EVALUATION AND CLASSIFICATION OF NATURAL RESOURCE DEPOSITS

L. Weber, Vienna
Content

Need for a harmonized minerals resources classification system

Different systems – different goals

Evaluation of global resources estimates (example: Rare Earth Elements)
Factors, influencing the economy of a mine

- Energy costs
- Labor costs
- Transportation costs (train, ship) etc
- Taxes
- Metal price
Parameters controlling economy of mining (internal / geological)

Quality of the deposit

- type of deposit
- quality of the orebody (massif, disseminated etc)
- grade of the ore
- processability of the ore

Bonity of the deposit

- Shape of the orebody (regular, irregular, tabular...)
- Accessability, depth

Size of the deposit
Modifying factors e.g. Cutoff grade

Lowest grade of the ore, allowing economic production

Parameter with permanent high variability

- As mineral prices rise and all other costs stay the same, the cutoff will fall...

- If energy prices rise, and other costs stay the same, the cutoff will rise, so that mining of low grade mineralizations will no longer be profitable

Cutoff grade is influencing the reserves / resources situation of a mineral deposit (permanently)
Cutoff grade vs resources

Grade of ore in % vs tonnage

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Development of the gold price

Goldpreis in USD - Historisch
production costs vs gold price
(in US$ trouz)

2012: 1900 US $ / trouz
2013: 1430 US $ / trouz
2010: 1225 US $ / trouz
2015: 1100 US $ / trouz

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Need for standardized reporting

For mining companies quoted on stock exchanges the use of reporting codes is mandatory. Reporting codes should guarantee reliable and transparent information for investors....
US Reporting standards

Form 10-K
The federal securities laws require publicly traded companies to disclose information on an ongoing basis. For example, (US) domestic issuers must submit annual reports on Form 10-K, quarterly reports on Form 10-Q, and current reports on Form 8-K for a number of specified events and must comply with a variety of other disclosure requirements.

Form 20-F
A form issued by the Securities and Exchange Commission (SEC) that must be submitted by all "foreign private issuers" that have listed equity shares on exchanges in the United States. Form 20-F calls for the submission of an annual report within six months of the end of the company's fiscal year, or if the fiscal year-end date changes.
**National Instrument 43-101:** National instrument for the *Standards of Disclosure for Mineral Projects* within Canada. The Instrument is a codified set of rules and guidelines for reporting and displaying information related to mineral properties owned by, or explored by, companies which report these results on stock exchanges within Canada. This includes foreign-owned mining entities who trade on stock exchanges overseen by the Canadian Securities Administrators even if they only trade on Over The Counter (OTC) derivatives or other instrumented securities...

**For TSX listing purposes, an NI 43-101 Technical Report would have to be accompanied by a Report prepared in accordance with NI 43-101.**
### Need for harmonization

More than 150 different classification systems

<table>
<thead>
<tr>
<th>Year</th>
<th>Country/Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1902</td>
<td>Institute of Metallurgy and Mining (IMM)</td>
</tr>
<tr>
<td>1926</td>
<td>Russia</td>
</tr>
<tr>
<td>1959</td>
<td>GDMB</td>
</tr>
<tr>
<td>1979</td>
<td>DDR, UN</td>
</tr>
<tr>
<td>1980</td>
<td><strong>USA (USBM, USGS)</strong></td>
</tr>
<tr>
<td>1989</td>
<td>Austria, <strong>JORC</strong> (revised 1999, 2013)</td>
</tr>
<tr>
<td>1994</td>
<td><strong>SAMREC</strong> (revised 2000, 2007)</td>
</tr>
<tr>
<td>1997</td>
<td><strong>UNFC</strong> (revised 2009)</td>
</tr>
<tr>
<td>2001</td>
<td><strong>PERC</strong> (revised 2008, 2013)</td>
</tr>
<tr>
<td>2003</td>
<td>Peru</td>
</tr>
<tr>
<td>2004</td>
<td>Chile</td>
</tr>
<tr>
<td>2005</td>
<td><strong>CIM</strong> (Canada, revised 2014)</td>
</tr>
<tr>
<td>2007</td>
<td>USA (SME, 2014)</td>
</tr>
<tr>
<td>2011</td>
<td>Russia (NAEN)</td>
</tr>
<tr>
<td>2014</td>
<td>MRC (Mongolia)</td>
</tr>
</tbody>
</table>

1994: Foundation of Committee for Mineral Reserves International Reporting Standards “CRIRSCO”
Resources classification „families“

**USGS** (McKelvey Box)

**CRIRSCO** (JORC, SAMREC....)

**UNFC**
USGS: The revised classification system is designed generally for all mineral materials. The classification of mineral and energy resources is necessarily arbitrary, because definitional criteria do not always coincide with natural boundaries. The system can be used to report the status of mineral and energy - fuel resources for the Nation or for specific areas.
JORC: The Code is applicable to all solid minerals, including diamonds, other gemstones, industrial minerals and coal, for which Public Reporting of Exploration Results, Mineral Resources and Ore Reserves is required by the Australian Securities Exchange and the New Zealand Stock Exchange.
CRIRSCO: applicable to all solid minerals, including diamonds, other gemstones, industrial minerals, stone and aggregates, and coal, for which Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves is required by the relevant regulatory authorities
UNFC-2009 applies to fossil energy and mineral reserves and resources located on or below the Earth’s surface. It has been designed to meet, to the extent possible, the needs of applications pertaining to energy and mineral studies, resources management functions, corporate business processes and financial reporting standards.
The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated.…. "McKelvey-Box"
Reserve Base
That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated....

The reserve base includes those resources that are currently economic reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources).
"McKelvey-Box"

<table>
<thead>
<tr>
<th>Cumulative Production</th>
<th>IDENTIFIED RESOURCES</th>
<th>UNDISCOVERED RESOURCES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demonstrated</td>
<td>Undiscovered</td>
</tr>
<tr>
<td></td>
<td>Measured</td>
<td>Hypothetical</td>
</tr>
<tr>
<td></td>
<td>Indicated</td>
<td>Probability Range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speculative</td>
</tr>
</tbody>
</table>

**Reserves**: That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials;
CRIRSCO (JORC, etc.)

**Exploration Results**

- **Mineral Resources**
  - Inferred
  - Indicated
  - Measured

- **Ore Reserves**
  - Probable
  - Proved

**Increasing level of geological knowledge and confidence**

- Consideration of mining, processing, metallurgical, infrastructure, economic, marketing, legal, environment, social and government factors (the “Modifying Factors”).
Concentration or occurrence of solid material of economic interest in or on the Earth’s crust in such form, grade (or quality), and quantity that there are reasonable prospects for eventual economic extraction. Location, quantity, grade (or quality), continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge, including sampling.

(=reserve base sensu USGS)
CRIRSCO (JORC, etc.)

Exploration Results
Mineral Resources
Inferred
Indicated
Measured
Ore Reserves
Probable
Proved

Increasing level of geological knowledge and confidence

Consideration of mining, processing, metallurgical, infrastructure, economic, marketing, legal, environment, social and government factors (the “Modifying Factors”).

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CRIRSCO (JORC, etc.)

**Economically Mineable** part of a *Measured and/or Indicated Mineral Resource*. Includes diluting materials and allowances for losses, .... and is defined by studies at Pre-Feasibility or Feasibility level as appropriate that include application of Modifying Factors. Such studies demonstrate that, at the time of reporting, extraction could reasonably be justified.

- **Measured**
- **Indicated**
- **Inferred**
- **Probable**
- **Proved**

Increasing level of geological knowledge and confidence

Consideration of mining, processing, metallurgical, infrastructure, economic, marketing, legal, environment, social and government factors (the "Modifying Factors").
economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. The confidence in the Modifying Factors is lower to a Proved Ore Reserve
CRIRSCO (JORC, etc.)

Economically mineable part of a Measured Mineral Resource. Implies a high degree of confidence in the Modifying Factors.
Proved reserves (111)  
blue, green, turquois  
Breakdown into small blocs  
(5 * 5 * 3 m) by quality  

Probable reserves (112) red
United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources (UNFC) - a universally acceptable and internationally applicable scheme for the classification and reporting of fossil energy and mineral reserves and resources...

http://www.unece.org/energy/se/reserves.html
In the **United Nations Framework Classification (UNFC)** the terms “reserves” and “resources” are not defined, because they both have specific, but different, definitions in the solid minerals and petroleum sectors. The terms are used purely in a generic sense to encompass all possible Classes and Sub-classes that are valid in UNFC-2009.
UNFC System vs CRIRSCO (JORC, etc)

CRIRSCO-UNFC mapping

<table>
<thead>
<tr>
<th>MAPPING:</th>
</tr>
</thead>
<tbody>
<tr>
<td>111 = Proved Reserves</td>
</tr>
<tr>
<td>112 = Probable Reserves</td>
</tr>
<tr>
<td>221 = Measured Resources</td>
</tr>
<tr>
<td>222 = Indicated Resources</td>
</tr>
<tr>
<td>223 = Inferred Resources</td>
</tr>
<tr>
<td>334 = Exploration Results</td>
</tr>
</tbody>
</table>
Main differences

**USGS:**
2-dimensional, national, global reporting all materials (exc. hydrocarbons)

**CRIRSCO:**
2-dimensional company-reporting all solid materials

**UNFC:**
3-dimensional national, global, company-reporting all materials

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**Cumulative Production**

<table>
<thead>
<tr>
<th>Identified Resources</th>
<th>Undiscovered Resources</th>
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<tbody>
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<td>Measured</td>
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** exploration results**

**Mineral Resources**

- Inferred
- Indicated
- Measured

**Ore Reserves**

- Probable
- Proved

**CRIRSCO-UNFC mapping**

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Content

Need for a harmonized minerals resources classification system

Different systems – different goals

Evaluation of global resources estimates (example: Rare Earth Elements)
Added value of resource estimates

Global trend analyses by linking resource data with

Regional facts
  global distribution (e.g. continents)

Geoscientific facts
  type of deposit,
  age of mineralisation

Geopolitical facts
  political risk estimation
  definition of prime exploration targets
REE-Resources by continents

Measured, indicated and inferred resources in metr. t
(L. WEBER & J. LIU, 2015)

- Mountain Pass
- Bayan Obo

REE grade in %

Size in metr. t

Africa
Oceania
Asia
Europe
N-America
S-America

m=2,908 Mio t
m=1,595 Mio t (excl. Jongiu)
REE-Resources by continents

Measured, indicated and inferred resources in metr. t
(L. WEBER & J. LIU, 2015)

Distribution of global REE resources by continents
(incl. / excl. Jongiu)

Europe       (17,6% )  32,4% (!)
North-America (13,3% )  24,4%
Africa        ( 8,9% )   16,7%
Asia          (52,4%)  12,5% (!)
Oceania       ( 6,0%)  11,0%
Latin America ( 1,6%)   3,0 %

Size in metr. t

0.01          1.00E+04  1.00E+05  1.00E+06  1.00E+07  1.00E+08  1.00E+09  1.00E+10
REE-Resources by type of deposits

Measured, indicated and inferred resources in metr. t

(L. WEBER & J. LIU, 2015)

Size in metr. t

REE grade in %

- Carbonatites
- Carbonatites lateritic
- Alkali assoc.
- Alkali assoc., Lat
- Ion abs. Clays
- Black-shales
- Hydro. (veins)
- Ironoxide-Copper Gold
- Paleo-placers
- Placers

$m=2,908$ Mio t
$m=1,595$ Mio t (excl. Jongiu)

Jongju N-Korea

Bayan Obo

Mountain Pass
REE-Resources by type of deposits

Measured, indicated and inferred resources in metr. t
(L. WEBER & J. LIU, 2015)

Distribution of global REE resources by type of deposits

<table>
<thead>
<tr>
<th>Type of Deposits</th>
<th>Measured (incl.)</th>
<th>Excluded Jongiu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonatites</td>
<td>(59,5%) 25,7%</td>
<td></td>
</tr>
<tr>
<td>Carbonatites, Lat</td>
<td>(12,9%) 23,8%</td>
<td></td>
</tr>
<tr>
<td><strong>Carbonatites (tot)</strong></td>
<td>(72,4%) 49,5%</td>
<td></td>
</tr>
<tr>
<td>Alkali assoc.</td>
<td>(21,2%) 38,8%</td>
<td></td>
</tr>
<tr>
<td>IOCG</td>
<td>( 4,1%)  7,6%</td>
<td></td>
</tr>
<tr>
<td>Ion abs. Clays</td>
<td>( 0,4%)  0,68%</td>
<td></td>
</tr>
</tbody>
</table>
REE-Resources by age of deposits

Measured, indicated and inferred resources in metr. t

(L. WEBER & J. LIU, 2015)

REE grade in %

Size in metr. t

Archean  Paleo-Prot  Meso-Prot  Neo-Prot  Paleocoic  Mesocoic  Paleogene  Neogene  Quart.

m=2,908 Mio t
m=1,595 Mio t (excl. Jongiu)
REE-Resources by political stability

Measured, indicated and inferred resources in metr. t
(L. WEBER & J. LIU, 2015)

- Measured: m=2,908 Mio t
- Indicated: m=1,595 Mio t (excl. Jongiu)

Size in metr. t

REE grade in %

- Extreme unstable
- Unstable
- Fair
- Stable
REE-Resources by **political stability**

Measured, indicated and inferred resources in metr. t
(L. WEBER & J. LIU, 2015)

- **Distribution of global REE resources by political stability**
  (excl. Jongiu) (incl. Jongiu)

<table>
<thead>
<tr>
<th>Stability</th>
<th>Measured</th>
<th>Indicated</th>
<th>Inferred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable</td>
<td>44.39%</td>
<td>14.73%</td>
<td></td>
</tr>
<tr>
<td>Fair</td>
<td>27.02%</td>
<td>24.14%</td>
<td></td>
</tr>
<tr>
<td>Unstable</td>
<td>17.11%</td>
<td>54.82%</td>
<td></td>
</tr>
<tr>
<td>extr., unst. able</td>
<td>11.58%</td>
<td>6.31%</td>
<td></td>
</tr>
</tbody>
</table>

**Size in metr. t**

- Extreme unstable
- Unstable
- Fair
- Stable
REE-Resources with low political risk

Measured, indicated and inferred resources in metr. t
(L. WEBER & J. LIU, 2015)

REE grade in %

Size in metr. t

Extreme unstable
unstable
fair
stable

Mountain Pass

m=2,908 Mio t
m=1,595 Mio t (excl. Jongiu)
„prime targets * by countries / types“

Measured, indicated and inferred resources in metr. t
(L. WEBER & J. LIU, 2015)

* Most important type of deposits in countries with low political risk

\[
\text{REE grade in } \% \\
\text{Size in metr. t}
\]
Geological setting:
Carbonatites and alkali-associated magmatic complexes in stable cratonic regions in association with major faulting systems (large scale rifting systems („graben-structures“)...
Conclusions

Need for harmonisation for classification systems
UNFC system: highest flexibility
(all types of materials, company, regional, global reporting)

Reliable and transparent resources data:
Decision base for investors, minerals policy (regional, global trend analysis

Requirements:
Harmonized classification system, transparent data