Recent Trends and Outlook for Global Exploration

Richard Schodde
Managing Director, MinEx Consulting
Adjunct Professor, Centre of Exploration Targeting, University of Western Australia

PDAC 2017
6th March 2017, Toronto
Overview

1. Background and Context  ... Why do the study? What’s its scope?
2. Trends in exploration spend  ... How much money did we spend?
3. Number of discoveries  ... How many deposits did we find?
4. Quality of the discoveries made  ... How many good deposits were found?
5. Where were the discoveries made?  ... Which countries did a good job?
6. Who made the discoveries?  ... Which companies did a good job?
7. Discovery performance  ... What was the cost per discovery?
    Did exploration create/destroy value?
8. Outlook for exploration  ... What’s the level of spending over next decade?
9. Conclusions  ... What can we learn from all of this?
1. BACKGROUND & CONTEXT
Context & coverage

- Study covers all countries in the World (previously mainly focused on the Western World)
- Study covers all metals (previously excluded Bulk Minerals)
- Have excluded discovery of satellite deposits feeding into an existing mill within an established mining camp (i.e. count Ekati as one world-class discovery, not 20 small discoveries)
- Analysis is based on deposits \( \geq \) “Moderate” in size (previously only considered \( \geq \) “Major” deposits)
  (i.e. now capture deposits >100 koz Au, >100kt Cu, >5 kt \( U_3O_8 \))
- Assesses both the quality and value of the discoveries (previously only considered quality)
Data sources & coverage

• Deposit info
  – Have a database of 60,352 mineral deposits around the world, including;
  – 55,988 unique deposits (i.e. excluding satellite deposits), of which,
  – 10,565 deposits are Moderate-sized (or larger), of which;
  – 7,578 deposits have a discovery history, and of these;
  – 5,234 Moderate-sized (or larger) deposits were found since 1950

• Exploration expenditures
  – Relied on SNL# for non-bulk exploration spend data post-1992, modified with actual expenditure data for Canada, Australia and China, plus global uranium expenditure data from the International Atomic Energy Agency
  – For prior years and bulk exploration spend, have made my own estimates based on various historical studies by industry, government agencies and published company reports

# SNL Metals & Mining data, an offering of S&P Global Market Intelligence

As a result, my numbers vary from what SNL report
Exploration expenditures reached an all-time high in 2011-2012

2. TRENDS IN EXPLORATION SPEND
Exploration expenditures: World
by Commodity: 1975-2016

2016 US$ billion

$33B in 2012

$3B in 2002

11x real increase in the last decade

$10.2B in 2016

69% fall in the last 4 years

Spend reached an all-time high in 2012

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
Exploration expenditures: World
by Commodity: 1975-2016

Gold continues to be the main target

Major decline in spend on Bulk Minerals, partially offset by increase in “Other”

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

MinEx Consulting
Strategic advice on mineral economics & exploration
Exploration expenditures: World
by Commodity: 1975-2016

Percentage of total spend

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>39%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Metals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Cu, Ni, Zn, Pb)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diamonds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>11%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Gold continues to be the main target

Major decline in spend on Bulk Minerals, partially offset by increase in “Other”

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

2016 US$ billion

$33B in 2012

$10B in 2016

$3B in 2002


Note: “Rest of World” refers to, Mongolia, Middle East and South West Asia (including India and Pakistan)

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
Exploration expenditures: World
by Region: 1975-2016

Note: Includes spend on Bulk Minerals
“Rest of World” refers to Mongolia, Middle East and South West Asia (including India and Pakistan)

China spends more on exploration than any other country in the World

Can+USA+Aust market share has halved in the last 2 decades

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, commodity, quality and value

3. NUMBER OF DISCOVERIES
Number of discoveries by size


Historically ~70-80 deposits were found each year in the World

Peaked at 149 discoveries in 2007

Collapse in the discovery rate?

Note: “Moderate” >100koz Au, >10kt Ni, >100Kt Cu, 250kt Zn+Pb, >5kt U₃O₈, >10Mt Fe, >20Mt Thermal Coal
“Major” >1Moz Au, >100kt Ni, >1Mt Cu, 2.5Mt Zn+Pb, >25kt U₃O₈, >100Mt Fe, >200Mt Thermal Coal
“Giant” >6Moz Au, >1Mt Ni, >5Mt Cu, 12Mt Zn+Pb, >125kt U₃O₈, >500Mt Fe, >1000Mt Thermal Coal

Need to factor in unreported discoveries for recent years

Caution: Incomplete data in recent years

Source: MinEx Consulting © March 2017
The perils of not factoring in unreported discoveries

To maintain the quality of our resource base... we need to replace what we mine through discovery and development

Observe only 1 major gold discovery in 2014 containing a total of 2 Moz

Conclusion ....

“exploration is not replacing the gold produced”

Source: Mark Bristow presentation at PDAC 2016
Mark’s data came from a modified version of SNL’s 2014 report on Gold Reserves Replacement Strategies ....

Note: SNL’s analysis is limited to gold deposits containing >2 Moz of Resources or >1 Moz of Reserves

Source: SNL report on Gold Reserves Replacement Strategies © 2014, SNL Metals & Mining data, an offering of S&P Global Market Intelligence
... the problem is that he (and many other people in the industry) ignored SNL’s health warning

As it generally takes at least three years for a deposit to progress from a promising discovery hole to a potentially economic resource, the number of discoveries can change from year to year as new resources are defined. As it takes time for drilling to define a sizable resource and for scoping studies to produce positive results, older discoveries are expected to be larger and more numerous annually than newer ones.

Source: SNL report on Gold Reserves Replacement Strategies © 2016, SNL Metals & Mining data, an offering of S&P Global Market Intelligence
... Factoring this in results in a completely conclusion on the discovery performance of the industry.

The reported amount of gold found in 2007 has grown from 4 Moz to 73 Moz.

Note: SNL's analysis is limited to gold deposits containing >2 Moz of Resources or >1 Moz of Reserves.

Source: SNL reports on Gold Reserves Replacement Strategies © various years
SNL Metals & Mining data, an offering of S&P Global Market Intelligence
Number of discoveries by size

Number

Source: MinEx Consulting © March 2017

Note: "Moderate" >100k oz Au, >10k Ni, >100k t Cu, 250k t Zn+Pb, >5k t U₃O₈, >10 Mt Fe, >20 Mt Thermal Coal
"Major" >1 Moz Au, >100k t Ni, >1 Mt Cu, 2.5 Mt Zn+Pb, >25k t U₃O₈, >100 Mt Fe, >200 Mt Thermal Coal
"Giant" >6 Moz Au, >1 Mt Ni, >5 Mt Cu, 12 Mt Zn+Pb, >125k t U₃O₈, >500 Mt Fe, >1000 Mt Thermal Coal
Number of discoveries by commodity


Gold accounts for half of all deposits found since 1980

Note: Based on discoveries >100k oz Au, >10kt Ni, >100Kt Cu, 250k t Zn+Pb, >5 kt U3O8, >10 Mt Fe, >20 Mt Thermal Coal

Caution: Incomplete data in recent years

Source: MinEx Consulting © March 2017
Much of the value created from exploration is associated with a handful of Tier 1 (World Class) discoveries

4. QUALITY OF THE DISCOVERIES
Number of discoveries by quality

Most discoveries are of mediocre quality
On average 2-3 Tier 1 deposits are found each year

Note: Tier 1 deposits are "Company making" mines. They are large, long life and low cost... etc >20 Years, >200 ktpa Cu or >250 koz pa Au, and Bottom Quartile costs. Have an NPV of >$1000m, and Expected Value of ~$2000m in 2013 $.
Tier 2 deposits are "Significant" deposits - but are not quite as large or long life or as profitable as Tier 1 deposits. They have an NPV of $200-1000m and EV of ~$500m in 2013 $.
Tier 3 deposits are small / marginal deposits. While they can be profitable they often only get developed at the top of the business cycle. At best they don't meet more than one of the Tier 1 or 2 criteria. NPV of $0 to $200m, EV of ~$100m in 2013 $.
Unclassified deposits are small deposits that are less than "Major " in size and/or of minimal value. EV of (say) ~$10m.

But only 12 Tier 1 deposits were found in the last decade

Source: MinEx Consulting © March 2017
Number of discoveries by value


Tier 1 deposits, while rare, account for half of the total value created.

Note: The analysis is based on a notional valuation (in constant 2013 US$) of $2000m, $500m, $80m and $10m for Tier 1, 2, 3 and Unclassified deposits respectively.

Caution: Values are indicative/approximate-only

Source: MinEx Consulting © March 2017
Over the last decade 414 Tier 1, 2 & 3 deposits were found in the World

5. WHERE WERE THE DISCOVERIES MADE?
Number of discoveries by region

Note: Based on discoveries >100k oz Au, >10kt Ni, >100k t Cu, 250k t Zn+Pb, >5k t U₃O₈, >10Mt Fe, >20Mt Thermal Coal

Source: MinEx Consulting © March 2017
Number of discoveries by region


Note: Based on discoveries >100k Oz Au, >10k Ni, >100k t Cu, 250k t Zn+Pb, >5k t U₃O₈, >10Mt Fe, >20Mt Thermal Coal

Australia did well... but many of the discoveries were small size.

Source: MinEx Consulting © March 2017
Over the last decade, 12 Tier-1, 69 Tier-2 and 333 Tier-3 discoveries were made. Although not plotted, an additional 453 unclassified discoveries were made, and an estimated 238 discoveries (of unknown Tier) are yet to be reported.
Over the last decade there were 12 Tier-1 discoveries …
4 of which were in Canada … and none in Australia.

N = 12

Source: MinEx Consulting © March 2017
In recent years most discoveries were made by Junior companies.

6. WHO MADE THE DISCOVERIES (IN THE WESTERN WORLD)?
Number of discoveries made by Company Type

Moderate+Major+Giant primary gold discoveries in Western World: 1950-2016

Number of Discoveries

Note: “Other” refers to Oil Companies, Private Companies and Industrial Companies
Figures are adjusted for shared discoveries

Source: MinEx Consulting © March 2017
Number of discoveries made by Company Type
Moderate+Major+Giant primary gold discoveries in Western World: 1950-2016

Note: “Other” refers to Oil Companies, Private Companies and Industrial Companies
Discoveries by unknown companies have been prorated
Figures are adjusted for shared discoveries

Junior Companies now account for 70% of all discoveries (by number) in the Western World

Source: MinEx Consulting © March 2017
Value of discoveries made by Company Type

Moderate+Major+Giant primary gold discoveries in Western World: 1950-2016

Note: “Other” refers to Oil Companies, Private Companies and Industrial Companies
Discoveries by unknown companies have been prorated
Figures are adjusted for shared discoveries

Junior Companies now account for 51% of all discoveries (by value) in the Western World

Source: MinEx Consulting © March 2017
What is the average cost per discovery and which countries and commodities performed better?

7. DISCOVERY PERFORMANCE
Number of discoveries versus expenditures

Even after adjusting for unreported discoveries, over the last decade, expenditures outpaced the number of deposits found.

Note: Discoveries based on deposits >= “Moderate” in size:
i.e. >100k oz Au, >10kt Ni, >100k t Cu, 250k t Zn+Pb, >5k t U₃O₈, >10Mt Fe, >20Mt Thermal Coal

No World exploration data prior to 1975

Source: MinEx Consulting © March 2017
Unit cost per discovery

Mineral discoveries in the **World**: All Commodities: 1975-2016

No data available prior to 1975

Note: Discoveries based on deposits >="Moderate" in size
i.e. >100koz Au, >10kt Ni, >100Kt Cu, 250kt Zn+Pb, >5kt U₃O₈, > 10Mt Fe, >20Mt Thermal Coal

Over the last decade the average cost per discovery has **tripled** in real terms

Estimated cost (includes adjustment for unreported discoveries)

The apparent blowout in China is probably due to under-reporting of recent discoveries

3 Year Rolling Average

2016 US$ million

$600

$500

$400

$300

$200

$100

No data


Source: MinEx Consulting © March 2017

MinEx Consulting

Strategic advice on mineral economics & exploration
Estimated value of discoveries versus expenditures


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: Values are indicative / approximate-only
No World exploration expenditure data prior to 1975

Source: MinEx Consulting © March 2017
## Discovery performance by Region: 2007-2016

<table>
<thead>
<tr>
<th>Region</th>
<th>Exploration Spend (2016 $b)</th>
<th>No of Discoveries #</th>
<th>Tier 1+2 Discoveries</th>
<th>Estimated Value (2016 $b)</th>
<th>Value / Spend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>$23</td>
<td>221</td>
<td>0 + 12</td>
<td>$12</td>
<td>0.54</td>
</tr>
<tr>
<td>Canada</td>
<td>$27</td>
<td>80</td>
<td>4 + 10</td>
<td>$16</td>
<td>0.62</td>
</tr>
<tr>
<td>USA</td>
<td>$12</td>
<td>31</td>
<td>1 + 3</td>
<td>$5</td>
<td>0.42</td>
</tr>
<tr>
<td>Latin America</td>
<td>$38</td>
<td>109</td>
<td>1 + 11</td>
<td>$13</td>
<td>0.33</td>
</tr>
<tr>
<td>Pacific/SE Asia</td>
<td>$10</td>
<td>39</td>
<td>2 + 2</td>
<td>$7</td>
<td>0.69</td>
</tr>
<tr>
<td>Africa</td>
<td>$25</td>
<td>197</td>
<td>2 + 15</td>
<td>$20</td>
<td>0.80</td>
</tr>
<tr>
<td>W Europe</td>
<td>$4</td>
<td>34</td>
<td>0 + 1</td>
<td>$2</td>
<td>0.40</td>
</tr>
<tr>
<td>China</td>
<td>$42</td>
<td>82</td>
<td>2 + 12</td>
<td>$13</td>
<td>0.32</td>
</tr>
<tr>
<td>FSU + EE</td>
<td>$13</td>
<td>52</td>
<td>0 + 2</td>
<td>$4</td>
<td>0.26</td>
</tr>
<tr>
<td>Rest of World</td>
<td>$5</td>
<td>22</td>
<td>0 + 1</td>
<td>$2</td>
<td>0.28</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$197</td>
<td>867</td>
<td>12 + 69</td>
<td>$92</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Note: Estimated value of discoveries is based on average notional value (in 2013$) of $2000m, $500m, $80m & $10m for Tier 1, 2, 3 and Unassigned discoveries respectively. Valuations are indicative only, and exclude unreported discoveries.

Source: MinEx Consulting © March 2017
## Discovery performance by Commodity: 2007-2016

### Note:
- Estimated value of discoveries is based on average notional value (in 2013$) of $2000m, $500m, $80m & $10m for Tier 1, 2, 3 and Unassigned discoveries respectively. **Valuations are indicative only, and exclude unreported discoveries.**

### Source:
MinEx Consulting © March 2017

<table>
<thead>
<tr>
<th>Region</th>
<th>Exploration Spend (2016 $b)</th>
<th>No of Discoveries #</th>
<th>Tier 1+2 Discoveries</th>
<th>Estimated Value (2016 $b)</th>
<th>Value / Spend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>$65</td>
<td>320 37%</td>
<td>4 + 17 26%</td>
<td>$30 32%</td>
<td>0.46</td>
</tr>
<tr>
<td>Copper</td>
<td>$35</td>
<td>102 12%</td>
<td>3 + 15 22%</td>
<td>$17 18%</td>
<td>0.47</td>
</tr>
<tr>
<td>Nickel</td>
<td>$7</td>
<td>34 4%</td>
<td>0 + 4 5%</td>
<td>$3 4%</td>
<td>0.47</td>
</tr>
<tr>
<td>Zinc+Lead</td>
<td>$11</td>
<td>30 3%</td>
<td>1 + 4 6%</td>
<td>$5 6%</td>
<td>0.50</td>
</tr>
<tr>
<td>Uranium</td>
<td>$10</td>
<td>28 3%</td>
<td>1 + 7 10%</td>
<td>$6 7%</td>
<td>0.61</td>
</tr>
<tr>
<td>Diamonds</td>
<td>$6</td>
<td>11 1%</td>
<td>0 + 1 1%</td>
<td>$1 1%</td>
<td>0.19</td>
</tr>
<tr>
<td>Iron Ore</td>
<td>$20</td>
<td>143 16%</td>
<td>0 + 3 4%</td>
<td>$6 7%</td>
<td>0.33</td>
</tr>
<tr>
<td>Coal</td>
<td>$24</td>
<td>64 7%</td>
<td>1 + 6 9%</td>
<td>$8 8%</td>
<td>0.33</td>
</tr>
<tr>
<td>Other</td>
<td>$21</td>
<td>135 16%</td>
<td>2 + 12 17%</td>
<td>$16 17%</td>
<td>0.75</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$197</td>
<td>867 100%</td>
<td>12 + 69 100%</td>
<td>$92 100%</td>
<td>0.47</td>
</tr>
</tbody>
</table>
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. Analysis excludes Nickel laterites.

Source: MinEx Consulting © March 2017
Expenditure have bottomed in 2016 and are forecast to increase by ~60% over the next four years

8. EXPLORATION OUTLOOK
Exploration spend versus gold and copper price
World: 1985-2016

Exploration spend moves in-line with commodity prices

With adjustments for other factors this can be used as a tool for predicting future exploration expenditures

Sources: LME (for prices) and SNL Metals & Mining data, an offering of S&P Global Market Intelligence
Forecast exploration expenditures: World
by Commodity: 1975-2025

2016 US$ billion

Expenditures have bottomed in 2016 and are projected to increase by 60% by 2020

$33B
in 2012

$10.2B
in 2016

$16B
in 2020

$18B
in 2025

WARNING: Forecast expenditures are highly sensitive to future commodity prices and economic activity

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 and commodity price estimates from Consensus Economics Feb 2017
9. 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%).
  – The country with the most exploration is China (26%) followed by Canada (11%) and Australia (10%)

• 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

• Most of the discoveries were of small size and low value
  – Tier-1 deposits (ie World Class) deposits are rare … and typically only 2-3 found each year. Over the last decade only 12 were found
  – In the last decade 4 of the Tier-1 discoveries were in Canada. None were found in Australia
Conclusions [2/4]

• Over the last 20 years the role and importance of the junior sector has risen.
  – In the Western World, Juniors accounted for ~70% of the total number of deposits found and 50% of the value created. Major & Moderate Producers found 18% of the number and 35% of the value.

• 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 ($86 to $238m in constant 2016 Dollars)

• Due to the lack of Tier-1 discoveries the industry switched from Wealth Creation to Wealth destruction … with the Value/Cost Ratio declining to 0.47
  – This should improve over time as more discoveries are reported
  – China massively increased its domestic spend but, to date, has little to show for it resulting in a V/C ratio of 0.33
  – Canada was much better - with a V/C ratio of 0.62. Australia was 0.54, and was let down by the lack of Tier-1 discoveries.
  – Latin America performed poorly with a V/C ratio of just 0.33.
Conclusions [3/4]

• Most of the commodities generated a similar V/C ratio. The outliers were Diamonds (0.19) and “Other” (0.75) … with the latter benefiting from significant discoveries of graphite, potash and lithium

• There are many factors associated with the recent decline in discovery performance. Some are structural and others are cyclical. These include the:
  – Progressive move to targets under-cover
  – Increased emphasis on brownfields exploration and feasibility-studies (which don’t deliver big discoveries) at the expense of greenfield exploration
  – Decline in drilling activity (if we don’t drill, we won’t find)
  – Input costs for drilling and geologists increased in the boom years (and have come back since)

  And don’t forget the ongoing issue of the inherent delay in reporting discoveries!
Conclusions [4/4]

- The long term outlook for exploration is positive. We are now at the bottom of the business cycle and subject to an expected moderate improvement in commodity prices, global exploration expenditures are set to rise by 60% over the next 4 years.

It's time to get back out in the field and start drilling!
Contact details

Richard Schodde
Managing Director
MinEx Consulting
Melbourne, Australia

Email: Richard@MinExConsulting.com
Website: MinExConsulting.com

Copies of this and other similar presentations can be downloaded from my website.