

Long term trends in global exploration – are we finding enough metal?

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Overview

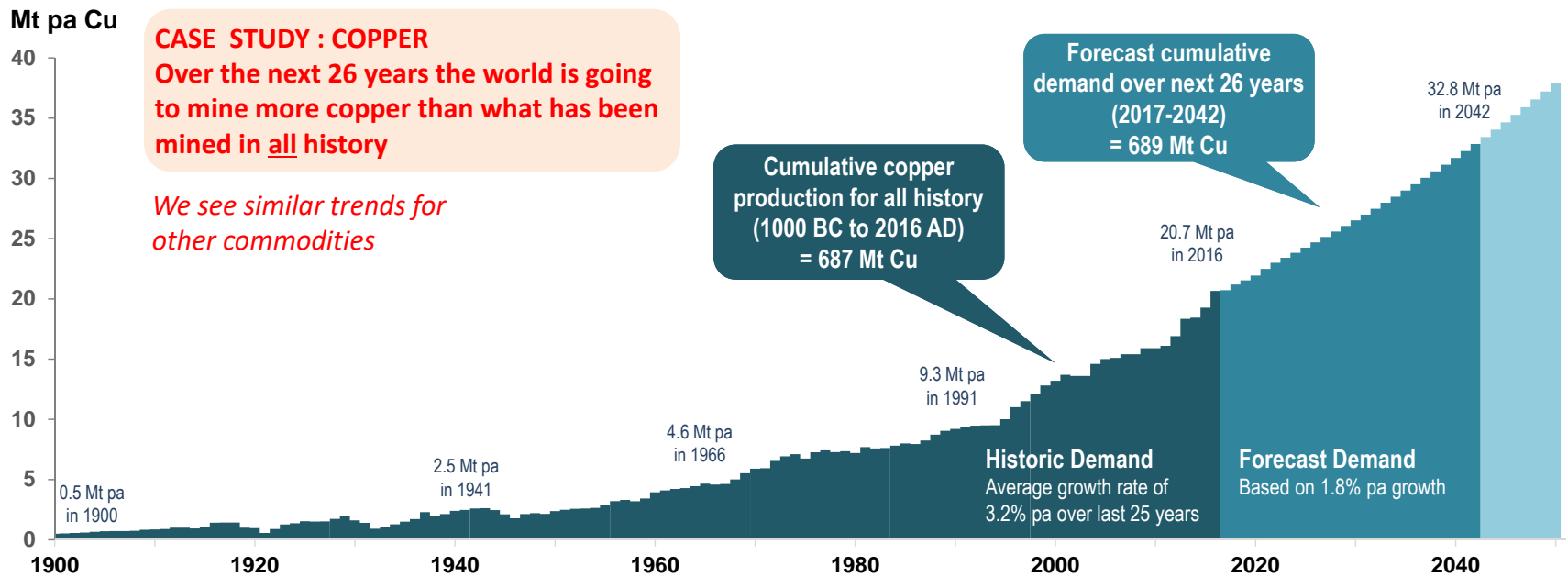
1. The Business Case for exploration
2. Long term trend in exploration expenditures
3. Long term outlook for exploration expenditures
4. Number of discoveries made
5. Long Term trends in Unit Discovery Costs
6. Forecast amount of metal discovered
7. Summary / Conclusions

Its simple – for the industry to be sustainable it need to find (good) new deposits to replace what it mines

1. BUSINESS CASE FOR EXPLORATION

The World's demand for metals doubles every 20-30 years

Primary copper production for World: 1900-2050



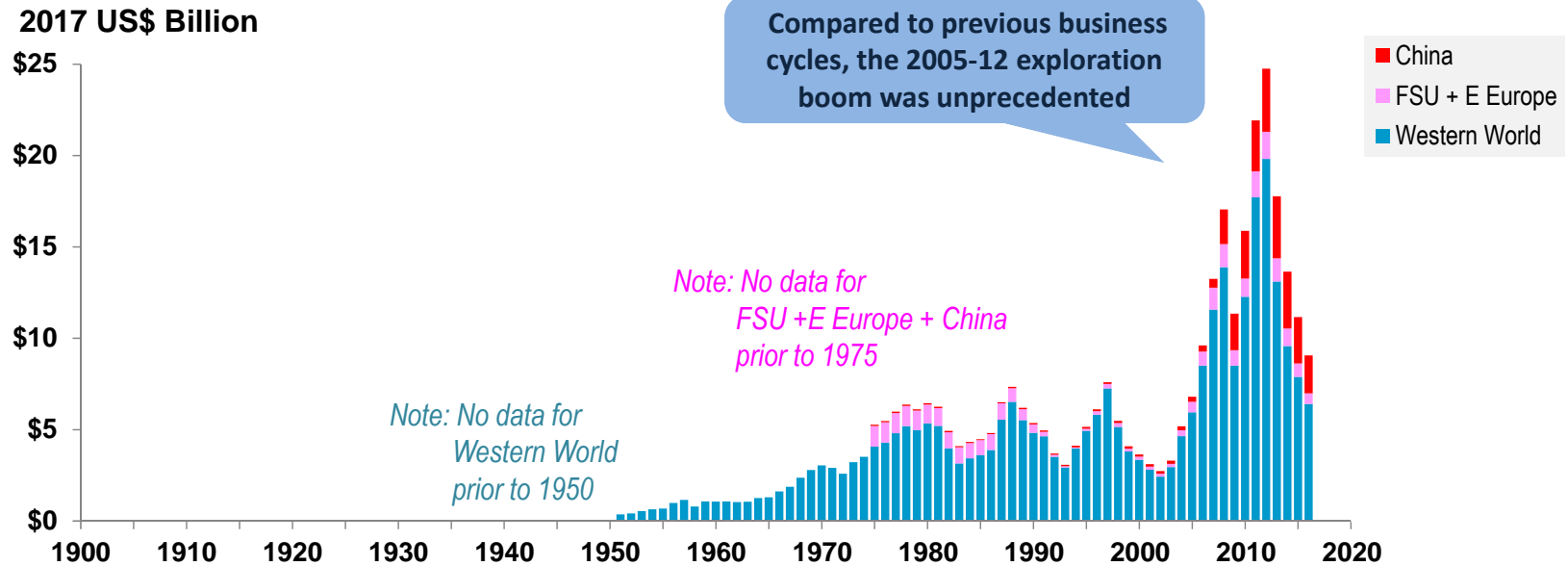
Source: MinEx Consulting © June 2017 based on historical data from USGS and the Australian Department of Industry

Over the last 50 years, exploration expenditures (in real terms) have increased 3-fold

2. LONG TERM TREND IN EXPLORATION EXPENDITURES

Exploration expenditures

Non-Bulk mineral exploration – World : 1950-2016



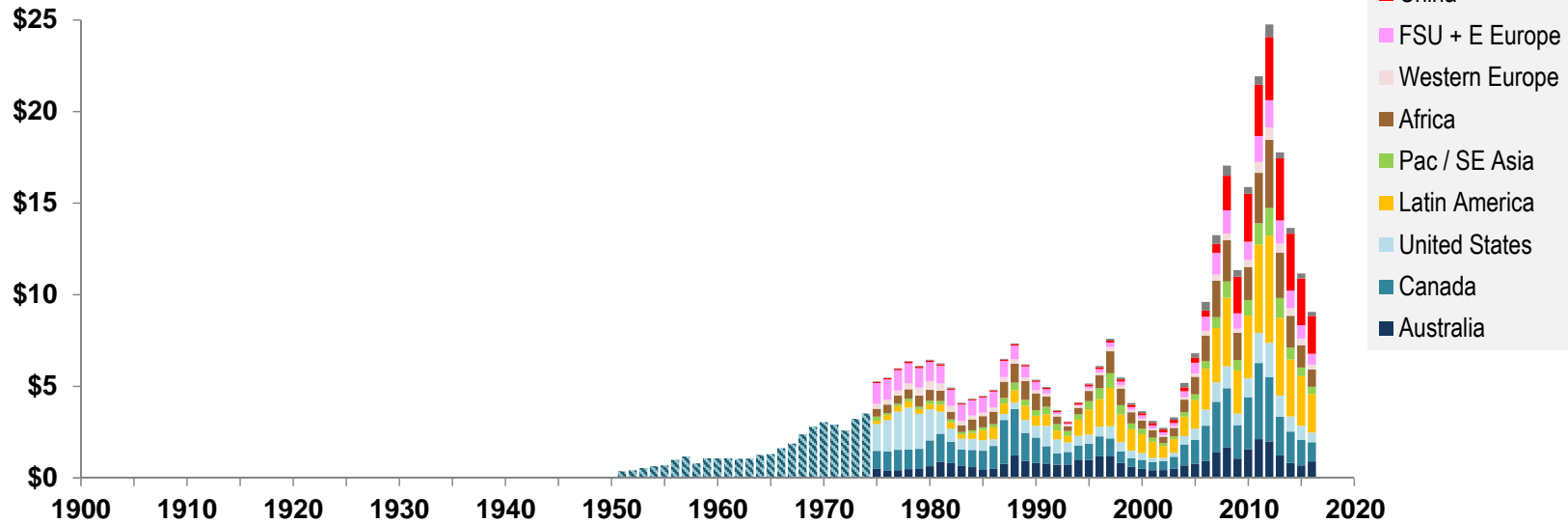
Note: Excludes expenditures on Bulk Minerals (i.e. bauxite, potash, phosphate, coal and iron ore)

Source: MinEx Consulting © October 2017

Exploration expenditures by Region

Non-Bulk mineral exploration – World : 1975-2016

2017 US\$ Billion



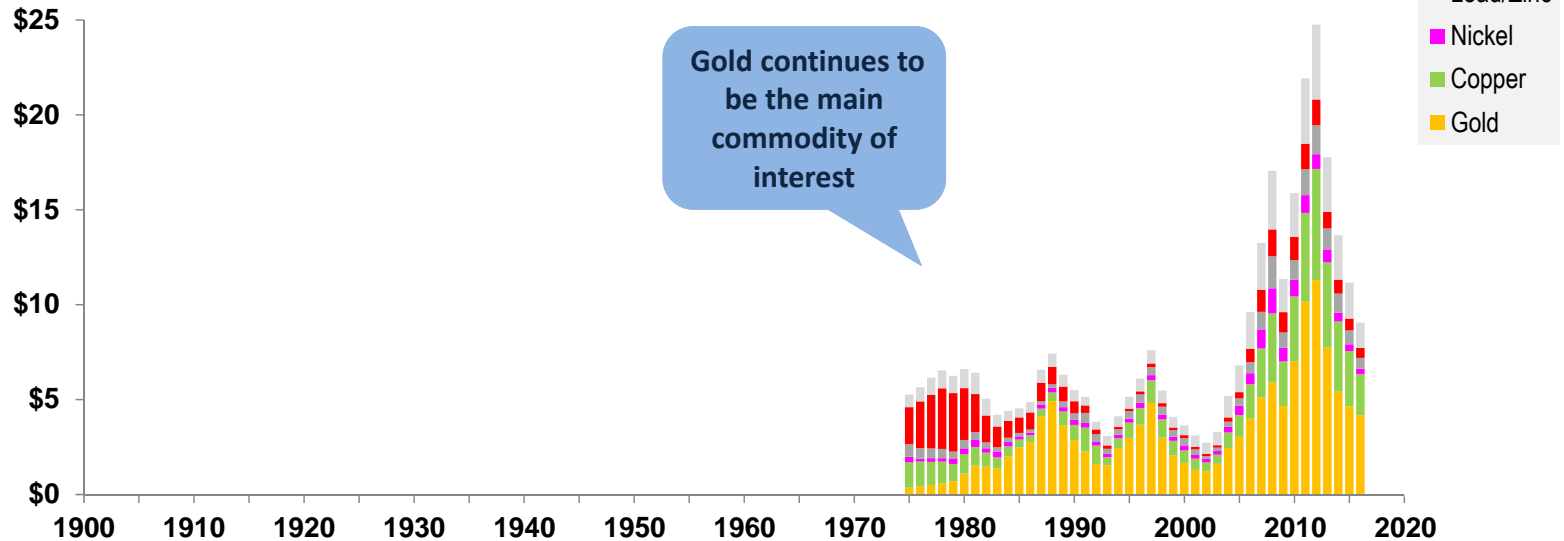
Note: Excludes expenditures on Bulk Minerals (i.e. bauxite, potash, phosphate, coal and iron ore)

Source: MinEx Consulting © October 2017

Exploration expenditures by Commodity

Non-Bulk mineral exploration – World : 1975-2016

2017 US\$ Billion



Note: Excludes expenditures on Bulk Minerals (i.e. bauxite, potash, phosphate, coal and iron ore)

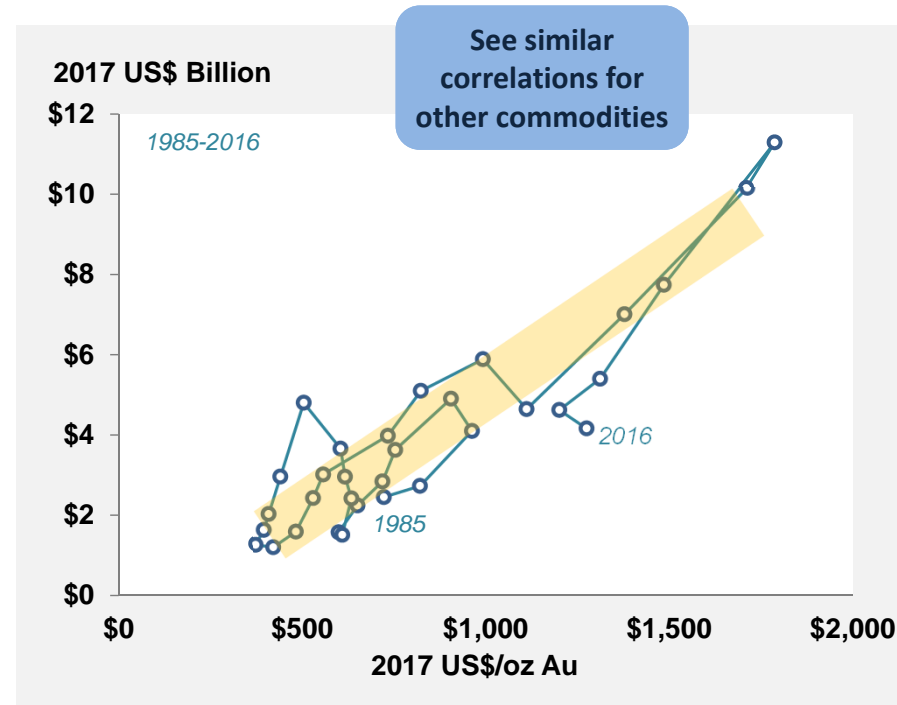
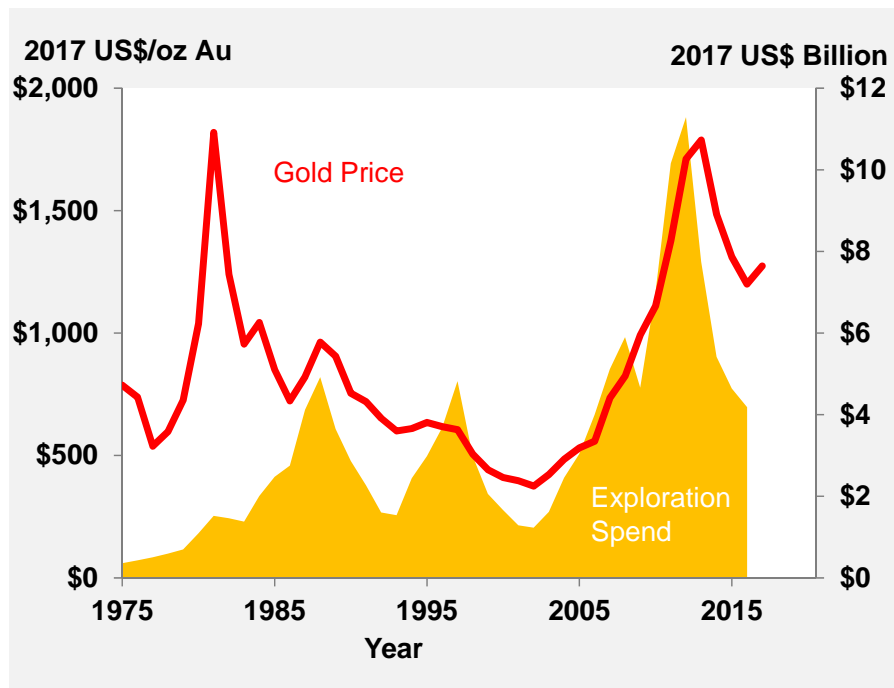
Source: MinEx Consulting © October 2017

The level of exploration spend is set to rise by 65% (in real terms) over the next decade

3. LONG TERM OUTLOOK FOR EXPLORATION EXPENDITURES

Exploration spend varies with the commodity price : Gold

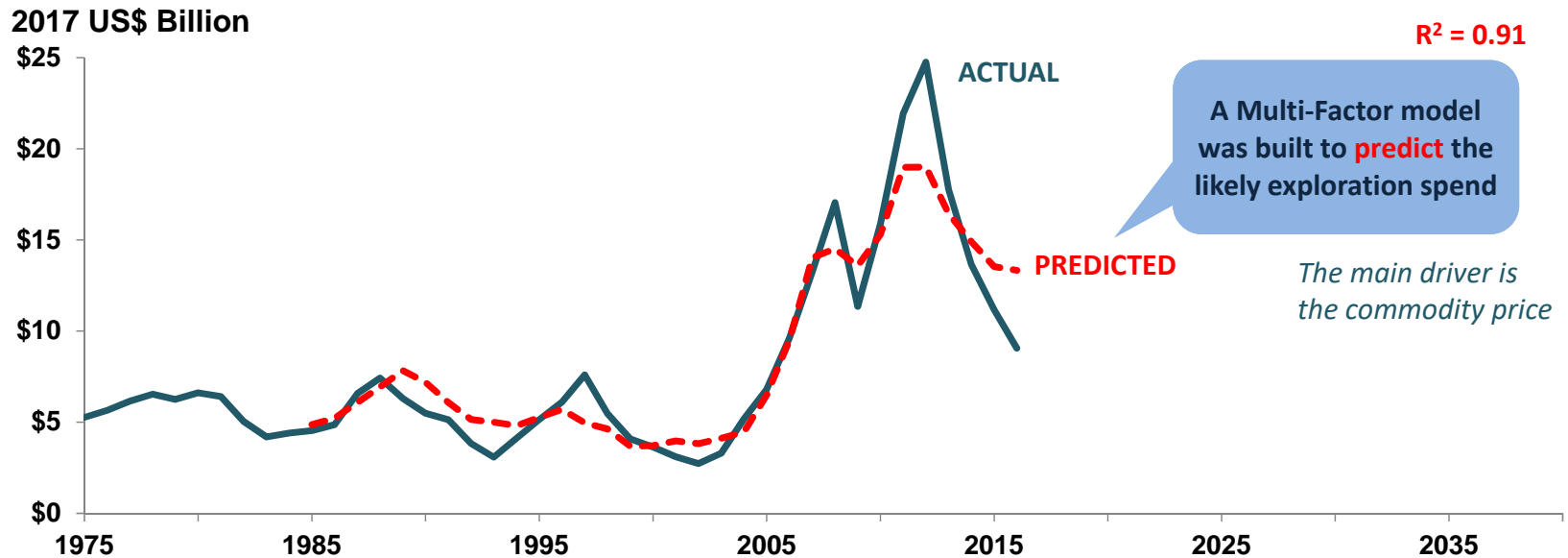
Gold price and exploration expenditures - World : 1975-2016



Source: MinEx Consulting © October 2017

Historical and Predicted Exploration expenditures

Non-Bulk mineral exploration – World : 1975-2016

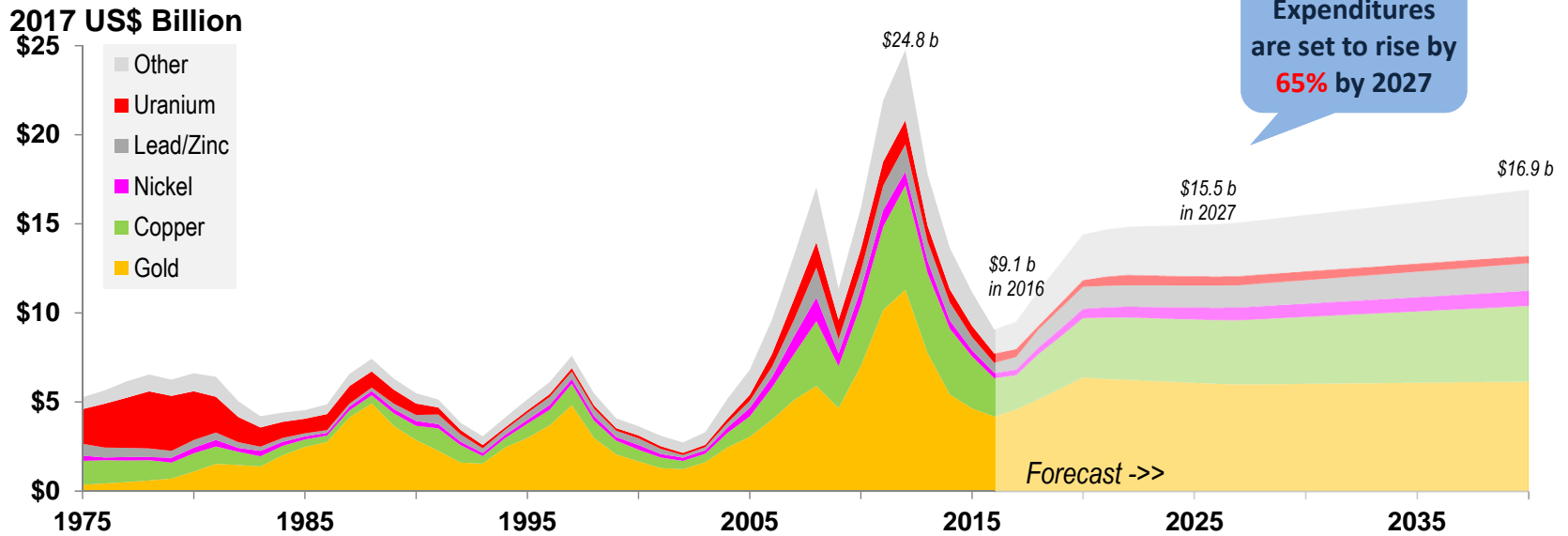


Note: Predicted spend is based on a set of multi-factor regression models for gold, copper, nickel, lead-zinc, uranium and other metals for the period 1985-2016

Source: MinEx Consulting © October 2017

Forecast Exploration expenditures by Commodity

Non-Bulk mineral exploration – World : 1975-2040



Note: Based on a long-run price (in constant 2017 US Dollars) of \$1150/oz Au, \$2.75/lb Cu, \$7.30/lb Ni, \$1.00/lb Zn, \$0.85/lb Pb and \$37/lb U₃O₈

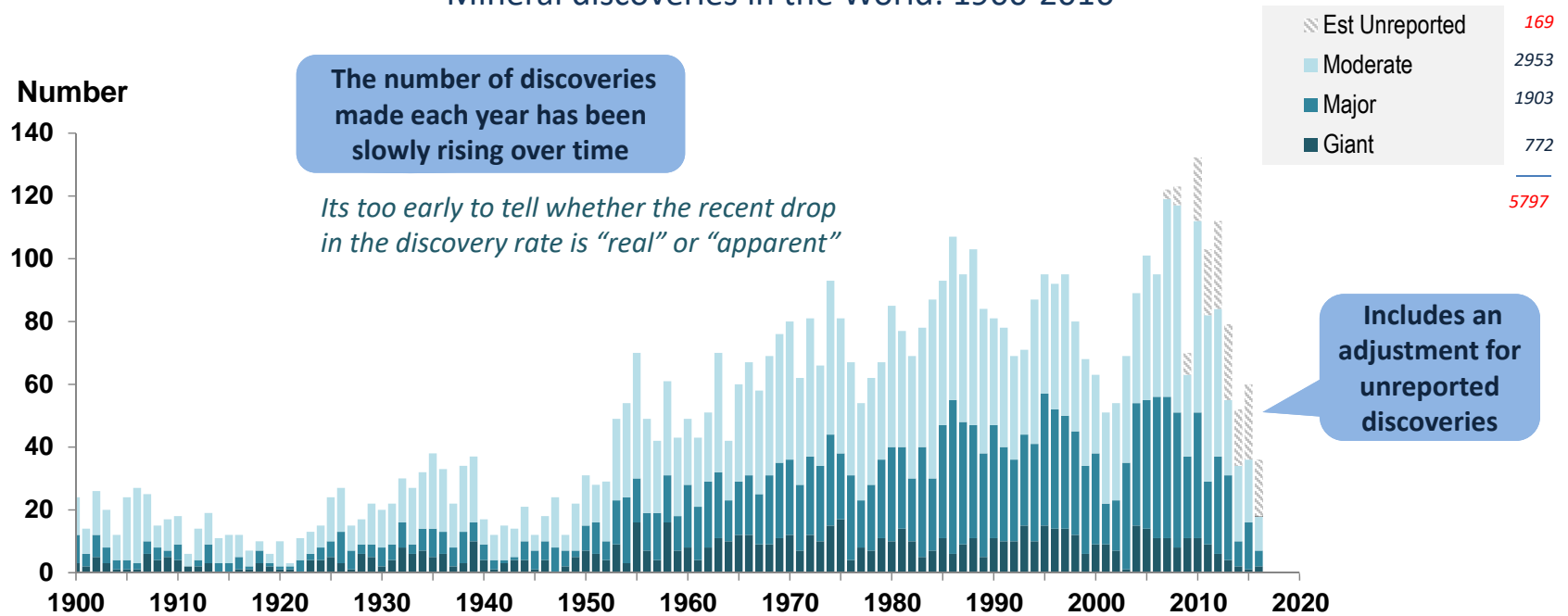
Source: MinEx Consulting © October 2017
Price forecast from Consensus Economics October 2017

The number of discoveries has slowly risen over time

4. LONG TERM TRENDS IN THE NUMBER OF DISCOVERIES MADE AND CONTAINED METAL

Number of discoveries by size

Mineral discoveries in the World: 1900-2016



Note: Excludes Bulk Mineral discoveries (i.e. bauxite, potash, phosphate, coal and iron ore)

"Moderate" >100koz Au, >10kt Ni, >100Kt Cu equiv, 250kt Zn+Pb, >5kt U₃O₈

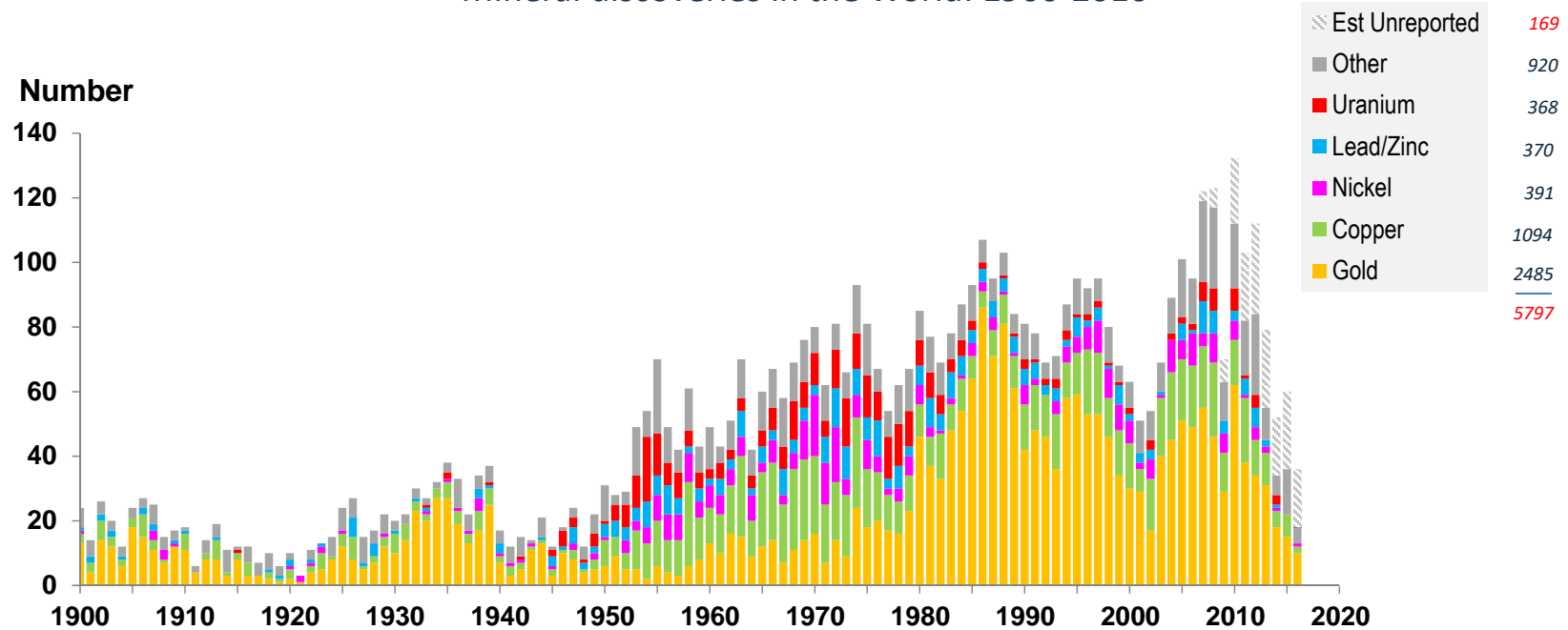
"Major" >1Moz Au, >100kt Ni, >1Mt Cu equiv, 2.5Mt Zn+Pb, >25kt U₃O₈

"Giant" >6Moz Au, >1Mt Ni, >5Mt Cu equiv, 12Mt Zn+Pb, >125kt U₃O₈

Source: MinEx Consulting © October 2017

Number of discoveries by commodity type

Mineral discoveries in the World: 1900-2016



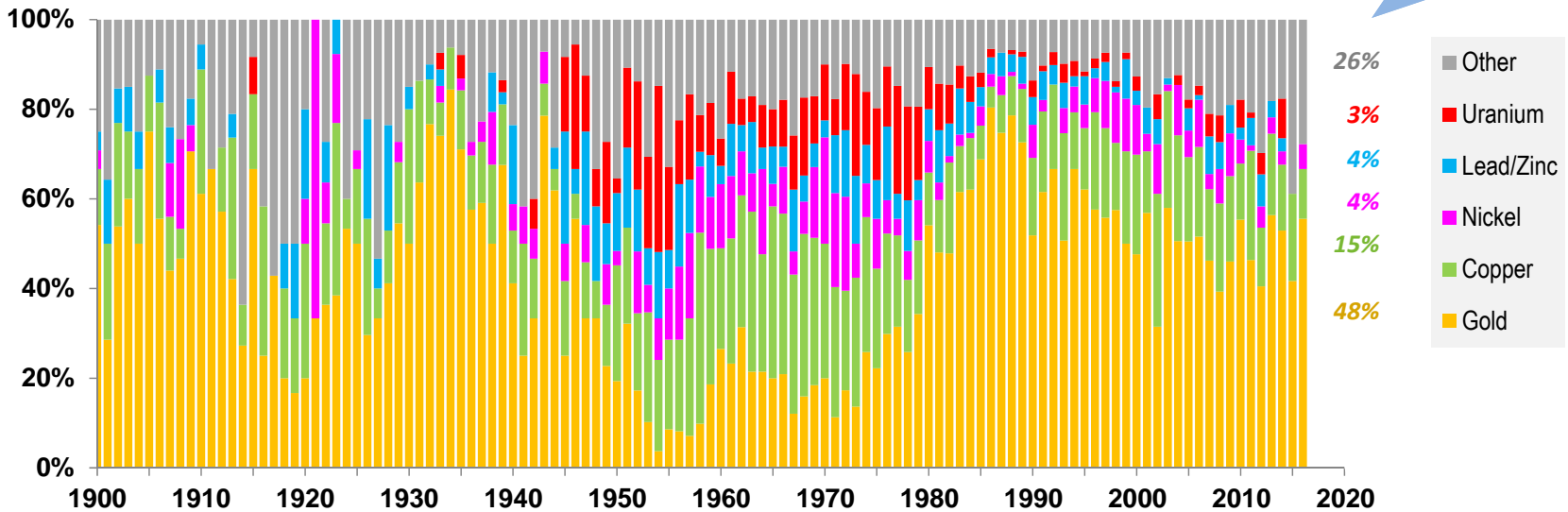
Note: Excludes Bulk Mineral discoveries (i.e. bauxite, potash, phosphate, coal and iron ore)

Source: MinEx Consulting © October 2017

Number of discoveries by commodity type

Mineral discoveries in the World: 1900-2016

Percentage of Total



Average over last 5 years

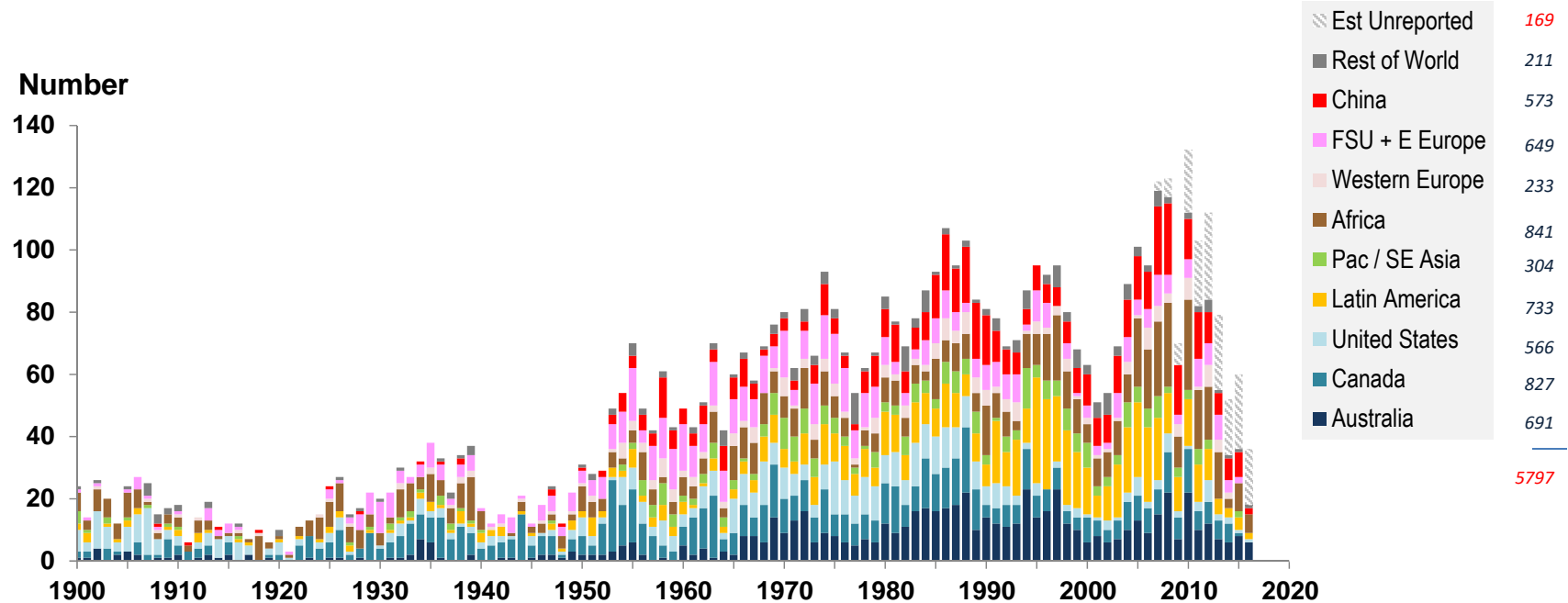
Gold continues to make up half of all of the discoveries

Source: MinEx Consulting © October 2017

Note: Excludes Bulk Mineral discoveries (i.e. bauxite, potash, phosphate, coal and iron ore)
 "Moderate" >100koz Au, >10kt Ni, >100Kt Cu equiv, 250kt Zn+Pb, >5kt U₃O₈
 "Major" >1Moz Au, >100kt Ni, >1Mt Cu equiv, 2.5Mt Zn+Pb, >25kt U₃O₈
 "Giant" >6Moz Au, >1Mt Ni, >5Mt Cu equiv, 12Mt Zn+Pb, >125kt U₃O₈

Number of discoveries by region

Mineral discoveries in the World: 1900-2016

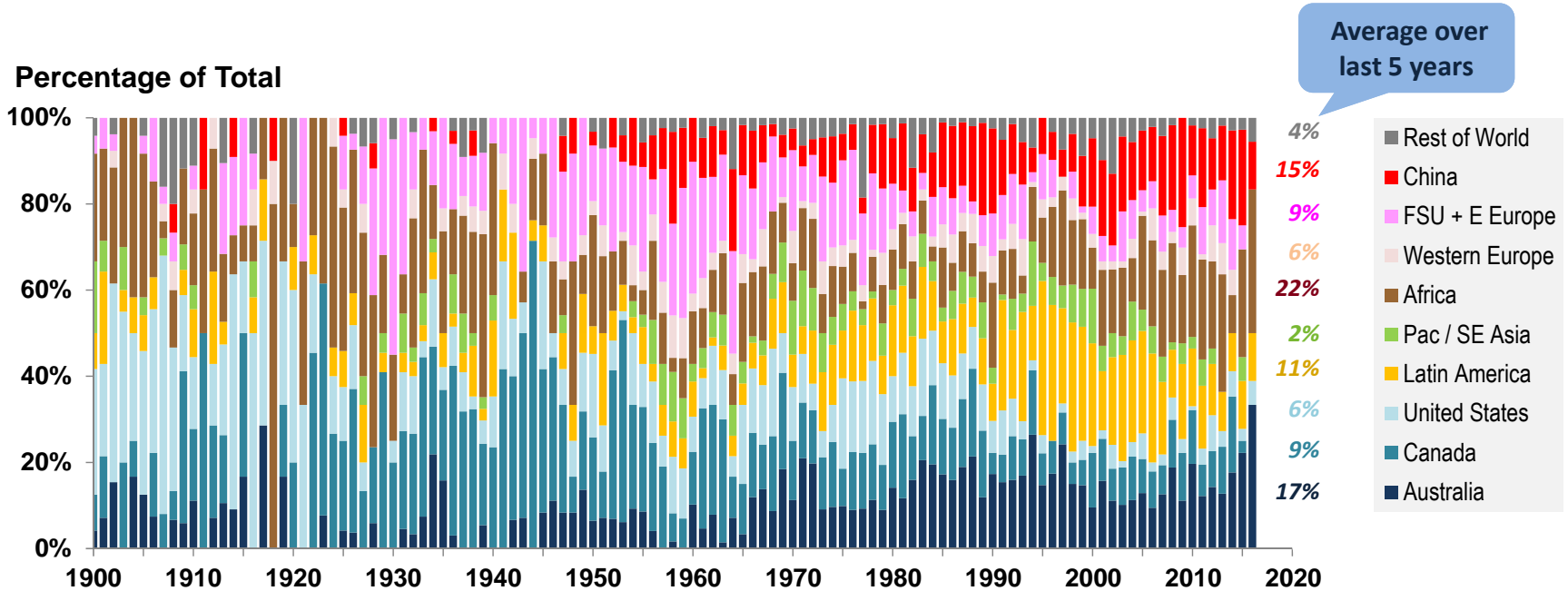


Note: Excludes Bulk Mineral discoveries (i.e. bauxite, potash, phosphate, coal and iron ore)

Source: MinEx Consulting © October 2017

Number of discoveries by region

Mineral discoveries in the World: 1900-2016



Note: Excludes Bulk Mineral discoveries (i.e. bauxite, potash, phosphate, coal and iron ore)

Source: MinEx Consulting © October 2017

Smoothed Data
(5 year rolling average)

Number of discoveries by region

Mineral discoveries in the World: 1900-2016

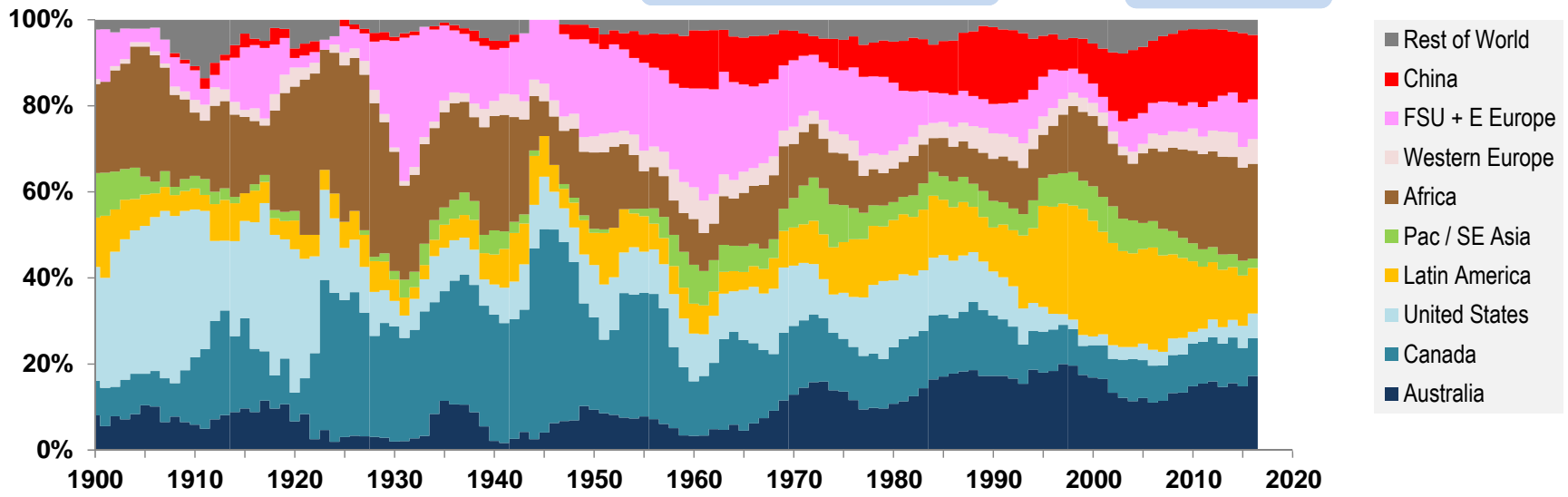
The relative importance of each Region changes over time

... is driven by geological maturity, technology, infrastructure and Country Risk

Russia dropped out following the collapse of the Soviet Union in 1991

Rise of China and the return of Africa

Percentage of Total



In the early 1900's USA was dominant ...

... followed by Canada

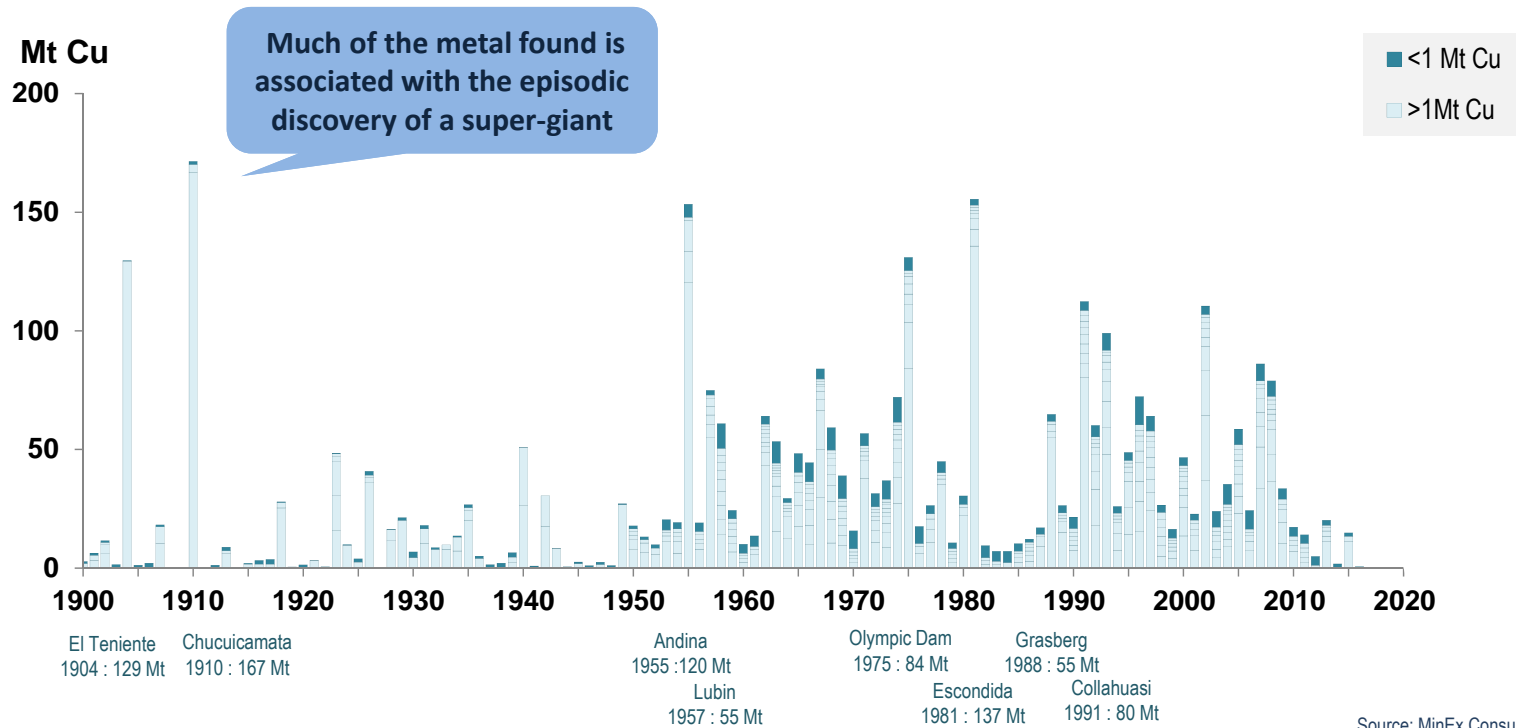
Australia continues to holds its share

Note: Excludes Bulk Mineral discoveries (i.e. bauxite, potash, phosphate, coal and iron ore)

Source: MinEx Consulting © October 2017

Amount of Metal discovered : **Copper**

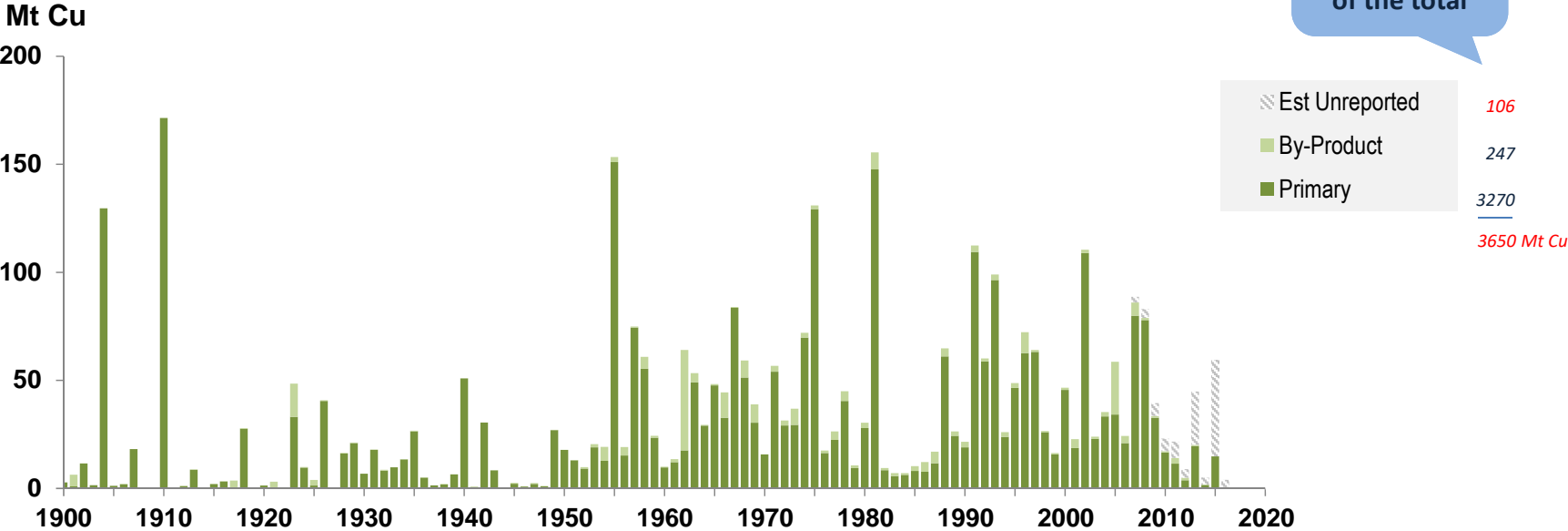
World: 1900-2016



Source: MinEx Consulting © October 2017

Amount of Metal discovered : Copper

World: 1900-2016

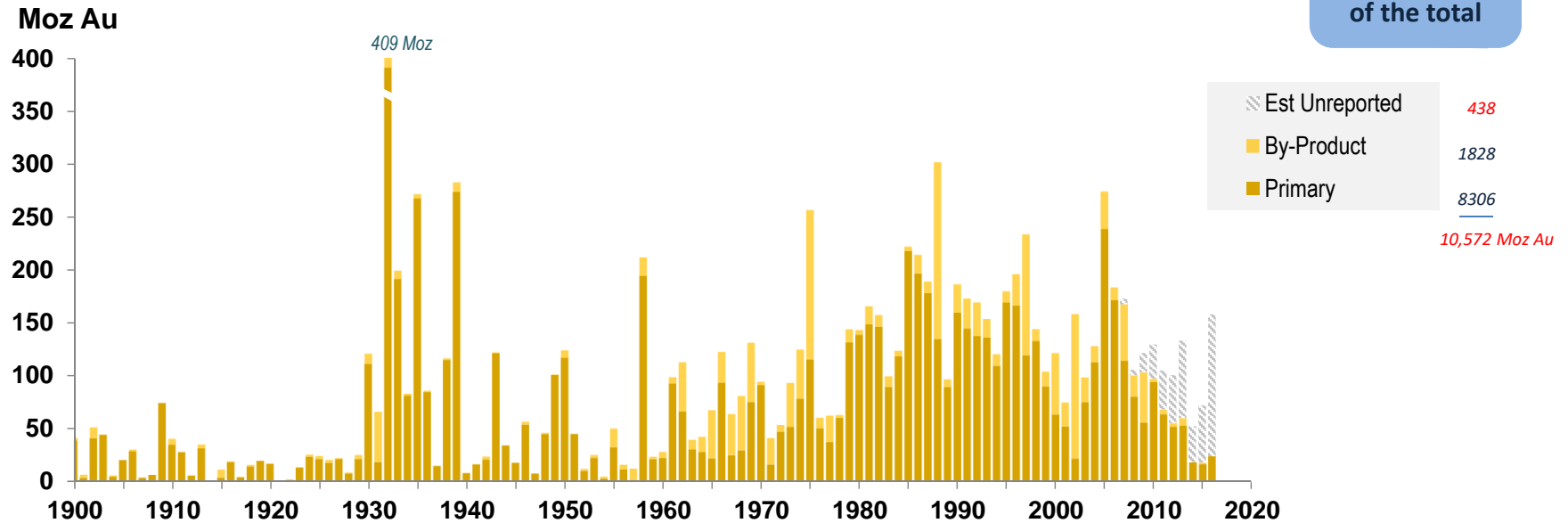


Source: MinEx Consulting © October 2017

Amount of Metal discovered : Gold

World: 1900-2016

By-Product Au makes up **18%** of the total

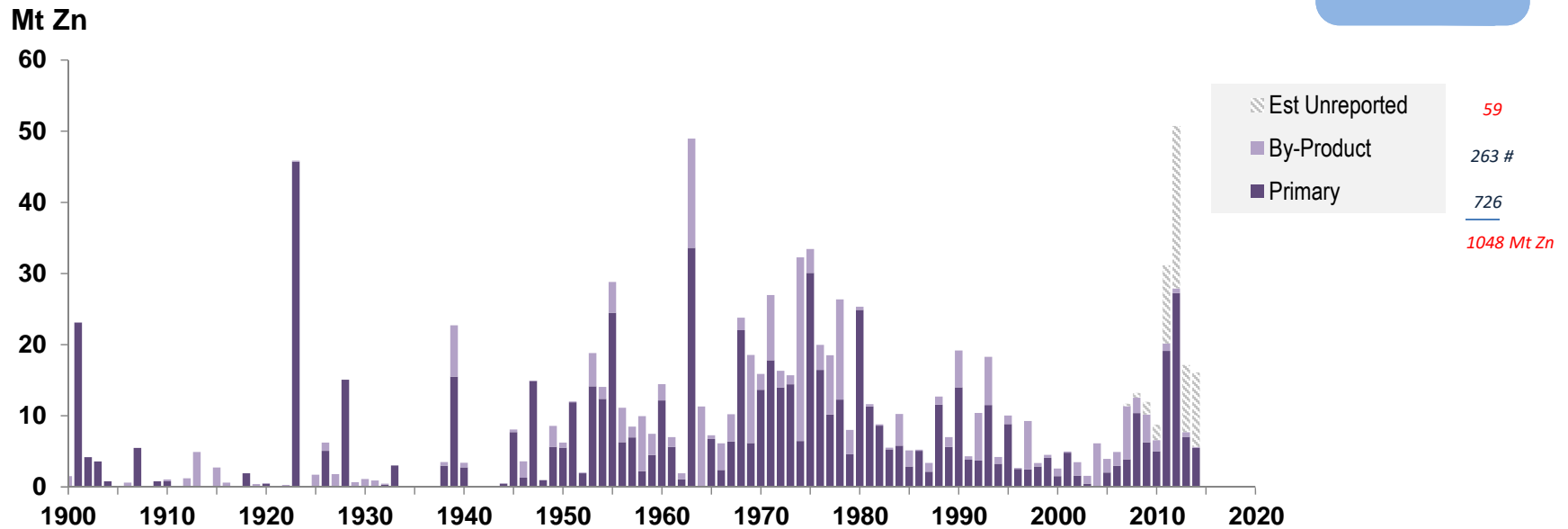


Source: MinEx Consulting © October 2017

Amount of Metal discovered : Zinc

World: 1900-2016

By-Product Zn makes up **27%** of the total



Note: Includes 23 Mt of Zn associated with Lead deposits

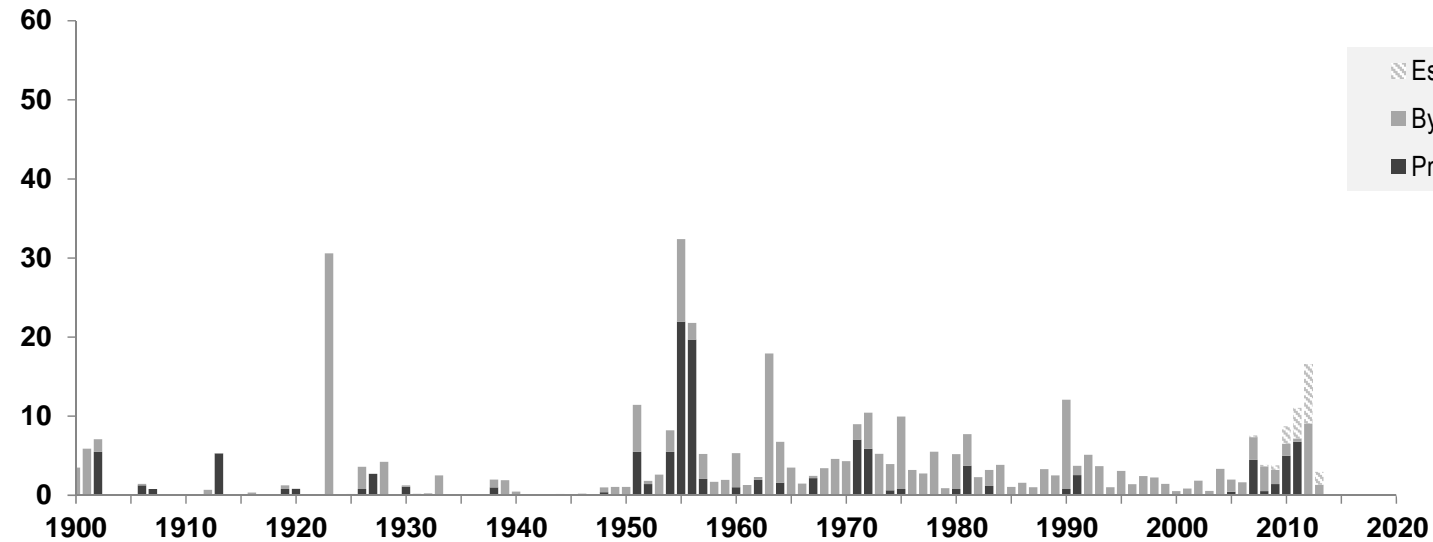
Source: MinEx Consulting © October 2017

Amount of Metal discovered : Lead

World: 1900-2016

By-Product Pb makes up **68%** of the total

Mt Pb



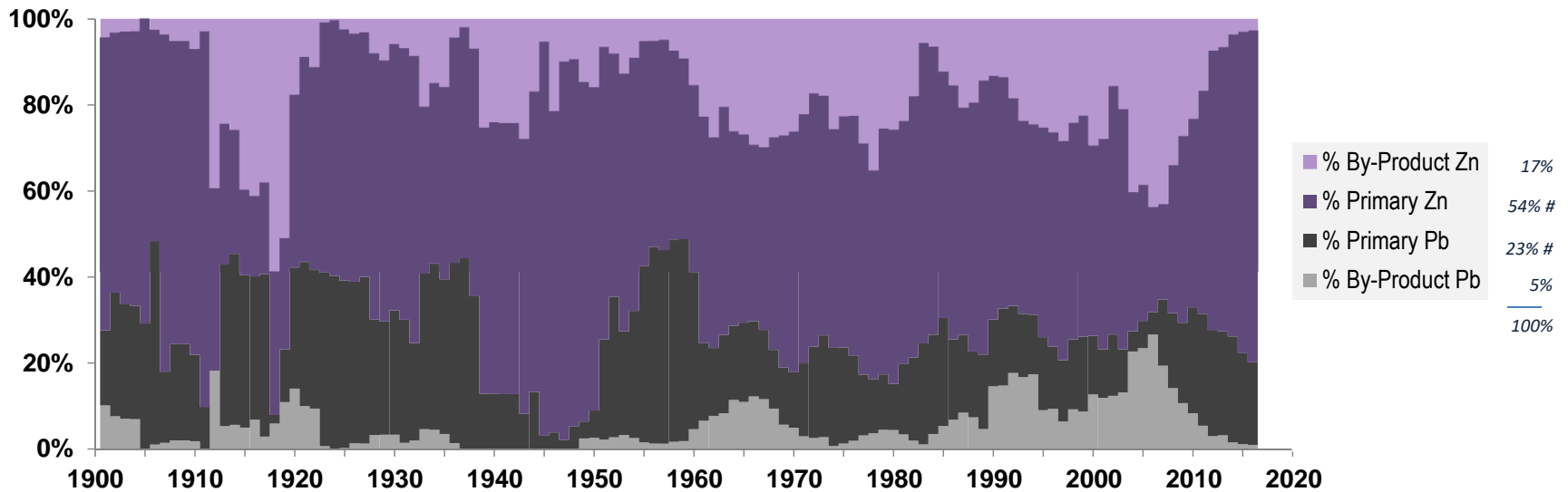
Note: Includes 191 Mt of Lead associated with Zinc deposits

Source: MinEx Consulting © October 2017

Ratio of Zinc + Lead discovered

World: 1900-2016

Total Zn+Pb discovered



Note: In this case, Primary includes Zn found in Pb deposits, and visa versa

These ratios mean that 1t of Primary Zn+Pb will (on average) contain 0.70t Zn + 0.30t Pb.

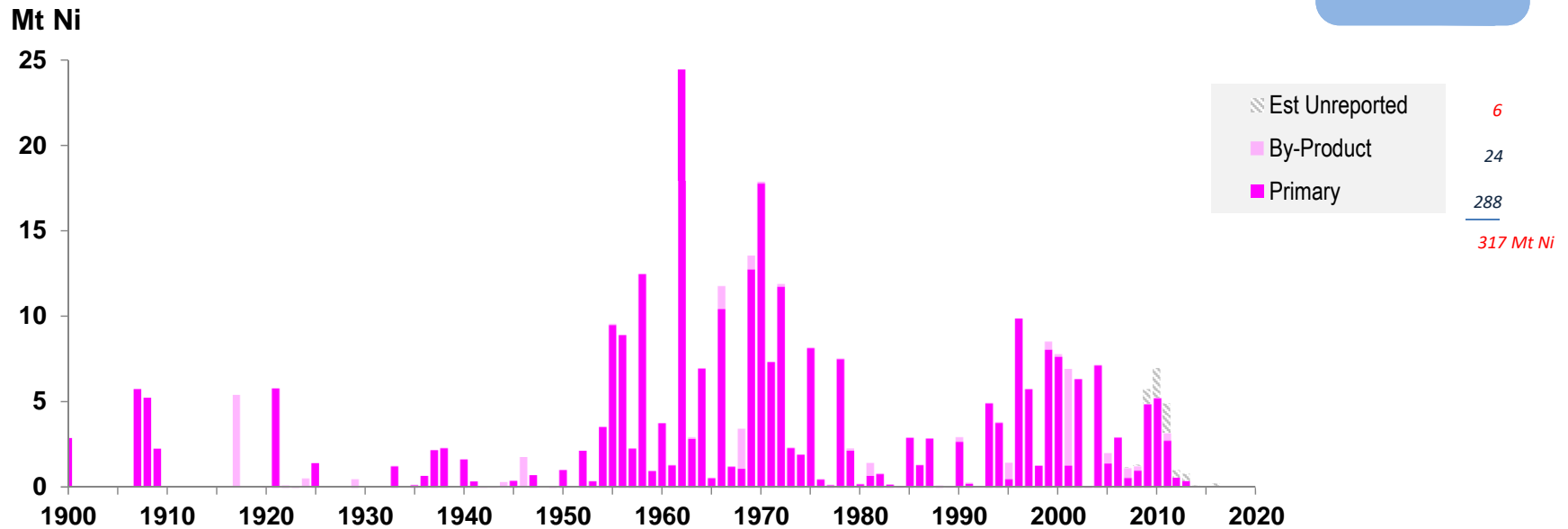
In addition, for every 1t of Primary Zn+Pb found, an additional 0.23t by-product Zn and 0.07t of by-product Pb will be found in other deposits

Source: MinEx Consulting © October 2017

Amount of Metal discovered : Nickel

World: 1900-2016

By-Product Ni makes up **8%** of the total



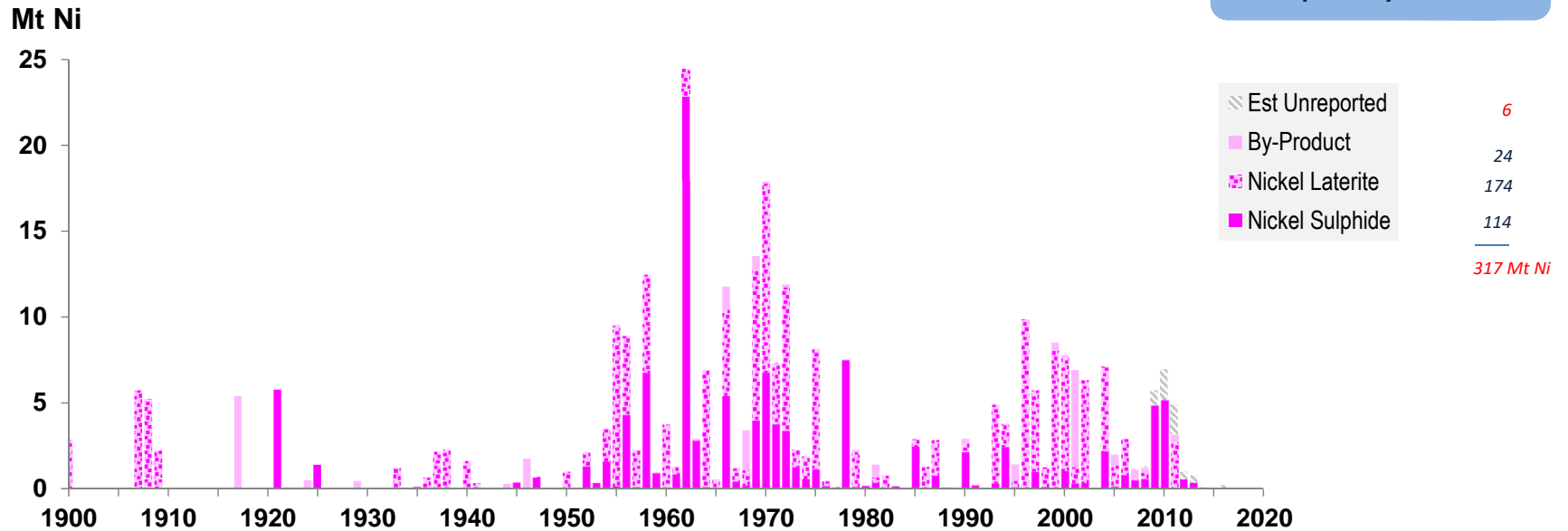
Note: Includes 23 Mt of Zn associated with Lead deposits

Source: MinEx Consulting © October 2017

Amount of Metal discovered : Nickel Laterite & Sulphide

World: 1900-2016

Ni Lat makes up **60%** of the primary total



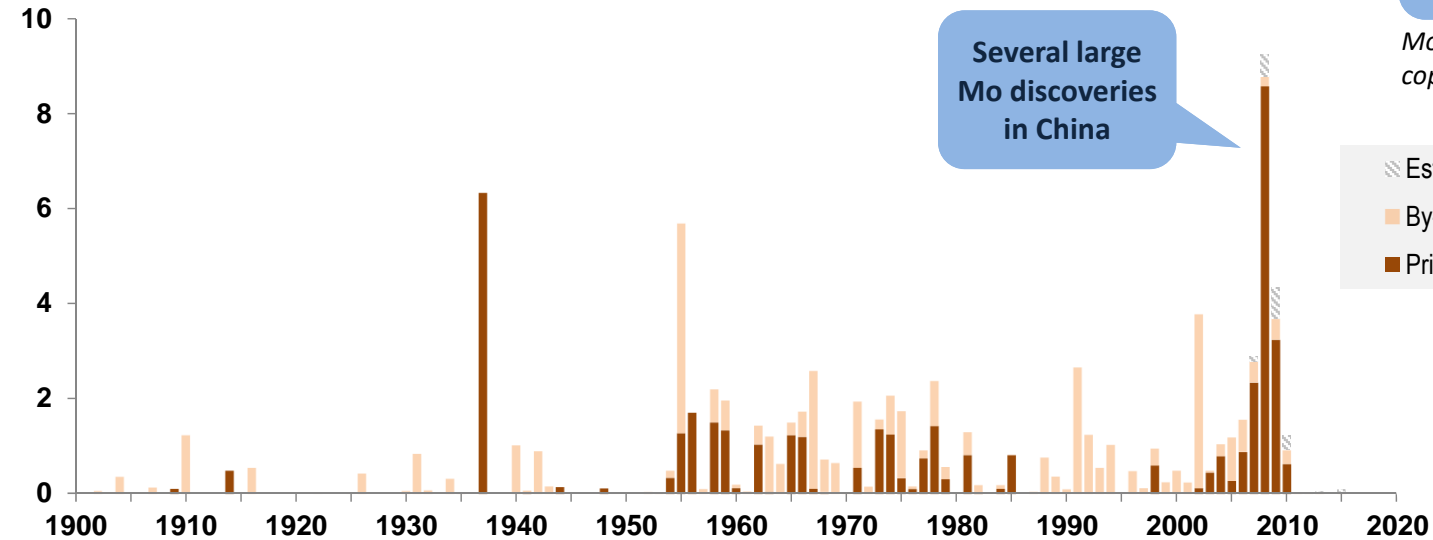
Note: By-Product credits make up 20% of Ni S, and 0% of Ni Lat

Source: MinEx Consulting © October 2017

Amount of Metal discovered : Molybdenum

World: 1900-2016

Mt Mo



By-Product Mo makes up **49%** of the total

Most of this is associated with copper deposits

Several large Mo discoveries in China

Est Unreported 1.6
 By-Product 40.9
 Primary 42.9
85.4 Mt Mo

Source: MinEx Consulting © October 2017

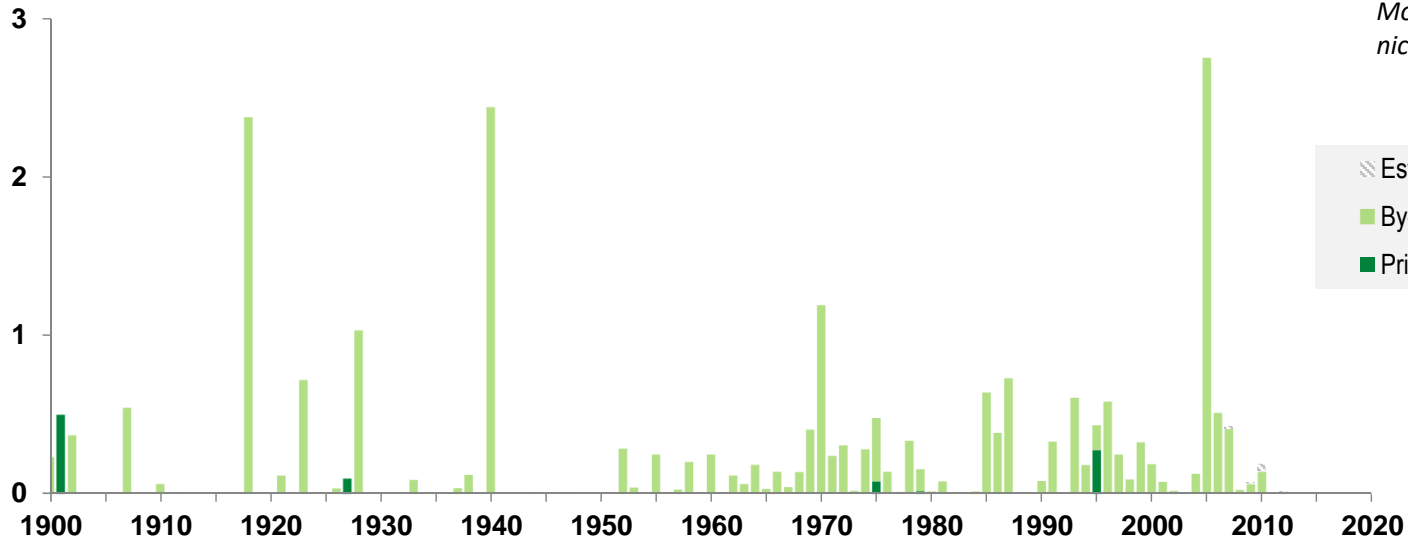
Amount of Metal discovered : Cobalt

World: 1900-2016

By-Product Co makes up **96%** of the total

Most of this is associated with nickel deposits

Mt Co



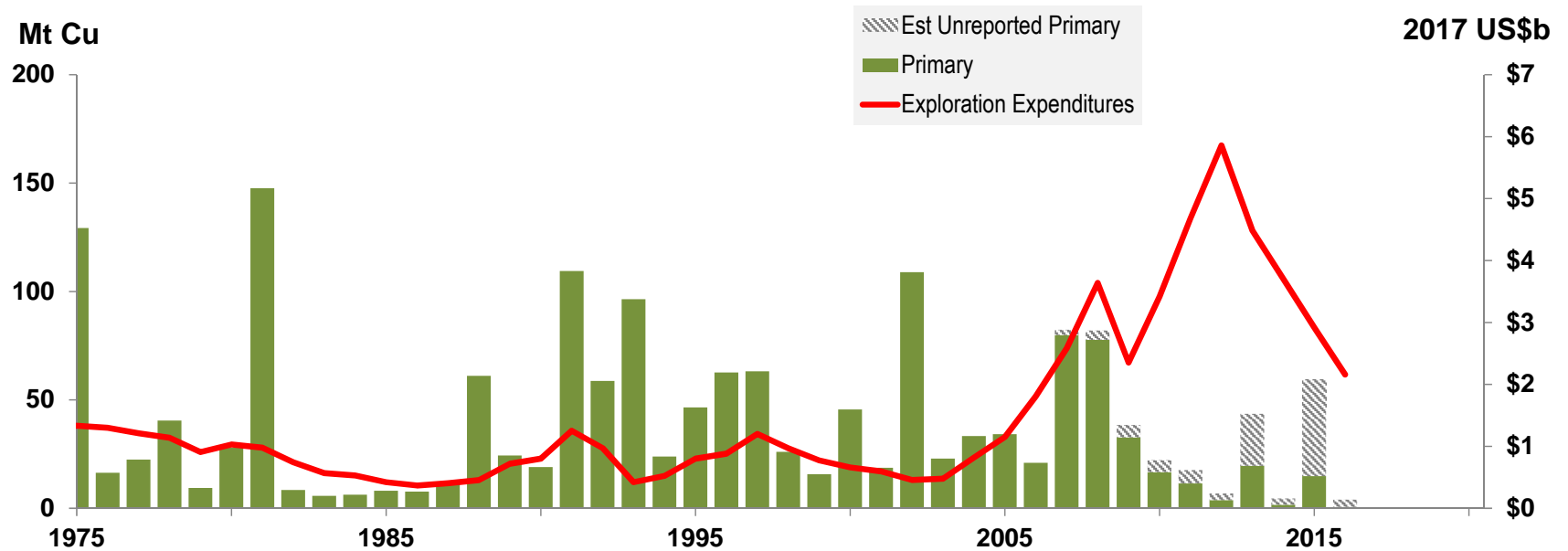
Source: MinEx Consulting © October 2017

For many commodities the unit cost (per Oz or lb found) has risen over time

5. LONG TERM TRENDS IN UNIT DISCOVERY COSTS

Exploration Expenditures and amount of Primary Metal discovered : Copper

World: 1975-2016

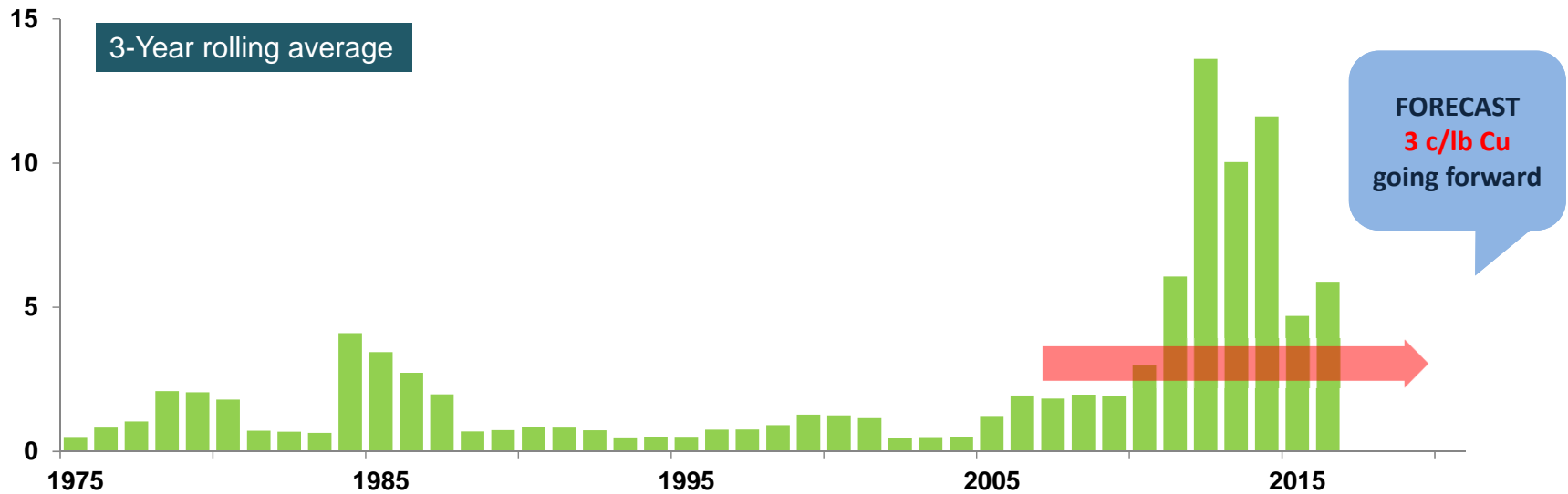


Source: MinEx Consulting © October 2017

Unit Discovery Cost : Copper

World: 1975-2016

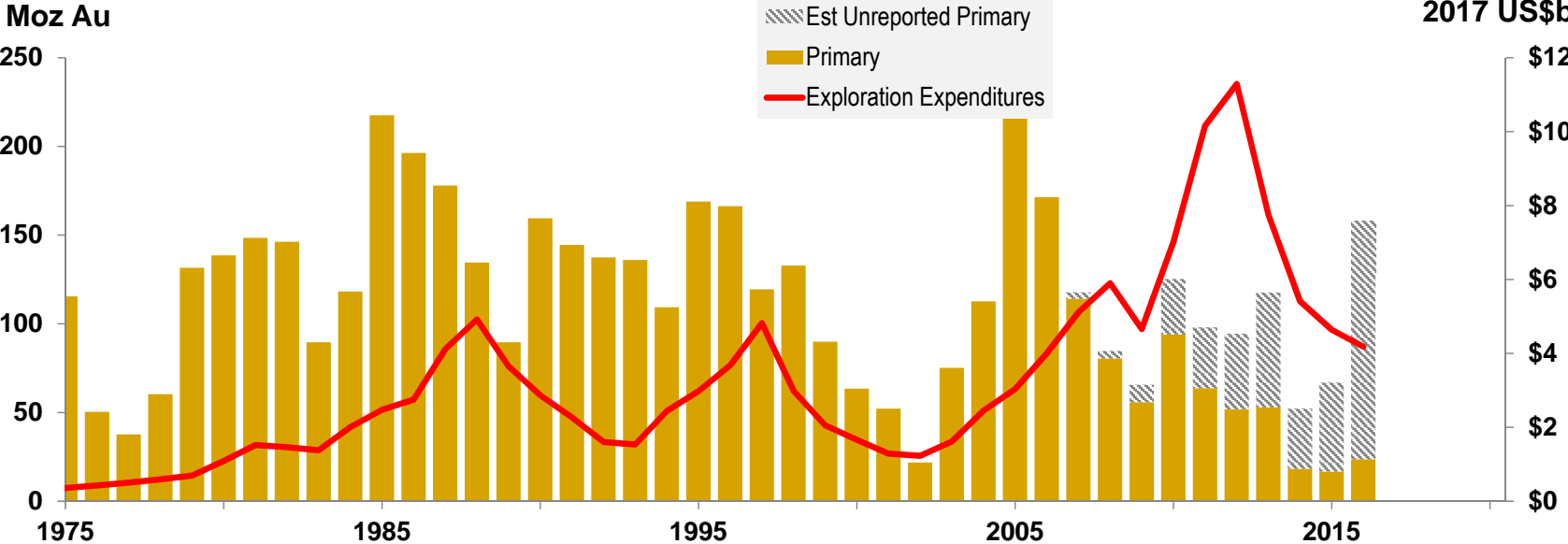
2017 US c/lb Cu



Source: MinEx Consulting © October 2017

Exploration Expenditures and amount of Primary Metal discovered : Gold

World: 1975-2016

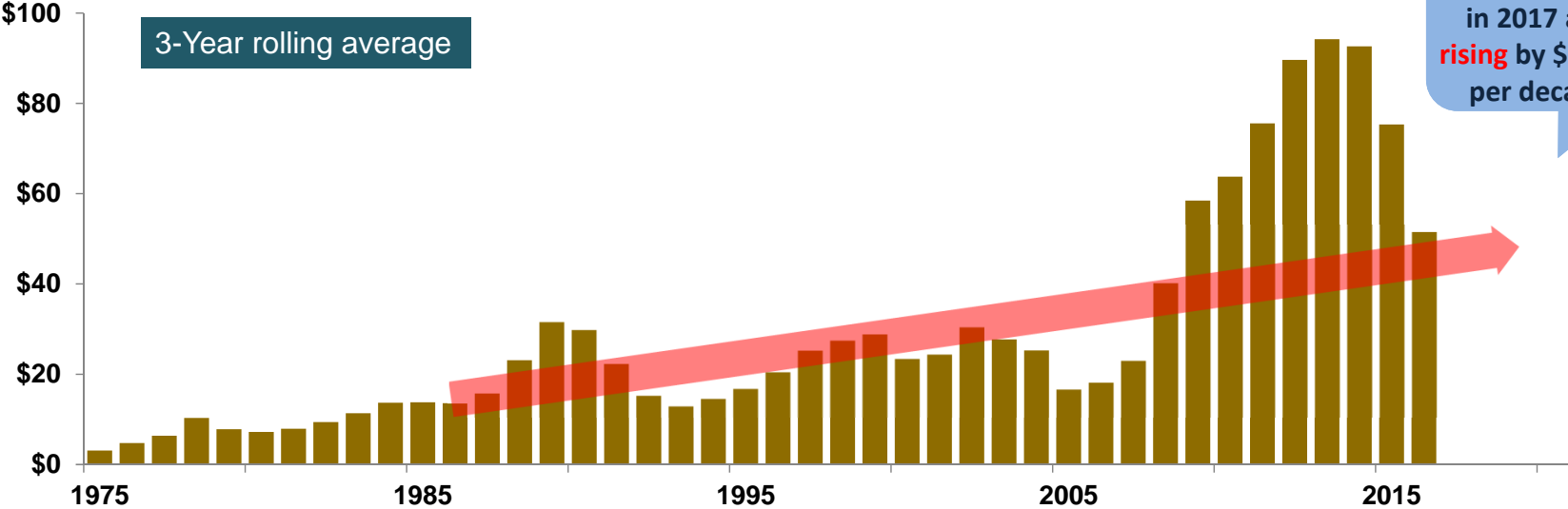


Source: MinEx Consulting © October 2017

Unit Discovery Cost : Gold

World: 1975-2016

2017 US \$/oz Au

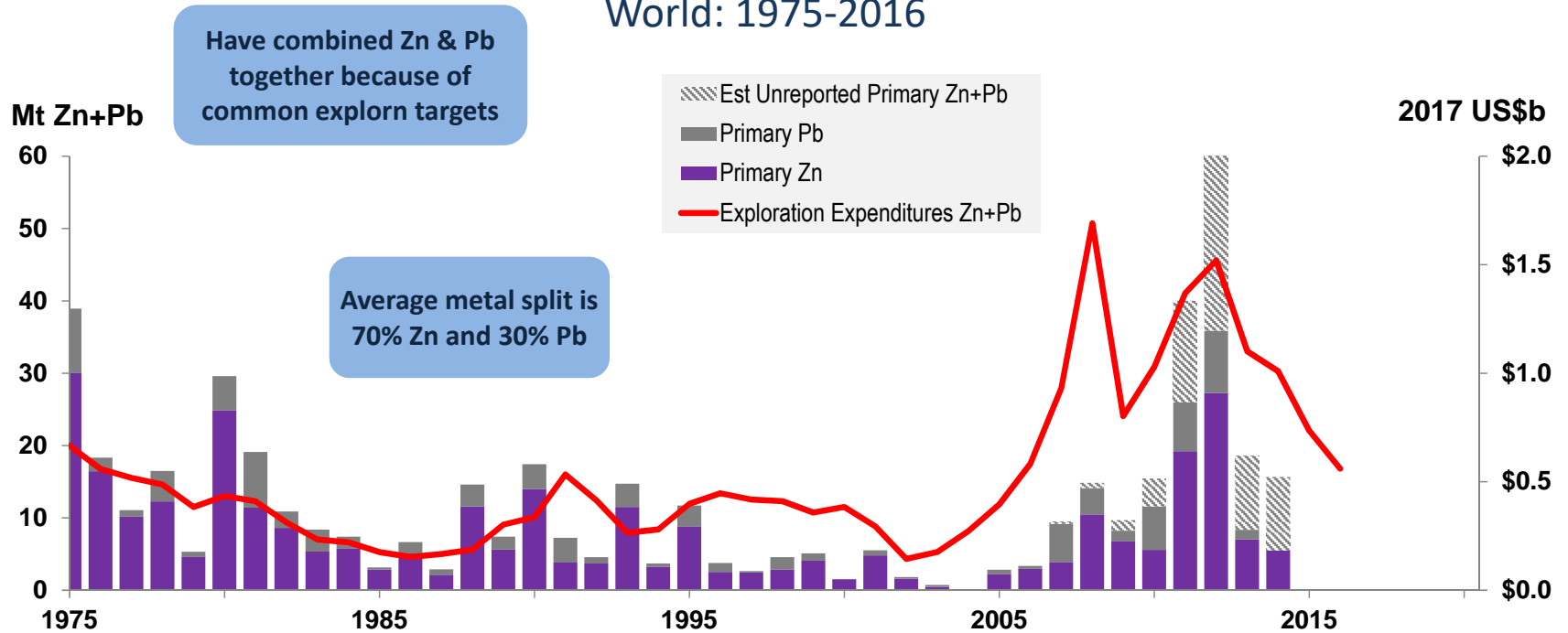


FORECAST
\$45/oz Au
in 2017 and
rising by \$10/oz
per decade

Source: MinEx Consulting © October 2017

Exploration Expenditures and amount of Primary Metal discovered : Zn+Pb

World: 1975-2016

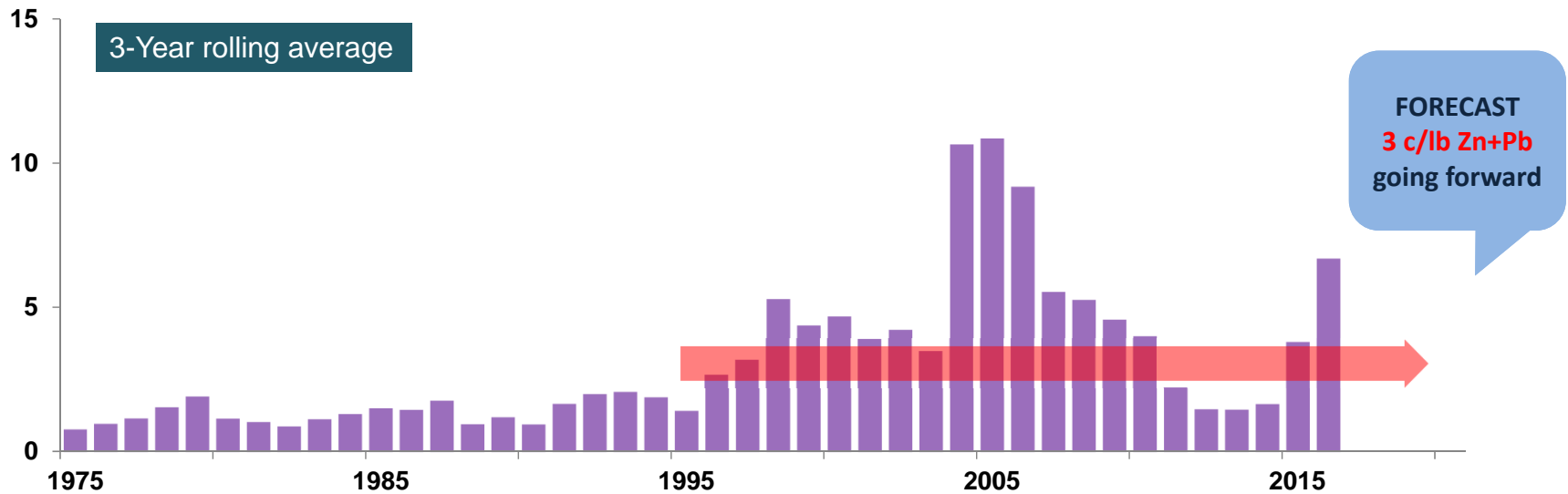


Source: MinEx Consulting © October 2017

Unit Discovery Cost : Zinc+Lead

World: 1975-2016

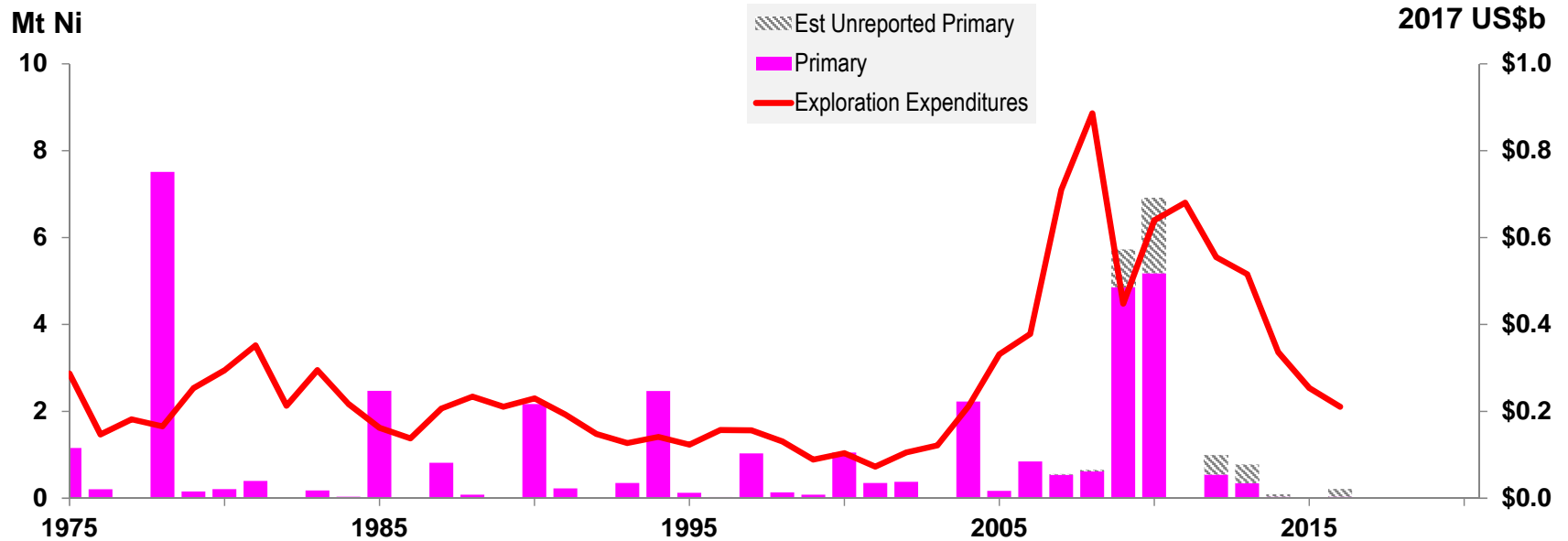
2017 US c/lb Zn+Pb



Source: MinEx Consulting © October 2017

Exploration Expenditures and amount of Primary Metal discovered : Nickel Sulphide

World: 1975-2016

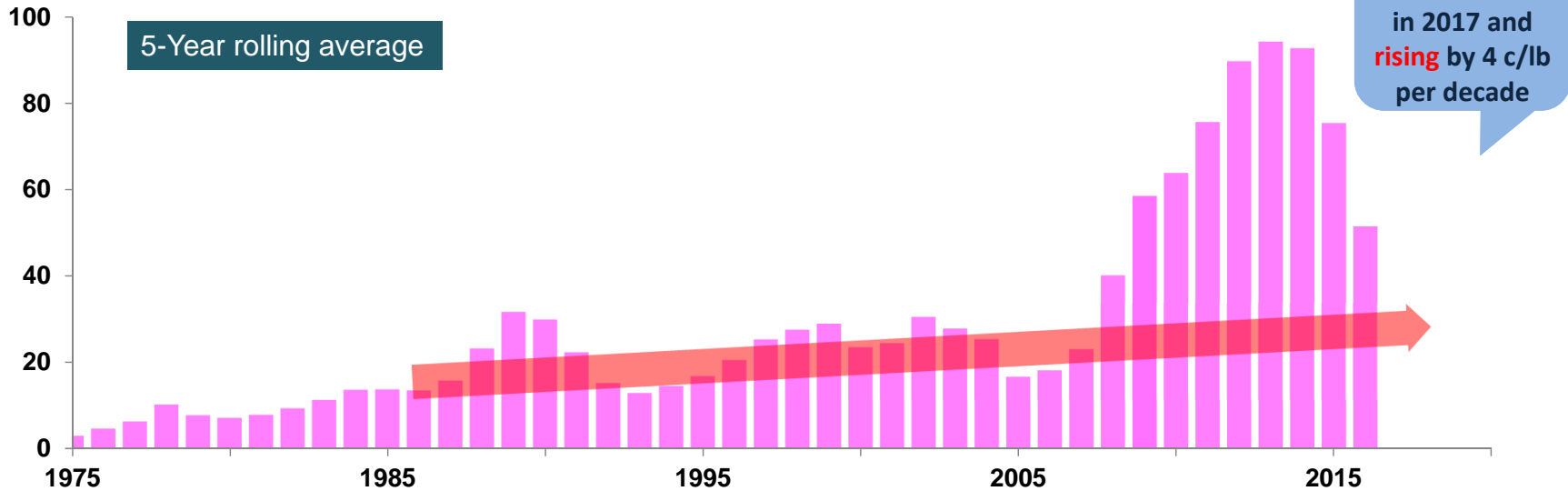


Source: MinEx Consulting © October 2017

Unit Discovery Cost : Nickel Sulphide

World: 1975-2016

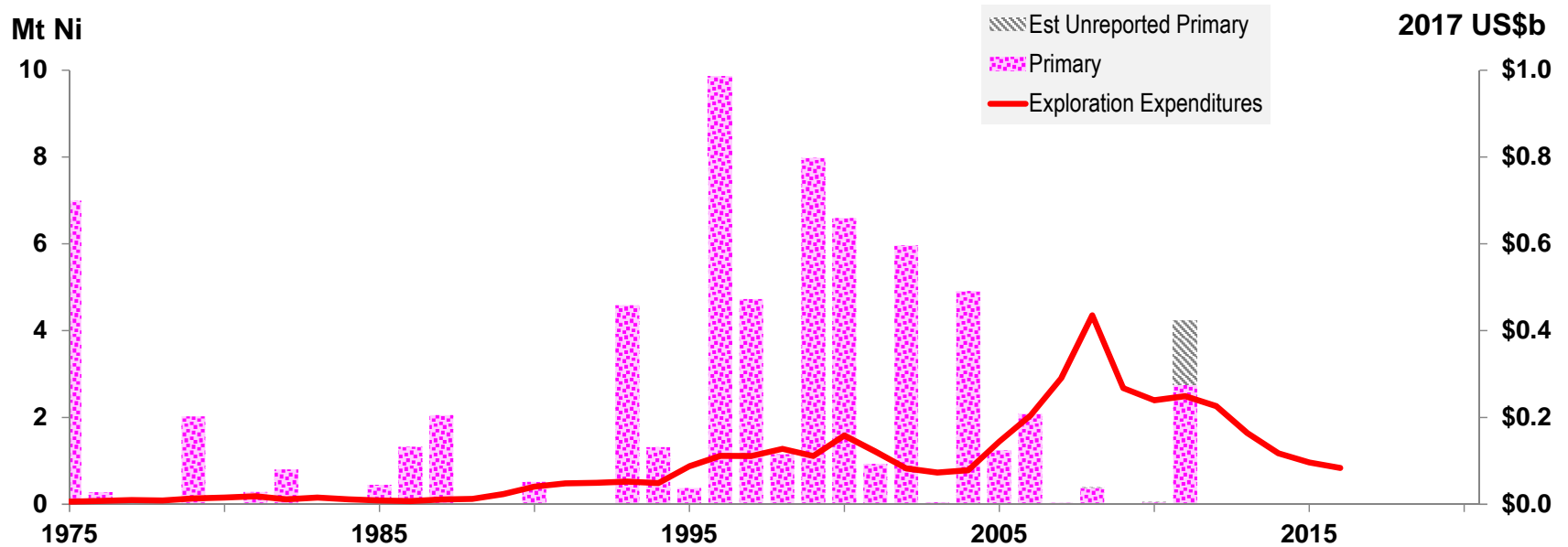
2017 US c/lb Ni



Source: MinEx Consulting © October 2017

Exploration Expenditures and amount of Primary Metal discovered : Nickel Laterite

World: 1975-2016

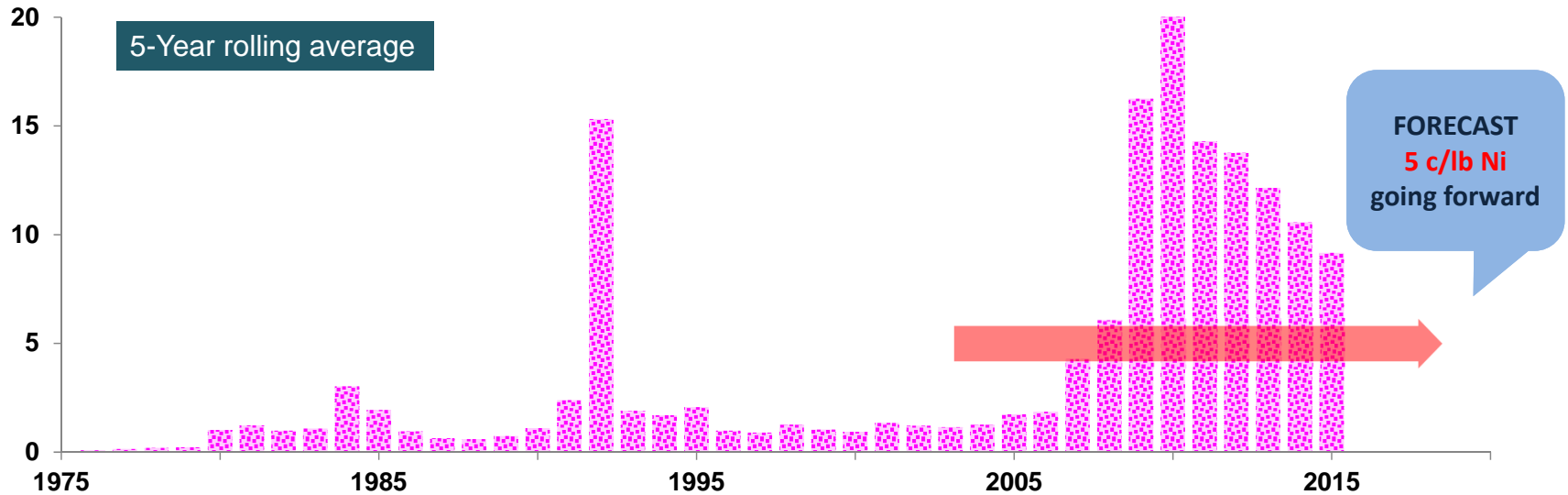


Source: MinEx Consulting © October 2017

Unit Discovery Cost : Nickel Laterite

World: 1975-2016

2017 US c/lb Ni



Source: MinEx Consulting © October 2017

Estimates are made of the amount of Au, Cu, Zn, Pb and Ni likely to be found over the next 25 years. This is then compared against the likely future amount required to sustain the projected mine production

6. FORECAST AMOUNT OF METAL DISCOVERED

Methodology used to forecast the future amount of gold discovered

Based on a **forecast gold price** of US\$1125/oz ...

The multi-factor regression model predicts that **global spend on gold exploration** in ten years time (i.e. in 2027) will be around \$6000 million

Based on past trends the likely **unit cost of discovery** in 2027 will be US\$55/oz

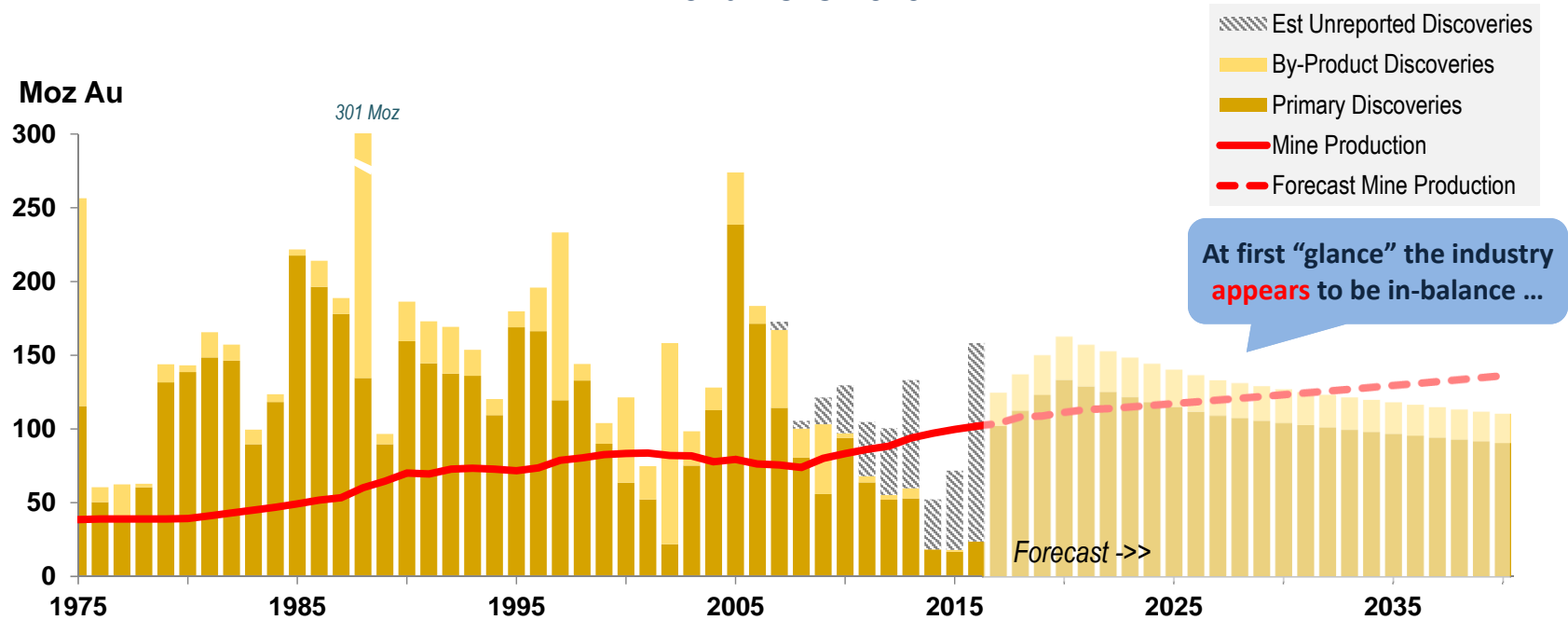
On this basis, the likely amount of **primary gold** discovered will be $[6000/55 =]$ 109 Moz

In addition, it is assumed the **by-product gold** makes up 18% of the total gold found (i.e. 24 Moz)

On this basis, **the total amount of gold discovered in 2027 should be $[109/(1-0.18) =]$ 133 Moz**

Forecast Discovery Rate versus Mine Production : Gold

World: 1975-2040



Note: Forecast discovery rate is based on long-run gold price of US\$1150/oz in constant 2017 US Dollars, and a unit discovery cost of US\$45/oz rising by \$10/oz per decade.

Note: Forecast production rate assumes a 1% pa growth rate post 2022

Source: MinEx Consulting © October 2017

... however, not all of the gold discovered will be produced

Based on past trends, it is likely that **only 70% of the gold discovered will have a mine built** on them. And the average delay between discovery and development is likely to be 15-20 years

Due to **mining and processing losses** only 90% of the contained metal in the primary gold deposits will be recovered as gold-bars

The recovery rates for by-product gold (in say, a copper deposit) is estimated to be lower at ~80%

On this basis, the forecast amount of gold produced from discoveries made in 2027 will be ...

$$109 \text{ Moz} \times 70\% \times 90\% + 24 \text{ Moz} \times 70\% \times 80\% = \mathbf{82 \text{ Moz}}$$

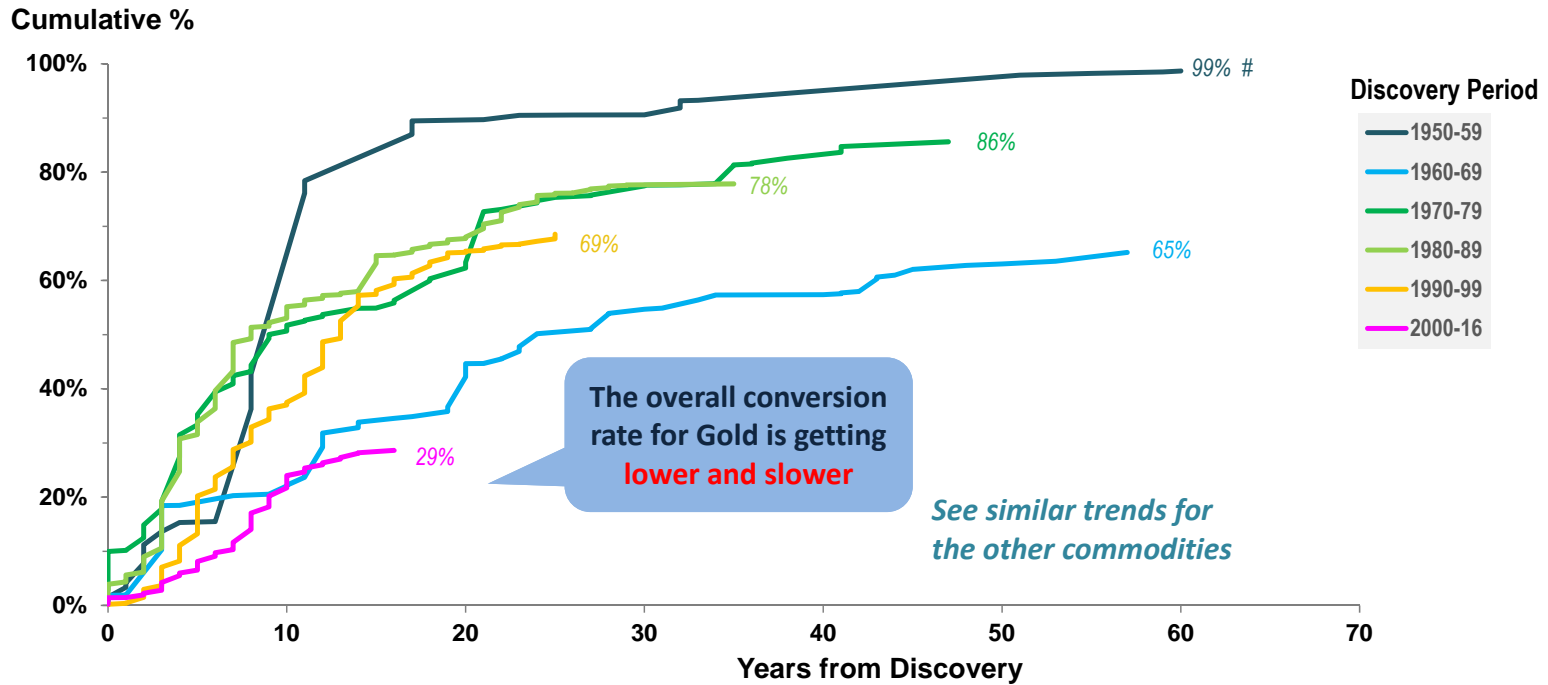
*In practice, the amount of gold produced could be less than this ... as not all of the reported resource is **economic to mine***

Global gold production in 2027 is forecast to be **119 Moz**

The forecast rate of discovery is **insufficient** to support this level of mining

Cumulative Metal in Discoveries that become mines: GOLD

All Discoveries in the World ≥ 100 koz



Cumulative % refers to those deposits that (eventually) turn into mines.

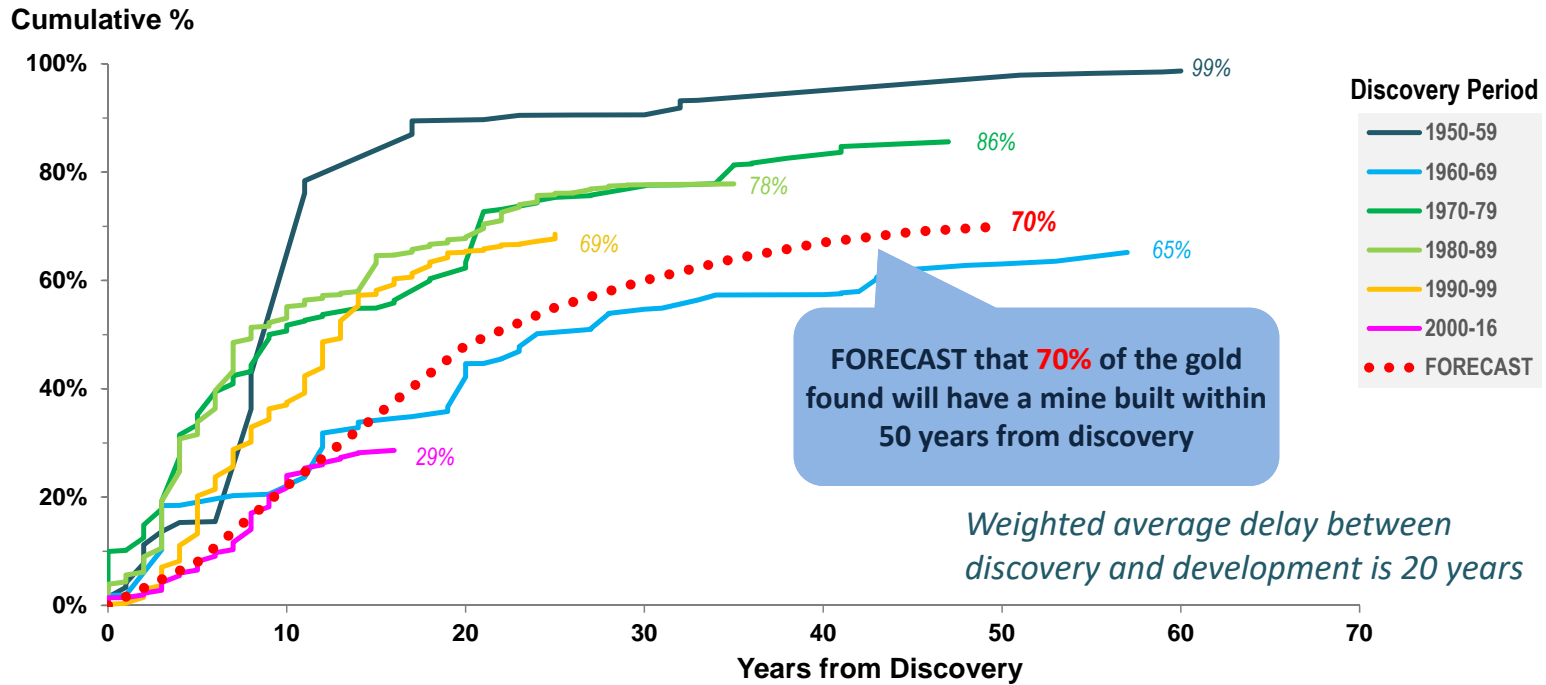
Caution: Even if the deposit does get mined, not all of the contained metal will be extracted /covered.

Note: The very high metal conversion rate in the 1950s is due to very large (and economic) gold discoveries in the Witwatersrand in South Africa

Source: MinEx Consulting © September 2017

Cumulative Metal in Discoveries that become mines: **GOLD**

All Discoveries in the World ≥ 100 koz

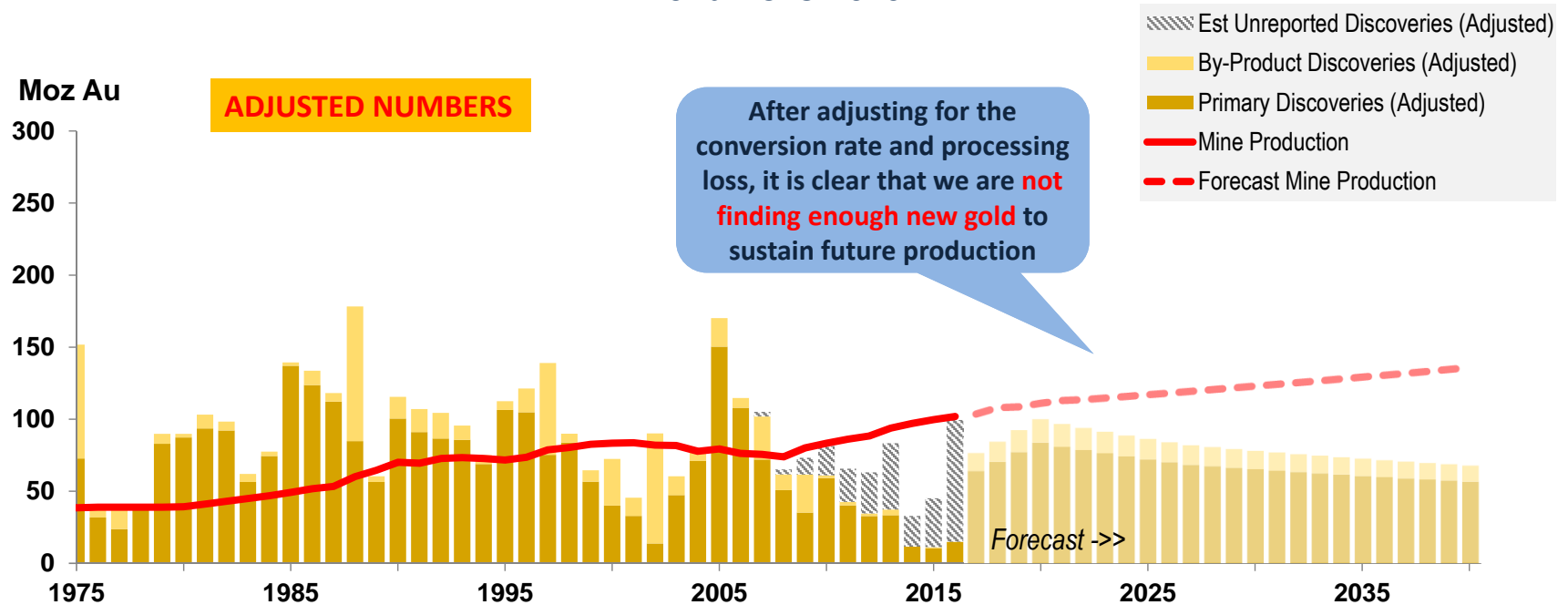


Caution: Not all of the gold contained in the deposit will be mined / recovered.

Source: MinEx Consulting © September 2017
for more details see MinEx's presentation at the 2017 China Mining Conference

Estimated Replacement Rate versus Mine Production : Gold

World: 1975-2040

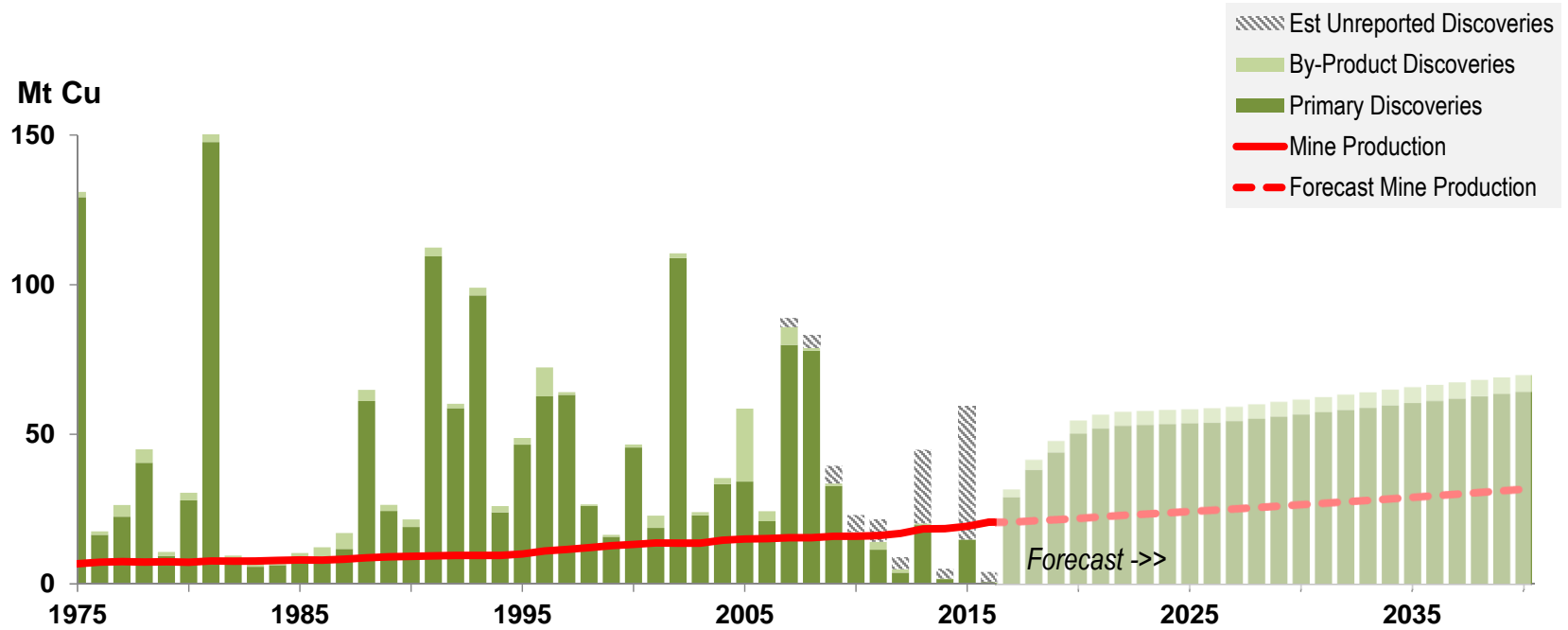


Note: Assumes a long-run gold price of US\$1150/oz in constant 2017 US Dollars.
 The Replacement rate is based on adjusting the Discovery Rate for a 70% conversion rate for mining, and a 10% loss for mining & processing (and 20% loss for by-product metal)

Source: MinEx Consulting © October 2017
 Price forecast from Consensus Economics October 2017

Forecast Discovery Rate versus Mine Production : Copper

World: 1975-2040



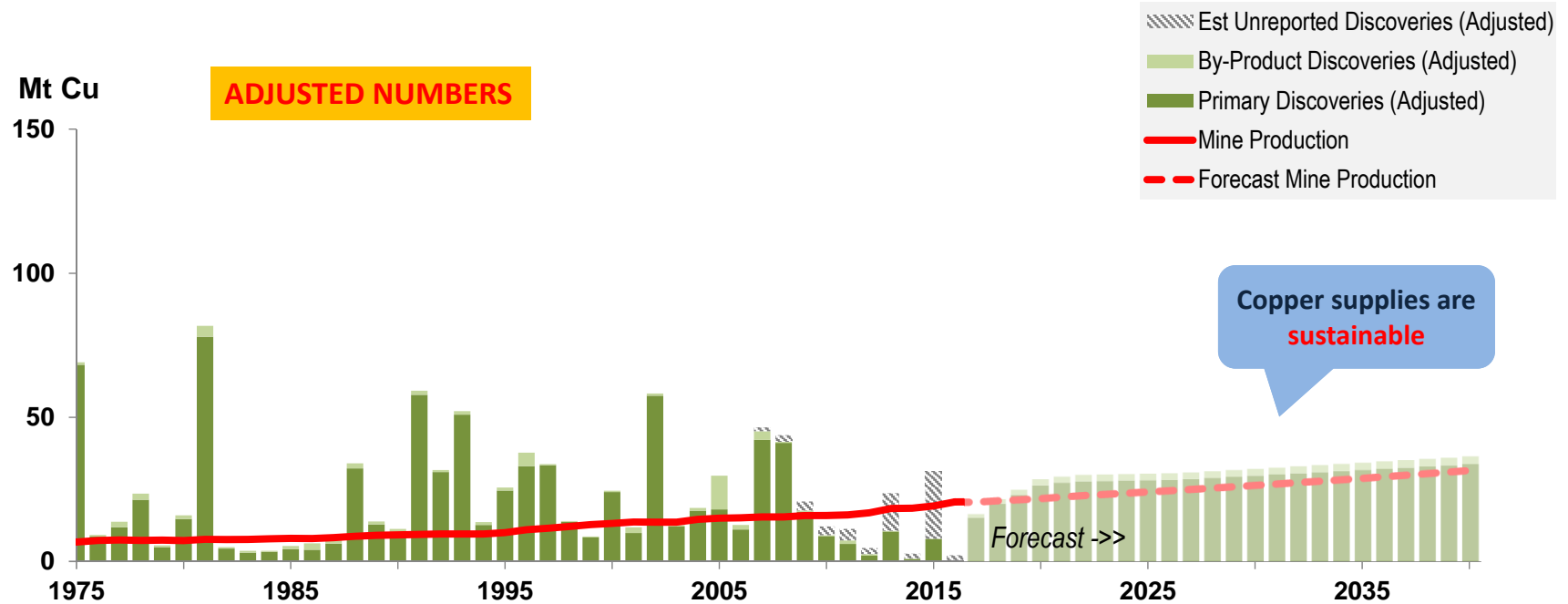
Note: Forecast discovery rate is based on long-run copper price of US\$2.75/lb in constant 2017 US Dollars, and a unit discovery cost of US 3.0 c/lb

Note: Forecast production rate assumes a 1.8% pa growth rate post 2022

Source: MinEx Consulting © October 2017
Price forecast from Consensus Economics October 2017

Estimated Replacement Rate versus Mine Production : **Copper**

World: 1975-2040

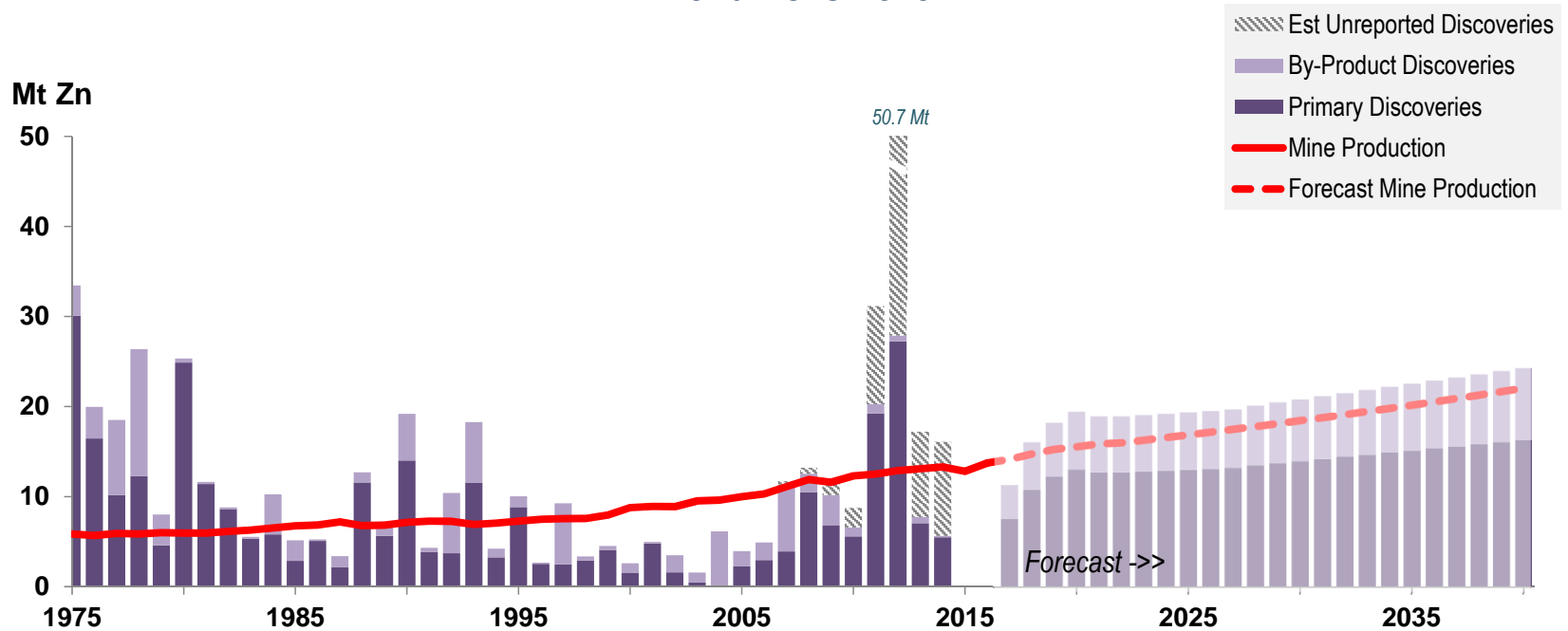


Note: Assumes a long-run gold price of US\$2.75/lb Cu in constant 2017 US Dollars.
 The Replacement rate is based on adjusting the Discovery Rate for a 60% conversion rate for mining, and a 12% loss for mining & processing (and 20% loss for by-product metal)

Source: MinEx Consulting © October 2017
 Price forecast from Consensus Economics October 2017

Forecast Discovery Rate versus Mine Production : Zinc

World: 1975-2040



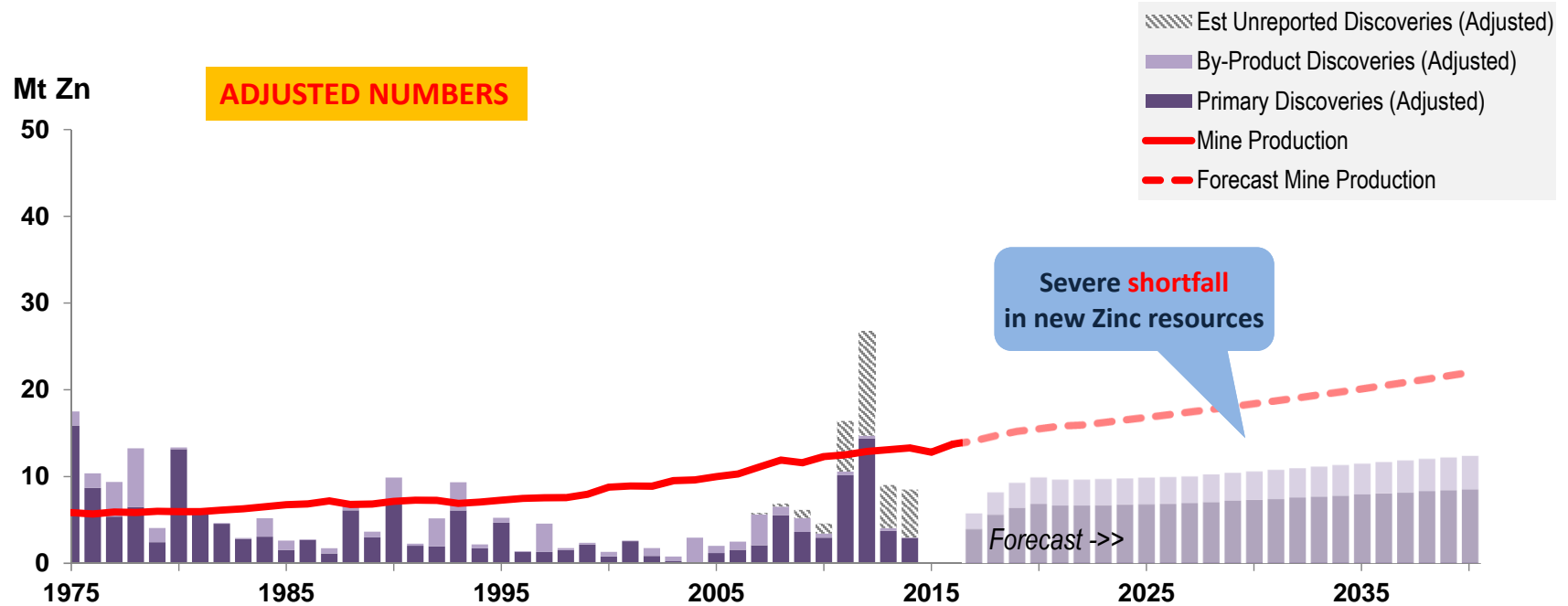
Note: Forecast discovery rate is based on long-run zinc price of US\$1.00/lb in constant 2017 US Dollars, and a unit discovery cost of US 3.0 c/lb for Zn+Pb (with a 70:30 split between Zn and Pb)

Note: Forecast production rate assumes a 1.8% pa growth rate post 2022

Source: MinEx Consulting © October 2017
Price forecast from Consensus Economics October 2017

Estimated Replacement Rate versus Mine Production : Zinc

World: 1975-2040

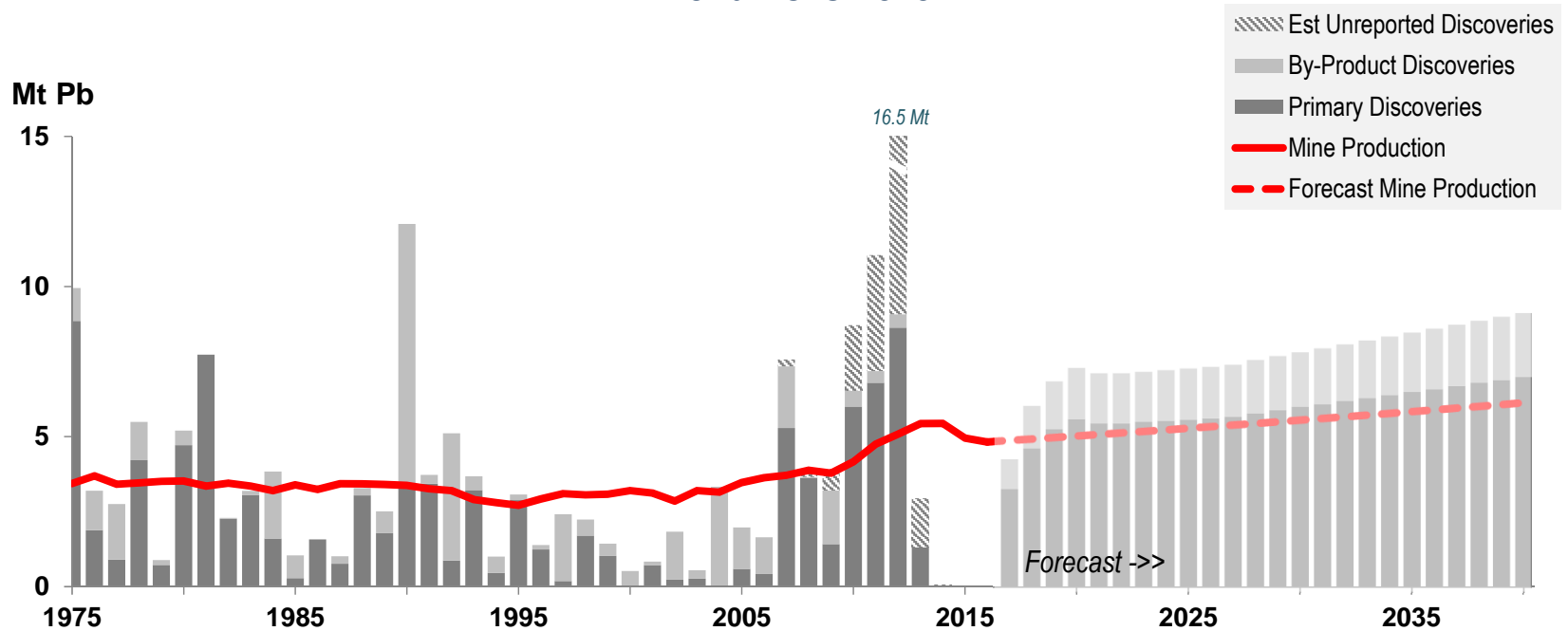


Note: Assumes a long-run zinc price of US\$1.00/lb in constant 2017 US Dollars.
 The Replacement rate is based on adjusting the Discovery Rate for a 60% conversion rate for mining, and a 12% loss for mining & processing (and 20% loss for by-product metal)

Source: MinEx Consulting © October 2017
 Price forecast from Consensus Economics October 2017

Forecast Discovery Rate versus Mine Production : Lead

World: 1975-2040



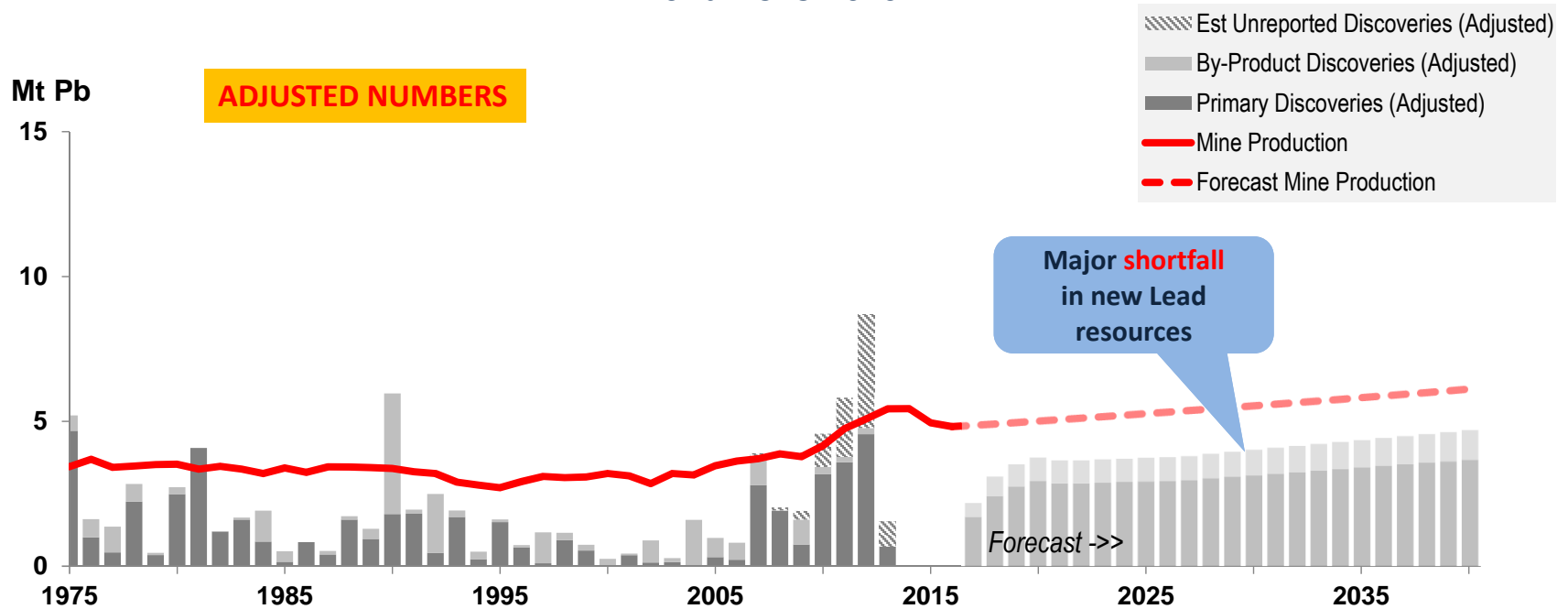
Note: Forecast discovery rate is based on long-run price of US\$1.00/lb Zn and \$0.85/lb Pb in constant 2017 US Dollars, and a unit discovery cost of US 3.0 c/lb for Zn+Pb (with a 70:30 split between Zn and Pb)

Note: Forecast production rate assumes a 1.0% pa growth rate post 2022

Source: MinEx Consulting © October 2017
Price forecast from Consensus Economics October 2017

Estimated Replacement Rate versus Mine Production : Lead

World: 1975-2040

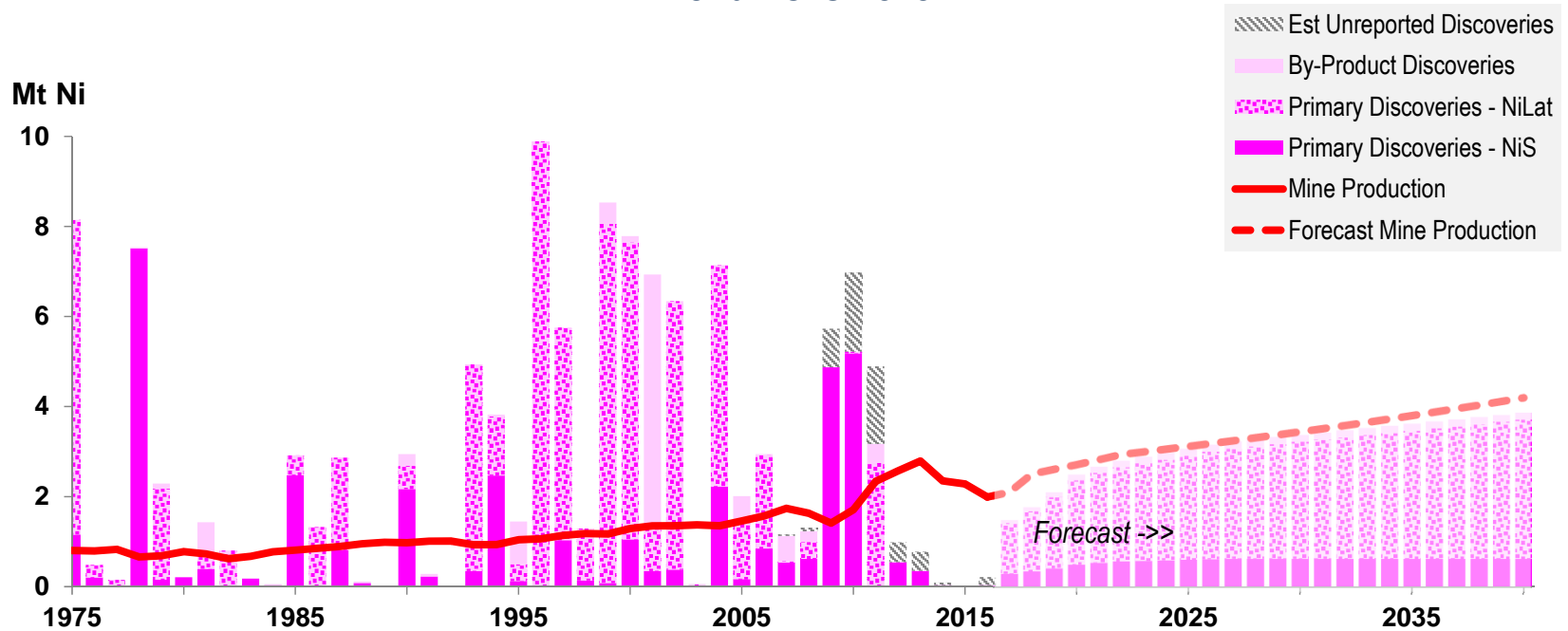


Note: Assumes a long-run price of US\$1.00/lb Zn and \$0.85/lb Pb in constant 2017 US Dollars.
 The Replacement rate is based on adjusting the Discovery Rate for a 60% conversion rate for mining, and a 12% loss for mining & processing (and 20% loss for by-product metal)

Source: MinEx Consulting © October 2017
 Price forecast from Consensus Economics October 2017

Forecast Discovery Rate versus Mine Production : Nickel

World: 1975-2040



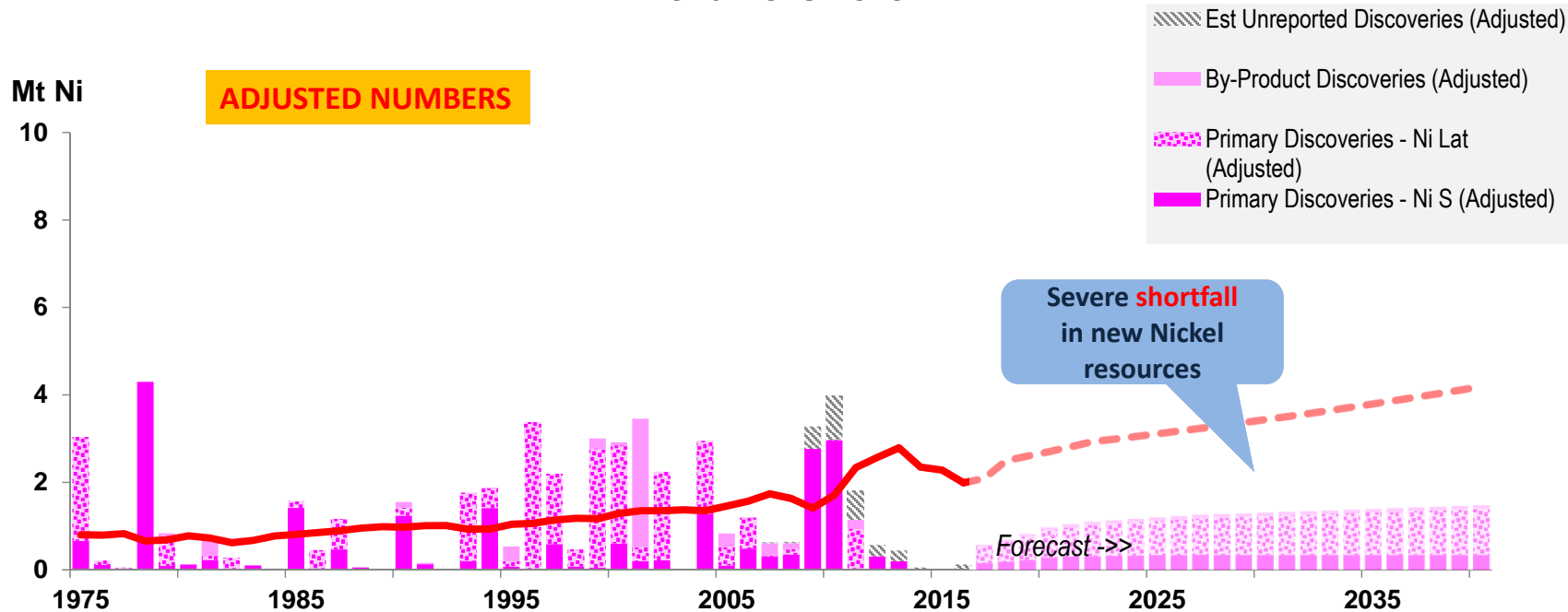
Note: Forecast discovery rate is based on long-run nickel price of US\$7.30/lb in constant 2017 US Dollars, and a unit discovery cost of US 5 c/lb for Nickel Laterites and 28 c/lb for Nickel Sulphides, rising by 4c/lb per decade

Note: Forecast production rate assumes a 2% pa growth rate post 2022

Source: MinEx Consulting © October 2017
Price forecast from Consensus Economics October 2017

Estimated Replacement Rate versus Mine Production : Nickel

World: 1975-2040



Note: Assumes a long-run nickel price of US\$7.30/lb in constant 2017 US Dollars.

The Replacement rate is based on adjusting the Discovery Rate for a 65% conversion rate for mining NiS (45% for NiLat), and a 12% loss for mining & processing (15% for NiLat) and 20% loss for by-product metal

Source: MinEx Consulting © October 2017
Price forecast from Consensus Economics October 2017

Implications

*In the short- to medium-term, industry will draw down on existing inventory of undeveloped resources. However to be sustainable in the longer term we need to either **spend more** on exploration or **be much better** at discovery.*

*If not, **the gold price will need to rise** ...*

- so as to stimulate additional exploration, and*
- encourage marginal projects to be developed.*

Higher gold prices will also ...

- help grow the resource base through lowering the cut-off grade, and*
- reduce overall consumer demand (and reduce mine production)*

Cautionary Note

“Health”
warning


It should be emphasised the above analysis of the long term sustainability of the mining industry involves several **simplifying** assumptions :

- ❌ Ignores the dynamic and uncertain nature of exploration
- ❌ Assumes steady commodity prices
- ❌ Doesn't take into consideration the time lag between discovery and development
- ❌ No consideration is made of the current inventory of undeveloped projects
- ❌ Doesn't model the effect of changes in prices and costs on output from existing mines
- ❌ Doesn't adjust for potential changes in metal demand

Many of these issues were addressed in a recent report by MinEx Consulting assessing the 40 year production outlook for the Australian gold industry

*Long-term forecast of Australia's mineral production and revenue
The outlook for gold: 2017-2057*

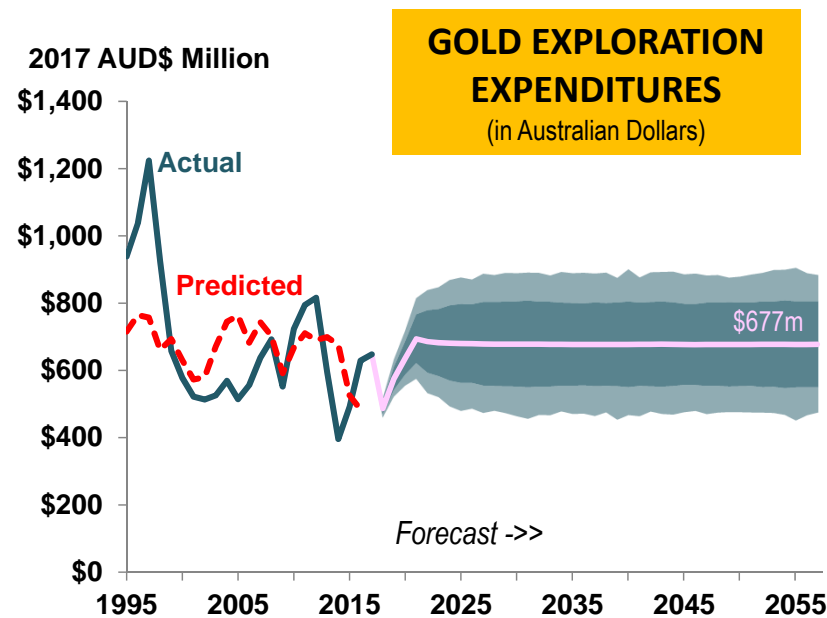
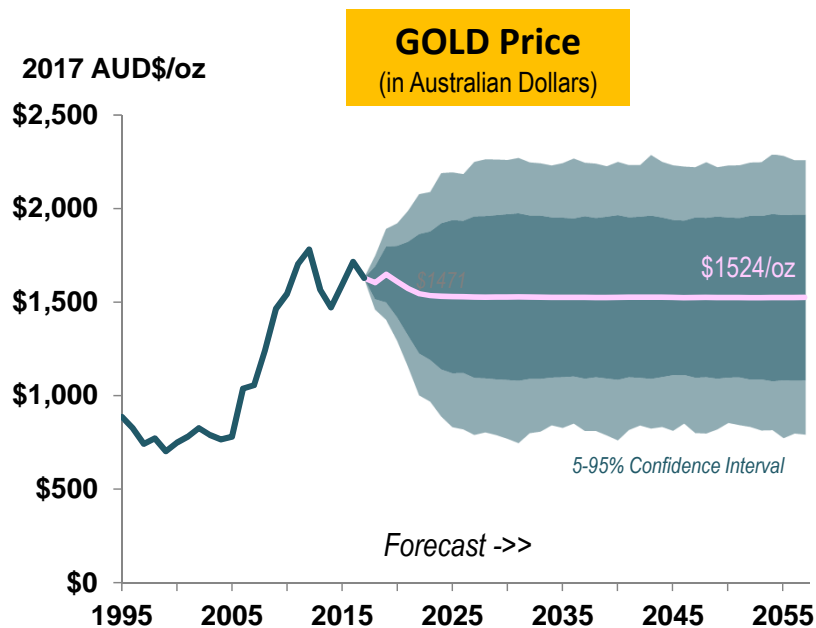
*By Richard Schodde
October 2017*



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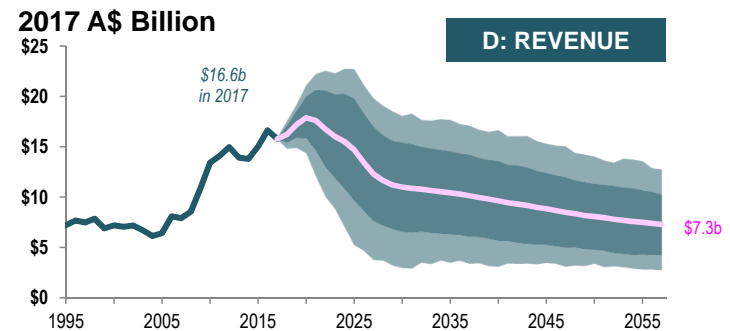
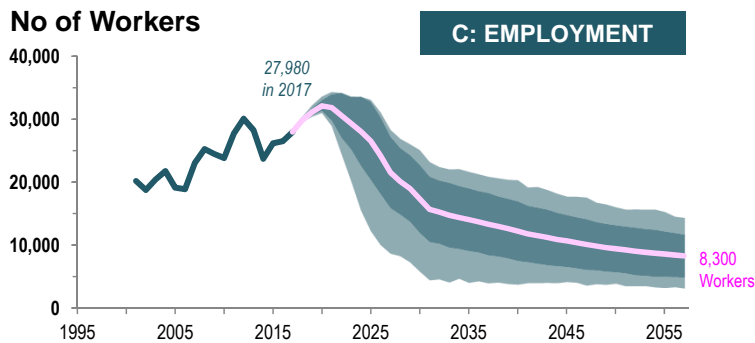
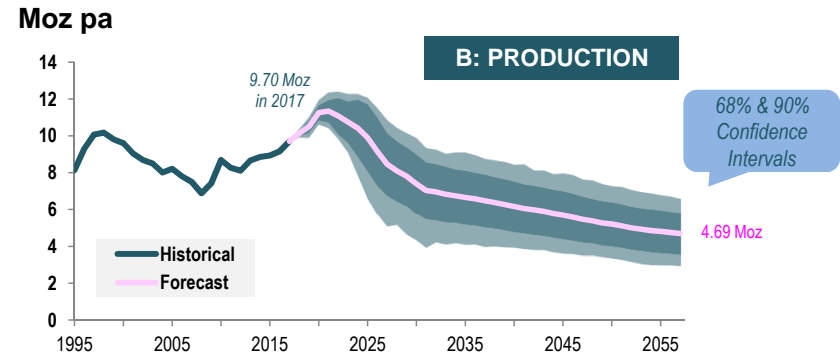
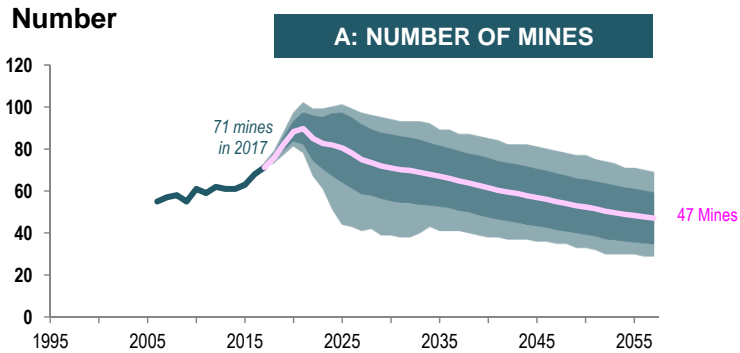
It uses a Monte-Carlo approach to model the effect of uncertainty of the likelihood of existing mines, new projects and exploration success

Forecast gold price and exploration expenditures - Australia : 1995-2057



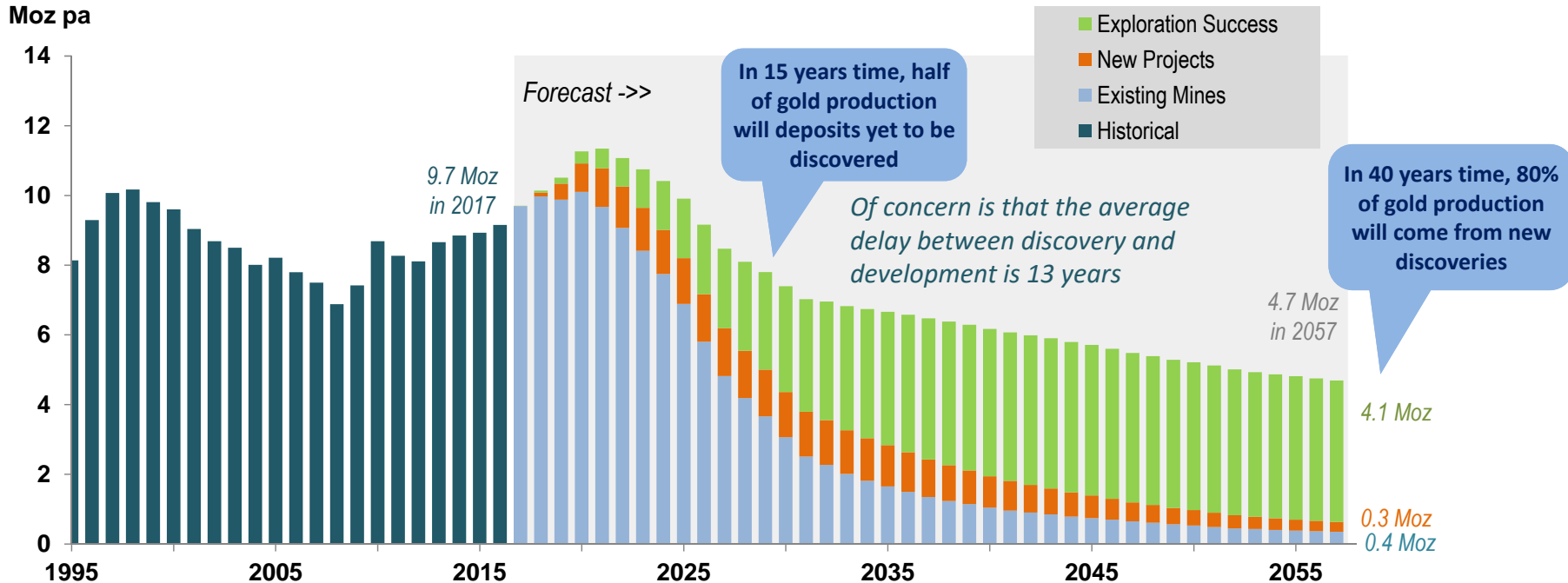
Source: MinEx Consulting © October 2017

Long term outlook for the Australian gold industry : 1995-2057



Source: MinEx Consulting © October 2017

Forecast sources of Gold Production Australia: 1995-2057



Note: Mean/Average forecast only. Due to uncertainty in commodity prices and exploration success the likely forecast figure (at a 90% Confidence Interval) will vary by +/-40%.

Source: MinEx Consulting © October 2017

Key take-aways from the Australian Gold study

- Even under a wide range of possible scenarios, it is clear that the long term sustainability of the industry critically depends on sustained exploration success
- Due to the long lead times between discovery and development – Government & Industry need to support exploration now ... to offset the real risk of a supply disruption in the medium term

7. SUMMARY /CONCLUSIONS

Summary / Conclusions [1/2]

1. The Business Case for exploration

- Over the next 26 years the World will produce as much copper as that mined in all history. To sustain the industry we need to find new deposits

2. Long term trend in exploration expenditures

- The industry is highly cyclical. Even so over the last 50 years, exploration expenditures (in real terms) have increased 3-fold

3. Long term outlook for exploration expenditures

- Expenditures are strongly linked to commodity prices. MinEx forecasts that global exploration expenditures will rise by 65% (in real terms) over the next decade

4. Number of discoveries made and contained metal

- Number of discoveries made has slowly risen over time. However it there has been recent drop-off in the rate of discovery

Summary / Conclusions [2/2]

5. Long Term trends in Unit Discovery Costs

- The unit cost of discovery for gold is projected to be US\$45/oz (and rising). Copper is 3c/lb, Zinc & Lead is 3 c/lb, nickel laterites is 5 c/lb and nickel sulphides are 28 c/lb (and rising)

6. Forecast amount of metal discovered

- After adjusting for the likelihood of discovery being converted into a mine, and factoring in mining & processing losses it appears that the industry is finding enough copper to sustain itself. But this is not the case for gold and lead. Severe shortfalls projects for zinc and nickel

*In the short- to medium-term, industry will draw down on existing inventory of undeveloped resources. However to be sustainable in the longer term we need to either **spend more** on exploration or **be much better** at discovery.*

If not, the gold price will need to rise ...

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