Exploration and discovery of base and precious metal deposits in the Pacific Rim over the last 50 years

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Overview

1. What’s covered by the Circum-Pacific Region?
2. Trends in exploration expenditures for copper and gold
3. Historic Mineral endowment of the CPR
4. Size and location of copper discoveries in the CPR
5. Size and location of gold discoveries in the CPR
6. Trends in discovery costs for copper and gold
7. Sillitoe’s 1995 analysis of the CPR
   - Size of deposits
   - Delays in making discoveries
8. MinEx analysis of the delay in making a discovery
9. Conclusions
Spans across 1/3rd of the World’s surface in 41 jurisdictions

1. CIRCUM-PACIFIC REGION
Jurisdictions within the Circum-Pacific Region

NE Asia
- Russian Far East (5 Oblasts)
- Japan
- Taiwan

SE Asia
- Indonesia
- Philippines
- Brunei

Central America
- Panama
- Costa Rica
- Nicaragua
- Honduras

Oceania
- New Zealand
- New Caledonia
- Solomon Island
- Fiji
- PNG

North America
- California
- Oregon
- Washington
- Nevada
- Alaska

Latin America
- Argentina
- Chile
- Peru
- Ecuador
- Colombia

Eastern Australia
- Queensland
- NSW
- Tasmania
- Victoria

41 Jurisdictions covering 16.3% of the World

Note: Excludes Antarctica

Source: Minex Consulting © April 2019
The Circum-Pacific countries account for nearly half of global spend for gold and copper.

2. TRENDS IN EXPLORATION EXPENDITURES
Exploration Expenditures on **Gold and Copper**
Pacific Rim Region: 1993-2018

Sources: MinEx Consulting estimates based on data from SNL, ABS (for Australia), NRCan (for Canada) and the Alaskan Division of Geological & Geophysical Survey
Exploration Expenditures on Gold by Region
Pacific Rim Countries: 1993-2018

Over the last decade the 7 PACRIM regions accounted for 41% of global gold expenditures. 

Sources: MinEx Consulting estimates based on data from SNL, ABS (for Australia), NRCan (for Canada) and the Alaskan Division of Geological & Geophysical Survey.
Exploration Expenditures on Copper by Region
Pacific Rim Countries: 1993-2018

Over the last decade the 7 PACRIM regions accounted for 49% of global copper expenditures

Sources: MinEx Consulting estimates based on data from SNL, ABS (for Australia), NRCan (for Canada) and the Alaskan Division of Geological & Geophysical Survey

No data for years prior to 1993

2018 US$ Billion

$0
$1
$2
$3
$4
$5
$6


$0.25 b in 2002

$2.92 b in 2012

$1.26 b in 2018

MinEx Consulting
Strategic advice on mineral economics & exploration
50% of the World’s copper resides within the circum-pacific region

3. HISTORIC KNOWN ENDOWMENT
Mineral Deposits in the Circum-Pacific Region

All Years : All Commodities

<table>
<thead>
<tr>
<th></th>
<th>Au</th>
<th>Cu</th>
<th>Ni</th>
<th>Zn/Pb</th>
<th>Other</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>1589</td>
<td>612</td>
<td>133</td>
<td>143</td>
<td>53</td>
<td>2973</td>
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<tr>
<td>Metal</td>
<td>4447 Moz</td>
<td>2409 Mt</td>
<td>148 Mt</td>
<td>601 Mt</td>
<td>xx</td>
<td></td>
</tr>
</tbody>
</table>

33% of all known deposits in the World

Share of World Pre-mined Resource

- Gold: 34%
- Precious (PGE, Ag, Dia, Gems): 50%
- Base Metal (Cu, Ni, Zn, Pb): 39%
- Uranium: 32%
- Mineral Sands: xx%
- Other: xx%

Source: Minex Consulting © April 2019
Since 1970 a total of 1303 Mt Cu has been found in 302 copper deposits in the circum-pacific region

4. SIZE AND LOCATION OF COPPER DISCOVERIES
Number of copper discoveries by **size**

Mineral discoveries in Circum-Pacific Region: 1950-2018

Note: Based on Moderate-, Major- and Giant-sized deposits
Moderate 0.101 Mt Cu, Major 1-5 Mt Cu, Giant >5 Mt Cu

Source: Minex Consulting © April 2019

Includes MinEx’s estimate of unreported discoveries
Million Tonnes of Copper found
Circum-Pacific Region: 1950-2018

Note: Based on Primary copper discoveries >100kt Cu
Includes an adjustment for unreported discoveries in recent years.
No expenditure data available prior to 1993

Source: Minex Consulting © April 2019
PACRIM Region Copper Discoveries: 1970-79

- Olympic Dam (100 Mt Cu)
- Los Pelambres [38 Mt]
- Los Bronces [34 Mt]
- Antamina [29 Mt]
- Quebrada Blanca [19 Mt]

Total Cu tonnage for the decade includes by-product metal from Au and other deposits.

Source: Minex Consulting © April 2019
PACRIM Region Copper Discoveries : 1980-89

Note: Bubble size refers to pre-mined resource of copper metal tonnes
Total Cu tonnage for the decade includes by-product metal from Au and other deposits

Source: Minex Consulting © April 2019
PACRIM Region Copper Discoveries: 1990-99

- **Collahuasi**: 91 Mt Cu
- **Tampakan**: 15 Mt Cu

Total Cu tonnage for the decade includes by-product metal from Au and other deposits.

Note: Bubble size refers to pre-mined resource of copper metal tonnes.

Source: Minex Consulting © April 2019
PACRIM Region Copper Discoveries: 2000-09

348 Mt Cu in 79 Cu deposits

Note: Bubble size refers to pre-mined resource of copper metal tonnes.
Total Cu tonnage for the decade includes by-product metal from Au and other deposits.

Source: Minex Consulting © April 2019
PACRIM Region Copper Discoveries: 2010-18

Note: Bubble size refers to pre-mined resource of copper metal tonnes. Total Cu tonnage for the decade includes by-product metal from Au and other deposits.

Source: Minex Consulting © April 2019
Since 1970 a total of 3011 Moz has been found in 658 gold deposits in the circum-pacific region

5. DISCOVERY HISTORY FOR GOLD
Number of gold discoveries by size
Mineral discoveries in Circum-Pacific Region: 1950-2018

Note: Based on Moderate-, Major- and Giant-sized deposits
Moderate 0.101 Mt Cu, Major 1-5 Mt Cu, Giant >5 Mt Cu

Source: Minex Consulting © April 2019
Moz of Gold found
Circum-Pacific Region: 1950-2018

Note: Based on Primary gold discoveries >100koz Au
Includes an adjustment for unreported discoveries in recent years.

Source: Minex Consulting © April 2019
PACRIM Region Gold Discoveries: 1970-79

Source: Minex Consulting © April 2019

Note: Bubble size refers to pre-mined resource of gold. Total Moz for the decade includes by-product metal from Cu and other deposits.
PACRIM Region Gold Discoveries: 1980-89

964 Moz in 232 Au deposits

Carlin – Barrick [77 Moz]
Lihir [68 Moz]
Yanacocha [57 Moz]
Porgera [36 Moz]
Pascua-Lama [22 Moz]

100 Moz Au
20 Moz
5 Moz

Note: Bubble size refers to pre-mined resource of gold
Total Moz for the decade includes by-product metal from Cu and other deposits

Source: Minex Consulting © April 2019
PACRIM Region Gold Discoveries: 1990-99

731 Moz in 163 Au deposits

- Donlin Creek [45 Moz]
- Cadia East [37 Moz]
- Turquoise Ridge [29 Moz]
- Penasquito [19 Moz]
- Veladero [20 Moz]
- 100 Moz Au
- 20 Moz
- 5 Moz

Note: Bubble size refers to pre-mined resource of gold. Total Moz for the decade includes by-product metal from Cu and other deposits.

Source: Minex Consulting © April 2019
PACRIM Region Gold Discoveries : 2000-09

778 Moz in 129 Au deposits

KSM [98 Moz]
Snowfield [35 Moz]
La Colosa [28 Moz]
Caspiche [25 Moz]

Note: Bubble size refers to pre-mined resource of gold
Total Moz for the decade includes by-product metal from Cu and other deposits

Source: Minex Consulting © April 2019
PACRIM Region Gold Discoveries: 2010-18

141 Moz in 64 Au deposits

Note: Bubble size refers to pre-mined resource of gold
Total Moz for the decade includes by-product metal from Cu and other deposits

Source: Minex Consulting © April 2019
Unit discovery costs in the Circum-Pacific Region have dramatically risen in the last decade

6. TREND IN DISCOVERY COSTS
Exploration Expenditures and number of discoveries: Copper
Circum-Pacific Region: 1950-2018

Note: Based on Primary copper discoveries >100kt Cu
Includes an adjustment for unreported discoveries in recent years.
No expenditure data available prior to 1993

Source: Minex Consulting © April 2019
Average cost per copper deposit found
PACRIM Region versus the World: 1975-2018

Note: Based on a 3-year rolling Average
Based on primary copper deposits >100kt Cu
Includes an adjustment for the number of unreported discoveries in recent years

Over the last decade unit discovery costs have significantly risen
PACRIM is simply following the same trend as the rest of the World …
… no real surprise given that it accounts for half of global spend

Source: Minex Consulting © April 2019
Exploration Expenditures and Mt Cu found: Copper
Circum-Pacific Region: 1950-2018

Note: Based on Primary copper discoveries >100kt Cu
Includes an adjustment for unreported discoveries in recent years.
No expenditure data available prior to 1993

Source: Minex Consulting © April 2019
Average cost per pound of copper found
PACRIM Region versus the World: 1975-2018

Over the last decade unit discovery costs have significantly risen

PACRIM is now twice as expensive as the global average

Notes:
- Based on a 3-year rolling Average
- Based on primary copper deposits >100kt Cu
- Includes an adjustment for the number of unreported discoveries in recent years

Source: Minex Consulting © April 2019
Exploration Expenditures and number of discoveries: Gold
Circum-Pacific Region: 1950-2018

Note: Based on Primary gold discoveries >100koz Au
Includes an adjustment for unreported discoveries in recent years.
No expenditure data available prior to 1993

Source: Minex Consulting © April 2019
Average cost per gold deposit found
PACRIM Region versus the World: 1975-2018

Note: Based on a 3-year rolling Average
Based on primary gold deposits >100k oz Au
Includes an adjustment for the number of unreported discoveries in recent years

Over the last decade unit discovery costs have significantly risen
PACRIM’s costs are higher than the global average

Source: Minex Consulting © April 2019
Exploration Expenditures and Moz found: Gold
Circum-Pacific Region: 1950-2018

Note: Based on Primary gold discoveries >100k oz Au
Includes an adjustment for unreported discoveries in recent years.
No expenditure data available prior to 1993

Source: Minex Consulting © April 2019
Average cost per ounce of gold found
PACRIM Region versus the World: 1975-2018

Over the last decade unit discovery costs have significantly risen

PACRIM's costs are higher than the global average

2018 US$ per Ounce

$0 $100 $200 $300


3-Year Rolling Average

$7/oz $16/oz $18/oz $220/oz

WORLD
$85/oz in 2018

PACRIM Region
$186/oz in 2017

Note: Based on a 3-year rolling Average
Based on primary gold deposits >100k oz Au
Includes an adjustment for the number of unreported discoveries in recent years

Source: Minex Consulting © April 2019
In a landmark paper Dick Sillitoe assessed the discovery history of 52 major precious and base metal deposits in the region

7. COMPARISON WITH SILLITOE’S 1995 STUDY OF THE REGION
EXPLORATION AND DISCOVERY OF BASE- AND PRECIOUS-METAL DEPOSITS IN THE CIRCUM-PACIFIC REGION DURING THE LAST 25 YEARS

RICHARD H. SILLITOE

METAL MINING AGENCY OF JAPAN

1995

Assessed 54 major deposits found in the period 1970-1994
38 gold
14 copper
1 silver
1 zinc

For the same time-period, MinEx has data on 296 major deposits found in the region
ie >1 Moz Au, > 1 Mt Cu
Sillitoe’s analysis was comprehensive and covered the entire region
Many of the deposits in Sillitoe’s study grew in size

**COPPER**
Change in Pre-Mined Resource

- On average, copper deposits grew in size by 3.1x

**GOLD**
Change in Pre-Mined Resource

- On average, gold deposits grew in size by 2.1x

Source: Minex Consulting © April 2019
Sillitoe found that, on average it took ~3 companies and ~19 years of exploration effort to make a discovery

8. PRE-DISCOVERY EFFORTS
It takes persistence and patience to make a discovery

Time delay and number of companies involved prior to the actual discovery of a Major base- or precious-metal deposit

The average exploration time for a Major discovery was 19 years. One third were found within 5 years.

On average, 2.8 companies explored the property prior to discovery.

Note: 9 of these discoveries had a delay of >40 years. Excluding these drops the average to 2.6 companies and 12 years.

Time spent (in years) exploring the property before the discovery was made

Number of Companies who explored the property before the discovery was made

Source: Minex Consulting © April 2019, based on discovery data from RH Sillitoe 1995
MinEx carried out a similar analysis, based on the discovery histories for 100 copper and gold projects, as given in NR43-101 reports.
It takes persistence and patience to make a discovery

Time delay and number of companies involved prior to the actual discovery of a significant copper or gold deposit

The average exploration time for a significant discovery was 12 years. One third were found within 5 years.

On average, 2.5 companies explored the property prior to discovery.

The successful company took on average 2.5 years to find the deposit.

Note: Analysis is based on 100 significant (>100k oz, >100 kt Cu) gold and copper discoveries in the Western World between 1960-2018. The analysis excludes any historical small-scale operations on the project lease.

Source: Minex Consulting © April 2019
The speed of discovery is slowing down

**Number of Companies to make the discovery**

- 1960-69: 1.7
- 1970-79: 2.3
- 1980-89: 2.7
- 1990-99: 2.4
- 2000-09: 2.8
- 2010-18: 2.6

*Avg = 2.5 Companies*

**Years required to make the Discovery**

- 1960-69: 6.9
- 1970-79: 8.1
- 1980-89: 7.5
- 1990-99: 14.2
- 2000-09: 13.8
- 2010-18: 14.7

*Avg = 12 Years*

**All Companies**

**Successful Company**

*Avg = 2.6 Years*

Note: Analysis is based on 100 significant (>100k oz, >100 kt Cu) gold and copper discoveries in the Western World between 1960-2018. The analysis excludes any historical small-scale operations on the project lease.

Source: Minex Consulting © April 2019
Summary

1. The Circum-Pacific Region covers 41 jurisdictions over 16% of the World’s surface area

2. Over the last decade the CPR accounted for 41% of the World’s exploration expenditures on gold. For copper, the figure was 49%.

3. The CPR hosts 50% of the World’s historic mineral endowment for copper and 34% of the World’s gold endowment.

4. Since 1970:
   - A total of 302 copper deposits containing ~1300 Mt Cu have been found in the CPR.
   - A total of 658 gold deposits containing ~3000 Moz Au have been found in the CPR.

   While the number of discoveries and the amount of metal found appears to have fallen off in recent years, this may simply be due to the inherent delay in drilling out a discovery. Deposits found 25 years ago are now 2-3x larger in size.

5. Unit discovery costs have risen in the last decade in the CPR. It currently costs ~$280m to make a copper discovery (or 3.2 cents/lb Cu) and $380m (or $186/oz) for a gold discovery. This is double the World average.

6. In 1995 Dick Sillitoe published a landmark study assessing the discovery history of 54 deposits in the CPR. He found that on average, it took 19 years and 2.8 companies to make a discovery.

7. MinEx carried out a study assessing 100 gold and copper discoveries (around the World) and found that, on average it took 12 years and 2.5 companies to make the discovery. The successful one (ie the last company in the chain) took 2.5 years to find the deposit. Over the last 40 years the rate of discovery appears to be slowing down.
Conclusions

The Circum-Pacific Region is highly fertile for copper and gold, and it will continue to deliver giant discoveries in the future.

.. However, of concern is that unit discovery costs are now higher than the World Average.
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