Industrial minerals resources: Reporting according to Clause 49 of JORC 2012

by Andrew Scogings and Rob Barnett

The current edition of The Australasian Joint Ore Reserves Committee (JORC) Code was published in 2012 and, after a transition period, the 2012 edition came into mandatory operation on Dec. 1, 2013. There is a significant change between JORC 2004 (Clause 44) and JORC 2012 (Clause 49) for the reporting of industrial mineral resources and reserves, which should be addressed by ASX-listed players in the industrial minerals space.

Definition of industrial minerals

Although the definition of industrial minerals is far from straightforward, a commonly used description is “any rock, mineral or other naturally occurring substance of economic value, exclusive of metallic ores, mineral fuels and gemstones; that is one of the nonmetallic minerals” (CIM, 2003 pp. 37). In essence, natural industrial minerals are minerals and rocks mined and processed for the value of their nonmetallurgical properties, hence for the benefits they impart to the products and processes in which they are used. Natural industrial minerals such as limestone may be mined and further processed into synthetic industrial minerals such as precipitated calcium carbonate (PCC); such advanced minerals can be specifically tailored to meet individual customer requirements.

Industrial minerals are commonly classified according to their end uses, where there are a diverse (and sometimes bewildering) number of specifications, for example chemical purity, density, insulating properties, mineralogy, particle shape, particle size distribution, thermal resistance, rheology, whiteness and oil or water absorption.

Recent interest in industrial minerals

Industrial minerals such as phosphates, potash, graphite and lithium (brines and pegmatites) have recently become the focus of much attention for listed exploration companies, particularly graphite and lithium due to developments in battery technologies related to the emerging electric-vehicle and green-energy markets. For instance, as reported by Industrial Minerals Magazine (April 2014), “Calculations by IM Data estimate that Tesla’s new plant will consume at least 28 kt (31,000 st) of spherical graphite every year, if operating at capacity. This equates to 93 kt (102,000 st) of flake graphite if produced to today’s standards, with raw material wastage of up to 70 percent. If achieved, battery demand for natural graphite will increase 112 percent from today’s levels of 83 kt/a (91,000 stpy).”

Consequently, the race has been on to report larger tonnage exploration targets and resources, with certain projects being described, for example, as the biggest or second biggest in the world, or worldclass and perhaps hundreds of millions of tonnes containing a certain percentage of a particular mineral. However, being the biggest does not necessarily mean being the best, and the authors’ intention is to highlight the need to report resources by market-related specification (Scogings, 2014a, 2014b, 2014c), as such headline claims run the risk of being seen as misleading by investors and regulators.

In this regard, attention is drawn to CIM (2003) guidelines page 37, where the issue of market size and technical barriers to entry is addressed.

“Market considerations incorporate not only the requirement for detailed market analyses and/or contracts of sale, but also recognition that markets for many industrial minerals are relatively small, may have a high degree of producer concentration, or may have very high technical barriers to entry, thus imposing limits or...
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Figure 2

Metal-casting “greensand” moulds made of silica sand, bentonite and carbonaceous additives. Bentonite is the bonding agent and is typically qualified according to mechanical bonding properties, in addition to thermal durability. (Source: AMCOL Metalcasting Group, MTL.)

As noted on the website of Industrial Minerals Magazine: “Without a market, an industrial mineral deposit is merely a geological curiosity.” Similarly, as noted by Border and Butt (2014, pp. 467) concerning the modifying factors for industrial minerals: “without a potential market, there can be no resource; without a good knowledge of the planned market (volume, price and competition), there is no reserve.”

JORC 2012 – Reporting resources and reserves according to specifications

The fundamental difference between JORC 2004 (Clause 44) and 2012 (Clause 49) is contained in an all-important new paragraph, which requires that industrial mineral resources or reserves must be reported in terms of mineral specifications.

“For minerals that are defined by a specification, the mineral resource or ore reserve estimation must be reported in terms of the mineral or minerals on which the project is to be based and must include the specification of those minerals.”

Further references to specifications are found in the JORC 2012 guidelines, of which excerpts are listed below:

“It may be necessary, prior to the reporting of a mineral resource or ore reserve, to take particular account of certain key characteristics or qualities such as likely product specifications, proximity to markets and general product marketability.”

“Some industrial mineral deposits may be capable of yielding products suitable for more than one application and/or specification. If considered material by the reporting company, such multiple products should be quantified either separately or as a percentage of the bulk deposit.”

It is noteworthy that ‘specification’ is referred to no less than four times in Clause 49, demonstrating its significance in reporting according to JORC 2012.

Industrial minerals pricing related to specifications

Industrial minerals that are commonly defined according to size and/or purity specifications include andalusite, barites, chromite, feldspar, graphite, limestone, magnesite, silica, vermiculite, wollastonite and zircon. Other minerals and clays such as attapulgite, bentonite and kaolin may be specified according to final product sizing and purity, but, more importantly, according to performance, in particular markets and applications as diverse as...
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civil engineering (Fig. 1), oil well drilling, cat litter, metal casting (Fig. 2), iron ore pelleting, paint, paper and plastics.

A quick glance at the “Price Listing” pages in *Industrial Minerals* Magazine (June 2014) highlights that different specifications and markets command a range of prices (Table 1). For example, barites for use as a weighting agent in drill muds varies between US$112/t and $145/t ($100/st and $131/st) f.o.b. Chennai according to SG. High-brightness, high-purity barites for paint applications commands even higher prices, up to $440/t ($400/st).

Another example is in the chromite price, which is generally directly related to specifications such as particle size, SiO₂, and Cr₂O₃ content and Cr/Fe ratio. The chromite sand price varies significantly according to specification and markets, between $230/t ($208/st) for chemical grade and $360/t ($325/st) for foundry grade f.o.b. South Africa.

Of particular importance in today’s industrial minerals arena, crystalline graphite may range from $700/t ($635/st) to as much as $1,300/t ($1,180/st). It is clear that such price variations could have a significant impact on the economics of a graphite project, especially considering the range of possible markets e.g. friction linings, lubricants, electrical, refractories and foundries.

From the above examples, it is obvious that when publicly reporting an industrial mineral resource it is insufficient to simply report a tonnage and the contained percentage of the mineral. Not only is this contrary to JORC 2012 requirements, but it could be misleading to investors. An example is, the case of a hypothetical flake graphite resource reported as 200 Mt (220 million st) at 10 percent graphitic carbon. Essentially, all this tells us is that the resource contains 20 Mt (22 million st) of in situ flake graphite, but it conveys nothing about the size range of graphite flakes; the likely purity of extracted graphite flakes or impurities such as sulfides that may impact on mineral extraction or possible markets.

The same would apply to a vermiculite deposit, where flake size and exfoliation characteristics are required to be reported. In the case of clay, such as bentonite, simply reporting a tonnage based on purity measurements (e.g. Cation Exchange Capacity or XRD mineralogy) conveys very little information as to possible market applications — if any. Individual bentonite deposits may have similar montmorillonite content, but perform entirely differently in markets as diverse as paper manufacture, metal casting or oil well drilling. Bentonite quality may be affected by depth of weathering, whereby ‘blue’ bentonite is oxidized to ‘yellow’ bentonite at shallow depths (Fig. 3). Such oxidized clay may have improved performance...
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Figure 3

Turkish bentonite in hand specimen, illustrating oxidized ‘yellow’ rind around remnant ‘blue’ bentonite core. The yellow bentonite has enhanced rheological properties compared with the blue bentonite. (Source: AMCOL Mineral Madencilik A S, an MTI company.)

For example, drilling bentonite clay by auger may improve rheological properties due to the shearing effect imparted by the auger flights. This is akin to extruding the clay through a die plate, a method sometimes used to improve rheological properties. Similarly, reverse cycle (RC) drilling will most likely result in reduced flake size of minerals such as graphite and vermiculite, or in reduced aspect ratio of acicular wollastonite, resulting from comminution by the hammer action of the drill bit. Based on the authors’ experience, RC drilling may reduce the average size and population distribution of mineral flakes significantly compared with diamond core drilling (DD), as illustrated in Fig. 5.

Appropriate quality tests (assays) as per JORC 2012 Clause 49 guidelines:

“Assays may not always be relevant, and other quality criteria may be more applicable. If criteria such as deleterious minerals or physical properties are of more relevance than the composition of the bulk mineral itself, then they should be reported accordingly.”

Similarly, the CIM (2003) guidelines to estimation of industrial minerals resources and...
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Table 1


<table>
<thead>
<tr>
<th>Mineral</th>
<th>Grade</th>
<th>Properties</th>
<th>Price Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barites</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCMA/API</td>
<td>bulk lump, SG 4.1, f.o.b. Chennai</td>
<td>US$</td>
<td>112-125</td>
</tr>
<tr>
<td>Paint grade</td>
<td>Chinese lump, CIF Gulf Coast</td>
<td>US$</td>
<td>235-275</td>
</tr>
<tr>
<td>Paint grade</td>
<td>ground, 96-98% BaSO₄, ex-works USA ($)/t</td>
<td>US$</td>
<td>315-400</td>
</tr>
<tr>
<td>Chromite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>grade, 46% Cr₂O₃ wet bulk, f.o.b. South Africa</td>
<td>US$</td>
<td>230-280</td>
</tr>
<tr>
<td>Refractory</td>
<td>grade, 46% Cr₂O₃ wet bulk, f.o.b. South Africa</td>
<td>US$</td>
<td>300-330</td>
</tr>
<tr>
<td>Foundry</td>
<td>+47% Cr₂O₃ dried 1 tonne big bags f.o.b. South Africa</td>
<td>US$</td>
<td>330-360</td>
</tr>
<tr>
<td>Foundry</td>
<td>45.8% Cr₂O₃ wet bulk, f.o.b. South Africa</td>
<td>US$</td>
<td>260-290</td>
</tr>
<tr>
<td>Graphite -</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crystalline</td>
<td>Fine, 90% C, -100 mesh</td>
<td>US$</td>
<td>750-850</td>
</tr>
<tr>
<td>Medium</td>
<td>94-97% C, +100-80 mesh</td>
<td>US$</td>
<td>1,050-1150</td>
</tr>
<tr>
<td>Large flake</td>
<td>94-97% C, +80 mesh CIF</td>
<td>US$</td>
<td>1,250-1300</td>
</tr>
<tr>
<td>Magnesia -</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fused</td>
<td>Lump, f.o.b. China 96% MgO</td>
<td>US$</td>
<td>600-630</td>
</tr>
<tr>
<td>Lump, f.o.b.</td>
<td>China 97% MgO</td>
<td>US$</td>
<td>890-1,000</td>
</tr>
<tr>
<td>Lump, f.o.b.</td>
<td>China 98% MgO</td>
<td>US$</td>
<td>1,023-1,100</td>
</tr>
</tbody>
</table>

Barites reserves (pp. 38-39) highlight the importance of physical properties as well as end products and markets:

“Critical elements to the mineral resource estimate for industrial minerals are: (i) the consideration of the physical and chemical properties of the subject mineral; (ii) the spatial relationship of these properties within the mineral occurrence and (iii) the relationship of the physical and chemical properties of the mineral to the available market(s).”

“Customer specifications for industrial mineral products are frequently based solely on physical properties rather than, or in addition to, chemical characteristics. Sample testing should include those tests that will provide the physical characteristics and chemical analyses that relate to the specifications of the end product.”

The responsibility falls on the competent person to ensure that exploration samples are tested for appropriate parameters in addition to basic tests for mineral content:

- Individual or appropriate composite samples should be evaluated according to size, purity of extracted minerals and/or market performance specifications.
- It may be difficult to find a commercial lab that can run such tests, as most industrial minerals testing is done in-house by producers. Either a current producer may be approached to test the samples, or test methods may need to be developed internally.
- Some test methods are industry standards, for example, bentonite rheology as outlined by the American Petroleum Institute and foundry bond testing specified by the American Foundrymen’s Society (Eisenhour and Reisch, 2006).
- Other test methods may be obtained from the British Geological Survey or similar institutions, for minerals such as graphite (e.g. Mitchell, 1993).

For example, bentonite may be characterized by a number of metrics such as purity, chemistry and exchangeable cations:

- In situ moisture.
- In situ bulk density.
- pH.
- Grit content.
- Purity – montmorillonite versus inert minerals (cation exchange capacity).
- Ca, Mg and Na exchangeable cations (calcium or sodium bentonite?).
- XRF (chemistry).
- XRD (mineralogy).

Figure 4

Plan view of a sodium bentonite deposit striking NW and dipping gently to the SW. Highly oxidized bentonite along the subcrop has high free swell > 20 ml. Blue bentonite at ~ 15 m depth has low Free Swell <10 ml. Strike length is approximately 350 m. (Source: AMCOL Australia, an MTI company.)
However, while indicative of purity and general characteristics, these measures do not necessarily indicate how the clay might perform in various applications; therefore selected tests may be required to determine market opportunities such as:

- Viscosity and fluid loss (drilling mud, civil engineering).
- Fluid loss, free swell and permeability (geosynthetic clay liners, membranes).
- Water absorption (iron ore pelletizing).
- Bond strength (metal casting) (Fig. 6).
- Thermogravimetric analysis (metal casting) (Fig. 7).
- Clump strength (cat litter).
- Acid activation (bleaching earth for edible oil purification).

**Conclusions**

- Clause 49 of JORC 2012 is a welcome and timely improvement to Clause 44 of JORC 2004.
- CIM (2003) guidelines on reporting of industrial minerals resources and reserves are an invaluable reference for the CP reporting according to JORC 2012.
- It is no longer sufficient to simply report a resource of contained industrial mineral.
- The estimation must include the specification of those minerals, if those minerals are defined by a specification.
- The drilling method used should be appropriate for the mineralization style. Be aware of the possible effects of drilling methods such as RC, rotary air blast and auger compared with core drilling or bulk samples.
- If multiple products are possible from a deposit, such multiple products should be quantified either separately or as a percentage of the bulk deposit. A typical example could be a bentonite deposit that yields metal casting and drilling products from different parts of the deposit based on weathering domains.
- Specific market-related testing and/or metallurgical testwork are very likely to be required for industrial minerals deposits. It is not sufficient to rely solely on traditional mineralogical or chemical purity (assay grade) tests as commonly used in metals exploration.
- Commercial laboratories may not be equipped to test minerals to industry specifications. In this case, test procedures could be developed either in-house or in conjunction with a commercial lab.

**References**

Thermogravimetric analysis of ‘5D’ bentonite from Queensland, Australia. Dehydroxylation peak at 695°C suggests high thermal durability suitable for metal-casting applications. (Source: AMCOL Australia, an MTI company.)


JORC 2012 Clause 49: Reporting of industrial minerals exploration results, mineral resources and ore reserves

Industrial minerals are covered by the JORC Code if they meet the criteria set out in Clauses 6 and 7 of the Code. For the purpose of the JORC Code, industrial minerals can be considered to cover commodities such as kaolin, phosphate, limestone, talc, etc.

For minerals that are defined by a specification, the mineral resource or ore reserve estimation must be reported in terms of the mineral or minerals on which the project is to be based and must include the specification of those minerals.

When reporting information and estimates for industrial minerals, the key principles and purpose of the JORC Code apply and should be borne in mind. Assays may not always be relevant, and other quality criteria may be more applicable. If criteria such as deleterious minerals or physical properties are of more relevance than the composition of the bulk mineral itself, then they should be reported accordingly.

The factors underpinning the estimation of mineral resources and ore reserves for industrial minerals are the same as those for other deposit types covered by the JORC Code. It may be necessary, prior to the reporting of a mineral resource or ore reserve, to take particular account of certain key characteristics or qualities such as likely product specifications, proximity to markets and general product marketability.

For some industrial minerals, it is common practice to report the salable product rather than the ‘as-mined’ product, which is traditionally regarded as the ore reserve. JORC’s preference is that, if the salable product is reported, it should be in conjunction with, not instead of, reporting of the ore reserve. However, it is recognized that commercial sensitivities may not always permit this preferred style of reporting. It is important that, in all situations where the salable product is reported, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported.

Some industrial mineral deposits may be capable of yielding products suitable for more than one application and/or specification. If considered material by the reporting company, such multiple products should be quantified either separately or as a percentage of the bulk deposit.