CIM Industrial Minerals Leading Practice Guidelines

Prepared by the
CIM Mineral Resource and Mineral Reserve Committee
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1. Introduction

1.1. Definition of Industrial Minerals

Industrial minerals are generally considered to include non-metallic minerals, mineral products, or materials that provide raw material inputs for the construction, chemical, and manufacturing industries. They are often relatively low-value and bulky materials that are generally used close to where they are produced; however, some raw materials may be transported hundreds of kilometres to manufacturers and customers (ENDM, 2021). They do not include the metallic minerals, mineral fuels, or gemstones, and are used in industries based on their physical and/or chemical properties (Wikipedia, 2021).

In contrast to most metallic minerals, a general distinguishing characteristic of the industrial minerals sector is their general low degree of market elasticity in relation to the market prices and product specifications. The estimation of either a Mineral Resource or a Mineral Reserve (MRMR) for an industrial minerals deposit can be affected to a significant degree by a number of factors that are not typically applicable to metallic mineral deposits. These factors can include such considerations as the particular physical and chemical characteristics of the final product, product quality issues, market size and market access. In some cases, such information may be confidential and proprietary.

One of the key challenges of the industrial minerals sector is to define a commonly accepted listing of which types of minerals, materials, or mineral deposits can be considered as industrial minerals (Mining Standards Task Force, 1999). Although definitions for what constitutes an industrial mineral can vary in detail, general descriptions can be found in American Geosciences Institute (2021), Fastmarkets IM (2021), Snowden (2019), SME (2021) and Wikipedia (2021). A brief listing of some of the materials and minerals that are generally considered to be industrial minerals is provided in Table 1. For the purposes of this document, all references to industrial minerals include not only the minerals, materials, and mineral deposits themselves, but also the various commercial products that are derived from these sources.

Table 1: Summary List of Common Industrial Minerals

Aggregates	Granite	Pumice
Alunite	Graphite	Quartz
Asbestos	Gypsum	Slate
Ball Clays	Halite (Salt)	Silica sand/Hydraulic fracturing sand
Barite	Kaolin	Soda Ash
Bauxite	Kyanite/Sillimanite/Andalusite	Sulfur
Bentonite/Diatomite/Fuller's Earth	Lime/Limestone/Dolomite	Talc and Pyrophyllite
Borates	Magnesium compounds	Titanium oxides
Calcium carbonates	Marble	Trona
Corundum	Mica	Vermiculite
Diamond (Industrial quality)	Natron	Wollastonite
Dimension Stone	Olivine	Zeolites
Feldspar and Nepheline Syenite	Perlite	Zirconium
Fluorspar	Phosphate	
Garnet (Industrial quality)	Potash/Potassium minerals	

Note: This summary is not intended to provide an exhaustive and comprehensive list of all industrial minerals.

1.2. Review of Leading Practice Guidelines

The Canadian Institute of Mining, Metallurgy and Petroleum's (CIM) Leading Practices Guidelines reflect current leading practices in exploration, mineral resource estimation and mineral reserve estimation within the boundaries of Canada. Experience has shown that over time leading practices become industry accepted practices. Current industry accepted practices are context specific and continually evolve as industry experience is gained, new technologies are adopted, and public expectations, market expectations, and government legal frameworks change. All of the CIM's Leading Practice Guidelines are intended to be updated on a periodic basis. For the purposes of this document, all references to the CIM's Leading Practice Guidelines are intended to include any updated versions of the referenced documents that may take place following the adoption of this document. As such, readers should consult the CIM website at www.cim.org to ensure that they are referring to the current version of the referenced document.

The CIM Definition Standards for Mineral Resources and Mineral Reserves (2014) (the "CIM Definition Standards") state that "When reporting Mineral Resource and Mineral Reserve estimates relating to an industrial mineral site, the Qualified Person(s) should be guided by the Estimation of Mineral Resources and Mineral Reserves Best Practice Guidelines for Industrial Minerals".

The main principles relating to preparation of MRMR estimates for metallic mineral deposits are provided in the 2019 edition of the CIM Estimation of Mineral Resources and Mineral Reserves Best Practices Guidelines (CIM 2019) ("2019 MRMR BP Guidelines"). Although these 2019 MRMR BP Guidelines provide guidance in relation to metalliferous and other deposits, many concepts discussed therein are also applicable to the preparation of MRMR estimates for industrial minerals deposits. However, estimation of MRMR for industrial minerals can require additional considerations. This document adopts by reference the principles and guidelines presented in the 2019 MRMR BP Guidelines which are not henceforth repeated herein. These 2023 Industrial Minerals Leading Practices Guidelines ("2023 IM LP Guidelines") focus on presenting additional guidance in relation to those aspects of MRMR estimation related specifically to industrial minerals.

While these 2023 IM LP Guidelines apply to the list of individual materials and mineral deposits shown above, additional individual Leading Practices Guidelines have been prepared for specific industrial minerals such as lithium brines (CIM, 2003a), rock hosted diamonds (CIM, 2003b), and potash/potassium minerals (CIM, 2003c).

2. History

On January 9, 2018, the CIM Council formed the CIM Mineral Resources and Mineral Reserves Committee (CIM MRMR Committee), which is a combination of the previous Standing Committee on Reserve Definitions and the Best Practices Committee. Among other responsibilities, the CIM MRMR Committee's mandate is to update the CIM Leading Practices Guidelines, including the 2003 IM BP Guidelines.

The 2023 CIM IM LP Guidelines were prepared by the CIM MRMR Committee to update an earlier version that was accepted by CIM Council on November 23, 2003 (CIM, 2003d). These 2023 IM LP Guidelines adopt the concepts presented in the 2003 version of the document and supplement them with descriptions of current industry accepted practices.

The first draft of the proposed updated language for the current document was peer reviewed by the CIM MRMR Committee during the October to December 2022 period. A revised draft of the document was presented for public review and comment from January 14, 2023 to April 14, 2023. A final draft of the document was presented to the CIM Council for approval on November 19, 2023. The 2023 CIM IM LP Guidelines were adopted by CIM Council on November 19, 2023.

This current document supersedes and replaces the November 23, 2003 version of the IM LP Guidelines.

3. General Considerations

A key characteristic to the preparation of MRMR estimates for industrial minerals is the recognition by the practitioner(s) of the inter-relationship that can exist between:

1. markets;
2. product specifications;
3. product development.

Due to the confidential and proprietary nature common to industrial minerals, the qualifications of the practitioners involved in the preparation of MRMR estimates should include, at a minimum, some background knowledge or experience regarding the industrial minerals sector. This experience can be achieved via participation in the design and/or production team at an industrial mineral deposit/operation or can be achieved via mentoring and guidance from more experienced colleagues. While knowledge and experience with the specific industrial mineral under consideration is preferred, in many cases the knowledge and experiences gained from other industrial minerals can also be relevant.

As with metallic minerals, a key concept relating to the industrial mineral sector is the distinction between Mineral Resources and Mineral Reserves where the selection of input parameters will vary based on the different level of understanding and certainty. As discussed in Pressacco, Evans, and Postle (2023), the purpose of a Mineral Resource estimate is to act as the basis by which Mineral Reserve estimates are prepared. Consequently, the preparation of a Mineral Resource estimate often is based on a lower level of knowledge and confidence than the preparation of Mineral Reserve estimates. Moreover, the level of knowledge and certainty for a Mineral Resource estimate may vary depending on the stage in the mining cycle that the subject mineral property is in. The level of knowledge and certainty is typically lowest for mineral properties that are at the exploration or discovery stage of the mining cycle, increasing with advancement of the mineral property through the Mineral Resource estimation stage, through the study stages, and ultimately to the production stage.

A Mineral Reserve estimate is inherently based on a higher level of knowledge and certainty than a Mineral Resource, as it benefits from the knowledge and experience gained during the preparation of the Mineral Resource estimate. The level of certainty for a Mineral Reserve will be lowest for a mineral property that is at the prefeasibility stage of the mining cycle and will increase as the property moves through the feasibility study stage and into the production stage.

For industrial minerals, the two considerations that are key in advancing the project from the exploration stage through the various stages of MRMR estimation are the potential product quality specifications and market acceptance. Typically, the size of the mineral deposit is a secondary consideration until a market opportunity is found that permits the declaration of a Mineral Reserve. As well, production rate estimates used in Mineral Reserve estimation are often determined by the size of the product market rather than the size of the deposit.

Leading Practice in the preparation of MRMR estimates for industrial minerals centres on determination of components of the markets, product specifications/sales value, and cost structure.

3.1. Market Considerations

Market considerations for Mineral Reserve estimation incorporate not only the requirement for detailed market analyses and/or sales contracts but also the recognition that markets for many industrial minerals are relatively small and may have a high degree of producer concentration and/or very high technical barriers to entry, thus imposing constraints on achievable market volumes. Market considerations for Mineral Resource estimation are generally less comprehensive and include only those items that are relevant to the "Reasonable Prospects for Eventual Economic Extraction (RPEEE)" requirement for a Mineral Resource as defined in the CIM Definition Standards (CIM, 2014). A discussion regarding those considerations that can satisfy the RPEEE requirement of a Mineral Resource is presented in Pressacco, Evans, and Postle (2023).

Identification of the market and the factors that influence market demand and potential for success in the market are critical to determining the "value" of an industrial mineral project. The suitability of an industrial mineral for use in specific applications can ultimately be determined only through detailed product analysis, market investigations and discussion with potential end users. Practitioners should thoroughly consider the following when evaluating the market potential for an industrial mineral deposit when preparing a MRMR estimate:

1. Market segments: The market for an industrial mineral is not typically a single entity related to a single product but can include multiple segments due to different product specifications and end uses. Table 2 presents a list of common industrial minerals and their uses depending on grades and other specifications. Prices and market demand are also different for each end use. It is therefore important to recognize the differing requirements of each market segment or end use.

2. Deposit location and transportation factors;

3. Market size;

4. Number of producers;

5. Availability of substitute minerals.

Table 2: Examples of Grade Restrictions and Important Properties for Select Industrial Minerals

Material	End Use/Market Segment	Grade Specifications	Properties Other Than Grade
Silica, garnet, corundum, and diamond	Abrasives		Hardness, friability, grain size
Asbestos	Fire resistance		Fibre length, vein angle
Attapurgite (Palygorskite)	Absorbent		Granule size, absorptivity, pH, bulk density, durability
Barium	Drilling mud	>90% $BaSO_4$	Density
	Glass	96 % to 98% $BaSO_4$	
	Pigments	>94% $BaSO_4$	Brightness, pH
Bauxite	Alumina	50% to 55% Al_2O_3	Silica, iron oxide, and TiO_2 content
	Refractories	59% to 61% Al_2O_3	
	Abrasives	>55% to 55% Al_2O_3	
Bentonite	Drilling mud		Viscosity, yield point, and filtrate volume
	Foundry sand		Water content, liquid limit, pH, and CaO content
	Absorbent		Granule size, absorptivity, pH, bulk density, and durability
Chromite	Pigments, wood preservation, stainless steel, and refractories	>45% Cr_2O_3	Cr:Fe ratio
Crushed Rock Aggregate			Los Angeles abrasion test, sulphate, soundness test, freeze-thaw test
Diatomite	Filtration		Flow rate, clarity, pH,

			particle/pore size distributions, absorptivity
	Fillers		Brightness, oil absorption
Feldspars	Glass	4% to 6% K_2O, 5% to 7% Na_2O, 19% Al_2O_3	
	Paint, plastic, and rubber fillers		Dry brightness, oil absorption, Hegman grind, particle size distribution, surface area, bulk density
Gilsonite	Printing inks, paints, protective coatings, oil well plugging agent		Softening point, ash content, particle size
Glauconite	Water treatment, soil conditioning	90% glauconite	<2% to 3% clay
Gypsum	Plaster, wallboard	Minimum 80% pure	<10% to 15% insolubles, <0.03% soluble evaporites, <1% to 2% hydrous clays
	Portland cement retarder		
	Mineral filler		Hardness, particle size, and shape
	Terra alba	95% pure	Whiteness
Foundry sand	Castings		AFS grain fineness number (GFN), permeability, thermal expansion, thermal conductivity, wettability, durability/attrition
Kaolin	Paper filler and coater, paint filler, ceramics		Brightness, colour, opacity, particle size, viscosity
	Absorbent		Granule size, absorptivity, pH, bulk density, durability
Limestone (Calcium carbonate)	Agricultural lime	>80% $CaCO_3$	<8% moisture, 80% -8 mesh
	Cement	>92% $CaCO_3$	
	Glass	>98% $CaCO_3$	<0.05% Fe_2O_3
	Lime manufacturing	>90% $CaCO_3$	<3% impurities
	Mine dusting	>95% $CaCO_3$	<2% SiO_2
Magnesite	Refractories	>85% sintered MgO	
Mica			Particle size, bulk density, moisture refractive index, brightness surface area, grit content
Nepheline Syenite	Glass	20% to 30% nepheline ($NaAlSiO_4$)	<0.1% Fe_2O_3, >23% Al_2O_3
	Ceramics		No dark minerals, fuse on firing

			to white
	Filler		High dry brightness, inertness, high bulking value
Perlite	Filtration		Flow rate, clarity, pH, particle/pore size distributions, absorptivity
Wollastonite	Asbestos and fiberglass alternative		Filler aspect ratio
	Filler, ceramics		Whiteness, brightness

Sources: Carr (1994), Lamar (1961) and Vanderbilt Minerals (2013)

3.1.1. Market Segments

The market for an industrial mineral generally consists of a number of distinct segments or sub-sectors. It is important to recognize the differing requirements or product specifications of each market segment and to relate these requirements to:

1. the physical and chemical properties of the specific deposit or material being assessed;
2. the proposed production and processing technology for the mineral product;
3. the applications knowledge of the mineral producer;
4. the market size available in each segment;
5. the price available for each market segment.

3.1.2. Location and Transportation Factors

The potential profitability of an industrial mineral can be significantly affected by location and transportation factors. The practitioner should recognize that the mere existence of an industrial mineral deposit does not imply that it constitutes a Mineral Resource as defined by the CIM Definition Standards. Under the CIM Definition Standards, a mineral deposit must demonstrate RPEEE to be classified as a Mineral Resource. For those instances where an industrial mineral deposit is located far from the processing site or final markets, the practitioner should consider the costs associated with the remote location and transportation when establishing the criteria by which the RPEEE requirement of a Mineral Resource will be met. In many cases, the additional costs related to a remote location or transportation are accounted for in the cut-off grade (or value) used to prepare Mineral Resource statements.

To be classified as a Mineral Reserve, a Mineral Resource must "demonstrate that at the time of reporting, extraction could be reasonably justified" (CIM, 2014). This is most commonly achieved by applying all of the required modifying factors to the Mineral Resource as described in the 2019 MRMR BP Guidelines (CIM, 2019).

If the mineral deposit is in a remote location, distant from transportation infrastructure and customers, so that there may be no realistic market or development potential for the mineral, the mineral deposit cannot satisfy the RPEEE requirement of the CIM Definition Standards and, as such, **cannot** be classified as either a Mineral Resource or a Mineral Reserve.

3.1.3. Market Size

Some industrial minerals are produced in small quantity and/or have specialized, low volume applications. The practitioner should understand the limits to market size for an industrial mineral and develop estimates of a Mineral Reserve using parameters that are consistent with the appropriate market size for that particular mineral product.

3.1.4. Number of Producers

Many industrial minerals are produced by a relatively small number of companies. In these cases, there may be significant barriers to market entry by a new producer. These barriers can include proprietary processing knowledge and/or specialized equipment, knowledge of mineral end use applications, long term contractual producer/customer relationships, or captive consumption. While preparing either a Mineral Resource or Mineral Reserve estimate in such circumstances, the practitioner should conduct sufficient investigations to ascertain that an identifiable market can be developed, that the intended product can be sold, and that there is a reasonable expectation that the mineral deposit could be placed into commercial production. When preparing MRMR estimates, the practitioner should satisfy themselves that the potential markets for the mineral product(s) do exist. Depending upon the stage of the mineral property, this includes:

1. For industrial minerals properties that are currently in production, evidence of market viability includes reviews of current product specifications relative to existing contractual requirements.

2. For industrial minerals properties that are at the advanced study stage, market viability can be demonstrated by securing expressions of interest or an offtake agreement for some portion of the proposed output from potential customers.

3. For early-stage industrial minerals properties, potential market viability can be demonstrated by the preparation of an independent market analysis.

3.1.5. Availability of Substitute Materials

Many final applications for industrial minerals can be satisfied by several competing minerals offering similar functional or chemical properties, and often at similar costs. Some examples include pyrophyllite as an alternative for talc in tile manufacture, anorthosite (plagioclase feldspar) for kaolin in reinforcing glass fibre manufacture, and nepheline syenite for feldspar in manufacture of glass and ceramics. The practitioner should therefore be aware of the potential for product substitution when establishing the anticipated level of market demand and/or market price for the subject mineral.

Many industrial minerals consumers are reluctant to change sources of supply over concerns of losing or interrupting a reliable long-term supply of the required product quality and volumes. Even when consumers are willing to change sources of supply, the time frame in which this occurs may be quite lengthy. The practitioner, in developing estimates of Mineral Resources or Mineral Reserves, should therefore incorporate provision for an extended period of customer applications trials and/or the requirement for large-scale bulk sampling.

3.2. Sales Value

Sale value considerations not only include an assessment of the price at which the product can be sold but also the recognition that markets for many industrial minerals are relatively small, may have a high degree of producer concentration, may be subject to substitution by competing minerals, or may have high technical barriers to entry due to either product specifications or applications knowledge. These factors both individually or in combination, can impose limits or constraints on achievable market volumes and thus may influence the declaration of either a Mineral Resource or Mineral Reserve.

Sales value is a revenue-side function comprising:

1. product quality in relation to consuming industry or customer specification;
2. product price;
3. project robustness.

Many industrial minerals can be used in multiple applications with very different prices. Value differentials can arise due to:

- the critical importance of a particular physical or chemical property of a mineral;
- the amenability of the mineral deposit to process and product differentiation;
- the deposit size and favourable logistics;
- the technical knowledge of the mineral producer.

Published prices for industrial minerals may be used as indicators of value in the estimation of Mineral Resources or Mineral Reserves but should be supplemented by additional pricing research to determine the potential value of the subject commodity. Published prices and actual transaction prices for a particular grade of an industrial mineral may vary substantially. As far as possible, the practitioner should ensure that price estimates used in estimation of Mineral Resources, and Mineral Reserves in particular can be confirmed by discussion with potential customers and/or commitments of sale.

The practitioner should recognize that specifications for industrial minerals in many applications are to some degree flexible. Consumers may be able to incorporate minerals with a wide variety of physical and/or chemical properties into their product either by adjusting the mixture of ingredients used in the manufacturing process, or by making modifications to the process. In many cases, consistency or predictability of a range of characteristics of the industrial mineral may be more important than one specific quality characteristic.

Prices and specifications for industrial minerals are usually established by negotiation between producer and consumer. Slight differences in specifications may result in very large differences in price and/or volume, and contracts are sometimes written for large tonnages of a product at a unique confidential price. The practitioner should recognize such considerations when preparing the Mineral Reserve estimate.

3.3. Cost Structure

Costs are comprised of:

1. mining costs;
2. processing costs;
3. transportation and special handling costs;
4. general and administration costs.

It is important to recognize that purchase decisions for most industrial minerals are based on delivered costs. Transportation and storage costs can be significant as many industrial minerals are produced in bulk. Mineral deposits necessitating high mining and/or processing costs or facing high transport and handling costs compared to competing deposits require careful consideration to determine if such deposits can meet the RPEEE test for the declaration of a Mineral Resource. Similarly, for those deposits that are either at the study stages of the mining cycle requiring high mining and/or processing costs or facing high transport and handling costs, or those for which the markets are relatively small in relation to the contemplated product output, the selection of the various input parameters should reflect the actual or anticipated conditions for that deposit to support the declaration of a Mineral Reserve.

4. Mineral Resource Estimation

4.1. Introduction

In general, the estimation methods, workflows, and principles used to prepare Mineral Resource estimates for industrial mineral deposits are very similar to those used for metallic mineral deposits.

The reader is referred to the appropriate sections of the 2019 MRMR BP Guidelines as amended from time to time for general guidance on:

- The Mineral Resource Database;
- Geological and Mineralization Interpretations;
- Mineral Resource Estimation.

A key difference relating to the preparation of Mineral Resource estimates for industrial mineral deposits is the understanding that besides tonnage and metal/mineral grade, there are other criteria that should be taken into account when evaluating the potential economic viability of an industrial minerals deposit (Harbin, 1999). These additional criteria relate principally to the various physical and/or chemical properties of an industrial minerals deposit that are fundamental components of their potential economic value. In many cases, the type and quality of an industrial mineral product can influence the selection of drilling and sampling methods, the type of analytical information collected, and the selection of analytical methods. Example considerations for sample collection and analysis can include as the following:

- collecting a representative sample of particle sizes, or mineral sizes, shapes and morphology;
- analyzing for such parameters as colour or brightness;
- determination of the modal mineralogy of a sample.

In a number of cases, the sample collection and analytical protocols for an industrial mineral are clearly set out in publicly available standards guidelines.

The preparation of Mineral Resource estimates for industrial minerals involves consideration of:

1. the physical and chemical properties of the subject mineral and the expectation of their beneficiation into a saleable product;
2. the quantity and spatial relationship of these properties within the mineral deposit;
3. the relationship of the physical and chemical properties of the mineral to the market requirements.

The properties of an industrial mineral occurrence can vary markedly between deposits of the same type as well as within the same deposit. In particular, many industrial minerals deposits are subject to a nugget effect. The nugget effect may be caused by grain size (e.g., large crystals in pegmatites may distort sample results). Within the context of a particular deposit or deposit type, a sufficient and appropriate number of samples is required to ensure that meaningful average sample results are obtained, and that impurities or other deleterious factors are identified and delineated (impurities may be localized and the sampling density and resource estimation method employed should recognize this fact). The precision of the analytical method should be adequately considered as mineral quantification and some other analytical techniques can be less precise than standard chemical analyses, thus necessitating the use of averages over a large number of samples.

4.2. The Mineral Resource Database

The type of the industrial mineral deposit under consideration can influence the selection of the appropriate drilling equipment, sample collection and preparation protocols, analytical methods, and Quality Assurance/Quality Control (QA/QC) programs undertaken during deposit delineation activities.

It is important to understand that the requirements relating to the ultimate product quality specifications should be considered at the deposit delineation stage to ensure that this information is collected in a systematic manner and with a high degree of confidence.

Knowledge of such product specification factors can influence the selection of an appropriate drilling method or sample selection and sample preparation protocols. For example, specialized drilling equipment may be required (e.g., triple-tube coring tools or specialized coring methods) to ensure that the complete particle size fraction of the material of interest is recovered or that a representative volume of material is collected (e.g., PQ-diameter core for coarse grained evaporite or pegmatitic deposits). Such knowledge can also influence the selection of appropriate analytical methods or design of the accompanying QA/QC programs. For example, the levels of contaminant elements or compounds can often play a major role in determining whether a Mineral Resource can be declared for an industrial mineral deposit. In these cases, it can be equally important to implement a QA/QC program for the contaminant elements or compounds in addition to the principal element or compound of economic interest. Additional guidance on the creation and execution of mineral exploration and deposit delineation drilling programs is presented in the 2018 Mineral Exploration Best Practices Guidelines (CIM, 2018), as amended from time to time.

Selection of drilling and sampling methods should not adversely affect the in-situ physical and/or chemical properties of the target mineral(s). For example, graphite is valued based on its graphitic carbon content, flake size, and flake size distribution. Drilling methods such as reverse circulation or percussion drilling can adversely affect graphite flake size and flake size distribution and, as a result reduce the in-situ value of graphite.

Customer specifications for industrial mineral products are frequently based on both physical properties and chemical characteristics for the mineral and the specified values of individual properties/characteristics of a particular mineral may vary by product application, as shown for several industrial minerals in Table 2. Sample testing should include tests that will address those physical and chemical properties that relate to the specifications for the end product.

Examples of factors relating to ultimate product quality specifications for an industrial mineral can include:

- Hardness;
- Colour;
- Particle size and dimensions;
- Particle size distribution;
- Particle size grade (or value) by size;
- Particle shape;
- Crystallinity;
- Maximum concentration of undesirable elements (or compounds);
- Minimum concentration of desired elements (or compounds);
- Product density;
- Product abrasiveness;
- Etc.

The list of items above are not necessarily a comprehensive list of all possible physical or chemical parameters of importance for the preparation of a Mineral Resource estimate of an industrial minerals deposit. Practitioners are encouraged to consider additional items as they may relate to any additional product quality specifications as appropriate.

Mineralogy may have a significant impact on the potential process options and value of an industrial mineral deposit. It may be insufficient to use assay values solely on a total element or compound basis in preparation of a Mineral Resource estimate for an industrial mineral deposit. In those cases where the chemical component of interest (and value) may be present in more than one mineral form or oxidation state, this information may impact the selection of processing options and the type and quality of final product that can be produced from a given deposit. In these cases, the analytical method should be able to determine the quantities of the various minerals, compounds, and/or oxidation state. For example, for lithium minerals, separate reporting of lithium and the relevant mineralogical composition represented by spodumene, petalite, lepidolite and other lithium mineral species should be undertaken where they are present. Similarly, heavy mineral deposits containing ilmenite, rutile and leucoxene should report the percent of each mineral in the overall mass and the TiO_2 content and the relevant amounts of FeO and Fe_2O_3 in each mineral. As well, preparation of a Mineral Resource estimate for a talc deposit using the Mg or MgO abundances only may not be sufficient. For this deposit class, the estimation of Mineral Resources should also consider the modal abundance of the talc minerals (along with all other relevant information).

Determination of the chemical and physical characteristics of an industrial mineral often involves procedures and tests that are specialized and not part of the routine activity of an analytical laboratory whose primary focus is on assaying base metal or precious metal samples. The practitioner should ensure that the physical and chemical analytical work conducted on the industrial mineral is appropriate and relevant to the identification of the properties of interest in the intended application(s), and that the laboratory has the requisite experience and necessary equipment to conduct the required tests. For a number of cases, standard testing and analytical protocols can be obtained from either industry-specific organizations or from national or international standards-developing organizations.

The drill hole databases that are used to store the resulting information should be structured to capture and store all relevant data required for Mineral Resource estimation. Additional guidance regarding creation and management of drill hole databases is provided in CIM (2019), as amended from time to time.

4.3. Geological and Mineralization Modelling

When preparing geological, structural, weathering, and mineralization models of an industrial minerals deposit, knowledge of the anticipated product quality specifications is key. The practitioner should use reasonable judgment in the context of the deposit type, style and formation of the particular mineral deposit being assessed and the anticipated end use(s) of the industrial mineral.

Preparation of geological, structural, and weathering models of an industrial minerals deposit applies many of the principles and practices that are used for modelling the main lithologic units, structural features and weathering profiles for metallic mineral deposits. Geological, structural, and weathering models should be prepared using sample data to estimate the volume and grade, material characteristics, or weathering state of the deposit under consideration. General guidance relating to the preparation of geological, structural, and weathering models is presented in CIM (2019), as amended from time to time.

However, additional considerations are often required. As described in “Section 4.2” above, these additional considerations are often related to those characteristics that can influence the quality, physical, or technical requirements of the anticipated final product. Practitioners preparing models of industrial minerals deposits should be aware of all physical or chemical requirements that could influence the final product quality and should adapt or modify their geological modelling workflows to incorporate these requirements into the geological and mineralization models. An example of an additional modelling consideration is modelling the distribution of deleterious elements or minerals.

Due to the large number of permutations, a detailed listing of all deleterious elements or minerals for all industrial minerals deposits is not possible. General guidance regarding the geology and key characteristics of selected industrial mineral deposits in Canada along with a description of some of the deleterious elements is presented in CIM Special Volume 29 (CIM, 1984).

Compared to metallic mineral deposits, preparing geological and mineralization models for an industrial minerals deposit based on the analytical results alone may not be sufficient. For example, several minerals containing the element or compound of interest may be present within the deposit with each contributing to the total concentration of the element or compound; however, one of those minerals may be preferred for a particular use because of its physical or chemical properties. Practitioners should be knowledgeable of the key elements relating to the final product specifications and apply suitable workflows when creating the interpretations of the geological and mineralization features.

4.4. Mineral Resource Estimation

The development of a Mineral Resource estimate can be an iterative process based on generally accepted industry practice and experience and reflective of the stage of the mineral property in the mining cycle. Considering that Mineral Resource estimates may be prepared for mineral properties at various stages in the mining cycle, the level of knowledge and information for a particular deposit will typically increase with time, defining the selection of appropriate technical and economic input parameters for preparation of a Mineral Resource estimate. The judgment and experience of individual practitioners and their colleagues with a given deposit type and related marketing considerations will also be a factor in the selection of appropriate technical and economic parameters applicable to a given industrial mineral deposit.

4.4.1. Cut-Off Grade (or Value) Estimation

In order for an industrial mineral deposit to be declared as a Mineral Resource, it is necessary to demonstrate that the deposit meets the RPEEE requirement as defined in the CIM Definition Standards (2014). The application of reasonably developed technical and economic parameters is a key concept towards meeting this requirement.

Cut-off grade (or value) is a standard, industry accepted method used for preparation of Mineral Resource statements. Common input parameters for the estimation of a cut-off grade (or value) include:

- Metal, mineral product, or commodity prices;
- Exchange rates (as appropriate);
- Operating costs, including:
    - Mining;
    - Processing;
    - General and Administration;
    - Transportation and treatment charges (as applicable);
    - Marketing;
- Metallurgical recoveries;
- Revenue-based royalties.

A key item to the determination of an appropriate cut-off grade (or value) is the selection of a price or value for the products. An industrial mineral may have multiple market applications, or it may be included in multiple end-products, all of which may have different product specifications and pricing. The practitioner should understand the physical and chemical characteristics of the industrial mineral in sufficient detail to determine its price for each intended market. In some cases, the producer may set the price for individual products whereby pricing is confidential and is not disclosed publicly.

Consideration of the market pricing for an industrial mineral product is critical to ensuring that the RPEEE requirement for an industrial mineral deposit is achieved, and the mineralization is classified as a Mineral Resource. The practitioner should also ensure that sufficient test work has been completed to indicate that the ultimate product from the deposit under consideration is saleable. The level of knowledge from metallurgical test work will generally increase as the mineral property advances through the mining cycle. Considering the importance of the final product quality and specifications to the marketability of an industrial mineral, the level of metallurgical test work can be an important factor in Mineral Resource classification and preparation of Mineral Resource statements.

In contrast to many metallic mineral products that are traded on open markets where the prices are readily available from a number of public domain sources, the prices for specific industrial minerals products are often set on a contract basis. While prices for a number of industrial minerals products are published on a regular basis by various trade journals, magazines, consulting firms, and websites, in some cases, the price of a particular product may only be determined either by means of a dedicated market study or by direct contract negotiations with potential end-users. Additional guidance in relation to the selection of appropriate product pricing is presented in CIM's guidance for commodity pricing (CIM, 2020).

Additional key inputs for evaluating RPEEE are the deposit location and the anticipated transportation costs involved with the envisioned conceptual operational scenario. The location of a mineral deposit is often an important consideration, as transportation costs for both mine operations as well as product shipping can influence the deposit's potential economic viability. For example, construction aggregates from a quarry in an urban area with multiple competing sources may have a maximum sales range of approximately 40 km. Conversely, in areas with few if any nearby sources of supply, a quarry may have a sales range of 300 km or more.

4.4.2. Estimating the Mineral Resource Quality

Multiple factors may be used in evaluating the quality or value of an industrial mineral deposit during the Mineral Resource estimation process. The practitioner should be aware of the methods available to estimate the relevant parameters of each block of a resource and should justify the selection of these parameters, and the estimation methods employed. Guidance regarding the considerations and requirements for estimation of Mineral Resources is presented in CIM (2019).

4.4.3. Classifying the Mineral Resource

General guidance for classification of Mineral Resources into either the Measured, Indicated, or Inferred confidence categories is provided in Chapter 6.11 of CIM (2019). In general, classification of material into one of the three Mineral Resource categories is based not only on the level of confidence in the continuity of the deposit, but also its characteristics, such as grade, thickness and other physical or chemical properties.

Industrial mineral deposits can differ significantly in their character and properties both from one another and from metallic mineral deposits. These differences may impact the data density required for assignment of the Mineral Resource into the various confidence categories. For example, the spacing of sampling points (e.g., drill holes) for an industrial mineral deposit that exhibits strong geological and grade continuity (e.g., a bed of homogeneous limestone or gypsum) will generally be larger than that for a typical volcanogenic massive sulphide (VMS) deposit where either continuity and/or grade of the mineralization are less uniform. Further, in base and precious metals deposits, the element of economic interest typically occurs in low concentrations (parts per million [ppm] in the case of gold, silver, and platinum group metals [PGM] or small percentages for base metal deposits) relative to the total volume of rock. Whereas, for many industrial mineral deposits, one of the mineral constituents or compounds forms a large portion of the deposit, resulting in much less uncertainty about continuity between widely spaced drill holes for the material of economic interest. Conversely, very closely spaced sampling may be required where small lateral or vertical changes in chemical composition, mineralogy, texture, colour, or morphology within an industrial mineral deposit, may have a significant impact on product utility.

Although a number of methods are currently employed to determine the level of confidence for classification of the Mineral Resource that include distance-based or geostatistical-based criteria, in all cases, the selection of the criteria for classification of the Mineral Resource into the three confidence categories is the responsibility of the practitioner. Examples of parameters used to assign material into the three Mineral Resource categories can be found in Parker and Dohm (2014). Where an industrial mineral deposit can produce several distinct products from different parts of the deposit, the practitioner should consider the "highest and best use" for each product and classify each respective part of the deposit separately. Note that the spatial extents of the mineral resources for various quality uses may overlap.

4.4.4. Mineral Resource Reports

Mineral Resource reports are the culmination of workflow commonly followed for the preparation of a Mineral Resource estimate. Mineral Resource statements can include reports of tonnages and grades (or value) of a material for either internal purposes or disclosure to the public domain. For the purposes of this document, all references to reporting describe such necessary reports and related documentation that are created as part of the normal-course work flow of preparing a Mineral Resource estimate for internal purposes. For clarity, all disclosure of a Mineral Resource estimate made by, or on behalf of, an issuer and intended to be, or reasonably likely to be, made available to the public in a jurisdiction of Canada must comply with the requirements of National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101).

Reporting of Mineral Resources should recognize that chemical and/or physical specifications constitute a significant factor in the economic potential of an industrial minerals deposit. In many cases, it is not sufficient to state the elemental concentrations alone for an industrial mineral deposit. Mineral Resource statements should be prepared using criteria developed to meet the product specification. In reporting Mineral Resources, the practitioner should ensure that all relevant quality factors and other relevant input parameters are included as part of the Mineral Resource reporting.

All Mineral Resource statements to the public domain, including those for industrial mineral deposits, must ensure that the RPEEE requirements of the CIM Definition Standards (2014), as amended from time to time, are met. General guidance in relation to the preparation of Mineral Resource statements is presented in Chapter 6.12 of CIM (2019).

5. Mineral Reserve Estimation

5.1. Introduction

After a Mineral Resource has been shown to be economically extractable by means of at least a Prefeasibility Study (PFS) or Feasibility Study (FS), portions or all Measured and Indicated Mineral Resources can be converted to Proven and Probable Mineral Reserves, respectively, through the application of Modifying Factors. Note that a practitioner can also convert Measured Mineral Resources to Probable Reserves if there are uncertainties concerning any of the modifying factors.

In addition to the modifying factors described in the 2019 MRMR BP Guidelines for metallic mineral deposits, key considerations regarding the modifying factors for industrial minerals can include:

- market demand/size relative to proposed output for the project;
- deposit location with respect to the target market;
- product specifications and the ability to meet them;
- product price and variations and fluctuations therein;
- availability of an offtake agreement, letter of intent, contract in-hand, or a marketing plan supported by an independent market analysis.

Market studies are often required in support of the preparation of Mineral Reserve estimates for an industrial minerals deposit. At a minimum, these studies include reviews and analyses of product specifications based on geologic and metallurgical testing, supply and demand forecasts, historical prices, forecasted long term prices, evaluation of competitors (including products and estimates of production volumes, sales, and prices), customer evaluation of product specifications and market entry strategies or sales contracts. The studies are typically prepared by independent third parties and often serve to provide justification for all assumptions, including those for material contracts required to develop and sell the Mineral Reserves.

In addition to the guidance presented in CIM (2019), estimation of a Mineral Reserve for an industrial mineral deposit should incorporate rigorous research and assessment of all quality factors including those specific to the commodity. The modifying factors listed above are discussed in more detail below.

5.2. Market Factors

The rigorousness of the Mineral Reserve estimate, particularly with respect to market factors, should incorporate an appropriate level of detail in consideration of:

- the stage of the project;
- availability of appropriate information;
- the level of investment required to place the project into production;
- ability of the target markets to absorb the anticipated product output.

The practitioner should clearly state what additional information is required in order to increase confidence in the estimate of the Mineral Reserve. Any uncertainties in the confidence of the estimate should be reflected by the appropriate classification of the material.

5.3. Product Specifications

Published specifications and standards for industrial minerals should be used primarily as a screening mechanism to establish the potential marketability of an industrial mineral. The ultimate suitability of an industrial mineral for use in specific applications can only be determined through detailed market investigations, product testing and discussions with potential consumers.

Many industrial minerals have minimum mineral or chemical grade and/or quality requirements for specific products. In addition, there may be maximum grade limits for deleterious minerals or chemicals. The practitioner should be aware of all such requirements and account for them in Mineral Reserve estimates.

The practitioner should be aware that test results for industrial minerals, especially the results of preliminary beneficiation tests, could be subject to significant scale-up challenges. The practitioner should ensure that laboratory test procedures adequately reflect the proposed production process. In some cases, bulk samples in excess of several hundreds of tonnes may be required to confirm scale-up. This may necessitate pilot-scale test work or start-up of production on a pilot basis prior to finalization of sales contracts.

5.4. Economic Analysis

Some industrial mineral ventures are relatively simple operations with low levels of investment and risk, where the operating entity has determined that a formal PFS or FS is not required for a production decision. The demonstration of the economic viability of a mineral deposit, as required under the 2019 MRMR BP Guidelines for the declaration of a Mineral Reserve, may be satisfied by actual profitable production at a small initial scale. Alternatively, where production has not yet commenced, there should be evidence of market and economic analyses. However, the lack of a formal PFS or FS for a venture should be clearly communicated to current and potential stakeholders who may consider the lack of such studies to be a risk.

5.5. Review of Mineral Reserve Estimates

As stated in the 2019 MRMR BP Guidelines, the practitioner should recognize that the time from discovery to development of a mineral deposit could be measured in years. Consequently, the practitioner should be aware of the need to regularly review the Mineral Reserve estimates in light of significant changes in markets or product specifications. Note that the shelf life of a technical report can be extended by incorporating a sensitivity analysis that covers the expected range of values of critical parameters. Nevertheless, the parameters that are used as a basis for the estimates should be updated at appropriate intervals to take into account significant changes that may affect the economic viability of a project. Changes in market factors are particularly important.

5.6. Mineral Reserve Reports

Mineral Reserve reports are the culmination of the series of steps required for the preparation of a Mineral Reserve estimate. Similar to Mineral Resources, Mineral Reserve statements can include reports of tonnages and grades (or value) of a material for either internal purposes or disclosure to the public domain. For the purposes of this document, all references to reporting describe such necessary reports and related documentation that are created as part of the normal-course work flow of preparing a Mineral Reserve estimate for internal purposes. For clarity, all public disclosure of Mineral Reserve estimates made by, or on behalf of, an issuer and intended to be, or reasonably likely to be, made available to the public in a jurisdiction of Canada must comply with the requirements of NI 43-101, as amended from time to time.

Reporting of Mineral Reserves should recognize that chemical and/or physical specifications constitute a significant factor in the economic potential of an industrial minerals deposit. In reporting Mineral Reserves, the practitioner should ensure that all relevant quality factors and other relevant input parameters are included as part of the Mineral Reserve statement.

6. Conclusions

Industrial minerals are generally considered to include non-metallic minerals that provide resources for the construction, chemical, and manufacturing industries. They include a wide variety of materials and minerals that are widely used in various manufacturing applications and products throughout the world.

While the 2019 MRMR BP Guidelines provide guidance in relation to the preparation of MRMR estimates for metalliferous and other deposits, many principles described therein are applicable to the preparation of MRMR estimates for industrial minerals deposits. However, estimation of MRMR for industrial minerals can require additional considerations because of their unique properties or limits on deleterious substances that may be imposed on an industrial mineral or industrial mineral product. The key to estimation of MRMR for industrial mineral deposits is the recognition by the practitioners of the inter-relationship that exists between:

1. markets;
2. product evaluation;
3. product development.

When preparing a Mineral Resource estimate for industrial mineral deposits, it is important to understand that besides tonnage and grade, there are additional criteria to be taken into account in evaluating the potential economic viability of an industrial minerals deposit. The preparation of Mineral Resource estimates for industrial minerals should take into consideration the physical and chemical properties of the subject mineral and the expectation of beneficiation into a saleable product, the quantity and spatial relationship of these properties within the mineral deposit, and the potential of the physical and chemical properties of the mineral to meet the market requirements. For the estimation of Mineral Reserves, the modifying factors for industrial minerals can include market demand/size relative to the proposed output for the project, deposit location with respect to the target market, product specifications and the ability to meet them, product price and its variations and fluctuations, and availability of an offtake agreement, letter of intent, contract in-hand, or marketing plan.

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