SAMREC Guideline Document for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves for Industrial Minerals

(“SAMREC Industrial Guidelines”)

1. INTRODUCTION

1.1 This Guideline Document, as updated from time to time, provides the methodologies and definitions of the relevant terms that shall be considered in the preparation of Public Reports on Exploration Targets, Mineral Resources and/or Mineral Reserves for Industrial Minerals (SAMREC Clause 73). It is to be read in conjunction with the SAMREC Code (2016 Edition).

1.2 Clauses 1-47 and Figure 1 of the SAMREC Code and the requirements of Table 1 in SAMREC also apply to the reporting of Exploration Results, Mineral Resources and Mineral Reserves for Industrial Minerals, unless otherwise stated in this document. The contents of Table 2 of this Guideline are supplementary to the requirements of Table 1 in SAMREC.

1.3 The text in the Industrial Guidelines has been drawn extensively and adapted from the CIM Industrial Minerals Leading Practice Guidelines, prepared by the CIM Mineral Resource and Mineral Reserve Committee (CIM, 2023). The text also draws on Appendices 6 and 7 of the International Reporting Template for the public reporting of Exploration Targets, Exploration Results, Mineral Resources and Mineral Reserves prepared by the Committee for Mineral Reserves International Reporting Standards (CRIRSCO, 2019).

2. INDUSTRIAL MINERALS

2.1 In contrast to most metallic minerals, a general distinguishing characteristic of the industrial minerals group is their 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 is affected to a significant degree by factors that are not typically applicable to metallic mineral deposits. These can include such considerations as the particular physical and chemical characteristics of the final product, mineral quality issues, market size and market access. In some cases, such information may be confidential and proprietary (CIM, 2023).

2.2 Industrial Minerals may be defined as “any rock, mineral, or other naturally occurring substance of economic value, exclusive of metal ores, mineral fuels, and gemstones: one of the non-metallics” (Bates, 1975). Industrial minerals have traditionally been defined as minerals and rocks mined and processed for the value of their non-metallurgical properties. They have also been defined as being non-metallic, non-fuel minerals.

2.3. Industrial minerals may be described as ‘natural’ or ‘synthetic’. For example, natural flake graphite may be mined and processed by grinding and flotation methods, whereas the primary feedstock for synthetic graphite is generally calcined petroleum coke. The two types of graphite may compete in markets such as battery anodes.

2.4 Industrial minerals may be incorporated into products (e.g. talc and calcium carbonate in plastics and paint; silica sand, feldspar and pigments in glass and ceramics; stone aggregate in concrete) or consumed in the manufacture of items (e.g. bentonite, coal dust and silica sand used to make foundry moulds, into which molten metal is poured). Industrial minerals may also be used to assist processes such as civil engineering or oil and gas drilling (e.g. barite and bentonite in water-based slurries) or used in their natural state (e.g. crushed and screened rock aggregate for railway line ballast).

2.5 A well-known saying in the world of industrial minerals is that "Without a market, an industrial mineral deposit is merely a geological curiosity. So, put simply, no market demand = no mineral development = no mineral trade." (O'Driscoll, 2006).

2.6 For purposes of this Guideline, the term Industrial Minerals includes Dimension Stone which is "*natural stone or rock that has been selected and finished (e.g., trimmed, cut, drilled or ground) to specific sizes or shapes. Color, texture and pattern, and surface finish of the stone are also normal requirements*" (Wikipedia, https://en.wikipedia.org/wiki/Dimension_stone, 2024).

2.7 For the purposes of this Guideline, 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 (CIM, 2023). A summary list of common industrial minerals is given in Appendix 1 (Section 14.1). The summary is not intended to provide and exhaustive and comprehensive list of all industrial minerals.

3. GENERAL CONSIDERATIONS

3.1 A key characteristic to the preparation of Exploration Results and MRMR estimates for industrial minerals is the recognition by the Competent Person(s) (CPs) of the inter-relationship that exists between:

- Markets,
- product specifications,
- product development (CIM, 2023).

3.2 Due to the confidential and proprietary nature common to industrial minerals, the qualifications of the CPs involved in the preparation of Exploration Results and 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 (CIM, 2023).

3.3 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.

Guidance	*The level of knowledge and certainty for a Mineral Resource estimate 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 (after CIM, 2023).* *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 (after CIM, 2023).*

3.4 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 Resource or 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 (CIM, 2023).

3.5 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 (CIM, 2023).

4. MARKET CONSIDERATIONS

4.1 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 SAMREC Code (for example, clause 24 and associated guidance) (after CIM, 2023). However, for Indicated and Measured Resource estimation market acceptance for the proposed industrial mineral/s should be shown to a degree accepted by the Competent Person (such market information may be confidential).

Guidance	*As a rule of thumb, the size (tonnage) of an industrial mineral deposit is a secondary consideration until a market opportunity is found that permits the declaration of a Mineral Reserve. The key consideration is whether product/s of appropriate quality can potentially be produced and marketed.*

4.2 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. CPs should thoroughly consider the following when evaluating the market potential for an industrial mineral deposit when preparing a MRMR estimate (CIM, 2023):

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. Appendix 1 in Section 14.1 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 (CIM, 2023).
2. Deposit location and transportation factors;
3. Market size;
4. Number of producers;
5. Availability of substitute minerals.
6. Market/s for industrial mineral deposits often include multiple segments due to underlying geological controls (e.g., weathering, mineralogy and chemistry) which result in different product specifications and end uses (Appendix 1 (Section 14.1) and Appendix 3 (Section 14.3)).

Guidance	*For example, a bentonite deposit may contain several layers (beds) of differing mineralogy that each supply markets as diverse as pet litter, civil engineering, oil drilling and metal casting. Weathering effects may add to the complexity of the product mix, such that shallow and highly weathered (oxidised) material may be suitable for foundry but not for civil engineering, whereas deeper (unoxidised) material may be suitable for both markets.* *Similarly, a lithium pegmatite deposit may be zoned both mineralogically and chemically and supply low iron petalite to glass and ceramics markets, compared with spodumene from another part of the pegmatite for conversion to lithium chemicals used in battery manufacture.* *Prices and market demand are also different for each end use, for example bulk shipments of cat litter are generally lower priced than foundry grade bentonite. It is therefore necessary to account for differing requirements of each market segment or end use. Regarding cat litter, it is worth noting that by the time it is packaged in small bags (several kg) and reaches the retail customer, cat litter is considerably higher priced than, for example drilling or foundry grades in their respective markets.*

5. SALES VALUE

5.1 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 (CIM, 2023). These factors both individually or in combination, can impose limits or constraints on achievable market volumes and thus may influence the declaration of MRMR. Sales value is a revenue-side function comprising:

- product quality in relation to consuming industry or customer specification;
- product price;
- project robustness (CIM, 2023).

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

- the critical importance of particular physical, mineralogical or chemical properties 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 (CIM, 2023).

5.3 Published prices for industrial minerals may be used as indicators of value in the estimation of MRMR 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 CP 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 (CIM, 2023).

5.4 The CP 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 (CIM, 2023).

5.5 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 (CIM, 2023).

6. COST STRUCTURE

6.1 It is important to recognise 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.

6.2 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 (CIM, 2023).

7. REPORTING EXPLORATION RESULTS

7.1 Reporting of Exploration Results for industrial mineral deposits differs from metallic deposits in that, apart from mineral grade and intersection width, there are other criteria such as potential product quality that should be considered.

7.2 Industrial mineral Exploration Results may include results like those typically reported for metallic deposits, such as:

7.2.1 Geophysical surveys and geology observations/mapping, often reported early on in a project. Reporting analytical results for grab samples or hand specimens should be treated with caution.

Guidance	*For example, the coarse crystal size of most zoned pegmatites makes selection of unbiased samples essentially impossible. Similarly, it is critical to discuss the likely dimensions of the pegmatite body being sampled. An isolated vein of limited width or length is unlikely to be of immediate, potential economic interest, regardless of the lithium content (even though small outcrops can lead to the discovery of significant deposits) (Scogings et al., 2016).*

7.2.2 Analytical ('assay') results including geochemistry of outcrop, drill sample, trench or bulk samples; visual estimates of drill hole intersections; or petrographic and mineralogical examination.

Guidance	*Taking lithium-bearing pegmatites as an example, lithium content may be reported in several ways, and it must be made clear which is being used. Analytical laboratories often report elemental lithium (Li), whereas Mineral Resources are usually reported as lithium oxide (Li_2O). Global lithium production is frequently reported as lithium carbonate (Li_2CO_3). If visual estimates are reported prior to receiving laboratory results, then the minerals of interest must be identified (e.g., graphite or spodumene) and include estimates of abundance as ranges.* *Lithium mineralogy is as important as Li_2O content and, consequently, must be discussed when reporting exploration results to comply with the requirements of the SAMREC Code. It is unacceptable to only report lithium contents (e.g. Li_2O %) without specifying which lithium minerals are present and the form in which they occur in the deposit. There are significant economic implications associated with the form in which lithium occurs, and compliance with the transparency principle of the SAMREC Code requires description of the main mineral species present and their physical characteristics in a deposit.* *It is recommended that public reports of lithium Exploration Results not be released until chemical analyses are available and are preferably supported at least by XRD (or other appropriate mineralogical tools) and/or petrographic data (Scogings et al., 2016).*

7.2.3 Unlike metallic deposits, metallurgical test results for industrial minerals are material and should be reported in Exploration Results announcements. Naturally there will be commercially confidential information that cannot be disclosed to the market. The key considerations under these circumstances should be:

- whether the results of the metallurgical or beneficiation analysis are material and provide context for announcements about industrial mineral Exploration Results; and
- if these results impact the project's prospects for eventual economic extraction.

Guidance	Metallurgical or beneficiation testing results announced as Exploration Results may include chemistry (e.g., grades or purity of andalusite, silica sand, spodumene), product performance tests on concentrates (e.g., andalusite, graphite, wollastonite, vermiculite), or rocks and minerals (e.g., aggregate, ball clay, bentonite, kaolin, talc).

7.2.4 Metallurgical, beneficiation or product performance tests results can be affected by the type of drilling and / or sampling method used. When drilling for minerals such as graphite, vermiculite or wollastonite, methods such as reverse circulation (percussion) will adversely affect intrinsic properties such as flake size or aspect ratio.

7.2.5 Therefore, size reduction by percussion drilling would have a material impact on the economics of projects where coarse flake, or high aspect ratio typically attract a higher price than finer flakes or crystals with low aspect ratio. A further example is that auger drilling may increase the viscosity of bentonite due to the shearing action of the auger flights, and the CP should be aware of such artefacts of drilling methods when reporting.

7.2.6 It is therefore required to comment per Table 1 (see Section 12) on the drilling method used, which may have a material impact on the industrial mineral being reported (Scogings et al., 2017).

8. MINERAL RESOURCE ESTIMATION

8.1 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 considered when evaluating the potential economic viability of an industrial minerals deposit (Harben (1999) in CIM, 2023). 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 (CIM, 2023). Example of considerations for sample collection and analysis include the following:

- collecting a representative sample suite to determine modal mineralogy, particle sizes, or mineral sizes, shapes, textures and morphology;
- analysing for such parameters as colour, brightness and chemistry;
- With many industrial minerals the required analytical methods to test for market acceptance are not available in commercial laboratories. In these cases, either an agreement with an existing industrial mineral company to use its laboratory or setting up a project laboratory with the necessary test equipment will be required. An additional problem is having external laboratory tests done (umpire tests) which need to be resolved to the competent person's satisfaction.
- Bulk samples for process ('metallurgy') tests and market acceptance will be required for both Mineral Resource and Mineral Reserve estimation.

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

- the physical and chemical properties of the subject mineral/s and the expectation of their beneficiation into a saleable product/s;
- the quantity and spatial relationship of these properties within the mineral deposit;
- the relationship of the physical and chemical properties of the mineral to the market requirements (CIM, 2023).

8.3 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, which may be caused by grain size (e.g., large crystals in pegmatites may distort sample results) (CIM, 2023). 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) (see Appendix 2 in Section 14.2). The precision of the analytical method/s 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 for a large sample population (CIM, 2023). In addition, composite and bulk sample tests are often applicable to support Mineral Resource and Mineral Reserve estimation.

8.4. CHEMICAL ANALYSES, QUALITY AND PERFORMANCE CHARACTERISTICS

8.4.1 Chemical analyses may not always be relevant for material evaluation, and other quality and performance characteristics may be more applicable and acceptable as the basis of the reporting. Where necessary, chemical analysis is used to verify the presence of possible minerals and related alteration (e.g. Appendix 2 in Section 14.2) that could produce important quality defects in finished products (CRIRSCO, 2019).

8.4.2 Chemical/compositional analysis may also identify mineral components and/or assemblages and are used to predict the future technical requirements of the quarrying-processing equipment and related tools (CRIRSCO, 2019).

8.4.3 Qualitative and aesthetic qualities (colour, grain, texture and their regularity in distribution) and/or their structural performance characteristics (compression and flexural strength, abrasion resistance, porosity, ability to be polished, radioactivity content, etc.) may be more important for the market and applicable and acceptable as the basis of the reporting (CRIRSCO, 2019).

8.4.4 If there is potential for ancillary products or by-products, or for mining/quarrying or processing waste, to be sold off-site for subsidiary uses in addition to the planned sales of primary products (i.e., other uses for non-saleable quarry production, such as secondary aggregate, engineering or other fill, sand or powder, or paving stone), the CP should reflect this in their report and comment on any significant implications (e.g., reductions in the amount of non-saleable material that could otherwise be used as a restoration material, minimisation of waste and related lower waste management costs and environmental impact) (CRIRSCO, 2019).

8.4.5 The factors underpinning the estimation of Mineral Resources (and Mineral Reserves) for industrial minerals are often the same as those for other deposit types covered by the SAMREC Code. It may be necessary, prior to the reporting of a Mineral Resource (or Mineral Reserve), to account for certain key characteristics, features or qualities of the target material. These may include final product specifications, proximity to markets, type, structure and demand of the market (very different area by area and, excluding some very well-established materials, possible changes in market requirements, and general product marketability) (CRIRSCO, 2019).

8.4.6 Many industrial mineral deposits may be capable of yielding different products (different materials and/or different market grades within the same material), suitable for more than one application and/or specification, or the production of more than one finished or semi-finished product, and for more than one final application and/or specification. They often are sold in the market with different prices (CRIRSCO, 2019).

8.5 DATA CONSIDERATIONS FOR THE MINERAL RESOURCE DATABASE

8.5.1 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 (CIM, 2023).

8.5.2 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 (CIM, 2023).

8.5.3 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 (CIM, 2023).

8.5.4 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 (CIM, 2023).

8.5.5 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 Appendix 3 in Section 14.3. Sample testing should include tests that will address those physical and chemical properties that relate to the specifications for the end product (CIM, 2023).

Examples of factors relating to ultimate product quality specifications for an industrial mineral can include moisture, colour, hardness, abrasiveness, bulk density or SG, particle size and dimensions (e.g., aspect ratio of wollastonite), particle size distribution, rheology, ceramic and refractory properties, deleterious elements or compounds (e.g. Hg and Pb in pharmaceutical or food grade minerals), minimum content of desired elements or compounds (e.g., Li_2O content in a spodumene concentrate) (see Appendix 2 in Section 14.2).

8.5.6 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. Competent Persons are encouraged to consider additional items as they may relate to any additional product quality specifications as appropriate (CIM, 2023).

8.5.7 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) (CIM, 2023).

8.5.8 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 CP 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. In some cases, standard testing and analytical protocols can be obtained from either industry-specific organisations or from national or international standards-developing organisations. (e.g., American Petroleum Institute ‘API’; ATSM International, formerly known as the American Society for Testing and Materials; International Organization for Standardization ‘ISO’) (CIM, 2023).

8.5.9 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 (CIM, 2023).

8.6 GEOLOGICAL AND MINERALISATION MODELLING

8.6.1 When preparing geological, structural, weathering, and mineralization models of an industrial minerals deposit, knowledge of the anticipated product quality specifications is key. The CP 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 (CIM, 2023).

8.6.2 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 (CIM, 2023).

8.6.3 However, 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 (CIM, 2023).

Due to the large number of permutations, a detailed listing of all deleterious elements or minerals for all industrial minerals deposits is not possible.

8.6.4 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. CPs 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 (CIM, 2023).

8.7 MINERAL RESOURCE ESTIMATION

8.7.1 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 CPs and Subject Matter Experts 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 (CIM, 2023).

8.7.2. Cut-Off Grade (or Value) Estimation

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 SAMREC. The application of reasonably developed technical and economic parameters is a key concept towards meeting this requirement (CIM, 2023).

- **Price**: 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 CP 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 (CIM, 2023).
- **Market Study**: The prices for specific industrial minerals products are often set on a contract basis. While prices for a range 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 (CIM, 2023).
- **Metallurgical test work**: The CP should also ensure that sufficient test work has been completed to indicate that the ultimate product(s) 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 (CIM, 2023).
- **Location & Transport**: Additional key inputs for evaluating RPEEE are the deposit location and the anticipated transportation costs involved with the envisaged 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 (CIM, 2023).

8.7.3 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 CP 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 (CIM, 2023).

8.7.4. Classifying the Mineral Resource

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 (CIM, 2023).

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 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 (CIM, 2023).

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 CP. Where an industrial mineral deposit can produce several distinct products from different parts of the deposit, the CP 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 (CIM, 2023).

8.7.5 Mineral Resource Report

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 CP should ensure that all relevant quality factors and other relevant input parameters are included as part of the Mineral Resource reporting (CIM, 2023).

All Mineral Resource statements to the public domain, including those for industrial mineral deposits, must ensure that the RPEEE requirements of the SAMREC Code are met.

9. MINERAL RESERVE ESTIMATION

9.1 In addition to the modifying factors described in SAMREC 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 (CIM, 2023).

9.2 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 (CIM, 2023).

9.3 In addition to the guidance in SAMREC, 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.

9.4 MARKET FACTORS

9.4.1 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 (CIM, 2023).

9.4.2 The CP 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 (CIM, 2023).

9.5 PRODUCT SPECIFICATIONS

9.5.1 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 (CIM, 2023).

9.5.2 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 CP should be aware of all such requirements and account for them in Mineral Reserve estimates. (CIM, 2023)

9.5.3 The CP 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 CP should ensure that laboratory test procedures adequately reflect the proposed production process. In some cases, bulk samples exceeding 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 (CIM, 2023).

9.6 ECONOMIC ANALYSIS

9.6.1 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 SAMREC 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 (CIM, 2023).

9.6.2 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 (CIM, 2023).

9.7 MINERAL RESERVE REPORTS

9.7.1 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. All public disclosure of Mineral Reserve estimates for industrial minerals made by, or on behalf of, an issuer and intended to be, or reasonably likely to be, made available to the public must comply with the requirements of SAMREC, as amended from time to time (CIM, 2023).

9.7.2 Reporting of Mineral Reserves should recognise that chemical and/or physical specifications constitute a significant factor in the economic potential of an industrial minerals deposit. In reporting Mineral Reserves, the CP should ensure that all relevant quality factors and other relevant input parameters are included as part of the Mineral Reserve statement (CIM, 2023).

10. DIMENSION STONE

There are certain unique characteristics of dimension stone that require specific assessment and reporting.

10.1 Appendix 7 to the CRIRSCO Template defines dimension stone as "*a technical/commercial term that includes all natural stones that can be quarried in blocks of different dimensions and processed by cutting or splitting, and that possess the technical and aesthetic properties required for their use in the building and construction industries*" (CRIRSCO, 2019).

Guidance	*In both mining methods and fields of application, dimension stone is distinct from any other material derived from natural rocks (such as: aggregates, cement materials, crushed stone, etc.) Whilst other materials are almost exclusively used for load bearing and filling functions and are largely utilised in public works, dimension stone materials offer special qualitative features which mean they can be used for different purposes and they can perform both structural and decorative architectural functions.* *In general, dimension stones can be quarried in regular and/or unshaped blocks by using different mining methods (drilling & splitting, diamond wire and diamond chain-saw cutting) and processed (cut, polished, and subjected to other surface treatments) to produce semi-finished products (slabs) and finished products (tiles and cut-to-size products).*

10.2 Qualitative and aesthetic qualities (colour, grain, texture and their regularity in distribution) and/or their structural performance characteristics (compression and flexural strength, abrasion resistance, porosity, ability to be polished, radioactivity content, etc.) may be more important for the market and applicable and acceptable as the basis of the reporting (CRIRSCO, 2019).

10.3 Many dimension stone deposits may be capable of yielding different products (different materials and/or different market grades within the same material), suitable for the production of more than one finished or semi-finished product, and for more than one final application and/or specification. They often are sold in the market with different prices. If considered material by the Competent Person, estimates for such multiple products should be included either separately or as percentages of the bulk of the deposit (CRIRSCO, 2019).

10.4 If there is potential for ancillary products or by-products, or for quarrying or processing waste to be re-utilised or to be sold off-site for subsidiary uses, in addition to the planned sales of the primary products as described above (e.g., aggregate, sand and powder as industrial mineral, building and paving stone, etc.), the CP should reflect this in the report and comment on any significant implications (e.g., reduction in the amount of non-saleable material, minimisation of waste and related lower waste management costs and environmental impact) (CRIRSCO, 2019).

Guidance	*The factors underpinning the estimation of Mineral Resources and Mineral Reserves for dimension stones are often not the same as those for other deposit types covered by the Template.* *It may be necessary, prior to the reporting of Mineral Resources and Mineral Reserves, to take account of certain particular key characteristics/features of the target material specific to dimension stone.* *These may include final product specifications, proximity to markets, type, structure and demand of the market (very different area by area and, excluding some very well- established materials, possible changes in market requirements, and general product marketability.* *These may also depend mainly on the market quality of the target material (colour, grain, texture and their regularity in distribution). A correct professional evaluation of the Market Quality, made by the CP in different ways, is the key to evaluating the final product marketability and is a key Modifying Factor in definition of Mineral Reserves for dimension stone.*

	The CP should explain in detail in the report, the method utilised for the Market Quality evaluation of the target dimension stones, and in case of the market the references cited, together with documents referenced or used. *Sometimes, otherwise non-saleable materials are sent off-site as mining waste or as other materials of potential economic value.* *Care should be taken to ensure that such materials are not 'double-counted' by being included as Mineral Resources and Mineral Reserves at both the site of production and at the site of reception where they are considered as useable products (with or without further processing to make them marketable) (CRIRSCO, 2019).*

10.5 In contrast with industrial minerals, for which it is common practice to report the saleable (or useable) product rather than the 'as mined' product, for dimension stones production the raw block or 'as mined' product is usually reported in all its forms, shapes and dimensions. These are also factors that drive the market and the success of a dimension stone project (CRIRSCO, 2019).

10.6 The Public Report may contain either the geological or commercial names of target dimension stones. In any case an explanation of these terms should be included in the report (CRIRSCO, 2019).

10.7 Other industry guidelines on the estimation and reporting of dimension stones may be useful but will under no circumstances override the provisions and intention of this Guideline for public reporting (CRIRSCO, 2019).

10.8 Many of the Modifying Factors are more relevant and specific to dimension stones than to metalliferous minerals. In particular, the legal control of MRMR may be very important, as well the permitting or consenting status, due to the local nature and often simple structure of the planning process for non-strategic and non-government owned minerals (CRIRSCO, 2019).

Guidance	*Reports should make clear the 'permitted' or 'non-permitted' status of the Mineral Resources and Mineral Reserves, and in addition Mineral Reserves particularly should only be quoted where the operator has legal control.*

10.9 MRMR of dimension stone deposits with the same material and owned by the same company, potentially serving localised/domestic or regional markets, may be reported on an aggregated basis on an appropriately defined geographical basis to reflect the particular economic constraints of the deposits being reported without divulging commercially sensitive information (CRIRSCO, 2019).

10.10 In certain cases, commercial sensitivity may prevent the publication of detailed information and data associated with Mineral Resources and Mineral Reserves of dimension stone deposits, and in such cases this should be clearly justified in the report (either prepared for an individual site or on an aggregated basis) (CRIRSCO, 2019).

10.11 These may also depend mainly on the market quality of the target material (colour, grain, texture and their regularity in distribution). A correct professional evaluation of the Market Quality, made by the CP in different ways, is the key to evaluating the final product marketability and is a key Modifying Factor in definition of Mineral Reserves for dimension stone (CRIRSCO, 2019).

11. PUBLIC REPORTING

11.1 Public reporting of industrial minerals projects is not restricted to documents compiled by/for listed companies in respect of on-going Stock Exchange requirements (Refer SAMREC Code Clause 3 for details). Public reports include any/all documents prepared for the purpose of informing investors, potential investors or other interested parties that may find their way into the public domain. Public reporting includes but are not limited to annual and quarterly company reports, media releases, information memoranda, technical papers (e.g. Competent Persons' Reports (CPRs)), website postings and public presentations. It is recognised that situations may arise in which supporting documentation, prepared by a CP for company or other private use, may not specifically be prepared in terms of the Code – in such situations, the documentation shall include a prominent statement to this effect. It is, however, recommended by the SAMREC Working Group, that the principles and standards in the Code and this Guideline document should be adopted as a minimum standard for all industrial mineral related documentation.

11.2 This Guideline addresses matters that relate to the public reporting of industrial minerals of all forms that are generally sold according to their product specifications and market acceptance.

11.3 When reporting information and estimates for industrial minerals, all the key principles and purpose of the SAMREC Code apply.

11.4 Unless it is a specific aspect of their instructions to reflect the range of product mixes and target markets for the deposit, the CP should normally report the MRMR within the framework of an existing mining plan, feasibility study or established set of product and market assumptions and objectives (CRIRSCO, 2019).

11.5 In certain cases, commercial sensitivity may prevent the publication of detailed information and data associated with MRMR of industrial minerals, and in such cases this should be clearly justified in the report (either prepared for an individual site or on an aggregated basis).

11.6 For industrial minerals, it is common practice to report the saleable (or useable) product rather than the 'as mined' product, as it is recognised that commercial sensitivities may not permit the publication of MRMR in the latter format which is the preferred style of reporting within the SAMREC Code (after CRIRSCO, 2019).

11.7 It is important that, in all situations where the saleable or usable product is reported, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported (CRIRSCO, 2019).

11.8 MRMR of industrial minerals serving localised or regional markets may be reported on an aggregated basis on an appropriately defined geographical basis to reflect the economic constraints of the deposits being reported without divulging commercially sensitive information (CRIRSCO, 2019). If considered material by the CP, such multiple products should be quantified either separately or as a percentage of the bulk of the deposit.

11.9 These may also depend mainly on the market quality of the target material (e.g., colour, grain, texture and their regularity in distribution). An appropriate professional evaluation of the Market Quality, made by the CP in several different ways, is the key to evaluating the final product marketability and is a key Modifying Factor in definition of Mineral Reserves for dimension stone (CRIRSCO, 2019).

11.9.1 The report may contain either the geological or commercial names of target dimension stones. In such case, an explanation of these terms should be included in the report (CRIRSCO, 2019).

11.10 Reports should make clear the 'permitted' or 'non-permitted' status of the MRMR, and, in addition, Mineral Reserves particularly should only be quoted where the operator has legal control (CRIRSCO, 2019).

Guidance	*It should be noted that many of the Modifying Factors are more relevant and/or specific to industrial minerals than to metalliferous minerals. Specifically the legal control may be more important, as well as the permitting status, due to the local nature of the planning process for non-strategic and non-government owned minerals (CRIRSCO, 2019).*

12. SAMREC TABLE 1 SPECIFICS FOR INDUSTRIAL MINERALS

Table 1 SAMREC Table 1 Specifics for Reporting of Industrial Minerals (CRIRSCO, 2019)

<table>
<tr><th colspan="3"></th><th>Exploration Results</th><th>Mineral Resources</th><th>Mineral Reserves</th></tr>
<tr><td colspan="6">Section 12: Reporting of Industrial Minerals</td></tr>
<tr><td rowspan="8">12.1</td><td rowspan="8">Specific for Reporting of Industrial Minerals</td><td>(i)</td><td colspan="3">Confirm that reports on Industrial Mineral deposits take cognisance of Section 79 of the Code and Sections 1 to 9 of Table 1.
Details of the drilling method(s) used must be fully described.</td></tr>
<tr><td>(ii)</td><td colspan="3">Describe the exploration or geologically specific specialised industry techniques appropriate to the minerals or stone under investigation.</td></tr>
<tr><td>(iii)</td><td colspan="3">Describe the nature and quality of sampling or specific specialised industry standard measurement tools appropriate to the minerals or stone under investigation.</td></tr>
<tr><td>(iv)</td><td colspan="3">Describe the appropriate saleable product qualities being reported.
Describe the basis for reporting (physical or chemical parameters, air-dried basis, dry basis, etc).
Reporting of deleterious chemical elements, or physical parameters is required.</td></tr>
<tr><td>(v)</td><td colspan="3">State assumptions regarding in particular mining/extraction methods, infrastructure, metallurgy/processing, environmental and social parameters.
Where no mining-related assumptions have been made, this should be explained.</td></tr>
<tr><td>(vi)</td><td colspan="3">Disclose and discuss the marketing parameters, customer specifications, testing, and acceptance requirements.</td></tr>
<tr><td>(vii)</td><td colspan="3">Discuss the nature, amount and representativeness of metallurgical/processing studies completed which form the basis for the various saleable materials that may be priced for different chemical and physical characteristics.</td></tr>
<tr><td>(viii)</td><td colspan="3">Present the defined reference point of the reported tonnages and grades/qualities.
Where the reference point is the place for a saleable product, a clarifying statement is included to ensure that the reader is fully informed as to what is being reported.
State whether the tonnages and grades/qualities of the material are as delivered to the plant of after recovery.</td></tr>
<tr><td>12.2</td><td>Additional for Reporting of Dimension Stone</td><td>(i)</td><td colspan="3">The appropriate saleable product qualities reported, including colour, grain, texture and their regularity in distribution.
The basis for reporting (physical or chemical parameters, compression and flexural strength, abrasion resistance, porosity, polishability, etc) should be reported,
Reporting of deleterious chemical elements, radioactivity or physical parameters is required.</td></tr>
</table>

13. REFERENCES

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14. APPENDICES

14.1 Appendix 1: Summary List of Common Industrial Minerals and Some Markets

Minerals	Markets
Aggregates (sand, stone, gravel)	Construction
Attapulgite (palygorskite)	Agriculture, drilling, pet litter, oil adsorbants
Ball Clay	Ceramics
Barite	Oil and gas drilling, paint, coatings, X-Ray protection
Bauxite	Refractories, water treatment (alum), abrasive (brown fused alumina), cement, chemicals
Bentonite (smectite)	Drilling, civil engineering, pet litter, metal casting, iron ore and chromite pelletising, edible oil refining, mineral oil refining, paper, wine and fruit juice clarification
Borates	Glass, foundry
Carbonates (calcium and magnesium)	Agriculture, paint, paper, plastics
Chromite	Metal casting, pigment for green glass, refractories, chrome chemicals
Coal dust	Metal casting
Corundum	Abrasives mainly all produced by fusing bauxite or alumina
Diamond (Industrial quality)	Abrasives
Diatomite	Absorbents, construction, filtration
Dimension Stone	Building and construction
Dolomite/Dolomitic Marble	Refractory, mineral filler, agriculture
Feldspar and Nepheline Syenite	Ceramics, glass, abrasive, filler
Fluorspar	Iron and steel, aluminium smelting, chemicals
Garnet (Industrial quality)	Abrasives
Graphite	Batteries, lubricants, refractories, metal casting, fire retardant, foil, pencils
Gypsum	Agriculture, cement, drilling, gypsum boards
Halite (Salt)	Chemicals, food, de-icing. In many cases of chemical use, especially for chlorine/caustic soda uses, "salt-in-brine" is solution mined salt that is never evaporated or dried to solid salt.
Kaolin	Ceramics, paint, paper, refractories
Kyanite/Sillimanite/Andalusite	Refractories
Limestone/Marble	Cement, lime, metallurgical, paper/plastic/paint, mine dust explosion suppression, agriculture
Lithium minerals (e.g. petalite, spodumene)	Technical applications: ceramics, glass, iron and steel castings. Chemicals (e.g. LiOH, Li_2CO_3): batteries, aluminium smelting, lubricants.
Magnetite	Density separation of minerals, e.g. coal
Mica	Paint, plastics, oil drilling, welding rods
Olivine	Refractories
Perlite	Agriculture, construction, filtration
Phosphate	Fertiliser, phosphoric acid
Potash/Potassium minerals	Fertiliser
Pumice	Construction, pozzolanic material in cement, abrasives, absorbents
Quartz	Ceramics, glass, electronics, ferrosilicon, silicon
Shale	Cement
Silica sand (quartz grains)	Ceramics, glass, foundry, filtration, fracking
Soda Ash	Glass, foundry, detergents
Talc and Pyrophyllite	Paint, paper, plastics
Titanium minerals	Pigments, welding
Vermiculite	Agriculture, horticulture, construction, fire resistance
Wollastonite	Ceramics, coatings, plastics
Zeolites	Absorbents
Zirconium minerals	Ceramics, refractories, chemicals, foundry

14.2 Appendix 2: Examples of Potential Deleterious Components in Industrial Mineral Deposits

Industrial minerals / rocks	Elements	Minerals	Mineral and geological textures
Aggregates	S, Cl	sulphides; reactive silica	joints, alteration, weathering
Andalusite	Fe, Ti, Si, K, Na	garnet, staurolite, magnetite	host rock softened by weathering, size distribution
Ball Clay	Fe	quartz	
Barite	Hg, Cd, Al, Si	quartz, sulphides	
Bentonite/smectite	S, Cl	quartz, feldspar, gypsum, salt	weathering may improve quality, coarse grained impurities e.g. quartz
Chromite	Fe, Si	plagioclase, pyroxene, clay	oikocrysts with entrained small chromite grains
Coal dust	S	sulphides	
Dimension Stone	S	sulphides, clays	joints, alteration, weathering
Feldspar and Nepheline Syenite	Fe, Ti	biotite, amphibole, pyroxene, zircon	mineral intergrowths
Graphite	S, Si, Fe, Mg, Ca	sulphides, quartz, clay	bimodal flake size populations (e.g., fine graphite entrained in felsic porphyroblasts, graphite split by secondary clay in weathered deposits)
Kaolin	Fe, K, Na	quartz, feldspar, goethite	fine or coarse grained, iron staining
Lithium minerals	Fe	iron in the spodumene structure, iron-rich minerals in mafic country rocks	Fine-grained spodumene-quartz intergrowths (SQI) difficult to liberate
Mineral Sands	Th	monazite	
Talc	Fe	serpentine, asbestiform minerals	
Quartz, Silica sand	Fe, Ti, Al, Zr	magnetite, ilmenite, goethite, zircon	mineral coatings e.g. goethite staining, entrained Fe-Ti minerals

14.3 Appendix 3: Examples of Industrial Minerals by Market, with Notes about Process and Test Methods

Industry Group	Examples of Minerals Uses	Examples of Process Methods	Examples of Test Methods	General comments
Abrasives	Garnet, staurolite, silica (quartz) sand	Screening as part of heavy mineral sands processing plus some hard rock mining of garnet	Particle size analysis, mineralogy, density	Silica sand was historically important but due to air-borne silica restrictions (respirable crystalline silica) it is rarely used now. Mineral refinery slags are widely used for abrasive 'sand' blasting. Brown fused alumina with less than 7% Fe_2O_3 used as an abrasive as is white fused alumina. Garnet sized 80 mesh used for water jet cutting
Agriculture	Phosphates	Flotation	Chemistry, soil availability	
	KCl	Solution and crystallisation	Chemistry	%K_2O equivalent
	Attapulgite	Drying, crushing & screening	Viscosity	Viscosity in saline water
	Gypsum	Crushing, screening and milling	Particle size analysis, chemical analysis	Gypsum is used in a wide range of industries with different specifications. Secondary gypsum is commonly sourced from phosphate fertiliser plants
	Limestone	Crushing, screening and milling	Chemical analysis - specification based on calcium carbonate equivalent	Transport distance to customer typically needs to be less than 100 km
Cement	Limestone	Crushing, screening	Chemical analysis, particle size, moisture	New projects will need bulk sample tests through bench laboratory/pilot plants
	Shale	Crushing, screening	Chemical analysis, particle size, moisture	
	Gypsum	Crushing, screening	Chemical analysis, particle size, moisture	
Ceramics	Ball clay	Shredding, air floated powder, slurry	Plasticity, chemical analysis	Whereas white ceramic products require low iron, iron is not a critical contaminant in red ceramics such as earthenware. However, constituents such as Fe (and Na, K, Al and Si) must remain consistent to maintain desired colour and firing properties. Ball clay is often carbonaceous, contains illite (mica) and adds plasticity and green strength
	Feldspar (Na, K)	Selective mining, crushing, milling, flotation	Chemical analysis, fired colour	
	Kaolin	Wet separation, magnetic separation	Chemical analysis, LOI, particle size and shape, mechanical strength, fired colour, rheology	
	Nepheline syenite (Na, K)	Selective mining, crushing, milling, flotation	Chemical analysis, mineralogy	
	Petalite		Chemical analysis, mineralogy	
	Silica sand	Size separation, washing	Chemical analysis	
	Zircon	Mineral sand processing	Size analysis and chemical analysis	
Civil engineering	Bentonite	Drying, soda ash activation (for Ca bentonites), screening and milling with air classification	Moisture, Particle size, Free Swell, Viscosity, Fluid Loss, grit content, cement grout bleed	Performance parameters often set by end user for site-specific conditions, e.g., tunnels (cement grout bleed) foundation piling (viscosity) or geosynthetic clay liners (swell and fluid loss). ASTM methods may be required
Construction	Sand	Washing, drying and screening	Mineralogy, size distribution, moisture	Specifications vary between governmental agencies and industrial users; e.g. rail ballast versus road aggregate. ASTM methods may be required
	Aggregate	Crushing and screening	Mineralogy, size analysis, civil engineering tests	

	Vermiculite	Screening, air separation (winnowing) and exfoliation by flash calcining	Bulk density for exfoliated product	Used for light weight concrete, horticulture and fire resistance
Drilling	Bentonite, hectorite	Drying, soda ash activation, screening and milling. Treated with quaternary alkylammonium ions (organoclay) for oil-based drilling fluids, or polymers to enhance rheology for water-based fluids	Viscosity (V600 & V300, Marsh Funnel), Yield Point, Plastic Viscosity, Fluid Loss, grit content, moisture	American Petroleum Institute (API) standards for oil and gas drilling. Otherwise, specifications set by end user for site-specific conditions
	Barite	Selective mining, density separation	Density (SG), particle size, chemical purity	
	Attapulgite, Sepiolite	Drying, milling with air classification	Viscosity, grit, moisture	
	Silica 'frac' Sand	Sand washing, screening, drying	Particle size, particle strength	
Energy Minerals	Flake graphite	Crushing, flotation, screening to produce feedstock for spheronisation	Chemistry (carbon and trace elements), particle size distribution	For spheronisation, C>95% and typically finer than 150 micron (100 mesh). Final spheroidal graphite ~10-20 microns. Synthetic graphite may also be used in batteries
	Lithium brines, lithium clays, Lithium minerals e.g. spodumene, lepidolite	Solution mining and precipitation from brines. Hard rock mining with crushing, density separation and/or flotation. Clay sources e.g. hectorite may have lithium extracted by chemical leaching	Chemistry and metallurgical test work	Spodumene the preferred hard rock lithium mineral. Lepidolite is used in China. Lithium mineral concentrates are used as feed for conversion to Li_2CO_3 or LiOH
Foundry	Silica Sand (quartz)	Sand washing, screening, drying	Size analysis, grain shape, moisture, purity	American Foundry Society (AFS) used for size and other specifications
	Chromite Sand	Crushing, density separation (spirals)	Size analysis, chemical analysis, turbidity, acid demand, moisture	
	Bentonite	Drying, soda ash activation (for Ca bentonites), screening and milling with air classification	Green and Dry compression and Wet tensile strength tests, cation exchange capacity, moisture, swelling index	Strength tests after calcining at 600°C (thermal durability) should be included
	Coal Dust	Milling with air classification	Coal tests e.g. ash, volatile content, moisture	High volatile coal
Glass	Feldspar (Na, K)	Crushing and milling, sometimes with further beneficiation such as flotation. Selective mining and ore sorting may be required	Chemistry, fused colour and fusion properties	Feldspars contribute alumina, but alkali content is important as are low Fe and Ti impurities
	Limestone	Crushing and milling with further beneficiation such as flotation possible	Chemical analysis, particle size, moisture	
	Silica	Mining of silica rock or sand	Chemical analysis, particle size, moisture	Silica (quartz) is the main ingredient in glass. As a rule of thumb, iron content is considered to be the main impurity

	Soda Ash	Solution mining and precipitation	Chemical analysis	Added as a flux
Fibreglass	Silica, feldspar, limestone, borates, lithium (petalite and spodumene)	Wide range of mining and processing techniques	Chemical analysis, particle size, moisture	While silica is the basis of fibreglass chemistry, there are special raw materials also required such as borates, fluorspar and iron oxide
Speciality Glass	Wide range including lithium, boron, colouring oxides, cerium and other rare earths, fluorspar, lead, potash, magnesia and zirconium minerals as well as the standard silica and feldspar	Wide range of mining and processing techniques	Chemical analysis, fused colour, particle size	Market knowledge is key in supplying speciality glass markets. Specifications may be very stringent, e.g., silica sand (quartz) for photovoltaic glass generally requires less than 150 ppm Fe_2O_3.
Paint, Paper & Plastic	Limestone, marble, mica, talc, kaolin, wollastonite, bentonite	Crushing, flotation (where required to remove impurities) and milling with air classification including specialised micronised milling and classification. Chemical bleaching of kaolin to improve brightness	Chemistry, colour (whiteness, but full colour determination required), particle size analysis as well as specialist industry tests. LOI important for kaolin	Different industries can have quality specifications that are specific to not only the industry group but also between different companies. Minerals are used as fillers and performance enhancers
Iron & Steel	Limestone/Dolomite	Crush to set sizes	Chemical, particle size measurement, decrepitation tests	Minimal fines
	Fluorspar	Crushing, hand sorting and gravity separation	Chemical analysis (CaF_2 content), particle size	Minimal fines
	Bentonite	Drying, soda activations, milling	Mechanical strength, water absorption, viscosity, swelling index	Used as a binder to pelletise magnetite fines for iron and steel smelting, and pelletising chromite fines for ferrochrome smelting
Refractories	Refractory bauxite	Calcining to various temperatures	Chemical and refractory tests	Generally maximum 2% Fe_2O_3 on a calcined basis, Alumina 86+% low alkalis
	Andalusite	Heavy media and magnetic separation	Chemistry, particle size and refractory tests	Sillimanite and kyanite also used but to lesser degree except for India and the USA
	Chromite	Density separation	Chemistry, particle size and refractory tests	Used in chrome magnesia or magnesia chrome refractories. Also used as a foundry moulding sand for steel castings
	Graphite	Flotation and screening	Chemistry (carbon content), particle size distribution, thermal stability, moisture	Broad range of specifications, dependent on refractory product
	Kaolin	Crushing and calcining	Chemical and refractory tests	Flint and fire clays
	Magnesia		Chemical and refractory tests	MgO content important
Welding	Fluorite, mica, rutile, manganese oxide, salt, KCl, graphite, Na and K feldspar, quartz, montmorillonite, talc, magnetite, zircon, calcined bauxite		Chemistry and particle size	Quantities used are small hence commercial grades are used