# Challenges of Exploring Under Deep Cover

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# Overview

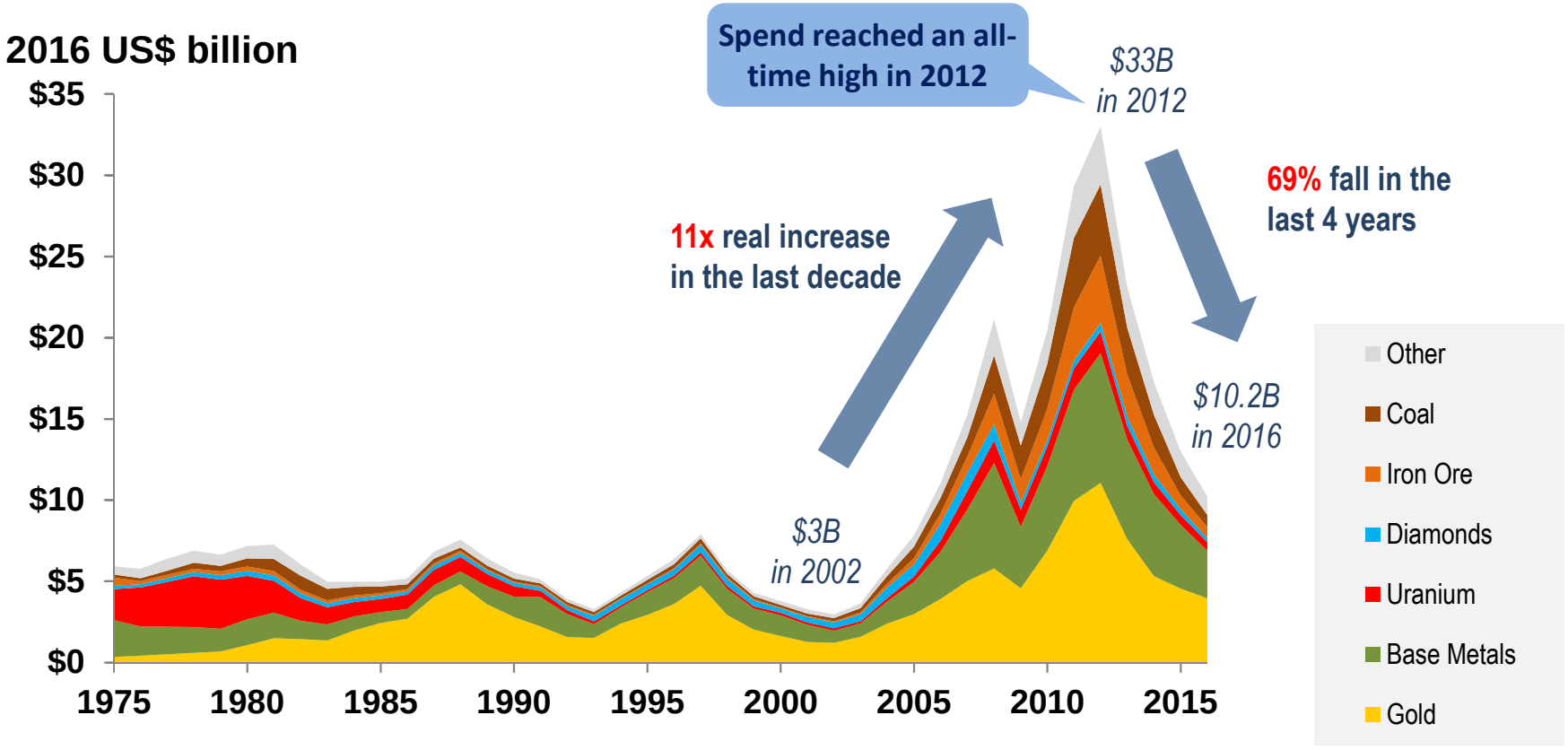
1. Long term trends in exploration
   … what did we spend & what did we find?
2. Factors behind the recent decline in discovery performance
3. Industry behaviour over the last business cycle
4. Long term trends in the depth of cover
5. Deep discoveries made since 2000
6. Discovery methods used
7. Conclusions

In spite of the massive boom in expenditures in 2002-12 discovery rates did not increase

# 1. LONG TERM TRENDS IN EXPLORATION

# Exploration expenditures: World

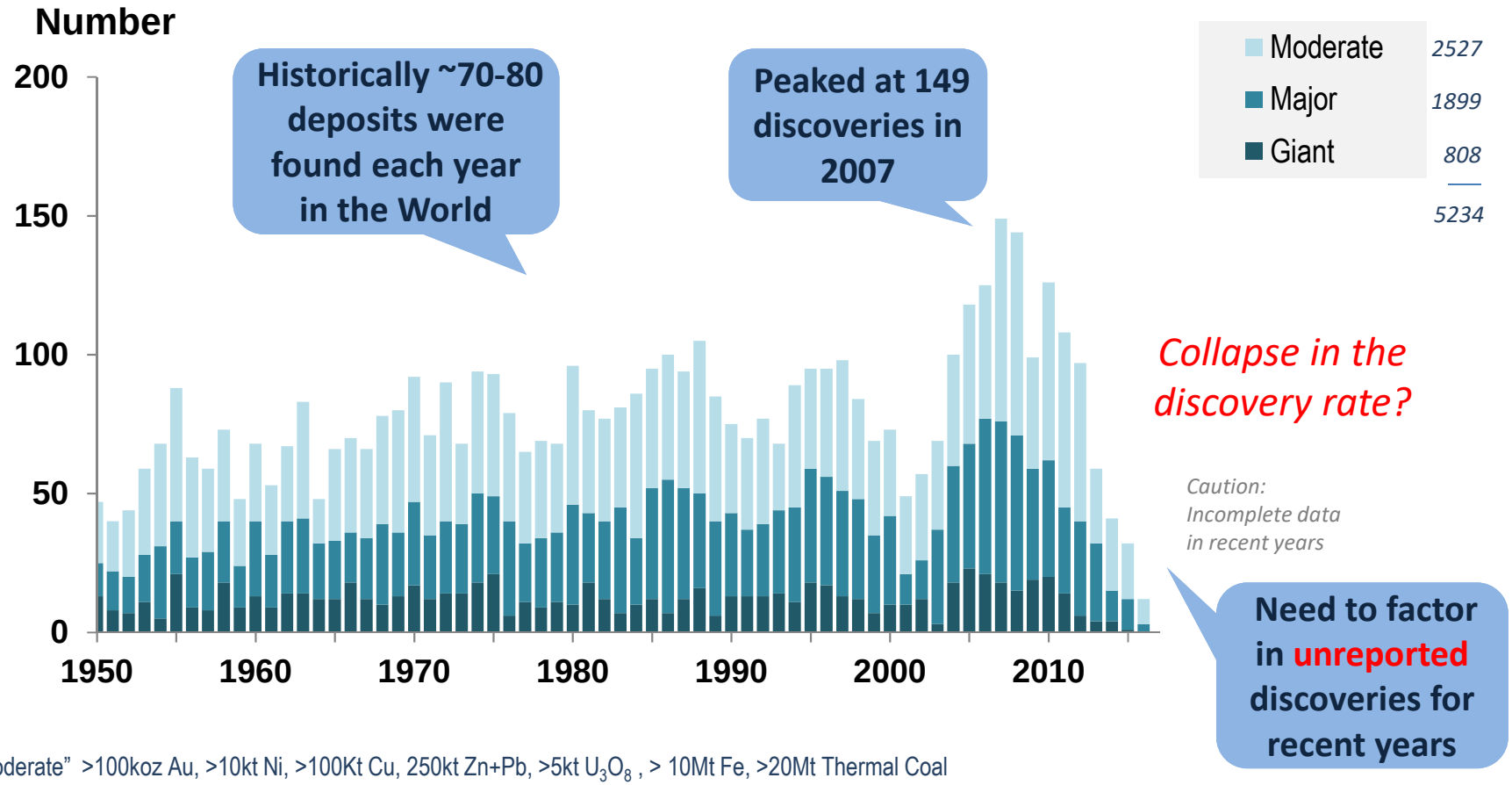
## by Commodity : 1975-2016




Sources: MinEx Consulting estimates © March 2017, based on data from ABS, NRCan, MLR (China), OECD and SNL Metals & Mining data, an offering of S&P Global Market Intelligence

# Number of discoveries by size

## Mineral discoveries in the World : All Commodities : 1950-2016

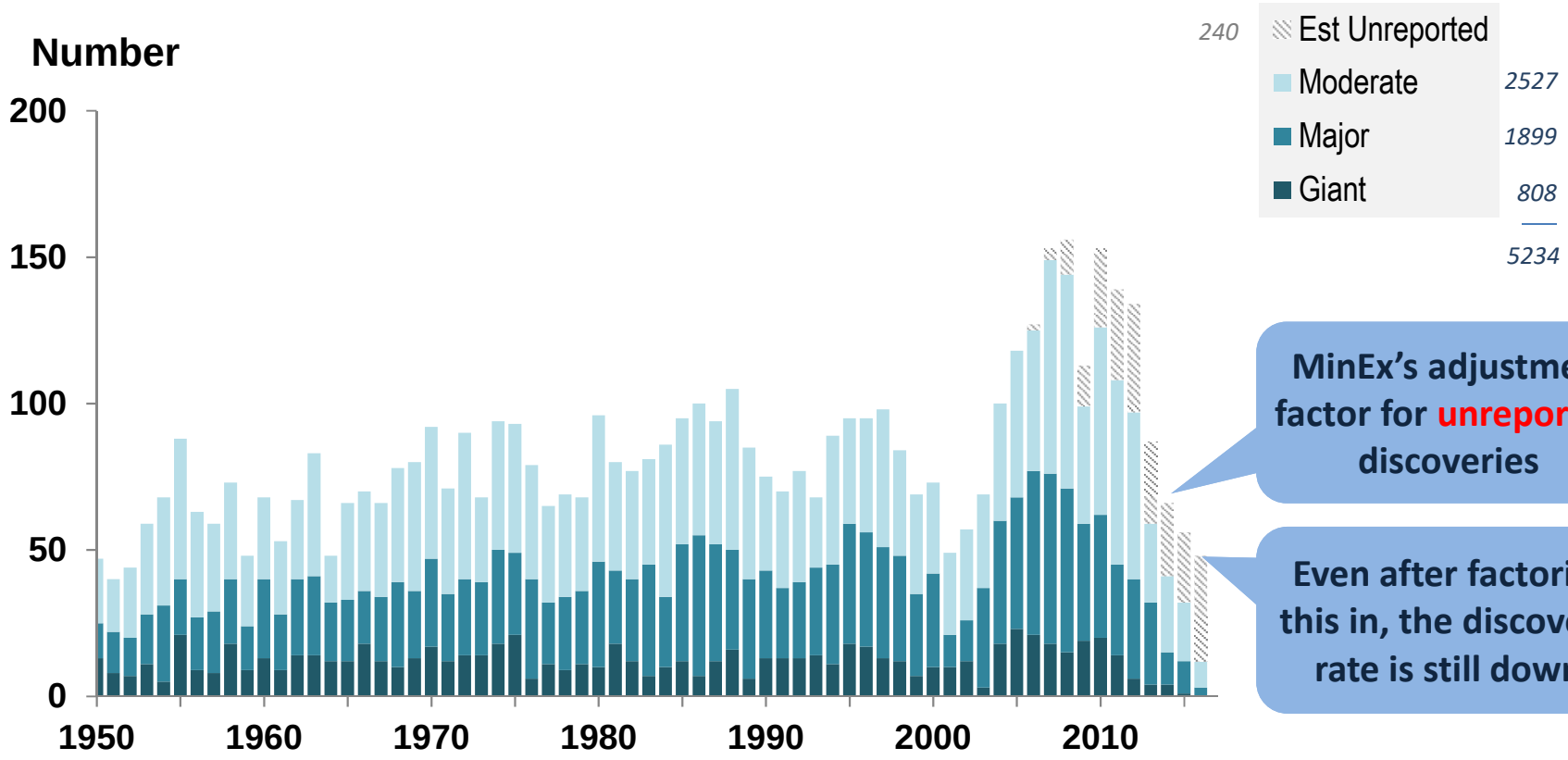



Note: "Moderate" >100koz Au, >10kt Ni, >100Kt Cu, 250kt Zn+Pb, >5kt $U_3O_8$ , > 10Mt Fe, >20Mt Thermal Coal
"Major" >1Moz Au, >100kt Ni, >1Mt Cu, 2.5Mt Zn+Pb, >25kt $U_3O_8$ , >100Mt Fe, >200Mt Thermal Coal
"Giant" >6Moz Au, >1Mt Ni, >5Mt Cu, 12Mt Zn+Pb, >125kt $U_3O_8$ . >500Mt Fe, >1000Mt Thermal Coal

Source: MinEx Consulting © March 2017

# Number of discoveries by size

## Mineral discoveries in the World : All Commodities : 1950-2016




Note: "Moderate" >100koz Au, >10kt Ni, >100Kt Cu, 250kt Zn+Pb, >5kt $U_3O_8$ , > 10Mt Fe, >20Mt Thermal Coal
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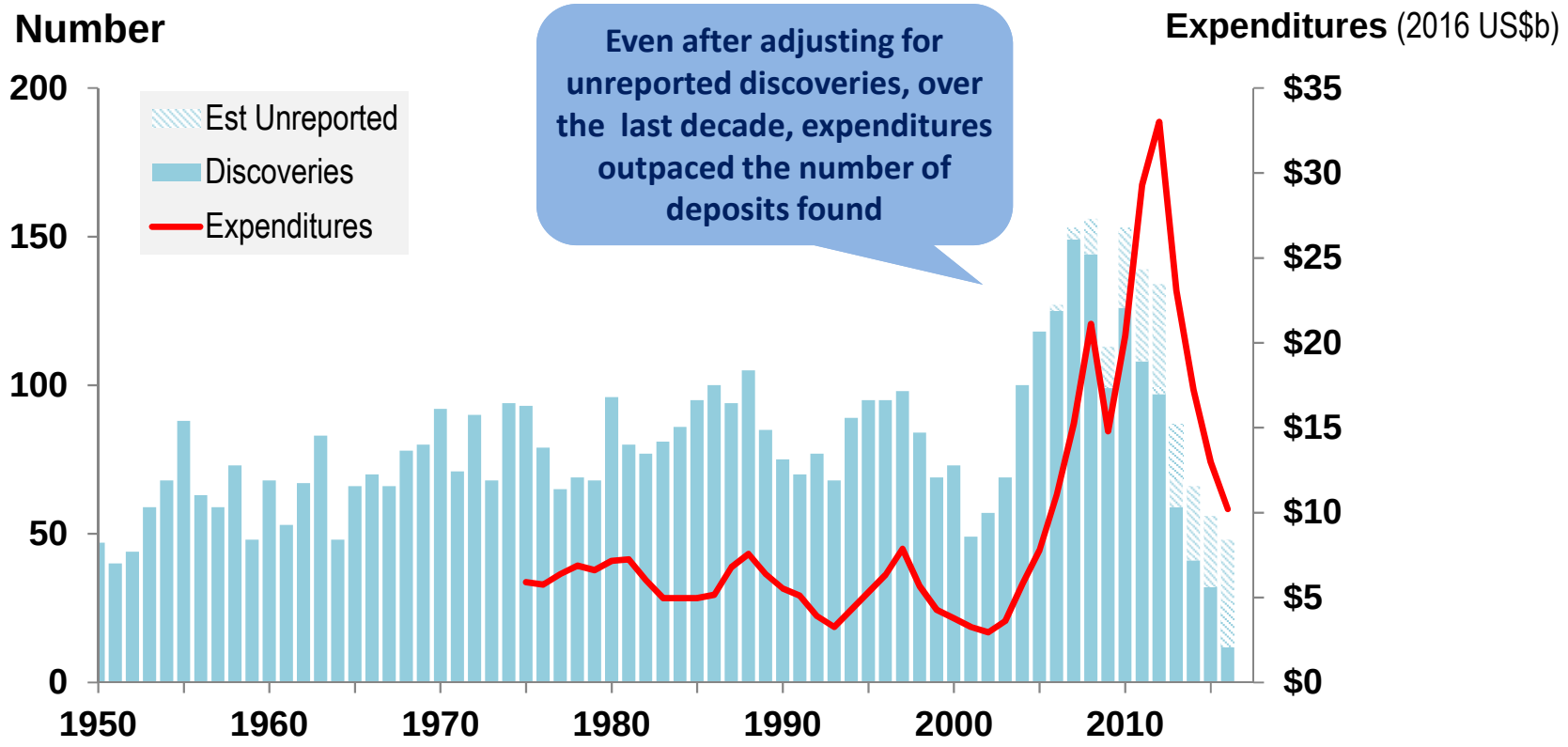
Source: MinEx Consulting © March 2017

# Number of discoveries versus expenditures

## Mineral discoveries in the World : All Commodities : 1950-2016




Note: Discoveries based on deposits >="Moderate" in size
i.e. >100koz Au, >10kt Ni, >100Kt Cu, 250kt Zn+Pb, >5kt $U_3O_8$ , > 10Mt Fe, >20Mt Thermal Coal

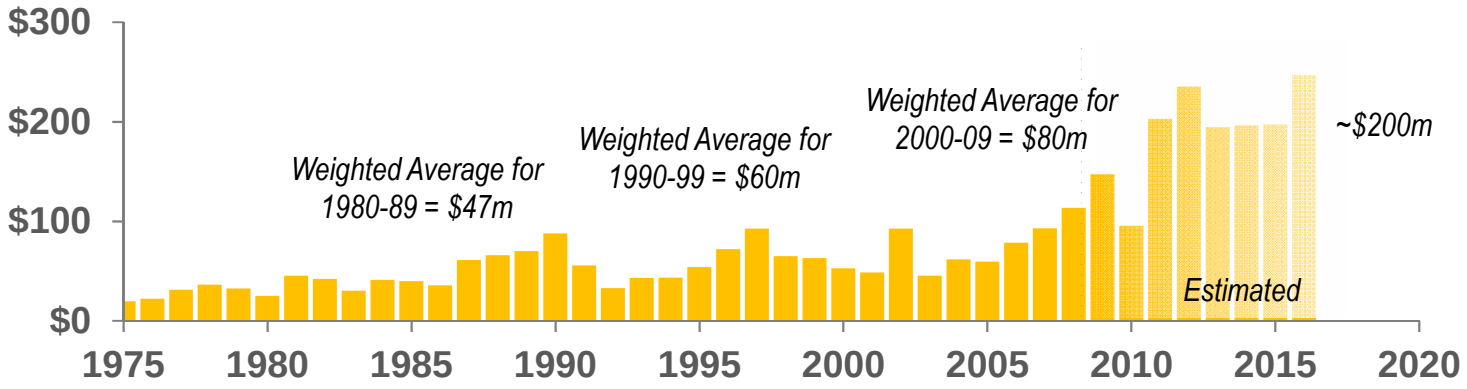
No World exploration data prior to 1975

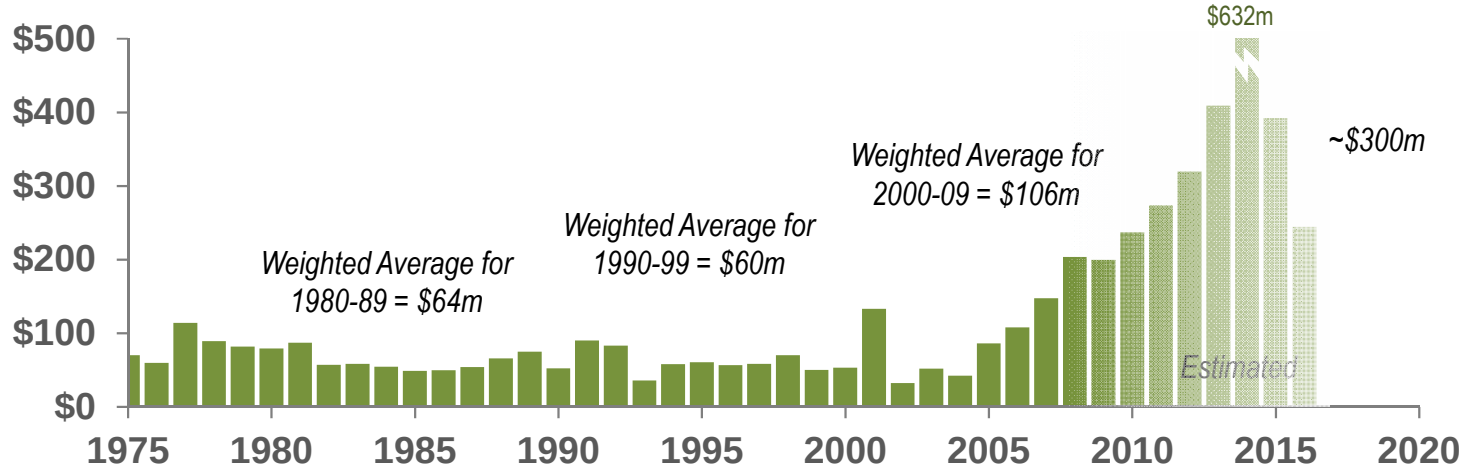
Source: MinEx Consulting © March 2017

# Discovery costs are rising

## Unit cost per for a moderate-sized gold or base metal discovery in the World

**Average Cost per Discovery** (2016 US$m)



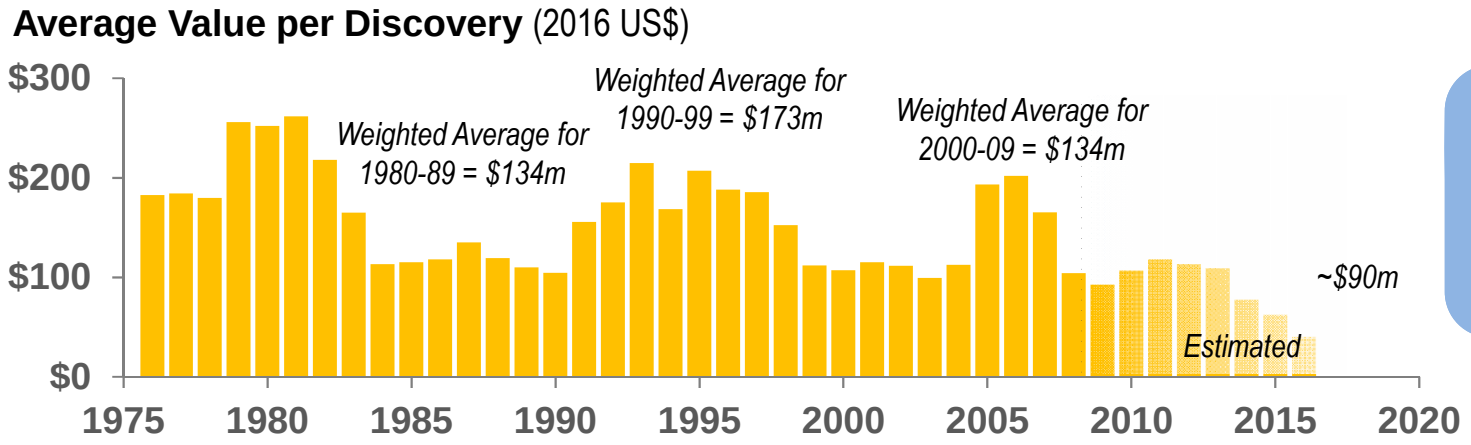

**Unit discovery costs have tripled in the last decade**

Note: Discoveries are for deposits >0.1 Moz Au or >0.1 Mt Cu-eq
Data from 2007 onwards have been adjusted for unreported deposits

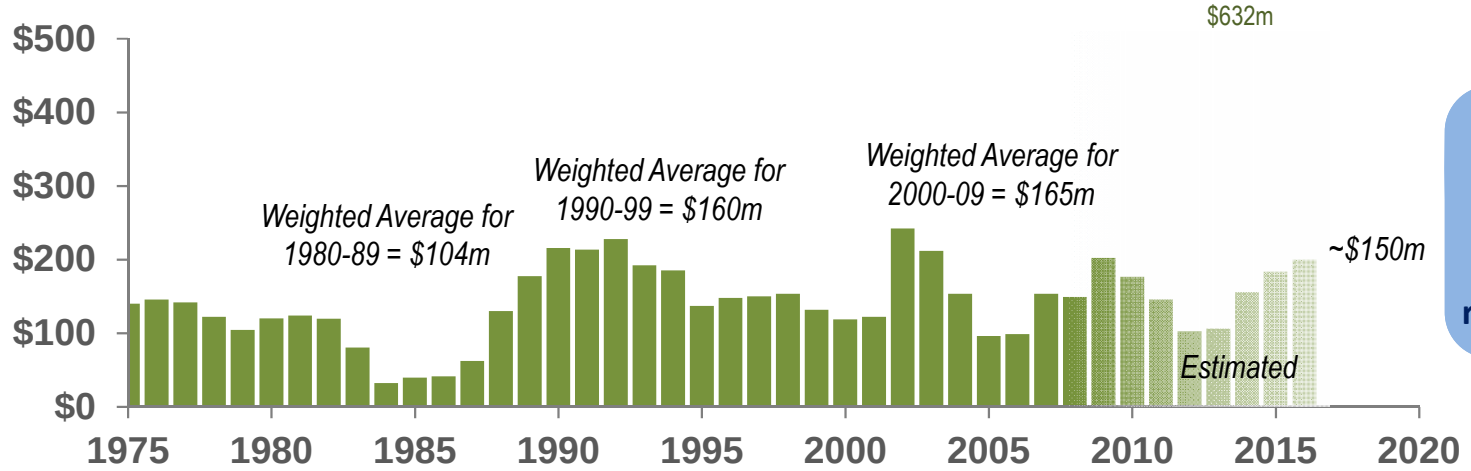
Source: MinEx Consulting © March 2017

# The unit value of discovery varies over time

## Estimated NPV per Gold or Base Metal discovery in the World




The average value/quality of gold discoveries has been **falling** over time



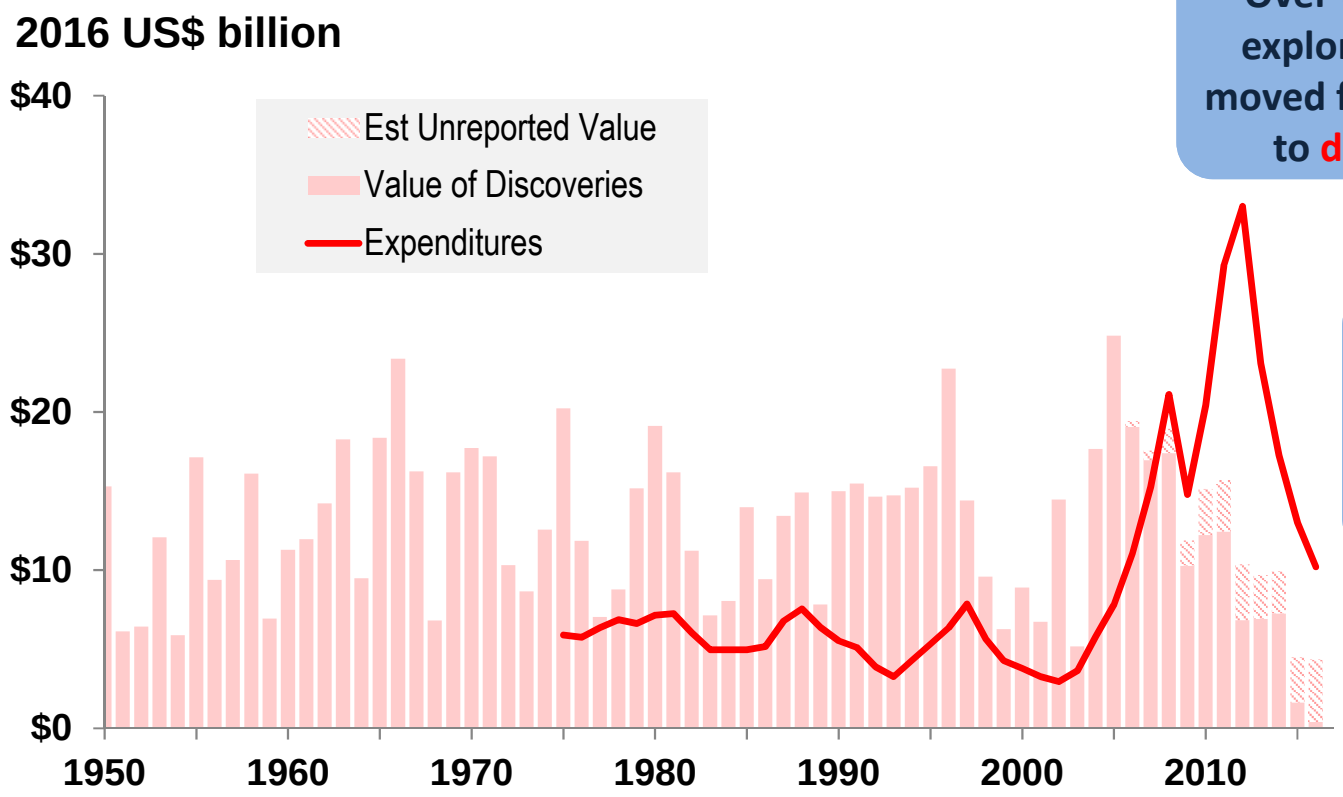

The average value/quality of base metal discoveries has remained **constant**

Note: Discovery values are indicative only, and based on rolling 3-year average
Data from 2007 onwards have been adjusted for unreported deposits

Source: MinEx Consulting © March 2017

# Estimated value of discoveries versus expenditures

## Mineral discoveries in the World : All Commodities : 1950-2016




**Over the last decade the exploration industry has moved from creating wealth to destroying wealth**

**This situation should improve over time as discoveries are drilled-out**

*Caution: Incomplete data in recent years*

**Caution: Values are indicative / approximate-only**

No World exploration expenditure data prior to 1975

Source: MinEx Consulting © March 2017

Industry is affected by structural and cyclical factors

# 2. FACTORS CAUSING THE RECENT DECLINE IN EXPLORATION PERFORMANCE

# Key Drivers for exploration

- Changes in commodity prices & exchange rates
  - Drives the overall size of the exploration budget
- Changes in input costs
  - Land access, offices & admin, geologists, drillers and community relations
- Fixed/Variable costs of running an exploration team
  - During downtimes, field work (and drilling) gets cut proportionately more
- Major new discoveries / commodity types / change in country risk
  - Success brings in new players (changes in risk/reward perception)
- New geological concepts and exploration tools
  - Potential to be more efficient and effective
- Increasing depth of cover
  - Technical risk increases and it is more expensive to explore

**Some factors are cyclical, others are structural**

**structural**

The move from boom to bust (and back again) impacts on our discovery rate and performance

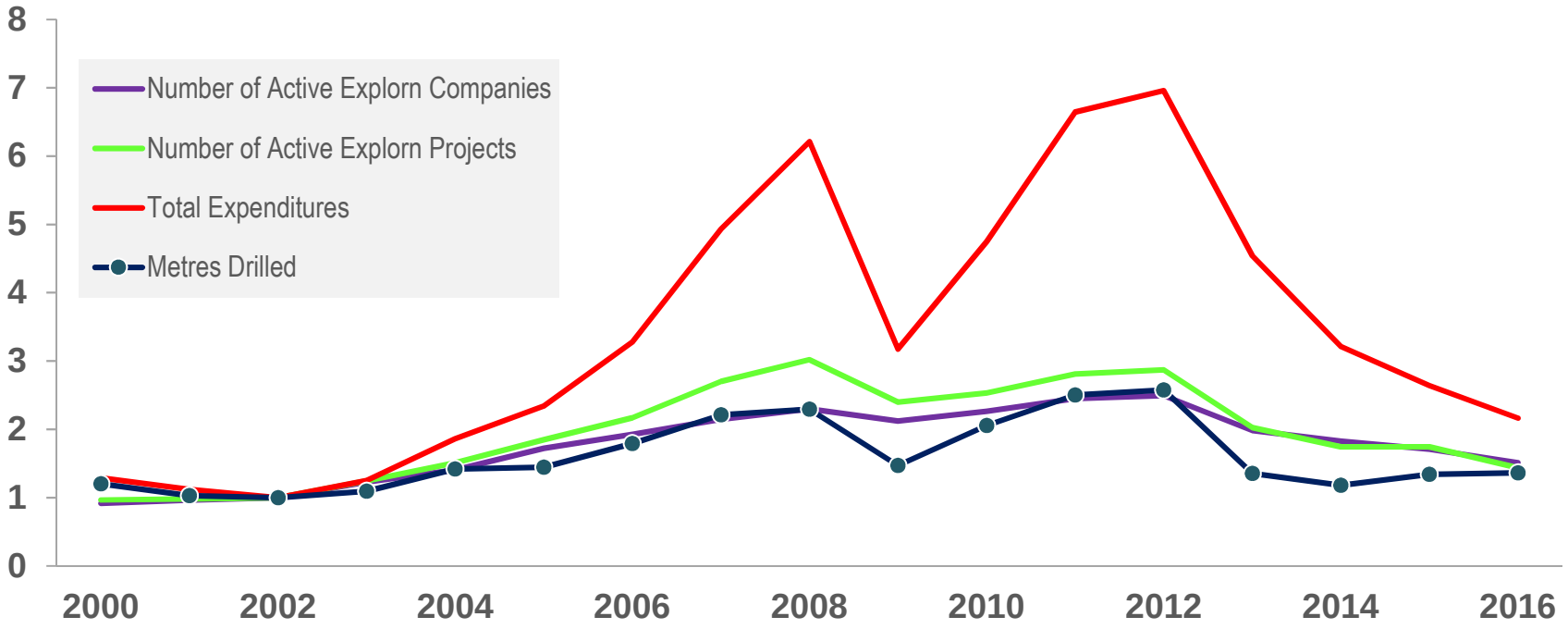
# 3. INDUSTRY BEHAVIOUR OVER THE LAST BUSINESS CYCLE

# Change in the level of exploration activities

## Canada + Australia : 2000-2016

**From 2002 to 2012 the number of exploration companies rose by 2.5x the number of exploration projects by 2.9x and total expenditures (in constant $) by 7.0x, but metres drilled only went up 2.6x**

**Change in Activity**
**Normalised to Year 2002 = 1**




Note: Excludes exploration and discoveries for Bulk Minerals
Discovery rate is based on deposits >="Moderate" in size
All costs are reported in constant 2016 US$

Source: Analysis by MinEx Consulting © March 2017
based on data from ABS, NRCan and SNL

# Change in the level of exploration activities

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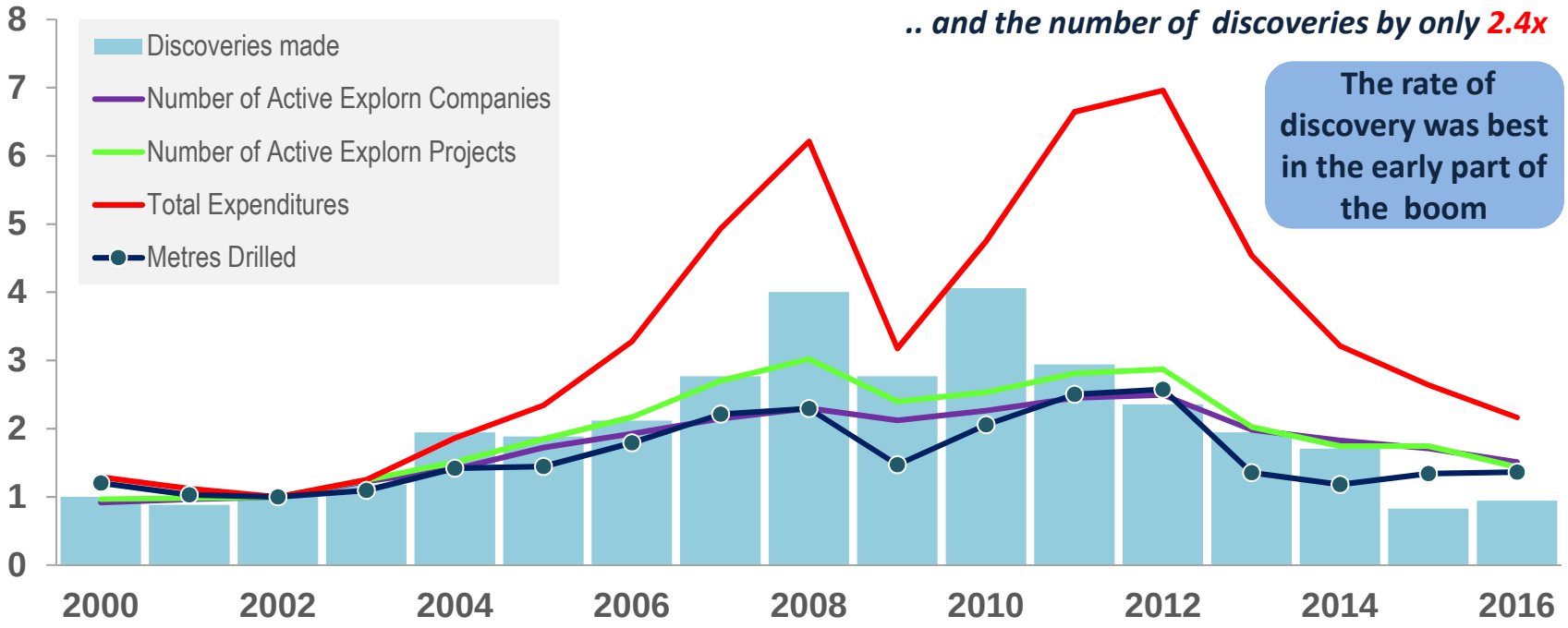
**From 2002 to 2012 the number of exploration companies rose by 2.5x the number of exploration projects by 2.9x and total expenditures (in constant $) by 7.0x, but metres drilled only went up 2.6x**

***.. and the number of discoveries by only 2.4x***

**The rate of discovery was best in the early part of the boom**

**Change in Activity**
**Normalised to Year 2002 = 1**




Note: Excludes exploration and discoveries for Bulk Minerals
Discovery rate is based on deposits >="Moderate" in size
All costs are reported in constant 2016 US$

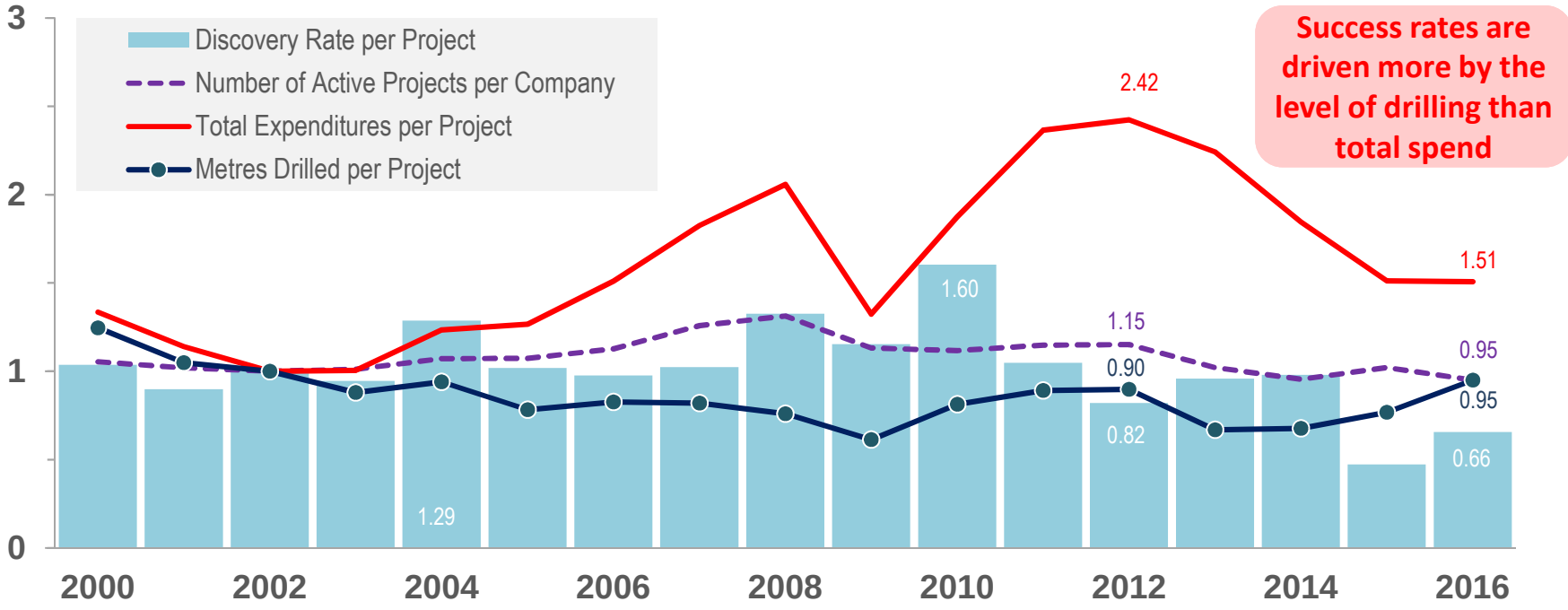
Source: Analysis by MinEx Consulting © March 2017
based on data from ABS, NRCan and
SNL Metals & Mining data, an offering of S&P Global Market Intelligence

# Change in the level of exploration activities per project

## Canada + Australia : 2000-2016

**For most of the period the discovery rate per project remained fairly constant (if anything it was better in the early-part of the up-cycle). In the down cycle, companies pruned back their portfolio of projects and spend per project, but also pruned back on the level of drilling**

**Change in Activity**
**Normalised to Year 2002 = 1**




**Success rates are driven more by the level of drilling than total spend**

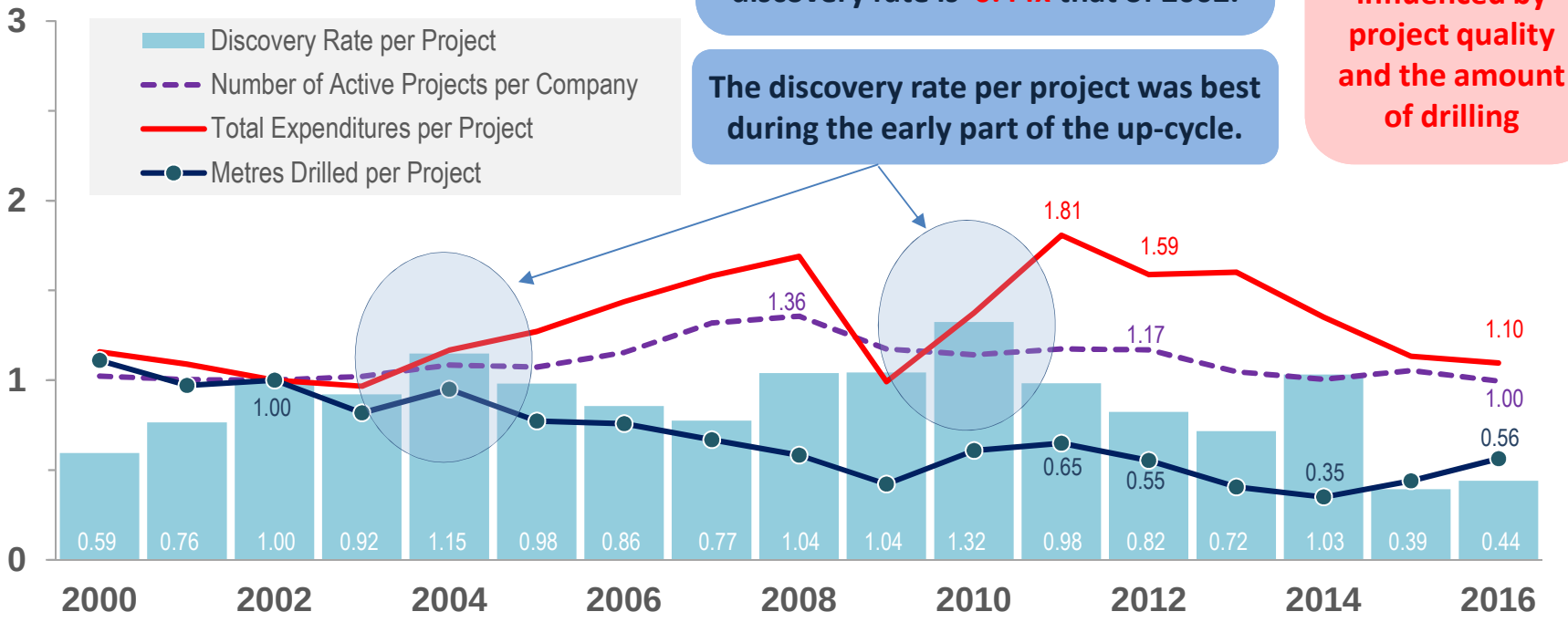
Note: Includes Greenfield and Brownfield exploration
Excludes exploration and discoveries for Bulk Minerals
Discovery rate is based on deposits >="Moderate" in size

Source: Analysis of 2602 companies by MinEx Consulting © March 2017 based on data from ABS, NRCan and SNL Metals & Mining data, an offering of S&P Global Market Intelligence

# Change in level of explorn activities per greenfield project

## Canada + Australia : 2000-2016

**Change in Activity**
**Normalised to Year 2002 = 1**




**Projects in 2016 have 1.10x level of spend to that of 2002, but only 0.56x the amount of drilling … and the unit discovery rate is 0.44x that of 2002.**

**The discovery rate per project was best during the early part of the up-cycle.**

**Success rates for greenfield exploration are influenced by project quality and the amount of drilling**

Caution: approximate only

Note: Excludes exploration and discoveries for Bulk Minerals
Discovery rate is based on deposits >="Moderate" in size

Source: Analysis of 2602 companies by MinEx Consulting © March 2017 based on data from ABS, NRCan and SNL Metals & Mining data, an offering of S&P Global Market Intelligence

# Keys learnings

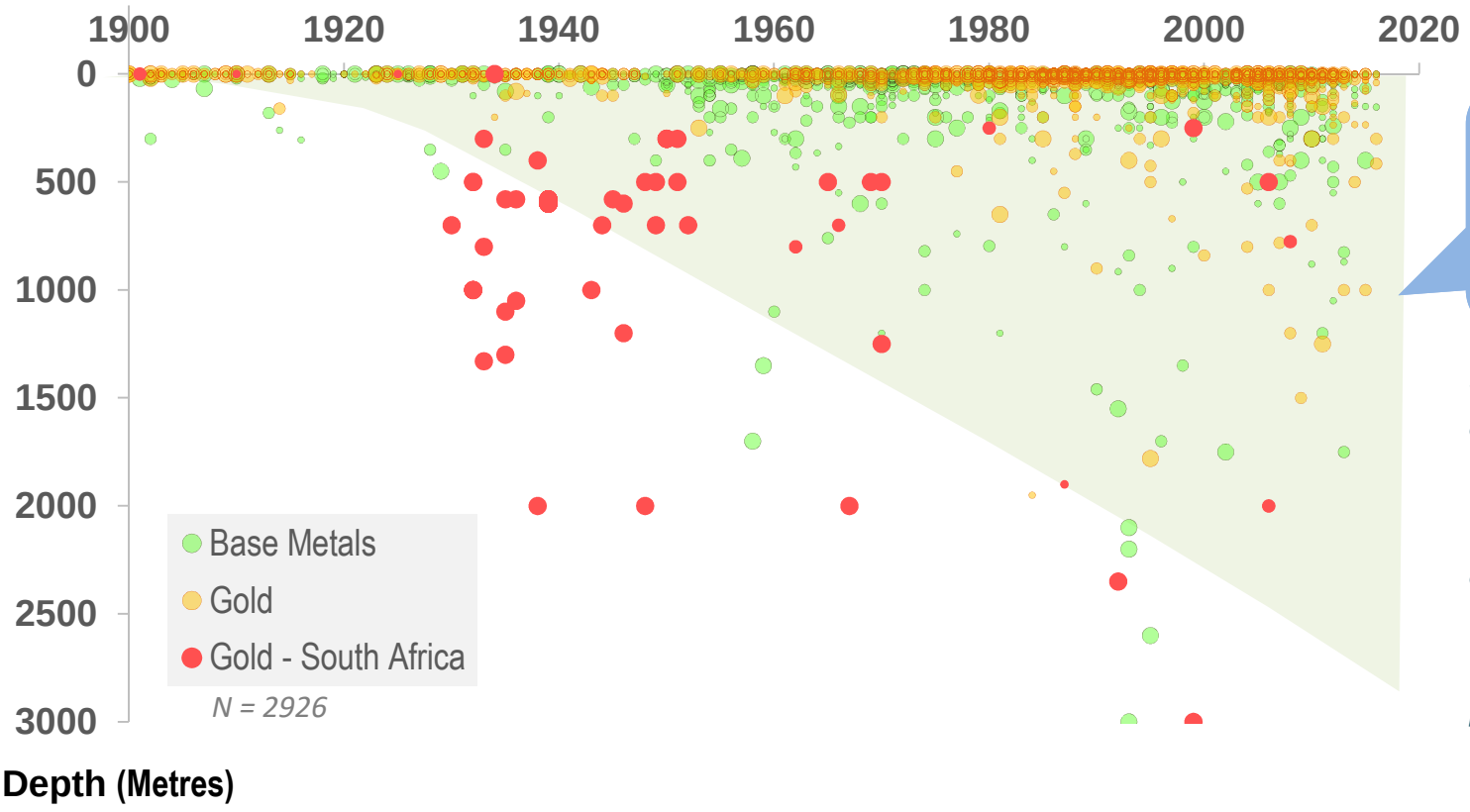
- Discovery performance is best in the first couple years of the up-cycle
- At the top of the cycle, companies tend to take on marginal projects and lose control of costs
- In the down-cycle companies need to quickly restructure their business to get the fixed/variable costs back in-balance
- Exploration success is driven by good ideas (and economic targets) and a healthy drilling budget

The challenge of exploring under deeper cover is a “slow-burn” story that will only get tougher over time.

# 4. LONG TERM TRENDS IN DEPTH OF COVER

# Depth of cover versus discovery year:

## Gold and Base Metal discoveries in the World : 1900-2016




**Industry is progressively looking under deeper cover over time**

***Such deposits are harder to find***

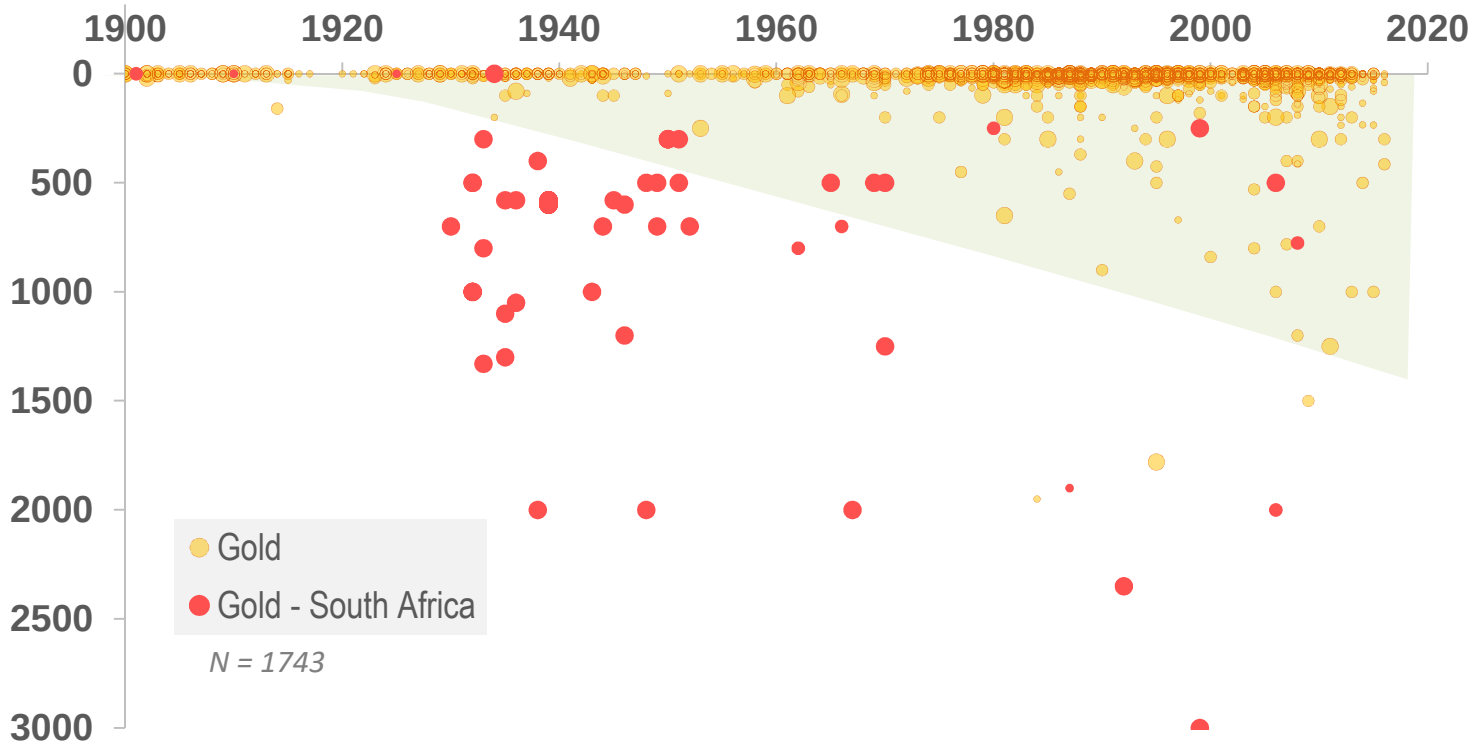
***… but this is a "slow-burn" story and doesn't explain the rapid decline in recent performance***

Note: Size of the bubble refers to Moderate, Major and Giant discoveries
Excludes satellite deposits within existing camps. Analysis excludes Nickel laterites and under-sea deposits

Source: MinEx Consulting © March 2017

# Depth of cover versus discovery year:

## Gold discoveries in the World : 1900-2016

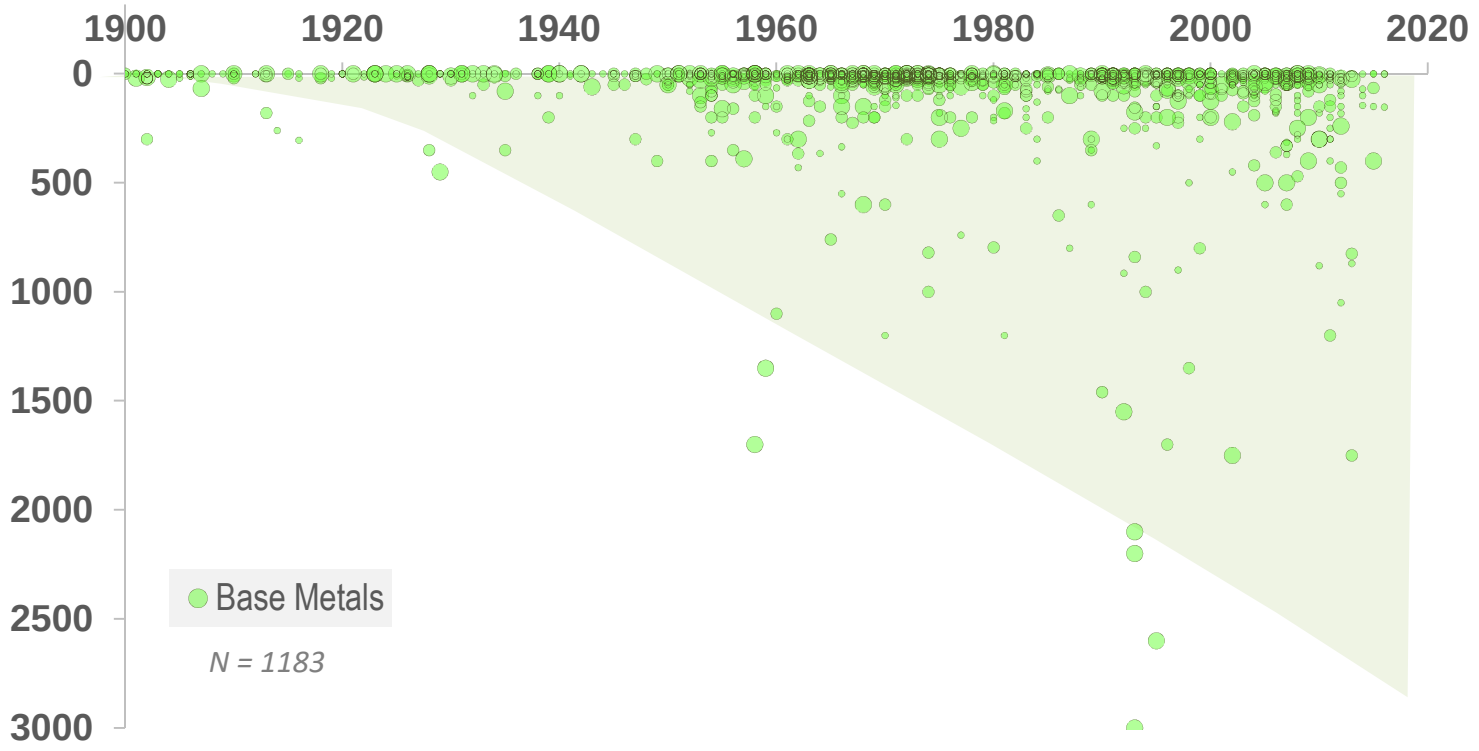



Note: Size of the bubble refers to Moderate, Major and Giant discoveries.
Excludes 615 deposits with no information on depth of cover.
Excludes satellite deposits within existing camps.

Source: MinEx Consulting © March 2017

# Depth of cover versus discovery year:

## Base Metal discoveries in the World : 1900-2016

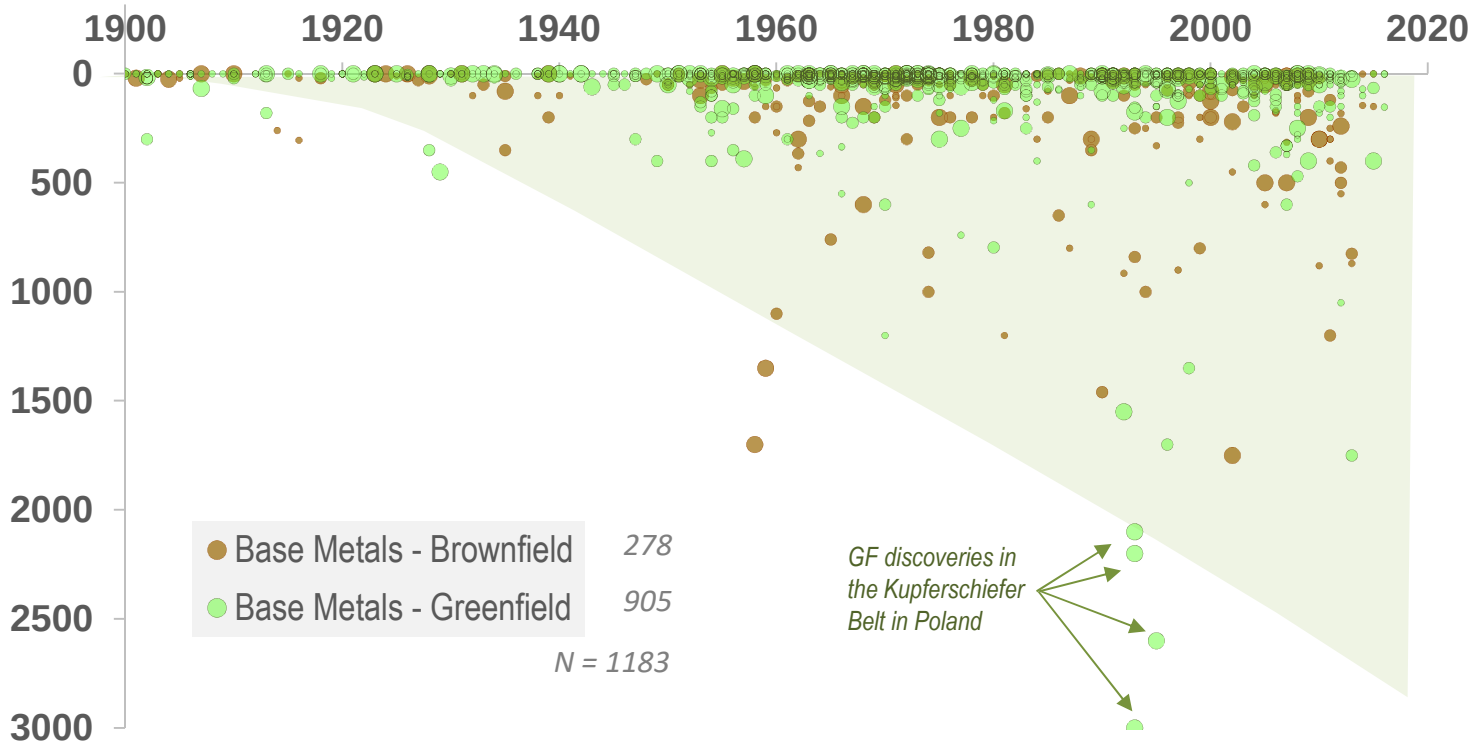



Note: Size of the bubble refers to Moderate, Major and Giant discoveries.
Excludes 383 deposits with no information on depth of cover.
Excludes satellite deposits within existing camps. Analysis excludes Nickel laterites and under-sea deposits.

Source: MinEx Consulting © March 2017

# Depth of cover versus discovery year:

## Base Metal discoveries in the World : Greenfield vs Brownfield 1900-2016



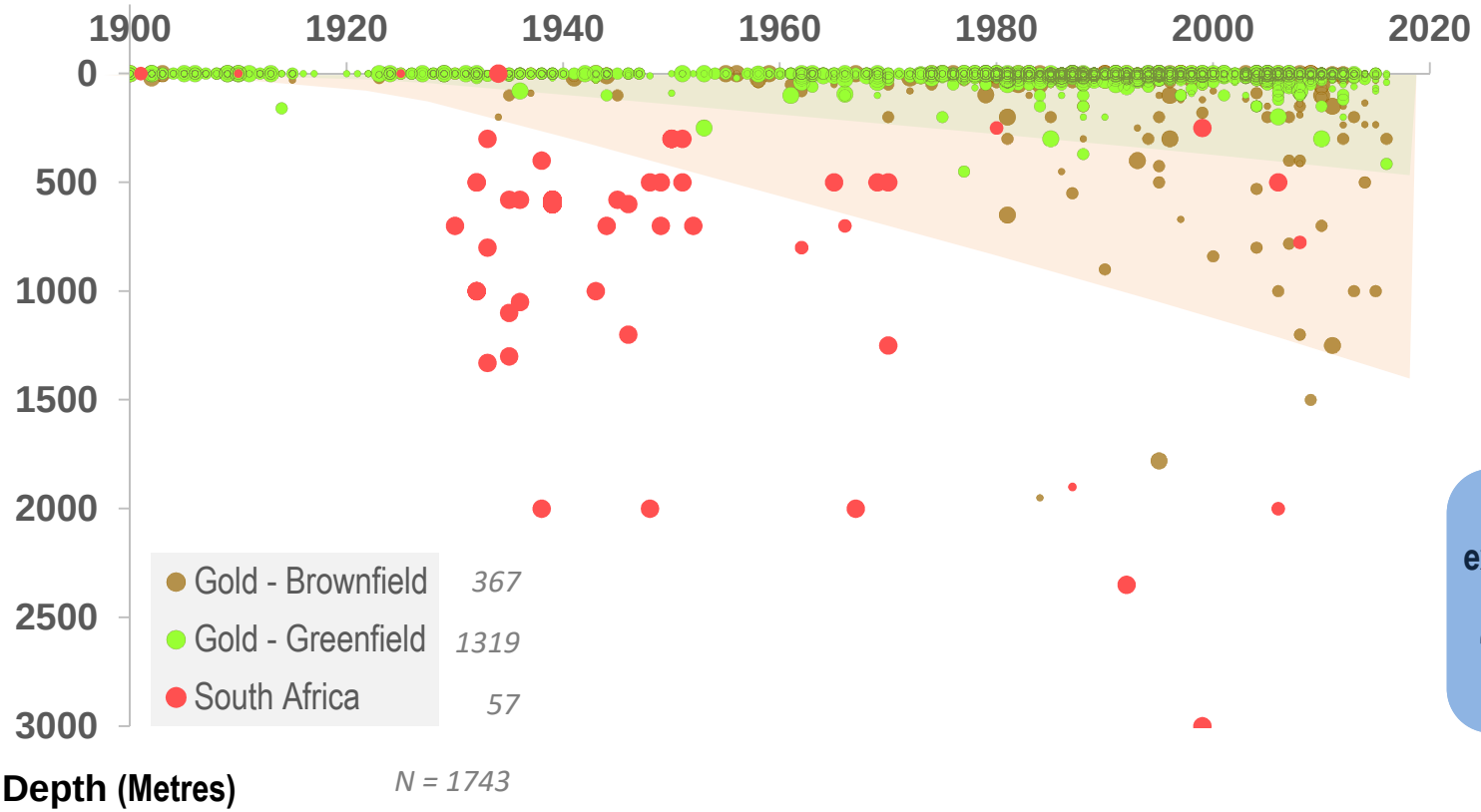

**Industry is more effective at exploring under deep cover for Base Metals than it is for Gold**

Note: Size of the bubble refers to Moderate, Major and Giant discoveries.
Excludes 383 deposits with no information on depth of cover.
Excludes satellite deposits within existing camps. Analysis excludes Nickel laterites and under-sea deposits.

Source: MinEx Consulting © March 2017

# Depth of cover versus discovery year:

## Gold discoveries in the World : Greenfield vs Brownfield : 1900-2016



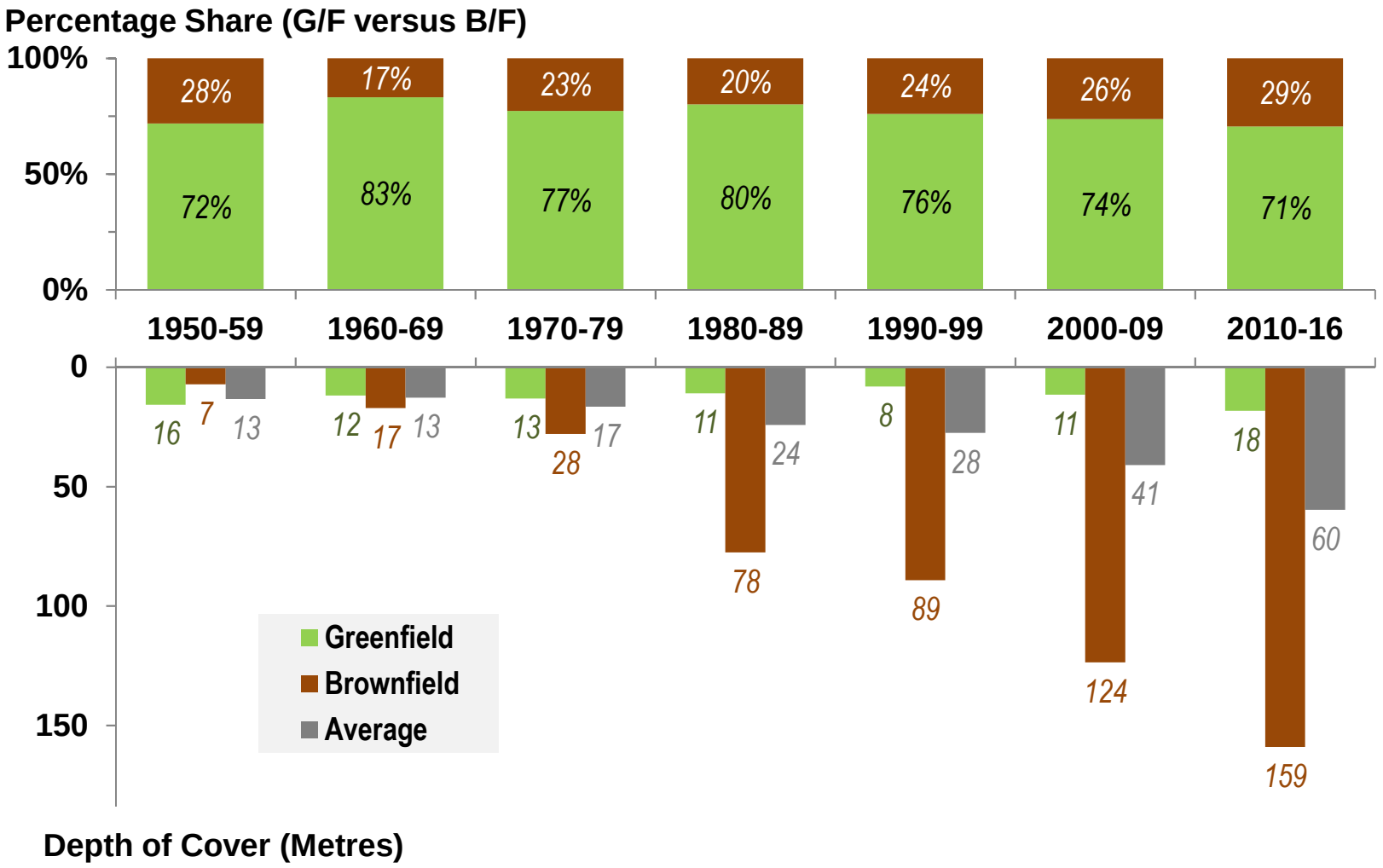

**Greenfields exploration for gold is still stuck at the "shallow-end" of the swimming pool**

Note: Size of the bubble refers to Moderate, Major and Giant discoveries.
Excludes 615 deposits with no information on depth of cover.
Excludes satellite deposits within existing camps.

Source: MinEx Consulting © March 2017

# Depth of cover has been slowly increasing over time

## Weighted average depth of cover for primary gold discoveries in the World

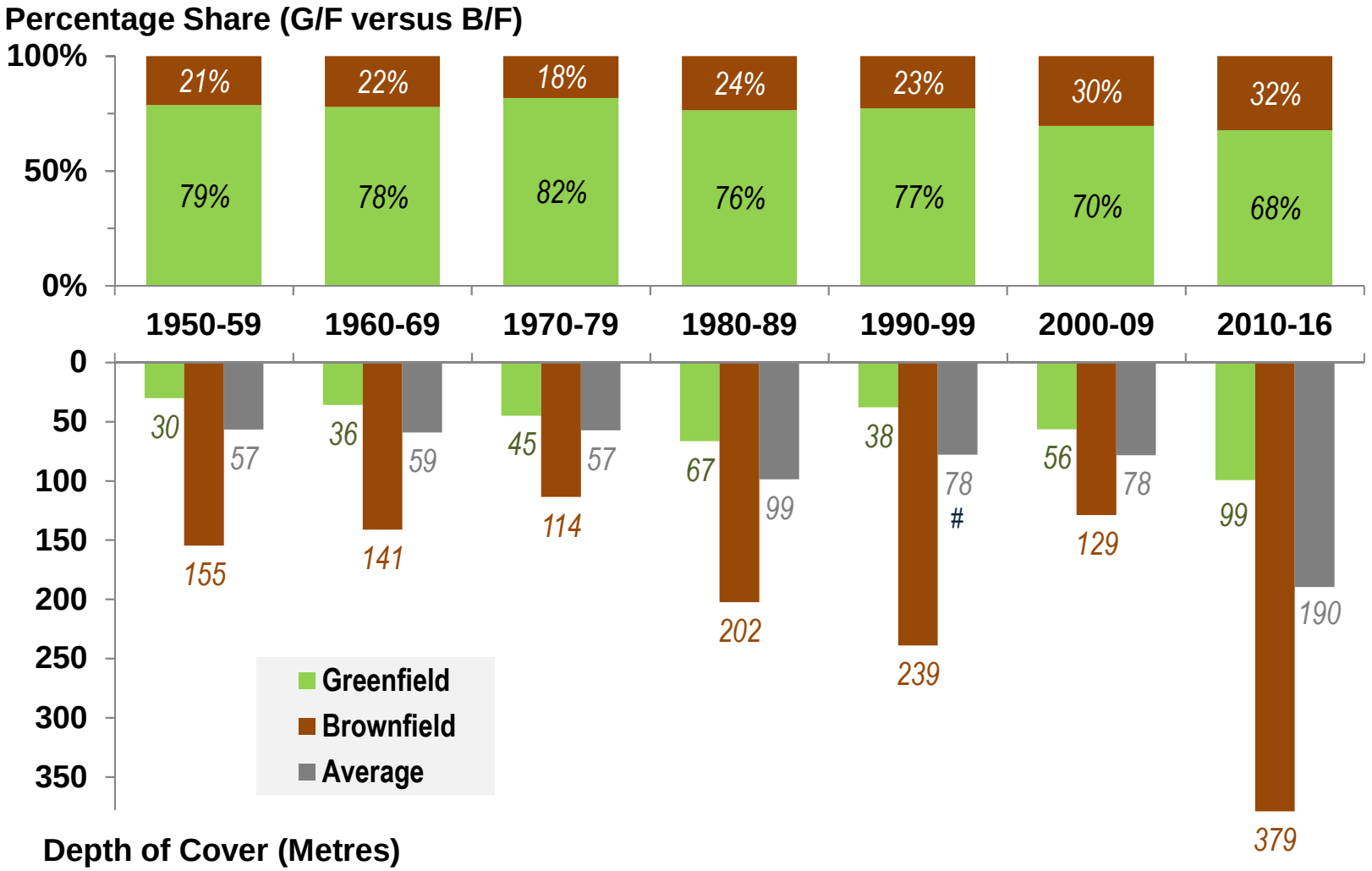



Note: Excludes South Africa

Source: MinEx Consulting © March 2017

# Depth of cover has been slowly increasing over time

## Weighted average depth of cover for base metal discoveries in the World

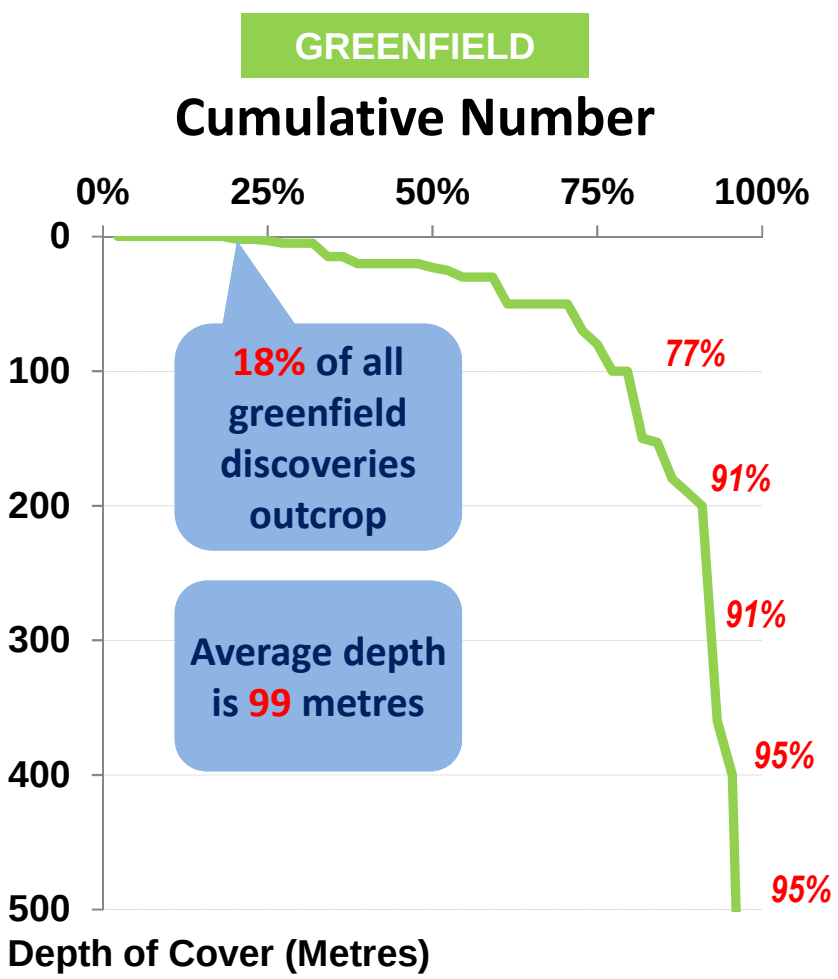


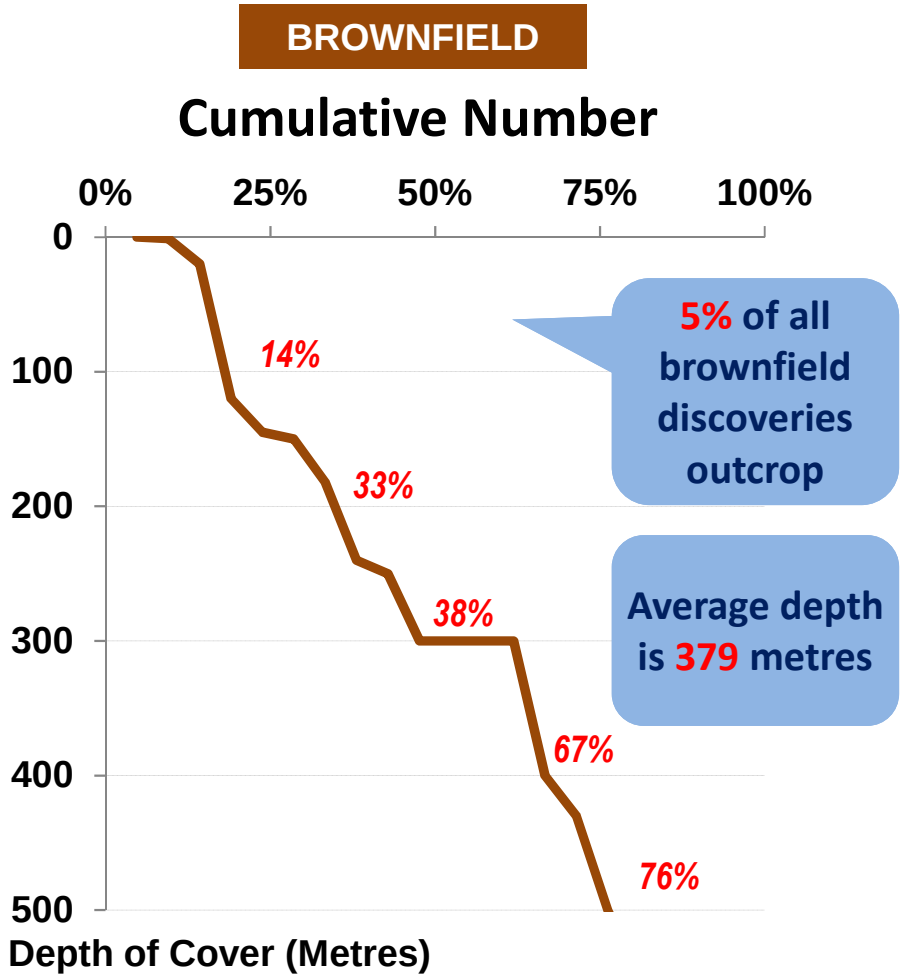

# Note: Excludes 9 very deep (and uneconomic) greenfield discoveries in 1990s on extensions to the Kupferschiefer Belt in Poland. Including them increases the average Greenfield depth to 203m and average total to 211m

Source: MinEx Consulting © March 2017

# Have a wide range of depths for Base Metals

Depth of cover for base metal deposits > 0.1 Mt-Cu equivalent found in the World: 2010-16



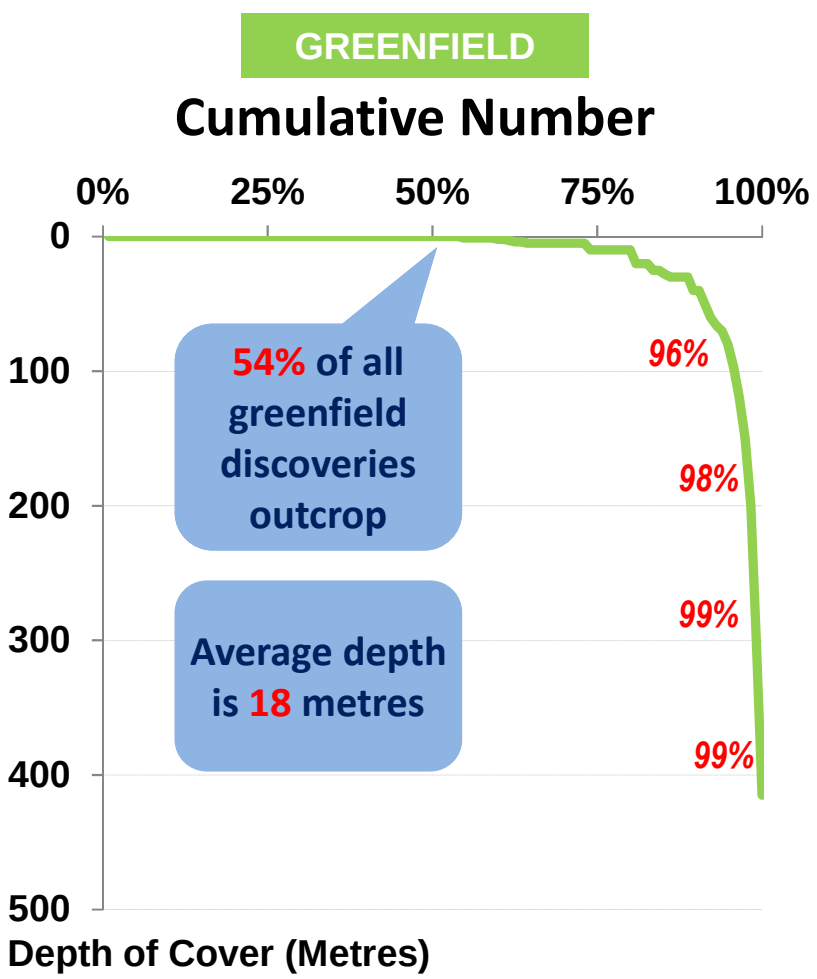



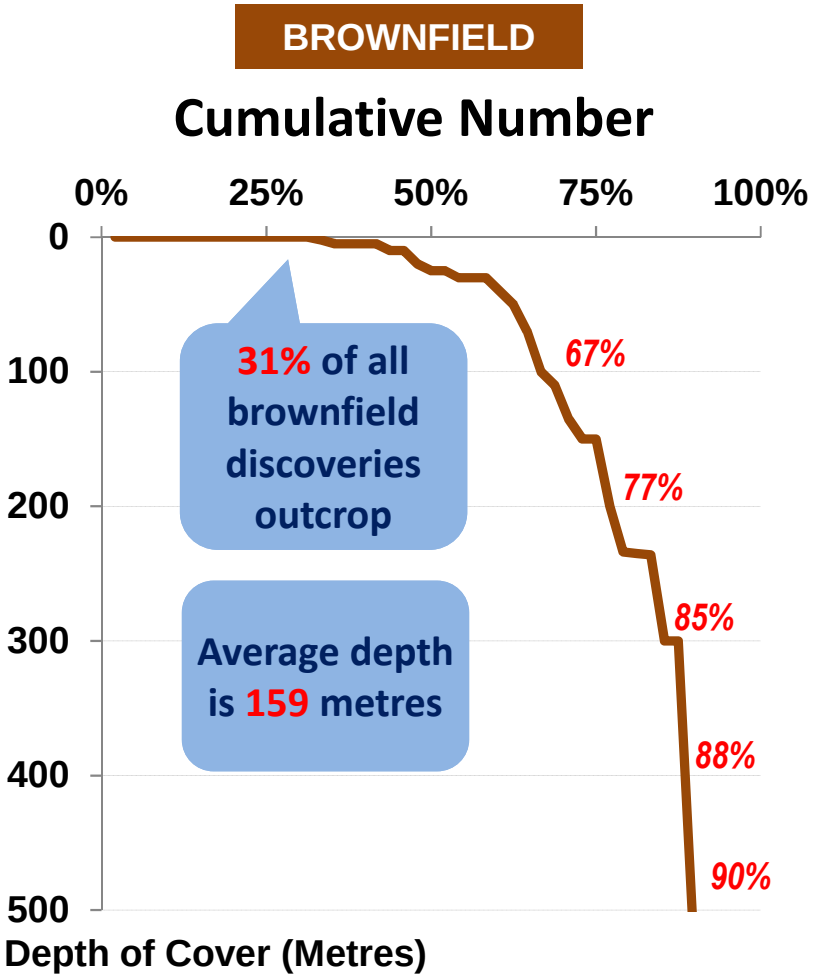

Note: Based on 44 greenfield and 21 brownfield discoveries.
Excludes Nickel Laterite deposits and Undersea Deposits

Source: MinEx Consulting © March 2017

# Most gold discoveries are still being made at (or near) surface

Depth of cover for gold deposits > 0.1 Moz found in the World: 2010-16




Note: Based on 115 greenfield and 48 brownfield discoveries.
Excludes South Africa

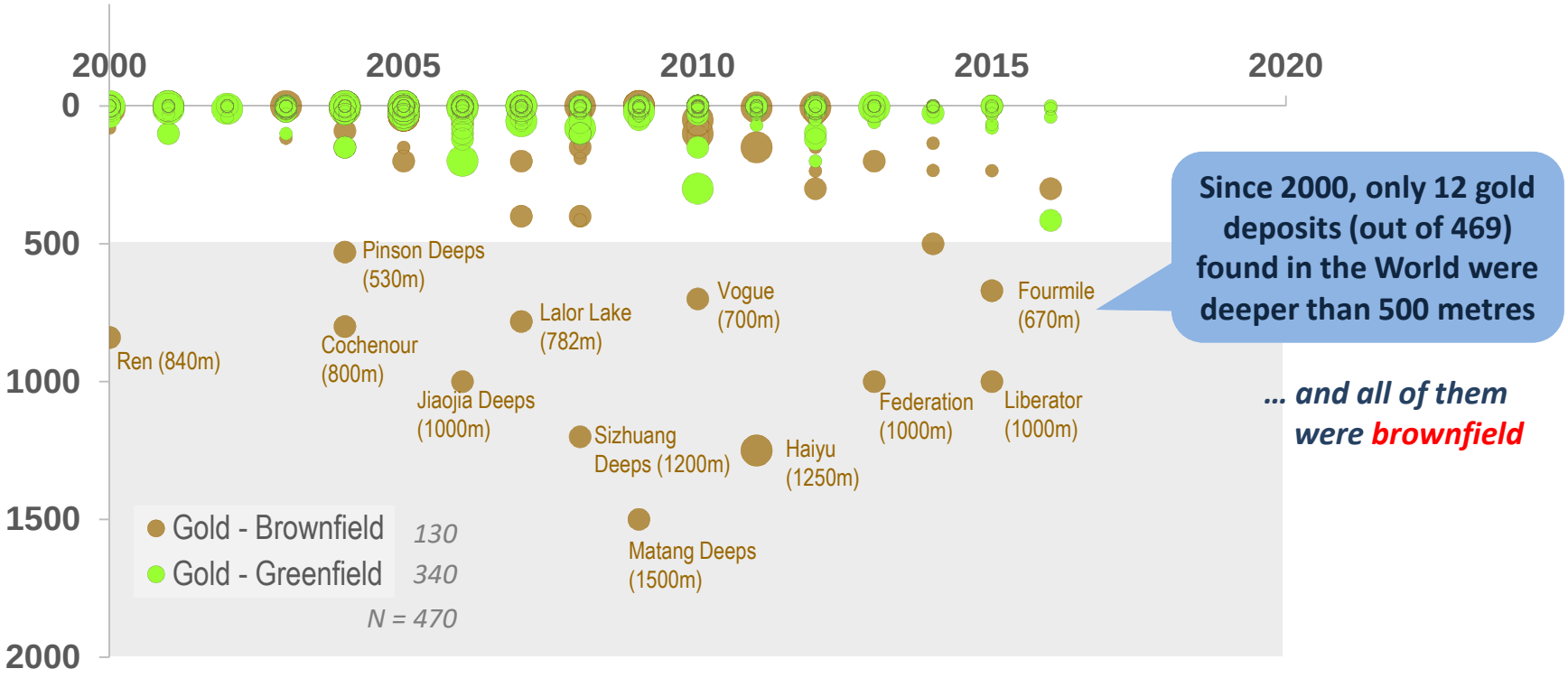
Source: MinEx Consulting © March 2017

Between 2000-16, out of the 800+ gold and base metal discoveries made in the World, only 21 were >500 metres deep

# 5. DEEP DISCOVERIES MADE SINCE 2000

# Depth of cover versus discovery year:

## Gold discoveries in the World : Greenfield vs Brownfield : 2000-2016

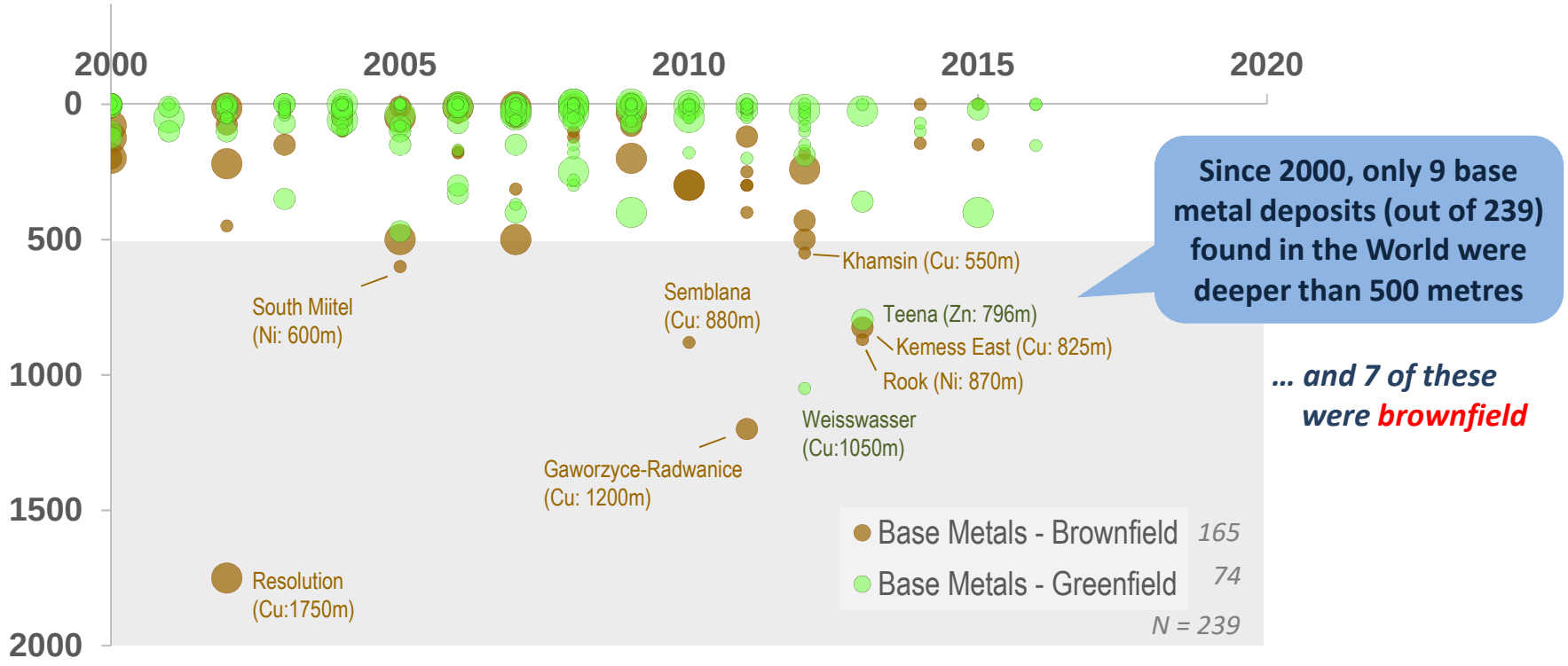



Note: Size of the bubble refers to Moderate, Major and Giant discoveries.
Excludes 100 deposits with no information on depth of cover. Excludes South Africa
Excludes satellite deposits within existing camps..

Source: MinEx Consulting © March 2017

# Depth of cover versus discovery year:

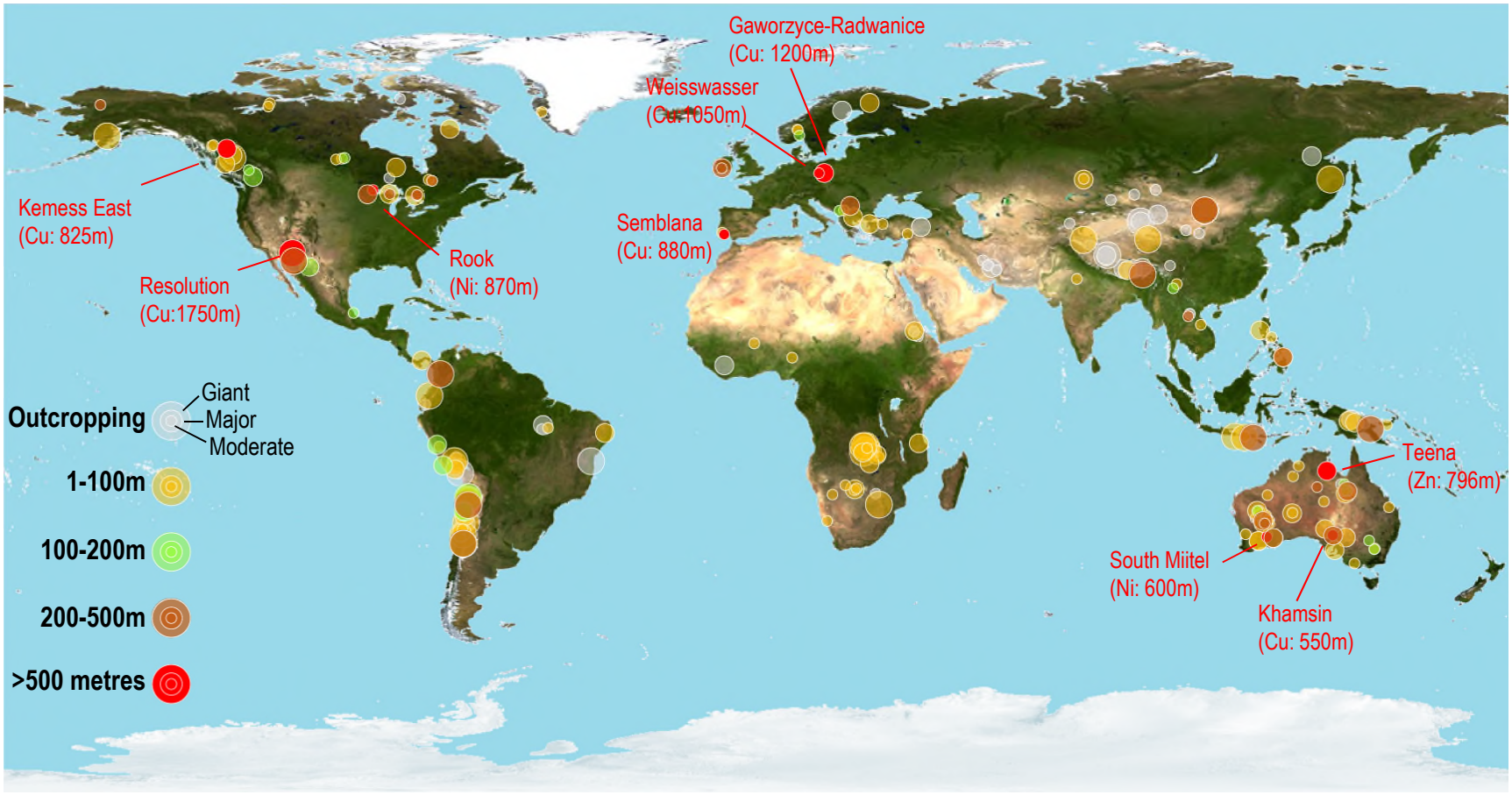
## Base Metal discoveries in the World : Greenfield vs Brownfield 2000-2016




Note: Size of the bubble refers to Moderate, Major and Giant discoveries.
Excludes 69 deposits with no information on depth of cover.
Excludes satellite deposits within existing camps. Analysis excludes Nickel laterites and under-sea deposits.

Source: MinEx Consulting © March 2017

# Depth of cover for Base Metal discoveries : 2000-16

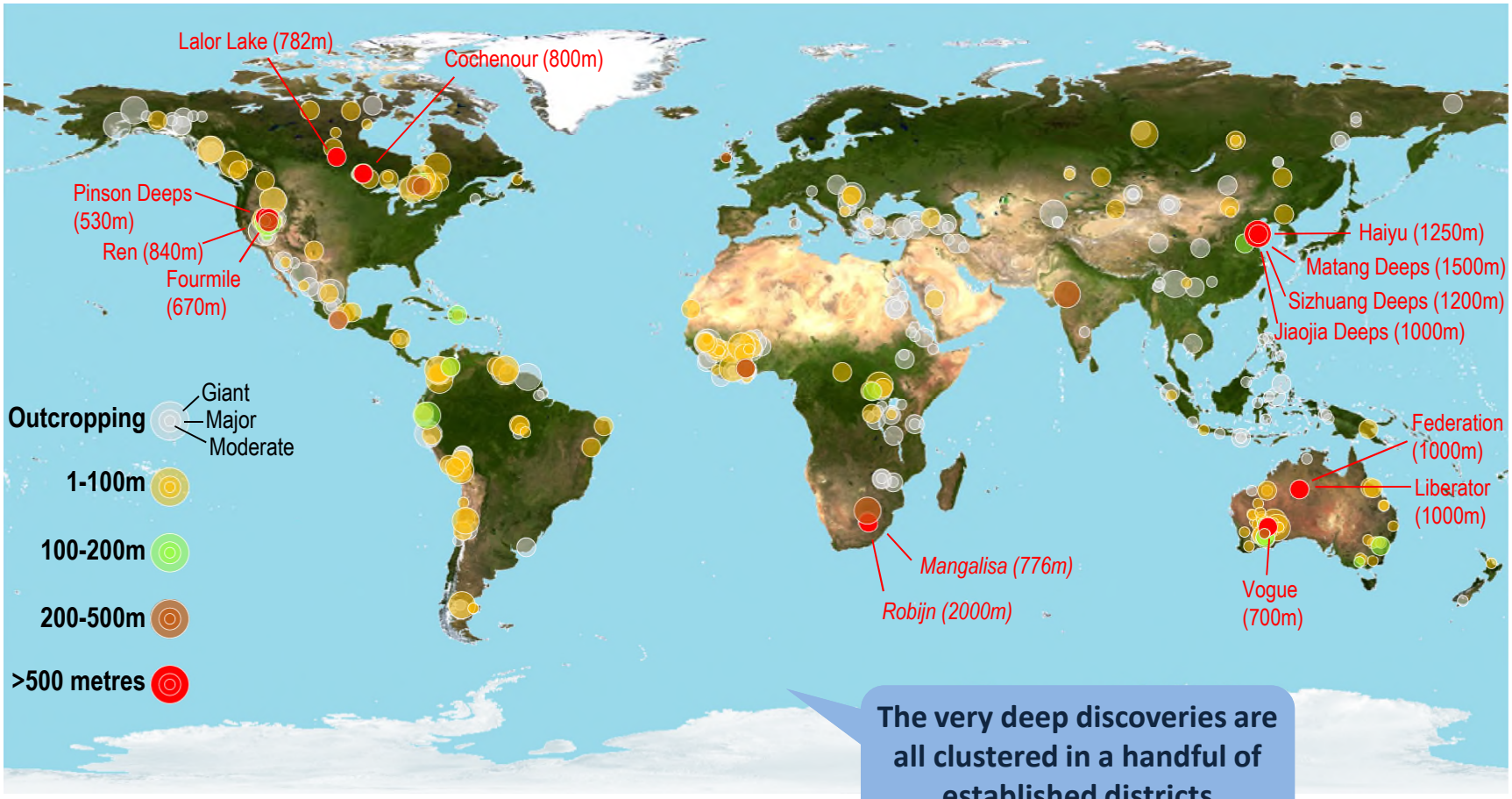



*N = 239*

Note: Size of the bubble refers to Moderate, Major and Giant discoveries.
Excludes 69 deposits with no information on depth of cover.
Excludes satellite deposits within existing camps. Analysis excludes Nickel laterites and under-sea deposits.

Source: MinEx Consulting © March 2017

# Depth of cover for Gold discoveries : 2000-16




Note: Size of the bubble refers to Moderate, Major and Giant discoveries.
For completeness have included South Africa. Excludes 99 deposits with no information on depth of cover.
Excludes satellite deposits within existing camps.

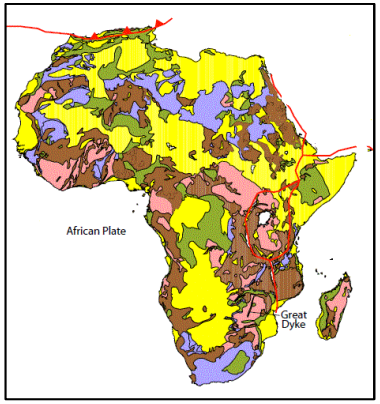
Source: MinEx Consulting © March 2017

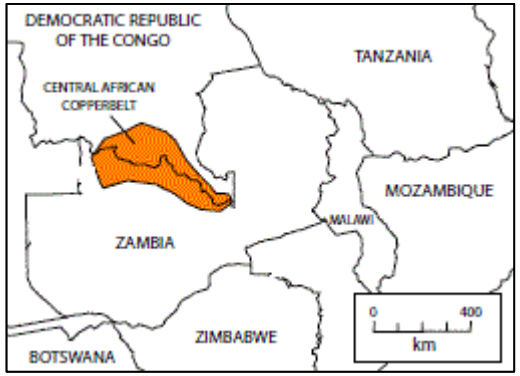
A wide range of exploration tools and techniques are available. Their effectiveness varies by commodity type and depth of cover

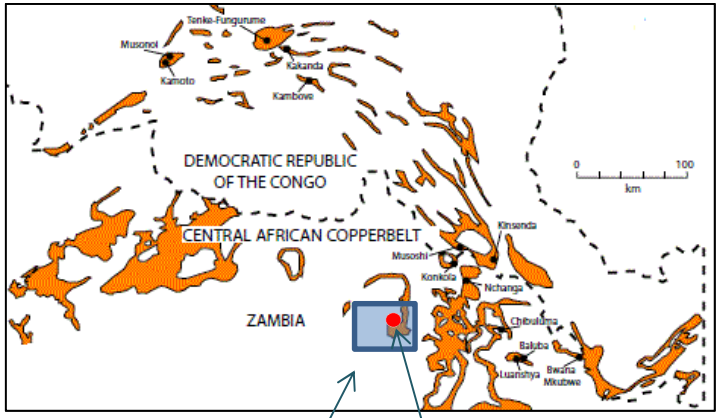
# 6. DISCOVERY METHODS USED

# Trends in exploration methods

The preferred search method used varies by commodity type, depth of cover and “scale”




Continental-Scale

Province-Scale

District-Scale

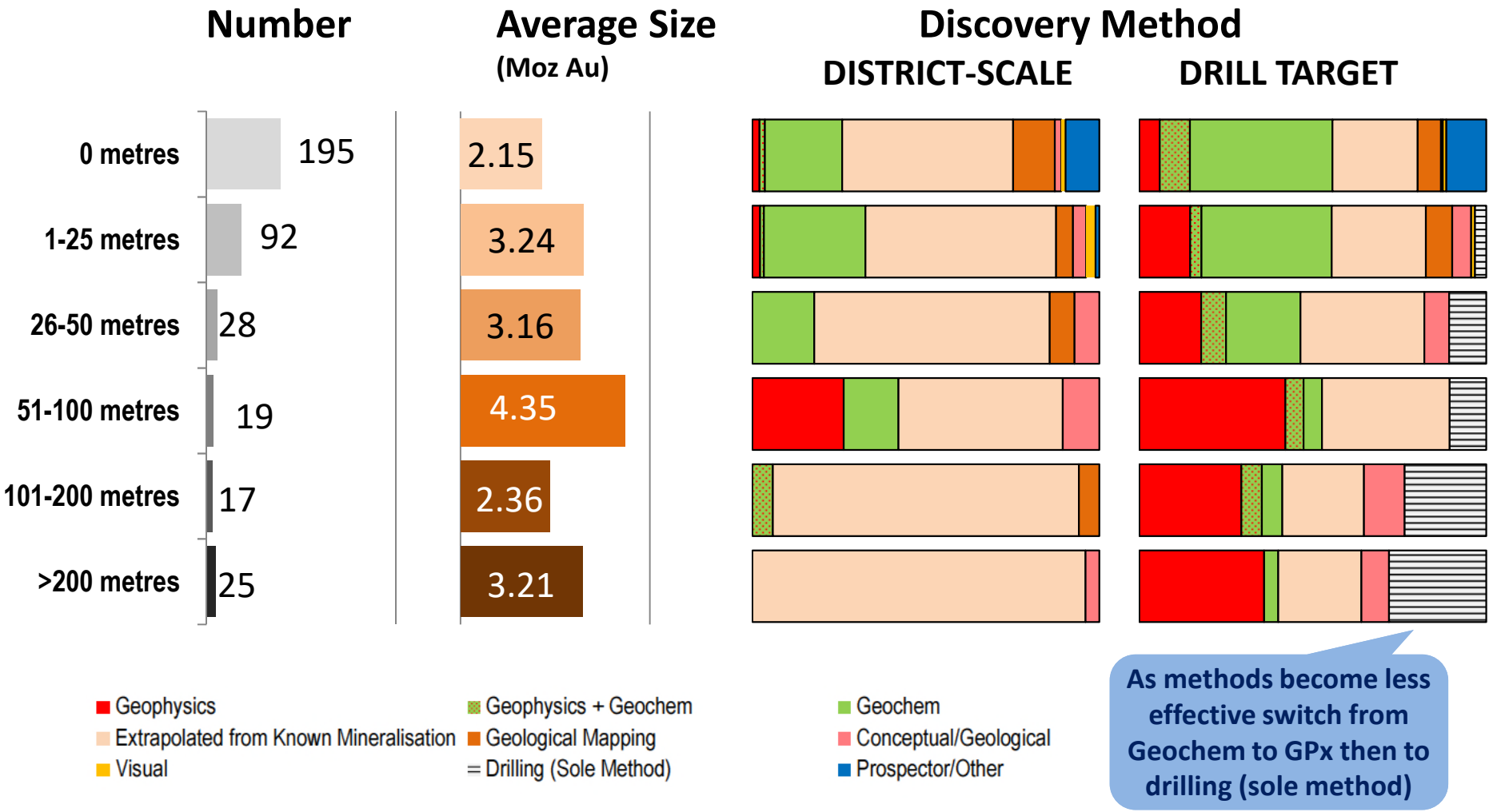
Project-Scale

Prospect-Scale

**MinEx has carried out a detailed analysis of the discovery history of 559 gold and base metal deposit found in the World at these two scales**

# Discovery method changes with depth

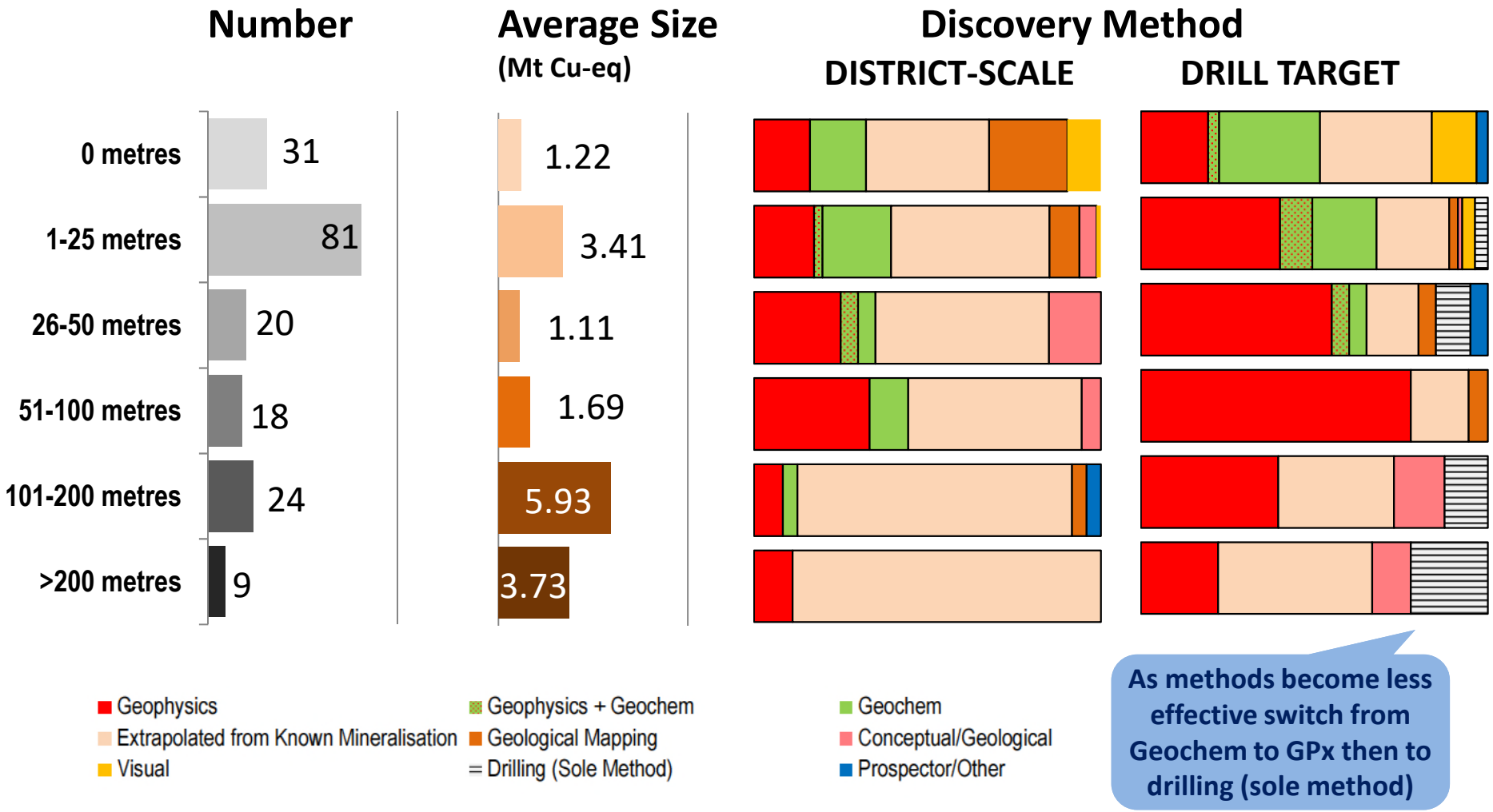
## Primary gold discoveries >0.1 Moz in World: 2000-2016




Source: MinEx Consulting © March 2017

# Discovery method changes with depth

## Primary base metal discoveries >0.1 Mt Eq in World: 2000-2016




Source: MinEx Consulting © March 2017

# 5. CONCLUSIONS

# Conclusions [1/4]

- Global exploration expenditures (for bulks and non-ferrous) reached an all-time high in 2012 (of US$33 billion). In the 4 years since then it has dropped by 69% to $10.2 billion
  - Gold continues to be the main target (39%) followed by base metals (29%) and bulk minerals (14%).

- Historically, ~70-80 Moderate-sized (or larger) deposits were found each year in the World. This peaked at 149 discoveries in 2007 and has fallen dramatically since then
  - However, we need to remember that it does take time for discoveries to be reported and fully-drilled out

- Over the last decade, due to a massive increase in spend and only modest increase in the number of deposits found, industry performance declined
  - Average cost per discovery went up 3x. It currently costs ~$200m to find a gold deposit and $300m for a base metal deposit. Challenge is that these deposits are (on average) only worth $90m and $150m respectively.

# Conclusions [2/4]

- The recent decline in driven by a combination of cyclical and structural factors. These include:
  - Higher commodity prices led to a boom in exploration – but it led to a doubling in the cost of running an office, hiring a geologist and drilling a hole.
  - The subsequent bust has resulted in lower input costs, but companies had gone into hibernation – resulting in very little fieldwork (and discoveries)
  - Discovery performance is best in the first 2 years of an up-turn … as companies re-activate their (best) projects.
- The move to exploring under progressively deeper cover is a slow-burn story
  - It only partially explains the recent poor performance for the industry.
  - The depth of cover issue varies by commodity and brownfield/greenfield and location (it's not an issue in Africa)
  - For Australia and Canada the issue will only get worse over time

# Conclusions [3/4]

- Simply focussing on the trend in the average depth of cover, can give a misleading impression of the challenge
  - In 2010-16 the average depth of cover for new gold and base metal discoveries was 60 metres. However this was made up of greenfield discoveries (at 18m) and brownfield discoveries (at 159m)
  - Over the last decade 54% of all greenfield discoveries made in the World were outcropping, and 96% were less than 100 metres.
  - Over period 2000-16, only 12 gold discoveries (out of 570) were >500 metres. All of these were brownfield targets in mature districts
  - For base metals, over the last decade, only 9 (out of 308) were >500 metres. Only two of these were greenfields. These were Teena (Zn in Queensland) and Weisswasser (Cu in Poland)

# Conclusions [4/4]

- Discovery methods vary with the commodity type and depth of cover
  - In 2010-16 the average depth of cover for new gold and base metal discoveries was 60 metres. However this was made up of greenfield discoveries (at 18m) and brownfield discoveries (at 159m)
  - Over the last decade 54% of all greenfield discoveries made in the World were outcropping, and 96% were less than 100 metres.
  - Over period 2000-16, only 12 gold discoveries (out of 570) were >500 metres. All of these were brownfield targets in mature districts
  - For base metals, over the last decade, only 9 (out of 308) were >500 metres. Only two of these were greenfields. These were Teena (Zn in Queensland) and Weisswasser (Cu in Poland). At these very deep levels the main exploration technique used is "extrapolation from known mineralisation

**To improve its performance, industry needs to develop better tools for exploring beyond 200 metres of cover**

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