NSSGA

NATIONAL STONE, SAND & GRAVEL ASSOCIATION

MINERAL IDENTIFICATION & MANAGEMENT GUIDE

NOTICE TO USERS OF THIS GUIDE: This Guide, in its original and updated forms, is neither intended to be, nor should be, relied upon as an Industry Standard or Best Practice. While NSSGA believes the Guide contains reasonable suggestions for helping many organizations identify and manage the presence of Protocol Mineral Fibers (as defined herein), Users of this Guide should consider these suggestions from among the many possible suggestions or sources of information available to them.

Considering the many possible differences across the thousands of U.S. aggregates operations, this Guide may or may not be suitable for any specific operation or part of a specific operation. Accordingly, it is the responsibility of the Users of this Guide to determine which suggestions, if any, they choose to use, modify, or ignore.

The program outlined in the Guide is intended to be tailored by qualified geologists and other professionals on behalf of the User, so that it is appropriate for the geologic, production, and other realities of one or more specific Users' sites.

NSSGA makes no warranty of any kind for the suitability of the Guide for any purpose.

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ROCK COMPANY[1] MINERAL IDENTIFICATION & MANAGEMENT GUIDE

INTRODUCTION

A. Purpose

This Mineral Identification & Management Guide ("Guide") provides a range of investigatory tools that may be used to assess whether *Protocol Mineral Fibers* (PMFs) are present at one or more of Rock Co.'s rock quarrying sites and/or sand & gravel production sites.

Protocol Mineral Fibers are defined in this Guide to include "asbestos" and "all other asbestiform amphiboles, asbestiform serpentines, and all durable asbestiform zeolites."

Stone, sand, and gravel are quarried or mined as aggregates from many parts of the U.S. where igneous and/or metamorphic rocks formed or were transported millennia ago. Certain of these rock materials have the potential to contain PMFs as minor constituents.

The goals of the program outlined in the Guide are to identify and manage areas where PMFs may occur, and to avoid producing aggregate materials that release airborne PMFs in excess of federal, state, or local limits for asbestos exposure, including Permissible Exposure Limits established by OSHA and MSHA. More specifically, the Guide is designed to help determine the presence of PMFs (if any), and their mineralogy, approximate quantity, and distribution at Rock Co.'s production operations.

The heart of the Guide involves matters of geology and mineralogy. Accordingly, Rock Co. has secured the services of one or more qualified geologists (hereinafter "the geologist") and other professionals to implement, administer, and maintain the program.

B. Protocol Mineral Fibers

1. **Asbestos PMFs**. "Asbestos" is a commercial term that includes six silicate minerals that belong to the serpentine and amphibole mineral groups—but are "asbestos" only when those minerals *crystallized in nature as asbestiform fibers* (i.e., crystallized with the mineralogical habit of "asbestos").

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[1] The term "Rock Co.," as used throughout this Guide, is a placeholder for the insertion of the name of the organization that elects to use the Guide (the "User").

Table 1 provides information about these six minerals. Note again that the minerals are (a) classified as "asbestos" only when they formed in nature with the asbestiform mineral habit; and (b) not classified as "asbestos" when they formed in nature with the nonasbestiform mineral habit.

Table 1. Asbestos and Nonasbestos Forms of Six Minerals.

Mineral (and Crystalline Habit)	Commercial or Common Name	CAS No.
Asbestiform Serpentine	Chrysotile Asbestos	12001-29-5
Asbestiform Riebeckite	Crocidolite Asbestos	12001-28-4
Asbestiform Cummingtonite-Grunerite	Amosite Asbestos	12172-73-5
Asbestiform Anthophyllite	Anthophyllite Asbestos	77536-67-5
Asbestiform Tremolite	Tremolite Asbestos	77536-68-6
Asbestiform Actinolite	Actinolite Asbestos	77536-66-4
Nonasbestiform Serpentine	Antigorite (see Note 4, below)	12135-86-3
Nonasbestiform Riebeckite	Riebeckite	17787-87-0
Nonasbestiform Cummingtonite-Grunerite	Cummingtonite-Grunerite	14567-61-4
Nonasbestiform Anthophyllite	Anthophyllite	17068-78-9
Nonasbestiform Tremolite	Tremolite	14567-73-8
Nonasbestiform Actinolite	Actinolite	13768-00-8

Notes:

1. "Asbestos" is regulated in the U.S. by numerous state and federal agencies, including EPA, OSHA, and MSHA. A full reference to all regulations is beyond the scope of this Guide. The User is encouraged to become familiar with all mineral fiber regulations for the jurisdictions in which they operate.

2. The term "asbestiform" means the mineralogical habit or form of a mineral in which ultra-fine single crystal fibers (fibrils) occur in bundles that can be separated into increasingly finer fiber bundles that typically display curvature.[2]

3. "Asbestos" possesses (certain) properties such as long fiber length and high tensile strength. Under the light microscope, samples exhibit the asbestiform habit as defined by several of the following characteristics: (a) mean aspect ratios ranging from 20:1 to 100:1 or higher for fibers longer than 5 µm, (b) very thin fibrils, usually less than 0.5 µm in width, (c) parallel fibers occurring in bundles, (d) fiber bundles displaying splayed ends, (e) fibers in the form of thin needles, (f) matted masses of individual fibers, and (g) fibers showing curvature.[3]

4. Lizardite (CAS No. 12161-84-1) is another nonasbestiform serpentine mineral. Rarely, asbestiform antigorite may be discovered; for the purposes of this Guide it is considered a PMF.

[2] See, for example, EPA, 1993. "Method for the Determination of Asbestos in Bulk Building Materials" (EPA/600/R-93/116).

[3] (a) National Institute of Standards and Technology (NIST), Certificate of Analysis, Standard Reference Material® 1867a, Uncommon Commercial Asbestos; (b) EPA, 1993.

2. **Other PMFs (Not Asbestos).** It is important to emphasize that Rock Co.'s Guide goes beyond "asbestos" and includes certain asbestiform minerals that Rock Co. has elected to treat as a potentially equivalent hazard as "asbestos." [4]

   These "Other PMFs" include a variety of (a) amphiboles that formed in nature with the asbestiform habit but are not classified as "asbestos" (e.g., asbestiform winchite, asbestiform richterite, asbestiform fluoroedenite, etc.); and (b) naturally occurring "durable asbestiform zeolites" (e.g., erionite). "Other PMFs" are not "asbestos" and they are not currently regulated by most U.S. authorities in the same manner as "asbestos."

   All PMFs exist more commonly in a prismatic crystal growth habit or form (i.e., a nonasbestiform habit or form). These nonasbestiform minerals tend not to grow with parallel alignment, but instead form multi-directional growth patterns. When enough pressure is applied, the crystals fracture easily, fragmenting into prismatic particles called cleavage fragments. While some cleavage fragments are acicular or needle shaped as a result of the tendency to cleave along two dimensions but not along a third, they do not possess the characteristics described above for asbestiform minerals. Furthermore, these cleavage fragments are not associated with asbestos-related diseases, as documented in the published, peer-reviewed scientific literature.

   It is not possible to create asbestos from common rock or cleavage fragments by crushing or processing them. Likewise, cleavage fragments cannot be created from "asbestos." When a PMF occurs in nature, the corresponding nonasbestiform habit of that mineral will also always be present. However, the converse is not always true due to the unique set of geologic conditions necessary for minerals to crystallize in the asbestiform habit.

[4] This Guide includes the "Other PMFs" out of an abundance of caution, based on reports that excess exposures to certain asbestiform fibers (that are not classified as "asbestos") may nonetheless have asbestos-like health effects. However, exposure and health effects data are absent or incomplete for some asbestiform mineral fibers; thus, the inclusion of "Other PMFs" in this Guide does not necessarily mean that they represent an equivalent hazard compared with "asbestos."

C. Section Index

Section 1
Periodic Inspection Program

The Periodic Inspection Program is a key component of this Guide. Field examination by the geologist may identify PMFs—or may simply highlight certain areas where PMFs are more (or less) likely to occur. For example, PMFs are more likely to occur if the rock material in question is metamorphic or igneous.

PMFs are less likely to occur if the rock material is sedimentary or an unconsolidated sediment in which the mineral components and/or depositional history indicate that no amphibole, durable zeolite, or serpentine mineral constituents exist (e.g., a carbonate rock that is not metamorphosed or intruded by igneous materials); or a Sand & Gravel deposit that is not derived from a geologic source terrain with rock that may contain PMFs.

A. Prioritize Operations for Inspection

Producers may operate more than one rock quarry and/or Sand & Gravel site. Before conducting on-site inspections, the geologist and other professionals should review existing information about the various production sites, seek additional information as necessary, and prioritize the sites for potential further action.

Many possible ranking or matrix schemes exist. Following are various suggestions and criteria for consideration; Rock Co.'s geologist and other professionals will use a scheme and criteria they determine to be most appropriate.

This Guide is not intended to apply to submerged deposits of any type.

1. List all production sites.

2. Sort the list of production sites according to likely or known rock characteristics, as listed below, generally in descending order of priority for further action:

    a. Igneous and metamorphic rocks, e.g.:
        - Granite, diorite, gabbro, peridotite, rhyolite, andesite, basalt, diabase, syenite, volcanic tuff, etc.
        - Marble, amphibolite, gneiss, quartzite, schist, serpentinite, etc.

    b. Alluvial deposits (with igneous or metamorphic rock origin, especially from a geologic terrain with rocks known to contain PMFs, or for which the origin is unknown);

    c. Metamorphic rock (limestone or dolomite altered by metamorphism or igneous intrusion);

   d. Sedimentary rock (unaltered by metamorphism or by igneous intrusion);

   e. Alluvial deposits (without igneous or metamorphic rock origin);

   f. Greenfield sites where any of the above conditions exist (see Section 3, Qualitative Geologic Survey).

3. Refine the sorted order with additional information. For example:

   a. Published geologic maps including drainages;

   b. Geologic literature, historical mine databases; etc. For example:
      - USGS Open File Reports (Van Gosen): 2005-1189 (v.2), 2006-1211 (v.1), 2007-1182 (v.1), 2010-1041 (v.1)
      - USDA-NRCS National Cooperative Soil Survey database
      - MSHA fiber exposure data
      - EPA references to mineralogical examinations of quarries

   c. Data from any previous site inspections (e.g., core drillings, air monitoring, conditions reported by a geologist or other reliable source, etc.).

   d. Alluvial deposits with igneous or metamorphic rock origin may be more complicated to prioritize. Variables that influence the presence of PMF's include:

      - Proximity to rock types known to produce PMFs
        - Source materials less than < X miles from site
        - Source materials X to Y miles from site
        - Source materials > Y miles from site

      - Characteristics, dimensions, concentration, and occurrence of PMFs in source rock type;

      - Size, maturity, and gradient of drainage;

      - How often drainage may intersect rock type(s) producing PMFs;

      - History of flooding/annual rainfall in region;

      - Alluvial deposits of uncertain origin (but unlikely to originate within or be intersected by igneous or metamorphic rocks), may be considered a lower priority for on-site investigation. However, if the deposit is proximate to an ultramafic or metamorphic or any geologic unit that may contain PMFs, the geologist may assign a priority level for further investigation.

e. Site conditions and characteristics, e.g.:
- Production (TPY, operating months per year, etc.)
- Projected life and expansion potential
- Climate (rainfall, prevailing wind, etc.)
- Product use (e.g., Riprap, road base, concrete, pulverized minerals, etc.)
- Proximity to population centers, highways, etc.

4. The resulting list or matrix comprises Rock Co.'s "Designated Sites."

5. Rock Co. will schedule the "Designated Sites" for Periodic Inspections based on the selection criteria for the site list or matrix, available resources for conducting the Periodic Inspections, and other factors that are likely to change from time to time.

   "Designated Site" status does not in any way imply that PMFs may be found at that site. Indeed, such a determination is the goal of the Periodic Inspections, other activities described in this Guide and elsewhere, and the professional judgement of the geologist and other professionals.

6. Continue to re-prioritize sites based on new information from site inspections, sample analyses, additional literature searches, and changes in site-specific variables (e.g., production metrics, product use, near-term plans for expansion, etc.).

B. Conduct the Periodic Inspections

The geologist and other professionals should develop the following protocol, processes, and tools:

1. A site inspection protocol for Designated Sites that describes the general inspection methods, resources, responsibilities, and inspection report content and format;

2. A sampling and analysis protocol that describes the goals and steps for effective sample collection, examination, and analysis.

Inspect Designated Sites annually or at such periods established by the geologist and other professional staff. The geologist should visually inspect all walls, floors and benches that are safely accessible to determine if PMFs are or may be present. (After the initial field evaluation, future periodic inspections may focus only on the active walls, floors and benches at a given site.)

In some cases, PMF identification may be obvious in the field. In other cases, indications for the potential presence of PMFs may include the type of rock mass or, e.g., the relationship to joints, faults/shear zones, or intrusions.

If the subject property is an undeveloped or a Greenfield alluvial opportunity, the geologist should inspect the property and all reasonably accessible rock faces and drainages for the presence of igneous and metamorphic rock.

PMF's that occur in an alluvial or fluvial resource are typically eroded from a host rock up-gradient. They may then be transported via fluvial processes or wind and distributed in a variable fashion when deposited. Therefore, it is often not possible to positively identify, delineate, or exclude PMFs from the product stream with standard field examination techniques. The geologist should understand the depositional environment and proximity of rock formations known to produce PMFs. Consider examining hand-shoveled samples, test pits, and available product, as well as pond and lake sediments. If PMFs are not found in the sediments, they are unlikely to be found at the site.

The geologist should document the presence and location (e.g., easting, northing, elevation), of PMFs or suspected PMFs, and take photographs and bulk samples. The geologist should examine all samples with a hand lens to determine if they should be evaluated microscopically (see Appendix).

Rock Co. further expects all employees who work at production sites to immediately report to the site management the potential discovery of any PMFs, so that an appropriate investigation may ensue.

Section 2
Program for Testing Settled Dust

The geologist and other professionals create the Settled Dust Sampling Protocol and designate a specific coordinator for the settled dust testing program. Typically, the coordinator will have an environmental health or safety background and may also perform other technical activities such as quality control or geology. Rock Co. may designate one or more coordinators depending on geography, production, number of sites, etc.

The coordinator ensures that all aspects of the Program are properly carried out.

A goal of this Section is to collect samples that reflect the complete production of a site over the sample period. The sampling protocol may vary depending on site conditions and the production and other characteristics at each Designated Site.

In lieu of collecting settled dust samples at Sand & Gravel operations, Rock Co. should consider collecting water samples and/or fines for analysis (see p. 12).

A. Process for Collecting Settled Dust Samples

1. Create a sample log. The log should contain the name of the quarry sampled, the exact sample location, the sample period start-date and end-date, and the sample collector's name. Additional information may include the specific areas of the site quarried, tonnage produced during the sample period, etc.

2. Collect at least two settled dust samples at each Designated Site. Collect samples simultaneously during the test period.

3. Use sample containers of similar size to a wide-mouth Nalgene® jar (approx. 4¾ in. dia. and 1¾ in. deep). A container with these dimensions will provide adequate surface area for proper collection of the settled dust sample. Label each container in advance with a unique site ID, sample number, the sampling start date, sample location, etc.

4. Select sample locations protected from thrown rock particles, wind, precipitation, and accidental disturbance by normal work activities. However, the location must allow for enough settled dust to accumulate inside the container over the sample period (approx. ¼ to ½ in. depth is usually adequate for analysis). Locations can include: inside surge tunnels and screening towers, under crushers, etc., and Q.C. labs that are dedicated to one specific production site.

5. Sampling periods typically last up to several weeks, depending on production rates, sample location (to avoid over- or under-filling of the container), and other variables. Experience

indicates that quarterly sampling is appropriate for many production sites, but a specific frequency may not be appropriate for all production volumes and site conditions.

6. Properly collected samples will have a consistency similar to flour. The samples should not be gritty, sandy, or contain rock chips, and should not exceed more than one handful of material. Large sample quantities or those containing rock chips suggest that the sample site is not appropriate or that the sample has been "scooped up" rather than settled from the airborne dust over the time period of interest. If samples appear to be improperly collected, the coordinator should work with site management to ensure that samples are correctly gathered in the future. This may mean repositioning the sample collection device to a different location.

7. After sample collection, seal each container, mark the sample end-date on the container label, and log the sample information into a sample log.

8. If the sample will be analyzed by an outside laboratory, first split the sample into two parts, one for analysis, the other for retention in a secure location by Rock Co. Split the sample in a clean, protected, and well-ventilated environment using a device specifically designed for splitting samples of this type. Transfer the sample from its original collection container into new, separate containers with screw-on lids. Seal the lids with tape and label each new container with the unique sample number and other information for positive identification. Be careful not to contaminate or cross-contaminate samples during the splitting and transfer process. Do not re-use sample storage containers.

9. Do not comingle settled dust samples with any other samples intended for any other purpose.

10. Prepare a chain-of-custody form if half of the split sample will be sent to an outside laboratory for analysis (Appendix).

11. The sample may be analyzed using the method titled "Method for the Determination of Asbestos in Bulk Building Materials" (EPA/600/R-93/116), or by a method equivalent to the EPA method.

12. The coordinator and geologist should promptly review the laboratory's analytical results.

13. If the laboratory analysis determines (and the geologist verifies) that the sample contains PMFs, Rock Co. should proceed to Section 3, Qualitative Geologic Survey.

B. Process for Collecting Fines or Water Samples at Sand & Gravel Operations

1. Create a sample log. The log should contain the name of the Sand & Gravel operation sampled, the exact sample location, sample date, and the sample collector's name. Additional information may include the specific areas of the site from which the fines or water samples originated.

2. Use sturdy sample containers with a screw-on lid capable of holding 250-500 g of fines, sediment, or water. Avoid glass containers. Label each container in advance with a unique site ID, sample number, the sampling date, sample location, etc.

3. Select sample locations in settling ponds or where fines or sediment are most likely to represent the Sand & Gravel produced at that site. Keep away from areas subject to accidental disturbance by normal work activities.

4. After sample collection, seal each container, mark the sample end-date on the container label, and log the sample information into a sample log.

5. If the sample will be analyzed by an outside laboratory, first split the sample into two parts, one for analysis, the other for retention in a secure location by Rock Co. Split the sample in a clean, protected, and well-ventilated environment. Transfer the sample from its original collection container into new, separate containers with screw-on lids. Seal the lids with tape and label each new container with the unique sample number and other information for positive identification. Be careful not to contaminate or cross-contaminate samples during the splitting and transfer process. Do not re-use sample storage containers.

6. Do not comingle fines/sediments and water samples with any other samples intended for any other purpose.

7. Prepare a chain-of-custody form if half of the split sample will be sent to an outside laboratory for analysis (Appendix).

8. The sample may be analyzed using the method titled "Method for the Determination of Asbestos in Bulk Building Materials" (EPA/600/R-93/116), or by an equivalent method.

9. The coordinator and geologist should promptly review the laboratory's analytical results.

10. If the laboratory analysis determines (and the geologist verifies) that the sample contains PMFs, Rock Co. should proceed to Section 3, Qualitative Geologic Survey.

Section 3
Qualitative Geologic Survey

The purpose of the Qualitative Geologic Survey (QGS) is to define the distribution of PMFs by a detailed field assessment conducted by the geologist. The QGS for PMFs is separate from and in addition to any other geologic assessment conducted for other purposes (e.g., to evaluate overburden and weathered rock, quality and quantity of reserves, groundwater and rock mechanics, etc.).

A. When to Conduct a QGS

Conduct a QGS at an operating site when PMFs have already been confirmed there and it is important to define and document the distribution of the PMFs.

A QGS may also be appropriate for other reasons, including the inspection opportunities provided by acquisitions or changes to existing operations and sites.

1. **QGS Based on Prior PMF Confirmation**. Rock Co. should conduct a QGS at its operating sites when any one of the following conditions exists:

    a. PMFs are confirmed from a Periodic Inspection (Section 1) or any other on-site inspection by the geologist;

    b. PMFs are confirmed in a settled dust sample, water sample, or fines/sediment sample (Section 2);

    c. PMFs are confirmed at a site during normal operations, as a result of drilling or other geologic or mining activity; or

    d. A governmental agency determines that PMFs may be present at a site.

2. **QGS Without Prior PMF Confirmation**. Rock Co. may decide to conduct a QGS without prior PMF confirmation, for example: Before or during major plant reconstruction or expansions at operating mine sites, including the addition of new mining acreage that has not yet been effectively evaluated for PMFs; Before or during the reactivation of an old production site that has never been evaluated for PMFs; and while evaluating the acquisition of a new Greenfield site.

    a. Expansions, Major Reconstruction, and Reactivation of Old Production Sites. The geologist will be guided by his or her knowledge of the site that is scheduled for expansion, reactivation, and/or major plant reconstruction. The geologist and other professionals should determine if it is best to conduct a Periodic Inspection at the site

(Section 1), or to conduct a QGS (Section 2), or to blend these and other processes according to the specific circumstances at hand.

b. Acquisition of a New Greenfield Site. Greenfield site acquisition and development can be resource intensive—and expensive. Any time that Rock Co. considers the purchase or leasing and development of a Greenfield site for future aggregates production, it should evaluate the potential of that site for the presence of PMFs. That evaluation may become a part of the normal acquisition or development process that gauges the quality and suitability of the Greenfield materials as aggregates.

   Factors to consider for the PMF evaluation may include the site's proximity to existing Rock Co. production sites; what's known about adjacent rock types and the validity of extrapolating from or interpolating among the characteristics of the adjacent rock types; an extensive literature review of the relevant geology, analysis of core samples and examination of rock outcrops for PMFs, etc. See Section 1 (Prioritization) for additional factors.

   If Rock Co. does not own the Greenfield site outright, the geologist and other professionals should first consult with a qualified attorney on matters including the proposed evaluation for PMFs at that location, and the development and disposition of data and reports and the existing confidentiality agreements with the leaser or seller.

B. General Process for the QGS

The general process for conducting a QGS should be similar from site to site. This is important for the sake of efficiency, project and resource management, and ability to compare the results of one site's QGS to another.

However, no two sites are identical and certain sites may differ in fundamental ways, e.g., Sand & Gravel operations often differ significantly compared with rock quarries. Accordingly, the QGS process must remain sufficiently flexible to yield a practical and useful report. Moreover, the geologist must be able to assert his or her professional experience and knowledge without being unduly constrained by a process that may not be adequate for every given site.

C. QGS for Rock Quarries

In hard rock deposits, rock type and geologic structure drive the potential for PMFs. Focus on areas where mining is within or near an igneous and metamorphic rock body. If present, PMF's tend to be more concentrated in veins, faults/shear zones, seams, or intrusions/geologic contacts, which can be highly variable in distribution.

1. Assign a unique site identification number for activities associated with this Guide. The number should be used on the chain-of-custody form that accompanies all samples for analysis by outside laboratories, without identifying a site by its actual name or location.

2. Conduct a comprehensive literature survey, specific to the area of the site, to serve as a basis for a field assessment and for a structural and/or mineralogical interpretation. This survey may generally include but is not limited to accessing public databases, including those of the USGS, the state Geologic Survey, and local universities and colleges having relevant records.

   While there may be no specific references to the presence or absence of PMFs, data regarding rock types and distribution, geologic structure and history will be useful to complete a holistic assessment. The initial review may include but is not necessarily limited to the review of published geologic maps of the area with drainages appropriately mapped; pertinent geologic literature; historic mine database of the region; historic asbestos mine database; etc.

3. Unless an adequate geologic evaluation plan already exists, create a geologic evaluation plan to serve as a guide for determining rock types and their distribution, the association of any PMFs with the various rock types, and an estimate of the relative quantities of each.

4. Unless an adequate field survey exists, conduct a field survey consisting of the geologic mapping of rock types and distribution of materials in the walls, floors and benches of the quarry and include available core and outcrop data. The resulting geologic map of the total mining property will be to scale on an appropriate aerial or topographic base and will document locations/elevations of available drilling and outcrops.

5. Unless adequate rock samples have already been collected, collect representative samples of rock materials in areas most likely to contain PMFs. Use a "targeted" sampling strategy to improve the likelihood of identifying and mapping any PMFs present. Detailed geologic mapping, including cross-sectional maps as appropriate, can help delineate any PMF containing zones in rock quarries. This will include any available core samples.

   Document all sample locations and elevations on the geologic maps as discussed above. Additionally, collect samples of dust and finely ground materials that have accumulated on beams, in surge tunnels, and under crushers or screening towers. Samples of drill cuttings should also be considered to help assess the immediate future mineralogy. These samples will be examined for PMFs (see Appendix). The results of this analysis should be included in the geologic report of the site.

   a. Collect samples from subsurface explorations. A drill hole location map is helpful to add context to the samples. Subsurface exploration samples can provide a more robust understanding of the distribution and trends throughout the whole of the deposit compared with other sampling methods. This assumes the auger samples or test pits consistently went to full depth for the aerial extent of the deposit and all material is recovered from the drilling. Select continuous composite samples based on an interval chosen by the geologist. Send samples to a qualified laboratory (see Appendix).

Consider additional drilling and sampling if it is determined from mapping at the site that drilling, sampling, and testing are inadequate to properly define the extent of PMFs, or if it is necessary to address specific targeted areas where the geologic information points to the presence of PMFs. It is not possible generically to define how much drilling, sampling, and testing may be required to satisfy this protocol at every site. Those and possibly other activities are governed by the complexity of the geology of any specific site, production variables, and other factors.

b. Collect samples from aggregate stockpiles. Stockpile samples can adequately represent all recently extracted products but will not fully represent any shifts or trends in the deposit. The geologist and other site professionals may establish a periodic stockpile sample schedule based on the type of deposit and the mine plan and attempt extrapolations based on the results. The geologist and other site professionals should determine how and when to sample stockpiles so that samples best represent the deposit and material being sold. Some materials may require more sampling; others may need little or no sampling.

It helps to understand the test method for PMF analysis. If the analytical method requires the sample to be pulverized to dust, it doesn't matter, for example, whether the product sampled is ½" or ¾" since both are likely produced from a 1" plus sized product.

c. Collect samples from safely accessible high walls. Samples from the exposed mining face should represent vertical and lateral exposure of the mining face/slope, while being spatially and temporally adequate to represent bulk aggregate volumes over time.

6. Record all data and information collected from the QGS, including geologic maps and cross-sections. Note the presence or absence of PMFs at the sample locations and potential quantities of PMFs, as estimated from laboratory analyses extrapolated by rock type through the reserve. On-site inspection records should include site name, inspection date, name of inspector and observations. Include the location (easting, northing, and elevation), photos, and description of any samples taken.

7. At this point, this QGS may be deemed complete, and the geologist may write or update a site geologic report. It is not possible to define the level of detail necessary for each report, as each site is different. Generally, the report will be a concise, executive summary, with references to key documents and findings. The report may also include recommendations for future activities at the site (Section 4).

D. QGS for Sand & Gravel Operations

The QGS is typically more difficult to apply to an alluvial resource. PMFs are less likely to occur in alluvial deposits compared with certain igneous and metamorphic hard rock bodies; PMF concentrations are diluted during erosion, transportation and deposition.

Many PMF bearing rocks (with exceptions that include serpentinite, greenstone, diabase, etc.) are less competent and weaker than rock typically used for aggregate production. Less competent, PMF-bearing rocks typically break down more quickly in a fluvial depositional environment. Consequently, transported PMFs are more likely to be found in the finer natural aggregate.

1. Assign a unique site identification number for activities associated with this Guide. The number should be used on the chain-of-custody form that accompanies all samples for analysis by outside laboratories, without identifying a site by its actual name or location.

2. Conduct a comprehensive literature survey, specific to the area of the site, to serve as a basis for a field assessment and for a structural and/or mineralogical interpretation. This survey may generally include but is not limited to accessing public databases, including those of the USGS, the state Geologic Survey, and local universities and colleges having relevant records.

   While there may be no specific references to the presence or absence of PMFs, data regarding rock types and distribution, geologic structure and history will be useful to complete a holistic assessment. The initial review may include but is not necessarily limited to the review of published geologic maps of the area with drainages appropriately mapped; pertinent geologic literature; historic mine database of the region; historic asbestos mine database; etc.

3. Unless an adequate geologic evaluation plan already exists, create a geologic evaluation plan to serve as a guide for determining alluvial deposits and their distribution, the association of any PMFs with the various deposits, and an estimate of the relative quantities of each.

4. Unless an adequate field survey exists, conduct a field survey consisting of the geologic mapping of types and distribution of materials at the site, including any available core and outcrop data. The resulting geologic map of the total mining property will be to scale on an appropriate aerial or topographic base and will document locations/elevations of available drilling and outcrops.

5. A "targeted" sample approach is typically more difficult to apply (or may not apply) to alluvial resources due to the frequently variable distribution of the materials. It is often the case that the best samples are standard QC samples that are dried to assess fines content.

   Sampling and testing methods in an alluvial deposit should represent bulk aggregate volumes. One single sample is unlikely to represent certain deposits. Consider the depositional environment (alluvial fans, braided stream deposits, meandering river deposits, colluvium, etc.). Consider the expected production and reserve quantity to help determine the sample method(s) and sample size. Again, it is possible that the best sample may come from standard QC samples that are dried to assess fines content.

If appropriate, the geologist should consider estimating modal rock type percentage collected in the drainage(s) at various locations.

Averaging quantitative results may be the best representation of products being sold on a bulk volume level. This may be weighted averages by production, sales, or sample sizes depending on what the geologist and other site professionals determine is the most representative.

Document all sample locations and elevations on the geologic map as discussed above. Additionally, collect samples of sediments/fines and water.

a. Collect samples from any subsurface explorations. A drill hole location map is helpful to add context to the samples. Subsurface exploration samples can provide a more robust understanding of the distribution and trends throughout the whole of the deposit compared with other sampling methods. This assumes the auger samples or test pits consistently went to full depth for the aerial extent of the deposit and all material is recovered from the drilling. Select continuous composite samples based on an interval chosen by the geologist. Send samples to a qualified laboratory (see Appendix).

   Consider additional drilling and sampling if it is determined from mapping at the site that drilling, sampling, and testing are inadequate to properly define the extent of PMFs, or if it is necessary to address specific targeted areas where the geologic information points to the presence of PMFs. It is not possible generically to define how much drilling, sampling, and testing may be required to satisfy this protocol at every site. Those and possibly other activities are governed by the complexity of the geology of any specific site, production variables, and other factors.

b. Collect samples from product stockpiles. Stockpile samples can adequately represent all recently extracted products but will not fully represent any shifts or trends in the deposit. The geologist and other site professionals may establish a periodic stockpile sample schedule based on the type of deposit and the mine plan and attempt extrapolations based on the results. The geologist and other site professionals should determine how and when to sample stockpiles so that samples best represent the deposit and material being sold. Some materials may require more sampling; others may need little or no sampling.

   It helps to understand the test method for PMF analysis. If the analytical method requires the sample to be pulverized to dust, it doesn't matter, for example, whether the product sampled is ½" or ¾" since both are likely produced from a 1" plus sized product.

c. Collect samples from safely accessible extraction points and outcrops. Samples should represent vertical and lateral exposure of the extraction points, while being spatially and temporally adequate to represent bulk aggregate volumes over time.

6. Record all data and information collected from the QGS, including geologic maps and cross-sections. Note the presence or absence of PMFs at the sample locations and potential quantities of PMFs, as estimated from laboratory analyses extrapolated by deposit type through the reserve. On-site inspection records should include site name, inspection date, name of inspector and observations. Include the location (easting, northing, and elevation), photos, and description of any samples taken.

7. At this point, this QGS may be deemed complete, and the geologist may write or update a site geologic report. It is not possible to define the level of detail necessary for each report, as each site is different. Generally, the report will be a concise, executive summary, with references to key documents and findings. The report may also include recommendations for future activities at the site (Section 4).

SECTION 4
Additional Steps

Based on the foregoing analysis, on information derived from other sources not included in the Guide, and on the professional judgement of the geologist and other professionals, Rock Co. may elect to take additional steps with the goal of avoiding or minimizing PMF contact.

Any additional steps are likely to be site specific and depend on a host of variables that may change from time to time. Accordingly, specific recommendations for any additional steps are beyond the scope of this Guide. However, strictly as suggestions for consideration, additional steps might include but are not limited to:

- Modifying the mining plan
- Modifying the areas of the property where mining and processing occurs
- Implementing personal or area air sampling
- Implementing fence line (site perimeter) air sampling
- Increased settled dust sampling
- Surface sampling in enclosed spaces (mobile equipment, control booths, etc.)
- Product sampling (stockpiles, conveyors, etc.)
- Employee training (recognizing PMFs)
- Creating a visual identification plan
- Special cleaning methods and schedules
- Implementing NSSGA's Occupational Health Program

Many of these additional steps should be directed by the geologist and a competent industrial hygienist who has experience with aggregate production and PMFs.

Appendix
Identification of Protocol Mineral Fibers

The geologist or analyst should microscopically analyze all samples as suggested by this Guide:

1. Inspect hand and core samples with the Binocular Microscope, ranging from 10x to 60x magnification. Using a fine steel pick (dental pick), scrape the surface of the suspect mineralization to determine if any of the minerals display the typical asbestiform habit and characteristics such as fiber bundles, splayed ends, or matted or fibrous masses.

2. Examine the sample by the PLM oil immersion method, using:

   a. Cargille Laboratories, Inc, NJ 07009, *certified* refractive index liquids, Series – A, $n_D^{25°C}$ 1.400 to 1.800. (https://cargille.com/); and

   b. Nikon Optiphot-2 Pol, Polarizing Light Microscope, 40x to 1000x magnification, with digital imagery capability; or a similar high-end instrument.

If PMFs are found, a representative sample may be sent to a qualified outside laboratory for verification and/or further analysis (See Section 2) to establish mineral identification. The analysis will include a count with dimensions (width and length) and digital images of PMFs.

Forward all samples that contain serpentine group minerals to a qualified outside laboratory for Transmission Electron Microscopy (TEM) analysis to determine the presence or absence of the asbestiform habit of chrysotile.

For the purposes of this Guide, "qualified laboratory" means a laboratory accredited by the American Industrial Hygiene Association and/or the NIST National Voluntary Laboratory Accreditation Program for asbestos analysis. The qualified laboratory must have mineralogical expertise and have the ability and experience to detect PMFs in the natural environment (e.g., rocks, soils, etc.) in accordance with the EPA analytical method and the NIST definition (see the Glossary).

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GLOSSARY

Actinolite - A bright-green or grayish-green monoclinic mineral of the amphibole group with the general formula: $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$. The specific chemical compositions for which the name actinolite formally applies are given by Leake et al., 1997. It sometimes occurs in the form of asbestos, and also in fibrous, radiated, or columnar forms in metamorphic rocks (such as schists) and in altered igneous rocks.

Aggregate - (a) A mass or body of rock particles, mineral grains, or a mixture of both. (b) Any of several hard, inert materials, such as sand, gravel, slag, or crushed stone, used for mixing with a cementing or bituminous material to form concrete, mortar, or plaster; or used alone, as in railroad ballast or graded fill. The term sometimes includes rock material used as chemical or metallurgical fluxstone, or filtration medium.

Amosite - A commercial term for an iron-rich, asbestiform variety of amphibole of the composition cummingtonite-grunerite, that is mined in the Transvaal region of South Africa.

Amphibole - A group of dark rock-forming ferromagnesian silicate minerals, closely related in crystal form and composition and having the general formula: $AB_2C_5Z_8O_{22}(OH,Cl,F)_2$, where *A* = Na, K; B = Mg, Fe^{2+}, Ca, or Na; C = Mg, $Fe^{2+,}$ Fe^{3+}, Li, Mn or Al; and Z = Si, Al, or Ti. It is characterized by a cross-linked double chain of tetrahedra with a silicon:oxygen ratio of 4:11, by columnar or fibrous prismatic crystals, and by good prismatic cleavage in two directions parallel to the crystal faces and intersecting at angles of about 56° and 124°; colors range from white to black. Most amphiboles crystallize in the monoclinic system, some in the orthorhombic. They constitute an abundant and widely distributed constituent in igneous and metamorphic rocks, and they are similar in chemical composition to the pyroxenes.

Anthophyllite - A clove-brown to colorless orthorhombic mineral of the *amphibole* group with an ideal formula of: $(Mg,Fe^{2+})_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$. Variations in composition permitted under the name anthophyllite are specified by Leake et al, 1997. Anthophyllite occurs in metamorphosed ultrabasic rocks, typically with olivine, pyroxene, or talc. It may be found in monomineralic aggregates of parallel or radiating asbestiform fibers. It has been mined for asbestos.

Asbestos - A commercial term applied to a group of silicate minerals that readily separate into thin, strong fibers that are flexible, heat resistant, and chemically inert, and therefore are suitable for uses (as in yarn, cloth, paper, paint, brake linings, tiles, insulation, cement, fillers, and filters) where incombustible, nonconducting, or chemically resistant material is required. According to the National Institute of Standards and Technology (NIST), Certificate of Analysis, Standard Reference Material® 1867a, Uncommon Commercial Asbestos, "asbestos minerals possess (certain) properties such as long fiber length and high tensile strength. Under the light microscope samples exhibit the asbestiform habit as defined by several of the following characteristics: 1) mean aspect ratios ranging from 20:1 to 100:1 or higher for fibers longer than 5 µm, 2) very thin fibrils, usually less than 0.5 µm in width, 3) parallel fibers occurring in bundles, 4) fiber bundles displaying splayed ends, 5) fibers in the form of thin needles, 6) matted masses of individual fibers, and 7) fibers showing curvature."

Asbestiform – (a) The habit of asbestos. (b) A technical term which refers to a mineral habit where mineral crystals grow in a single dimension, until they form long, thread-like fibers with aspect ratios ranging from 20:1 to 100:1 or higher for fibers longer than 5 µm ; very thin fibrils, usually less than

0.5 µm in width; parallel fibers occurring in bundles; and one or more of the following: fiber bundles displaying splayed ends, matted masses of individual fibers, or fibers showing curvature.

Chrysotile – A white, gray, or greenish orthorhombic or monoclinic mineral of the serpentine group: $Mg_3Si_2O_5(OH)_4$. Chrysotile is a highly fibrous, silky variety of serpentine, and constitutes what was historically the type of asbestos most commonly used.

Cleavage fragment - A fragment of a crystal that is bounded by smooth surfaces, formed by preferential breakage from a larger crystal along the planes of relatively weak chemical bonds. The shapes of a cleavage fragment are defined by the number and orientation of the most well-developed cleavage planes in the parental mineral.

Crocidolite – The commercial name for riebeckite asbestos. A lavender-blue, indigo-blue, or leek-green asbestiform variety of the amphibole riebeckite.

Designated Sites – For the purposes of this Guide, Designated Sites are Production sites that Rock Co. has identified for Periodic Inspection. "Designated Site" status does not in any way imply that PMFs may be found at that site.

Erionite - A white, relatively common sedimentary zeolite, found in either acicular or fibrous habits. Erionite and many other natural zeolites are typically associated with weathered volcanic tuffs. Asbestiform erionite is referred to as woolly erionite.

Fiber - Commonly, a slender, elongated, threadlike object or structure. In regulatory and biomedical literature, "fiber" has been used many ways, and has no specific, standalone meaning. Generally, "fiber" is a relative term that has come to mean any elongated particle that satisfies specific dimensional constraints. Dimensional constraints placed on the definition of the term "fiber" are specific to the particular analytical method/exposure metric by which fiber concentrations are determined for a particular application. In contrast to other terms such as "asbestiform," "fiber" is not linked to a specific list of mineralogical properties which give it a consistent meaning across analytical methods and/or exposure metrics.

Fibrous - A relative term that is used to denote a material composed primarily of fibers or one that appears to be composed of fibers.

Greenfield - Land from which aggregate materials have not previously been mined.

Habit - The characteristic crystal form or combination of forms of a mineral, including characteristic irregularities; the way a mineral grows or is formed in nature.

Igneous - Said of a rock or mineral that solidified from molten or partly molten material, i.e., from a magma or lava; also, applied to processes leading to, related to, or resulting from the formation of such rocks. Igneous rocks constitute one of three main classes into which rocks are divided, the others being metamorphic and sedimentary.

Metamorphic - Pertaining to the process of rock transformation by heat, pressure, and/or hydrothermal solutions, referred to as metamorphism, or to its results.

Muck pile - Broken material left over after a tunnel has been bored, or a surface area has been affected by drilling and blasting

NIST - National Institute of Standards and Technology.

Nonasbestiform - not asbestiform in habit.

Overburden - Term used to describe rock and/or soil which lies above an economically valuable material (ore) that contains material intended to be used in end product. Overburden is distinct from tailings, the material that remains after economically valuable components have been extracted from processed ore.

Peer-reviewed - The process of subjecting scholarly work, research, or ideas to the scrutiny of others who are experts in the same field. Generally, peer-review is a process used to screen manuscripts and funding applications.

PLM - Polarized Light Microscopy.

Prismatic - Term for a mineral habit of an elongated mineral with sides that are defined by planes having parallel intersections.

Protocol Mineral Fiber - Defined in the Introduction of this Guide. As used herein, the term includes chrysotile, actinolite asbestos, crocidolite, amosite, anthophyllite asbestos, and tremolite asbestos, as well as all asbestiform amphiboles, asbestiform serpentines, and all durable asbestiform zeolites. Durable asbestiform zeolites include, but are not limited to, erionite and mordenite.

Reserve - Portion of quarry or Sand & Gravel deposit which can economically be mined given the then-existing state of mining practices and related technology.

Serpentine - A group of common rock-forming minerals having the simplified general formula: $Mg_3Si_2O_5(OH)_4$. Serpentines have a greasy or silky luster, a slightly soapy feel, and a tough, conchoidal fracture; they are usually compact but may be granular or fibrous, and are commonly green, greenish-yellow, or greenish-gray and often veined or spotted with green and white. Serpentines are always secondary minerals, derived by alteration of magnesium-rich silicate minerals (especially olivines), and are found in metamorphic rocks; they generally crystallize in the monoclinic system. Translucent varieties are used for ornamental and decorative purposes, often as a substitute for jade. The minerals in the serpentine group include antigorite, lizardite, and chrysotile.

Site Inspection Protocol - Describes for Designated Sites the general inspection methods, resources, responsibilities, and inspection report content and format.

TEM - Transmission Electron Microscopy.

Tremolite - A white to dark-gray monoclinic mineral of the amphibole group with an ideal formula: $Ca_2Mg_5Si_8O_{22}(OH)_2$. The specific chemical compositions to which the name tremolite formally applies are given by Leake et al., 1997. It has varying amounts of iron and may contain manganese and chromium. Tremolite occurs in long blade-shaped or short stout prismatic crystals and in columnar, fibrous, or granular masses or compact aggregates, generally in metamorphic rocks such as crystalline dolomitic limestones and talc schists. It is a constituent in much commercial talc. Under some conditions, it may form asbestos.

Zeolites - A generic term for a large group of white or colorless (sometimes tinted red or yellow by impurities) hydrous aluminosilicate minerals that have an open framework structure of interconnected $(Si,Al)O_4$ tetrahedra with exchangeable cations and H_2O molecules in structural cavities. Zeolites have long been known to occur as well-formed crystals in cavities in basalt and as authigenic minerals in the sediments of saline lakes and the deep sea and especially in beds of altered tuff. They form during and after burial, generally by reaction of pore waters with solid aluminosilicate materials (e.g., volcanic glass, feldspar, biogenic silica, and clay minerals).

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