Recent trends in mineral exploration
- are we finding enough?

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Overview

• Trends in Exploration Expenditures
  - Level of expenditure and key drivers
• Current “Hot Spots” for Exploration
• Trend in Discovery Rates
  - Metal found, Unit Discovery Costs for Au, Cu and U₃O₈
• Trends in conversion rates (from Discovery > Development)
  - Not all discoveries get mined, and those that do may take many years
• Impact of changes in cut-off grade on available resources
  - Resources can significantly grow with lower cut-off grades ...needs economies of scale, innovation in technology and higher prices to happen
• Are we finding enough metal ?
  – Implications on long run commodity prices
• Conclusions
Spending on minerals exploration over the last 60 years

TRENDS IN EXPLORATION EXPENDITURES
Exploration Expenditures: Western World

Gold is still the “main game”!

Sources: MinEx Consulting estimates, based on data from ABS, NRCan, Tilton (1988), Wallace (1992,93) and Metal Economics Group © 2010
Exploration Expenditures: Western World

Sources: MinEx Consulting estimates, based on data from ABS, NRCan, Tilton (1988), Wallace (1992,93) and Metal Economics Group © 2010
Exploration expenditures are driven by commodity prices

Gold price versus exploration on gold in the Western World: 1950-2010

In recent years there has been a strong correlation between price and spend.

Sources: MinEx Consulting estimates. Post 1992 expenditure data from Metal Economics Group © 2010
Exploration expenditures are driven by commodity prices

$U_3O_8$ price versus exploration on uranium in the Western World: 1950-2010

In recent years there has been a strong correlation between price and spend

Exploration expenditures are driven by commodity prices $U_3O_8$ price versus exploration on uranium in the Western World: 1950-2010

In recent years there has been a strong correlation between price and spend

Sources: MinEx Consulting estimates Sept 2011, based on OECD Red Book
Current “Hot Spots” for mineral exploration

RECENT DISCOVERIES AROUND THE WORLD
Significant mineral deposits: World
All years

Significant discoveries have been made on all continents

Note: Excludes bulk mineral deposits

Source: MinEx Consulting © Nov 2011
Significant mineral deposits: World Discovered since 2000

N = 223

Note: Supergiant >60Moz Au, >10Mt Ni, >25Mt Cu equiv
Giant >6Moz Au, >1Mt Ni, >5Mt Cu equiv
Major >1Moz Au, >100Kt Ni, >1Mt Cu equiv

Source: MinEx Consulting © Nov 2011
Significant mineral deposits: World Tier 1 deposits discovered since 2000

- Pebble (CuAu: 2002)
- Oyu Tolgoi (CuAu: 2002)
- Fruta del Norte (Au: 2004)
- Golpu Deeps (CuAu: 2009)
- Cortez Hills (Au: 2002)
- Moto (Au: 2004)
- Lagunas Norte (Au: 2001)
- Vogue (Au: 2010)
- La Colosa (Au: 2006)
- Eucla (Min Sands: 2004)
- Detour Lake (Au: 2005)
- Tasiast Extension (Au: 2010)
- Los Sulfatos (CuMo: 2007)
- Cote Lake (Au: 2010)
- Tasiast Extension (Au: 2010)

N = 14

Note: Excludes bulk mineral deposits

Source: MinEx Consulting © Nov 2011
Significant mineral deposits: World Discovered since 2000

Note: Excludes bulk mineral deposits

Super giant: >60 Moz Au, >10 Mt Ni, >25 Mt Cu equiv
Giant: >6 Moz Au, >1 Mt Ni, >5 Mt Cu equiv
Major: >1 Moz Au, >100 Kt Ni, >1 Mt Cu equiv

Current “Hot Spots”

Source: MinEx Consulting © Nov 2011
Estimated unit finding costs for various metals

TRENDS IN DISCOVERY COSTS
Discovery costs for gold are rising
Primary gold in Western World: 1950-2010

Assume ~$30/oz for next decade

Source: MinEx Consulting © Nov 2011
Discovery costs for uranium are rising

Uranium in Western World: 1950-2010

**Discovery Cost (June 2011 US$/lb U₃O₈)**

5 Year rolling average

Assume ~$4/lb U₃O₈ for next decade

Note: Based on all primary uranium deposits >0.5 kt U₃O₈. Includes adjustment for deposits with no reported discovery year.

Source: MinEx Consulting © Sept 2010
Until recently, discovery costs for copper have been fairly steady

Copper in Western World: 1950-2010

Between 1950-2000, the discovery cost for copper averaged 1 c/lb of resource

Assume 2c/lb Cu for next decade

Note: The reported costs exclude credits for by-product metal

Source: MinEx Consulting © Sept 2009
How many discoveries turn into mines, and how long does it take?

TRENDS IN CONVERSION RATES
Conversion factors for exploration

• Not all discoveries are developed into mines
  – Historically only 50-70% are mined
  – The conversion rate depends on project economics, business risk and social issues

• Even for those that do get developed, there is often a delay of 10-15 years between discovery and commencement of mining

Key factors on the likelihood and speed of conversion are:
the size, quality and location of the discovery
Current status of gold deposits
Primary gold deposits found in the World: 1950-2011

On average only 60-70% of gold deposits get developed

Source: MinEx Consulting © Oct 2011
Current status of copper deposits
Copper deposits found in low-risk countries: 1950-2011

Analysis based on 556 copper deposits >0.1 Mt Cu found in Australia, North America, Western Europe and Chile

Source: MinEx Consulting © July 2011
Development time for successful copper projects
Copper projects in low risk countries: 1950-2011

For copper, it typically takes 5 to 25 years (average 12 years) from discovery to mine start up.

Bigger projects tend to take longer to get into production.

The variation in development–time with size is influenced by the amount of pre-existing infrastructure available and the amount of Government red-tape involved. Many of the smaller projects are near existing mining operations (i.e., are brownfield projects).

Analysis based on 556 copper deposits >0.1 Mt Cu found in Australia, North America, Western Europe and Chile

Source: MinEx Consulting © July 2011
Development time for successful gold projects

Primary gold projects in the World: 1950-2011

For gold, it typically takes 5 to 20 years (average 10 years) from discovery to mine start up.

Analysis based on 571 Primary gold deposits >0.1 Moz

Source: MinEx Consulting © Nov 2011
Much of the recent growth in resources is due to lower cut-off grades

**IMPACT OF CUT-OFF GRADE**
Impact of using a lower cut-off grade

• Most deposits have a “halo” of low grade ore surrounding a high-grade core

• The reported size of the deposit will depend on the cut-off grade used
  – As a rule of thumb, lowering the cut-off grade by 50%, increases the ore tonnes by 4-8x and the contained metal by 2-4x
  – The cut-off grade is driven by economics .... which, in turn, are driven by commodity prices, costs and level of business risk

Costs are influenced, energy & labour-intensity, innovations in mining and processing methods and economies of scale

The ratio varies with the type of deposit
Impact of changes in grade on resource size (Example 1)
Shahuindo Gold Deposit in Peru

"Estimate that 40% of the growth in resources for this discovery came from lowering the cut-off grade."
Impact of changes in grade on resource size (Example 2)
12 giant porphyry deposits: 1929-2008

Top 12 Porphyry Mines in 1929

Chuquicamata
Braden (El Teniente)
Morenci
Utah (Bingham Canyon)
Ray
Chino
Miami
Nevada (Ely/Robinson)
Inspiration
Andes (Potrerillos)
New Cornelia
Copper Queen

Sources: Parsons (1933) and MinEx Consulting March 2010
ARE WE FINDING ENOUGH METAL?
Are we finding enough metal?

• Key drivers
  – Current discovery rates ... is slowing down
  – Conversion rates (from discovery to operating mine) ... only 60-80%
  – Lag between discovery and development ... typically 10-15 years
  – Likely losses on mining ... typically 5-10%
  – Current and (more importantly) future mining rates

• Modifying factors
  – Current inventory of undeveloped projects (and their quality)
  – Ability to increase resources through lowering the cut-off grade
  – Long term costs
  – Impact of environmental and social factors)
  – Long term prices

Given the feedback loops, is this an input or an output??

Given the long delays to convert a discovery into a mine, need to consider size of market at that time
How much metal do we need to find?

To ensure no supply interruptions in the longer term the industry needs to be finding 2-3x as much metal as it currently mines.
Mining & Discovery rates for Copper
Amount of copper mined and copper found in the World: 1950-2009

CAUTION: Not all discoveries get turned into mines, and not all of the metal is recovered.

Note: Chart include minor adjustment for deposits missing from the database
Is based on discoveries > 0.1 Mt Cu

Sources: MinEx Consulting Feb 2010.
Production data from USGS
Mining & Discovery rates for Gold
Amount of gold found and mined in the World: 1950-2010

Note: Chart include minor adjustment for deposits missing from the database
Is based on discoveries > 0.1 Moz

Sources: MinEx Consulting Nov 2011.
Production data from USGS
Mining & Discovery rates for Uranium
Amount of Primary $U_3O_8$ found and mined in the World: 1950-2010

Note: Chart excludes Olympic Dam (Cu-U-Au deposit) found in 1975 – contains 2517 kt $U_3O_8$

Note: Chart include minor adjustment for deposits missing from the database
Is based on discoveries > 0.5 kt $U_3O_8$

Sources: MinEx Consulting Sept 2010.
Production data from USGS
Mining & Discovery rates for Nickel
Amount of nickel found and mined in the World: 1950-2009

Caution: Chart excludes deposits with unknown discovery date, or deposits not captured in the database

Sources: MinEx Consulting Aug 2010. Production data from USGS
Estimated Discovery/Production ratios

<table>
<thead>
<tr>
<th></th>
<th>Gold</th>
<th>Copper</th>
<th>Uranium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit discovery costs</td>
<td>~$30/oz</td>
<td>~2 c/lb</td>
<td>~$4/lb</td>
</tr>
<tr>
<td>Mine Production</td>
<td>2010 = 78 Moz 2020 = 90 Moz</td>
<td>2010 = 16 Mt 2020 = 21 Mt</td>
<td>2010 = 60 kt 2020 = 90 kt</td>
</tr>
<tr>
<td>Discovery/Production Ratios</td>
<td>[A] [P]</td>
<td>[A] [P]</td>
<td>[A] [P]</td>
</tr>
<tr>
<td>At 2010 Production Rate</td>
<td>1.2x 2.3x</td>
<td>2.0x 3.4x</td>
<td>0.9x 1.7x</td>
</tr>
<tr>
<td>At 2020 Production Rate</td>
<td>1.0x 2.0x</td>
<td>1.5x 2.6x</td>
<td>0.6x 1.1x</td>
</tr>
</tbody>
</table>

[A] = Average exploration spending rate over last decade (2001-10)  
[P] = Peak exploration spending rate (in 2010)  
Target is >2x  
Source: MinEx Consulting © Nov 2011
Implications for the future

• In order to meet future needs for new mines:
  – Need to maintain exploration spending at current high levels (it can’t revert back to the 10 year historic average)
  – The Gold sector is tight – ironically saved by fact that expected growth in production is “flat” #
  – Expected strong growth in Uranium mining will put that sector under a lot of stress
  – To offset increasing unit discovery costs, the industry need to find new ways and places to explore

Ultimately the supply/demand problem will be solved through higher prices and/or improvements in mining & processing technologies (both of which allow the use of lower cut-off grades, and allow marginal projects to be developed)

# It could be argued that the current lack of good gold projects is the reason why the industry isn’t growing
The future for Exploration

SUMMARY/CONCLUSIONS
Summary / Conclusions (1/2)

- **Exploration Expenditures are cyclical**
  - Industry is currently spending ~$14 billion up from $8b pa over the last decade

- **The current hot spots for exploration success are Latin America, Yukon/Alaska, Northern Ontario, West Africa, East Africa and China**

- **Discovery Rates are rising for many commodities (especially gold)**
  - Over next decade the average rate is projected to be $30/oz Au, 2 c/lb Cu and $4/lb U₃O₈

- **Not all discoveries turn into mines**
  - Conversion rates are only 60-80%, depending on the metal, size, quality and location

- For the successful projects, there is a lag of 10-15 years between discovery and development

- Even at current (high) exploration expenditure rates, many industry sectors (particularly uranium) struggle to find sufficient deliver good projects
Summary / Conclusions (2/2)

- In the longer term the market will “balance itself” through the complex interplay between:
  - Level of exploration spending
  - Efficiency and effectiveness of exploration activities
  - Speed of converting discoveries into mines
  - The current inventory of undeveloped projects (quality & number)
  - Proportion of new projects that are economically viable
  - Innovations in technology (that make marginal projects viable)
  - Changes in mining costs and business risk
  - Change in cut-off grades (which can increase/decrease available resources)
  - Growth in primary metal demand
  - Commodity Prices

- Given the long delays between discovery and development, there is a real risk that some industry sectors could face supply constraints in the short term.

This is both a challenge and an opportunity!
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