Net Smelter Return models and their use in exploration, evaluation and exploitation of polymetallic deposits

University of Toronto, April 19, 2017

Raymond Goldie
Independent Analyst and Director
DISCLAIMER

Don’t invest in anything based on what I say

I thank Charles Beaudry and Bill Mercer, March 2017, for this insight.
“Outstanding ...results,’ said ...
FNX:
Hole 1186F returned 1.5% copper, 
2.2% nickel and 5.1 grams TPM, 
of platinum, palladium and gold. 
Hole 1186C cut 2.3% copper, 0.3% 
nickel and 7.4 grams TPM”

Source: FNX Mining, Victoria deposit, Sudbury, May 10 2010
Numbers expressed in millions of U.S. dollars:

\[\text{Earnings by segment}\]

For the year ended December 31, 2016.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Revenue $\text{^1} \</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kansanshi$^4$</td>
<td>1,449</td>
</tr>
<tr>
<td>Sentinel$^5$</td>
<td>153</td>
</tr>
<tr>
<td>Las Cruces</td>
<td>358</td>
</tr>
<tr>
<td>Guelb Moghrein</td>
<td>213</td>
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<td>Pyhäsalmi</td>
<td>123</td>
</tr>
<tr>
<td>Corporate &amp; other$^6$</td>
<td>72</td>
</tr>
</tbody>
</table>

\text{Total} 2,673

Source: First Quantum Minerals Inc.
Definition of *managementese* in English:

noun

- Management jargon, frequently characterized by verbiage, opacity, and euphemism.

Origin

1970s; earliest use found in Canadian. From management + -ese.

Source: Oxford Dictionaries
The Hidden Benefits of Geologists Pursuing MBA’s

The evidence suggests that Geologists with MBAs do not earn significantly more but over a career that investment will pay off by making you more attractive and marketable to a broader range of career opportunities.

Source: careersinmining.com
The term “gross value” is not a misrepresentation, but it is misleading. A sugar beet farmer realizes that, if sugar is 60 cents a pound, a sugar refinery will not pay her 60 cents a pound for the sugar contained in the beets that she sells.
Numbers expressed in millions of U.S. dollars:

### Earnings by segment

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Source: First Quantum Minerals Inc.
Source: Globe and Mail
CuEq Metal Equivalent Calculator for Mining Results

By: Staff @ Geology for Investors  in Results and Analysis, Tools

Metal equivalent calculations are often used to compare similar deposits with slightly different metal ratios: CuEq (copper equivalent) and AuEq (gold equivalent) are most common in copper porphyry deposits. Silver equivalent (AgEq) may be used in a silver mine with lead and zinc or other base metal credits. A nickel deposit may have PGE, gold or other minor constituents.

Source: Geologyforinvestors.com
• 36% of mining energy was found to be consumed by comminution equipment.
• Comminuting Au and Cu ores requires 0.2% global and 1.3% Australian electricity.

Source: Ballantyne & Powell 2014, Minerals Engineering
Copper concentrate

Source: Alibaba.com
Minerals of economic interest that do not respond to conventional flotation:

Most oxide, hydroxide, carbonate and silicate minerals such as chrysocolla, gahnite, nickeliferous olivine... and even some sulphides (such as violarite, or sulphides encapsulated in non-metallic minerals)
Copper Concentrates

Average mill recovery = 81.7%
Average grade of copper concentrate = 25.1%
A 1.0 unit deduction in a concentrate grading 25.1% copper would mean that the smelter would pay for \( \frac{25.1 - 1.0}{25.1} = 96\% \) of the copper contained in the concentrate.
Lead Concentrates

*Lead concentrates – Source CWA Engineers*

**Average mill recovery = 72.0%**

**Average grade of lead concentrate = 58.4%**
A 3.0 unit deduction in a concentrate grading 58.4% lead would mean that the smelter would pay for \( \frac{(58.4-3.0)}{58.4} = 94.9\% \) of the contained lead.
Zinc Concentrates

Average mill recovery = 75.5%
Average grade of zinc concentrate = 54.1%

“Barclays said … it expected tightness in the zinc market to ‘remain … as concentrate shortages could lead to smelter outages outside China’.”

Source: CNBC, January 2017

Zinc concentrate storage facilities, Polaris mine – Source.nunatsiaqonline.ca
“Barclays said ... it expected tightness in the zinc market to ‘remain ... as concentrate shortages could lead to smelter outages outside China’.”

Source: CNBC, January 2017
“Teck Resources and smelter Korea Zinc have agreed annual zinc concentrate supply contracts with treatment charges (TCs) of $172 per tonne and have effectively removed ...price participation ... several sources with knowledge of the matter told Metal Bulletin.”

Source: Metal Bulletin, March 2017
Bulk Lead-Zinc Concentrates

Imperial Smelting Process (ISP)

Schematic representation of an ISP furnace

Source: JDS
Molybdenum Concentrates

Source: Qiao Xing Universal Resources, Inc.

Average mill recovery = 62.7%

Average grade of molybdenum concentrate = 52.2%
VANCOUVER, BRITISH COLUMBIA--(Marketwire - Nov. 5, 2009) - Ivanhoe Mines (TSX:IVN)(NYSE:IVN)(NASDAQ:IVN) announced today that it has received an initial, independent NI 43-101 Resource Estimate for the high-grade Merlin molybdenum and rhenium deposit, which comprises part of Ivanhoe Australia's Mt. Dore Project in the Cloncurry District in northwestern Queensland.
Ore grading 5% Zn, 1 oz/short ton Ag; no Cu, Pb or Au:

NSR = US$53.88/tonne

Netback* = 43.9%

* Netback = (NSR / gross value of metals contained in the ore) at US$0.94/lb Zn and US$0.85/lb Pb
Ore grading 5% Zn, 1 oz/short ton Ag; no Cu, Pb or Au:

NSR = US$53.88/tonne

Netback* = 43.9%

Ore grading 5% Pb, 1 oz/short ton Ag; no Cu, Pb or Au:

NSR = Cdn$70.19/tonne

Netback* = 62.5%

* Netback = (NSR / gross value of metals contained in the ore) at US$0.94/lb Zn and US$0.85/lb Pb
Precious Metal Recovery and Refining

JBR is a processor of materials containing silver, gold and other PGM metals.

Source: JBR Recovery Ltd.
Source: periodictable.com
<table>
<thead>
<tr>
<th>Mn</th>
<th>Fe</th>
<th>Co</th>
<th>Ni</th>
<th>Cu</th>
<th>Zn</th>
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<tbody>
<tr>
<td>ANGANANESE</td>
<td>IRON</td>
<td>COBALT</td>
<td>NICKEL</td>
<td>COPPER</td>
<td>ZINC</td>
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<tr>
<td>55</td>
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<td>57</td>
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<td>55.85</td>
<td>58.71</td>
<td>63.546</td>
<td>63.546</td>
<td>65.39</td>
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<table>
<thead>
<tr>
<th>Tc</th>
<th>Ru</th>
<th>Rh</th>
<th>Pd</th>
<th>Ag</th>
<th>Cd</th>
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<tbody>
<tr>
<td>TECHNETIUM</td>
<td>RUTHENIUM</td>
<td>RHODIUM</td>
<td>PALLADIUM</td>
<td>SILVER</td>
<td>CADMIUM</td>
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<td>45</td>
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<td>48</td>
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<td>98.9</td>
<td>101.07</td>
<td>102.91</td>
<td>106.42</td>
<td>107.87</td>
<td>112.41</td>
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</table>

<table>
<thead>
<tr>
<th>Re</th>
<th>Os</th>
<th>Ir</th>
<th>Pt</th>
<th>Au</th>
<th>Hg</th>
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</thead>
<tbody>
<tr>
<td>RHENIUM</td>
<td>OSMIUM</td>
<td>IRIDIUM</td>
<td>PLATINUM</td>
<td>GOLD</td>
<td>MERCURY</td>
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<tr>
<td>75</td>
<td>76</td>
<td>77</td>
<td>78</td>
<td>79</td>
<td>80</td>
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<tr>
<td>186.21</td>
<td>190.23</td>
<td>192.22</td>
<td>195.08</td>
<td>196.97</td>
<td>200.59</td>
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Source: frompo.com
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Source: FNX Mining, Victoria deposit, Sudbury, May 10 2010
Typical penalty materials in concentrates ("nasties"):
As, Bi, Cd, Cl, Co, Ni (in Cu or Zn conc.), Cu (in Mo and Zn conc.), F, Fe (in Zn conc.), Mg (in Cu and Ni conc.), Hg, Ni (in Cu conc.) Sb, Se, SiO$_2$ (in Zn conc.), S (in Pb conc.), Th
The former Samatosum mine, Adams Lake area, British Columbia. Source: salmonarm.wordpress.com
The Ok Tedi copper-gold mine. Source: ramumine.wordpress.com
• $$: yes!
• NSRs: yes!
• Au equiv and TPM: no!
• Mineralogy rules!
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