cu-oxide deposits
 - 30%
 - 70%
- Costs reduced through economies of scale and new technologies
- As costs went down, so too did cut-off grades ... thereby further growing the resource
 - Halving the ore grade increased ore tonnes by x6 and metal by x3
- Prices are a output – not an input. They are driven by supply & demand

Contact details

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QUESTIONS ?