-FINAL-

Background Soil Summary Report
Libby Asbestos Superfund Site, Montana

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List of Acronyms and Abbreviations

%	percent
<	less than
≥	greater than or equal to
µm	micrometers
ABS	activity-based sampling
AC	actinolite
AMSL	above mean sea level
BNSF	Burlington Northern and Santa Fe Railroad
CARB	California Air Resource Board
CB&I	CB&I Federal Services, LLC
CH	chrysotile
CHISQ	Chi-square
COC	contaminant of concern
DQA	data quality assessment
DQO	data quality objective
EDD	electronic data deliverable
EDS	energy dispersive spectroscopy
EMSL04	EMSL Analytical, Inc. laboratory in Cinnaminson, New Jersey
EMSL27	EMSL Analytical, Inc. laboratory in Libby, Montana
EPA	U.S. Environmental Protection Agency
ESATR8	Environmental Services Assistance Team, Region 8
FBAS	fluidized bed asbestos segregator
FSDS	field sample data sheet
ft^2	square feet
g^{-1}	per gram (dry weight)
Grace	W.R. Grace and Company
H&S	health and safety
HAZWOPER	Hazardous Waste Operations and Emergency Response
HEI-AR	Health Effects Institute-Asbestos Research
Hygeia	Hygeia Laboratories, Inc.
ID	identification
ISO	International Organization for Standardization
LA	Libby amphibole
MDEQ	Montana Department of Environmental Quality
mm	millimeter
mm^2	square millimeters
NaK	sodium and potassium are present in spectra
NAM	non-asbestos material
NaX	only sodium is present in spectra
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology

NVLAP	National Voluntary Laboratory Accreditation Program
OA	other amphibole-type asbestos
OSHA	Occupational Safety and Health Administration
OU	operable unit
PCME	phase contrast microscopy-equivalent
PE	performance evaluation
PLM	polarized light microscopy
PLM-Grav	polarized light microscopy-gravimetric
PLM-VE	polarized light microscopy-visual estimation
QA	quality assurance
QAPP	quality assurance project plan
QATS	Quality Assurance Technical Support
QC	quality control
RESI	Reservoirs Environmental Services, Inc.
ROM	record of modification
s/cc	structures per cubic centimeter
s/g	structures per gram
SAED	selected area electron diffraction
SAP	sampling and analysis plan
Site	Libby Asbestos Superfund Site
SOP	standard operating procedure
SPF	Sample Preparation Facility
TEM	transmission electron microscopy
TR	tremolite
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WRTA	winchite/richterite/tremolite/actinolite
XK	only potassium is present in spectra
XRD	x-ray powder diffraction
XX	neither sodium nor potassium are present in spectra

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1 INTRODUCTION

The community of Libby is in northwestern Montana, located 7 miles southwest of a vermiculite mine that operated from the 1920s until 1990 (**Figure 1-1**). The mine began limited operations in the 1920s and was operated on a larger scale by the W.R. Grace Company (Grace) from approximately 1963 to 1990. Studies revealed that the vermiculite from the mine contains amphibole-type asbestos, referred to as Libby amphibole (LA).

Epidemiological studies revealed that workers at the mine had an increased risk of developing asbestos-related lung disease (McDonald *et al.* 1986, 2004; Amandus and Wheeler 1987; Amandus *et al.* 1987; Whitehouse 2004; Sullivan 2007). Additionally, radiographic abnormalities were observed in 17.8 percent (%) of the general population of Libby including former workers, family members of workers, and individuals with no specific pathway of exposure (Peipins *et al.* 2003; Whitehouse *et al.* 2008; Antao *et al.* 2012; Larson *et al.* 2010, 2012a, 2012b). Although the mine has ceased operations, historic or continuing releases of LA from mine-related materials could be serving as a source of ongoing exposure and risk to current and future residents and workers in the area.

1.1 Site Background

The Libby Asbestos Superfund Site (Site) was listed on the U.S. Environmental Protection Agency (EPA) National Priorities List in October 2002. The Site includes homes and businesses that may have become contaminated with asbestos as a result of the vermiculite mining and processing conducted in and around Libby, as well as other areas that may have been affected by mining-related releases of asbestos. For long-term management purposes, the Site has been divided into eight operable units (OUs) (**Figure 1-2**):

- *OU1, Former Export Plant* – OU1 is defined geographically by the parcel of land that included the former Export Plant and the Montana State Highway 37 embankments, and is situated on the south side of the Kootenai River, just north of the downtown area of the City of Libby.

- *OU2, Former Screening Plant* – OU2 includes areas impacted by contamination released from the former Screening Plant. These areas include the former Screening Plant, the Flyway property, the Montana State Highway 37 right-of-way adjacent to the former Screening Plant and/or Rainy Creek Road, and privately owned properties.

- *OU3, Libby Vermiculite Mine* – OU3 includes the former vermiculite mine and the geographic area (including the ponds, streams, and forested area as well as the Kootenai River and Rainy Creek Road) surrounding the former vermiculite mine that has been affected by releases from the mine.

- *OU4, Libby Residential/Commercial Areas* - OU4 is defined as residential, commercial, industrial (not associated with Grace mining operations), and public properties, including schools and parks in and around the City of Libby or those properties that have received material from Grace mining operations.

- *OU5, Former Stimson Lumber Mill* – OU5 is defined geographically by the parcel of land that included the former Stimson Lumber Company.

- *OU6, Burlington Northern and Santa Fe (BNSF) Railroad* – OU6 is owned and operated by the BNSF railroad, and is defined geographically by the BNSF property boundaries from the eastern boundary of OU4 to the western boundary of OU7 and extent of contamination associated with the Libby and Troy rail yards.

- *OU7, Town of Troy* – OU7 includes all residential, commercial, and public properties in and around the Town of Troy, located 20 miles northwest of downtown Libby.

- *OU8, Roadways* – OU8 is comprised of the United States and Montana State Highway rights-of-way within the OU4 and OU7 boundaries.

1.2 Document Purpose

One of the sources of human exposure to LA at the Site is from contaminated outdoor soil, especially under circumstances when the soil is being actively disturbed. Measurement of LA levels released to air during a source disturbance activity is referred to as "activity-based sampling" (ABS). The EPA has performed extensive ABS studies at the Site, seeking to characterize airborne levels of LA that occur in association with soil disturbance activities. In some cases, these studies have detected LA fibers in ABS air samples collected from locations where the soil is not expected to have mine-related contamination (EPA 2010a). This raises the possibility there is some "non-zero" background level of LA in the Kootenai Valley soils and parent materials from which the present soils have developed that is not attributable to anthropogenic releases from vermiculite mining and processing activities. For the purposes of this report, the term "background" is used to refer to soils that are not expected to be affected by anthropogenic releases from vermiculite mining and processing activities. Because it is the EPA's policy not to clean up soils to a concentration lower than background (EPA 2002), it is important for risk managers to gain information on the nature and magnitude of these naturally-occurring levels.

The EPA has conducted several investigations at the Site to characterize LA in soil from areas that are thought to be representative of background conditions. It is difficult to distinguish between LA resulting anthropogenic activities (e.g., wind-blown dust associated with the Libby mine) and LA resulting from geologic processes. Therefore, steps were taken in the development and execution of the sampling investigations to ensure samples were representative of soil horizons and naturally-deposited parent materials that have not been

impacted by anthropogenic releases of LA and to avoid soils and natural deposits that may have been impacted by anthropogenic-produced dust. The purpose of this document is to summarize the results of these investigations.

1.3 Kootenai Valley Physical Characteristics

This section describes the physical characteristics of the Kootenai Valley in the Libby and Troy areas, including the geology, soils, topography, and surface water hydrology as they pertain to the possible distribution of LA in background soils.

1.3.1 Geology and Soils

The mountains surrounding the Kootenai Valley are generally composed of folded, faulted, and metamorphosed blocks of Precambrian sedimentary rocks and minor basaltic intrusions. Primary rock types are meta-sedimentary argillites, quartzites, and marbles (Ferreira *et al.* 1992).

The vermiculite deposit at Vermiculite Mountain is located approximately 7 miles northwest of Libby in the Rainy Creek drainage. The vermiculite deposit specific to the Libby vermiculite mine is classified as a deposit within a large ultramafic intrusion, such as pyroxenite plutons, which is zoned and cut by syenite or alkalic granite and by carbonatitic rock and pegmatite. The formation of vermiculite and asbestiform amphiboles in the Libby mine deposit have been assessed to be the result of the hydrothermal alteration of augite by high-temperature silica-rich solutions (Larsen and Pardee 1929; Boettcher 1967; Van Gosen *et al.* 2002; Meeker *et al.* 2003).

The Vermiculite Mountain deposit is contained within the Rainy Creek alkaline-ultramafic complex. The Rainy Creek complex is described as the upper portion of a hydrothermally altered alkalic igneous complex composed primarily of magnetite pyroxenite, biotite pyroxenite, and biotitite (Boettcher 1967). The original ultramafic body is an intrusion into the Precambrian Belt Series of northwestern Montana, likely deposited during the early Cretaceous Period (Langer *et al.* 2010). A syenite body southwest of and adjacent to the altered pyroxenite is associated with numerous syenite dikes that cut the pyroxenites. Generally, the Vermiculite Mountain amphiboles are classified as one of three main types including, in order of decreasing abundance, winchite (approximately 84%), richterite (approximately 11%), and tremolite (approximately 6%). Other minerals include magnesio-riebeckite, edenite, and magnesio-arfvedsonite (Meeker *et al.* 2003). Generally, Vermiculite Mountain amphiboles occur as either vein-fillings or replacement of the primary pyroxene of the Rainy Creek complex. Traditionally, amphibole asbestos is believed to occur as a vein-filling mineral formed during hydrothermal or low-temperature alteration. The amphiboles in samples from Vermiculite Mountain appear to be forming as direct replacements of pyroxene through fluid infiltration in microfractures (Meeker *et al.* 2003).

During Pleistocene time, the Kootenai Valley was located beneath glacial Lake Kootenai, which was present as a result of glacial advances from the most recent Pinedale glacial advance more

than 16,000 years ago (Langer *et al.* 2010). Glacial advances scoured what is now Vermiculite Mountain and deposited sediments in the Rainy Creek delta of glacial Lake Kootenai (**Figure 1-3**). When the glaciers receded, Lake Kootenai gradually drained, resulting in erosion of the Rainy Creek delta and redeposition of glacial sediments down the entire Kootenai River drainage below the elevation of 2,450 feet above mean sea level (AMSL) (Locke and Smith 2004; Smith 2006). Glacial Lake Kootenai finally drained around 11,000 years ago (Ehlers and Gibbard 1996) and the Kootenai River occupied its present channel. The presence of amphibole asbestos in alluvial sediment layers has been demonstrated at several locations in the Kootenai Valley (Adams *et al.* 2010). The U.S. Geological Survey (USGS) (Adams *et al.* 2010) reported the presence of multiple layers of glacial sediments containing amphibole material from Vermiculite Mountain in active gravel quarries near Libby. The USGS also reported that some soils from a sample area within the valley contained a range of 0.004% to 0.047% LA (by mass).

The sequence of events that occurred as Pleistocene glaciation waned and ice receded to the north includes deposition of lacustrine and glacial outwash sediments sourced from multiple locations, including the area of Vermiculite Mountain, as well as locations to the south, southeast, and north of the Kootenai Valley (Langer *et al.* 2010). Amphibole asbestos eroded by glaciation was deposited as glacial outwash in the vicinity of Rainy Creek and as lacustrine sediments in nearby areas of glacial Lake Kootenai. Additionally, some of this sediment was dispersed more broadly in downstream locations during erosion and redeposition associated with changing lake levels as the ice receded and temporarily re-advanced. Much of the glacial outwash and lacustrine sediments observed in the Kootenai Valley were derived from locations other than Vermiculite Mountain. For example, sediment sources in the Libby area other than Vermiculite Mountain include Pipe Creek and Quartz Creek north of Libby, as well as sources south and southeast of Libby. In the Troy area, drainages to the south of Troy fed the glacial lakes that eventually coalesced to form glacial Lake Kootenai, and much of the lacustrine sediments and glacial outwash sediments in the Troy area were likely derived from these sources to the south (**Figure 1-3**).

It is possible that large amounts of material containing amphibole asbestos were eroded from Vermiculite Mountain during Pleistocene glaciation and this material was subsequently deposited over a broad area through deposition of glacial outwash and lacustrine sediments. Sediment samples from glacial deposits analyzed by Langer *et al.* (2010) show that Pleistocene glaciation likely resulted in amphibole asbestos from Vermiculite Mountain being deposited in lacustrine sediments in glacial Lake Kootenai and re-deposited during a re-advance of the Purcell Trench Glacier lobe. Two thin, discrete lake bottom deposits have been determined to contain LA-bearing sediments but these layers are covered in most places with more than 30 meters of other fine-grained sediments that do not contain LA from Vermiculite Mountain (Langer *et al.* 2010). The distribution of lacustrine sediment layers that potentially contain LA from Vermiculite Mountain was described in Langer *et al.* (2010). Ongoing erosion of the lacustrine sediment exposures, as well as disturbance of sediments by human activity, likely resulted in additional dispersal of glacial deposits that potentially contain amphibole asbestos.

Some soils in the Kootenai Valley have formed in lacustrine sediments, glacial till, loess, and loess that has been influenced by volcanic ash. The sediments and till are largely derived from the pre-Cambrian sedimentary rocks. **Figure 1-4** shows the soils that have formed on lacustrine and glacial outwash deposits, some of which have been reworked by wind. Much of the soil within the Libby and Troy communities has been modified by residential construction, industrial operations, and residential activities. These modifications include soil disturbance during construction, road building, railroad operations, gardening, incorporating vermiculite into the soil, and other activities.

The remnant lacustrine sediment terraces that surround Libby and Troy (**Figure 1-4**) generally have a fine-silty textured surface layer and are underlain by silt loam and clay loam texture sediments (U.S. Department of Agriculture [USDA] 1995). The fine-textured surface layers have developed directly from loess, or from mixtures of loess and glacial deposited materials, including lacustrine sediments. The loess in the Kootenai Valley has generally been influenced by volcanic ash depositions. The primary soil type in Libby (USDA soil unit 103) has developed in alluvial deposits and has a surface layer of gravelly silt loam. This soil is underlain by stratified alluvial deposits of sand, silt, and gravel (USDA 1995). The main soil type in Troy (USDA soil unit 108) developed on lacustrine and glacial outwash terraces and has a silt loam surface texture.

X-ray powder diffraction (XRD) analyses by the USGS of shallow, subsurface soil from more than 10 sites in the Libby area show that it is composed of major (greater than 20%) quartz, minor (5% to 20%) muscovite (or illite) and albitic feldspar; and trace (less than 5%) orthoclase, clinoclore, non-fibrous amphibole (likely magnesio-hornblende), calcite, amorphous material (probably organic), and possible pyrite and hematite. Other minerals are likely present at levels below 0.5% and are generally not detectable by routine XRD analysis. These mineral components represent the average components for the area and likely vary to some extent depending on local conditions. Surface soil contains the above components with the addition of more organic material (Van Gosen *et al.* 2002).

1.3.2 Topography and Surface Water Hydrology

The topography in the vicinity of Kootenai Valley is generally characterized by mountainous terrain exhibiting steep-sided valley walls. Portions of the Kootenai Valley, particularly in the intermontane Purcell Trench near Bonners Ferry, are characterized by relatively flat terrain and broad flood plains. Pleistocene glaciation has influenced the local topography through erosion and glacial sediment deposition. Examples of local topographic features associated with Pleistocene glaciation include cirques high in the mountains created by alpine glaciers, broadened valleys created by continental glacial lobes, moraines, glacial outwash terraces, and glacial lake-bed surfaces. A prominent regional feature of the effects of Pleistocene glaciation is the Purcell Trench west of Troy, which is a broad intermontane valley sculpted by the advancement of a glacial lobe southward between the Purcell and Cabinet Mountains in the east and the Selkirk Mountains in the west.

The Kootenai River is the primary river in the Kootenai Valley. The river flows in a westward to northwestward direction, cutting a deep valley through Libby and Troy. Several tributaries feed the river from the north and south and have carved smaller valleys in the surrounding mountains. Several lakes in the area also lie in the Kootenai River drainage, including numerous alpine lakes at higher elevations. The flow direction of the river and its tributaries is generally controlled by the underlying geologic bedrock structure and is affected in localized areas by the presence of Pleistocene glacial till, moraine, outwash, and lacustrine deposits (Langer *et al.* 2010).

1.4 LA Characteristics

The main contaminant of concern at the Site is asbestos. The vermiculite deposit near Libby contains a distinct form of naturally-occurring amphibole asbestos that is comprised of a range of mineral types and morphologies. Historically, the form of asbestos present in the vermiculite deposit was classified as tremolite/actinolite (Larsen and Pardee 1929; Larsen 1942; McDonald *et al.* 1986; Amandus and Wheeler 1987; Leake *et al.* 1997; Wylie and Verkouteren 2000; Bandli and Gunter 2006; Sanchez *et al.* 2008).

More recently, the USGS performed electron probe micro-analysis and XRD analysis of 30 samples obtained from asbestos veins at the mine (Meeker *et al.* 2003). Using new mineralogical naming rules recommended by Leake *et al.* (1997) and Hawthorne *et al.* (2012), the results indicate that the asbestos at the mine includes a number of related amphibole types. The most common forms are winchite and richterite, with lower levels of tremolite, magnesio-riebeckite, edenite, and magnesio-arfvedsonite. Some minerals may also be classified as actinolite, depending on the valence state of iron. Because there are no toxicological data to distinguish differences in toxicity among these different forms (and mineralogical name changes do not alter the asbestos form present), the EPA does not believe it is important to attempt to distinguish among these various amphibole types. Therefore, the mixture of asbestos present at the Site is referred to as "Libby amphibole" or LA.

2 SOIL ANALYSIS METHODS

While there are a number of analytical methods currently available for the analysis of asbestos in solid media, these methods have predominantly been developed for the analysis of various building materials that contain relatively high asbestos contents, and the methods are not generally intended for assessing lower level asbestos contamination (less than 1%) in environmental media such as soil.

Currently, there are two analytical methods that are used at the Site for the analysis of soils as part of investigative studies – polarized light microscopy (PLM) and transmission electron microscopy (TEM). Each of these methods is described in greater detail below.

2.1 PLM

PLM uses the fact that light passing through a translucent mineral will interact with the internal crystal structure of the mineral, and the transmitted light (that which passes through the particle) tends to be polarized, having a higher intensity in some orientations than in others. Because this polarization effect depends on the composition and/or structure of the mineral, it is possible to distinguish asbestos from non-asbestos and to classify different types of asbestos based on the optical properties (e.g., refractive index, birefringence) of the particle. When a soil sample is analyzed by PLM using visual area estimation (referred to as "PLM-VE"), the analyst utilizes visual estimation techniques to determine the asbestos content of the soil.

The Libby-specific analytical method for PLM-VE (standard operating procedure [SOP] SRC-LIBBY-03) was first developed in March 2003. The PLM-VE method is based on preparation and analysis procedures in National Institute of Occupational Safety and Health (NIOSH) Method 9002, Issue 2 (NIOSH 1994), EPA/600/R-93/116 (EPA 1993), and California Environmental Protection Agency Air Resources Board (CARB) Method 435 (CARB 1991), with project-specific modifications specifically for use at the Site. It is intended mainly for analysis of asbestos in soil or other similar soil-like media. In general, the Libby-specific PLM-VE method is similar to NIOSH Method 9002 with the following exceptions:

- Soil samples are sieved and ground prior to analysis
- Analysts utilize LA-specific calibration materials and results for LA are reported as mass fraction
- LA concentrations less than 1% are stratified into three semi-quantitative classification bins (rather than two)

2.1.1 Preparation Method

At the Site, soil samples for analysis by the Libby-specific PLM methods are first processed in accordance with SOP ISSI-LIBBY-01. Sample preparation is performed at the Sample

Preparation Facility (SPF) located in Troy, Montana. In brief, each soil sample is dried and sieved through a ¼-inch screen. Particles retained on the screen (if any) are referred to as the "coarse" fraction. Particles passing through the screen are referred to as the fine fraction, and this fraction is ground (250 micrometers [µm]) by passing it through a plate grinder[1]. The resulting material is referred to as the "fine ground" fraction. The fine ground fraction is split into four equal aliquots; one aliquot is submitted for analysis and the remaining three aliquots are archived for possible future analysis.

2.1.2 Analysis Method and Results Reporting

The coarse fractions are examined gravimetrically in accordance with SOP SRC-LIBBY-01, referred to as "PLM-Grav". PLM-Grav provides a screening method to examine the coarse soil fraction for evidence of asbestos mineral content using stereomicroscopy with confirmation of asbestos by PLM. Only seven of the samples evaluated in this report had a coarse fraction (all samples were collected from the Libby City Pit). In all cases, the PLM-Grav result was non-detect for LA. Thus, PLM-Grav results are not presented or discussed further in this report.

The fine ground aliquots are examined using PLM-VE in accordance with SOP SRC-LIBBY-03. PLM-VE is a semi-quantitative method that utilizes LA-specific reference materials to allow assignment of fine ground samples into one of four reporting "bins", as follows:

- Bin A (ND): non-detect
- Bin B1 (Trace): LA detected at levels lower than the 0.2% (by mass) LA reference material
- Bin B2 (<1%): LA detected at levels lower than the 1% (by mass) LA reference material but greater than or equal to the 0.2% LA reference material
- Bin C (≥1%): LA detected at levels greater than or equal to the 1% LA reference material; results are reported to the nearest whole percent

2.2 TEM

One limitation of the PLM-VE method is that the analysis results only provide semi-quantitative information on soil concentrations less than 1%. Studies have shown asbestos concentrations of potential health concern may be released to air from soils with low levels (less than 1%) of asbestos contamination. For this reason, the EPA has been engaged in an ongoing effort to develop and evaluate methods for the characterization of low levels of asbestos in soil. One such method utilizes a fluidized bed asbestos segregator (FBAS) to prepare soil samples for analysis by TEM. For convenience, this method is referred to as "FBAS-TEM" in this report. The

[1] It is recognized that grinding the soil sample could alter the structures types and dimensions present in the sample (e.g., grinding may break apart a bundle into numerous individual fibers); however, because the goal of PLM-VE is to quantify the total asbestos content (as mass %), grinding will not alter this estimate (and has been shown to reduce sample heterogeneity).

FBAS-TEM preparation and analysis methods are described in more detail below.

Performance evaluation (PE) studies of the FBAS-TEM method (Januch *et al.* 2013) using LA-spiked PE standards with a range of nominal mass percent levels show that the method detection limits achieved following FBAS preparation were less than 0.01% (by mass), which is approximately 100-times lower than the detection limits that are reliably achieved using other analytical methods for asbestos in soil (e.g., PLM-VE).

2.2.1 Preparation Method

At the Site, the FBAS preparation technique is performed at the Troy SPF in accordance with OEAFIELDSOP-102[2] developed by EPA Region 10, *Sampling, Preparation, and Operation of the Fluidized Bed Asbestos Segregator*. In brief, soil samples are dried and sieved through an 850-µm sieve to remove large particles or debris. (Note: Samples are not ground.) An aliquot of the sieved sample is combined with laboratory-grade sand and placed inside a glass vessel that is conical on both ends, and mounted vertically on the FBAS. Typically, 1-5 grams of soil are combined with sufficient sand to yield a total weight of 20 grams. A vacuum pump is used to draw air through the sample/sand mixture inside the glass vessel and "fluidize" sample (i.e., when the pressure drop through the solid particles offsets the weight of the particles, they begin to circulate and act as a fluid). Small, lightweight particles are elutriated from the sample and are captured on a 25-millimeter (mm) mixed cellulose ester filter with a pore size of 0.8-µm. The resulting air filter is then sent to one of the TEM analytical laboratories for analysis.

2.2.2 Analysis Method

The FBAS-generated filters are used to prepare grids for TEM analysis. Initially, grids were prepared directly, using grid preparation techniques in basic accordance with Section 9.3 of International Organization for Standardization (ISO) Method 10312:1995(E) (ISO 1995). However, beginning in 2010, FBAS-generated filters were prepared using the rock flour preparation technique prior to making grids (see Section 4.1.1 for more information on this preparation technique).

Prepared grids were analyzed for asbestos by TEM in accordance with ISO 10312 counting and recording rules, as modified by Libby-specific laboratory modification requirements[3]. To reduce the potential level of effort to complete the TEM analysis, grid openings were examined using a tiered approach, as follows:

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[2] Depending upon the study, some samples were prepared using the FBAS preparation techniques specified in the site-specific FBAS SOP ESAT-LIBBY-01. The two SOPs are approximately equivalent.
[3] See the *Libby Lab* eRoom for the Libby-specific TEM ISO laboratory modifications.

High Magnification Analysis

The TEM analyst began the analysis utilizing a magnification of 20,000x. All amphibole structures (including not only LA but other amphibole asbestos types as well) that had appropriate selected area electron diffraction (SAED) patterns and energy dispersive spectroscopy (EDS) spectra, and having length ≥ 0.5 µm and an aspect ratio ≥ 3:1, were recorded on the FBAS-specific TEM laboratory bench sheets and electronic data deliverable (EDD) spreadsheets.

A minimum of two grid openings from each of two grids were examined. Examination of grid openings continued until one of the following was achieved:

1. The target analytical sensitivity (6.3E+03 per gram [g^{-1}]) was achieved,
2. 50 LA structures were recorded, or
3. A total area of 1.2 square millimeters (mm^2) of filter had been examined (approximately 120 grid openings, assuming a grid opening size of 0.01 mm^2).

When one of these criteria was achieved, the final grid opening was completed and the analysis ended.

Low Magnification Analysis

After completing the initial examination at 20,000x magnification, if fewer than 50 LA structures were recorded, and the target analytical sensitivity had not yet been achieved, the TEM analyst switched to a lower magnification of 5,000x and continued to record only phase contrast microscopy-equivalent (PCME) structures (i.e., length > 5 µm, width ≥ 0.25 µm, aspect ratio ≥ 3:1) until one of the following was achieved:

1. The target analytical sensitivity (6.3E+03 g^{-1}) was achieved,
2. 50 LA structures were recorded, or
3. A total area of 3.0 mm^2 of filter had been examined (approximately 300 grid openings, assuming a grid opening size of 0.01 mm^2).

When one of these criteria was achieved, the final grid opening was completed and the analysis ended.

2.2.3 Data Recording Requirements

When samples are analyzed by TEM, the analyst records the size (length, width) and structure type (e.g., fiber, bundle) of each individual asbestos structure observed. The TEM analyst also recorded the mineral type of each individual asbestos structure observed. Mineral type is determined by EDS and SAED:

- EDS is a method that takes advantage of the fact that an atom excited by absorbing a high energy electron will tend to re-emit the absorbed energy at a wavelength that is characteristic of the absorbing atom. Thus, when a particle is examined under a TEM instrument equipped with EDS, it is possible to obtain data on the atomic composition of each particle being examined. This makes it easy to distinguish organic fibers from mineral fibers, and also allows for distinguishing between different types of mineral fibers.

- SAED is a method based on the fact that crystalline structures diffract electrons to form a diffraction pattern that is characteristic of the underlying crystal structure. Thus, when a particle is examined under a TEM instrument equipped with SAED, it is possible to obtain a diffraction pattern that is helpful in distinguishing organic from mineral fibers, and in classifying the nature of the mineral fiber.

Each observed structure is assigned to one of the following four categories:

LA Libby amphibole. Structures having an amphibole SAED pattern and an elemental composition similar to the range of fiber types observed in ores from the Libby mine (Meeker *et al.* 2003). This is a solid solution series of minerals including winchite and richterite, with lower amounts of tremolite, magnesio-arfvedsonite, magnesio-riebeckite, and edenite/ferro-edenite. Depending on the valence state of iron, some minerals may also be classified as actinolite.

OA Other amphibole-type asbestos. Structures having an amphibole SAED pattern and an elemental composition that is not similar to fiber types from the Libby mine. Examples include crocidolite, amosite, and anthophyllite. There is presently no evidence that OA fibers are associated with the Libby mine.

CH Chrysotile. Structures having a serpentine SAED pattern and an elemental composition characteristic of chrysotile. There is presently no evidence that CH fibers are associated with the Libby mine.

NAM Non-asbestos material. These may include non-asbestos mineral fibers such as gypsum, glass, or clay, and may also include various types of organic and synthetic fibers derived from carpets, hair, etc. *Recording of NAM structures is not required, but analysts may note when mineral fibers with EDS similar to LA are observed, such as pyroxene.*

<u>EDS Characterization Requirements</u>

Meeker *et al.* (2003) used EDS and electron microprobe analysis to characterize the elemental content of a large number of LA structures derived from ore samples obtained from the mine, and found substantial variability in the elemental composition between (and sometime even within) individual structures. Based on the elemental composition, LA structures could be

classified into several different mineralogical categories, depending on the relative amounts of sodium and potassium. Most structures from the Vermiculite Mountain ore body contained detectable levels of both sodium and potassium (Meeker *et al.* 2003; Gunter and Sanchez 2009). In contrast, most commercial forms of actinolite and tremolite usually lack both sodium and potassium (Bern *et al.* 2002).

Use of EDS to classify an amphibole structure as LA is complicated by a number of factors, including, but not limited to, a) inherent variability in chemical composition of different LA structures, b) dependence of the spectrum on random variables, such as structure thickness, orientation, and proximity to other particles, and c) variation between instruments in sensitivity to different elemental constituents. Because of these factors, relative errors of 20% or more have been noted (Meeker and Lowers 2004), which affect the ability of the analyst to properly classify amphibole structures. For these reasons, it is not possible to define a unique EDS spectrum for LA structures (EPA 2008). Rather, each laboratory is required to develop an EDS "reference library" of LA for each TEM instrument using site-specific reference materials (prepared from samples collected at the mine) to illustrate the range of EDS conditions that encompass LA and guide the classification of amphibole structures observed in Site samples during TEM analysis.

Based on the expectation that the presence of sodium and potassium is key to distinguishing between amphibole types at the Site, the TEM analysts are also required to record structure-specific information on the elemental composition, as determined by EDS, of all amphibole structures, as follows:

NaK Both sodium and potassium are clearly present
NaX Only sodium is clearly present
XK Only potassium is clearly present
XX Neither sodium nor potassium are clearly present

In addition, TEM analysts also identify a probable mineral classification for all recorded asbestos structures. Mineral classes that may be assigned include the following:

WRTA – winchite/richterite/tremolite/actinolite
AC – actinolite
TR – tremolite
AT – actinolite/tremolite (too close to call)
AM – amosite
AN – anthophyllite
CH – chrysotile
CR – crocidolite
PY – pyroxene
NR – non-regulated amphibole
OT – other
UN – unknown

The designation "WRTA" is used to indicate a structure that is consistent with those that are observed in samples from the vermiculite mine in Libby. Structures identified as WRTA, AC, TR, or AT are classified as LA structures (regardless of their sodium/potassium content).

Figure 2-1 presents example EDS of the range of mineral classes that are classified as LA. Panel A presents a spectrum for an LA structure with both sodium and potassium (NaK) reported as WRTA, Panel B presents a spectrum for an LA structure without sodium and potassium (XX) reported as AC, and Panel C presents a spectrum for an LA structure without sodium and potassium (XX) reported as TR. Note that the presence of copper peaks in these spectra examples are a consequence of interference from the copper in the TEM grids.

2.2.4 Results Reporting

Standardized laboratory EDD spreadsheets have been developed specifically for the Site to ensure consistency between laboratories in the presentation and submittal of asbestos analytical data. The TEM analyst records the raw information for structure observed (i.e., structure type, dimensions, mineral type, sodium potassium content, etc.) and grid opening examined. From this information, the total number of LA structures is quantified and the concentration of LA in soil (C_{soil}) is calculated as LA structures per gram of soil (s/g), as follows:

$$C_{soil} = N \times S$$

where:

C_{soil} = Concentration of LA in soil (s/g)
N = Number of asbestos structures counted
S = Analytical sensitivity (g^{-1})

The analytical sensitivity (S) is calculated as follows:

$$S = EFA / (GO \times A_{GO} \times f \times M \times Q_R)$$

where:

S = Analytical sensitivity (g^{-1})
EFA = Effective filter area (mm^2)
GO = Number of TEM grid openings evaluated
A_{GO} = Area of one TEM grid opening (mm^2)
f = Indirect filter preparation dilution factor, if applicable
M = Mass of soil placed in the FBAS (g)
Q_R = Flow ratio; this is the fraction of the volume of air passed through the soil sample (V_{total}) that is filtered through the air filter (V_{filter}), and is calculated as:

$$Q_R = V_{filter} / V_{total}$$

PE studies of the FBAS method (Januch *et al.* 2013) using LA-spiked PE standards with a range of nominal mass percent levels show there is an approximately linear relationship between the concentration of LA in PE standards (as mass percent) and the reported total LA soil concentration (as s/g). Thus, it is possible to estimate the LA soil concentration as mass percent from the measured total LA soil concentration expressed as s/g as follows:

$$C_{soil} \text{ (as mass percent)} = C_{soil} \text{ (as s/g)} / 3.6E+07$$

For example, a total LA soil concentration of 1E+05 s/g is estimated to be approximately 0.003% LA (by mass).

3 DATA MANAGEMENT

3.1 Sample Collection, Documentation, Handling, and Custody

All samples generated as part of the investigations discussed in this report were collected, documented, and handled in accordance with Libby-specific SOPs, as specified in the investigation-specific sampling and analysis plan/quality assurance project plans (SAP/QAPPs) (EPA 2010b; CDM Smith 2011, 2012a, 2012b, 2012c; Tetra Tech 2012).

All samples collected were identified with unique sample identification (ID) numbers that included an investigation-specific prefix (e.g., the prefix TK- identifies samples collected as part of the Troy background soil investigation). Data on the sample type, location, collection method, and collection date of all samples were recorded both in a field logbook maintained by the field sampling team and on a field sample data sheet (FSDS) designed to facilitate data entry into the Site databases (see below). All samples collected in the field were maintained under chain of custody during sample handling, preparation, shipment, and analysis.

3.2 Analytical Results Recording

As noted above, standardized EDDs have been developed specifically for the Site to ensure consistency between laboratories in asbestos results reporting. In general, a unique EDD has been developed for each analytical method and environmental medium. Each EDD provides the analyst with a standardized laboratory bench sheet and accompanying data entry form for recording asbestos analytical data. The data entry forms contain a variety of built-in quality control functions that improve the accuracy of data entry and help maintain data integrity. These spreadsheets also perform automatic computations of analytical input parameters (e.g., sensitivity, dilution factors, and concentration), thus reducing the likelihood of analyst calculation errors. The EDDs generated by the laboratories are uploaded directly into the site databases (see Section 3.4).

3.3 Hard Copy Data Management

Hard copies of all field documentation are stored in the Libby and Troy field offices. All analytical bench sheets are scanned and included in the analytical laboratory job reports. These analytical reports are submitted to the Site laboratory coordinator and stored electronically.

3.4 Electronic Data Management

Detailed information regarding electronic data management procedures and requirements for the Site is provided in the *EPA Data Management Plan for the Libby Asbestos Superfund Site* (EPA 2012). In brief, sample and analytical electronic data are stored and maintained in Scribe, a software tool developed by EPA's Environmental Response Team to assist in the process of

managing environmental data. A Scribe "project" is a Microsoft Access® database. Multiple Scribe projects can be stored and shared through Scribe.NET, which is a web-based portal that allows multiple data users controlled access to Scribe projects. Data summarized in this report were downloaded from multiple Site projects on Scribe.NET on 1/24/2014 and combined into a single Microsoft Access® database. A frozen copy of this database is provided in **Appendix A** of this report. Any changes made to the Scribe projects since this download will not be reflected in the database.

4 CHARACTERIZATION OF LA IN SOIL

The EPA has conducted numerous investigations at the Site seeking to characterize airborne levels of LA that occur in association with soil disturbance activities. One study was the *2007-2008 OU4 Outdoor Residential ABS* study. The detailed results of this study are summarized in EPA (2010a). In brief, this study collected ABS air samples from residential yards during simulated mowing, raking, and digging activities. The types of properties evaluated in this study included several properties where soil removal actions had been completed and the ABS activity was performed on soils that represented "clean fill" materials. Clean fill is soil material that is brought in from borrow pits (many of which are located within the Kootenai Valley) to replace materials that have been removed as part of a soil removal action. Because these fill materials are not exposed until excavation, it is believed that they are not impacted by mining-related releases. Contrary to what might have been expected, LA fibers were present in ABS air from areas that were comprised of clean fill, which raised the possibility that there is some non-zero level of LA in soils of the Kootenai Valley that is not attributable to anthropogenic releases from vermiculite mining and processing activities.

Since the *2007-2008 OU4 Outdoor Residential ABS* study, several investigations have been performed to characterize LA in soil at the Site from areas that are thought to be representative of "background" conditions. The following sections summarize these investigations.

4.1 Background Soil Investigations

This section summarizes three background soil investigations completed for the Site, including the 2010 Libby pilot study, the 2011 Libby background study, and the 2012 Troy background study.

4.1.1 2010 Libby Pilot Study

<u>Study Design</u>

The EPA has collected and analyzed a large number of soil samples from the Libby area since beginning work at the Site in 1999. Prior to 2010, sample analyses used semi-quantitative and subjective evaluation techniques with relatively low sensitivity (PLM-VE and field-based visual vermiculite estimates). In addition, no soil samples were collected intentionally to be representative of background. Thus, the EPA conducted a pilot study (EPA 2010b) in 2010 to collect and analyze soil samples to provide an initial characterization of the range and distribution of background levels of LA (and potentially other forms of asbestos) in Libby area soils.

Locations were selected for evaluation based on the following criteria:

1. To facilitate access, locations shall be on County, State, or Federal land.

2. Locations shall be in the Kootenai Valley near OU4 at an elevation that is not higher than the maximum level of the historic glacial lake level (i.e., 2,450 feet AMSL) (Langer *et al.* 2010).

3. Locations shall be situated in an upwind (southwest) or crosswind direction relative to the mine and/or known processing areas (e.g., former Export Plant).

4. There shall be no evidence of historic or recent anthropogenic activities (in the past 50 to 100 years) that would have resulted in substantial disturbance or mixing of soil.

5. Locations shall not be within about 100 meters of any known or suspected local vermiculite emission sources (e.g., railroads, highways, vermiculite processing areas).

6. To the extent feasible, locations should be able to accommodate possible future ABS.

A total of 20 candidate locations in 11 different background areas (Areas A-K) were sampled near Libby as part of this study. **Figure 4-1** provides a map of these background soil locations. At each background location, two 30-point soil composites were collected from an area of approximately 300 square feet (ft^2). At each of the 30 soil sampling points, a soil sample was collected using a 1-inch stainless steel coring device to a depth of approximately 6 inches. The top 1 inch of each core was removed to minimize the potential contribution of historic deposition of airborne LA released from past mining, milling, and transporting activities. The 0-1 inch interval of each core sample for each composite was combined and archived for possible future analysis. The 1-6 inch interval of each core was combined and homogenized for FBAS preparation and analysis by TEM (see Section 2.2).

In addition, an aliquot of the soil was analyzed to characterize the basic mineral content of the soils. Three basic mineralogical analyses were performed to characterize these soils:

- Particle size distribution (percent sand, silt, and clay) in accordance with ASTM D422
- Optical petrographic analysis by PLM with quantitation by the point counting technique in basic accordance with EPA/600/R-93/116 (EPA 1993)
- XRD analysis in basic accordance with preparation and analysis methods described in NIOSH Method 7500, NIOSH Method 9000, and ASTM D934

<u>Results</u>

Appendix B presents the detailed mineralogical analysis results. **Table 4-1** summarizes the mineral characterization results for each soil sample. These results are shown graphically in **Figure 4-2** (by location) and **Figure 4-3** (across all background locations). As shown, quartz and albite were predominant in most soils and the XRD analysis showed a higher content of micas.

XRD detected vermiculite at background locations A and J. PLM point counting detected amphibole at background locations A, C, H, and I. For most samples, the soil particle size was very fine, with 40% or more of the particles within the silt and clay (<75 µm) fraction.

For this study, FBAS filters were prepared using standard filter and grid preparation methods, meaning that filters were generated using FBAS, adjusting the soil mass fluidized to optimize filter particulate loading such that grids could be prepared directly from the filter for TEM analysis. However, during the FBAS preparation of these background soil samples, the FBAS preparation laboratory noted the presence of "glacial flour" in the soil samples, which resulted in overloaded filters, even when soil mass fluidized was small. Because of this issue, the preparation and analysis of these background samples was halted prior to the completion of all the analyses. **Table 4-2** presents the results for the samples that were prepared by FBAS and analyzed by TEM. As shown, LA structures were observed in 3 of the 17 background soil samples[4] analyzed.

Rock Flour Preparation Method

To alleviate the issue of overloaded filters for these samples, the Environmental Services Assistance Team Region 8 (ESATR8) laboratory developed the "rock flour" preparation method (TechLaw, Inc. 2011). This preparation method was developed based on techniques published by Webber *et al.* (2008) for enriching amphibole fiber recovery from solid media. In brief, filters are generated using the FBAS while maximizing the soil mass (5 grams) such that the resulting filter is intentionally overloaded. At the TEM laboratory, the FBAS filter is ashed using the same procedures described in Libby-specific SOP EPA-LIBBY-08. The resulting ash residue is suspended in water, sonicated, and the suspension allowed to settle in a graduated cylinder for 3 hours. This process allows the heavier soil particles to settle out, but the asbestos fibers, which have a larger surface area to weight ratio, remain in suspension (Webber *et al.* 2008). After the settling time has elapsed, an aliquot of the top portion of the suspension is placed onto a new filter, which is used to prepare grids for analysis by TEM.

Table 4-3 presents the FBAS-TEM results for four background samples prepared using the rock flour preparation technique. These four samples were selected because LA structures were detected in the original direct preparation analysis (see **Table 4-2**). For comparison purposes, the results from the direct preparation analysis are also shown. As shown, LA structures were observed in all four background soil samples. EDS determined the presence of amosite structures in two samples. For two samples, the number of LA structures was significantly higher[5] using the rock flour preparation technique than the direct preparation, despite the fact the direct preparation had a lower (better) analytical sensitivity. This suggests that the rock

[4] One LA structure was also detected in a 4th sample, but the structure was not counted because it crossed a non-countable grid bar.
[5] As determined using the Poisson ratio comparison test in Nelson (1984), based on a 90% confidence interval.

flour preparation technique is effective at concentrating the asbestos fiber loading on the prepared filter. It is also possible that the sonication step of the rock flour preparation is increasing the number of asbestos structures due to the dispersion of bundles and clusters. Section 5.4.4 discusses the potential effect of the rock flour preparation technique on result interpretation.

Based on these results, starting in 2011, all Site soil samples have been prepared for TEM analysis using FBAS have utilized the rock flour preparation technique.

4.1.2 2011 Libby Investigation

Study Design

Based on the results of the 2010 Libby background pilot study, the EPA determined that additional data were needed to characterize LA in background soils. In 2011, a follow-up investigation was performed in the same 11 background areas (Areas A-K) evaluated in 2010 (see **Figure 4-1**). This investigation included the collection of ABS air samples during soil disturbance activities (CDM Smith 2012a).

The ABS digging activities were performed using soils collected from each background area and composited in a 5-gallon container; hence, this ABS scenario is referred to as the "bucket of dirt" digging scenario. Prior to collecting soil material, the top 0-1 inches of soil and any vegetation were carefully removed and set aside. Soil materials were collected from a depth of 1-6 inches below ground surface. Enough soil material was obtained from each background area to fill a 5-gallon container. An aliquot of the collected soil was prepared by FBAS, using the rock flour preparation technique, and analyzed by TEM (see Section 2.2).

The 5-gallon container was brought to a standardized location where the ABS soil disturbance scenario was conducted. The ABS activity was performed using a hand trowel, simulating a child digging and playing in the dirt (see **Figure 4-4**). Three digging ABS events were performed for each background area. The resulting ABS air samples were analyzed for asbestos by TEM using modified[6] ISO Method 10312 Annex E counting and recording rules. In brief, grid openings were examined under low magnification (~5,000x) and only those asbestos structures that were PCME (i.e., length > 5 µm, width ≥ 0.25 µm, aspect ratio ≥ 3:1) were recorded. Asbestos air concentrations must be expressed as PCME in order to estimate potential human health exposures and perform risk calculations. *[Note: The evaluation of potential risks is beyond the scope of this document. Human health risks from exposures to LA are evaluated in the Site-wide human health risk assessment.]*

[6] At the Libby Site, there are several Libby-specific analytical method modifications in effect. Consult the governing SAP/QAPP document for specific information on which laboratory modifications applied for each investigation.

Results

Table 4-4 presents the measured ABS air and TEM-FBAS soil concentrations for each background area for each sampling event. In this table, results for ABS air samples are expressed as PCME LA structures per cubic centimeters of air (s/cc), since this is the metric used to evaluate potential human health exposures and risks. Soil concentration results are expressed based on both total[7] LA and PCME LA (as s/g). **Figure 4-5** provides a graphical presentation of these results based on the mean concentration across the three sampling events. As seen, LA was detected in ABS air at four background locations (A, B, G, and J). Recall that for locations A and J, the XRD analysis performed in 2010 showed vermiculite levels of about 3-7% at these locations (see **Table 4-1**). As shown in **Table 4-4**, LA was detected in soils at every background location, with the highest total LA soil concentrations measured at locations J, E, and K. These results indicate that analysis of soil by TEM following FBAS preparation appears to be a more sensitive metric of LA detection than the "bucket of dirt" ABS scenario.

The average total LA concentration in soil across all background locations is about 5E+05 s/g. Based on the LA-specific regression equation presented in Januch *et al.* (2013), this is approximately 0.014% by mass. Note that this regression was developed based on the analysis of LA-specific PE standards (spiked with a known mass of LA) following FBAS preparation and direct preparation of the resulting filter. Thus, the application of this regression to samples prepared using the rock flour preparation method is uncertain, and predicted mass percent estimates may be biased high.

A review of sodium and potassium content and mineral type assignments for the total LA structures observed in soil during the TEM-FBAS analysis (see **Figure 4-6**) shows structures classified as WRTA and containing sodium and potassium (NaK) as well as structures that were ranked as AC and TR without sodium and potassium (XX). In fact, about one-third of the total LA structures recorded were classified as XX. Although fewer LA structures were observed in ABS air, a similar observation exists, with both NaK and XX structures observed. As noted above, according to Meeker *et al.* (2003), asbestos structures originating from the Vermiculite Mountain ore body contain detectable levels of both sodium and potassium, whereas other potential sources of LA may not. This would indicate that a portion of the LA structures observed in these soils likely do not originate from the Vermiculite Mountain ore body. These results are consistent with the data presented in Gunter and Sanchez (2009), which indicated that not all amphiboles isolated from soil samples in Libby were from the Vermiculite Mountain ore body, as evidenced by the lack of sodium and/or potassium in the EDS.

[7] Total LA structures include all structures with a length > 0.5 um and an aspect ratio ≥ 3:1.

4.1.3 2012 Troy Investigation

Study Design

Based on the results of the 2011 background study conducted for OU4 (see Section 4.1.2), it was determined that a similar study of background soils should be conducted specific to OU7, which includes the town of Troy, located approximately 20 miles northwest of Libby. In 2012, an investigation was performed by the Montana Department of Environmental Quality[8] (MDEQ) to evaluate LA levels in background soils near OU7 (Tetra Tech 2012).

The OU7 background soil sample locations were selected using geologic maps, the 1995 Soil Survey of the Kootenai National Forest Area (USDA 1995), visual inspections, and other criteria described below. The 1995 Soil Survey provided important soil information and maps to select the sites. Soil mapping units were differentiated based on landform, slope, parent material, vegetation, aspect, elevation, and rock outcrop. Background soil samples were collected from mapping units for soils that developed from parent materials deposited during the historical glacial Lake Kootenai era. The soil mapping units are shown in **Table 4-5**.

In addition to using the delineated soils, other criteria applied in the selection of locations for the collection of background soil samples were:

1. Locations must be on city, county, state, or federal land or lands currently being leased by a government entity.

2. Locations must be in or near Troy at an elevation no higher than the maximum level of the historical glacial lake level (2,450 feet AMSL).

3. There can be no evidence of historical or recent anthropogenic activities (in the past 50 to 100 years) that would have resulted in substantial disturbance or mixing of soil.

4. Locations must not be within about 100 meters of any known or suspected local vermiculite emission sources (such as railroads and highways).

5. Locations will not be representative of clean fill material.

6. No visible vermiculite should be observed.

A total of 11 background soil samples were collected as part of the OU7 background soil study. **Figure 4-7** provides a map of the background soil locations for the OU7 study. Similar to the

[8] MDEQ is responsible for technical support and field sampling activities related to OU7 (Troy). The EPA is responsible for these activities in OU4 (Libby).

2011 background soil study conducted for OU4, the OU7 study included the collection of ABS air samples during "bucket of dirt" digging (see Section 4.1.2). The resulting ABS air samples were analyzed for asbestos by TEM using modified ISO Method 10312 Annex E counting and recording rules. A single digging ABS event was performed for each background area. In addition to the ABS air samples, two soil samples from each background area (1-6 inch depth interval) were prepared by FBAS, using the rock flour preparation technique, and analyzed by TEM. For 5 of the 22 soil samples, the FBAS filters were prepared in triplicate and the resulting filters were prepared and analyzed by three different TEM laboratories (see Section 2.2).

Results

Table 4-6 presents the measured ABS air and TEM-FBAS soil concentrations for each OU7 background location. In this table, results for ABS air samples are expressed as PCME LA s/cc, since this is the metric used to evaluate potential human health exposures and risks. Soil concentration results are expressed based on both total LA and PCME LA (as s/g). **Figure 4-8** provides a graphical presentation of these results.

As shown, LA was detected in 7 of 11 OU7 background locations based on ABS air and in 10 of 11 OU7 based on soil. PCME LA ABS air concentrations were highest for the Shannon Flats locations, while total LA soil concentrations were highest for the East Side Road Forest Service #2 location. The average total LA concentration in soil across all OU7 background locations is about 1E+05 s/g. Based on the LA-specific regression equation presented in Januch *et al.* (2013), this is approximately 0.003% by mass, which is about five times lower than the soil concentrations measured in Libby background areas.

A review of sodium and potassium content and mineral type assignments for the LA structures observed in soil (based on total LA) and ABS air (based on PCME LA) during the TEM analysis (see **Figure 4-9**) shows that about one-third of all LA structures did not have sodium and potassium peaks (XX) in the EDS. These results are similar to what was observed in Libby background areas (see Section 4.1.2) and indicate that a portion of the LA structures observed in these soils likely do not originate from the Vermiculite Mountain ore body.

4.2 Libby Borrow Source Soil

Study Design

As discussed above, the results of the *2007-2008 OU4 Outdoor Residential ABS* study showed that LA fibers were detected in ABS air samples collected from areas representative of clean fill materials at properties that have had a removal. This raised the possibility that there may be some non-zero level of LA in soils from topsoil borrow sources that is not attributable to anthropogenic releases from vermiculite mining and processing activities. Therefore, in 2011, the EPA conducted an investigation (CDM Smith 2012a) to provide information on LA concentrations in soils from topsoil borrow sources that have been used as fill material at Libby.

This investigation evaluated multiple topsoil borrow sources located throughout the Kootenai Valley, including the Boothman Pit, the Fink Pit, the Feller Pit, and the Noble Ranch House Pit #1 outside of Libby. **Figure 4-10** shows the location of the Kootenai Valley topsoil borrow source areas that were evaluated in this investigation. In addition, a topsoil borrow source in Eureka, Montana (Valley View Pit) was also investigated.

The evaluation of each borrow source used a study design equivalent to that employed for the evaluation of background locations. In brief, this investigation included the collection of ABS air samples using the "bucket of dirt" ABS digging scenario (see Section 4.1.2). The resulting ABS air samples were analyzed for asbestos by TEM using modified ISO Method 10312 Annex E counting and recording rules. Three digging ABS events were performed for each borrow source area.

For active borrow sources, soils were collected from available fill material piles. In cases where the borrow source had been reclaimed, soils were collected from locations next to the reclaimed area. Prior to collection, the top layer of soil and vegetation was carefully removed and set aside. Soil materials were collected to a depth similar to that which was used when the borrow source was active (i.e., 6-18 inches below ground surface). An aliquot of the collected soil was prepared by FBAS, using the rock flour preparation technique, and analyzed by TEM in basic accordance with modified ISO 10312 counting and recording rules. During the FBAS preparation, filters were prepared in triplicate for each soil sample and analyzed separately by different TEM laboratories (see Section 2.2).

<u>Results</u>

Table 4-7 presents the ABS air concentration (as PCME LA s/cc) and TEM-FBAS soil concentration results (as total LA and PCME LA s/g) for each borrow source for each sampling event. **Figure 4-11** provides a graphical presentation of these results based on the mean concentration across the three sampling events. As seen, LA was detected in ABS air at two borrow sources – Boothman Pit and Fink Pit, with the highest air concentrations measured at the Fink Pit. LA was detected in soil at all Kootenai Valley borrow sources. On average, the total LA soil concentration in the borrow sources was about 3E+05 s/g, which is approximately 0.009% by mass (Januch *et al.* 2013) and similar to concentrations measured in Libby background soils (see Section 4.1.2). No LA was detected in ABS air or soil from the Valley View Pit in Eureka.

A review of the types of LA structures observed in borrow source soil (see **Figure 4-12**) shows structures classified as WRTA and containing sodium and potassium (NaK) as well as structures that were ranked as AC and TR without sodium and potassium (XX). The frequency of XX structures was highly variable across borrow sources, ranging from about 30% of all LA structures ranked as XX at the Boothman Pit to about 75% for the Feller Pit. For ABS air, all LA structures observed were NaK and classified as WRTA.

4.3 Libby City Pit

Study Design

The Libby City Pit has been utilized as a source of structural fill material. The pit is located in Libby, just north of the Kootenai River, near the intersection of Highway 37 and Pipe Creek Road. Eight gravel samples (FM-00013 to FM-00020) were collected from each of the onsite stockpiles within the pit on April 17, 2012. Each sample was collected as a 30-point composite from the top 6 inches of the stockpile; samples were analyzed by PLM-VE. The PLM-VE analysis reported trace (Bin B1) levels of LA in the fine-ground fraction for four of the eight samples, which indicates that LA was present at levels lower than 0.2% (by mass).

In the fall of 2012, a study was conducted to provide an inter-laboratory evaluation of the PLM-VE results and to better characterize the low levels of LA in these samples using TEM-FBAS. One of the archived fine-ground aliquots for each sample was analyzed by PLM-VE by a different laboratory than the one that performed the original analysis. In order to better characterize LA concentrations in these eight samples, the unaltered archived portion {A} of each sample was prepared by FBAS, using the rock flour preparation technique. During the FBAS preparation, filters were prepared in triplicate for each soil sample and analyzed separately by different TEM laboratories (see Section 2.2).

Results

Table 4-9 presents the PLM-VE results (for the original analysis and the re-analysis) and the FBAS soil concentration results (as total LA and PCME LA s/g) for each Libby City Pit sample. As seen, all of the PLM-VE analyses performed by the inter-laboratory (Hygeia Laboratories, Inc. [Hygeia]) were ranked as non-detect (Bin A). These results are consistent with recent inter-laboratory results for PLM-VE, which shows that the ESATR8 laboratory (which was the original PLM laboratory) is able to identify trace levels of LA in soil more reliably that the other PLM laboratories (see Section 5.3.3 for more information).

The FBAS-TEM results show that LA was detected in every soil sample (in one or more filter replicates). **Figure 4-14** presents the mean total LA soil concentration (s/g) in each soil sample. As seen, there does not appear to be a correlation between the PLM-VE result and the TEM-FBAS soil concentration (i.e., samples ranked as trace [Bin B1] by PLM-VE do not necessarily have a higher soil concentration by TEM-FBAS). The average total LA concentration across all samples was about 7E+05 s/g, which is approximately 0.02% by mass (Januch *et al.* 2013). These results are consistent with the data presented by Adams *et al.* (2010), which also sampled materials from these sand pits. Analysis of materials in these pits by scanning electron microscopy indicated LA was present at varying depths at concentrations of about 0.06% to 0.08% (by mass).

Similar to what was observed in background and borrow source soils, the types of LA structures observed in Libby City Pit soil samples included a mixture of NaK (WRTA) and XX (AC and TR), with about 40% of all LA structures ranked as XX (see **Figure 4-15**). These results support the conclusion that a portion of the LA structures observed in these soils likely do not originate from the Vermiculite Mountain ore body.

4.4 Libby Curb-to-Curb Residential ABS

Study Design

Previous OU4 outdoor ABS efforts did not include residential properties in which a full yard removal (i.e., a "curb-to-curb" soil removal) had been conducted. Thus, in 2011, the EPA performed an investigation to collect outdoor ABS air data at "curb-to-curb" properties (CDM Smith 2011). Because the entire yard for these properties has been removed and replaced, ABS air collected at these properties should be representative of topsoil borrow source soils.

Eleven residential properties were selected for evaluation. These properties were selected because they had undergone a "curb-to-curb" yard removal between 2008 and 2010. A total of three sampling events were conducted at each property[9] in the summer of 2011. During each event, ABS activities were conducted using an ABS script representing a composite of typical residential soil disturbance activities, including mowing, raking, and digging activities. The mowing portion of the ABS composite represented a one-pass mowing of the entire yard (there was no specified sampling duration). The raking portion of the ABS composite represented a one-pass raking of the entire yard (there was no specified sampling duration). The digging portion of the ABS composite represented digging a hole at each of 2 to 6 locations, simulating sprinkler maintenance activities (i.e., digging with a long shovel and trowel). The resulting ABS air samples were analyzed for asbestos by TEM using modified ISO Method 10312 Annex E counting and recording rules.

During each ABS event, one surficial (0-3 inch) 30-point composite soil sample was collected to be representative of the entire yard. The sampling points within the 30-point composite included the 2 to 6 sub-locations selected for digging. Soil samples were analyzed by PLM-VE (preparation by FBAS was not performed).

Results

Detailed results for the curb-to-curb ABS study are provided in the *2011 OU4 Residential ABS Data Summary Report* (CDM Smith 2013a). **Table 4-8** summarizes the soil results and measured ABS PCME LA air concentrations for each property for each sampling event. Soil concentrations by PLM-VE were reported as non-detect (Bin A) for all but one soil sample, which was reported

[9] One property elected to only participate in one of the three sampling events.

as trace (Bin B1), and visible vermiculite was rarely observed by the field team during sample collection (low levels were observed in only 2 of 31 soil samples collected). However, PCME LA was detected in air in one or more ABS air samples for six properties. In general, PCME LA concentrations in air tended to be fairly low for most samples, with concentrations usually less than about 0.001 PCME LA s/cc. Only one property (AD-001713) consistently had detected PCME LA concentrations in ABS air for all three sampling events. Most notable was that concentrations in two ABS air samples from two different properties exceeded 0.01 PCME LA s/cc. For these two properties, ABS results tended to be highly variable between sampling events, ranging from non-detect (<0.00022 PCME LA s/cc) to higher than 0.01 PCME LA s/cc depending upon the sampling event. Review of the LA structure-specific attributes in one of these samples (EX-20201) showed that nearly all of the PCME LA structures observed were ranked as TR without sodium or potassium (XX)[10].

In reviewing information on the fill material sources that were in use at the time of the curb-to-curb removals (2008-2010), it appears that the primary topsoil borrow pits in use were the Noble Pit and the Noble Ranch House Pit #1. **Figure 4-13** presents a comparison of the curb-to-curb ABS air concentrations to those measured in ABS air samples collected for the topsoil borrow sources (see Section 4.2). As shown, with the exception of the two properties discussed above, the outdoor ABS air concentrations measured at most curb-to-curb properties were similar to the ABS air concentrations measured at borrow sources.

4.5 Comparative Exposure Study

Study Design

The investigations discussed above support the conclusion that LA is present in background soils in the Kootenai Valley. In 2012, the EPA conducted a study to collect data on LA concentrations in a variety of media from towns near the Site that are not impacted by the mine to provide a frame of reference for comparisons to the Site (CDM Smith 2012c). The study measured LA concentrations in outdoor ABS air and other environmental source media (i.e., soil, tree bark, duff material[11]). Samples were collected from locations near Eureka, Helena, and Whitefish, Montana. In the past, Eureka and Helena had been selected for the purposes of providing reference data associated with ambient air monitoring. The town of Whitefish was selected for this investigation because it is one of the two nearest towns (Eureka being the second) in the predominant downwind direction (northeast) of the former vermiculite mine.

To avoid sampling access issues, sample collection areas near each city were selected in locations that were state or federally-owned. Three sampling locations for each city, identified as Area A, B, or C (e.g., Helena Area A), were sampled. Locations were placed such that they

[10] Subsequent analysis of the corresponding low volume filter (EX-20202) corroborated this observation.
[11] Duff material consists of leaf litter, pine needles, and organic debris on the ground surface.

were representative of various compass directions around each city. To minimize potential impacts from anthropogenic sources, locations outside of the city limits were selected. Sampling locations were placed in areas that were accessible *via* forest service roads and that appeared to have adequate tree cover (based on a review of aerial images). **Figure 4-16** provides a map of the sampling locations for each town.

At each sampling location, two different types of outdoor ABS scenarios were evaluated – the "bucket of dirt" digging scenario (equivalent to the ABS scenarios performed for the Background Soil [Section 4.1] and Borrow Source [Section 4.2] studies) and a fireline scenario (simulating a fire fighter digging a fireline by hand using a Pulaski tool). In addition to ABS air samples, surficial soil (0 to 3 inches) was collected within each 100-ft^2 digging ABS location to serve as the composite soil sample of source material for the digging ABS activity. Enough soil was collected from 30 sub-locations evenly distributed within each ABS area to fill a 5-gallon bucket and then homogenized. Prior to conducting ABS air sampling, approximately 1,000 grams of soil was taken from the homogenized soil used to fill the 5-gallon bucket for preparation by FBAS, using the rock flour technique. During the FBAS preparation, filters were prepared in triplicate for each soil sample and analyzed separately by different TEM laboratories (see Section 2.2).

Results

Detailed results for the *Comparative Exposure Study* are provided in CDM Smith (2013b). **Table 4-10** presents the results of the TEM-FBAS analysis of each soil sample. As seen, LA structures were observed in one or more replicates for every city (i.e., Eureka, Helena, and Whitefish). On average, total LA soil concentrations ranged from about 3E+03 to 7E+04 s/g, which is about 10 to 100 times lower than background soil concentrations measured at the Site. For these soil samples, the LA structures observed were ranked as being characteristic of AC or TR; no sodium or potassium (XX) was noted in the EDS spectra for any of these structures. This would indicate that the amphibole structures observed in these soils do not originate from the Vermiculite Mountain ore body (Meeker *et al.* 2003).

Table 4-10 also presents the results of the ABS air samples, stratified by sampling location and ABS disturbance scenario. As shown, no LA structures were observed in any of the ABS air samples. These results demonstrate that, despite the fact that detectable levels of asbestos were noted in the soils, active disturbances of these soils did not result in releases of asbestos to air.

5 DATA QUALITY ASSESSMENT

A data quality assessment (DQA) reviews existing data to establish their quality and to determine if and how any data quality limitations may influence data interpretation (EPA 2006). A DQA also reviews data to determine if they are adequate to meet the established data quality objectives (DQOs) and are sufficient to support decision-making.

There were several quality assurance (QA) procedures and quality control (QC) measures that were implemented during the various background soil studies to ensure that the resulting data were of high quality. A summary of the planned QA/QC procedures is provided in the governing SAP/QAPP for each study (EPA 2010b; CDM Smith 2011, 2012a, 2012b, 2012c; Tetra Tech 2012). Each SAP/QAPP was developed and approved by the governing agency (EPA or MDEQ) prior to the collection of any study samples. The SAP/QAPP provides a detailed discussion of the DQOs, the planned study design, the sample collection, analysis, and data reporting procedures, and all QA/QC requirements.

The following sections provide an overview of the QA programs implemented in the field, the soil preparation laboratory, and the analytical laboratories (Section 5.1), discuss the results of the verification and validation efforts for the background soil datasets (Section 5.2), and review the results of field and laboratory QC samples (Section 5.3). Section 5.4 reviews the adequacy of the data summarized in this report and discusses potential data limitations and biases that could affect data interpretation and decision-making.

5.1 Overview of Quality Assurance Program

5.1.1 Field

Field QA activities include all processes and procedures that have been designed to ensure that field samples are collected and documented properly, and that any issues/deficiencies associated with field data collection or sample processing are quickly identified and rectified. Detailed information can be found in the governing SAP/QAPP for each study. The following bullets summarize the components of the field QA program implemented as part of the studies summarized in this report.

- **Field Team Roles, Responsibilities, and Oversight –** There are a variety of field personnel involved in the sampling investigations for the Site and each individual has assigned roles and responsibilities. The field team leader oversees all sample collection activities to ensure that governing documents are implemented appropriately. The field QA manager is responsible for ensuring that all field efforts are conducted in accordance with appropriate QA guidelines. In addition, formal field surveillances and/or field audits may also be performed, as specified in the governing SAP/QAPP.

- **Field Team Training –** Individuals involved in the collection, packaging, and shipment of samples must have appropriate training, including Occupational Safety and Health Administration (OSHA) 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) and relevant 8-hour refreshers, respiratory protection, and asbestos awareness training.
- **Orientation –** Field personnel are required to attend an orientation session with the field Health and Safety (H&S) manager, as well as an orientation session on sample collection techniques.
- **Investigation-Specific Documentation –** Field personnel are required to review and understand all applicable governing documents associated with the sampling investigation, including the SAP/QAPP, all associated SOPs, and the applicable H&S plans.
- **Readiness Reviews –** Prior to beginning field sampling activities, meetings are conducted to discuss and clarify the objectives, equipment and training needs, field SOPs, QC samples, and H&S requirements for each investigation.
- **Field Documentation Review –** Field documentation is completed by field staff using investigation-specific field forms. These field forms provide a standardized method of documenting sample information generated in the field. Field documentation is reviewed on a regular basis to ensure the accuracy of the recorded sample information.
- **Equipment Maintenance/Calibration –** All field equipment is maintained in accordance with manufacturer specifications and site-specific SOPs. For air samples, each air sampling pump is calibrated to the desired flow rate using a primary calibration standard prior to sample collection.
- **Equipment Decontamination –** Field equipment used in sample collection is decontaminated in accordance with site-specific SOPs. Any disposable equipment or other investigation-derived waste is handled in conformance with SOP requirements.
- **Sample Custody/Tracking** - All samples collected at the Site are tracked and managed in accordance with site-specific SOPs for sample custody and tracking using appropriate chain of custody (COC) forms.
- **Field QC Samples** - A variety of different types of field QC samples have been collected as part of the studies included in this report. These QC samples provide information on potential contamination arising from sample collection methods as well as information on result precision. (See Section 5.3 for a summary of field QC results.)
- **Modification Documentation –** Major deviations to the SAP/QAPP that modify the sampling approach and associated guidance documents are recorded on a field record of modification (ROM) form. These ROMs are reviewed and approved by the governing agency.

5.1.2 Soil Preparation Laboratory

All background soil samples collected as part of the studies discussed in this report were sent to the SPF in Troy, Montana for preparation prior to analysis. The following bullets summarize

components of the SPF QA procedures that ensure the soil preparation processes are conducted in accordance with governing procedures and the resulting measurements are scientifically sound and of acceptable and documented quality.

- **Personnel Training -** Individuals involved in the processing of samples are required to have read and understood all associated soil processing SOPs as well as the facility H&S plan. In addition, personnel must meet appropriate H&S requirements, including respirator fit testing, annual medical monitoring, and OSHA 40-hour HAZWOPER with annual 8-hour refresher training.
- **Documentation Review –** Sample preparation documentation is completed by SPF staff using site-specific forms. These forms provide a standardized method of documenting sample preparation information generated. This documentation is reviewed on a regular basis to ensure the accuracy of the recorded preparation information.
- **Equipment Maintenance/Calibration –** All weight scales, ventilation hoods, FBAS units, sampling pumps, and drying ovens used in sample preparation are maintained and calibrated each day in accordance with manufacturer specifications.
- **Equipment Decontamination –** Sample preparation equipment that is reused is decontaminated between each sample in accordance with Libby-specific SOPs ISSI-LIBBY-01 (for PLM equipment) and OEAFIELDSOP-102 (for FBAS equipment).
- **Contamination Monitoring –** The SPF performs regular contamination monitoring to evaluate worker safety, ensure laboratory cleanliness, and help assess the potential for cross-contamination of samples submitted to the facility.
- **Sample Custody/Tracking –** All samples collected processed at the SPF are tracked and managed in accordance with COC requirements and sample documentation methods for the Site.
- **Preparation QC Samples –** A variety of different types of preparation QC samples have been included in the preparation of samples using the FBAS and in the sieving/grinding of samples for PLM analysis. These QC samples provide information on potential contamination arising from sample preparation methods as well as information on result precision. (See Section 5.3 for a summary of preparation QC results.)
- **Modification Documentation –** Major deviations from the Libby-specific preparation SOP are recorded on an SPF ROM form. These ROMs are reviewed and approved by the EPA (or their designee).

5.1.3 Analytical Laboratories

All laboratories selected for analysis of samples for asbestos are part of the Libby analytical laboratory team. These laboratories have all demonstrated experience and expertise in analysis of LA in environmental media, and all are part of an ongoing site-specific QA program designed to ensure accuracy of analytical and consistency of reported analytical results between laboratories. These laboratories are audited by the EPA Quality Assurance Technical Support

(QATS) contractor and the National Institute of Standards and Technology (NIST)/National Voluntary Laboratory Accreditation Program (NVLAP) on a regular basis.

Laboratory QA activities include all processes and procedures that have been designed to ensure that data generated by an analytical laboratory are of high quality and that any problems in sample preparation or analysis that may occur are quickly identified and rectified. The following bullets summarize the laboratory QA procedures that are required of each laboratory that analyzes samples from the Site.

- **Laboratory QA Management Plan –** Each laboratory has developed a laboratory-specific *QA Management Plan* that provides a detailed description of the procedures and policies that are in place at their laboratory to ensure laboratory quality.
- **Certifications –** All analytical laboratories are subject to national, local, and project-specific certifications and requirements. Each laboratory is accredited by the NIST/NVLAP for the analysis of airborne asbestos by TEM and/or analysis of bulk asbestos by PLM. This includes the analysis of NIST/NVLAP standard reference materials, or other verified quantitative standards, and successful participation in two proficiency rounds per year each of bulk asbestos by PLM and airborne asbestos by TEM supplied by NIST/NVLAP.
- **Laboratory Auditing –** All laboratories are required to participate in a site-specific laboratory audit conducted by the EPA QATS contractor. These audits ensure samples are handled and analyzed in accordance with the program-specific documents and analytical method requirements (or approved site-specific laboratory modification forms).
- **Team Training/Mentoring Program –** Laboratories are required to participate in a training/mentoring program to ensure laboratories can demonstrate the ability to perform reliable analyses at the Site. The training process includes a review of morphological, optical, chemical, and electron diffraction characteristics of LA using site-specific reference materials, as well as training on project-specific analytical methodology, documentation, and administrative procedures used on the Libby site.
- **Technical Discussions/Conferences –** Laboratories participate in regular technical discussions with EPA and their contractors, as well as attend professional/technical conferences. These discussions enable the laboratory and technical team members to have an ongoing exchange of information regarding all analytical and technical aspects of the project.
- **Analyst Training –** All TEM and PLM analysts are required to undergo method-specific training and must understand the application of standard laboratory procedures and methodologies, including the Libby-specific analytical methods. Analysts must familiarize themselves with the Libby-specific method deviations, project-specific documents, and visual references and demonstrate proficiency prior to conducting analyses on Site samples.
- **Data Reporting –** Standardized bench sheets and data entry spreadsheets have been developed specifically for the Libby project to ensure consistency between laboratories

in the presentation and submittal of analytical data. All analysts are trained in the project-specific reporting requirements and data reporting tools utilized in transmitting results.

- **Laboratory QC Samples –** A variety of different types of laboratory QC analyses have been collected as part of the investigations conducted at the Site. These QC analyses provide information on potential contamination arising from laboratory preparation and analysis methods as well as information on result accuracy and precision. (See Section 5.3 for a summary of analytical laboratory QC results.)
- **Laboratory Contamination Monitoring –** Each analytical laboratory performs regular contamination monitoring to evaluate worker safety and ensure laboratory cleanliness in compliance with their SOPs and certification requirements.
- **Modification Documentation -** Changes or revisions needed to improve or document specifics about analytical methods or laboratory procedures are documented using a laboratory ROM form. These ROMs are reviewed and approved by the EPA (or their designee).

5.2 Data Review, Verification, and Validation

5.2.1 Data Review and Verification

The Scribe project databases have a number of built-in quality control checks to identify unexpected or unallowable data values during upload into the database. Any issues identified by these automatic upload checks were resolved by consultation with the field teams and/or analytical laboratory before entry of the data into the database. After entry of the data into the database, several additional steps were taken to ensure the data were recorded and entered correctly.

In order to ensure that the database accurately reflects the original hard copy documentation, all data downloaded from the database were examined to identify data omissions, unexpected values, or apparent inconsistencies. In addition, a subset (usually 10%) of the samples and analytical results for the background soil studies underwent a detailed verification. In brief, verification involves comparing the data for a sample in the database to information on the original hard copy FSDS form and on the original hard copy analytical bench sheets for that sample. This verification process is performed in accordance with Libby-specific SOPs EPA-LIBBY-09 (TEM data), EPA-LIBBY-10 (PLM data), and EPA-LIBBY-11 (field sample information). Any omissions or apparent errors identified during the verification were submitted to the field teams and/or analytical laboratories for resolution in the database and in the hard copy documentation. All tables, figures, and appendices (including all hard copy documentation and the database provided in **Appendix A**) generated for this report reflect corrected data.

5.2.2 Data Validation

Unlike data verification, where the goal is to identify and correct data reporting errors, the goal of data validation is to evaluate overall data quality and to assign data qualifiers, as appropriate, to alert data users to any potential data quality issues.

Data validation is performed by the EPA QATS contractor (CB&I Federal Services, LLC [CB&I], formerly Shaw Environmental & Infrastructure Group), with support from technical support staff that are familiar with investigation-specific data reporting, analytical methods, and investigation requirements. For the Libby project, data validation of TEM and PLM results is performed in accordance with Libby-specific validation SOP that were developed based on the draft *National Functional Guidelines for Asbestos Data Review* (EPA 2011).

In 2013, CB&I prepared a summary of the QA/QC aspects of the laboratory program for the Site from 2010 to 2012 (CB&I 2013). This report provides detailed information on the validation procedures performed and provides a narrative on the quality assessment for each type of analysis (e.g., TEM, PLM), including the data qualifiers assigned and the reason(s) for these qualifiers to denote when results do not meet acceptance criteria. In brief, results for approximately 5% of the analyses in the database, analyzed by five different laboratories between 2010 and 2012, were validated by CB&I. Very few asbestos results were qualified (less than 0.5% of all analyses reviewed) were J-qualified as a result of the validation. One of the samples that was qualified (EX-20426) was an air sample collected during the curb-to-curb ABS program (see Section 4.4). This sample was J-qualified due to the failure of the laboratory to perform and/or document daily calibration activities. No other samples utilized in this report were qualified as a consequence of the data validation.

5.3 Quality Control Results

5.3.1 General

Because the number of QC samples directly related to any specific investigation may be too limited to draw meaningful conclusions regarding overall data quality, results for QC samples and analyses are evaluated by the EPA QATS contractor on a program-wide basis. The detailed program-wide QC report for 2010 to 2012 (which encompasses the time period of sampling investigations discussed in this report) is provided in CB&I (2013). The following bullets summarize the overall conclusions of the CB&I (2013) report:

- Blank samples (e.g., lot blanks, field blanks, preparation blanks, laboratory blanks) show that inadvertent contamination of field samples with LA or other forms of asbestos is not of significant concern, in the field, at the soil preparation laboratory, or at the analytical laboratory.

- For TEM, there is generally good concordance for intra-laboratory analyses. However, there are differences in methods and procedures between analytical laboratories that have the potential to influence TEM results. These differences are discussed in more detail in Section 5.3.2.

- For PLM-VE, concordance rates rank as acceptable for intra-laboratory analyses. However, inter-laboratory analyses suggest that there are differences in implementation of the analytical procedures that have the potential to influence the PLM-VE results. These differences are discussed in more detail in Section 5.3.3.

5.3.2 TEM-Specific

Results of the recent TEM inter-laboratory analyses show that there are differences in structure counting and recording methods between the analytical laboratories (CB&I 2013). In general, there were some differences noted in the number of LA structures counted and in the differentiation of LA structures from NAM structures (e.g., pyroxene). Thus, ABS air and TEM-FBAS soil concentrations presented in this report should be interpreted as estimates that are influenced both by analytical uncertainty (Poisson counting error) and laboratory variability.

Between-laboratory differences have also been noted on the determination of sodium and potassium content of LA structures. For example, until recently (fall 2013), the EMSL Analytical laboratory in Libby, Montana (EMSL27) used EDS instrument evaluation, rather than analyst visual observation, to assign the presence/absence of sodium and potassium in the EDS spectra (TechLaw, Inc. 2013). Because the instrument could detect the presence of sodium and potassium even when visual peaks were not obvious, this resulted in EMSL27 assigning a classification of "NaK" to all LA structures. In the background soil studies, EMSL27 only reported detected LA in five samples (<2% of the analyses) and, in all samples, the presence of LA structures with NaK was supported by replicate filter analyses performed by other TEM laboratories. Thus, this issue is not likely to affect overall conclusions about NaK content presented in this report.

Corrective actions were implemented in October 2013 to address the NaK classification issues at EMSL27 (TechLaw, Inc. 2013).

5.3.3 PLM-Specific

Results of recent inter-laboratory assessments for the PLM-VE method show that there are differences in results reporting between the analytical laboratories (CB&I 2012, 2013). In particular, the ESATR8 laboratory can detect the presence of "trace" levels of LA (Bin B1) where other (non-ESATR8) PLM laboratories cannot (i.e., non-ESATR8 laboratories rank the same sample as non-detect [Bin A]). The ability of ESATR8 to detect low levels of LA may be due to differences in the implementation of the steps of the PLM-VE analysis procedure. During the

PLM laboratory audits, it was noted that only one laboratory (ESATR8) performed a manual grinding of the soil sample using a mortar and pestle prior to analysis by PLM-VE. It is possible that this additional grinding step reduces heterogeneity in the soil sample. It was also noted that ESATR8 employed a much more vigorous manual agitation of the sample prior to stereomicroscopy examination than the other laboratories. Sample agitation is used to cause asbestos structures to "rise" to the surface of the soil particles to allow for easier observation. It is possible that these preparation steps actually improve the ability of the analyst to detect trace amounts of LA in the sample. This may explain why ESATR8 reported trace levels of LA for the Libby City Pit samples while the inter-laboratory did not (see Section 4.3). For the purposes of this report, since the primary focus of this report is on TEM results (either ABS air or FBAS filter results), there are no anticipated negative implications on the PLM-VE analyses associated with the between-laboratory variability in PLM-VE results.

5.4 Data Adequacy

All studies summarized in this report were conducted in accordance with the governing SAP/QAPP, which was specifically designed to achieve the stated DQOs. All studies were able to be successfully implemented (i.e., samples were collected, prepared, and analyzed in accordance with the SAP/QAPPs, SOPs, and applicable ROMs) and the resulting data are considered to be representative and complete unless stated otherwise. As noted above, any issues identified during data verification have been corrected and there were very few samples that were qualified as a consequence of the data validation. However, there are some differences between the TEM laboratories in data reporting that have the potential to influence reported ABS air and TEM-FBAS soil concentrations.

The following subsections evaluate other analysis conditions that have the potential to influence reported ABS air and TEM-FBAS soil concentrations and data interpretation.

5.4.1 Evaluation of Filter Loading Evenness

The TEM analysis examines only a small fraction of the total filter. For the purposes of computing a concentration for a sample, it is assumed that the filter is evenly loaded and the estimated concentration for the portion of the filter examined is applicable to the entire filter (sample). An assessment of filter loading evenness is performed using a Chi-square (CHISQ) test, as described in ISO 10312 Annex F2. If a filter fails the CHISQ test for evenness, the reported result may not be representative of the true concentration in the sample, and the results should be given low confidence.

An evaluation of filter loading for 122 ABS air filters and 173 FBAS-generated filters analyzed by TEM showed that all filters passed the CHISQ test (i.e., p-value ≥ 0.001) (see **Appendix A** for analysis-specific CHISQ p values). These results indicate that uneven filter loading is not of significant concern for the ABS air or TEM-FBAS soil results that are summarized in this report.

5.4.2 Evaluation of ABS Filter Preparation Method

For most ABS air samples (95 of 122 samples), the TEM analysis was performed using grids that were prepared directly from the collected air filter in basic accordance with the grid preparation procedures described in Section 9.3 of ISO 10312. For the remaining 27 ABS air samples (see **Table 5-1**), air filter was deemed to be overloaded (i.e., more than 25% particulate loading on the filter) or unevenly loaded; thus, an indirect preparation (with ashing) of the filter was performed in accordance with Libby-specific SOP EPA-LIBBY-08. In brief, the filter was ashed, the resulting ashed residue was suspended in water and sonicated, and an aliquot of this water was applied to a second filter, which was then used to prepare grids for TEM analysis.

As shown in **Table 5-1**, of the 27 ABS air samples that were prepared indirectly, 12 samples were reported as non-detect. Thus, the preparation method is not affecting the reported air concentration for these samples. For the remaining 15 samples, which encompass ABS air samples from the 2012 Troy Background Soil study, the 2011 Libby Background Soil study, and the Libby Curb-to-Curb Residential ABS study, the reported PCME LA air concentration has the potential to be biased high due to the use of the indirect preparation technique.

For chrysotile asbestos, indirect preparation often tends to increase structure counts due to dispersion of bundles and clusters (Hwang and Wang 1983; Chesson and Hatfield 1990; Health Effects Institute-Asbestos Research [HEI-AR] 1991; Breysse 1991). For amphibole asbestos, the effects of indirect preparation are generally much smaller (Bishop *et al.* 1978; Sahle and Laszlo 1996; Harris 2009). The EPA has conducted Libby-specific studies to evaluate the potential effect of indirect preparation on reported LA air concentrations. These studies show that indirect filter preparation may increase PCME LA air concentrations by a factor of about 2-3 relative to direct preparation (Berry *et al.* 2014; Goldade and O'Brien 2014). The insensitivity of PCME LA air concentration estimates to preparation method is likely due to the fact that a majority of the LA structures observed for Libby air samples tend to be "free" fibers (i.e., fibers not associated with bundles, matrices, or clusters) that are not subject to dispersal during an indirect preparation (Berry *et al.* 2014). Thus, the preparation of ABS air samples using an indirect preparation method is likely to be a relatively minor source of uncertainty for LA.

5.4.3 Evaluation of FBAS Filter Replicates

For the soils from the Libby Borrow Source Study, the Libby City Pit evaluation, the Comparative Exposure Study, and a subset of the samples from the 2012 Troy Background Soil Study, three replicate FBAS filters were prepared and submitted to three different analytical laboratories for rock flour preparation and TEM analysis. A total of 37 soil samples were analyzed in triplicate. Results for each filter replicate were evaluated on a pairwise basis using the Poisson ratio test recommended by Nelson (1982), based on a 90% confidence interval. **Appendix C** presents a detailed summary of this FBAS filter replicate evaluation.

There were several instances where the differences in the reported soil concentration between the replicates were statistically significant. In general, when results differed between two laboratories, there was usually a consistent pattern in which TEM laboratory reported a higher concentration. For example, reported total LA soil concentrations for 6 of the 15 borrow samples analyzed by Hygeia and Reservoirs Environmental Services, Inc. (RESI) were statistically different (see **Appendix C.1**). In all cases, soil concentrations reported by RESI were higher than those reported by Hygeia and were within a factor of about 8. Similarly, for the Libby City Pit soils (see **Appendix C.2**), ESATR8 reported higher total LA soil concentrations for 4 of 8 samples compared to the EMSL Analytical, Inc. laboratory in Cinnaminson, New Jersey (EMSL04); total LA soil concentrations were within a factor of about 7. These results suggest that there may be systematic differences between the laboratories in the way the rock flour preparation and TEM-FBAS analysis is performed. However, despite these differences, reported soil concentrations between the laboratories tend to be within a factor of 10.

5.4.4 Evaluation of FBAS Rock Flour Preparation Method

As described above, with the exception of a subset the 2010 Libby Background Soil Pilot Study samples, all soil samples that were prepared using the FBAS and analyzed by TEM utilized the rock flour filter preparation technique. As described previously (see Section 4.1.1), the rock flour preparation technique is an indirect preparation method that includes sonication and aqueous settling to maximize the ability to detect asbestos structures in soils that have a fine particle grain size.

<u>Bias Due to Indirect Preparation</u>

It is expected that the sonication step of the rock flour preparation has the potential to increase asbestos structure counts due to the dispersion of bundles and clusters, but there are no site-specific studies that provide information on the magnitude of this potential bias. However, because all soils were prepared using the same technique, all reported soil concentrations should be biased equally. Thus, relative comparisons of LA concentrations in soil between different locations would not be affected due to use of the rock flour preparation method, but absolute estimates of LA concentrations in soil have the potential to be biased high.

<u>Between-Laboratory Differences in Rock Flour Preparation Implementation</u>

As discussed above (Section 5.4.3), there do appear to be systematic differences between the TEM laboratories in the way the rock flour preparation and TEM-FBAS analysis is performed. In particular, in late 2013, it was recognized that one of the laboratories (EMSL27) deviated from the protocol and allowed the settling time to extend well beyond the three hours specified in the procedure (EMSL 2014). In addition, the volume of water drawn off the top of the aqueous suspension was not sonicated or shaken prior to filtration. Both of these deviations would result in the reported soil concentration being biased low.

A total of 165 TEM-FBAS analyses have been performed on filters prepared using the rock flour preparation technique. Of these analyses, the EMSL27 laboratory performed 27 TEM-FBAS analyses (9 analyses for the Comparative Exposure Study, 13 analyses for the Libby Borrow Source Study, and 5 analyses for the Troy Background Study). As shown in **Appendix C**, the EMSL27 filter replicate results did appear to be biased low relative to the other laboratories. In all cases, their results comprised only one of the three analyses performed for each sample triplicate (i.e., soil concentration results are available from two other TEM laboratories). As discussed in Section 5.4.3, differences in reported soil concentrations between FBAS filter replicates analyzed by different TEM laboratories (including EMSL27) is usually within about 10.

Corrective actions were implemented in January 2014 to address the rock flour preparation technique deviations at EMSL27 (EMSL 2014).

5.5 Conclusions

The various background soil studies at the Site have generated a large amount of data on the concentration of LA in background soils. The EPA has invested substantial effort in the QA/QC program for the Site to ensure that these data are of high quality and are sufficient to support decision-making. Key elements of the QA/QC program included:

- The development of detailed investigation-specific SAP/QAPPs to guide all sample collection and analysis efforts.
- Application of site-specific SOPs for sample collection, preparation, and analysis.
- Extensive training and oversight of all field and laboratory staff and operations.
- Ongoing modifications to improve methods and document procedures to address any issues identified by field staff, laboratory staff, or data users.
- The development of electronic data management tools for recording and transferring data that include a variety of error checks and error traps.
- The collection and analysis of a variety of different types of QC samples to ensure cross-contamination does not occur and to evaluate result accuracy and precision.
- Ongoing verification and validation of electronic data in the project databases.

As noted above, there are some analysis issues that have the potential to influence reported ABS air and TEM-FBAS soil concentrations and data interpretation:

- ABS air filters prepared using indirect preparation methods may be biased slightly high (factor of 2-3).
- Use of the rock flour preparation method in preparing FBAS-generated filters may tend to bias reported LA soil concentrations high, but the degree to which they may be biased is not known.
- There are likely to be systematic between-laboratory differences in the way the rock flour preparation and TEM-FBAS analysis is performed. For a given sample, differences

in reported TEM-FBAS soil concentrations between the laboratories are likely within a factor of 10.

This data quality assessment concludes that the samples collected as part of the various background soil studies are of acceptable quality and are considered to be appropriate for their intended use, taking into consideration their potential variability and uncertainty.

6 CONCLUSIONS

Based on the results from the investigations discussed above, the following conclusions can be made:

- LA structures have been consistently detected in background soils within the Kootenai Valley that are not thought to be affected by anthropogenic releases from vermiculite mining and processing activities. While background soil concentrations are variable (see **Figure 6-1**), in general, the average total LA concentration in background soil is about 5E+05 s/g, which is estimated to be approximately 0.014% LA by mass. However, absolute estimates of soil concentrations have the potential to be biased high due to the use of the rock flour preparation technique.

- The types of LA structures in background soils within the Kootenai Valley include a mixture of elemental compositions (see **Figure 6-2**), including structures with sodium and potassium (NaK) and structures without sodium or potassium (XX) that are reported as AC or TR. These results indicate that a portion of the LA structures observed at the Site likely do not originate from the Vermiculite Mountain ore body (Meeker *et al.* 2003; Gunter and Sanchez 2009). Outside the Kootenai Valley (i.e., Eureka, Helena, Whitefish), LA structures observed in soil all lack sodium and potassium (XX) and are reported as AC or TR.

- The concentration of LA in background soils (<0.02% by mass) is well below the detection limit of traditional PLM methods (e.g., PLM-VE), but is able to be reliably detected following FBAS preparation (using the rock flour preparation technique) and analysis by TEM. Analysis of soil following FBAS preparation appears to be a more sensitive metric of LA detection in soil than either ABS or field visible vermiculite observations.

Taken together, these results support the conclusion there is a non-zero level of LA in soils within the Kootenai Valley that is not attributable to vermiculite mining and processing activities at the Site. Further, these results support the data reported by other researchers, including Gunter and Sanchez (2009), Adams *et al.* (2010), and Langer *et al.* (2010), indicating that low-level detections of amphibole fibers in background soils within the Kootenai Valley originated from normal geologic and geomorphic processes unrelated to mining and milling of vermiculite ore from Vermiculite Mountain.

7 REFERENCES

Adams, D. T., Langer, W. H., Hoefen, T. M., Van Gosen, B. S., and Meeker, G. P. 2010. Examination of Libby, Montana Fill Material for Background Levels of Amphibole from the Rainy Creek Complex Using Scanning Electron Microscopy and X-Ray Microanalysis. U.S. Geological Survey, Open-File Report 2010-1056. http://pubs.usgs.gov/of/2010/1056/

Amandus, H.E., and Wheeler, R. 1987. The Morbidity and Mortality of Vermiculite Miners and Millers Exposed to Tremolite-Actinolite: Part II Mortality. *American Journal of Industrial Medicine* 11:15-26.

Amandus, H.E., Wheeler, P.E., Jankovic, J., and Tucker, J. 1987. The morbidity and mortality of vermiculite miners and millers exposed to tremolite-actinolite: Part I Exposure Estimates. *American Journal of Industrial Medicine* 11:1-14.

Antao, V.C., Larson, T.C., Horton, D.K. 2012. Libby vermiculite exposure and risk of developing asbestos-related lung and pleural diseases. *Current Opinion in Pulmonary Medicine* 18(2):161-167.

Bandli, B. R., and Gunter, M. E. 2006. A review of scientific literature examining the mining history, geology, mineralogy, and amphibole asbestos health effects of the rainy creek igneous complex, Libby, Montana, USA. *Inhalation Toxicology* 18:949-962.

Bern, A., Meeker, G.P., and Brownfield, I. 2002. Guide to the Analysis of Soil Samples from Libby, Montana for Asbestos Content by Scanning Electron Microscopy and Energy Dispersive Spectroscopy. U.S. Geological Survey, Administrative Report, prepared for the U.S. Environmental Protection Agency Region 8.

Berry, D. *et al.* 2014. Comparison of Amphibole Air Concentrations Resulting from Direct and Indirect Filter Preparation and Transmission Electron Microscopy Analysis. *[manuscript in review]*

Bishop K., Ring S., Suchanek R., Gray D. 1978. Preparation losses and size alterations for fibrous mineral samples. *Scanning Electron Microscopy* I:207.

Boettcher, A.L. 1967. The Rainy Creek alkaline—Ultramafic igneous complex near Libby, Montana, Part I—Ultramafic rocks and fenite. *Journal of Geology* 75:526–553.

Breysse, P.N. 1991. Electron microscopic analysis of airborne asbestos fibers. *Critical Reviews in Analytical Chemistry* 22:201-227.

CARB (California Air Resources Board). 1991. Determination of Asbestos Content of Serpentine Aggregate (Method 435). California Environmental Protection Agency, Air Resources Board.

Adopted June 6.
http://www.capcoa.org/Docs/noa/%5B21%5D%20CARB%20Method%20435.pdf

CB&I (CB&I Federal Services, LLC, formerly Shaw Environmental, Inc.). 2012. Quarterly Evaluation of Inter-Laboratory Polarized Light Microscopy – Visual Area Estimation (PLM-VE) Results. Prepared for U.S. Environmental Protection Agency, Region 8 by Shaw Environmental, Inc. November 20.

CB&I. 2013. Annual QA/QC Summary Report (2010-2012), Libby Asbestos Superfund Site. Prepared for U.S. Environmental Protection Agency, Region 8 by CB&I. Final - November 14.

CDM Smith. 2011. Sampling and Analysis Plan: 2011 Residential Activity-Based Sampling, Libby Asbestos Site, Operable Unit 4. Prepared for U.S. Environmental Protection Agency, Region 8. July 15.

CDM Smith. 2012a. Sampling and Analysis Plan 2011- Miscellaneous Activity-Based Sampling-Libby Asbestos Site, Operable Unit 4 (EP-W-05-049). June (Revision 2).

CDM Smith. 2012b. Addendum to the 2011 Miscellaneous ABS Sampling and Analysis Plan: Re-analysis of Gravel Samples Collected from the Libby City Pit. June 7.

CDM Smith. 2012c. Sampling and Analysis Plan/Quality Assurance Project Plan Comparative Exposure – Eureka, Helena, Whitefish Libby Asbestos Site, Operable Unit 4. Prepared for U.S. Environmental Protection Agency, Region 8. July (Revision 1).

CDM Smith. 2013a. Data Summary Report: 2011 Residential Activity-Based Sampling, Libby Asbestos Superfund Site, Operable Unit 4. Prepared for U.S. Environmental Protection Agency, Region 8. Draft - May 21.

CDM Smith. 2013b. Data Summary Report: Comparative Exposure Study Libby Asbestos Superfund Site, Operable Unit 4- Prepared for U.S. Environmental Protection Agency, Region 8. Final - July 26.

Chesson, J., and Hatfield, J. 1990. Comparison of Airborne Asbestos Levels Determined by Transmission Electron Microscopy (TEM) Using Direct and Indirect Transfer Techniques. U.S. Environmental Protection Agency, Exposure Evaluation Division, Office of Toxic Substances, Office of Pesticides and Toxic Substances.

Elhers, J. and Gibbard, P.L.. 1996. *Quaternary and Glacial Geology.* John Wiley and Sons, Inc. ISBN 0471955760. 590 pp.

EMSL (EMSL Analytical, Inc.). 2014. Memorandum: FBAS Internal Investigation. From Roy Pescador (EMSL Analytical Inc.) to Douglas Kent (TechLaw, Inc.). January 27.

EPA (U.S. Environmental Protection Agency). 1993. Method for the Determination of Asbestos in Bulk Building Materials. U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/116. July. http://www.ntis.gov/search/product.aspx?abbr=PB93218576

EPA. 2002. Role of Background in the CERCLA Cleanup Program. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9285.6-07P. April 26. http://www.epa.gov/swerrims/riskassessment/pdf/role.pdf

EPA. 2006. Data Quality Assessment: A Reviewer's Guide. EPA QA/G-9R. U.S. Environmental Protection Agency, Office of Environmental Information. EPA/240/B-06/002. February. http://www.epa.gov/QUALITY/qs-docs/g9r-final.pdf

EPA. 2008. Characteristic EDS Spectra for Libby-Type Amphiboles. Produced for U.S. Environmental Protection Agency, Region 8 by Syracuse Research Corporation- Final. March 18.

EPA. 2010a. Activity-Based Sampling Report, Operable Unit 4, Libby, Montana, Superfund Site. U.S. Environmental Protection Agency, Region 8. June 2.

EPA. 2010b. Characterization of Asbestos Concentrations in Background Soils in Libby, Initial Range-Finding Pilot Study- Final. October 18.

EPA. 2011. National Functional Guidelines for Asbestos Data Review. U.S. Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation. Draft – August.

EPA. 2012. EPA Data Management Plan, Libby Asbestos Superfund Site. U.S. Environmental Protection Agency, Emergency Response DATA Team- Version 2012.1. January 18.

Ferreira, R.F., D.B. Adams, and R.E. Davis. 1992. Development of Thermal Models for Hungry Horse Reservoir and Lake Koocanusa, Northwestern Montana and British Columbia. U.S. Geological Survey, Water-Resources Investigations Report 91-4134. February. http://pubs.er.usgs.gov/publication/wri914134

Goldade, M.P., and O'Brien, W.P. 2014. Use of Direct Versus Indirect Preparation Data for Assessing Risk Associated with Airborne Exposures at Asbestos-contaminated Sites. *Journal of Occupational and Environmental Hygiene* 11(2):67-76. http://dx.doi.org/10.1080/15459624.2013.843779

Gunter, M.E., and Sanchez, M.S. 2009. Amphibole forensics: Using the composition of amphiboles to determine their source, the Libby, Montana. *American Mineralogist* 94:837-840.

Harris, J. 2009. TEM observations of amphiboles from El Dorado hills study. Geological Society of America Abstracts with Programs, October 21, 2009. Vol. 41, No. 7, p. 703.

Hawthorne, F., R. Oberti, G. Harlow, W. Maresch, R. Martin, J. Schumacher, and M. Welch. 2012. Nomenclature of the amphibole super group. *American Mineralogist* 97:2031-2048.

Health Effects Institute – Asbestos Research (HEI-AR). 1991. Asbestos in Public and Commercial Buildings: A Literature Review and Synthesis of Current Knowledge. Health Effects Institute – Asbestos Research. Cambridge, Massachusetts.

Hwang, C.Y., and Wang, Z.M. 1983. Comparison of methods of assessing asbestos fibre concentrations. *Archives of Environmental Health* 38:5-10.

ISO (International Organization for Standardization). 1995. Determination of Asbestos Fibers – Direct-transfer Transmission Electron Microscopy Method. ISO 10312:1995(E).

Januch, J., Brattin, W., Woodbury, L., & Berry, D. 2013. Evaluation of a fluidized bed asbestos segregator preparation method for the analysis of low-levels of asbestos in soil and other solid media. *Analytical Methods* 5:1658-1668.

Langer , W. H., Van Gosen, B. S., Meeker, G. P., Adams, D. T., and Hoefen, T. M. 2010. The dispersion of fibrous amphiboles by glacial processes in the area surrounding Libby, Montana, USA. *Environmental Earth Science* 64:157-168.

Larsen, E. S. 1942. Alkalic rocks of Iron Hill, Gunnison County, Colorado. U.S. Geological Survey Professional Paper 197A.Washington DC: U.S. Geological Survey.

Larsen, E.S. and Pardee, J.J. 1929. The stock of alkaline rocks near Libby, Montana. *Journal of Geology* 37:97-112.

Larson T.C., Meyer C.A., Kapil V., Gurney J.W., Tarver R.D., Black C.B., and Lockey J.E. 2010. Workers with Libby amphibole exposure: retrospective identification and progression of radiographic changes. *Radiology* 255(3):924-933.

Larson T.C., Lewin M., Gottschall E.B., Antao V.C., Kapil V., Rose C.S. 2012a. Associations between radiographic findings and spirometry in a community exposed to Libby amphibole. *Occupational and Environmental Medicine* 69(5):361-366.

Larson T.C., Antao A.C., Bove F.J., Cusack C. 2012b. Association between cumulative fiber exposure and respiratory outcomes among Libby vermiculite workers. *Journal of Occupational Environmental Medicine* 54(1):56-63.

Leake, B.E., Woolley, A.R., Arps, C.E.S., Birch, W.D., Gilbert, M.C., Grice, J.D., Hawthorne, F.C., Kato, A., Kisch, H.J., Krivovichev, V.G., Linthout, K., Laird, J., Mandarino, J.A., Maresch, W.V., Nickel, E.H., Rock, N.M.S., Schumacher, J.C., Smith, D.C., Stephenson, N.C.N., Ungaretti, L., Whittaker, E.J.W., and Youzhi, G. 1997. Nomenclature of the amphiboles—Report of the subcommittee on amphiboles of the International Mineralogical Association, Commission on New Minerals and Mineral Names. *American Mineralogist* 82:1019–1037.

Locke W., and Smith L.N. 2004. Pleistocene mountain glaciation in Montana, USA. In: Ehlers J, Gibbard PL (eds) *Quaternary Glaciations – Extent And Chronology, Part II – North America: Developments In Quaternary Science 2.* Elsevier, Amsterdam, pp 125–129.

McDonald, J.C., McDonald, A.D., Armstrong, B., and Sebastien, P. 1986. Cohort study of mortality of vermiculite miners exposed to tremolite. *British Journal of Industrial Medicine* 43:436-444.

McDonald J.C., Harris J., Armstrong B. 2004. Mortality in a cohort of vermiculite miners exposed to fibrous Amphibole in Libby, Montana. *Occupational and Environmental Medicine* 61:363-366.

Meeker G.P., Bern A.M., Brownfield I.K., Lowers H.A., Sutley S.J., Hoeffen T.M., and Vance J.S. 2003. The composition and morphology of amphiboles from the Rainy Creek Complex, Near Libby, Montana. *American Mineralogist* 88:1955-1969.

Meeker G.P. and L.A. Lowers. 2004. Analytical Error the Identification of Fibrous and Asbestiform Amphiboles: Implications for the Analytical and Regulatory Communities. *Microscopy and Microanalysis* 10 (Suppl. 2):902-903.

National Institute of Occupational Safety and Health (NIOSH). 1994. Method 9002, Issue 2. Asbestos (bulk) by PLM. www.epa.gov/region9/toxic/noa/eldorado/pdf/NIOSH9002.pdf

Nelson, W. 1982. *Applied Life Data Analysis*. John Wiley & Sons, New York. pp 438-446.

Peipins, L.A., Lewin, M., Campolucci, S., Lybarger, J.A., Kapil, V., Middleton, D., Miller, A., Weis, C., Spence, M., and Black, B., 2003. Radiographic abnormalities and exposure to asbestos-contaminated vermiculite in the community of Libby, Montana, USA. *Environmental Health Perspectives* 111:1753-1759.

Sahle W. and Laszlo I. 1996. Airborne inorganic fibre monitoring by transmission electron microscope (TEM): Comparison of direct and indirect sample transfer methods. *Annals of Occupational Hygiene* 40:29-44.

Sanchez, M. S., Gunter, M. E., & Dyar, M. D. 2008. Characterization of historical amphibole samples from the former vermiculite mine near Libby, Montana, USA. *European Journal of Mineralogy* 20:1043–1053.

Smith, L.N. 2006. Pleistocene glacial deposits in the Libby and Lake River Valley Areas, Lincoln County, Montana. *Northwest Geology* 35:87–90.

Sullivan, P.A. 2007. Vermiculite, respiratory disease and asbestos exposure in Libby, Montana: Update of a cohort mortality study. *Environmental Health Perspectives* 115(4):579-585.

TechLaw, Inc. 2011. Controlling Matrix Interference Effects of Rock Flour in the Fluidized Bed Method for Analysis of Asbestos in Soil. Environmental Services Assistance Team, Region VIII. August 25.

TechLaw, Inc. 2013. EMSL-Libby LA Structure Classification Deliberative Report. Prepared for U.S. Environmental Protection Agency, Region 8. December 10.

Tetra Tech 2012. Background Soil Study Sampling and Analysis Plan and Quality Assurance Project Plan for Operable Unit 7 of the Libby Asbestos Superfund Site. November (Revision 0).

USDA (U. S. Department of Agriculture), Forest Service and Natural Resources Conservation Service. 1995. Soil Survey of Kootenai National Forest Area, Montana and Idaho. September.

Van Gosen, B.S., Lowers H.A., Bush A.L. , Meeker G.P., Plumlee G.S., Brownfield I.K., and Sutley S.J. 2002. Reconnaissance Study of the Geology of U.S. Vermiculite Deposits - Are Asbestos Minerals Common Constituents? U.S. Geological Survey Bulletin 2192. http://pubs.usgs.gov/bul/b2192/b2192.pdf

Webber, J. S., Blake, D. J., Ward, T. J., & Pfau, J. C. 2008. Separation and characterization of respirable amphibole fibers from Libby, Montana. *Inhalation Toxicology* 20(8):733-740.

Whitehouse AC. 2004. Asbestos-related pleural disease due to tremolite associated with progressive loss of lung function: Serial observations in 123 miners family members, and residents of Libby, Montana. *American Journal of Industrial Medicine* 46:219-225.

Whitehouse A.C., Black C.B., Heppe M.S., Ruckdeschel J., Levin S.M. 2008. Environmental exposure to Libby asbestos and mesotheliomas. *American Journal of Industrial Medicine* 51:877-880.

Wylie, A. G., and Verkouteren, J. R. 2000. Amphibole asbestos from Libby, Montana: Aspects of nomenclature. *American Mineralogist* 85:1540–1542.

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Background Soil Summary Report
Libby Asbestos Superfund Site, Montana

TABLES

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Table 4-1
2010 Libby Background Study Mineralogy Results

Background Location	Sample ID	Depth Interval (in)	D422 (%)					PLM 400 PC (%)							XRD (%)						
			Gravel 4.75 mm-3/8 in	Sand 2mm - 4.75 mm	Sand 425 um - 2 mm	Sand 75 um - 425 um	Silt and Clay < 75 um	ALBITE/ ANORTHITE	AMPHIBOLES	CALCITE	GRANULAR	MICAS	QUARTZ	WORM PARTICLES	ALBITE/ ANORTHITE	AMPHIBOLES	CALCITE	KAOLINITE	MICAS	QUARTZ	VERMICULITE
A	BK-00002	1-4	6.39	18.22	19.78	29.09	26.52	28.3	0.9	0.9	27.8	1.8	28.7	2.1	20.3	< 2	< 2	4	24.5	32.5	7.2
	BK-00004	1-4	4.16	11.34	22.19	33.64	28.66	27.1	< 0.25	< 0.25	30.1	2.9	28.5	1.8	24.8	< 2	< 2	3	20.6	34.5	3.2
B	BK-00006	1-4	1.32	9.98	19.75	27.22	41.73	28.7	< 0.25	< 0.25	27	2	28.7	2	22.1	< 2	< 2	4	21.6	35.2	< 2
	BK-00008	1-4	8.53	22.95	21.81	28.74	17.98	25.8	< 0.25	0.2	29.3	1.7	27.3	1.7	21.7	< 2	< 2	2.9	22	35.2	< 2
C-1	BK-00010	1-6	17.4	26.85	24.49	11.07	20.19	37.4	< 0.25	1	11.7	4.9	41.3	1.9	17.6	< 2	< 2	3.1	49.2	26.3	< 2
	BK-00012	1-6	19.45	31.61	21.91	8.13	18.89	37.9	< 0.25	< 0.25	11.2	5.1	41.8	2.2	16.6	< 2	< 2	3.4	49.5	27.8	< 2
C-2	BK-00014	1-6	0.47	2.67	18.02	39.31	39.53	30.8	1	< 0.25	22	1.7	35.2	4.4	26.4	< 2	< 2	< 2	32.9	36	< 2
	BK-00016	1-6	0.64	4.3	27.93	37.68	29.44	32.2	< 0.25	< 0.25	22.9	1.7	36.9	4.7	23.6	< 2	< 2	< 2	31.4	39.4	< 2
C-3	BK-00018	1-6	0.73	4.87	22.31	30.14	41.95	33.4	< 0.25	< 0.25	19	2.9	37.9	1.9	29.9	< 2	< 2	< 2	26.3	37.7	< 2
	BK-00020	1-6	0.21	4.36	24.08	29.27	42.08	30.9	< 0.25	1	20.5	3.2	41.2	1	21.6	< 2	< 2	2.6	37.7	35.8	< 2
D	BK-00022	1-6	0.75	4.53	17.75	24.99	51.98	35.9	< 0.25	< 0.25	9.6	2.5	47.9	< 0.25	24.6	< 2	< 2	< 2	31	40.7	< 2
	BK-00024	1-6	0	1.89	15.02	26.68	56.41	32.6	< 0.25	< 0.25	23.1	1.7	37.3	4.7	17.9	< 2	< 2	2.2	51.5	27.6	< 2
E-1	BK-00038	1-6	0	0.49	3.78	54.43	41.3	28.4	< 0.25	< 0.25	28.4	6.7	33.1	< 0.25	22.3	< 2	< 2	< 2	22.3	52.5	< 2
	BK-00040	1-6	0.23	0.51	3.89	56.72	38.65	32.4	< 0.25	< 0.25	10.7	10.7	43.3	< 0.25	23.4	< 2	< 2	< 2	15.2	59.6	< 2
E-2	BK-00042	1-6	1.86	9.34	25.1	46.26	17.43	20.1	< 0.25	< 0.25	25.2	2.1	42.1	< 0.25	22.4	< 2	< 2	< 2	16.7	48	< 2
	BK-00044	1-6	0.6	9.37	25.99	24.2	39.83	24.7	< 0.25	1.1	12.4	2.5	49.5	0.2	22.6	< 2	< 2	2	18.5	45.3	< 2
E-3	BK-00046	1-6	0.36	2.05	15.92	27.99	53.69	31.6	< 0.25	< 0.25	21.1	2.2	36.9	3.1	26.6	< 2	< 2	< 2	17.6	49.2	< 2
	BK-00048	1-6	0.77	3.25	16.2	28.68	51.1	22.7	< 0.25	< 0.25	27.1	3.7	40.8	2.7	29.7	< 2	< 2	< 2	17.5	48.4	< 2
F-1	BK-00062	1-6	0	2.53	11.92	23.83	61.73	33.3	< 0.25	< 0.25	15.5	5.9	39.2	3.5	24.5	< 2	< 2	2.6	27.7	41.5	< 2
	BK-00064	1-6	0	3.08	13.99	22.76	60.18	25.8	< 0.25	< 0.25	16.4	6	45.7	3.7	23.2	< 2	< 2	2.8	32.9	37.5	< 2
F-2	BK-00066	1-6	0	0.68	6.07	22	71.25	28.7	< 0.25	1	29	2	36.8	< 0.25	53.5	< 2	< 2	< 2	16.3	26.2	< 2
	BK-00068	1-6	0.06	1.83	5.9	22.76	69.45	26.5	< 0.25	< 0.25	26.3	2.2	42.7	< 0.25	38.4	< 2	< 2	< 2	27.1	30.2	< 2
G-1	BK-00054	1-6	0.31	3.12	13.87	25.15	57.54	15.1	< 0.25	< 0.25	40.3	< 0.25	40.3	2	23	< 2	< 2	2.2	23.8	48.4	< 2
	BK-00056	1-6	0.21	3.08	15.6	26.4	54.7	25.9	< 0.25	< 0.25	31.1	2	36.3	2	26.7	< 2	< 2	< 2	21.7	48.1	< 2
G-2	BK-00058	1-6	0.1	1.97	10.2	24.72	63.01	27.9	< 0.25	< 0.25	27.9	< 0.25	38.9	2.2	20.8	< 2	< 2	2.3	28.2	44	< 2
	BK-00060	1-6	0	1.58	9.35	25.75	63.32	28	< 0.25	< 0.25	17.4	5.9	42	3.4	24.2	< 2	< 2	< 2	24.3	45.1	< 2
H-1	BK-00034	1-6	1.71	7.35	15.82	25.36	49.75	26.4	1	1	30.8	7.1	30.8	< 0.25	28.8	< 2	< 2	2.5	29.4	36.2	< 2
	BK-00036	1-6	0.57	3.82	15.3	26.54	53.76	28.2	< 0.25	< 0.25	28.2	4.6	33	< 0.25	27.7	< 2	< 2	< 2	32.2	33.8	< 2
H-2	BK-00050	1-6	5.79	25.15	36.96	17.78	14.32	15.1	< 0.25	< 0.25	45.4	< 0.25	30.4	< 0.25	34.2	< 2	< 2	3.9	26.3	22.4	< 2
	BK-00051	1-6	12.71	35.97	32.62	12.01	6.69	13.9	< 0.25	0.9	44.3	< 0.25	31.6	< 0.25	32.2	< 2	< 2	3.3	23.6	25.8	< 2
I-1	BK-00070	1-6	0.8	10.07	27.1	21.32	40.71	22.6	< 0.25	< 0.25	21.4	2.5	48.6	2.5	20.7	< 2	< 2	2.5	30.3	42.1	< 2
	BK-00072	1-6	1.57	14.23	29.95	21.86	32.4	21.6	< 0.25	< 0.25	26.5	4.2	43	1	22.8	< 2	< 2	2	34.9	36.5	< 2
I-2	BK-00074	1-6	0.17	5.53	20.7	20.65	52.96	19.8	1	< 0.25	29.5	1	44.4	2	21.8	< 2	< 2	3.2	36.2	32.6	< 2
	BK-00076	1-6	0.19	3.05	8.45	35.4	52.92	24	< 0.25	< 0.25	28.9	2	40.9	1.5	18.4	< 2	< 2	3.1	42.4	29.6	< 2
I-3	BK-00078	1-6	0.21	5.3	23.52	23.69	47.27	21.8	< 0.25	< 0.25	31.7	2	40.6	2	19.9	< 2	< 2	2.5	35.8	38.3	< 2
	BK-00080	1-6	0.52	5.03	28.62	23.84	41.99	25.2	< 0.25	1	29.7	1.7	39.6	1.7	24.8	< 2	< 2	2.2	33.9	35.3	< 2
J	BK-00030	1-6	0	2.27	9.69	44.22	43.82	28.8	< 0.25	< 0.25	28.8	6.6	32.7	< 0.25	27.1	< 2	< 2	3.3	20.2	39.6	6.1
	BK-00032	1-6	0	1.78	14.86	43.71	39.65	26.3	< 0.25	< 0.25	30.7	7	30.7	< 0.25	22.7	< 2	< 2	2.1	23.1	42.2	4.9
K	BK-00026	1-6	1.18	14.75	22.41	25.27	36.38	32.3	< 0.25	< 0.25	23.1	1.7	36.7	1	18.1	< 2	< 2	2.8	50.1	26.7	< 2
	BK-00028	1-6	1.47	9.98	21.49	28.29	38.77	28.7	< 0.25	< 0.25	28.7	1	38.2	< 0.25	16.4	< 2	< 2	< 2	33.2	44.4	< 2

% = percent
< = less than
D422 = ASTM method D422
in = inches
mm = millimeters
PLM 400 PC = polarized light microscopy by point counting (400 points examined)
um = micrometers
XRD = x-ray diffraction

See Appendix B for the detailed mineralogical analysis results and a description of the analytical methods.

Table 4-2
2010 Libby Background Pilot Study Soil FBAS Results

Background Location	Sample ID	Depth Interval (in)	Sensitivity $(g)^{-1}$	No. Total LA Structures	Soil Conc. (s/g)
A	BK-00002	1-4	2.5E+04	0	0.0E+00
	BK-00004	1-4	2.5E+04	1	2.5E+04
B	BK-00006	1-4	2.5E+04	0	0.0E+00
	BK-00008	1-4	2.5E+04	0	0.0E+00
C-1	BK-00010	1-6	5.0E+04	1	5.0E+04
C-2	BK-00014	1-6	2.5E+04	0	0.0E+00
	BK-00016	1-6	2.5E+04	0	0.0E+00
C-3	BK-00018	1-6	2.5E+04	1	2.5E+04
	BK-00020	1-6	2.5E+04	0	0.0E+00
D	BK-00024	1-6	2.5E+04	0	0.0E+00
E-2	BK-00044	1-6	1.7E+04	0	0.0E+00
H-2	BK-00050	1-6	2.5E+04	0	0.0E+00
I-2	BK-00076	1-6	5.0E+04	0	0.0E+00
J	BK-00030	1-6	2.5E+04	0	0.0E+00
	BK-00032	1-6	2.5E+04	0	0.0E+00
K	BK-00026	1-6	2.5E+04	0 *	0.0E+00
	BK-00028	1-6	2.5E+04	0	0.0E+00

** One non-countable LA structure was observed.*

FBAS = fluidized bed asbestos segregator
g^{-1} = per gram
ID = identification
in = inches
LA = Libby amphibole
s/g = structure per gram

Table 4-3

2010 Libby Background Pilot Study Soil FBAS Results for Direct and Rock Flour Preparation

Background Location	Sample ID	Depth Interval (in)	Direct Preparation			Rock Flour Preparation			Notes
			Sensitivity $(g)^{-1}$	No. Total LA Structures	Soil Conc. (s/g)	Sensitivity $(g)^{-1}$	No. Total LA Structures	Soil Conc. (s/g)	
A	BK-00004	1-4	2.5E+04	1	2.5E+04	2.2E+04	1	2.2E+04	
C-1	BK-00010	1-6	5.0E+04	1	5.0E+04	2.3E+05	3	7.6E+04	**
C-3	BK-00018	1-6	2.5E+04	1	2.5E+04	3.8E+04	1	3.8E+04	
K	BK-00026	1-6	2.5E+04	0*	0.0E+00	1.5E+05	4+	3.8E+04	**

** One non-countable LA structure was observed.*

+ Two amosite structures also recorded.

** Soil concentration for filters prepared by rock flour preparation are statistically higher than filters prepared by direct preparation (as determined based on the Poisson ratio test at a 90% confidence interval).

FBAS = fluidized bed asbestos segregator

g^{-1} = per gram

ID = identification

in = inches

LA = Libby amphibole

s/g = structure per gram

TABLE 4-4. 2011 Libby Background ABS Air and FBAS Soil Results

		ABS AIR RESULTS				SOIL RESULTS*				
Background Area	Event	Sample ID	Achieved sensitivity (cc^{-1})	ABS PCME LA Air Conc. (s/cc)		Sample ID	Total LA Soil Conc. (s/g)		PCME LA Soil Conc. (s/g)	
				Event Conc.	Mean across events		FBAS Event Conc.	Mean across events	FBAS Event Conc.	Mean across events
A	Event 1	EX-30381	6E-03	5E-02	3E-02	EX-30383	6E+05	3E+05	0E+00	5E+04
	Event 2	EX-30385	3E-03	5E-02		EX-30386	2E+05		7E+04	
	Event 3	EX-30389	1E-03	6E-03		EX-30390	2E+05		7E+04	
B	Event 1	EX-30102	2E-03	0E+00	7E-03	EX-30104	6E+04	3E+05	0E+00	7E+04
	Event 2	EX-30105	2E-03	0E+00		EX-30107	4E+05		5E+04	
	Event 3	EX-30392	3E-03	2E-02		EX-30394	5E+05		1E+05	
C	Event 1	EX-30395	2E-04	0E+00	0E+00	EX-30397	2E+05	2E+05	7E+04	5E+04
	Event 2	EX-30401	2E-04	0E+00		EX-30403	3E+05		4E+04	
	Event 3	EX-30407	2E-04	0E+00		EX-30409	9E+04		4E+04	
D	Event 1	EX-30398	2E-04	0E+00	0E+00	EX-30400	7E+05	3E+05	2E+05	1E+05
	Event 2	EX-30405	2E-04	0E+00		EX-30406	9E+04		4E+04	
	Event 3	EX-30411	2E-04	0E+00		EX-30412	9E+04		1E+05	
E	Event 1	EX-30414	2E-04	0E+00	0E+00	EX-30416	6E+05	6E+05	2E+05	1E+05
	Event 2	EX-30424	6E-04	0E+00		EX-30425	5E+05		7E+04	
	Event 3	EX-30432	2E-04	0E+00		EX-30434	6E+05		1E+05	
F	Event 1	EX-30417	2E-04	0E+00	0E+00	EX-30419	3E+05	2E+05	1E+05	7E+04
	Event 2	EX-30426	2E-04	0E+00		EX-30428	2E+05		7E+04	
	Event 3	EX-30436	2E-04	0E+00		EX-30437	3E+05		4E+04	
G	Event 1	EX-30421	2E-04	0E+00	2E-04	EX-30422	6E+05	3E+05	1E+05	9E+04
	Event 2	EX-30430	2E-04	7E-04		EX-30431	3E+05		4E+04	
	Event 3	EX-30439	2E-04	0E+00		EX-30440	9E+04		1E+05	
H	Event 1	EX-30110	2E-04	0E+00	0E+00	EX-30113	0E+00	3E+05	0E+00	5E+04
	Event 2	EX-30116	2E-04	0E+00		EX-30119	4E+05		0E+00	
	Event 3	EX-30124	2E-04	0E+00		EX-30126	5E+05		1E+05	
I	Event 1	EX-30129	2E-04	0E+00	0E+00	EX-30130	4E+05	3E+05	0E+00	4E+04
	Event 2	EX-30131	3E-04	0E+00		EX-30133	1E+05		0E+00	
	Event 3	EX-30134	2E-04	0E+00		EX-30136	3E+05		1E+05	
J	Event 1	EX-30137	2E-04	4E-04	2E-03	EX-30442	7E+05	2E+06	2E+05	5E+05
	Event 2	EX-30445	2E-04	0E+00		EX-30452	1E+06		7E+04	
	Event 3	EX-30448	7E-04	7E-03		EX-30454	5E+06		1E+06	
K	Event 1	EX-30139	2E-04	0E+00	0E+00	EX-30443	5E+05	5E+05	1E+05	2E+05
	Event 2	EX-30447	2E-04	0E+00		EX-30453	6E+05		3E+05	
	Event 3	EX-30451	2E-04	0E+00		EX-30455	4E+05		1E+05	
				Mean across all background areas:	**4E-03**			**5E+05**		**1E+05**

**No visible vermiculite was observed in any Libby background soil sample.*

ABS = activity-based sampling
cc^{-1} = per cubic centimeter
FBAS = fluidized bed asbestos segregator
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/cc = structures per cubic centimeter
s/g = structures per gram

TABLE 4-5
Troy Soil Mapping Units for Background Soil Sampling

Soil Mapping Unit	Elevation Mapped	Distinguishing Characteristics
102: Andic Dystric Eutrochrepts, lacustrine terraces	2,000 to 3,700	Soils formed in lacustrine deposits. Silt loam and silty clay loam textures
106: Andic Dystrochrepts, glacial outwash terraces	2,000 to 4,000	Soils formed in glacial outwash deposits. Surface loess layer 4 to 14 inches thick
108: Andic Dystric Eutrochrepts, lacustrine terraces – Andic Dystrochrepts, glacial outwash terraces, complex	2,000 to 4,000	Formed in lacustrine and glacial outwash deposits intricately mixed. Stratified layers of sand and gravel and silt loam and silty clay loam sediments
110: Eutrochrepts, glacial outwash terraces	2,000 to 3,500	Soils formed in glacial outwash deposits that have been reworked by wind

TABLE 4-6
2012 Troy Background ABS Air and FBAS Soil Results

Background Location Description	ABS AIR RESULTS			SOIL RESULTS*										
					Total LA Soil Conc. (s/g)					PCME LA Soil Conc. (s/g)				
	Sample ID	Achieved Sensitivity (cc^{-1})	ABS PCME LA Air Conc. (s/cc)	Sample ID	Filter Replicate #1	Filter Replicate #2	Filter Replicate #3	Mean across replicates	Mean across samples	Filter Replicate #1	Filter Replicate #2	Filter Replicate #3	Mean across replicates	Mean across samples
Shannon Flats, East	TK-00047	3E-04	3E-03	TK-00011	1E+05	0E+00	0E+00	3E+04	2E+04	0E+00	0E+00	4E+04	1E+04	6E+03
				TK-00013	0E+00	--	--	--		0E+00	--	--	--	
Shannon Flats, West	TK-00049	2E-04	2E-03	TK-00015	0E+00	--	--	--	0E+00	0E+00	--	--	--	0E+00
				TK-00017	0E+00	--	--	--		0E+00	--	--	--	
USFS - Old Hwy 2 - North	TK-00051	7E-04	1E-03	TK-00002	4E+04	--	--	--	2E+04	0E+00	--	--	--	0E+00
				TK-00004	0E+00	--	--	--		0E+00	--	--	--	
USFS - Old Hwy 2 - South	TK-00054	2E-04	2E-04	TK-00006	0E+00	--	--	--	2E+05	0E+00	--	--	--	0E+00
				TK-00008	4E+05	--	--	--		0E+00	--	--	--	
USFS #1 Southside Road	TK-00055	2E-04	2E-04	TK-00035	0E+00	--	--	--	5E+04	0E+00	--	--	--	2E+04
				TK-00037	9E+04	--	--	--		4E+04	--	--	--	
Troy LandFill	TK-00057	4E-04	4E-04	TK-00019	2E+05	--	--	--	1E+05	8E+04	--	--	--	5E+04
				TK-00021	8E+04	--	--	--		2E+04	--	--	--	
Garrison Road, Old Gravel Pit	TK-00059	2E-04	0E+00	TK-00023	4E+04	--	--	--	2E+04	0E+00	--	--	--	8E+03
				TK-00025	0E+00	--	--	--		2E+04	--	--	--	
Garrison Road, County Gravel Pit	TK-00070	4E-04	0E+00	TK-00027	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	2E+05	6E+04	1E+05
				TK-00029	0E+00	--	--	--		2E+05	--	--	--	
Airport Gravel Pit	TK-00072	4E-04	2E-03	TK-00031	0E+00	0E+00	7E+05	2E+05	2E+05	0E+00	0E+00	2E+05	6E+04	7E+04
				TK-00033	2E+05	--	--	--		7E+04	--	--	--	
East Side Road Forest Service #2	TK-00074	2E-04	0E+00	TK-00039	5E+05	0E+00	3E+06	1E+06	7E+05	3E+05	0E+00	2E+05	2E+05	2E+05
				TK-00041	3E+05	--	--	--		1E+05	--	--	--	
Cornwell Gravel Pit	TK-00076	2E-03	0E+00	TK-00043	0E+00	0E+00	0E+00	0E+00	5E+04	0E+00	0E+00	2E+05	6E+04	5E+04
				TK-00045	9E+04	--	--	--		4E+04	--	--	--	
Mean across background areas:			**8E-04**						**1E+05**					**4E+04**

**No visible vermiculite was observed in any Libby background soil sample.*

ABS = activity-based sampling
cc^{-1} = per cubic centimeter
ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/cc = structures per cubic centimeter
s/g = structures per gram

TABLE 4-7. 2011 Libby Borrow Source ABS Air and FBAS Soil Results

		ABS AIR RESULTS				SOIL RESULTS*										
				ABS PCME LA Air Conc. (s/cc)			Soil Total LA Conc. (s/g)					Soil PCME LA Conc. (s/g)				
Borrow Source	Event	Sample ID	Achieved sensitivity (cc^{-1})	Event Conc.	Mean across events	Sample ID	FBAS Replicate #1	FBAS Replicate #2	FBAS Replicate #3	Mean across replicates	Mean across events	FBAS Replicate #1	FBAS Replicate #2	FBAS Replicate #3	Mean across replicates	Mean across events
Boothman Pit	Event 1	EX-30108	1E-04	0E+00	7E-05	EX-30112	9E+04	0E+00	0E+00	3E+04	1E+05	4E+04	0E+00	0E+00	1E+04	5E+04
	Event 2	EX-30114	1E-04	2E-04		EX-30118	6E+04	5E+05	5E+04	2E+05		2E+04	3E+05	0E+00	1E+05	
	Event 3	EX-30121	1E-04	0E+00		EX-30125	9E+04	3E+05	0E+00	1E+05		3E+04	4E+04	2E+04	3E+04	
Noble Ranch House Pit #1	Event 1	EX-30468	1E-04	0E+00	0E+00	EX-30469	6E+04	6E+04	0E+00	4E+04	9E+04	0E+00	6E+03	0E+00	2E+03	3E+04
	Event 2	EX-30471	1E-04	0E+00		EX-30472	3E+04	9E+04	0E+00	4E+04		0E+00	2E+04	0E+00	6E+03	
	Event 3	EX-30474	1E-04	0E+00		EX-30475	3E+05	3E+05	5E+04	2E+05		1E+05	4E+04	2E+04	7E+04	
Fink Pit	Event 1	EX-30476	1E-04	2E-04	2E-04	EX-30479	0E+00	4E+05	0E+00	1E+05	2E+05	0E+00	5E+04	0E+00	2E+04	4E+04
	Event 2	EX-30480	1E-04	2E-04		EX-30482	4E+05	1E+05	1E+05	2E+05		1E+05	3E+04	2E+04	6E+04	
	Event 3	EX-30483	1E-04	1E-04		EX-30485	2E+05	3E+05	0E+00	2E+05		1E+05	4E+04	0E+00	5E+04	
Feller Pit	Event 1	EX-30486	1E-04	0E+00	0E+00	EX-30489	1E+06	2E+06	8E+05	1E+06	9E+05	3E+05	4E+04	2E+05	2E+05	2E+05
	Event 2	EX-30490	1E-04	0E+00		EX-30492	2E+05	1E+06	0E+00	5E+05		1E+05	3E+05	0E+00	1E+05	
	Event 3	EX-30493	1E-04	0E+00		EX-30495	6E+05	2E+06	5E+05	9E+05		7E+04	2E+05	2E+05	1E+05	
Valley View Pit (Eureka, MT)	Event 1	EX-30458	1E-04	0E+00	0E+00	EX-30459	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
	Event 2	EX-30462	1E-04	0E+00		EX-30460	0E+00	0E+00	0E+00	0E+00		0E+00	0E+00	0E+00	0E+00	
	Event 3	EX-30464	3E-04	0E+00		EX-30461	0E+00	0E+00	0E+00	0E+00		0E+00	0E+00	0E+00	0E+00	
		Mean across Kootenai Valley borrow sources:			**6E-05**						**3E+05**					**7E+04**

**No visible vermiculite was observed in any borrow source soil sample.*

ABS = activity-based sampling
cc^{-1} = per cubic centimeter
ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/cc = structures per cubic centimeter
s/g = structures per gram

TABLE 4-8
ABS AIR RESULTS FOR PROPERTIES WITH A CURB-TO-CURB SOIL REMOVAL
Libby Asbestos Superfund Site, Libby, Montana

Property ID	Soil Removal Date	SOIL RESULTS		AIR RESULTS						
				EVENT 1		EVENT 2		EVENT 3		MEAN
		PLM-VE LA Bin Result[+]	Visible vermiculite[++]	Sample ID	PCME LA Air Conc. (s/cc)	Sample ID	PCME LA Air Conc. (s/cc)	Sample ID	PCME LA Air Conc. (s/cc)	PCME LA Air Conc. (s/cc)
AD-001713	Jun-08	A,A,A	none (90-pts)	EX-20215	2.2E-04	EX-20360	1.2E-02	EX-20509	1.6E-03	4.7E-03
AD-001722	Jun-08	A,A,B1	none (90-pts)	EX-20218	0.0E+00	EX-20422	4.6E-04	EX-20512	0.0E+00	1.5E-04
AD-001893	Jul-08	A,A,A	none (90-pts)	EX-20263	0.0E+00	EX-20389	0.0E+00	EX-20548	0.0E+00	0.0E+00
AD-000414	Oct-08	A,A,A	3 low, 87 none	EX-20201	1.1E-02	EX-20348	0.0E+00	EX-20469	0.0E+00	3.8E-03
AD-001904	Jul-09	A,A,A	none (90-pts)	EX-20473	0.0E+00	EX-20622	0.0E+00	EX-20710	0.0E+00	0.0E+00
AD-000353	Jul-09	A,A,A	none (90-pts)	EX-20208	6.6E-04	EX-20356	0.0E+00	EX-20504	0.0E+00	2.2E-04
AD-003155	May-10	A,A,A	none (90-pts)	EX-20267	0.0E+00	EX-20385	0.0E+00	EX-20543	0.0E+00	0.0E+00
AD-004293	Jun-10	A, n/c, n/c	1 low, 29 none	EX-20151	1.1E-04	n/c	n/c	n/c	n/c	1.1E-04
AD-004749	Jun-10	A,A,A	none (90-pts)	EX-20223	0.0E+00	EX-20426	0.0E+00 *	EX-20520	0.0E+00	0.0E+00
AD-002292	Jun-10	A,A,A	none (90-pts)	EX-20271	0.0E+00	EX-20382	6.5E-04	EX-20552	0.0E+00	2.2E-04
AD-002171	Oct-10	A,A,A	none (90-pts)	EX-20284	0.0E+00	EX-20398	0.0E+00	EX-20560	0.0E+00	0.0E+00

Notes:
ABS - activity-based sampling
PCME - phase contrast microscopy equivalent
LA - Libby Amphibole Asbestos
Conc. - concentration
s/cc - structures per cubic centimeter
n/c - not collected

[+] Bin results for each of three sampling events are reported (separated by commas).
[++] Visible vermiculite results across all 30-point soil composites are summarized.
* Sample result was J-qualified by the data validator due to the failure of the laboratory to perform and/or document daily calibration activities.

TABLE 4-9. Soil Results for Samples from the Libby City Pit

Sample ID	PLM-VE LA Bin Result		FBAS Total LA Soil Conc. (s/g)				FBAS PCME LA Soil Conc. (s/g)			
	ESATR8	Hygeia	Replicate #1	Replicate #2	Replicate #3	Mean across replicates	Replicate #1	Replicate #2	Replicate #3	Mean across replicates
FM-00013	Trace	ND	0E+00	3E+04	6E+04	3E+04	0E+00	0E+00	0E+00	0E+00
FM-00014	ND	ND	9E+05	1E+06	2E+05	9E+05	5E+05	6E+05	0E+00	3E+05
FM-00015	Trace	ND	2E+06	2E+06	4E+05	1E+06	6E+05	5E+05	3E+05	5E+05
FM-00016	ND	ND	1E+06	2E+06	9E+05	1E+06	3E+05	7E+05	2E+05	4E+05
FM-00017	ND	ND	3E+05	2E+06	5E+04	7E+05	2E+05	6E+05	2E+04	2E+05
FM-00018	ND	ND	8E+05	6E+05	1E+05	5E+05	2E+05	7E+04	6E+04	1E+05
FM-00019	Trace	ND	2E+05	9E+05	3E+05	5E+05	2E+05	2E+05	1E+05	2E+05
FM-00020	Trace	ND	3E+05	4E+05	2E+05	3E+05	1E+05	7E+04	1E+05	1E+05
					mean across replicates:	**7E+05**				**2E+05**

No visible vermiculite was noted in any Libby City Pit soil sample.

FBAS = fluidized bed asbestos segregator

ID = identifier

LA = Libby amphibole asbestos

ND = non-detect (Bin A)

PCME = phase contrast microscopy-equivalent

PLM-VE = polarized light microscopy using visual area estimation

s/g = structures per gram

TABLE 4-10
Comparative Exposure Investigation: ABS Air and FBAS Soil Results

Location	Soil Sample ID	Soil Total LA Conc. (s/g)					ABS Air Sample ID			PCME LA Air Conc. (s/cc)		
		FBAS Replicate #1	FBAS Replicate #2	FBAS Replicate #3	mean by location	mean across locations	Digging	Fireline Actor 1	Fireline Actor 2	Digging ABS	Fireline ABS Actor 1	Fireline ABS Actor 2
Helena Area A	CX-00001	2E+04 1 XX AC	0E+00	0E+00	8E+03	3E+03	CX-00005	CX-00009	CX-00011	0.0	0.0	0.0
Helena Area B	CX-00015	0E+00	0E+00	0E+00	0E+00		CX-00014	CX-00021	CX-00023	0.0	0.0	0.0
Helena Area C	CX-00025	0E+00	0E+00	0E+00	0E+00		CX-00029	CX-00033	CX-00035	0.0	0.0	0.0
Whitefish Area A	CX-00050	0E+00	0E+00	0E+00	0E+00	1E+04	CX-00055	CX-00057	CX-00060	0.0	0.0	0.0
Whitefish Area B	CX-00062	0E+00	0E+00	0E+00	0E+00		CX-00066	CX-00068	CX-00070	0.0	0.0	0.0
Whitefish Area C	CX-00037	0E+00	9E+04 1 XX TR	0E+00	3E+04		CX-00042	CX-00044	CX-00047	0.0	0.0	0.0
Eureka Area A	CX-00093	0E+00	0E+00	0E+00	0E+00	7E+04	CX-00097	CX-00099	CX-00101	0.0	0.0	0.0
Eureka Area B	CX-00083	0E+00	9E+04 1 XX AC	0E+00	3E+04		CX-00087	CX-00089	CX-00091	0.0	0.0	0.0
Eureka Area C	CX-00072	9E+04 1 XX AC	5E+05 1 XX AC	0E+00	2E+05		CX-00077	CX-00079	CX-00081	0.0	0.0	0.0

No visible vermiculite was noted for any soil sampling point

cm^2 = square centimeter
g = grams
ID = identifier
LA = Libby amphibole
PCME = phase contrast microscopy equivalent

XX = no sodium or potassium present
AC = actinolite
TR = tremolite

Table 5-1. ABS Air Filters Prepared Using the Indirect Preparation Method

Study	Location	Sample ID	Indirect Preparation F-factor	Achieved Sensitivity $(cc)^{-1}$	PCME LA	
					No. of Structures	Air Conc. (s/cc)
2012 Troy Background ABS	Shannon Flats, East	TK-00047	0.05	0.00030	9	0.0027
	Shannon Flats, West	TK-00049	0.075	0.00022	9	0.0020
	USFS - Old Hwy 2 - North	TK-00051	0.0225	0.00068	2	0.0014
	USFS #1 Southside Road	TK-00055	0.075	0.00022	1	0.00022
	Troy LandFill	TK-00057	0.0375	0.00040	1	0.00040
	Garrison Road, County Gravel Pit	TK-00070	0.0375	0.00041	0	0
	Airport Gravel Pit	TK-00072	0.0375	0.00040	4	0.0016
	East Side Road Forest Service #2	TK-00074	0.1	0.00022	0	0
	Cornwell Gravel Pit	TK-00076	0.0075	0.0020	0	0
2011 Libby Background ABS	A	EX-30381	0.005	0.0058	8	0.046
		EX-30385	0.025	0.0030	16	0.048
		EX-30389	0.05	0.0015	4	0.0060
	B	EX-30102	0.015	0.0018	0	0
		EX-30105	0.015	0.0018	0	0
		EX-30392	0.01	0.0030	7	0.021
	E1	EX-30424	0.1	0.00061	0	0
	I	EX-30131	0.1	0.00028	0	0
	J	EX-30448	0.0375	0.00073	9	0.0066
2011 Borrow Source ABS	Valley View Pit	EX-30464	0.1	0.00026	0	0
2011 Curb-to-curb ABS	AD-000414	EX-20469	0.25	0.00020	0	0
	AD-004293	EX-20151	0.75	0.00011	1	0.00011
	AD-000414	EX-20201	0.25	0.00046	25	0.011
	AD-000353	EX-20208	0.75	0.00022	3	0.00066
	AD-001713	EX-20360	0.05	0.0011	11	0.012
Comparative Exposure Study	Helena Area A	CX-00005	0.1	0.00028	0	0
	Helena Area B	CX-00014	0.1	0.00028	0	0
	Helena Area C	CX-00029	0.1	0.00028	0	0

ABS = activity-based sampling
$(cc)^{-1}$ = per cubic centimeter of air
ID = identifier
LA = Libby amphibole
PCME = phase contrast microscopy equivalent
s/cc = structures per cubic centimeter of air

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Background Soil Summary Report
Libby Asbestos Superfund Site, Montana

FIGURES

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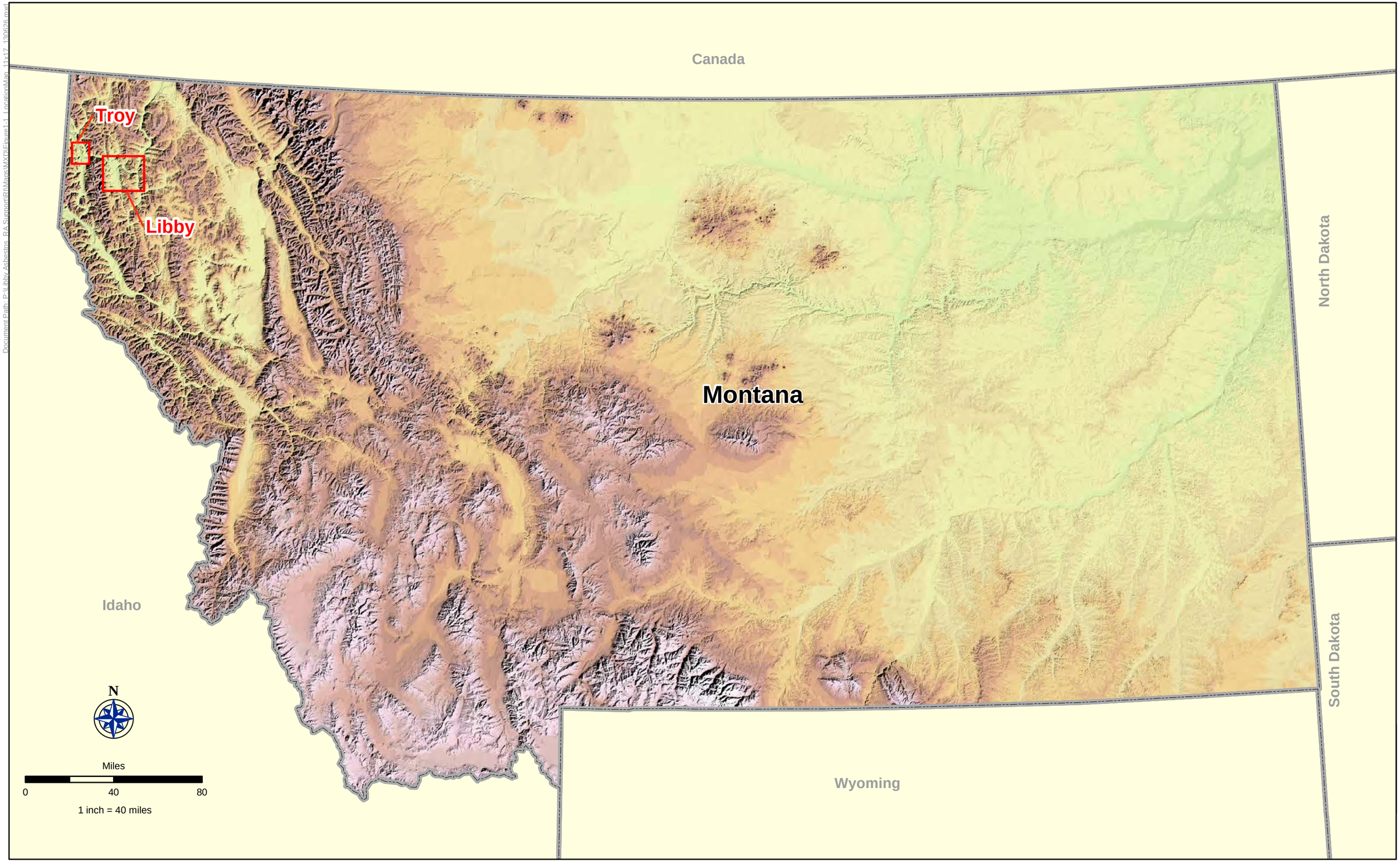


CDM Smith

Site Location Map
Libby, Montana

FIGURE 1-1

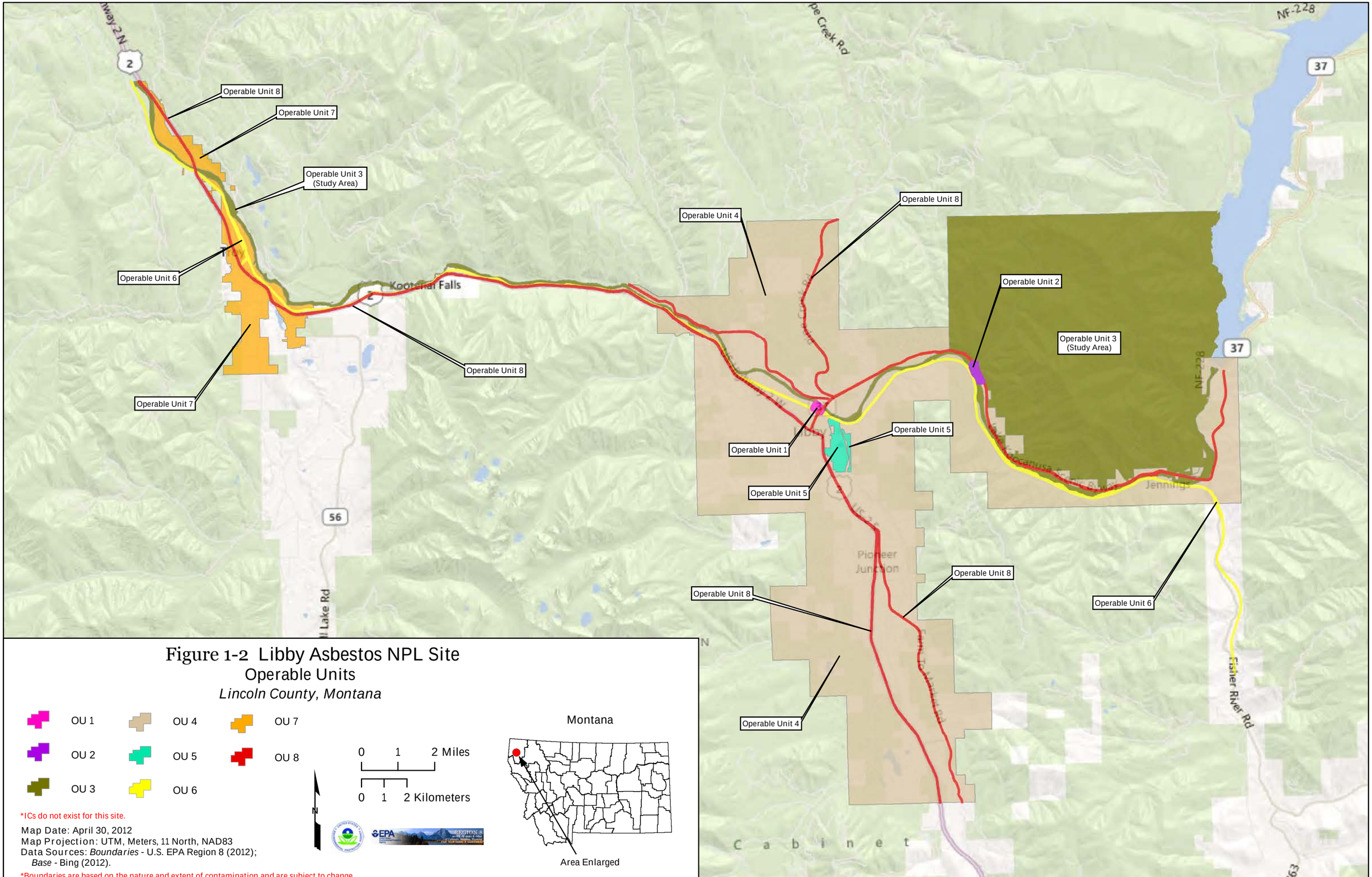
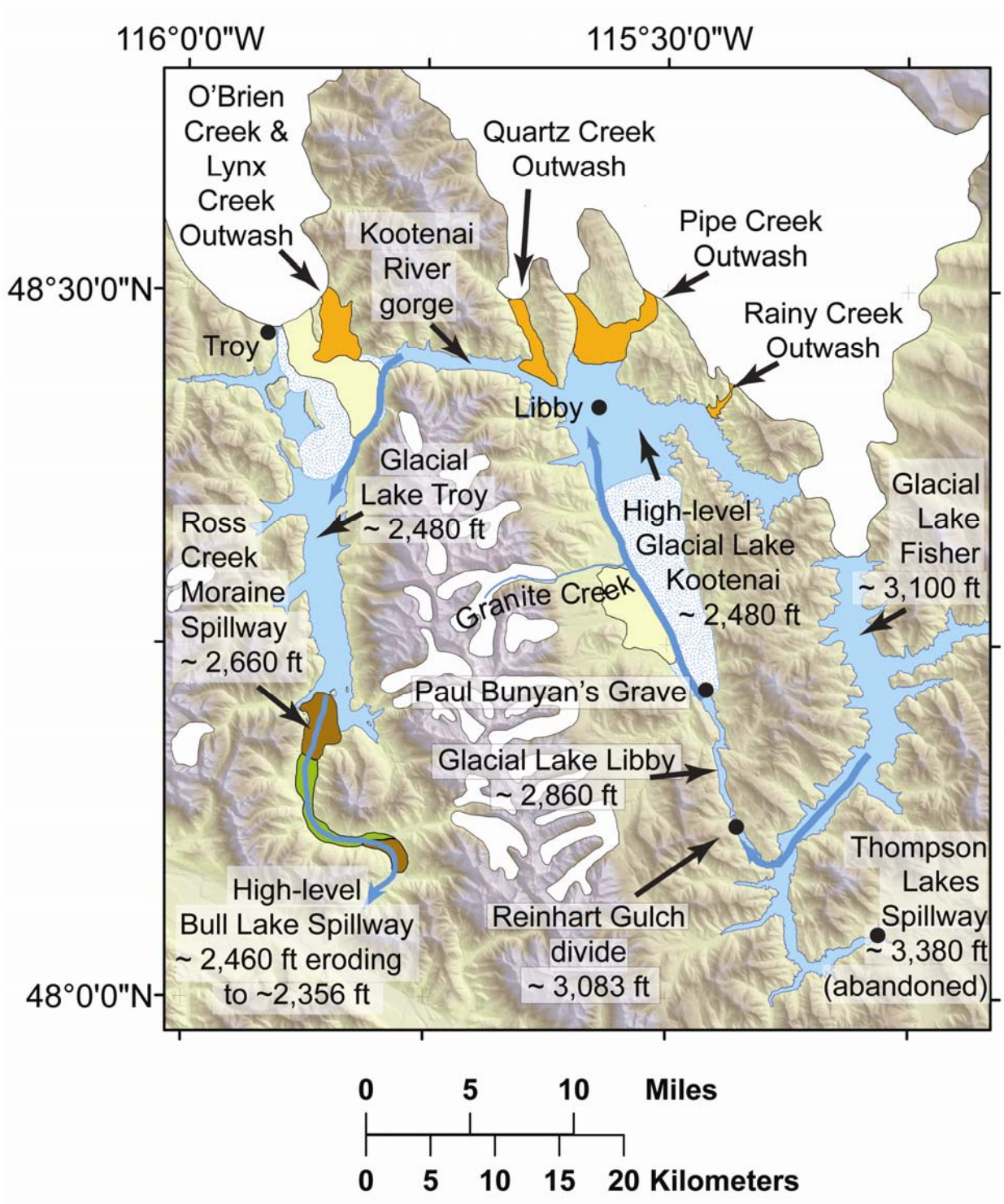


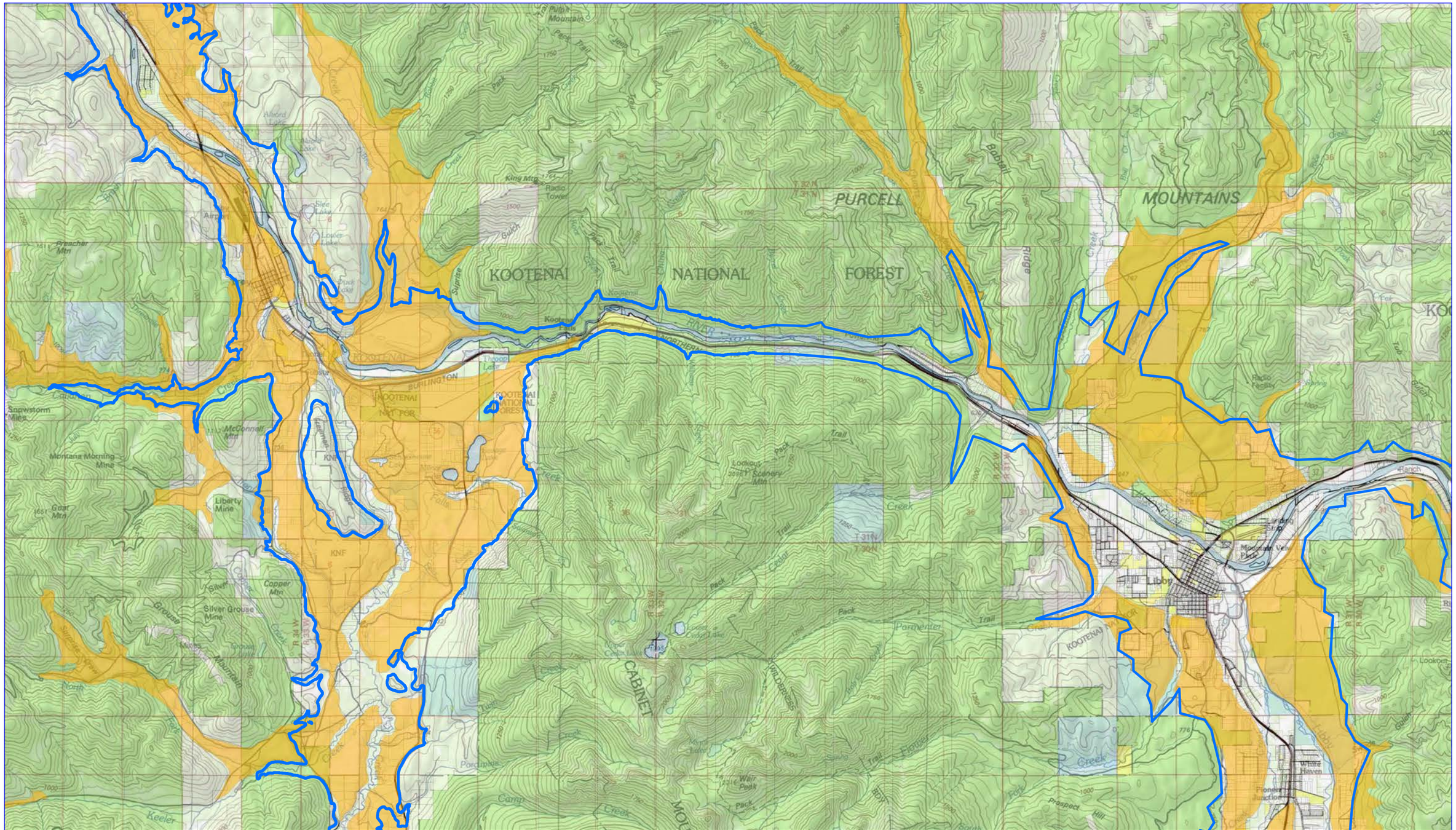
Figure 1-2 Libby Asbestos NPL Site
Operable Units
Lincoln County, Montana

Figure 1-3

Glacial Lake Kootenai During Pleistocene Time



Source: Figure 5 in Langer et al. (2010); used with author permission.



Basemap Source: USGS
Parcel Info: Montana Cadastral Database, Montana Dept. of Administration, Information Technology Services Division
SURRGO Soils: NRCS

Maximum Elevation of Glacial Lake
(2,450 feet above sea level)

Soil mapping Units 102, 106, 108, and 110.
Lacustrine Sediments and Glacial Outwash Deposits

N

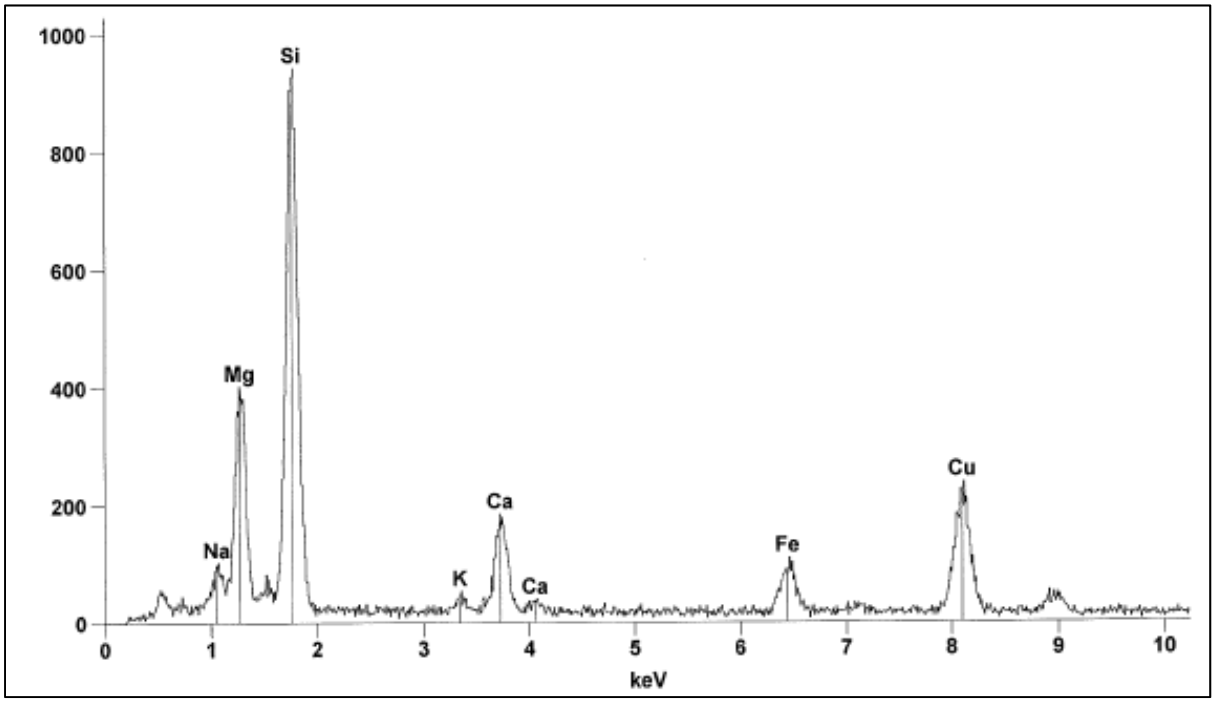
0 1,000 Meters

Background Soil Summary Report

FIGURE 1-4
Kootenai Valley Soils Formed in Lacustrine Sediments and Glacial Outwash Deposits

FIGURE 2-1. Examples of EDS Spectra for LA Structures

Panel A: WRTA, NaK



Panel B: AC, XX

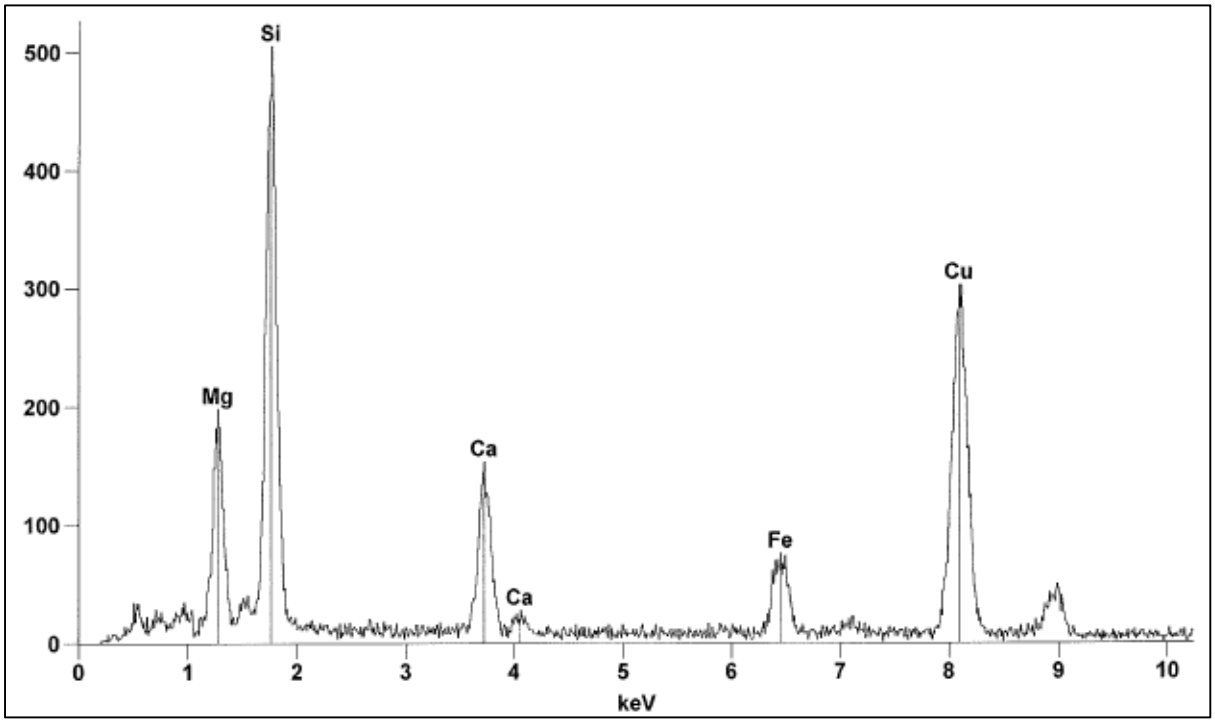
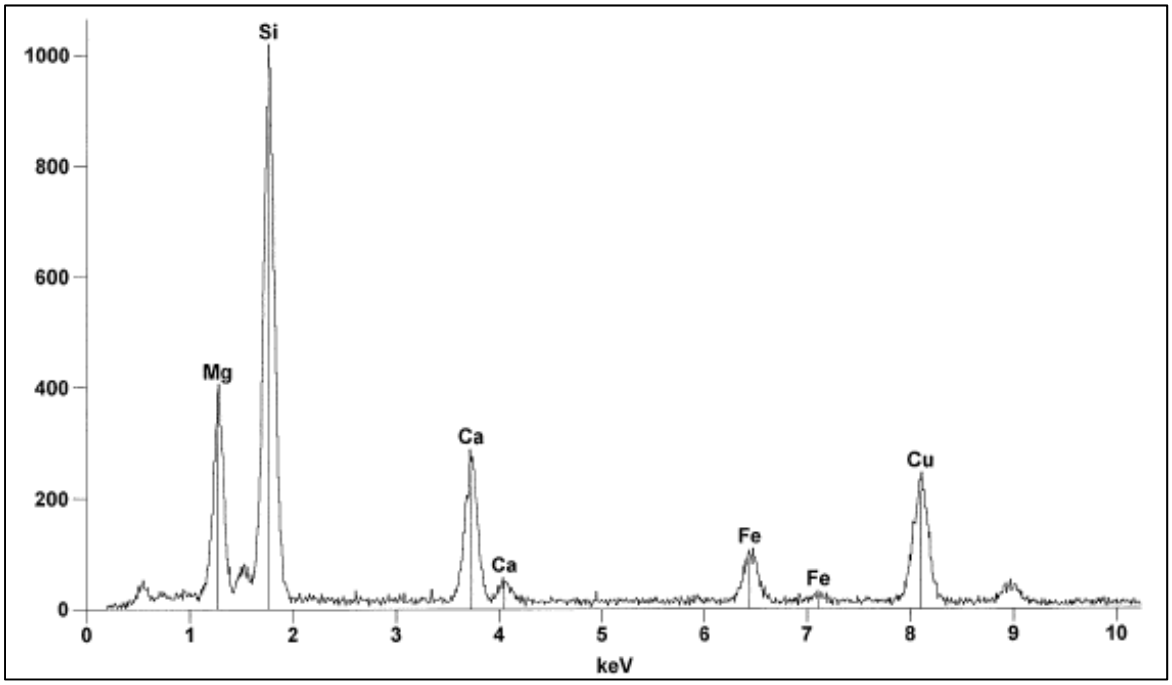


FIGURE 2-1. Examples of EDS Spectra for LA Structures (cont.)

Panel C: TR, XX



Source: ESAT Region 8 Laboratory

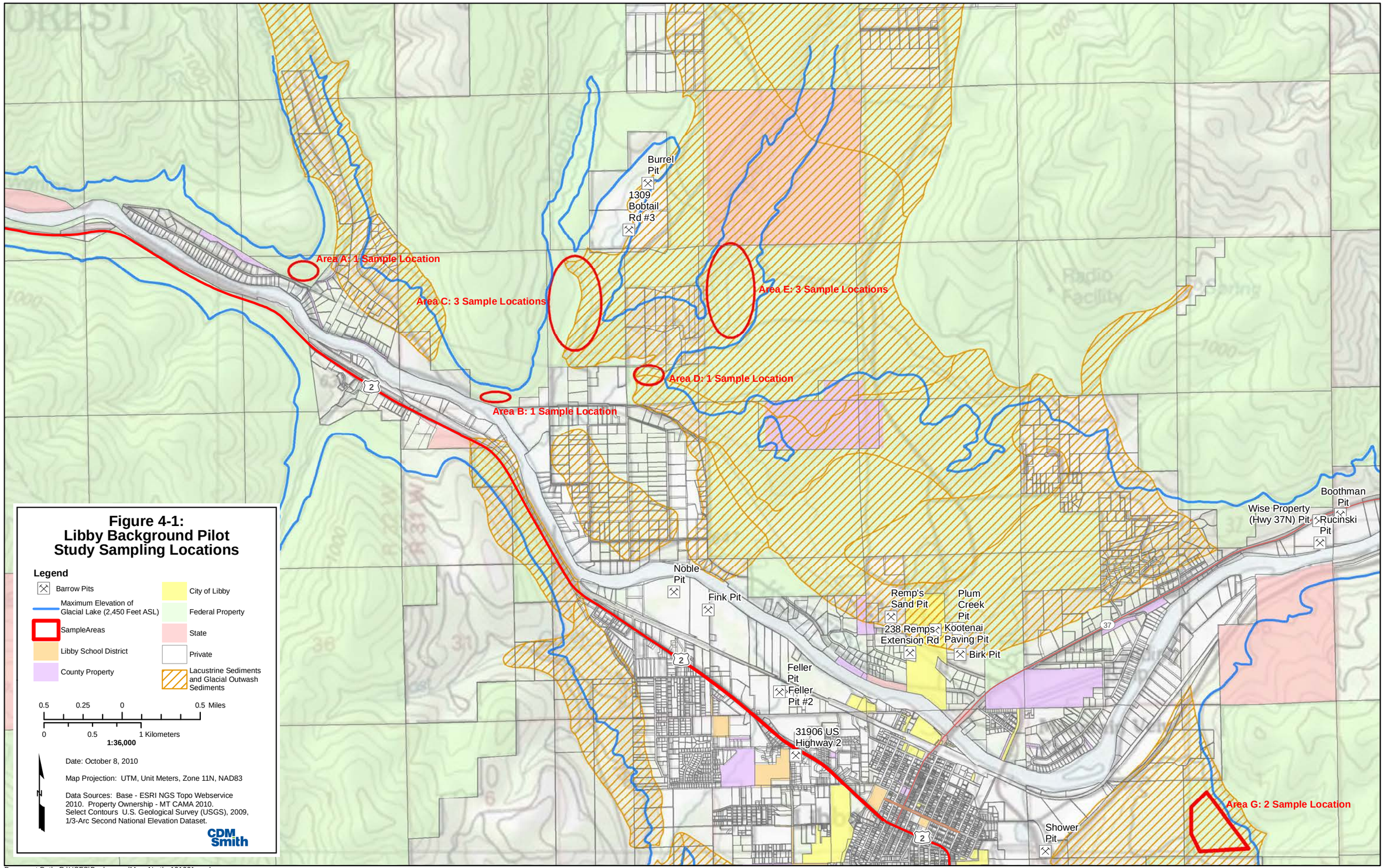


Figure 4-1: Libby Background Pilot Study Sampling Locations

Document Path: R:\USFS\BackgroundMap_North_131231.mxd

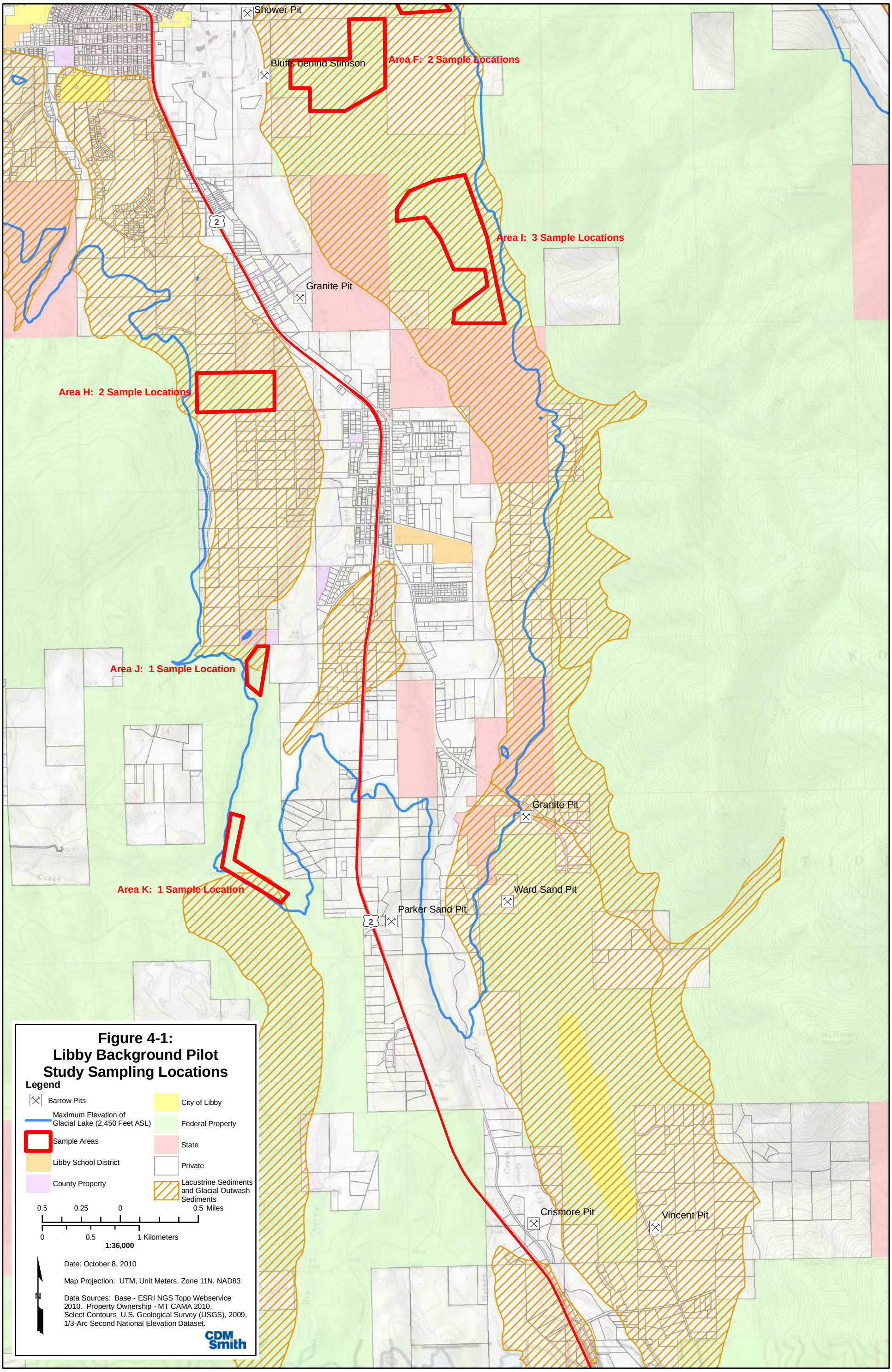
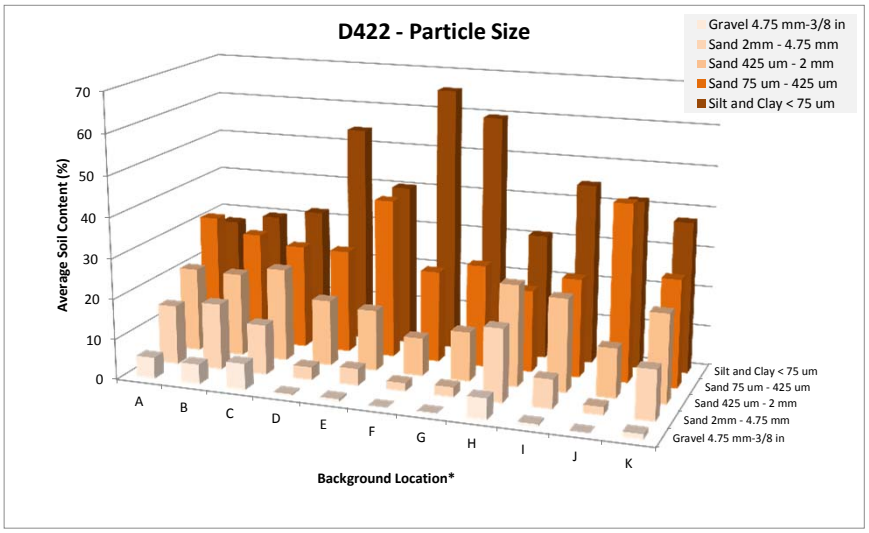
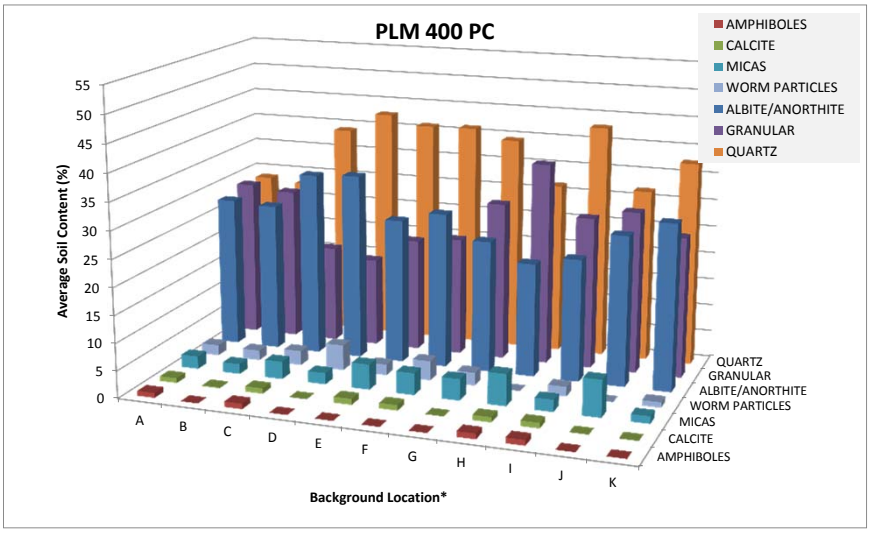
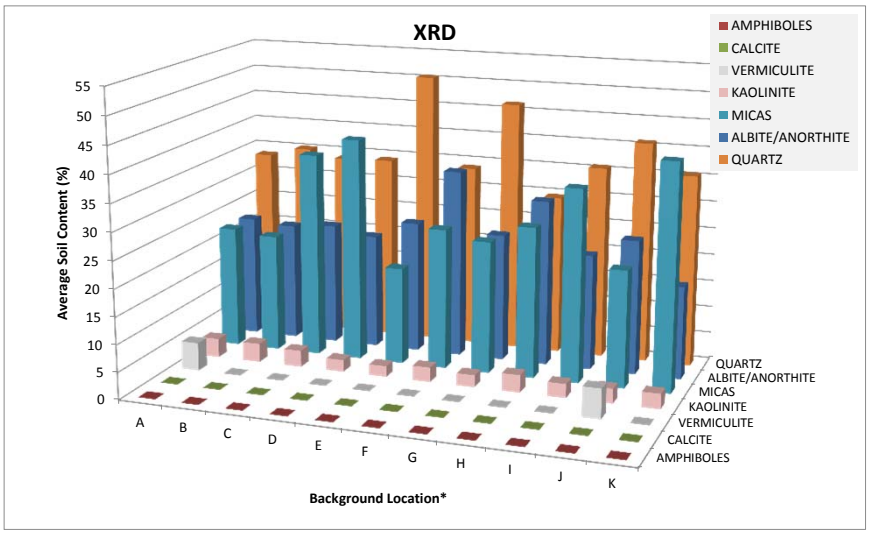


Figure 4-1: Libby Background Pilot Study Sampling Locations

Figure 4-2
2010 Libby Background Pilot Study Mineralogy Results (by Location)



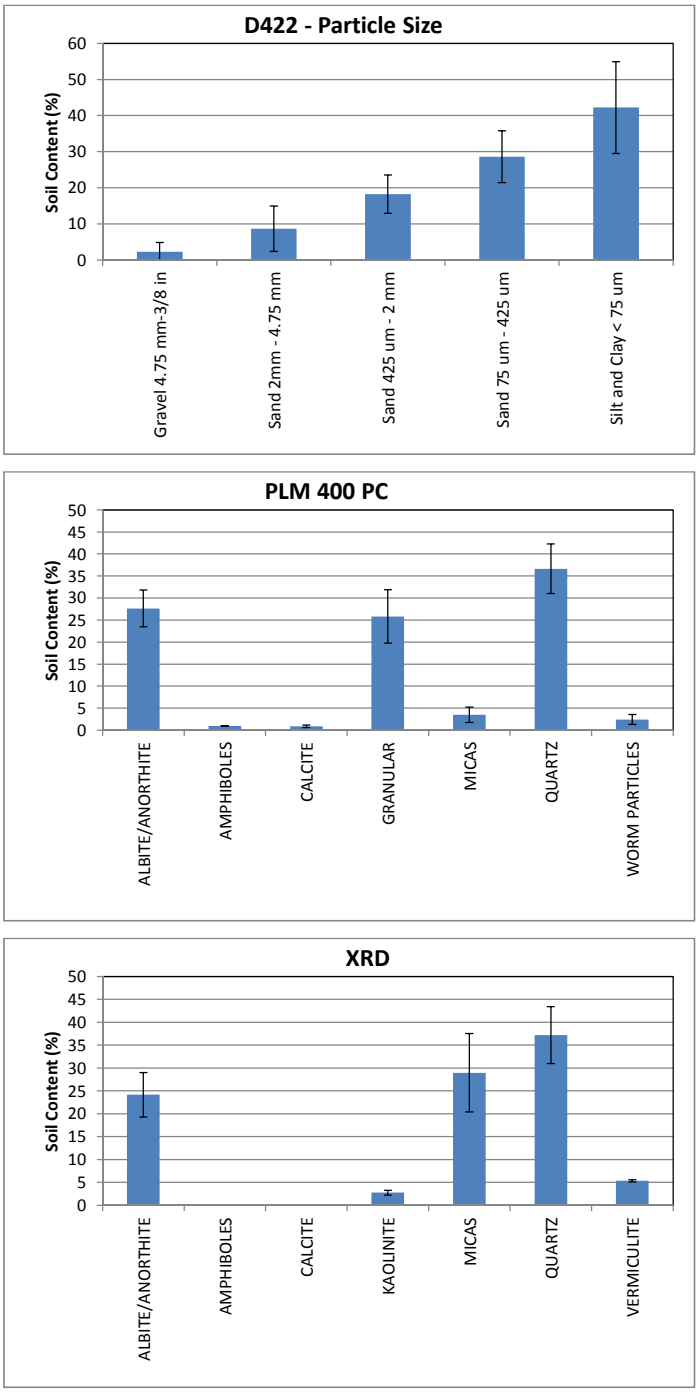




*See Figure 4-1 for a map of the Libby background locations

% = percent	mm = millimeters
< = less than	PLM 400 PC = polarized light microscopy by point counting (400 points examined)
D422 = ASTM method D422	um = micrometers
in = inches	XRD = x-ray diffraction

Figure 4-3
2010 Libby Background Pilot Study
Mineralogy Results (Across Location)

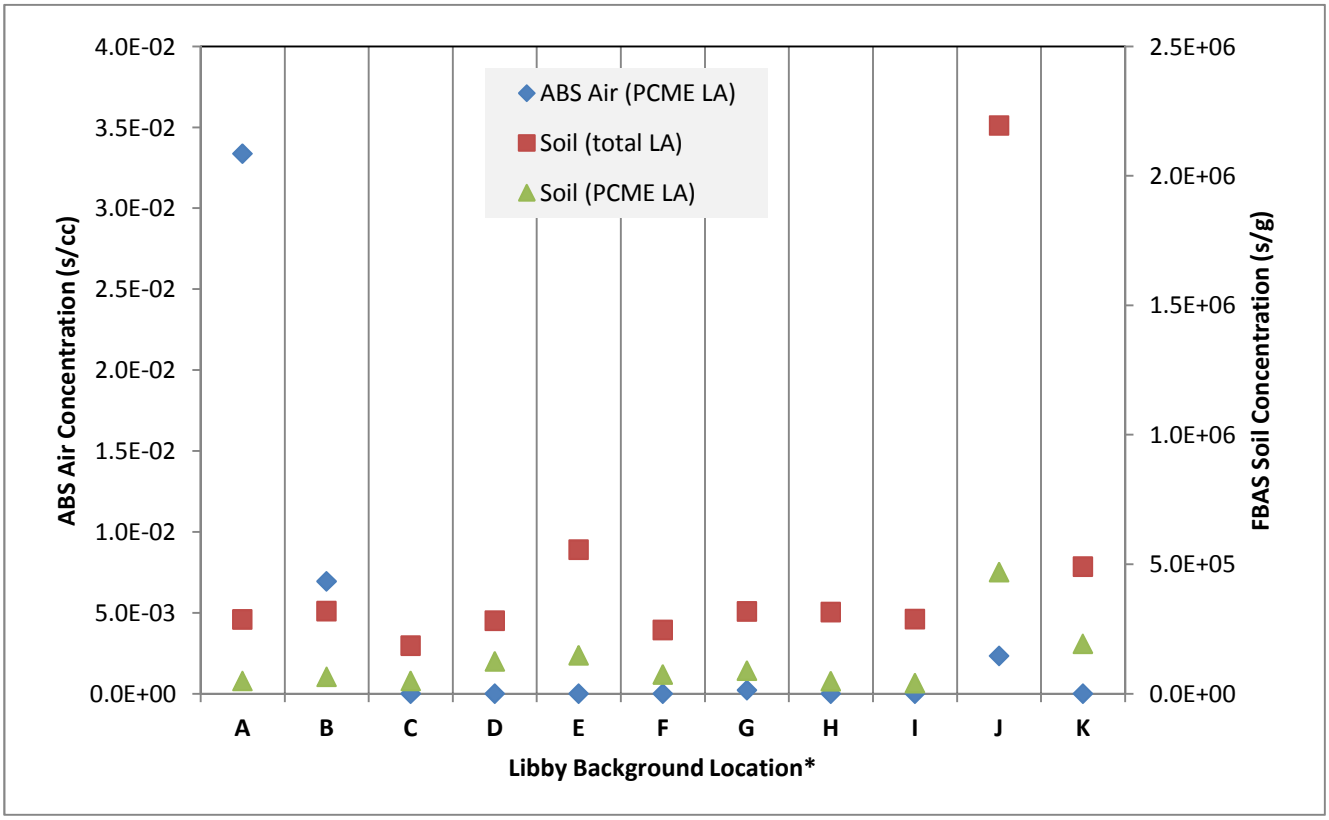


Bars represent average across all background locations; error bars are +/- 1 standard deviation.

% = percent
< = less than
D422 = ASTM method D422
in = inches
mm = millimeters
PLM 400 PC = polarized light microscopy by point counting (400 points examined)
um = micrometers

FIGURE 4-4. Example Photographs of the "Bucket of Dirt" ABS Activities

FIGURE 4-5. 2011 Libby Background ABS Air and FBAS Soil Results



*See Figure 4-1 for a map of the Libby background locations.

ABS = activity-based sampling

FBAS = fluidized bed asbestos segregator

LA = Libby amphibole asbestos

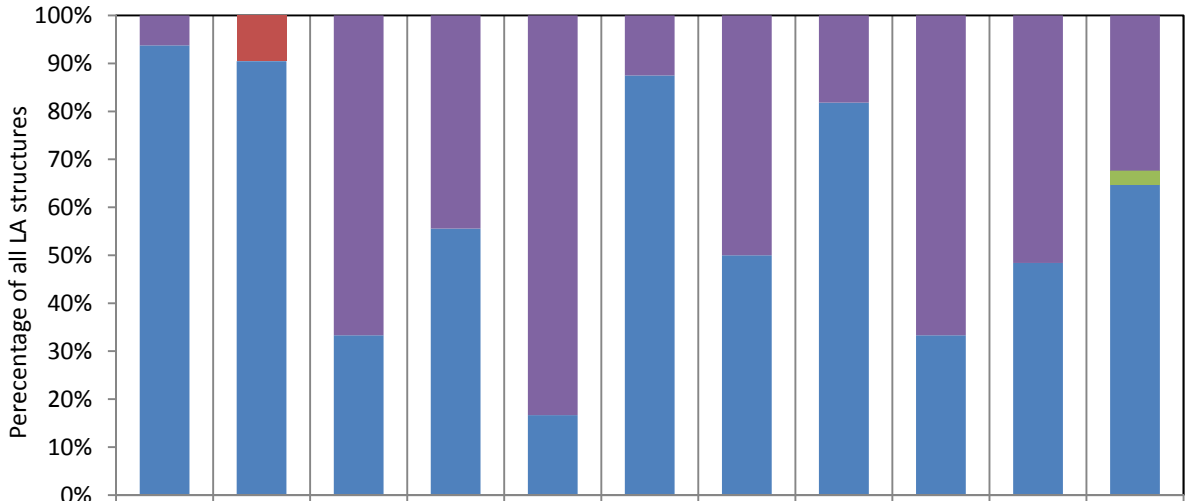
PCME = phase contrast microscopy-equivalent

s/cc = structures per cubic centimeter

s/g = structures per gram

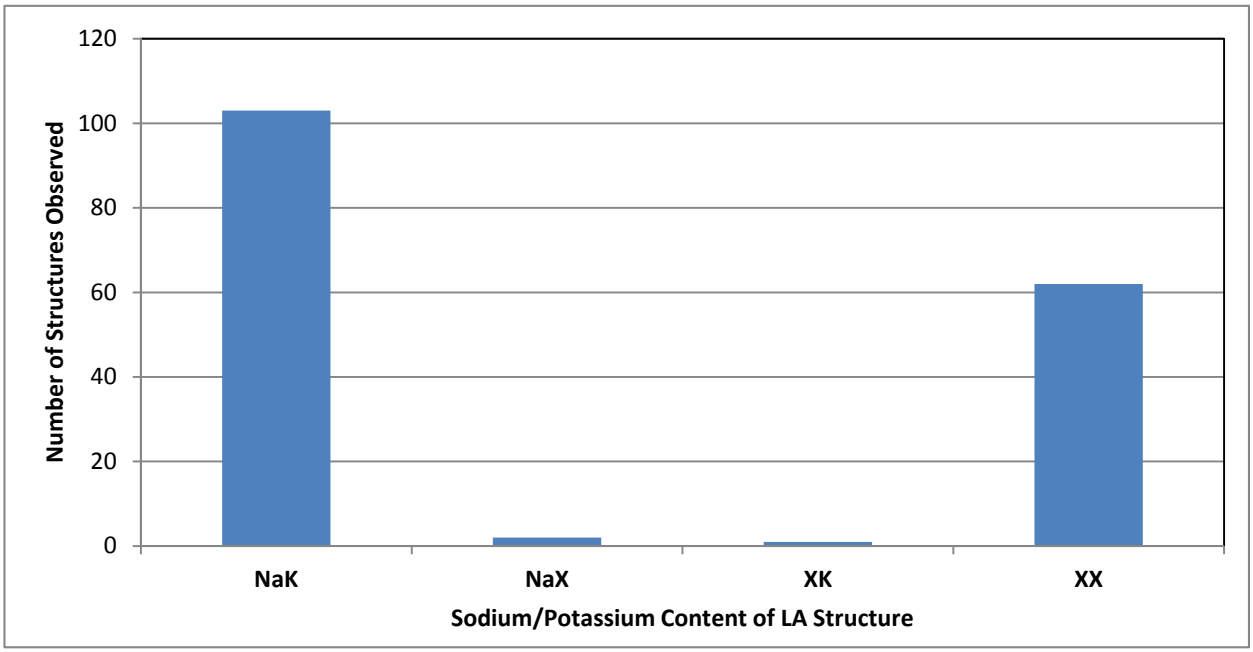
FIGURE 4-6. NaK Content of LA Structures in Libby Background Soils

Panel A: NaK Content by Background Area



No. of structures	A	B	C3	D	E1	F	G	H1	I	J	K
XX	1		4	4	15	1	4	2	4	16	11
XK											1
NaX		2									
NaK	15	19	2	5	3	7	4	9	2	15	22

Panel B: NaK Content across All Background Areas



% = percent

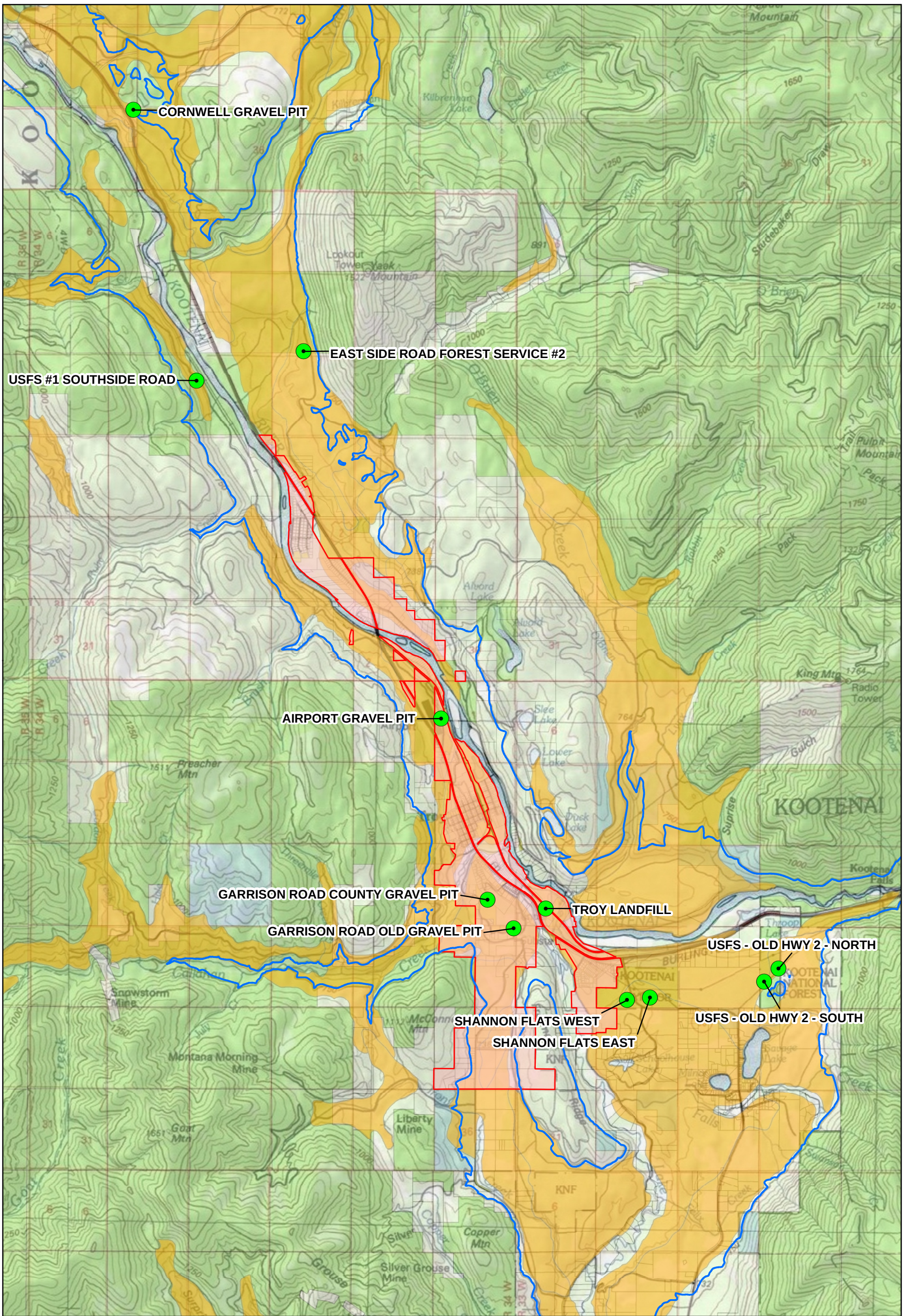
LA = Libby amphibole asbestos

NaK = contains sodium and potassium

NaX = contains sodium

XK = contains potassium

XX = contains neither sodium nor potassium



Legend

- Background Sampling Area
- Maximum Elevation of Glacial Lake (2,450 feet above sea level)
- Soil mapping Units 102, 106, 108, and 110. Lacustrine Sediments and Glacial Outwash Sediments

Property Ownership

- Federal
- State Land
- Local Government
- Private
- Operable Unit 7 Area

N

0 1 Miles

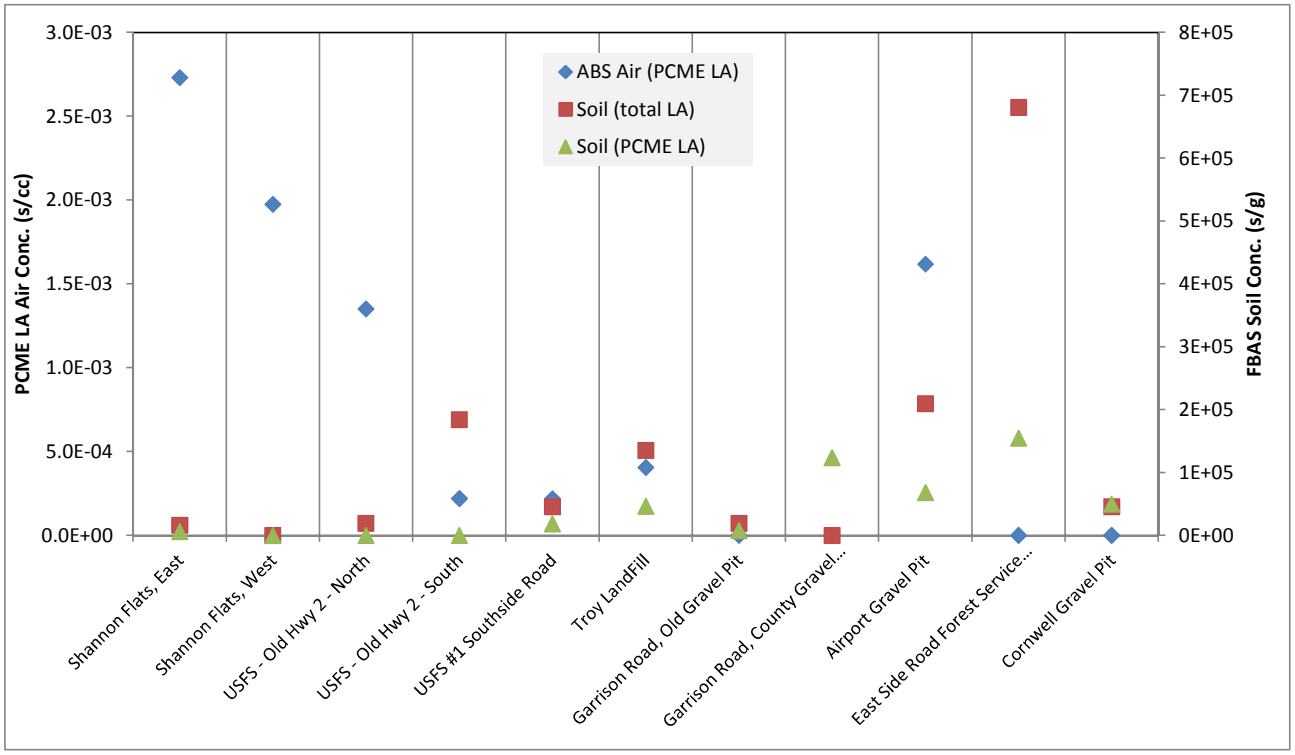
Topographic Map Source: Copyright:© 2011 National Geographic Society, i-cubed
SURRGO Soils: NRCS

Background Soil Summary Report
Libby Asbestos Superfund Site, Libby, Montana

FIGURE 4-7
LOCATION OF
TROY BACKGROUND SAMPLING AREAS

FIG4-5_TROY_BACKGROUND_SAMPLING_AREAS_111813.mxd - DWH - TTEMI HELENA

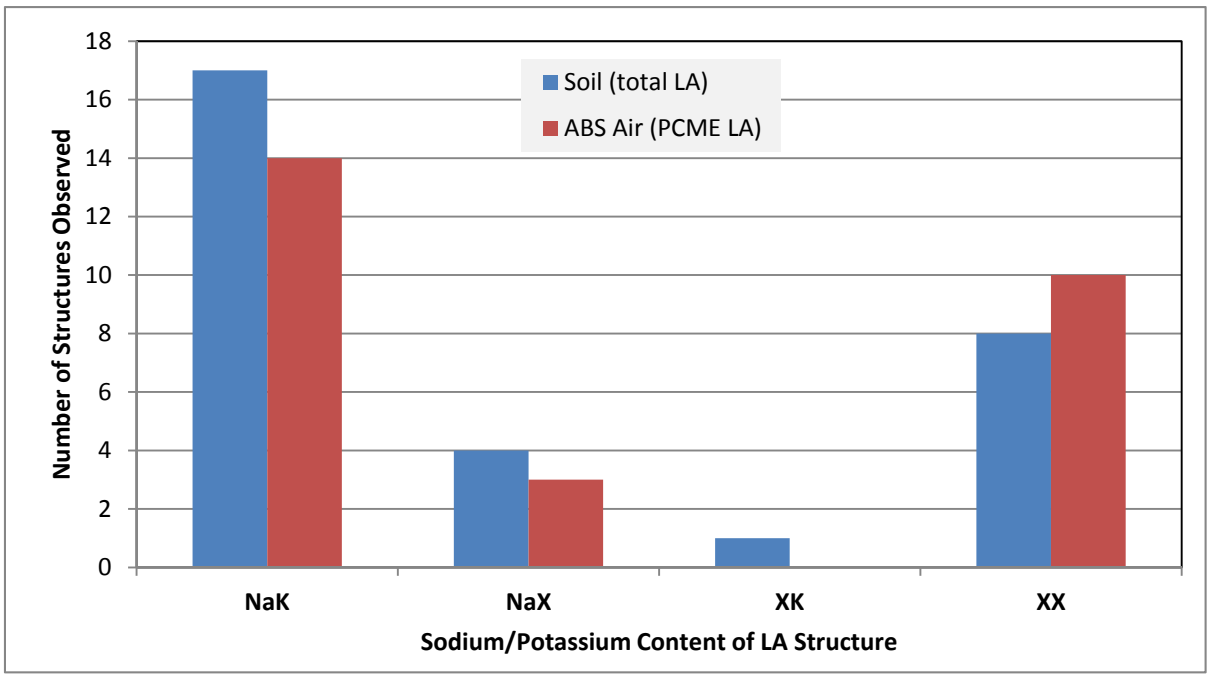
FIGURE 4-8
2012 Troy Background ABS Air and FBAS Soil Results



See Figure 4-7 for a map of the Troy background locations.

ABS = activity-based sampling
FBAS = fluidized bed asbestos segregator
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/cc = structures per cubic centimeter
s/g = structures per gram

FIGURE 4-9. NaK Content of LA Structures in Troy Background Samples



LA = Libby amphibole asbestos

NaK = contains sodium and potassium

NaX = contains sodium

XK = contains potassium

XX = contains neither sodium nor potassium

Borrow Pits

1,000 500 0 1,000 2,000

Feet
1 inch = 2,000 feet

Map Date: 12/31/2013

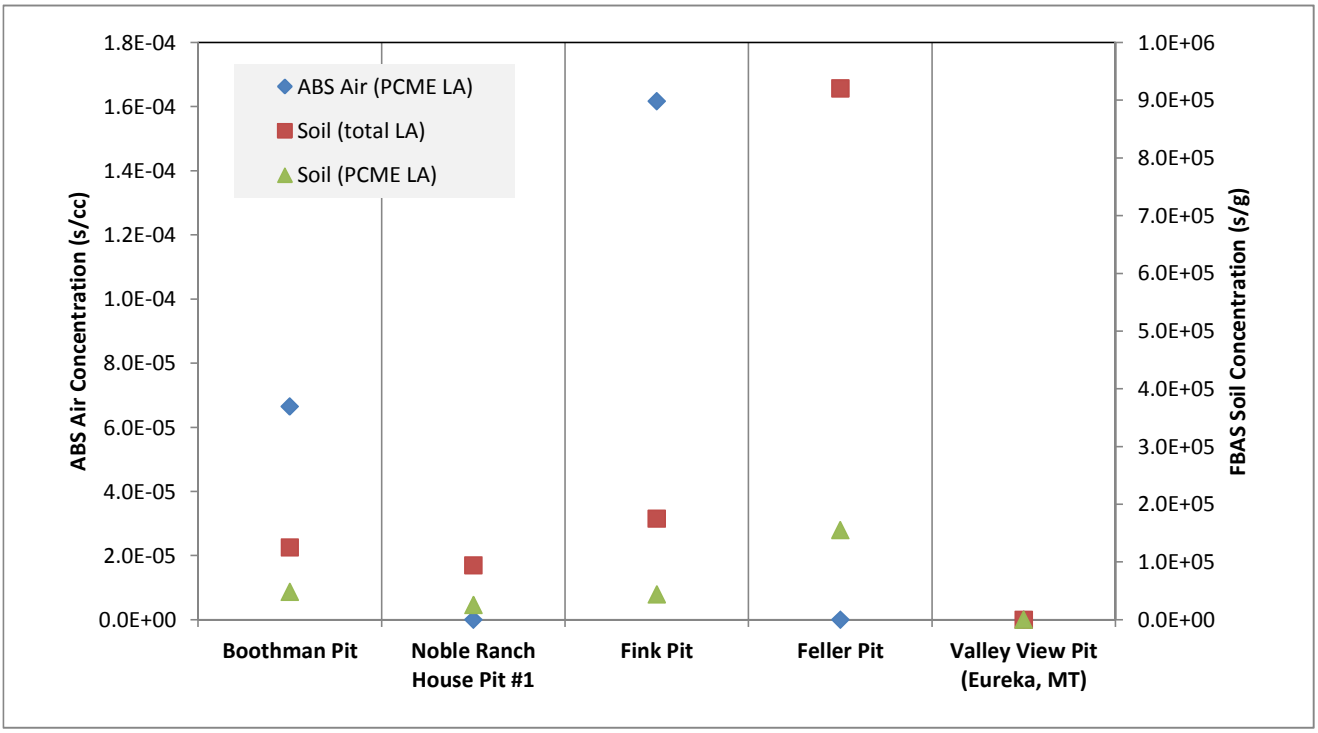
Figure 4-10
Borrow Source Sampling Locations

2011 OU4 Miscellaneous ABS SAP

CDM Smith

CDM Map File: R:\2603-Volpe\Libby\GIS\MXD_Pits\Fill_Material_Pits_131232_11x17.mxd

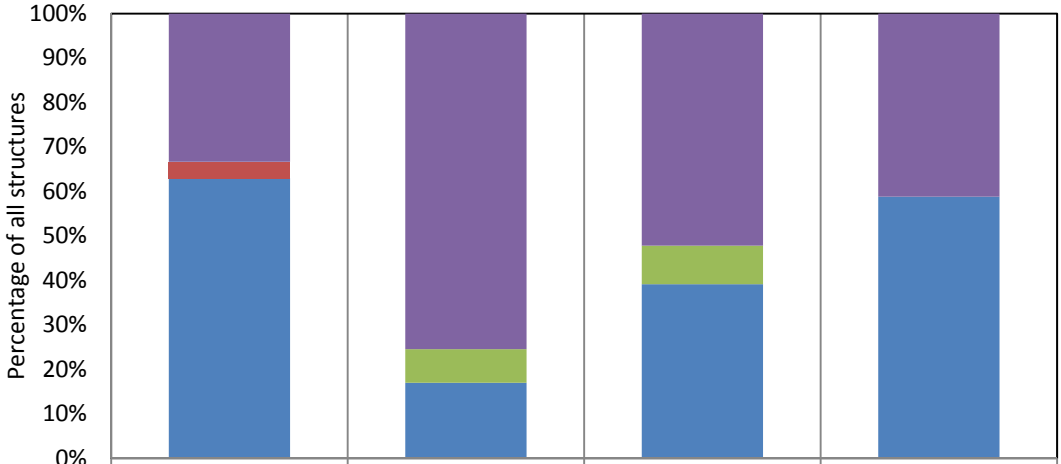
FIGURE 4-11. 2011 Libby Borrow Source ABS Air and FBAS Soil Results



ABS = activity-based sampling
FBAS = fluidized bed asbestos segregator
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/cc = structures per cubic centimeter
s/g = structures per gram

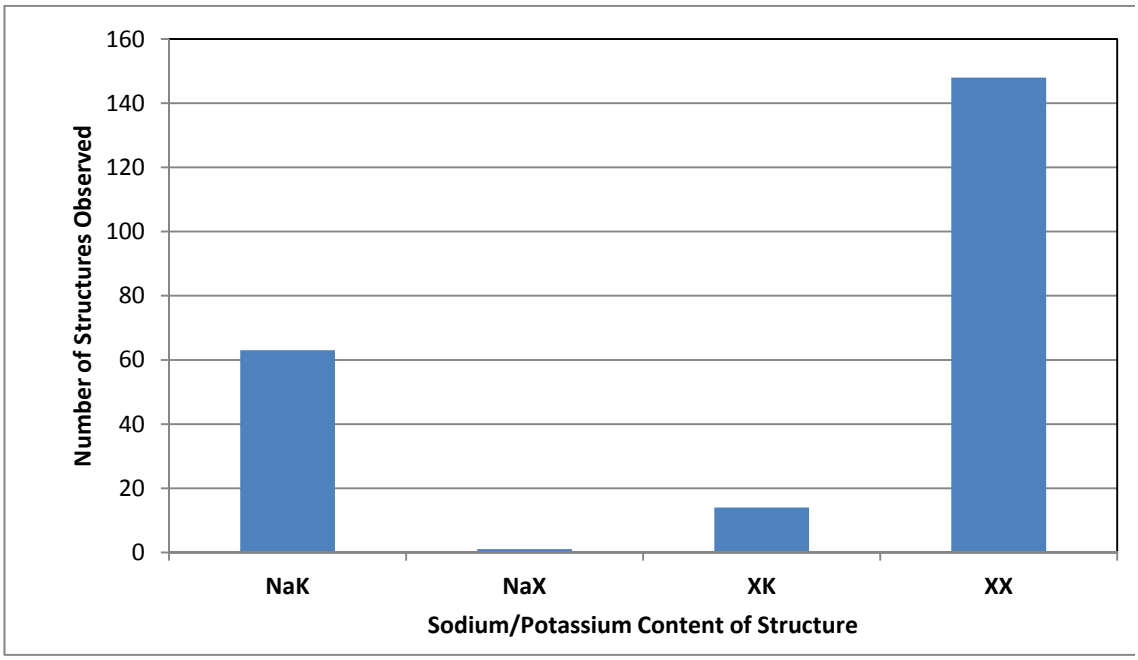
FIGURE 4-12. NaK Content of LA Structures in Borrow Source Soils

Panel A: NaK Content by Borrow Area



No. of structures	Boothman Pit	Feller Pit	Fink Pit	Noble Ranch House Pit #1
XX	9	120	12	7
XK		12	2	
NaX	1			
NaK	17	27	9	10

Panel B: NaK Content across All Borrow Areas



% = percent

LA = Libby amphibole asbestos

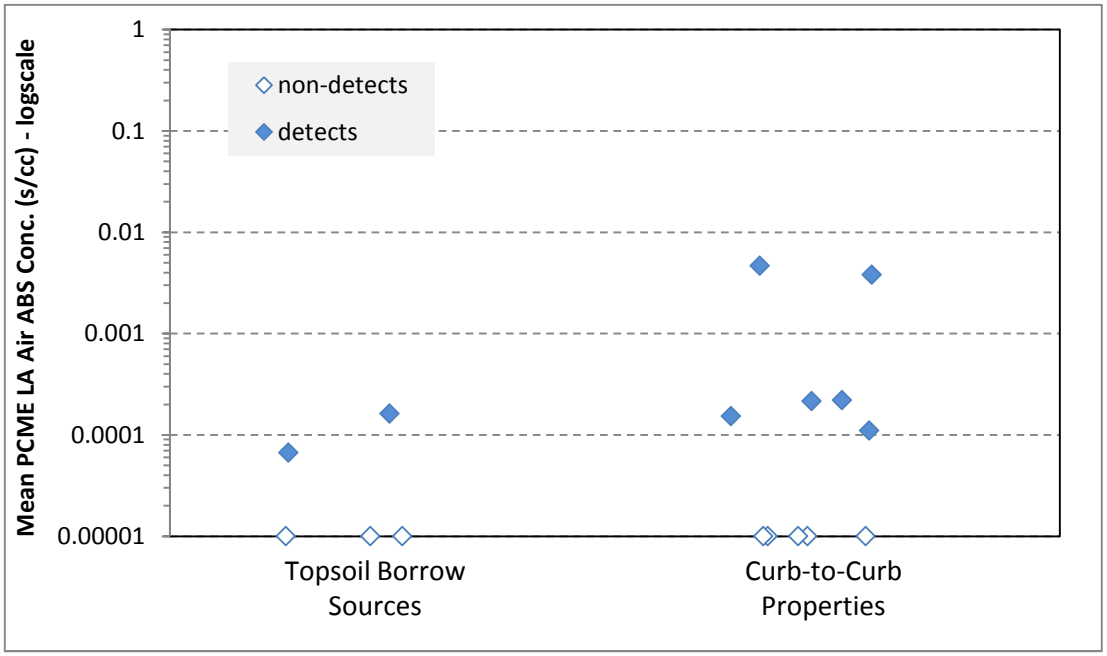
NaK = contains sodium and potassium

NaX = contains sodium

XK = contains potassium

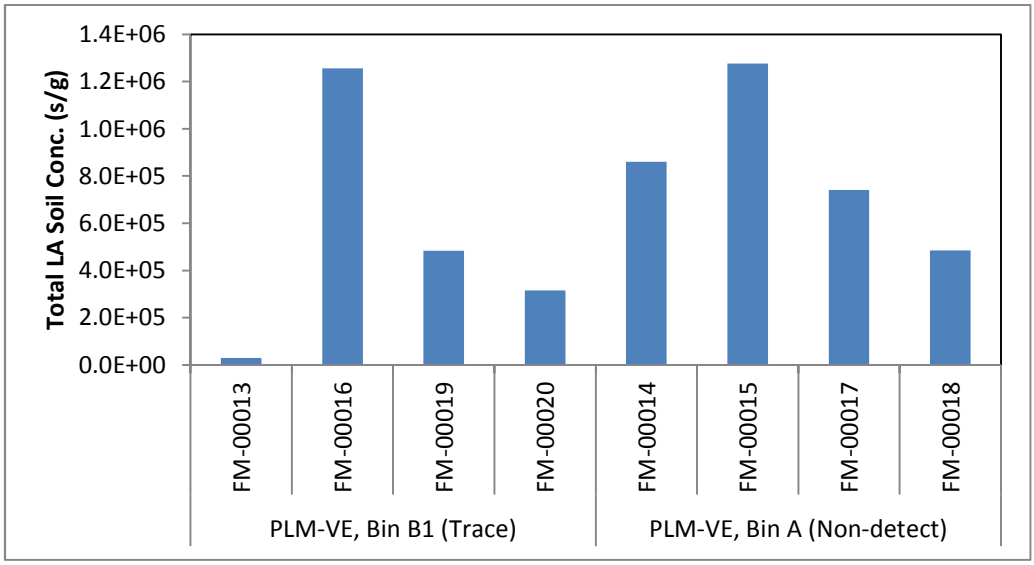
XX = contains neither sodium nor potassium

FIGURE 4-13. SCATTERPLOT OF ABS AIR CONCENTRATIONS FOR TOPSOIL BORROW SOURCES AND CURB-TO-CURB PROPERTIES



Non-detects are shown as open symbols and plotted at 0.00001 s/cc.

FIGURE 4-14. Soil Results for Samples from the Libby City Pit

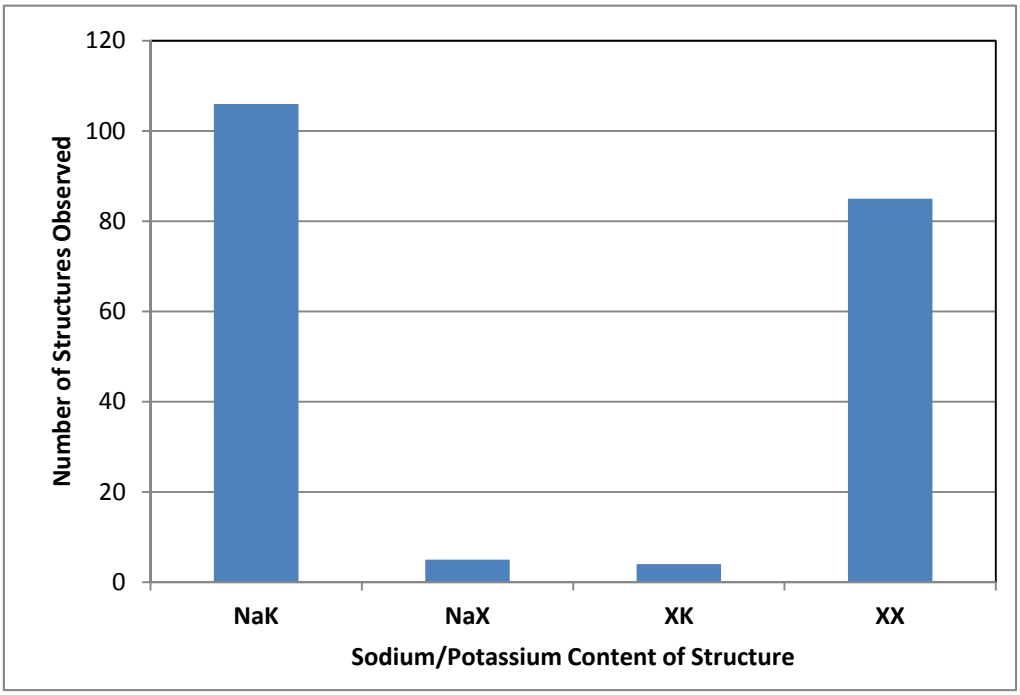


LA = Libby amphibole asbestos

PLM-VE = polarized light microscopy using visual area estimation

s/g = structures per gram

FIGURE 4-15 NaK Content of LA Structures in Libby City Pit Soil Samples



NaK = contains sodium and potassium

NaX = contains sodium

XK = contains potassium

XX = contains neither sodium nor potassium

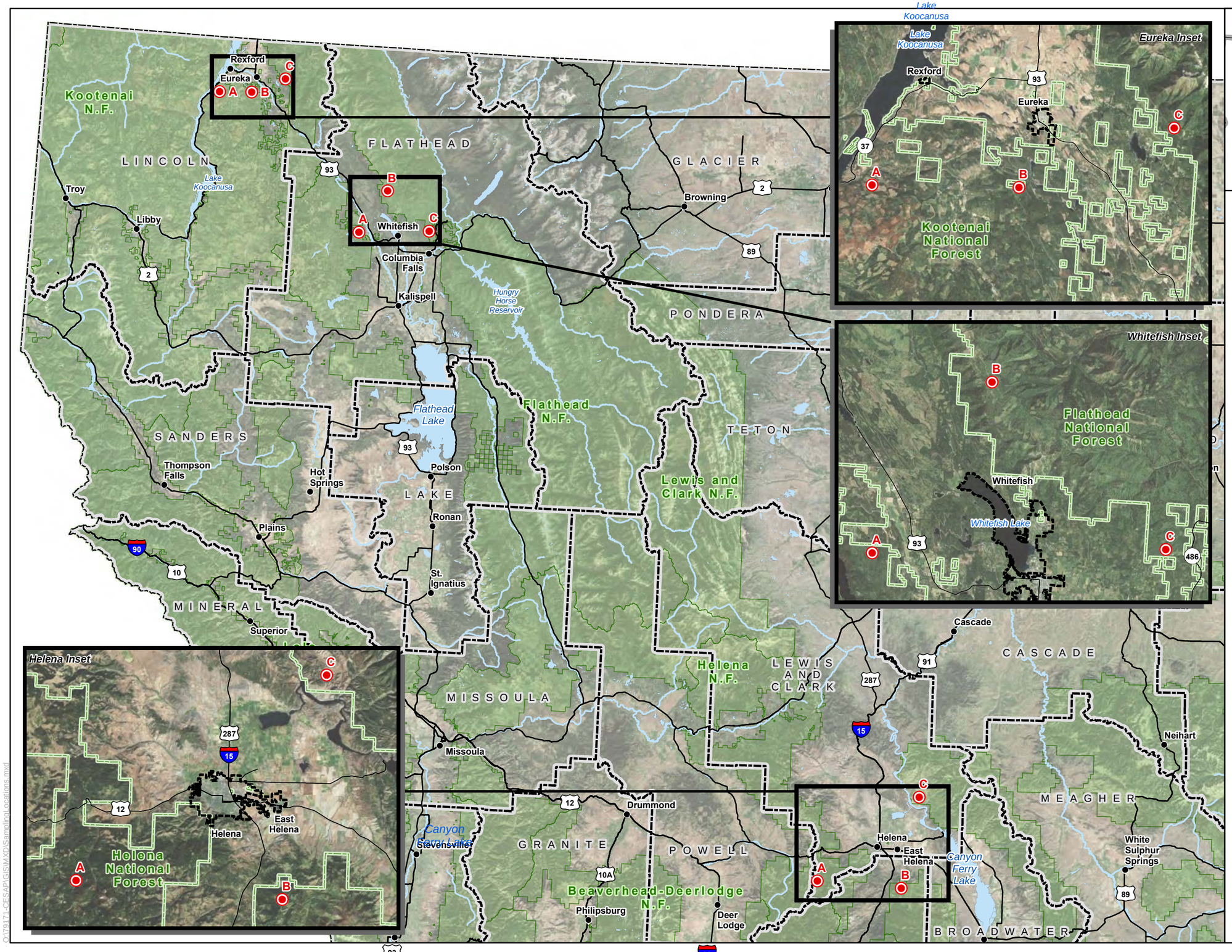


Figure 4-16: Sampling Locations for Eureka, Helena, and Whitefish

[Revision 1]

Legend

- Samping Location
- Populated Place
- Primary Road
- Waterbody
- River
- US Administrative Forest
- County Boundary

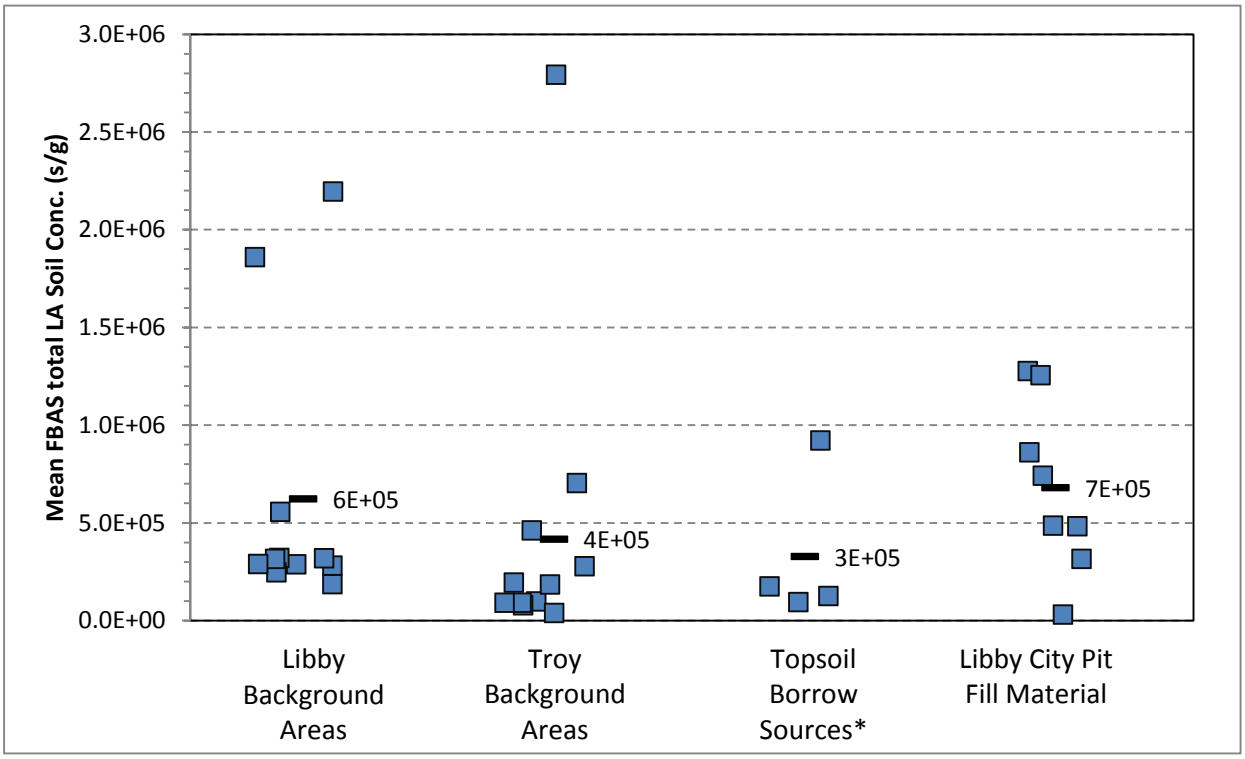
Data Sources:
Bing Maps Aerial Imagery,
US Census, USGS,
USDA, ESRI

CDM Smith

C:\79171-CESAP\GIS\MXD\SamplingLocations.mxd

FIGURE 6-1

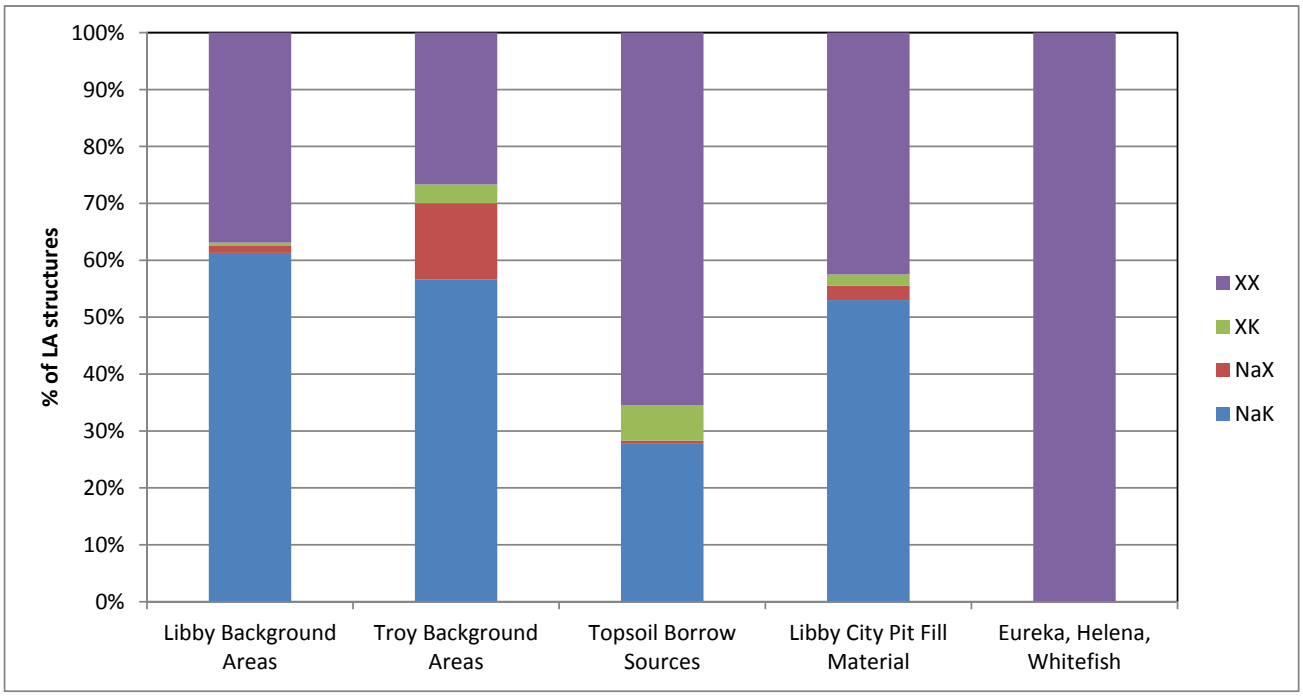
Scatterplot of Total LA Soil Concentrations in Backgound Soils



*Only includes sources within the Kootenai Valley.
Each square represents the measured concentration for each location.
The mean concentration for each soil type is shown as a horizontal bar.

FBAS = fluidized bed asbestos segregator
LA = Libby amphibole
s/g = structures per gram

FIGURE 6-2
NaK Content of Total LA Structures in Background Soil Samples



% = percent
LA = Libby amphibole
NaK = contains sodium and potassium
NaX = contains sodium
XK = contains potassium
XX = contains neither sodium nor potassium

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Background Soil Summary Report
Libby Asbestos Superfund Site, Montana

APPENDICES

Background Soil Summary Report
Libby Asbestos Superfund Site, Montana

Appendix A
Background Soil, Microsoft Access® Database (as of 1/24/2014)

[provided electronically]

Background Soil Summary Report
Libby Asbestos Superfund Site, Montana

Appendix B
2010 Libby Background Soil, Mineralogical Results Laboratory Report

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Materials Science

Attn.: Doug Kent
TechLaw, Inc.
ESAT Region 8
16194 W. 45th Drive
Golden, CO. 80403
Phone: 303-312-7725 Fax:

EMSL Case No.:	361100122
Sample(s) Received:	01/17/11
Date of Analysis:	01/26/11
Date Printed:	02/03/11
Reported By:	J.Newton

- Laboratory Report -

Project: TECHLAW
BACKGROUND PILOT STUDY
Site # 08BC

Microscopic Analysis:	*John Newton* *Senior Materials Scientist*	*Dana D'Ulisse* *Materials Analyst*	26 January 2011 *Date*
ASTM D422:	*Rebecca Taylor* *Materials Analyst*		25 January 2011 *Date*
XRD Analysis:	*Jian Hu, Ph.D.* *Senior Materials Scientist*		31 January 2011 *Date*
QA/QC :	*Eugenia Mirica, Ph.D.* *Laboratory Manager*		31 January 2011 *Date*

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Procurement of Samples and Analytical Overview:

The material arrived at EMSL Analytical's corporate laboratory in Cinnaminson, NJ on 01/17/11. The package arrived in satisfactory condition with no evidence of damage to the contents. The data reported herein has been obtained using the following equipment and methodologies.

Methods & Equipment:	
Microscopic Analysis:	*Polarized Light Microscopy (PLM) – Zeiss Universal* *Fluorescence Microscopy – Zeiss Universal* *Reflected Light Microscopy (RLM) – Nikon Optiphot 100* *Gravimetic Reduction – Sample preparation ASTM D4959* *EPA 400 Point Count (modified)*
Grain Size Analysis:	*ASTM D422, Modified* *Balance – Metler AB265-S (0.01g sensitivity)*
X-Ray Diffraction (XRD) analysis:	*X-Ray Powder Diffractometer with Cu X-ray tube - Rigaku* *JADE Plus XRD pattern processing software* *ICDD/JCPDS database*

Background:

Microscopic Analysis:

Forty samples consisting of soil were submitted for the purpose of quantifying the dominant minerals, organic content and possible "worm" detritus. The analysis was performed in three parts, gravimetric reduction, mineral identification and quantitation.

XRD analysis:

Forty samples consisting of soil were submitted for the purpose of identifying the minerals in the samples and estimating the relative percentages.

Particle Size:

Forty samples consisting of soil were submitted for the purpose of grain size following method ASTM D422.

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Summary of Microscopy Results:

The following tables summarize the data obtained during the analysis of the soil samples. Included in the summary are moisture and organic content as measured by gravimetric reduction. Mineral and "worm" content are measured by a modified 400 Point Count technique using Polarized Light Microscopy (PLM). These techniques are explained in depth in the Results and Discussion section of this report.

Table 1-1. Results for Sample BK-00002 to BK-00016

Sample ID	BK-00002	BK-00004	BK-00006	BK-00008	BK-00010	BK-00012	BK-00014	BK-00016
Description	Br Loam	Br Loam	Br Loam	Br Loam	White	White	Tan	Tan
Wt % Moisture	2.2	3.0	3.9	2.0	1.3	1.0	0.9	1.6
Wt % Organic [A]	8.2	10.5	12.6	14.9	1.9	1.7	2.3	1.6
PC %	%	%	%	%	%	%	%	%
Quartz	28.7	28.5	28.7	27.3	41.3	41.8	35.2	36.9
Albite/ Anorthite	28.3	27.1	28.7	25.8	37.4	37.9	30.8	32.2
Mica	1.8	2.9	2.0	1.7	4.9	5.1	1.7	1.7
Calcite	0.9	<LOQ	<LOQ	<LOQ	1.0	<LOQ	<LOQ	<LOQ
Granular [B]	27.8	30.1	27.4	29.3	11.7	11.2	22.0	22.9
Amphibole [C]	0.9	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	1.0	<LOQ
Worm Particles [D]	2.1	1.8	2.0	1.7	1.9	2.2	4.4	4.7
Unidentified [E]	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*

A. Predominantly composed of plant fiber including root structure, wood fragments and tricomes. May also include insect fragments or other organic detritus.

B. Fine mineral grains that are not identifiable due to particle size and/or agglomeration. Category includes clays, fine mica fragments or other crystalline particles less than three microns (<3µ).

C. Minerals with a refractive index greater than 1.56, ≥5:1 aspect ratio and/or present as a cleavage fragment. No acicular, fibrous or fiber bundles were detected. Further analysis may be necessary to confirm the identification.

D. Isotropic, clear, amorphous, cellular structures consistent with figure 12.

E. Particles that may not be classified as mineral or organic in origin by this method. Category includes fine amorphous agglomerates and opaque materials.

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Table 1-2: Results for Sample BK-00018 to BK-00032

Sample ID	BK-00018	BK-00020	BK-00022	BK-00024	BK-00026	BK-00028	BK-00030	BK-00032
Description	Tan	Tan	White	Lt.Tan	Lt.Tan	Lt.Tan	Tan	Tan
% Moisture	0.9	1.1	0.8	0.3	0.3	0.9	0.6	0.6
% Organic [A]	4.1	1.3	1.8	0.5	0.5	2.6	2.3	3.8
	%	%	%	%	%	%	%	%
Quartz	37.9	41.2	47.9	37.3	36.7	38.2	32.7	30.7
Albite/ Anorthite	33.4	30.9	35.9	32.6	32.3	28.7	28.8	26.3
Mica	2.9	3.2	2.5	1.7	1.7	1.0	6.6	7.0
Calcite	<LOQ	1.0	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Granular [B]	19.0	20.5	9.6	23.1	23.1	28.7	28.8	30.7
Amphibole [C]	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Worm Particles [D]	1.9	1.0	0.0	4.7	1.0	<LOQ	<LOQ	<LOQ
Unidentified [E]	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*

Table 1-3: Results for Sample BK-00034 to BK-00048

Sample ID	BK-00034	BK-00036	BK-00038	BK-00040	BK-00042	BK-00044	BK-00046	BK-00048
Description	Tan	Tan	Lt.Tan	Lt.Tan	Br Loam	Br Loam	Tan	Tan
% Moisture	1.0	0.9	0.2	0.3	2.4	2.4	0.9	0.5
% Organic [A]	2.1	3.2	1.4	0.6	8.1	9.2	4.5	2.0
	%	%	%	%	%	%	%	%
Quartz	30.8	33.0	33.1	43.3	42.1	49.5	36.9	40.8
Albite/ Anorthite	26.4	28.2	28.4	32.4	20.1	24.7	31.6	22.7
Mica	7.1	4.6	6.7	10.7	2.1	2.5	2.2	3.7
Calcite	1.0	<LOQ	<LOQ	<LOQ	<LOQ	1.1	<LOQ	<LOQ
Granular [B]	30.8	28.2	28.4	10.7	25.2	12.4	21.1	27.1
Amphibole [C]	1.0	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Worm Particles [D]	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.2	3.1	2.7
Unidentified [E]	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*

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Table 1-4: Results for Sample BK-00050 to BK-00064

Sample ID	BK-00050	BK-00051	BK-00054	BK-00056	BK-00058	BK-00060	BK-00062	BK-00064
Description	Br Loam	Br Loam	Tan	Lt.Tan	Lt.Tan	Lt.Tan	Lt.Tan	Lt.Tan
% Moisture	4.3	8.4	0.3	0.1	0.5	1.0	1.3	0.6
% Organic [A]	6.5	6.7	2.3	1.9	1.9	2.0	1.3	0.5
	%	%	%	%	%	%	%	%
Quartz	30.4	31.6	40.3	36.3	38.9	42.0	39.2	45.7
Albite/ Anorthite	15.1	13.9	15.1	25.9	27.9	28.0	33.3	25.8
Mica	<LOQ	<LOQ	<LOQ	2.0	<LOQ	5.9	5.9	6.0
Calcite	<LOQ	0.9	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Granular [B]	45.4	44.3	40.3	31.1	27.9	17.4	15.5	16.4
Amphibole [C]	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Worm Particles [D]	<LOQ	<LOQ	2.0	2.0	2.2	3.4	3.5	3.7
Unidentified [E]	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*

Table 1-5: Results for Sample BK-00066 to BK-00080

Sample ID	BK-00066	BK-00068	BK-00070	BK-00072	BK-00074	BK-00076	BK-00078	BK-00080
Description	Tan	Tan	Lt.Tan	Lt.Tan	Tan	Lt.Tan	Lt.Tan	White
% Moisture	0.7	0.6	0.6	0.7	1.9	2.4	0.7	1.0
% Organic [A]	1.6	1.9	1.2	1.7	2.5	1.9	0.9	1.1
	%	%	%	%	%	%	%	%
Quartz	36.8	42.7	48.6	43.0	44.4	40.9	40.6	39.6
Albite/ Anorthite	28.7	26.5	22.6	21.6	19.8	24.0	21.8	25.2
Mica	2.0	2.2	2.5	4.2	1.0	2.0	2.0	1.7
Calcite	1.0	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	1.0
Granular [B]	29.0	26.3	21.4	26.5	29.5	28.9	31.7	29.7
Amphibole [C]	<LOQ	<LOQ	<LOQ	<LOQ	1.0	<LOQ	<LOQ	<LOQ
Worm Particles [D]	<LOQ	<LOQ	2.5	1.0	2.0	1.5	2.0	1.7
Unidentified [E]	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*

Br- brown, Lt- Light, Loam- containing visible organic material

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Table 1-6: Results of QC Samples

Sample ID Description	BK-00016 Original	BK-00016 QC	BK-00030 Original	BK-00030 QC	BK-00054 Original	BK-00054 QC	BK-00078 Original	BK-00078 QC
% Moisture	1.6	N/A	0.6	N/A	0.3	N/A	0.7	N/A
% Organic [A]	1.6	N/A	2.3	N/A	2.3	N/A	0.9	N/A
	%		%		%		%	
Quartz	36.9	38.9	32.7	40.6	40.3	44.8	40.6	41.9
Albite/ Anorthite	32.2	32.0	28.8	31.8	15.1	33.8	21.8	31.0
Mica	1.7	2.5	6.6	2.4	<LOQ	1.2	2.0	3.5
Calcite	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Granular [B]	22.9	19.7	28.8	20.5	40.3	13.7	31.7	18.3
Amphibole [C]	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Worm Particles [D]	4.7	3.0	<LOQ	0.7	2.0	3.2	2.0	3.2
Unidentified [E]	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*	*Remainder*

Mica, due to its soft, brittle nature, tends to break into fine particles that will naturally result in slightly wider ranges. Mica easily breaks down to particles straddling the resolvable limit of the PLM.

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Summary of XRD Analysis Results:

XRD analysis was carried out on sub-samples selected using a riffle-splitter. Sub-samples were pulverized at liquid nitrogen temperature using a SPEX CertiPrep Freezer Mill to prepare homogenized fine particles, before packed onto standard XRD powder sample holders for analysis. ICDD/JCPDS database was used to match minerals with the diffraction peaks. The relative percentages of the minerals were estimated based on the intensities of their strongest peaks, after taking into consideration the published Reference Intensity Ratio values for related minerals. The results were adjusted for moisture and organics concentration and normalized. The Reference Intensity Ratio values used for estimating the mineral percentages are 3.60 for Quartz, 0.36 for Mica, 1.06 for Albeit/Anorthite, 0.95 for Kaolinite, 2.0 for Calcite, and 0.76 for Vermiculite. Due to substantial variation in the published Reference Intensity Ratio values and the uncertainty with the composition and identification of the minerals in the samples, the estimated percentages may not be accurate and should only be considered qualitative. In addition, the percentages of the crystalline minerals may be greatly overestimated if there is a significant amount of amorphous minerals present in the samples.

The results are listed in Tables 2-1 to 2-6.

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Table 2-1. XRD results for samples BK-00002 to BK-00016

Sample ID	BK-00002	BK-00004	BK-00006	BK-00008	BK-00010	BK-00012	BK-00014	BK-00016
Wt %	%	%	%	%	%	%	%	%
Quartz	32.5	34.5	35.2	35.2	26.3	27.8	36.0	39.4
Mica [a]	24.5	20.6	21.6	22.0	49.2	49.5	32.9	31.4
Albite/ Anorthite [b]	20.3	24.8	22.1	21.7	17.6	16.6	26.4	23.6
Kaolinite [c]	4.0	3.0	4.0	2.9	3.1	3.4	Trace	Trace
Amphiboles [d]	Trace	Trace	Trace	Trace	ND	ND	ND	Trace
Vermiculite [e]	7.2	3.2	ND	Trace	Trace	ND	ND	ND
Calcite	ND	ND	ND	ND	ND	ND	ND	ND

Notes:

a. The identification of Mica is mainly based on a diffraction peak at about 8.853 degree 2θ. This identification could not be confirmed by the method used in this analysis due to considerable variation in the composition of Mica and overlapping peak positions among the minerals.

b. Current analysis can not distinguish Albite from Anorthite or any members in Plagioclase Feldspar group.

c. The identification of Kaolinite is mainly based on a diffraction peak at about 12.457 degree 2θ. This identification could not be confirmed by the method used in this analysis due to considerable variation in the composition of Kaolinite and overlapping peak positions among the minerals.

d. The identification of Amphiboles is mainly based on a diffraction peak at about 10.548 degree 2θ. This identification could not be confirmed by the method used in this analysis due to considerable variation in the composition of Amphiboles and overlapping peak positions among the minerals.

e. The identification of Vermiculite is mainly based on a diffraction peak at about 6.157 degree 2θ. This identification could not be confirmed by the method used in this analysis due to considerable variation in the composition of Vermiculate and overlapping peak positions among the minerals.

Mineral percentages are reported as “Trace” if the mineral is detected but the estimated percentage is less than 2%.

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Table 2-2. XRD results for samples BK-00018 to BK-00032

Sample ID	BK-00018	BK-00020	BK-00022	BK-00024	BK-00026	BK-00028	BK-00030	BK-00032
Wt %	%	%	%	%	%	%	%	%
Quartz	37.7	35.8	40.7	27.6	26.7	44.4	39.6	42.2
Mica [a]	26.3	37.7	31.0	51.5	50.1	33.2	20.2	23.1
Albite/ Anorthite [b]	29.9	21.6	24.6	17.9	18.1	16.4	27.1	22.7
Kaolinite [C]	Trace	2.6	Trace	2.2	2.8	Trace	3.3	2.1
Amphiboles [d]	ND	ND	ND	Trace	Trace	Trace	Trace	Trace
Vermiculite [e]	ND	ND	ND	ND	Trace	ND	6.1	4.9
Calcite	ND	ND	ND	ND	Trace	ND	ND	ND

Table 2-3. XRD results for samples BK-00034 to BK-00048

Sample ID	BK-00034	BK-00036	BK-00038	BK-00040	BK-00042	BK-00044	BK-00046	BK-00048
Wt %	%	%	%	%	%	%	%	%
Quartz	36.2	33.8	52.5	59.6	48.0	45.3	49.2	48.4
Mica [a]	29.4	32.2	22.3	15.2	16.7	18.5	17.6	17.5
Albite/ Anorthite [b]	28.8	27.7	22.3	23.4	22.4	22.6	26.6	29.7
Kaolinite [C]	2.5	Trace	Trace	Trace	Trace	2.0	Trace	Trace
Amphiboles [d]	ND	Trace	Trace	Trace	Trace	ND	ND	Trace
Vermiculite [e]	ND	ND	ND	ND	ND	ND	ND	ND
Calcite	ND	ND	ND	ND	ND	ND	ND	ND

Table 2-4. XRD results for samples BK-00050 to BK-00064

Sample ID	BK-00050	BK-00051	BK-00054	BK-00056	BK-00058	BK-00060	BK-00062	BK-00064
Wt %	%	%	%	%	%	%	%	%
Quartz	22.4	25.8	48.4	48.1	44.0	45.1	41.5	37.5
Mica [a]	26.3	23.6	23.8	21.7	28.2	24.3	27.7	32.9
Albite/ Anorthite [b]	34.2	32.2	23.0	26.7	20.8	24.2	24.5	23.2
Kaolinite [C]	3.9	3.3	2.2	Trace	2.3	Trace	2.6	2.8
Amphiboles [d]	Trace	ND	ND	ND	Trace	Trace	Trace	Trace
Vermiculite [e]	Trace	ND	ND	ND	Trace	Trace	Trace	Trace
Calcite	ND	ND	ND	ND	ND	ND	ND	ND

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Table 2-5. XRD results for samples BK-00066 to BK-00080

Sample ID	BK-00066	BK-00068	BK-00070	BK-00072	BK-00074	BK-00076	BK-00078	BK-00080
Wt %	%	%	%	%	%	%	%	%
Quartz	26.2	30.2	42.1	36.5	32.6	29.6	38.3	35.3
Mica [a]	16.3	27.1	30.3	34.9	36.2	42.4	35.8	33.9
Albite/ Anorthite [b]	53.5	38.4	20.7	22.8	21.8	18.4	19.9	24.8
Kaolinite [C]	Trace	ND	2.5	2.0	3.2	3.1	2.5	2.2
Amphiboles [d]	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Vermiculite [e]	ND	ND	Trace	Trace	Trace	Trace	Trace	Trace
Calcite	ND	ND	ND	ND	ND	ND	ND	ND

Table 2-6. XRD results for QC samples

Sample ID	QC BK-00016	QC BK-00030	QC BK-00054	QC BK-00078
Wt %	%	%	%	%
Quartz	38.0	36.8	51.3	36.0
Mica [a]	29.9	22.2	19.1	36.5
Albite/ Anorthite [b]	26.3	29.6	25.3	20.4
Kaolinite [C]	Trace	2.9	Trace	3.3
Amphiboles [d]	Trace	Trace	Trace	Trace
Vermiculite [e]	Trace	5.1	ND	Trace
Calcite	ND	ND	ND	ND

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Summary of ASTM D422 Results:

The following tables summarize the data obtained during the analysis of the soil samples by ASTM D422.

Sample ID Location	**BK-00002**	**BK-00004**	**BK-00006**	**BK-00008**
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	6.39	4.16	1.32	8.53
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	18.22	11.34	9.98	22.95
Medium Sand (425 µm – 2.00 mm)	19.79	22.19	19.75	21.81
Fine Sand (75 µm – 425 µm)	29.09	33.64	27.22	28.74
Silt & Clay				
< 75 µm	26.52	28.66	41.73	17.98

Silt & Clay includes all particles less than seventy-five microns (<75µm). Separation of silt from clay requires hydrometry (*ASTM D422, Section 7*), a technique that was not performed on these samples.

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Sample ID Location	BK-00010	BK-00012	BK-00014	BK-00016
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	17.40	19.45	0.47	0.64
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	26.85	31.61	2.67	4.30
Medium Sand (425 µm – 2.00 mm)	24.49	21.91	18.02	27.93
Fine Sand (75 µm – 425 µm)	11.07	8.13	39.31	37.68
Silt & Clay				
< 75 µm	20.19	18.89	39.53	29.44

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Sample ID Location	BK-00018	BK-00020	BK-00022	BK-00024
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	0.73	0.21	0.75	0.00
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	4.87	4.36	4.53	1.89
Medium Sand (425 µm – 2.00 mm)	22.31	24.08	17.75	15.02
Fine Sand (75 µm – 425 µm)	30.14	29.27	24.99	26.68
Silt & Clay				
< 75 µm	41.95	42.08	51.98	56.41

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Sample ID Location	BK-00026	BK-00028	BK-00030	BK-00032
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	1.18	1.47	0.00	0.00
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	14.75	9.98	2.27	1.78
Medium Sand (425 µm – 2.00 mm)	22.41	21.49	9.69	14.86
Fine Sand (75 µm – 425 µm)	25.27	28.29	44.22	43.71
Silt & Clay				
< 75 µm	36.38	38.77	43.82	39.65

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Sample ID Location	BK-00034	BK-00036	BK-00038	BK-00040
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	1.71	0.57	0.00	0.23
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	7.35	3.82	0.49	0.51
Medium Sand (425 µm – 2.00 mm)	15.82	15.30	3.78	3.89
Fine Sand (75 µm – 425 µm)	25.36	26.54	54.43	56.72
Silt & Clay				
< 75 µm	49.75	53.76	41.30	38.65

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Sample ID Location	BK-00042	BK-00044	BK-00046	BK-00048
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	1.86	0.60	0.36	0.77
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	9.34	9.37	2.05	3.25
Medium Sand (425 µm – 2.00 mm)	25.10	25.99	15.92	16.20
Fine Sand (75 µm – 425 µm)	46.26	24.20	27.99	28.68
Silt & Clay				
< 75 µm	17.43	39.83	53.69	51.10

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Sample ID Location	BK-00050	BK-00051	BK-00054	BK-00056
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	5.79	12.71	0.31	0.21
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	25.15	35.97	3.12	3.08
Medium Sand (425 µm – 2.00 mm)	36.96	32.62	13.87	15.60
Fine Sand (75 µm – 425 µm)	17.78	12.01	25.15	26.40
Silt & Clay				
< 75 µm	14.32	6.69	57.54	54.70

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Sample ID Location	BK-00058	BK-00060	BK-00062	BK-00064
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	0.10	0.00	0.00	0.00
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	1.97	1.58	2.53	3.08
Medium Sand (425 µm – 2.00 mm)	10.20	9.35	11.92	13.99
Fine Sand (75 µm – 425 µm)	24.72	25.75	23.83	22.76
Silt & Clay				
< 75 µm	63.01	63.32	61.73	60.18

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Sample ID Location	BK-00066	BK-00068	BK-00070	BK-00072
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	0.00	0.06	0.80	1.57
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	0.68	1.83	10.07	14.23
Medium Sand (425 µm – 2.00 mm)	6.07	5.90	27.10	29.95
Fine Sand (75 µm – 425 µm)	22.00	22.76	21.32	21.86
Silt & Clay				
< 75 µm	71.25	69.45	40.71	32.40

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Sample ID Location	BK-00074	BK-00076	BK-00078	BK-00080
Particle size range	**Wt %**	**Wt %**	**Wt %**	**Wt %**
Gravel				
> 1”	0.00	0.00	0.00	0.00
3/4” – 1”	0.00	0.00	0.00	0.00
3/8” – 3/4”	0.00	0.00	0.00	0.00
4.75 mm - 3/8”	0.17	0.19	0.21	0.52
Sand				
Coarse Sand (2.00 mm – 4.75 mm)	5.53	3.05	5.30	5.03
Medium Sand (425 µm – 2.00 mm)	20.70	8.45	23.52	28.62
Fine Sand (75 µm – 425 µm)	20.65	35.40	23.69	23.84
Silt & Clay				
< 75 µm	52.96	52.92	47.27	41.99

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Results and Discussion for Microscopic Analysis:

Sample Preparation:

The samples were received in a uniform state with a grain size less than 0.5mm and no large organic material. Sample preparation was limited to hand mixing for uniformity prior to collecting sub-samples by the cone and quarter method. Sub-samples were collected for gravimetric reduction, stereomicroscopy, Polarized Light Microscopy (PLM) and X-Ray Diffraction Spectrometry (XRD). Gravimetric reduction and stereomicroscopy did not require additional preparation. PLM samples were analyzed both as received and after hand grinding to <90 micron grain size. XRD was performed on <45 micron sieve fractions. XRD was only performed during this phase of analysis on specific samples to verify the identification achieved during microscopic analysis.

Gravimetric Reduction:

The samples were homogenized by hand mixing and a weighted sub-sample was subjected to 105°C in a convection oven. The samples were monitored until no further weight loss was evident. The difference between the Initial Weight and the Dry Weight of the soil is calculated as the Percent Moisture. *See ASTM D2974, Test Method A*

The dried samples were subjected to 550°C in a muffle furnace to measure the loss of organic material. The samples were monitored until no further weight loss was evident. The difference between the Dry Weight and the Ash Weight of the soil is calculated as the Percent Organic Content. *Modified ASTM D2974, Test Method C (Modifications 550°C and porcelain covered crucibles used)*

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Mineral Identification:

Identification of the minerals present in the sample was performed by PLM. The samples were found to be a mixture of quartz, feldspar and mica with trace amounts of calcite and amphiboles. The feldspar group was found to be consistent with Albite and Anorthite. For the purposes of this report these two minerals are recorded as total Albite/Anorthite. The mica group was found to be consistent with Muscovite and Phlogopite. For the purposes of this report these two minerals are recorded as total Mica. X-Ray Diffraction Spectrometry (XRD) was used to confirm the identification. Amphiboles were noted in trace amounts in limited samples. Further identification was not performed. The identification of the individual minerals was based upon the following criteria: suspected amphiboles were not identified. Identification of the suspected "worm" particles was performed by morphology and isotropic nature.

	Quartz	Albite	Muscovite	Phlogopite	Clinochlore	Calcite
Habit	Conchoidal Fracture Bladed edges	Blocky, striated, granular, tabular	Lamellar	Lamellar	Massive, granular	Blocky
Cleavage	---	Perfect	Perfect	Perfect	Perfect	Perfect
Fracture	Conchoidal	Good	Brittle, sectile	Uneven	Uneven	Perfect
n	1.54 *w* 1.544 *ϵ* 1.553	1.53 α 1.527 *y* 1.538	1.60 α 156-1.572 *y* 1.599-1.615	1.56-1.64 α 1.53-1.59 *y* 1.56-1.64	1.54 α 1.57-1.588 *y* 1.576-599	1.66 *w* 1.64-1.66 *ϵ* 1.486
2V	---	76-82 (45)	30-47	0-15	0-36	---
Luster	Vitreous	Vitreous	Vitreous	Vitreous-pearly	Vitreous	Vitreous
Color	Clear	W,Gy,Gr	W,Gy,Br	Br,Gy,Y,R-Br	Bk,Bl,dk.Gr,Gy	Cl,W,Y
Luminescence	---	SW= R/Bl LW= Wh		SW= lt.Y LW= lt.Bl-W		SW= Y,Bl,Gr LW= Y,Bl,Gr

Table 7: Parameters for mineral identification during the quantitative process.

W-white, Gy-gray, Gr-green, Br-brown, Y-yellow, R-red, Bl-blue, lt.-light

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Quantitation (explanation of method modification):

Quantitation of the minerals and "worm" fragments was performed by a modified 400-Point Count technique. The basis of the technique is to identify and count 400 non-empty points throughout a microscope slide preparation. The term "non-empty" refers to a superimposed point on a reticule that intersects with a particle grain. Any point that does not fall on a particle grain, i.e. empty space, is not counted. The percent of each mineral type is calculated from the total of all the non-empty points yielding a percent concentration. The single modification to the standard method is the use of a cross-hair reticule instead of the 25 point count reticule. The modification was necessary due to the type and concentration of minerals present in the sample.

The 25-Point Count reticule, often known as a Chalkley Point reticule, was developed to speed the quantitative process while ensuring randomized point placement. A single point reticule will require a minimum of 400 fields of view to perform quantitation. The use of the Chalkley Point reticule can reduce the total fields of view required to as low as 16, assuming all points fall on a grain, thus greatly reducing the time required during analysis. Unfortunately the samples submitted for analysis contain minerals that require more extensive analysis than separating asbestos fibers from non-fibrous material. The outcome is that each mineral grain must be relocated to the center of the field in order to acquire the characteristics necessary for identification. This results in displacement of the 24 other points. Once identification is complete, relocating the grain to its original point while reorienting the remaining 24 displaced points is not possible without extensive imaging to ensure reorientation of all grains under all points.

Randomization is an issue when analysts move to a new field while observing the sample. It is human nature to orient the eyes onto shapes and colors during motion. This phenomenon can result in an unconscious reaction to stop the motion of the slide causing a bright or unusually shaped grain to orient onto a point where it is counted. The issue of randomization is nullified by simply removing the analyst's eyes from the microscope during reorientation of the slide to the next field. Once the slide has been moved to a new field of view the analysts can then observe the random grain. Randomization is also enhanced by using multiple preparations and acquiring the fields from a non-linear slide motion ensuring points are observed over the entire microscope slide preparation instead of along a single axis.

Due to the extensive analysis required to achieve identification of the grains it was necessary to use the single point system regardless of the additional time required to achieve the 400 point requirements. No other modifications to the method were employed.

- Appendix 1 -

Examples of Grain Identification During PLM Analysis

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Examples of Quartz grains during analysis.

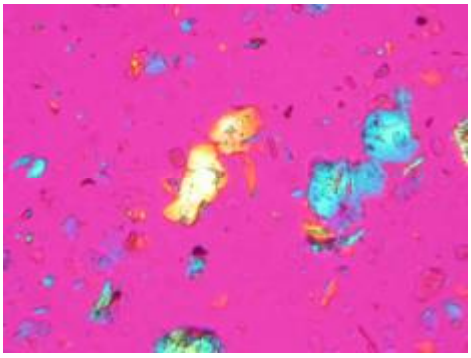

Fig. 1: Quartz by PLM (XP530) showing the sign of elongation and morphology.

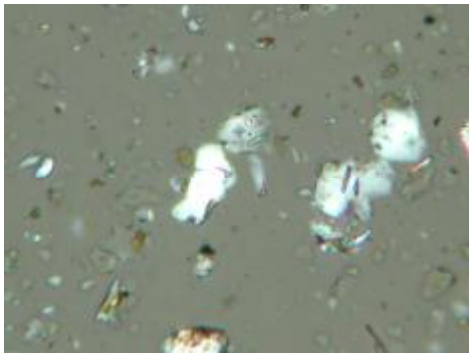

Fig. 2: Quartz by PLM (SXPL) showing Pleochroism and morphology.

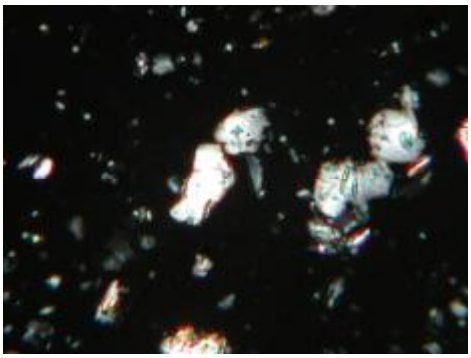

Fig. 3: Quartz (XPL) showing the general birefringence.

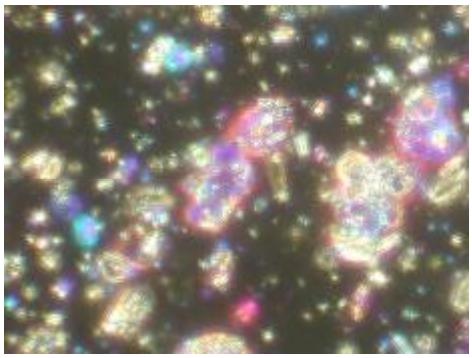

Fig. 4: Quartz (DS) showing the dispersion staining color in 1.540 RI liquid.

XP530: Cross Polarized light with a first order red (530nm) filter
SXPL: Slightly uncrossed polarized light
XPL: Cross Polarized light
DS: Dispersion Staining

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Examples of Albite/Anorthite grains during analysis.

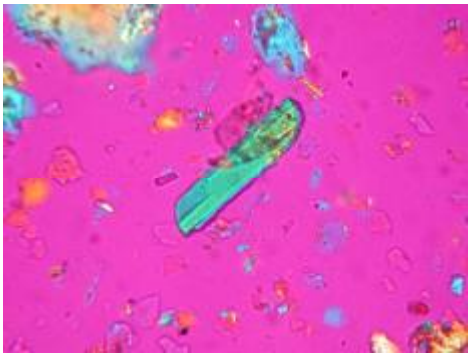

Fig. 5: Albite by PLM (XP530) showing the sign of elongation and morphology.

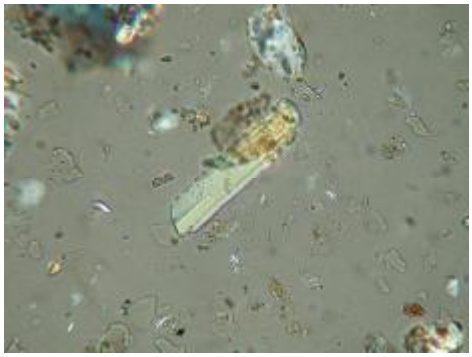

Fig. 6:Albite by PLM (SXPL) showing Pleochroism and morphology.

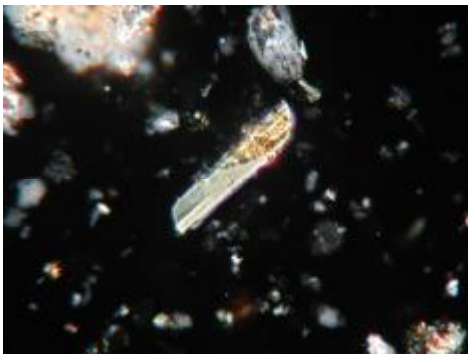

Fig. 7: Albite (XPL) showing the general birefringence.

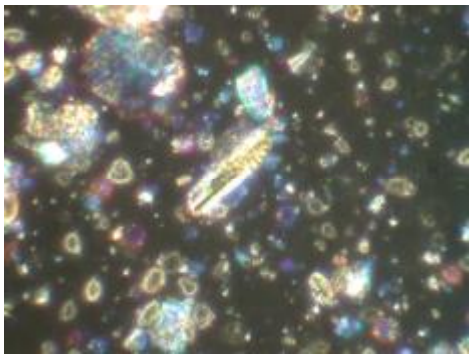

Fig. 8: Albite (DS) showing the dispersion staining color in 1.540 RI liquid.

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Examples of Mica grains during analysis.

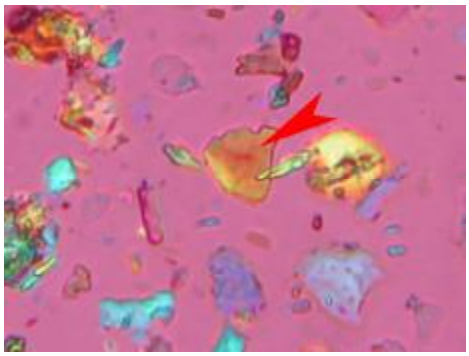

Fig. 9: Quartz by PLM (XP530) showing the sign of elongation and morphology.

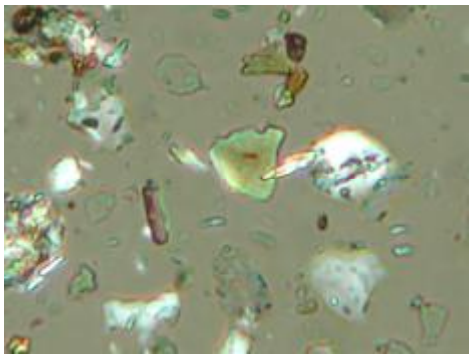

Fig. 10: Quartz by PLM (SXPL) showing Pleochroism and morphology.

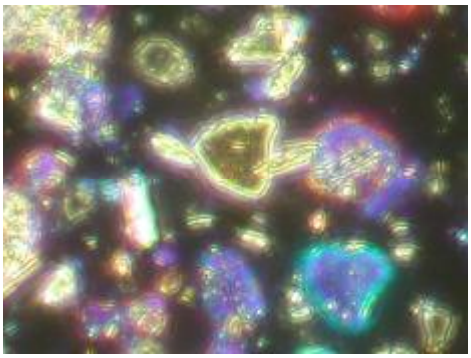

Fig. 11: Quartz (DS) showing the dispersion staining color in 1.540 RI liquid.

Examples of “worm” fragments during analysis.

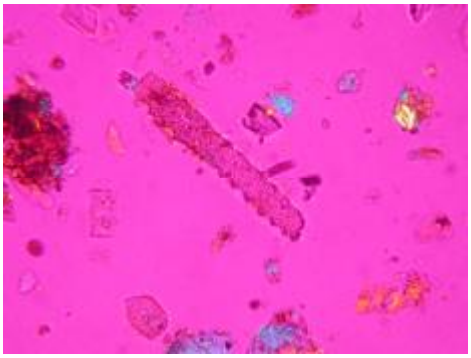

Fig. 12: PLM (XP530) “Worm” parts

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- Appendix 2 -

Examples of Sample Grains During PLM Analysis

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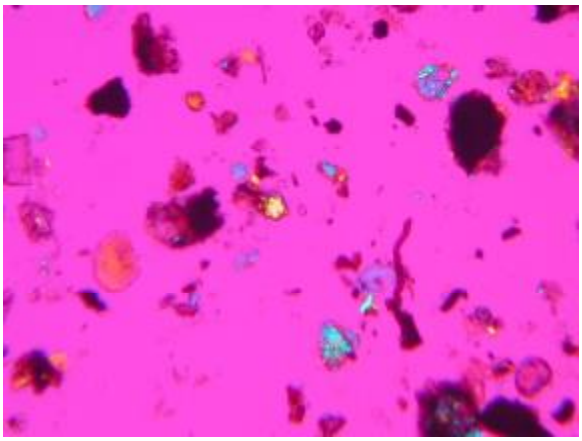

Fig. 13: Image of sample BK-00002 (XP530) showing a combination of quartz, albite, mica, organic debris and non-uniform mineral/organic conglomerates.

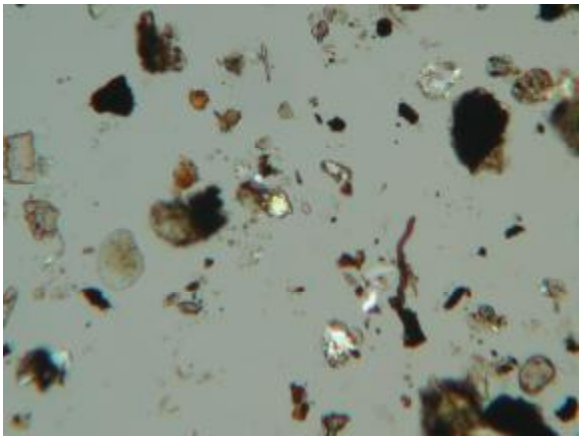

Fig. 14: Image of sample BK-00002 (SXPL) showing the color of the minerals.

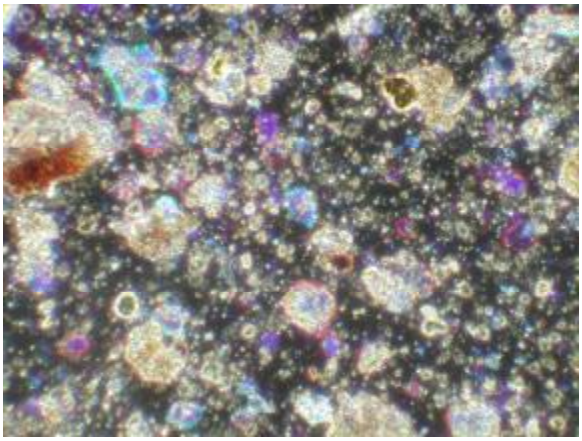

Fig. 15: Image of sample BK-00002 (DS) showing the dispersion staining of the quartz and albite grains in 1.540 RI liquid.

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- Appendix 3 -

Mineral Identification Flow-Chart Used During Quantitative Analysis

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TECHLAW
361100122
PLM MINERAL ID FLOWCHART

1/20/11

RI (1.54)

<1.54

ALBITE

TABULAR
BLOCKY
* STRIATED
* 2V-76-82°
VITREOUS
* SW R/BL
* LW WH

@ 1.54

QUARTZ

* CONCHOIDAL
* RUTILATED

CLINOCHLORE

* MASSIVE
* GRANULAR
CL - PERFECT
F - UNEVEN
VITREOUS
DARK BLACK
BL
GR
GY

>1.54

MUSCOVITE

LAMELLAR
CL - PERFECT
* F - BRITTLE SCALE
VITREOUS
W, GY, BR
* 2V - 30-47°

PHLOGOPITE

LAMELLAR
CL - PERFECT
* F - UNEVEN
* 2V 0-15°
VITREOUS
* SW = LT YELLOW
* LW = LT. BL
* H = 2-2.5

OTHER →

CALCITE

BLOCKY
UNIAXIAL COLOR
CL - PERFECT
F - GOOD
TWINNING COMMON

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- Appendix 4 -

XRD Spectra

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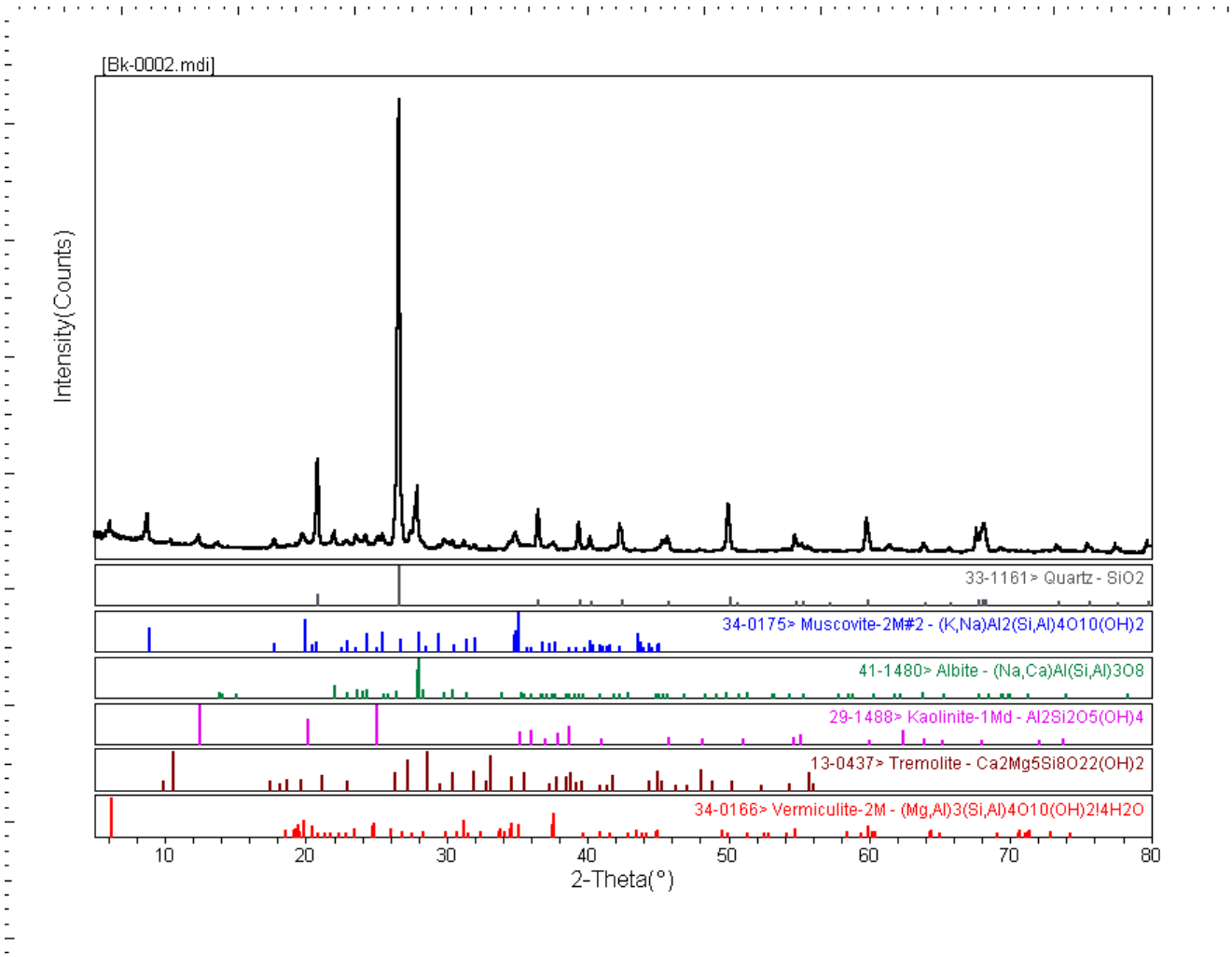

Fig. 16: XRD spectrum of sample BK-00002.

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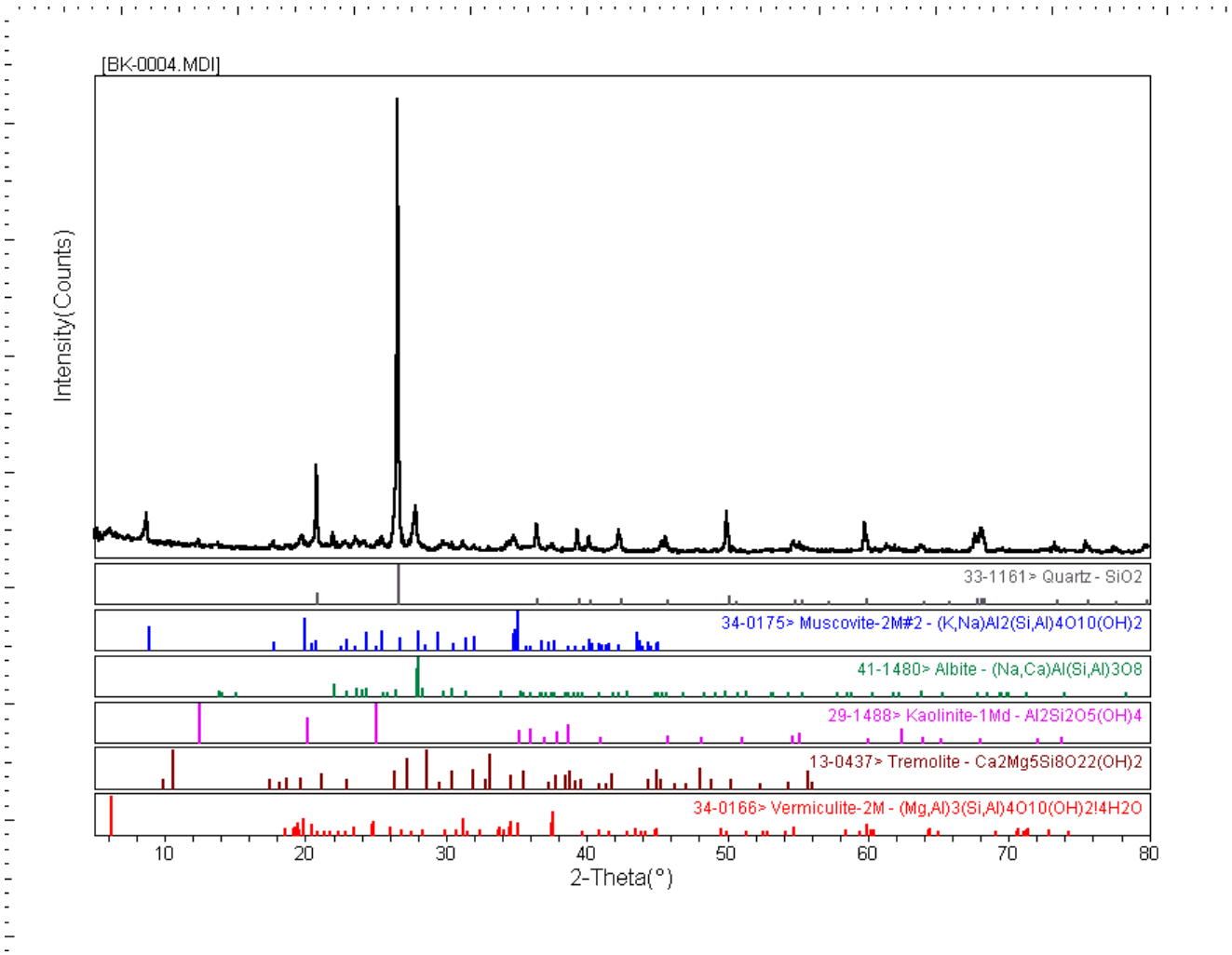

Fig. 17: XRD spectrum of sample BK-00004.

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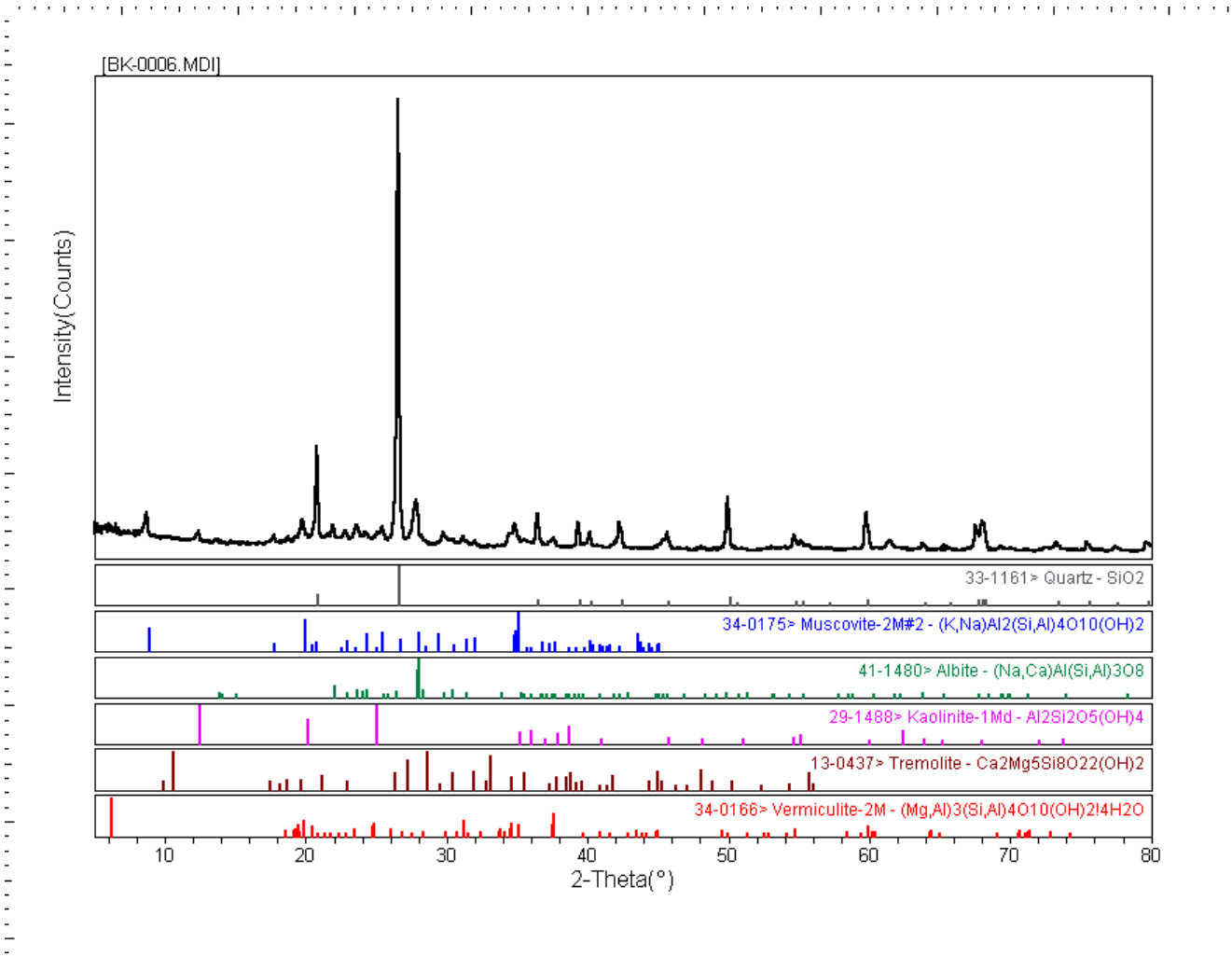

Fig. 18: XRD spectrum of sample BK-00006.

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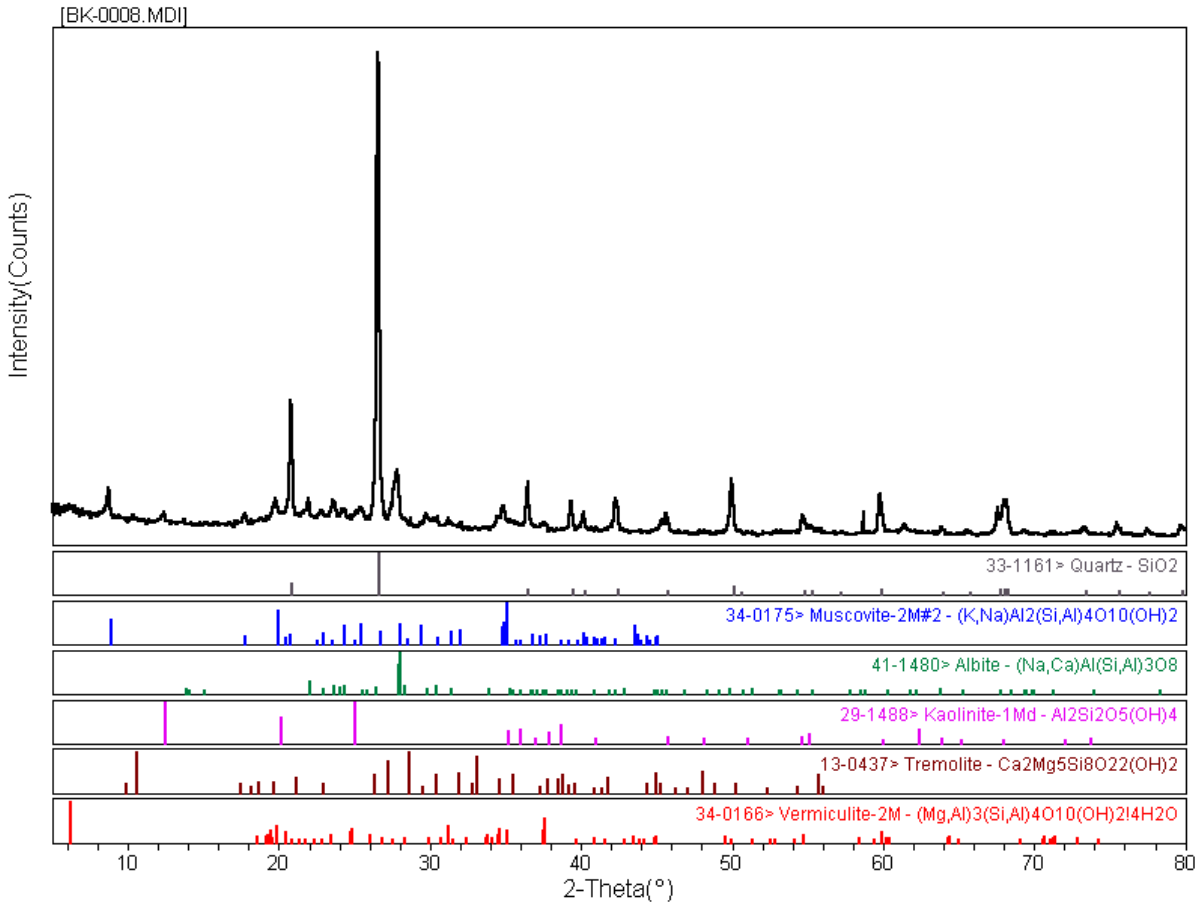

Fig. 19: XRD spectrum of sample BK-00008.

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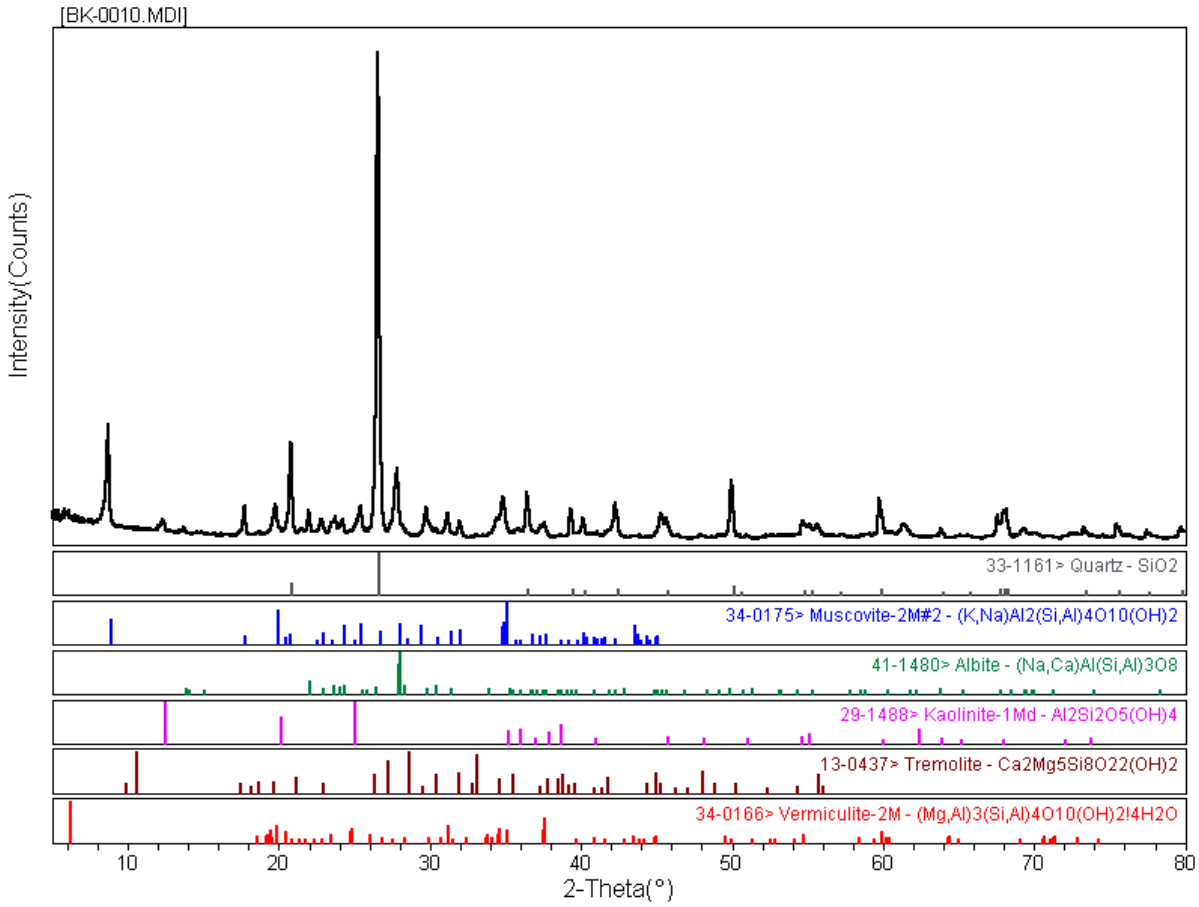

Fig. 20: XRD spectrum of sample BK-00010.

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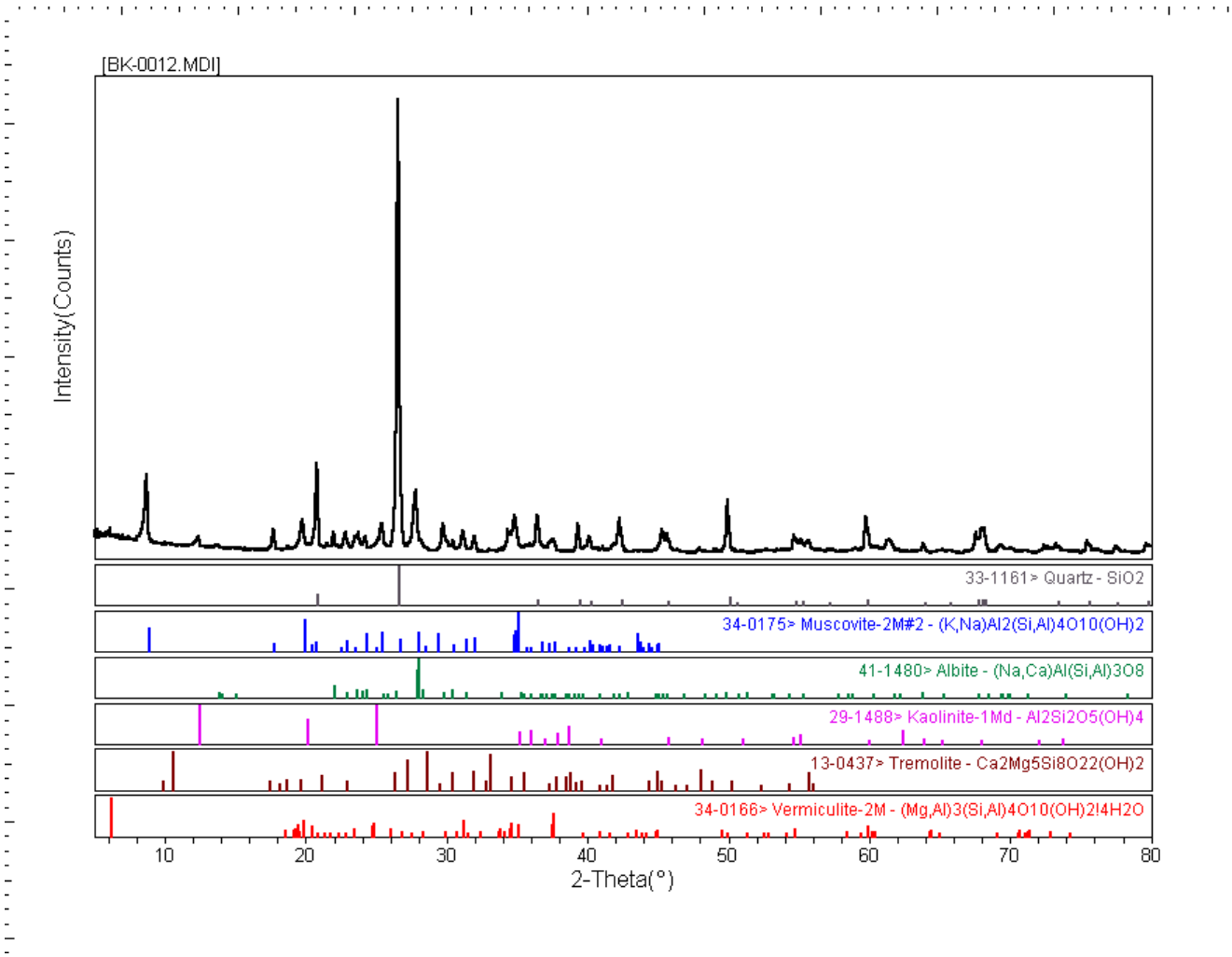

Fig. 21: XRD spectrum of sample BK-00012.

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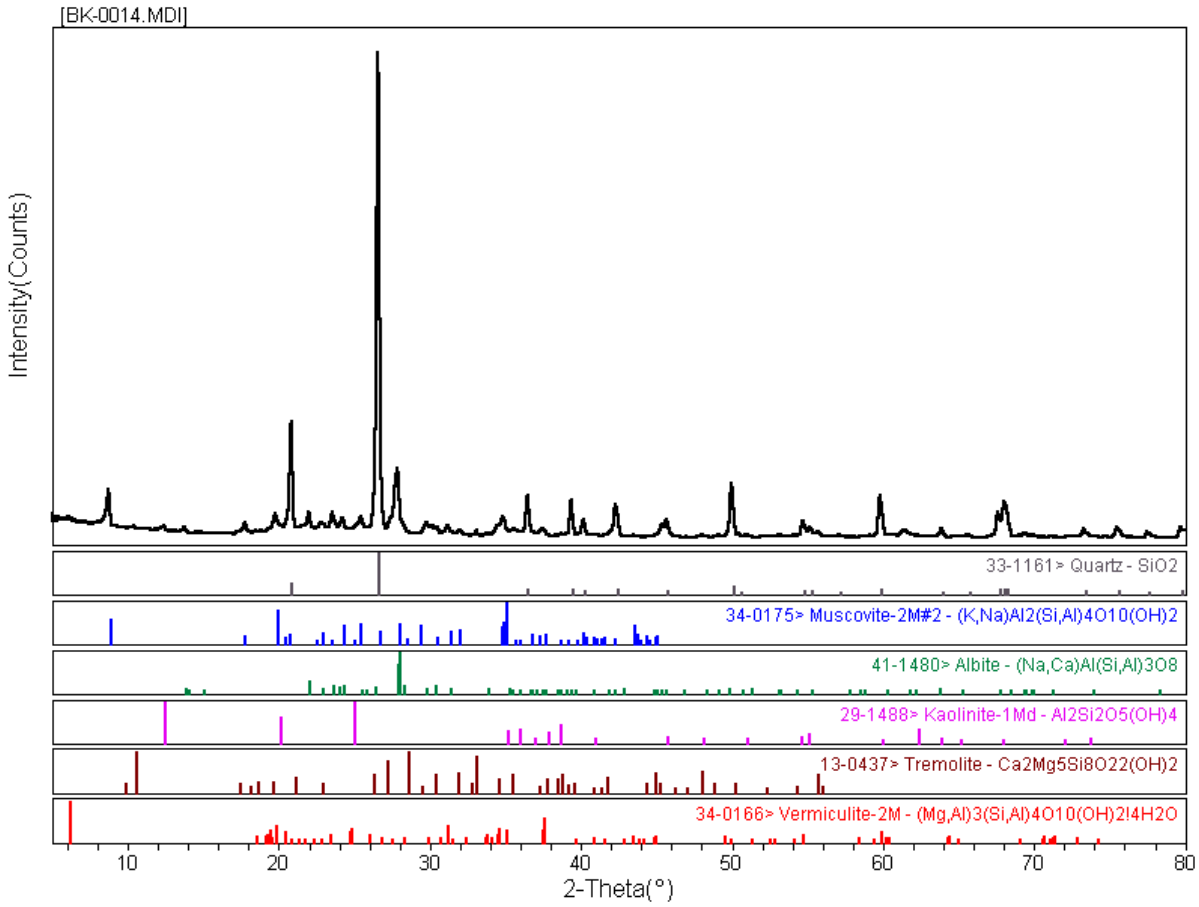

Fig. 22: XRD spectrum of sample BK-00014.

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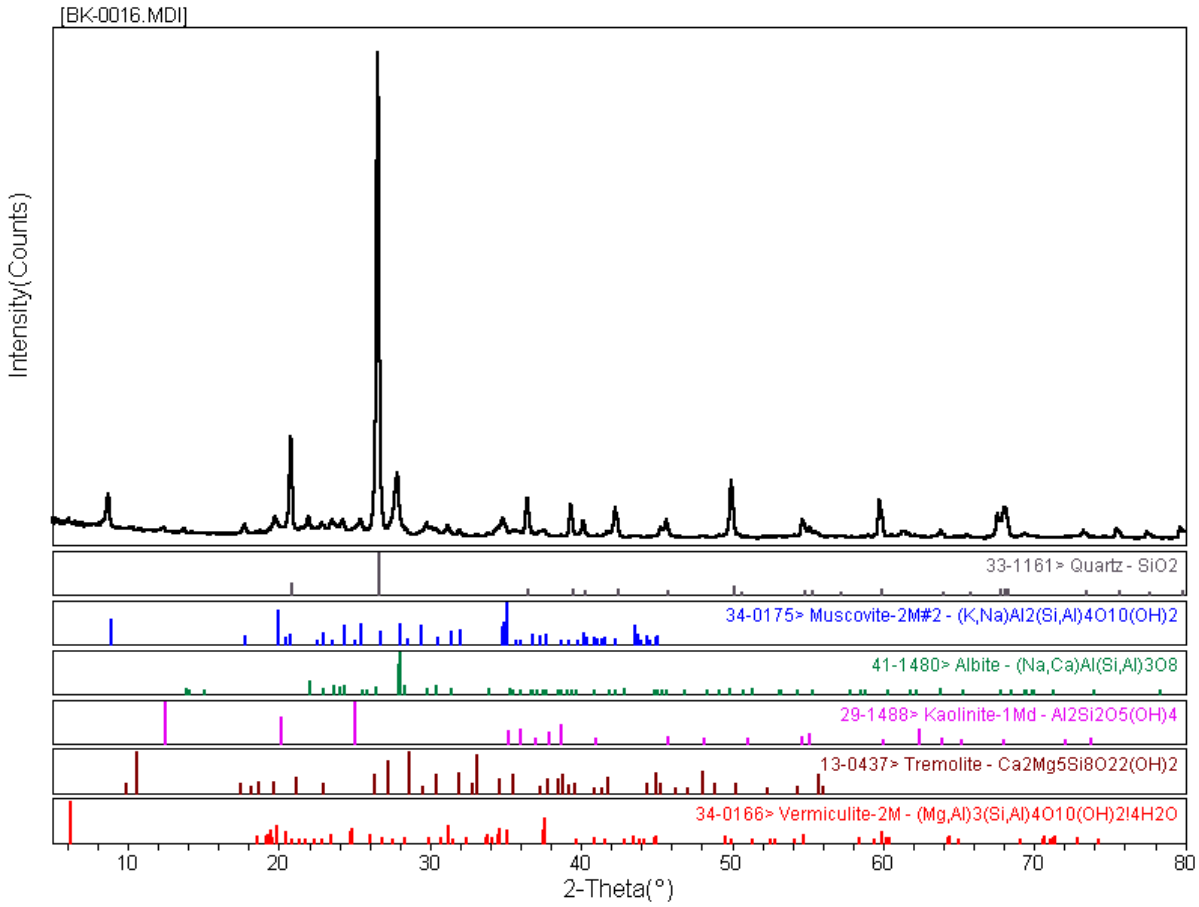

Fig. 23: XRD spectrum of sample BK-00016.

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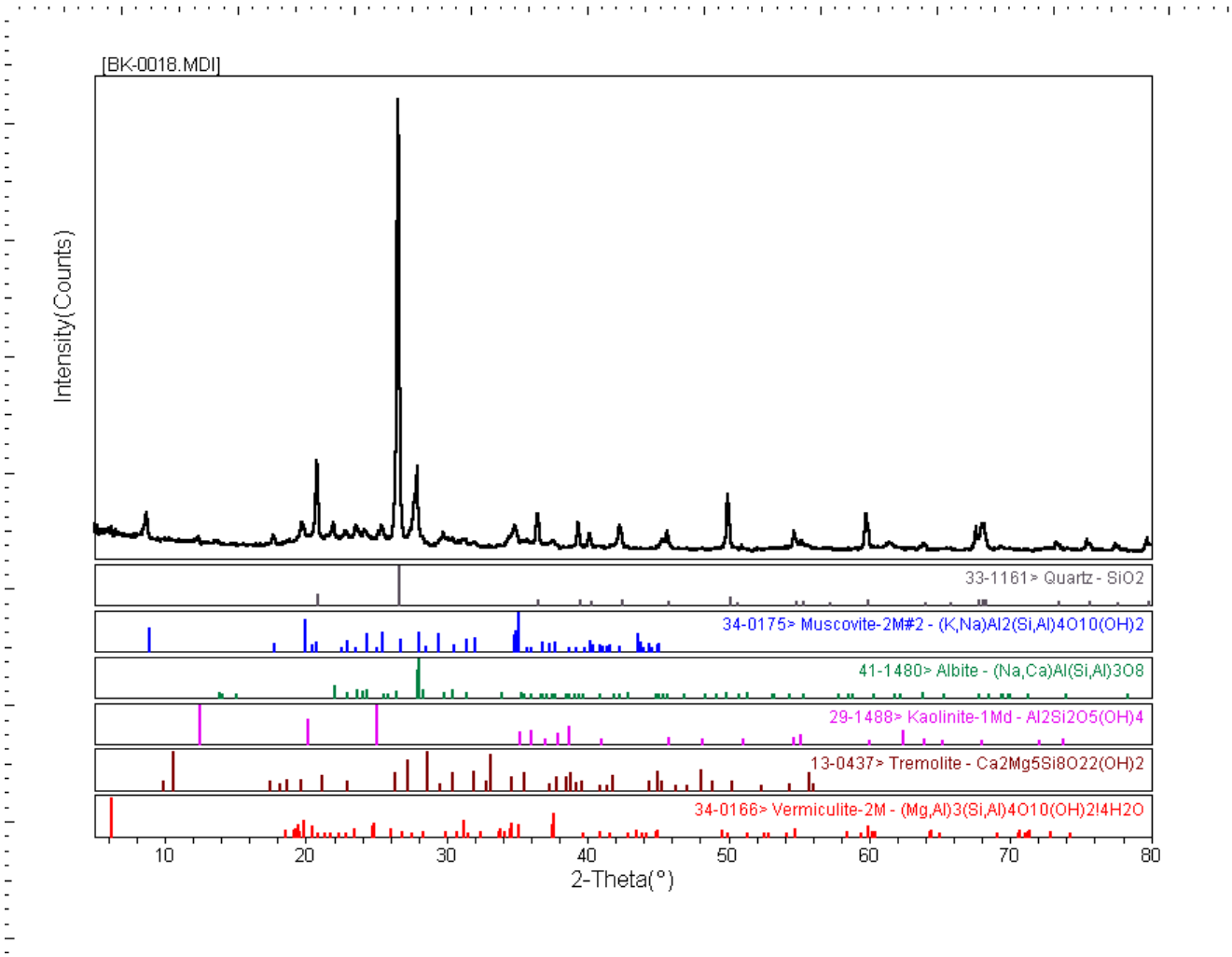

Fig. 24: XRD spectrum of sample BK-00018.

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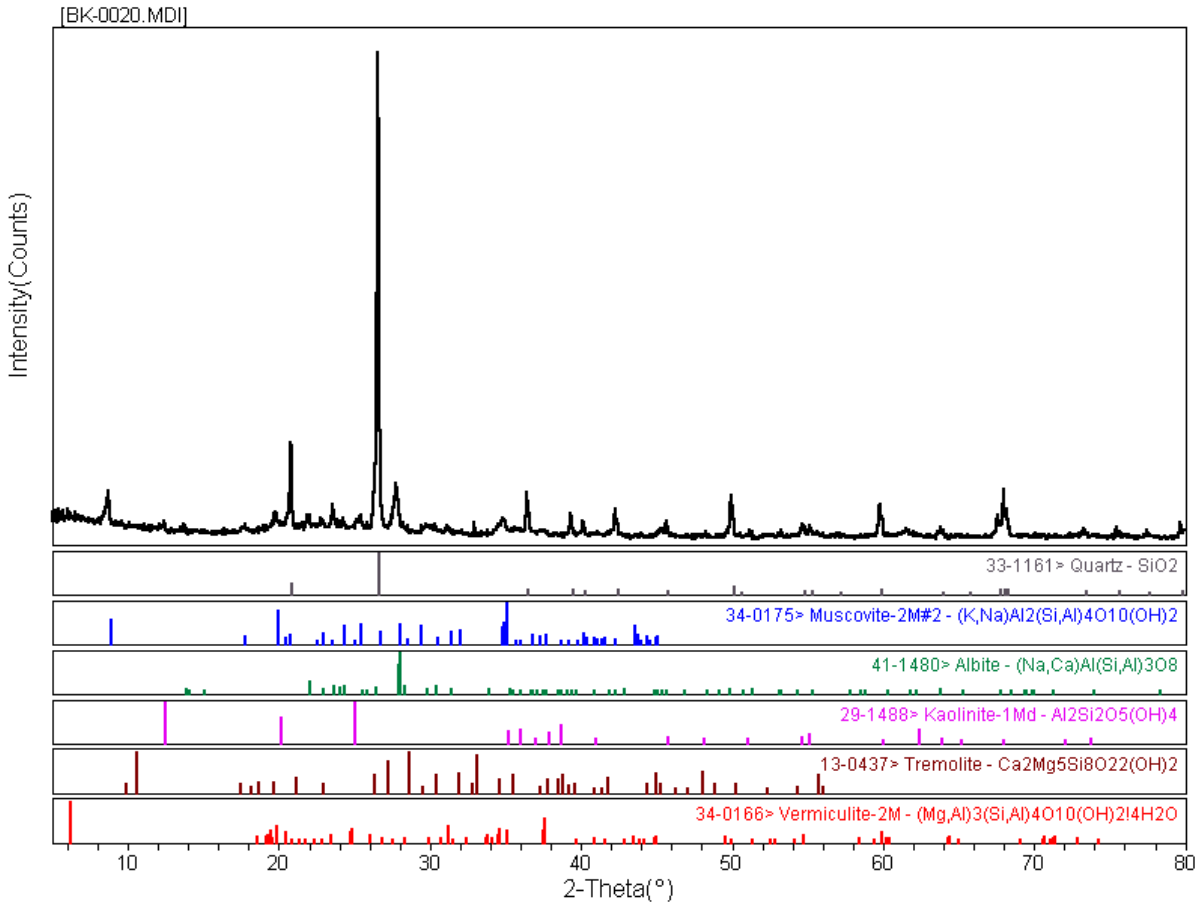

Fig. 25: XRD spectrum of sample BK-00020.

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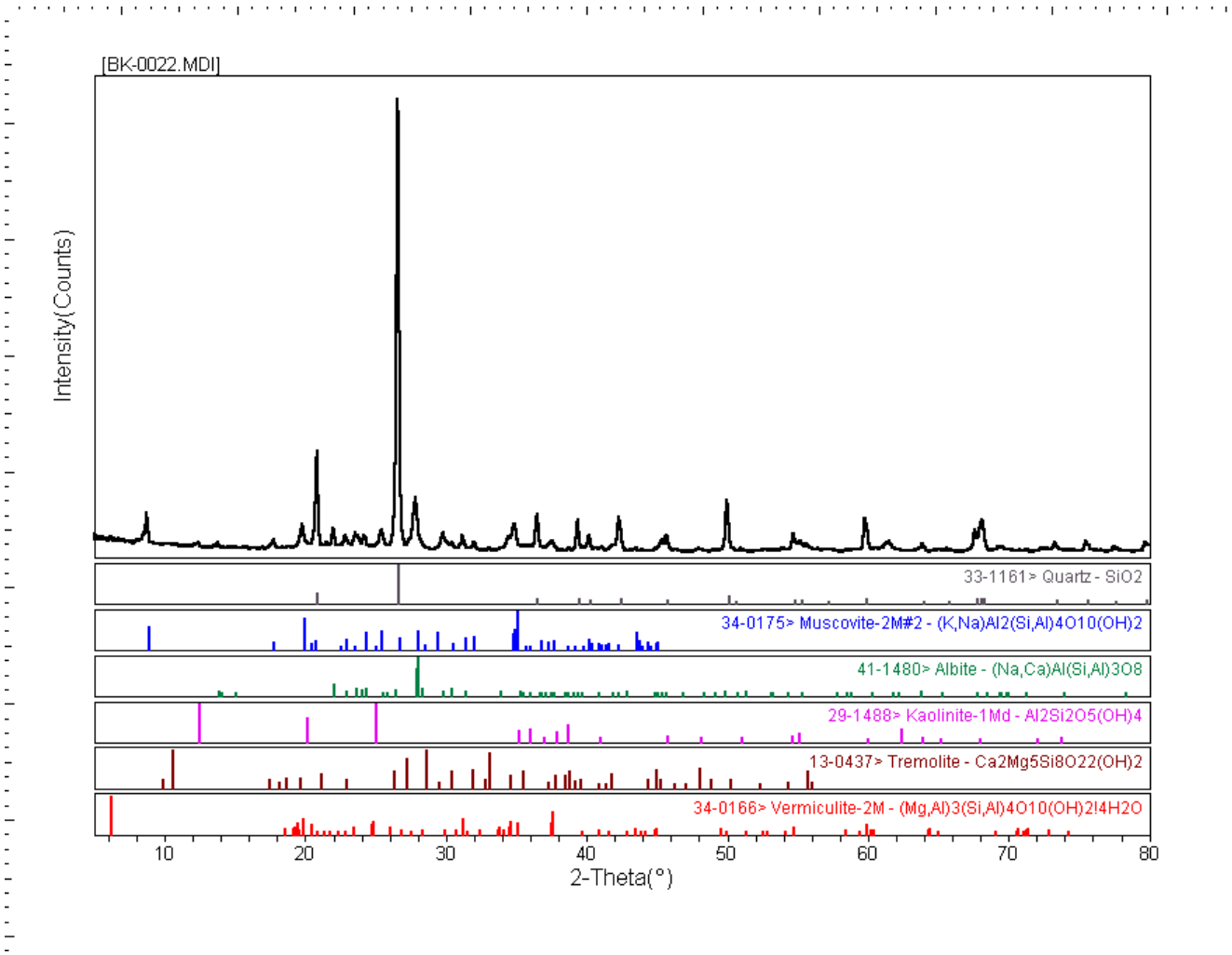

Fig. 26: XRD spectrum of sample BK-00022.

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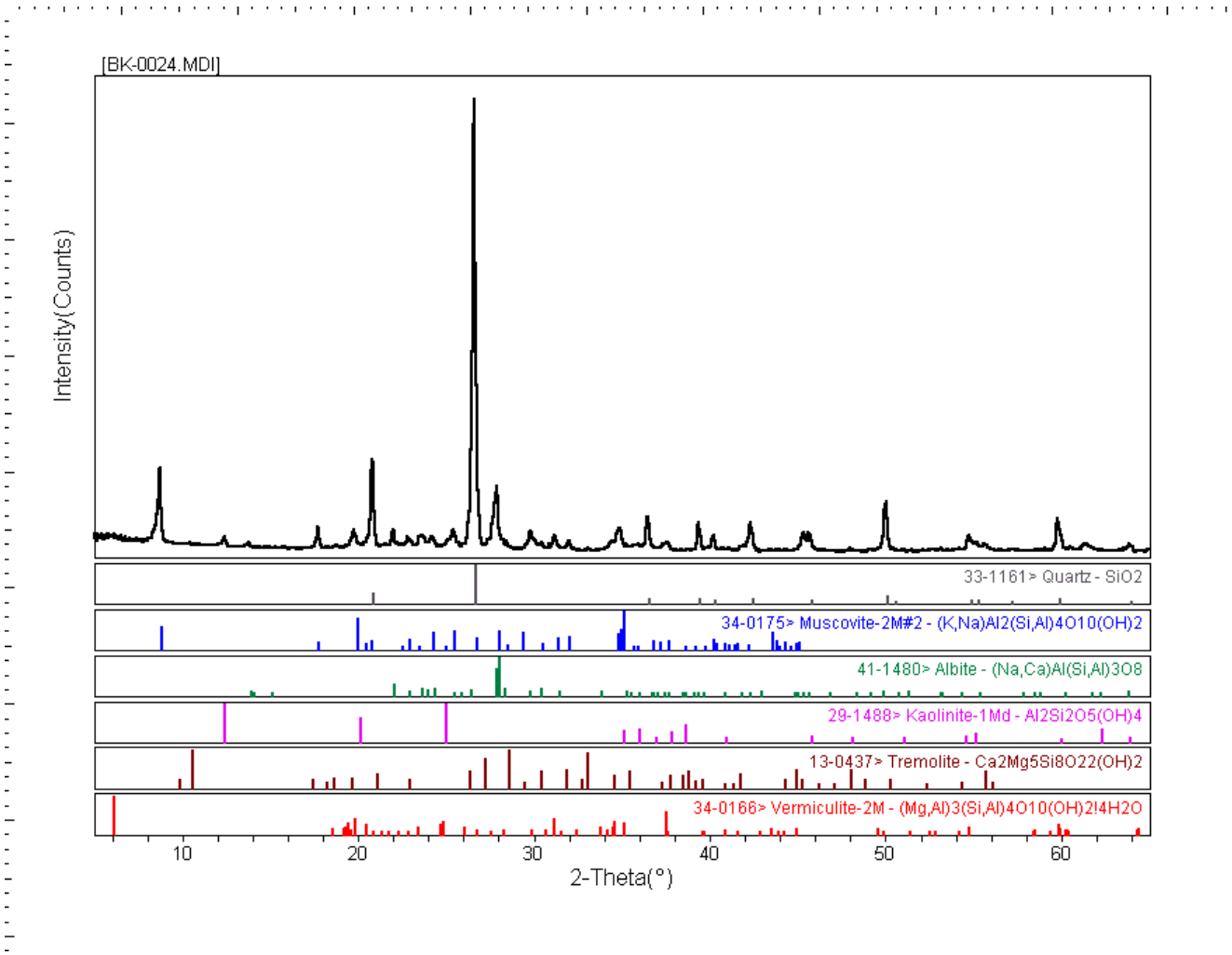

Fig. 27: XRD spectrum of sample BK-00024.

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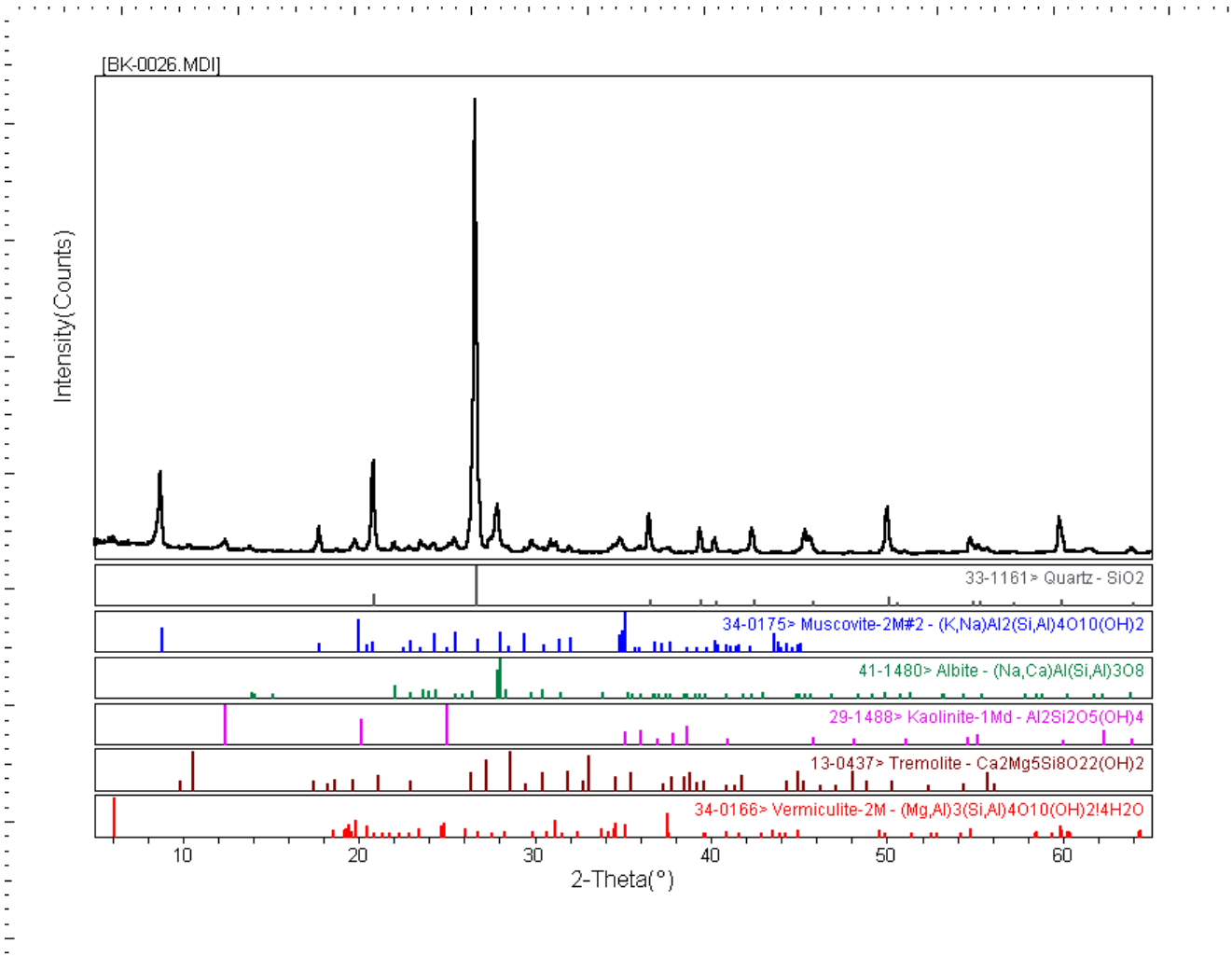

Fig. 28: XRD spectrum of sample BK-00026.

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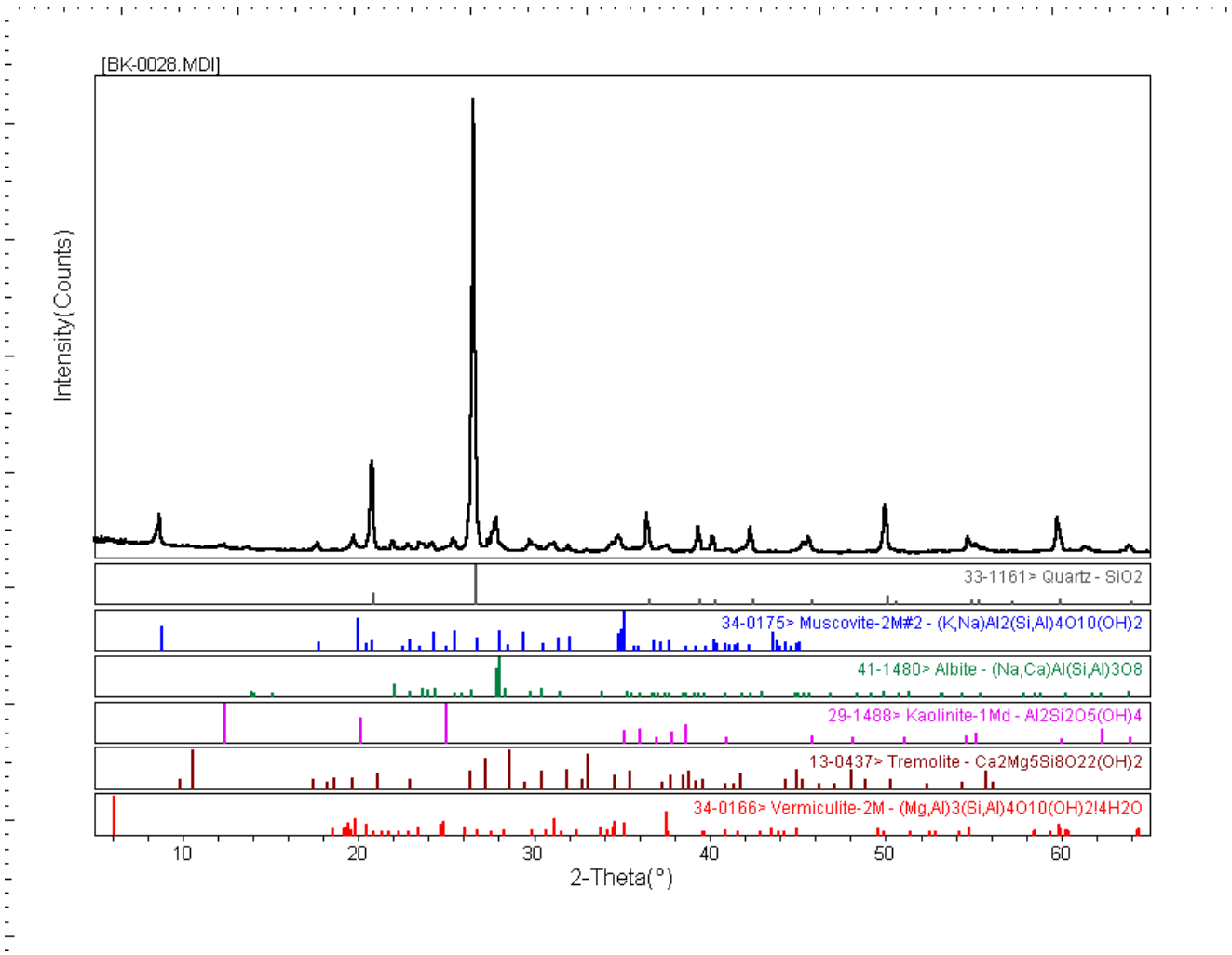

Fig.e 29: XRD spectrum of sample BK-00028.

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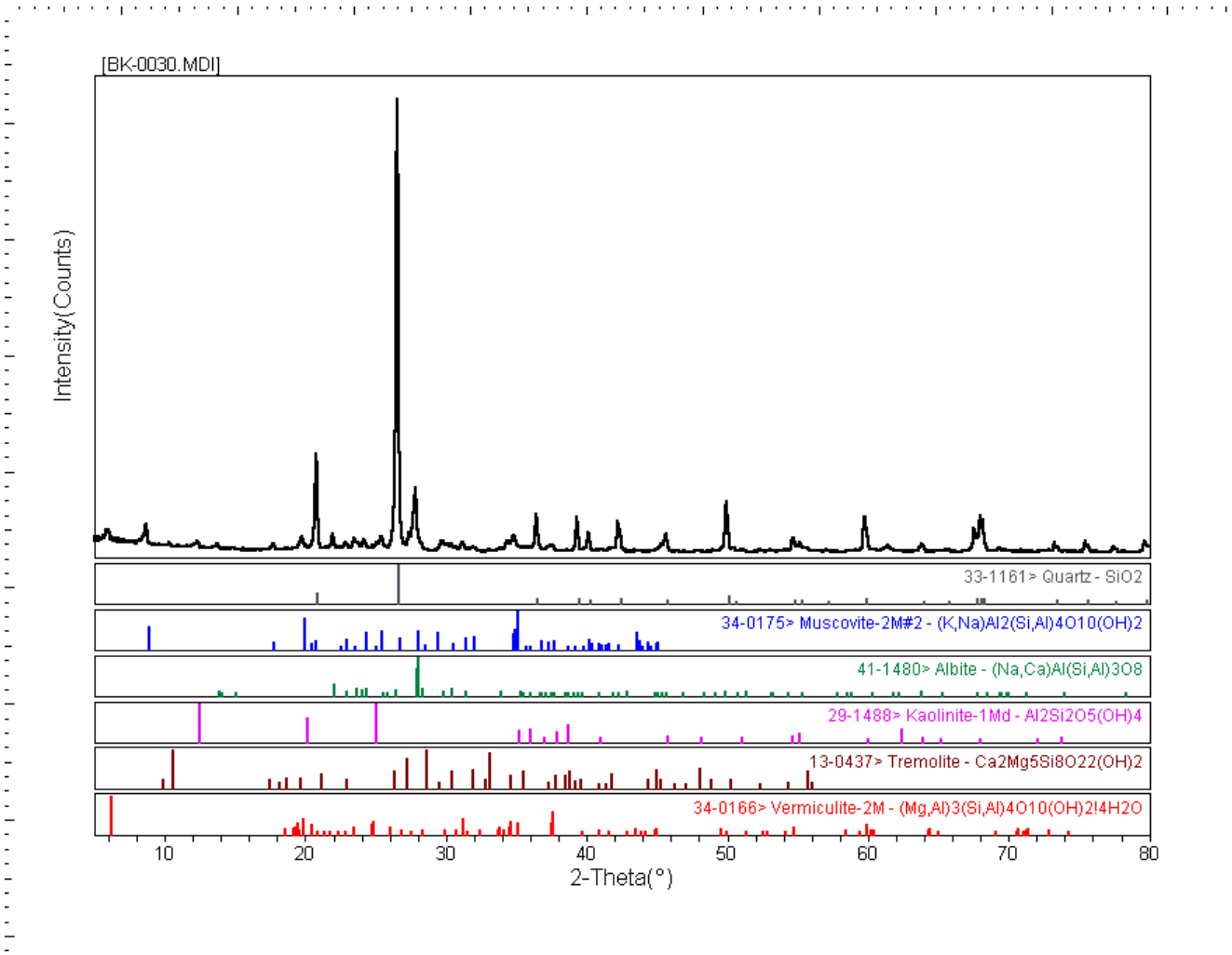

Fig. 30: XRD spectrum of sample BK-00030.

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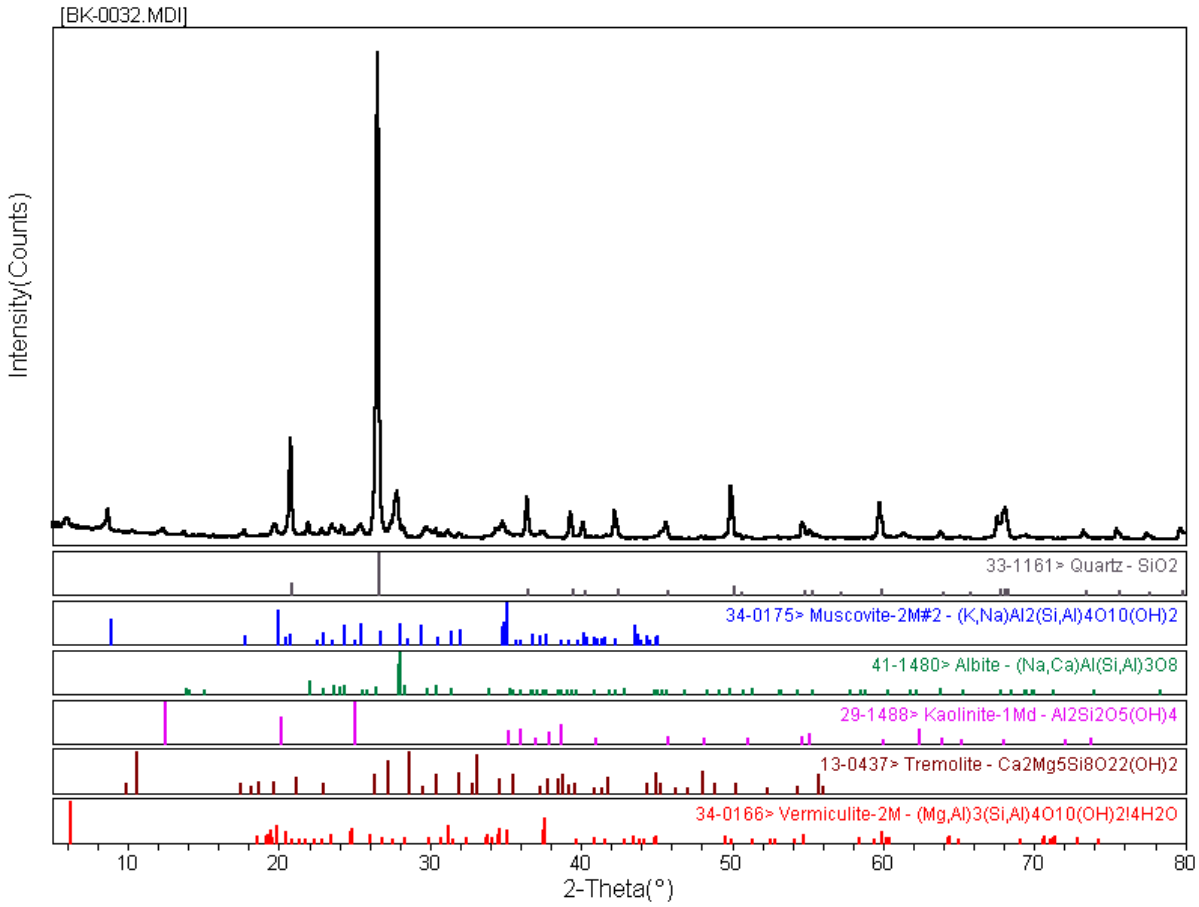

Fig. 31: XRD spectrum of sample BK-00032.

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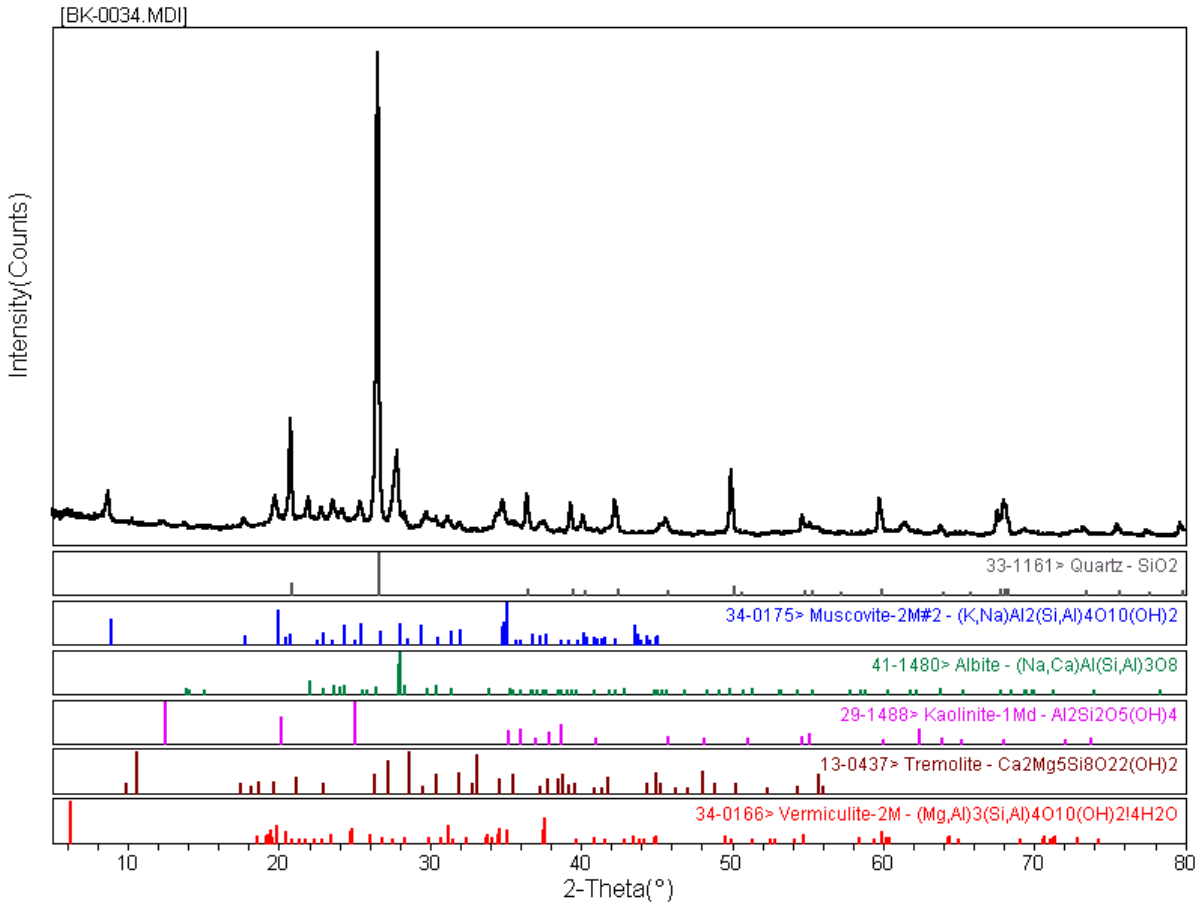

Fig.e 32: XRD spectrum of sample BK-00034.

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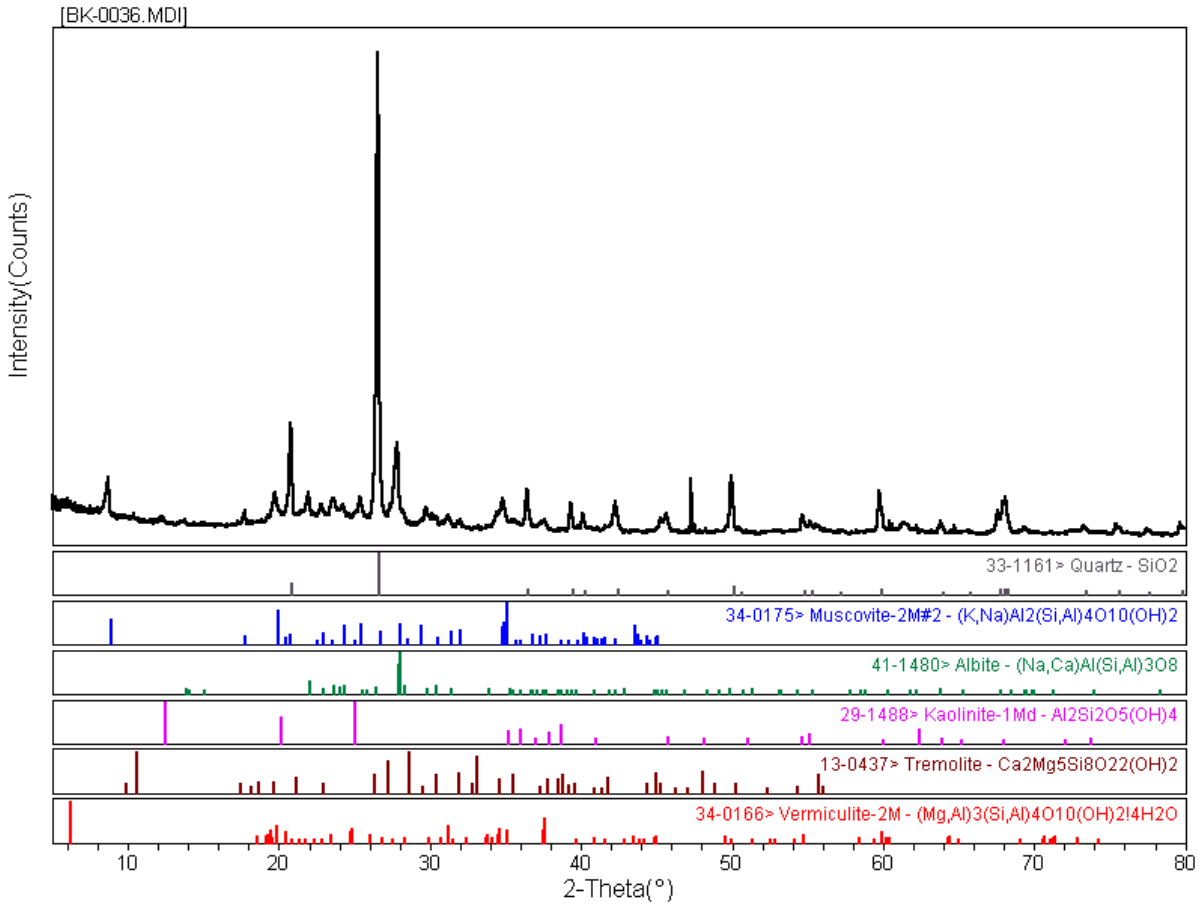

Fig. 33: XRD spectrum of sample BK-00036.

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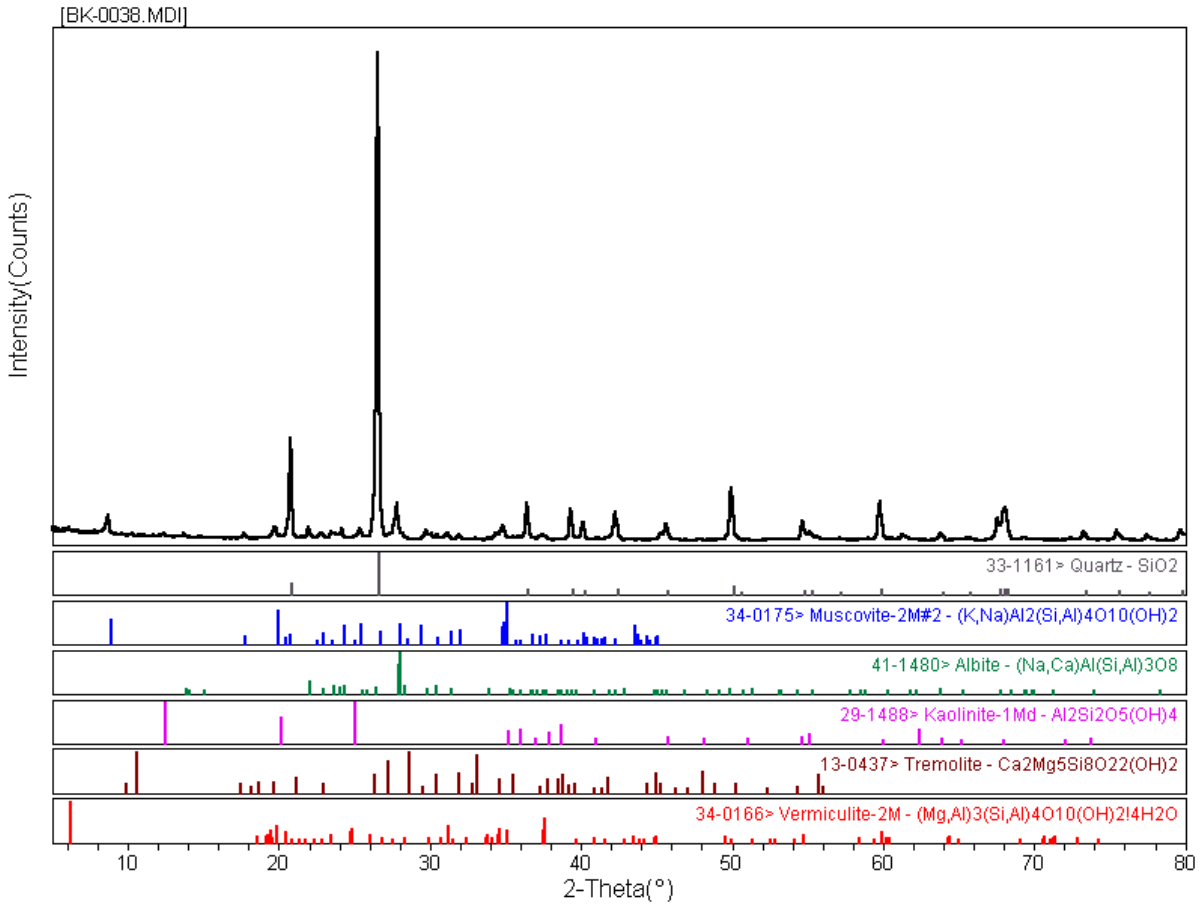

Fig. 34: XRD spectrum of sample BK-00038.

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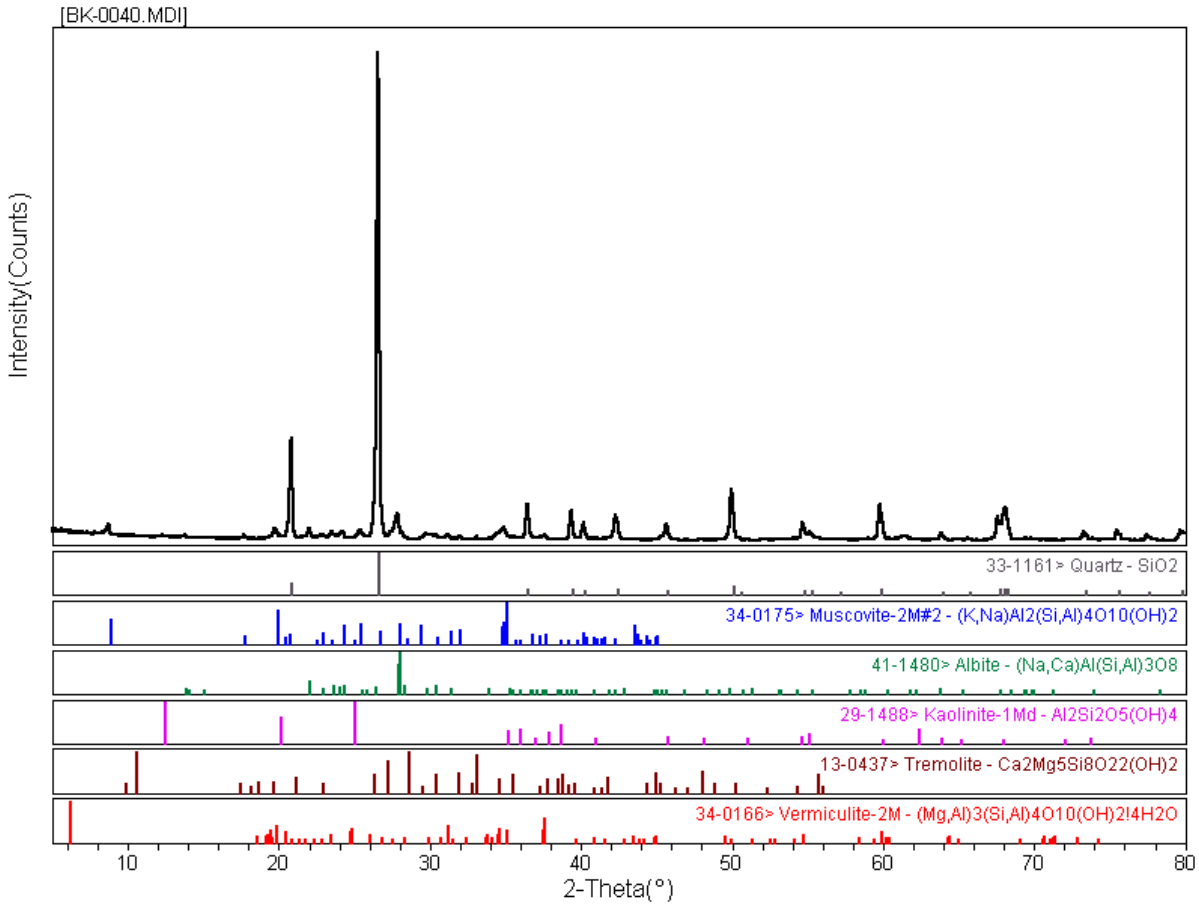

Fig. 35: XRD spectrum of sample BK-00040.

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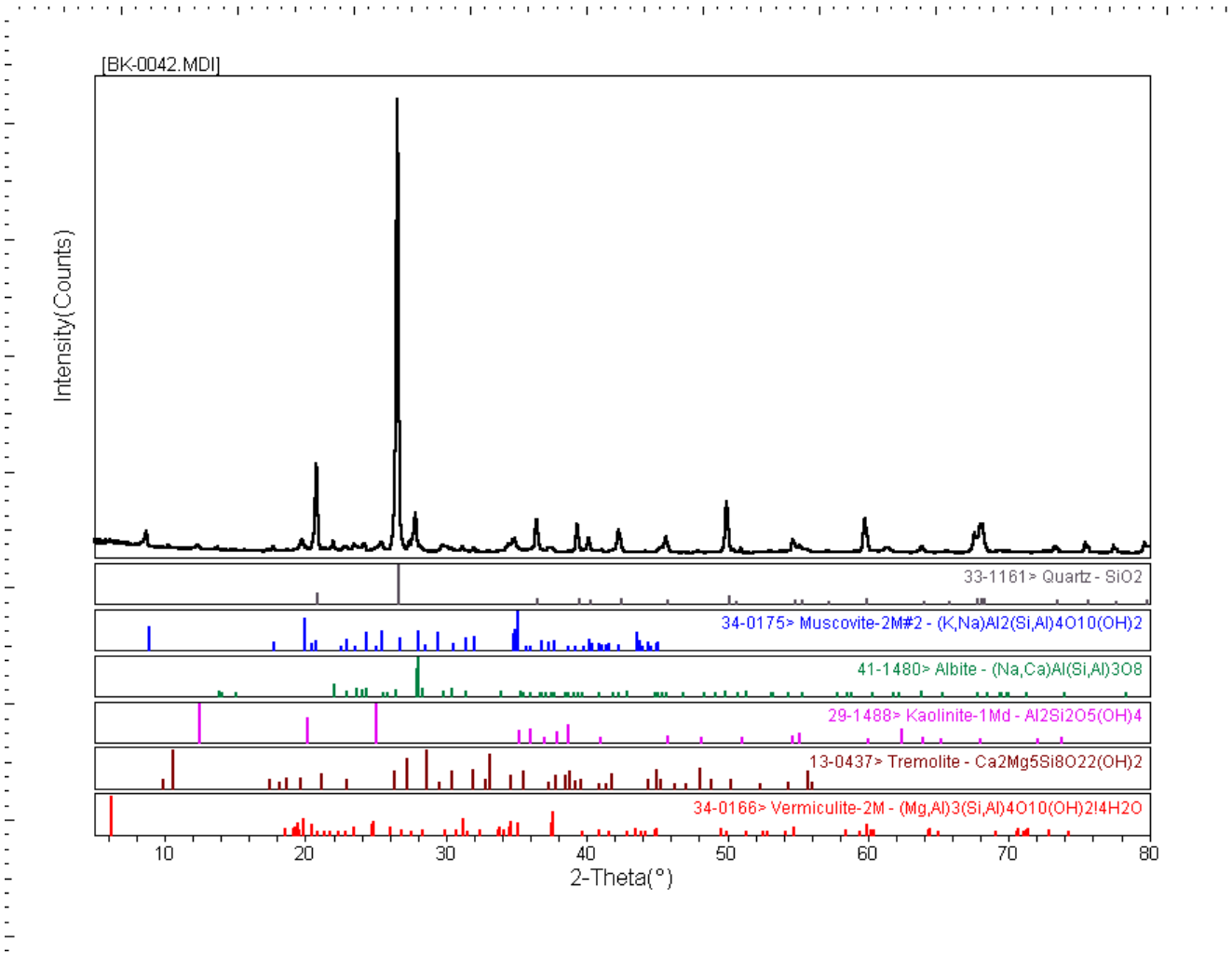

Fig. 36: XRD spectrum of sample BK-00042.

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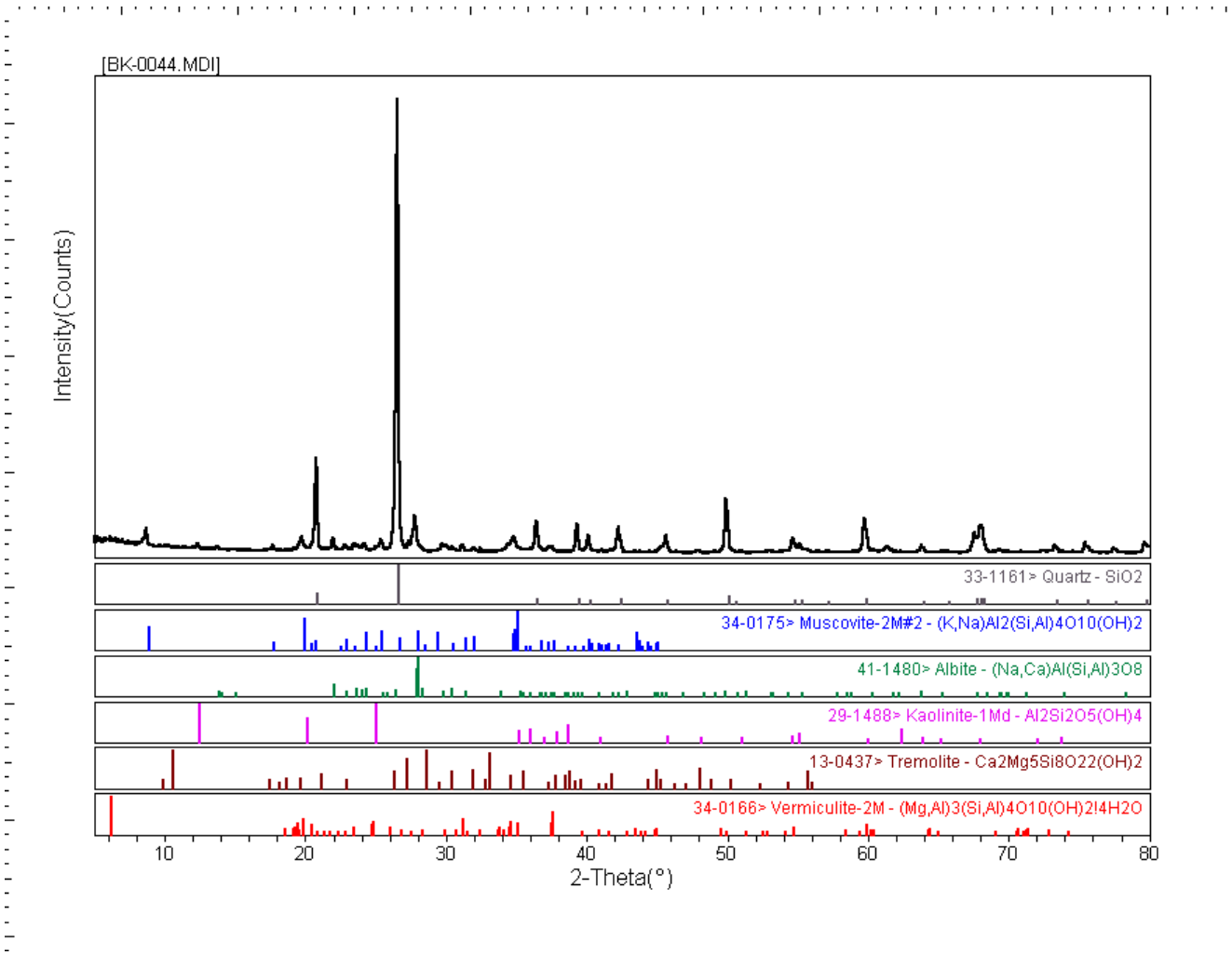

Fig. 37: XRD spectrum of sample BK-00044.

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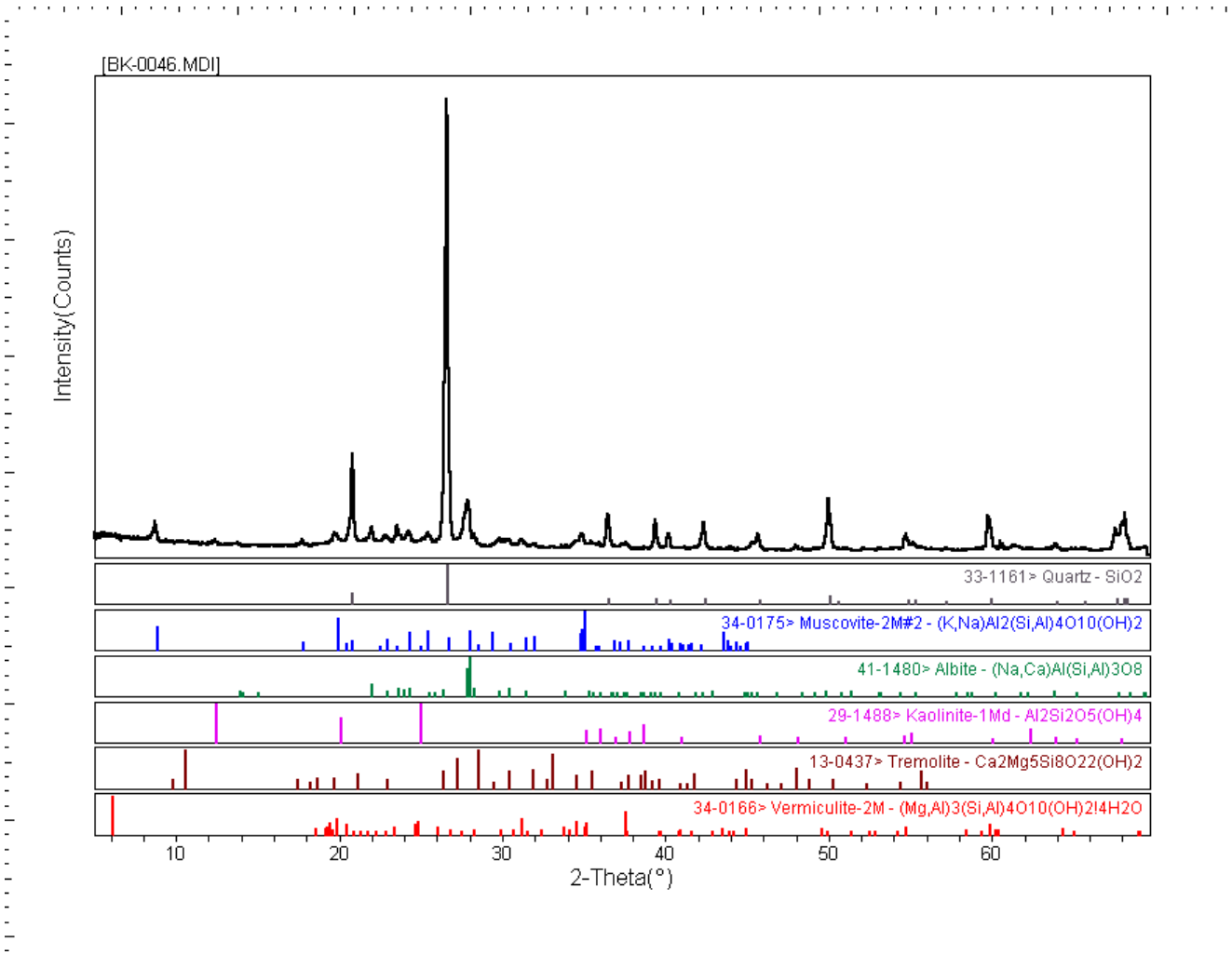

Fig. 38: XRD spectrum of sample BK-00046.

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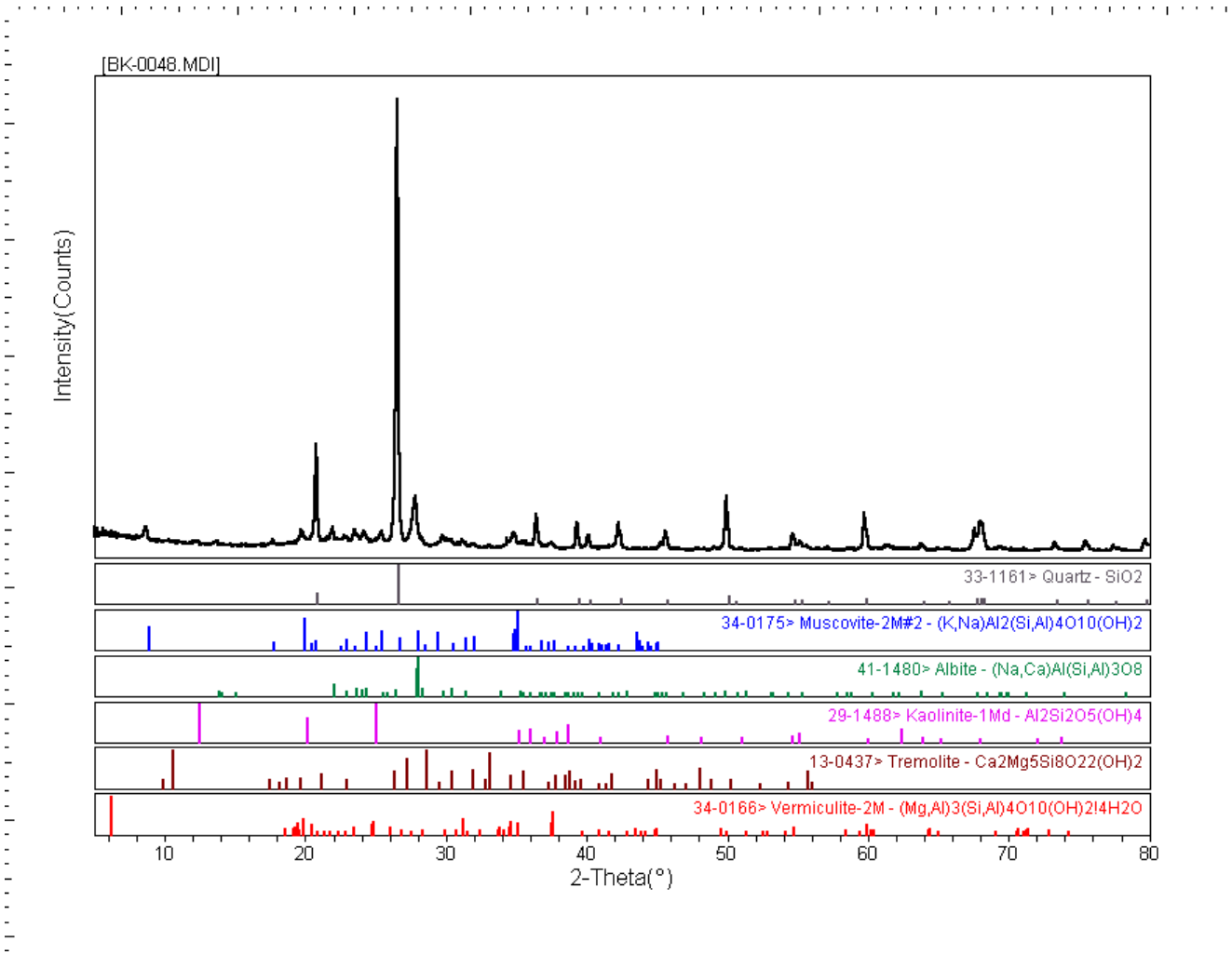

Fig. 39: XRD spectrum of sample BK-00048.

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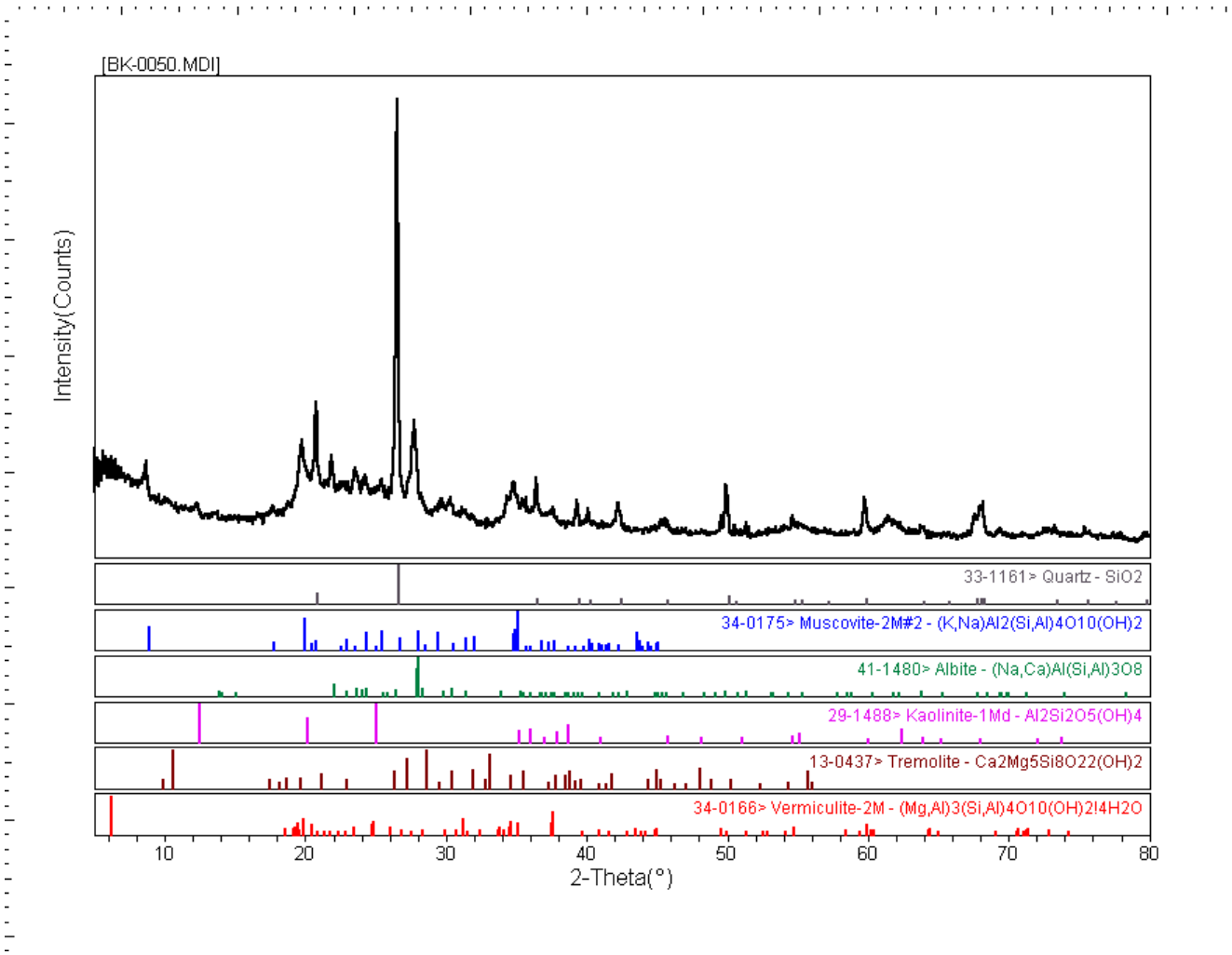

Fig. 40: XRD spectrum of sample BK-00050.

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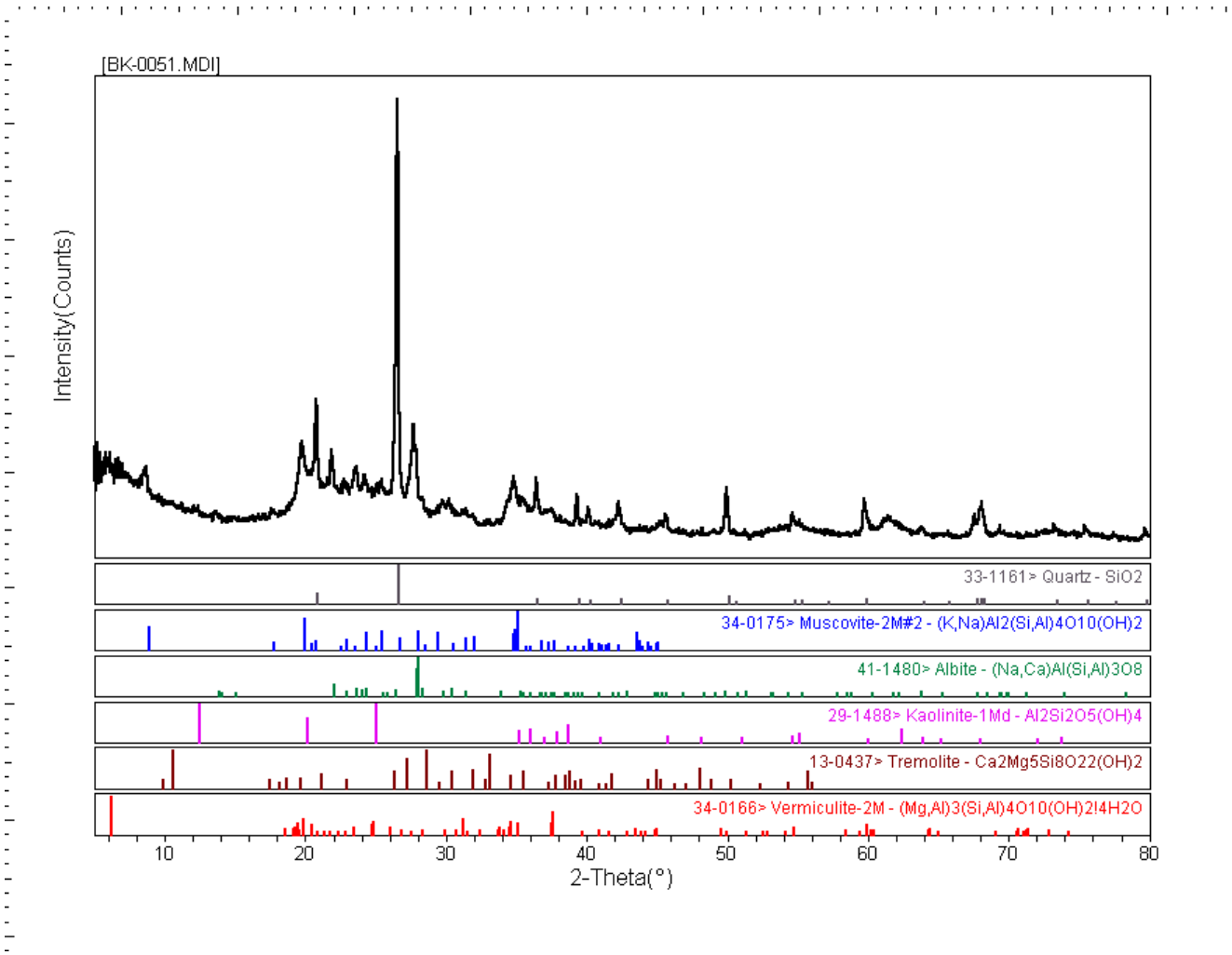

Fig. 41: XRD spectrum of sample BK-00051.

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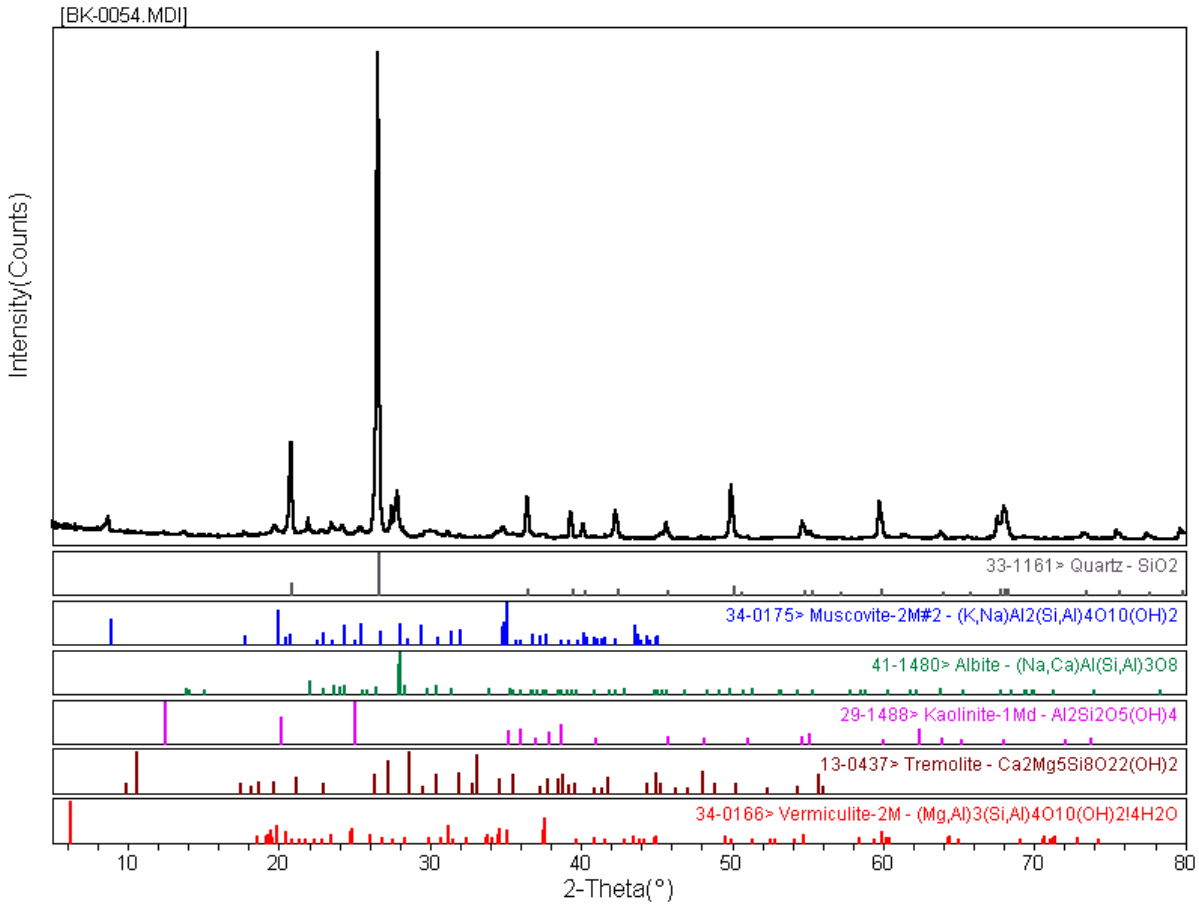

Fig. 42: XRD spectrum of sample BK-00054.

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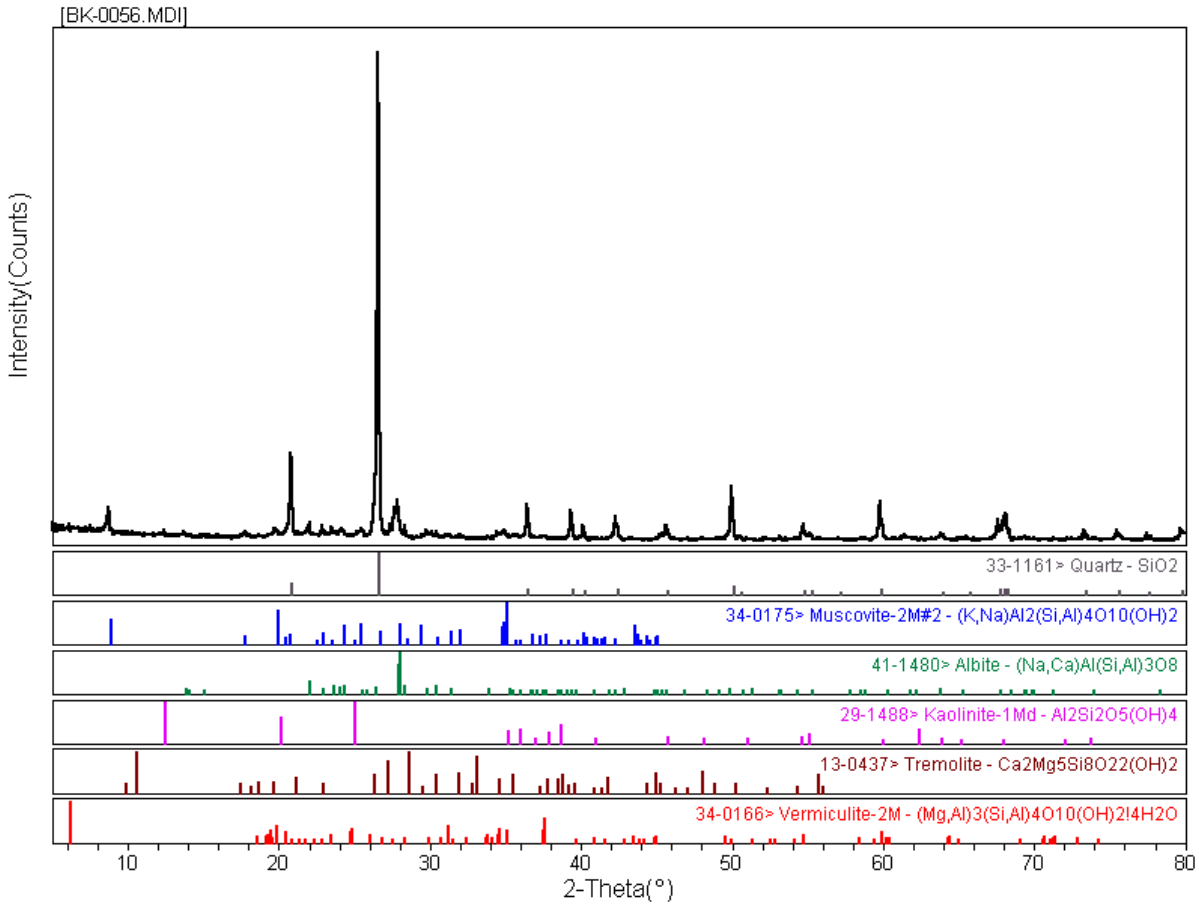

Fig. 43: XRD spectrum of sample BK-00056.

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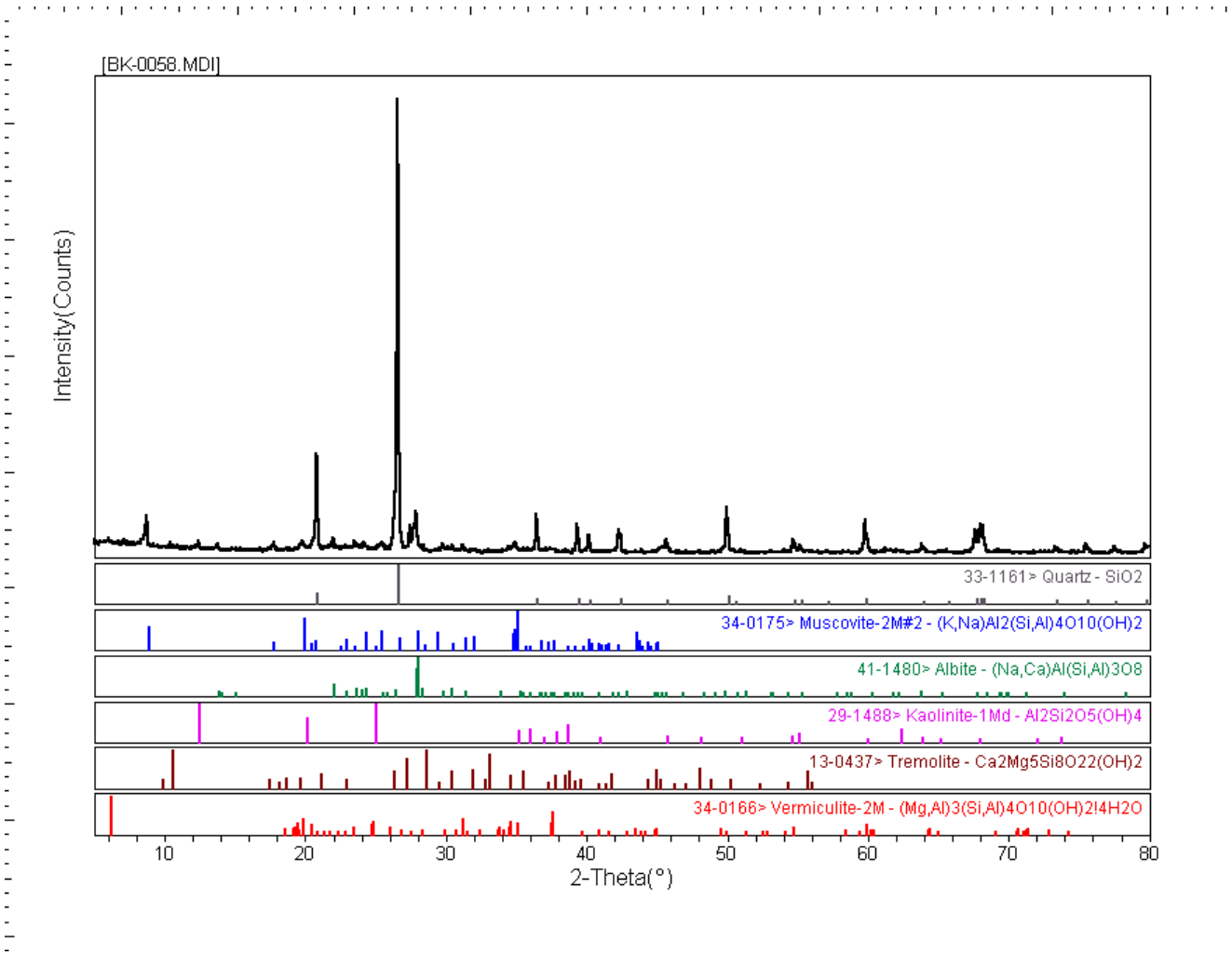

Fig. 44: XRD spectrum of sample BK-00058.

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Phone: (856) 858-4800

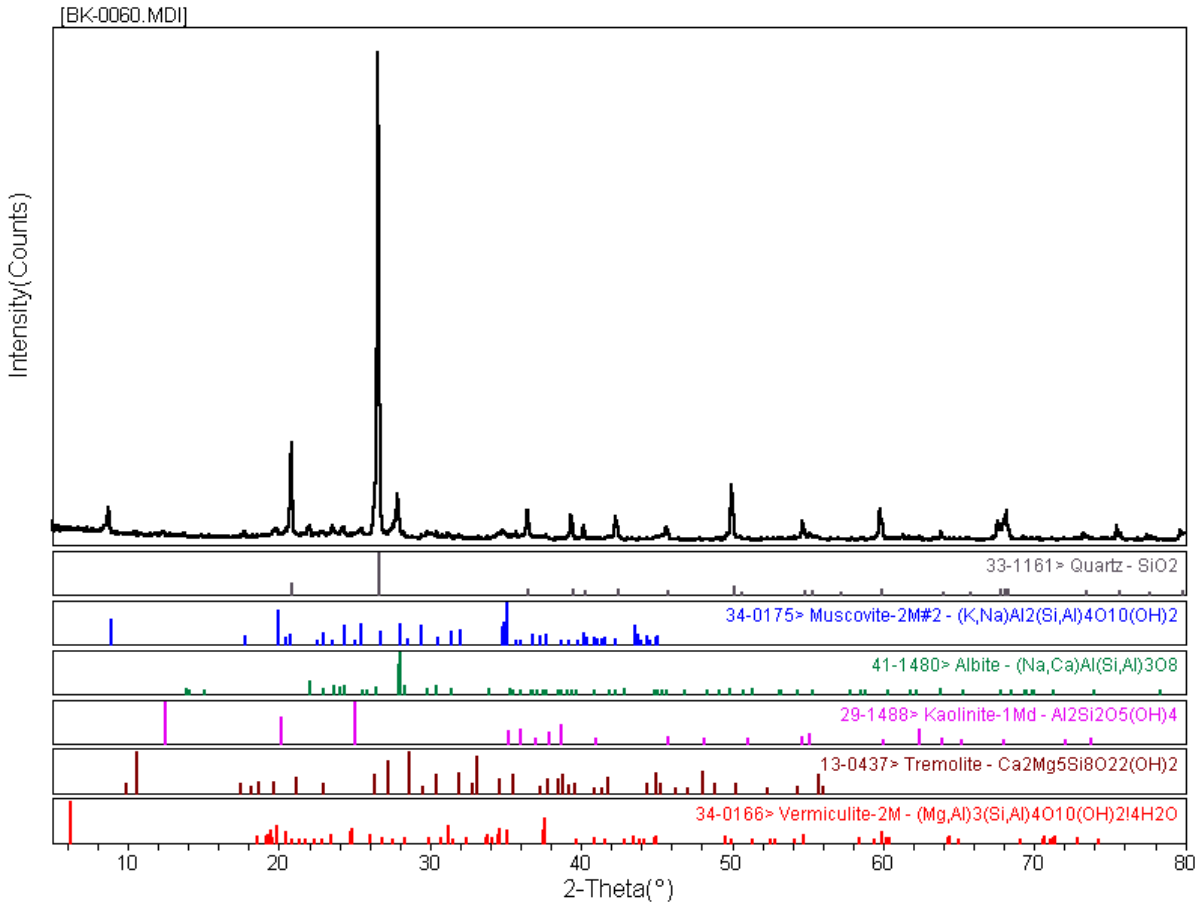

Fig. 45: XRD spectrum of sample BK-00060.

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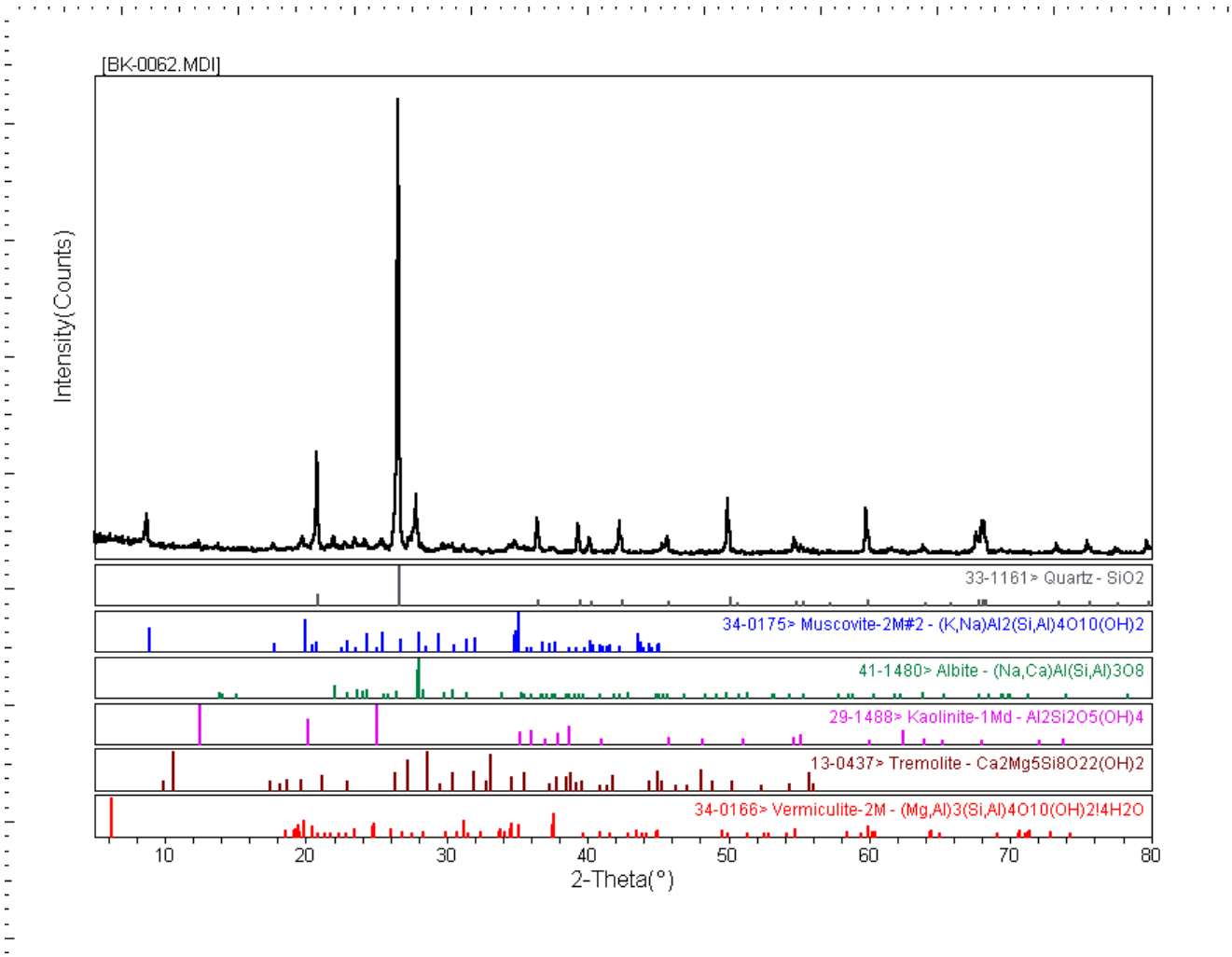

Fig. 46: XRD spectrum of sample BK-00062.

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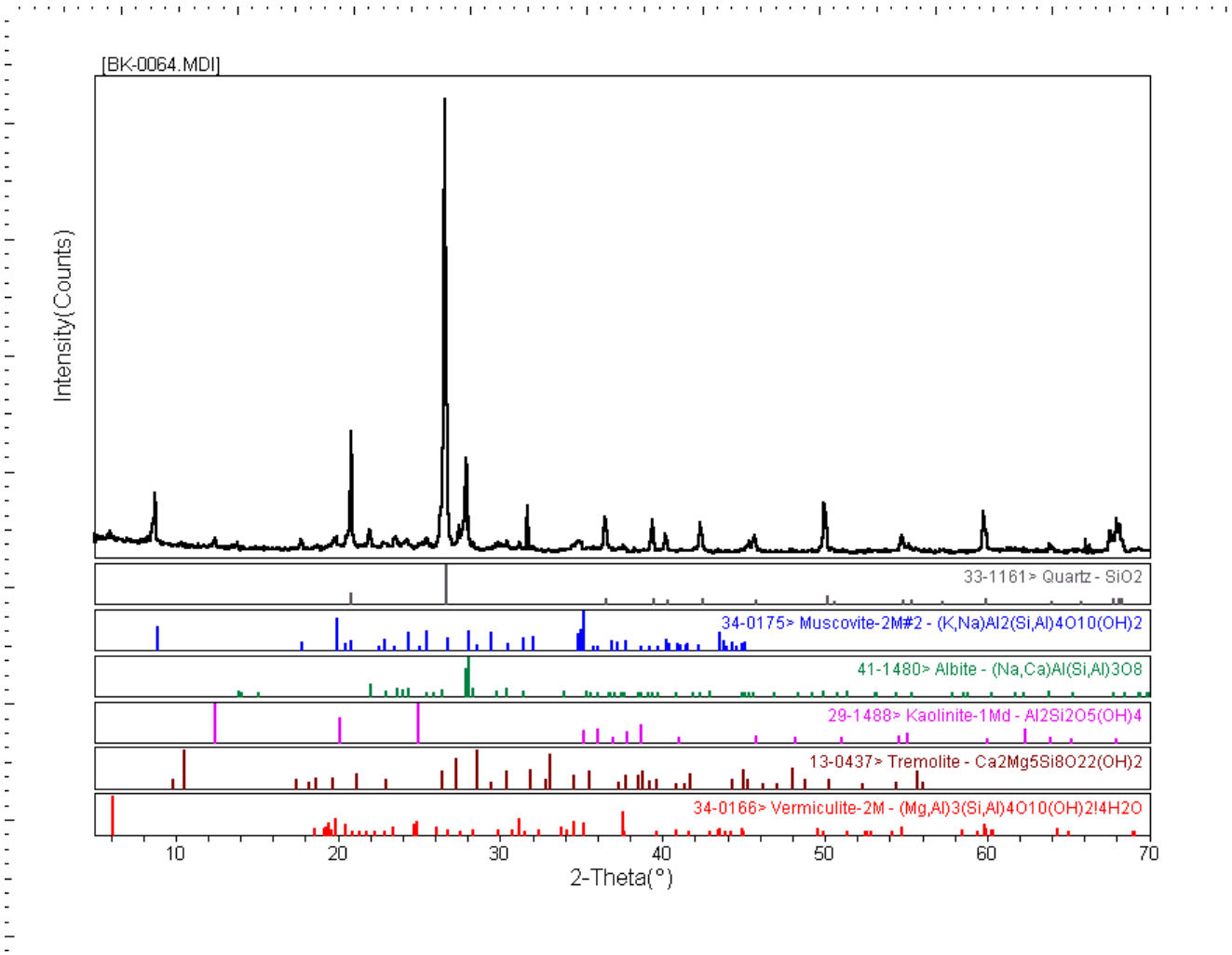

Fig. 47: XRD spectrum of sample BK-00064.

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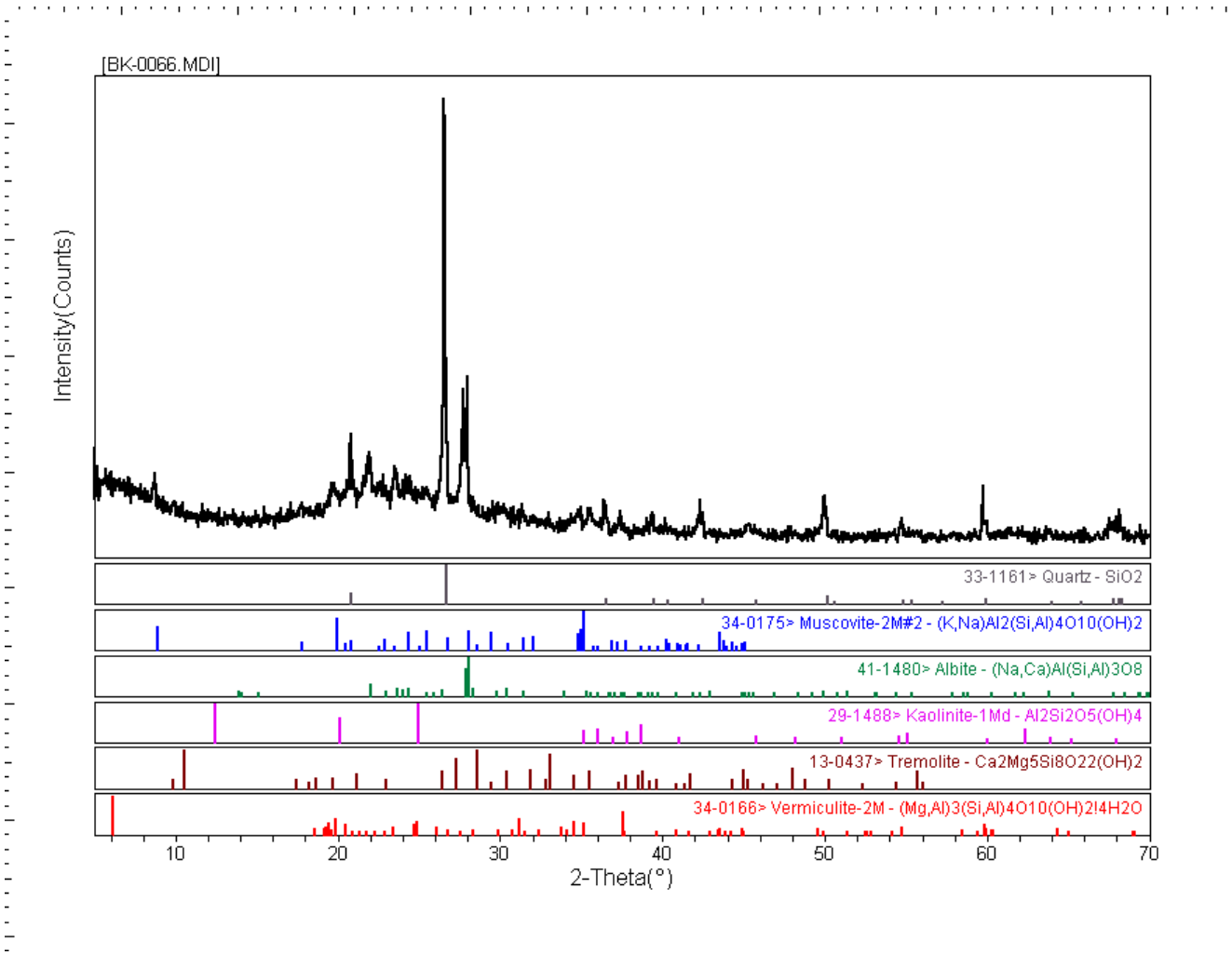

Fig. 48: XRD spectrum of sample BK-00066.

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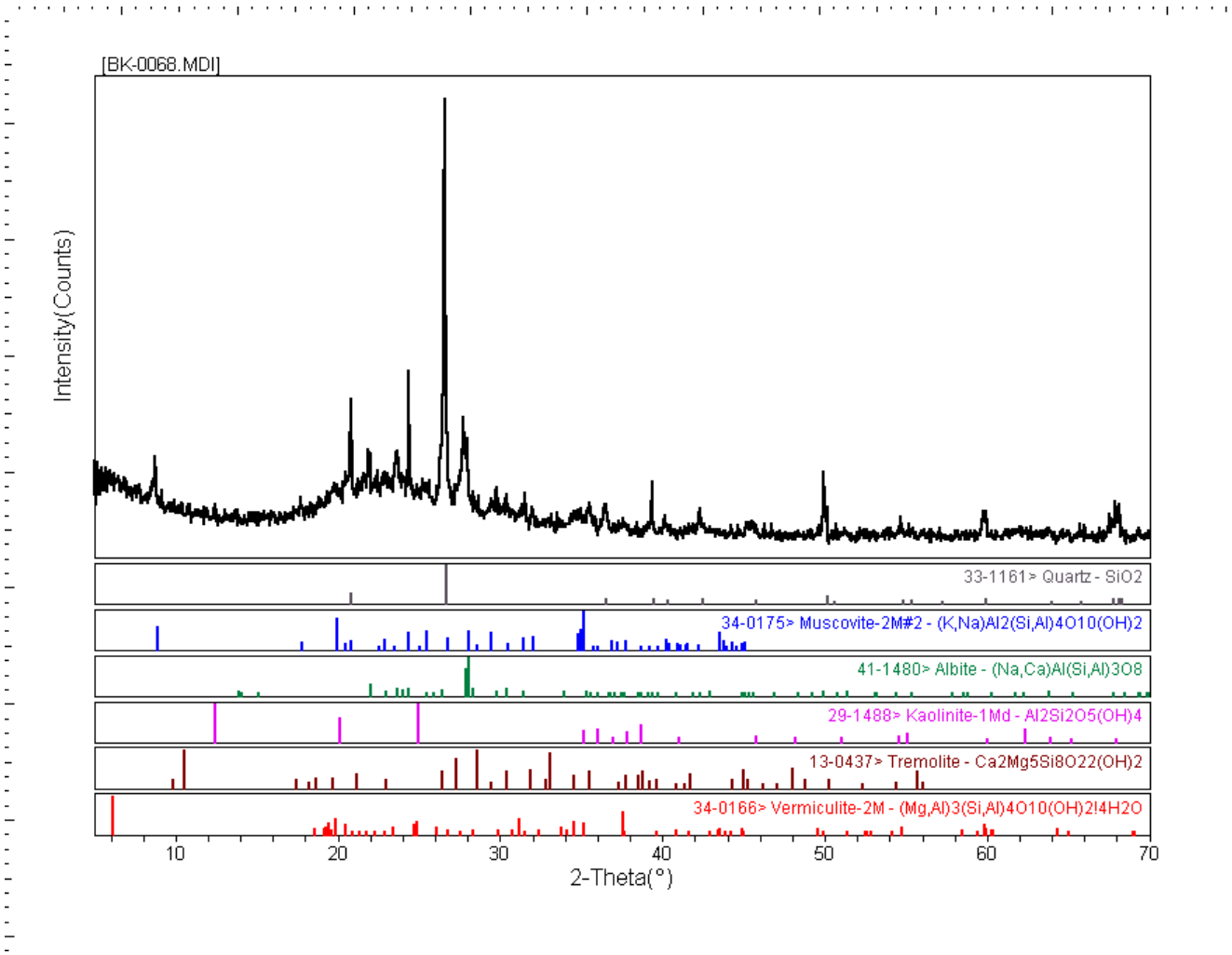

Fig. 49: XRD spectrum of sample BK-00068.

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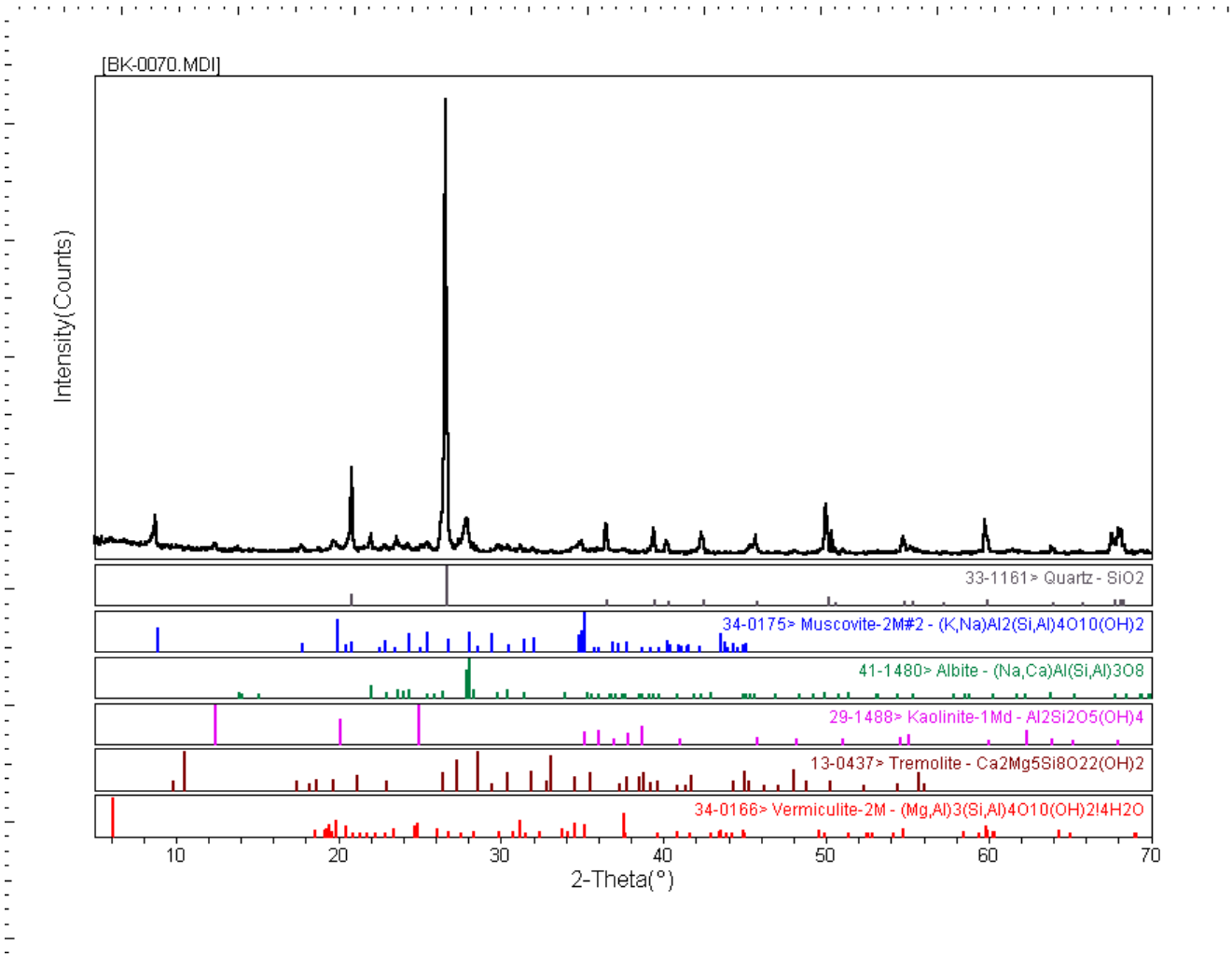

Fig. 50: XRD spectrum of sample BK-00070.

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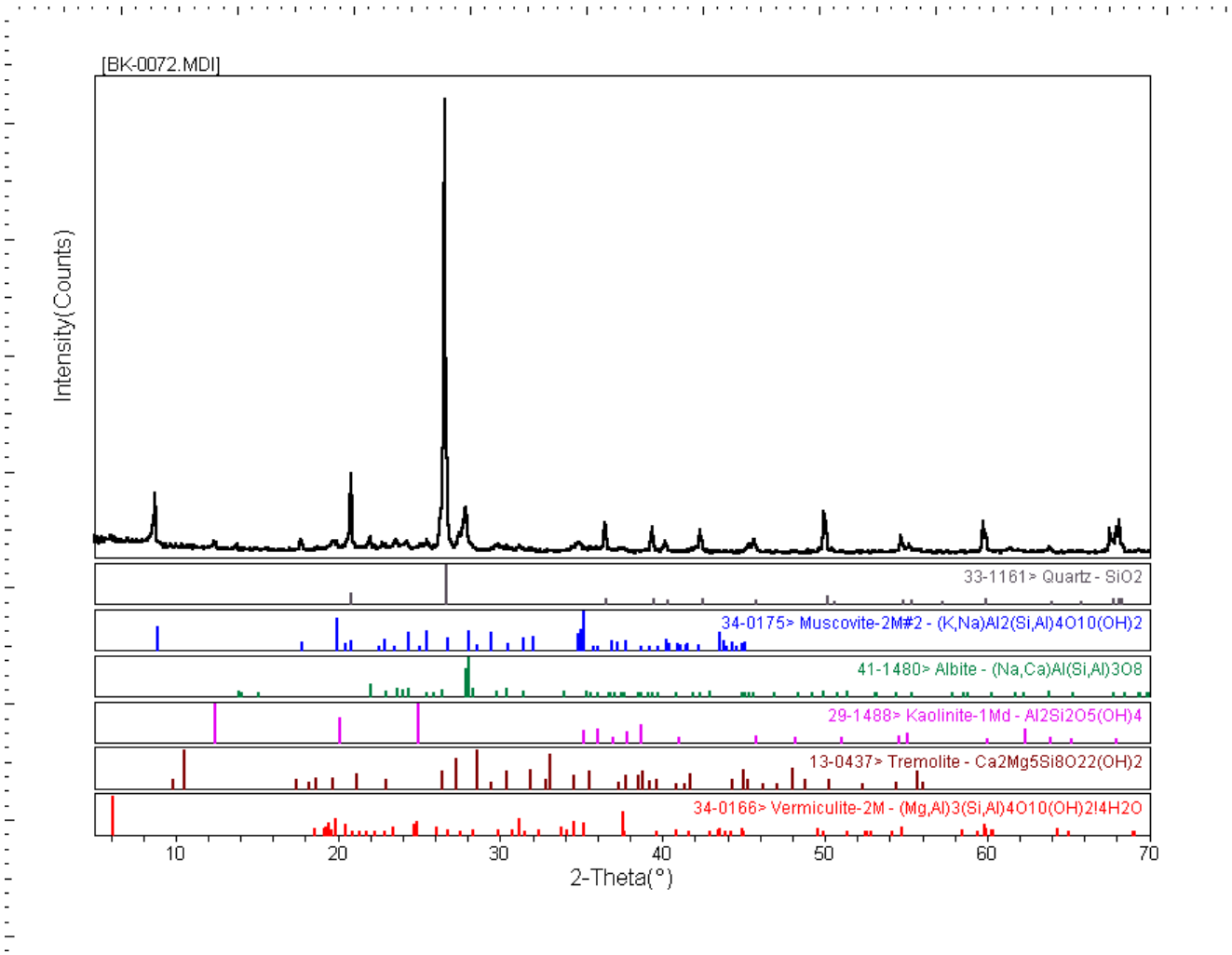

Fig. 51: XRD spectrum of sample BK-00072.

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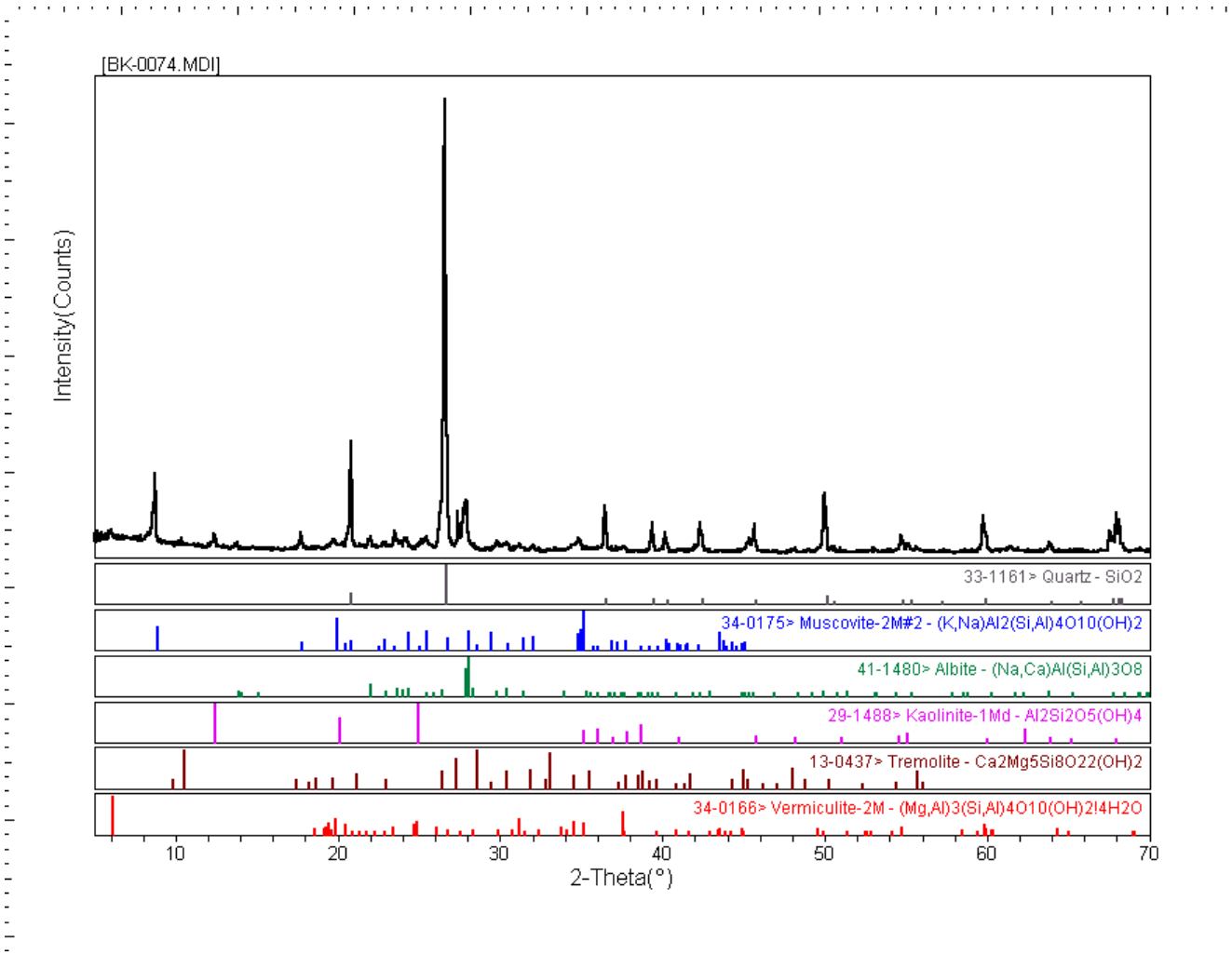

Fig. 52: XRD spectrum of sample BK-00074.

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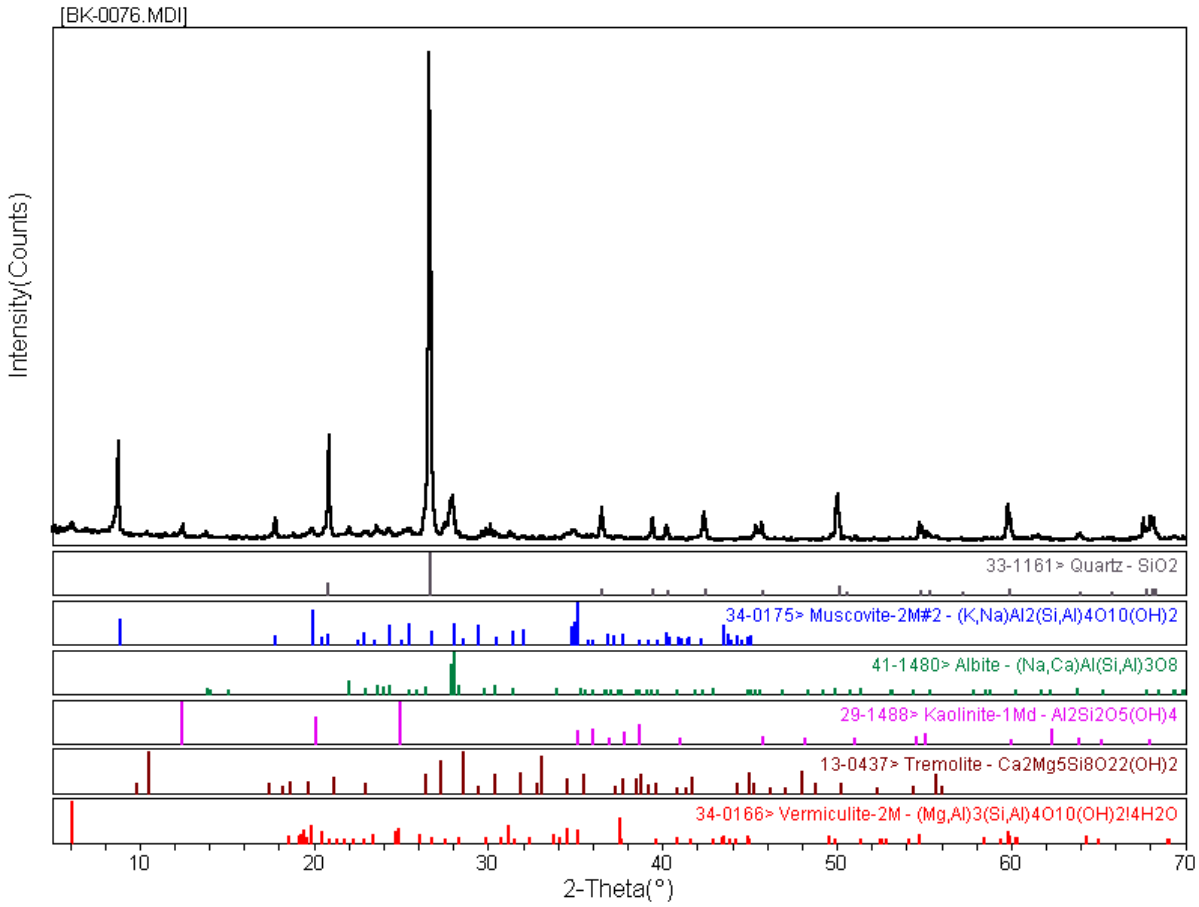

Fig. 53: XRD spectrum of sample BK-00076.

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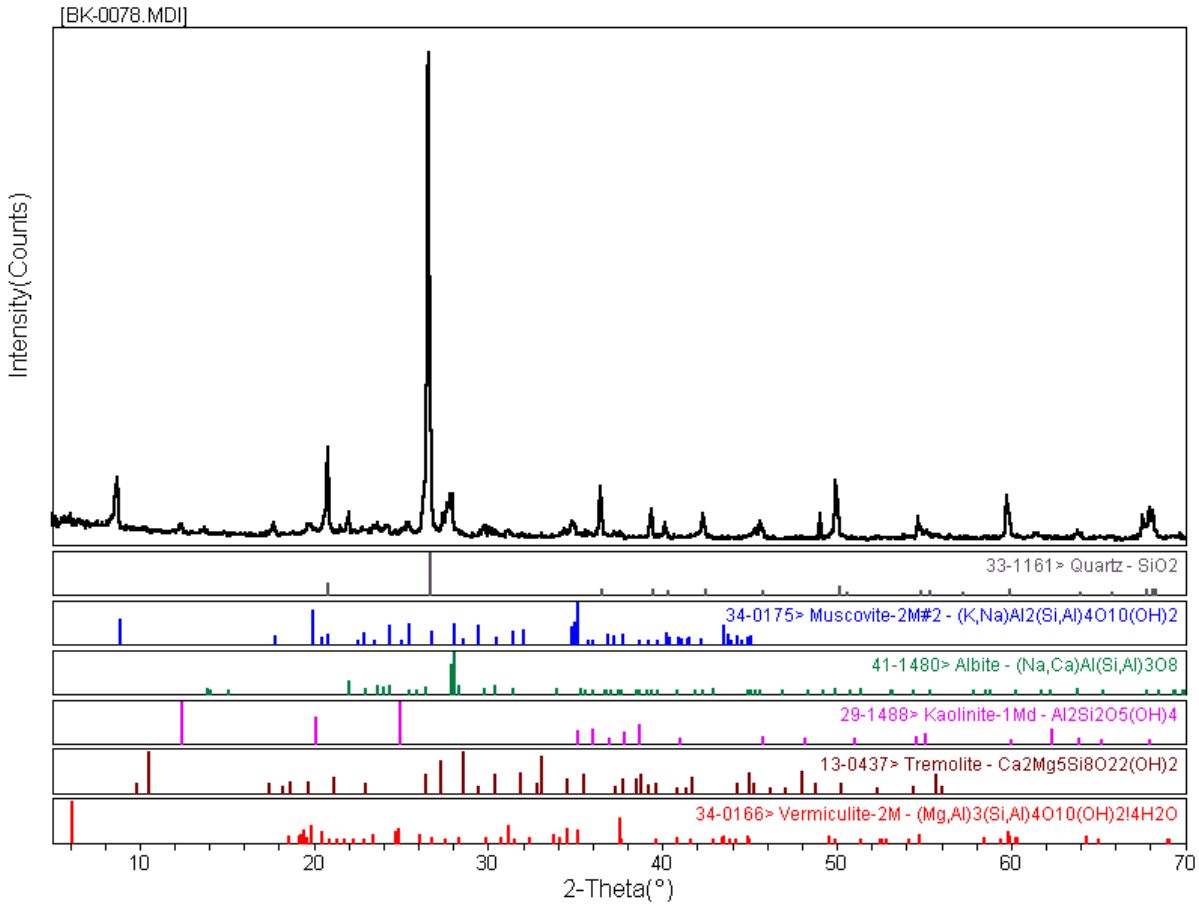

Fig. 54: XRD spectrum of sample BK-00078.

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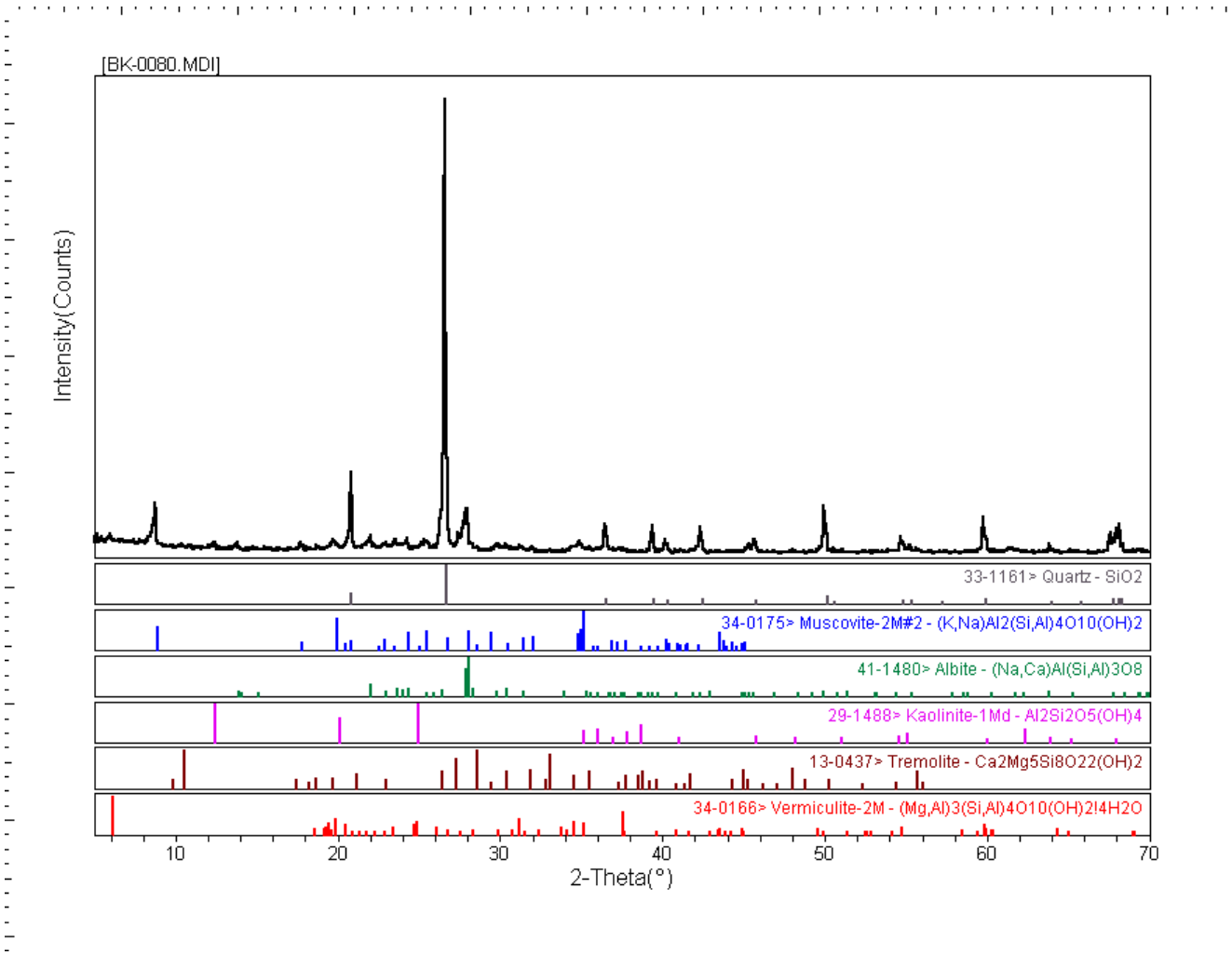

Fig. 55: XRD spectrum of sample BK-00080.

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Descriptions & Definitions:

None Detected (ND) denotes the absence of an analyte in the subsample analyzed. Trace levels of the analyte may be present in the sample below the limit of detection (LOD).

Limit of Detection (LOD): The minimum concentration that can be theoretically achieved for a given analytical procedure in the absence of matrix or sample processing effects. Particle analysis is limited to a single occurrence of an analyte particle in the sub-sample analyzed.

Limit of Quantitation (LOQ): The minimum concentration of an analyte that can be measured within specified limits of precision and accuracy during routine laboratory operating conditions

Terms, Conditions, and Limitations:

1. Sample Retention: Samples analyzed by EMSL will be retained for 60 days after analysis date. Storage beyond this period is available for a fee with written request prior to the initial 30 day period. Samples containing hazardous/toxic substances which require special handling may be returned to the client immediately. EMSL reserves the right to charge a sample disposal fee or return samples to the client.

2. Change Orders and Cancellation: All changes in the scope of work or turnaround time requested by the client after sample acceptance must be made in writing and confirmed in writing by EMSL. If requested changes result in a change in cost the client must accept payment responsibility. In the event work is cancelled by a client, EMSL will complete work in progress and invoice for work completed to the point of cancellation notice. EMSL is not responsible for holding times that are exceeded due to such changes.

3. Warranty: EMSL warrants to its clients that all services provided hereunder shall be performed in accordance with established and recognized analytical testing procedures and with reasonable care in accordance with applicable federal, state and local laws. The foregoing express warranty is exclusive and is given in lieu of all other warranties, expressed or implied. EMSL disclaims any other warranties, express or implied, including a warranty of fitness for particular purpose and warranty of merchantability.

4. Limits of Liability: In no event shall EMSL be liable for indirect, special, consequential, or incidental damages, including, but not limited to, damages for loss of profit or goodwill regardless of the negligence (either sole or concurrent) of EMSL and whether EMSL has been informed of the possibility of such damages, arising out of or in connection with EMSL's services thereunder or the delivery, use, reliance upon or interpretation of test results by client or any third party. We accept no legal responsibility for the purposes for which the client uses the test results. EMSL will not be held responsible for the improper selection of sampling devices even if we supply the device to the user. The user of the sampling device has the sole responsibility to select the proper sampler and sampling conditions to insure that a valid sample is taken for analysis. Any resampling performed will be at the sole discretion of EMSL, the cost of which shall be limited to the reasonable value of the original sample delivery group (SDG) samples. In no event shall EMSL be liable to a client or any third party, whether based upon theories of tort, contract or any other legal or equitable theory, in excess of the amount paid to EMSL by client thereunder.

36110012 2

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Lab: EMSL04
200 Route 130 North
Cinnaminson, NJ 08077

ESAT Region 8 / TECHLAW
LibbyFBASPrepLab/CO
Site #: 08BC
NoSamples: 40

No: BK-10001
Lab Contact: Charlie LaCerra
Lab Phone: 856-303-2540
DateShipped: 1/13/2011

Lab #	Sample #	Tag	Collected	Matrix	Sample Type	Analyses	COCTurnaround	COCTurnaroundUnits
	BK-00002	AL1	10/18/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00004	AL1	10/19/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00006	AL1	10/19/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00008	AL1	10/19/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00010	AL1	10/19/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00012	AL1	10/19/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00014	AL1	10/20/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00016	AL1	10/20/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00018	AL1	10/20/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00020	AL1	10/20/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00022	AL1	10/20/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00024	AL1	10/20/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00026	AL1	10/21/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00028	AL1	10/21/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00030	AL1	10/21/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00032	AL1	10/21/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00034	AL1	10/21/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00036	AL1	10/21/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00038	AL1	10/22/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00040	AL1	10/22/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day

Special Instructions: BK Mineralogical Suite consists of the following:
1. Soil Grain Size Analysis by Modified ASTM D422 (Percent clay, silt, and sand by sieve only / no hydrometry)
2. Petrographic Analysis by PLM-400 point count
3. Mineral identification and percentages by XRD Analysis via Modified NIOSH 9000

Please contact DOUG KENT (303)312-7725 with any questions.

SAMPLES TRANSFERRED FROM

CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
20	[illegible]	01/13/11	Ken Bleakley	1/17/11	9:10						

36110008122

Send To:
Lab: EMSL04
200 Route 130 North
Cinnaminson, NJ 08077

ESAT Region 8 / TECHLAW
LibbyFBASPrepLab/CO
Site #: 08BC
NoSamples: 40

No: BK-10001
Lab Contact: Charlie LaCerra
Lab Phone: 856-303-2540
DateShipped: 1/13/2011

Lab #	Sample #	Tag	Collected	Matrix	Sample Type	Analyses	COCTurnaround	COCTurnaroundUnits
	BK-00042	AL1	10/22/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00044	AL1	10/22/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00046	AL1	10/22/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00048	AL1	10/22/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00050	AL1	10/25/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00051	AL1	10/25/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00054	AL1	10/26/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00056	AL1	10/26/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00058	AL1	10/26/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00060	AL1	10/26/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00062	AL1	10/26/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00064	AL1	10/26/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00066	AL1	10/28/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00068	AL1	10/28/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00070	AL1	10/27/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00072	AL1	10/27/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00074	AL1	10/27/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00076	AL1	10/27/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00078	AL1	10/27/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day
	BK-00080	AL1	10/27/2010	Soil	Field Sample	BK Mineralogical Suite	10	Day

Special Instructions: BK Mineralogical Suite consists of the following:
1. Soil Grain Size Analysis by Modified ASTM D422 (Percent clay, silt, and sand by sieve only / no hydrometry)
2. Petrographic Analysis by PLM-400 point count
3. Mineral identification and percentages by XRD Analysis via Modified NIOSH 9000

Please contact DOUG KENT (303)312-7725 with any questions.

SAMPLES TRANSFERRED FROM

CHAIN OF CUSTODY #

Items/Reason	Relinquished by	Date	Received by	Date	Time	Items/Reason	Relinquished By	Date	Received by	Date	Time
20	D Spicher	01/13/11	K Beckley	1/17/11	9:10						

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Background Soil Summary Report
Libby Asbestos Superfund Site, Montana

Appendix C
Comparison of FBAS Filter Replicates by Study

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APPENDIX C.3. Between-Replicate Evaluation of the Comparative Exposure Study FBAS Soil Results

Location	Sample ID	Total LA									
		FBAS Replicate #1 (ESATR8)			FBAS Replicate #2 (Hygeia)			FBAS Replicate #3 (EMSL27)			Replicates that are statistically different
		Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	
Helena Area A	CX-00001	2E+04	1	2E+04	9E+04	0	0E+00	3E+04	0	0E+00	
Helena Area B	CX-00015	5E+04	0	0E+00	3E+04	0	0E+00	2E+04	0	0E+00	
Helena Area C	CX-00025	5E+04	0	0E+00	9E+04	0	0E+00	3E+04	0	0E+00	
Whitefish Area A	CX-00050	5E+04	0	0E+00	9E+04	0	0E+00	4E+04	0	0E+00	
Whitefish Area B	CX-00062	2E+04	0	0E+00	9E+04	0	0E+00	2E+04	0	0E+00	
Whitefish Area C	CX-00037	2E+04	0	0E+00	9E+04	1	9E+04	2E+04	0	0E+00	
Eureka Area A	CX-00093	2E+04	0	0E+00	9E+04	0	0E+00	2E+04	0	0E+00	
Eureka Area B	CX-00083	2E+04	0	0E+00	9E+04	1	9E+04	2E+04	0	0E+00	
Eureka Area C	CX-00072	9E+04	1	9E+04	5E+05	1	5E+05	4E+04	0	0E+00	
			mean:	**1E+04**			**7E+04**			**0E+00**	

ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/g = structures per gram

APPENDIX C.3. Between-Replicate Evaluation of the Comparative Exposure Study FBAS Soil Results (cont.)

Location	Sample ID	PCME LA									
		FBAS Replicate #1 (ESATR8)			FBAS Replicate #2 (Hygeia)			FBAS Replicate #3 (EMSL27)			Replicates that are statistically different
		Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	
Helena Area A	CX-00001	9E+03	0	0E+00	4E+04	0	0E+00	1E+04	0	0E+00	
Helena Area B	CX-00015	2E+04	0	0E+00	1E+04	0	0E+00	7E+03	0	0E+00	
Helena Area C	CX-00025	2E+04	0	0E+00	4E+04	0	0E+00	1E+04	0	0E+00	
Whitefish Area A	CX-00050	2E+04	0	0E+00	4E+04	0	0E+00	2E+04	0	0E+00	
Whitefish Area B	CX-00062	9E+03	0	0E+00	4E+04	0	0E+00	7E+03	0	0E+00	
Whitefish Area C	CX-00037	9E+03	0	0E+00	4E+04	2	7E+04	7E+03	0	0E+00	1<2 2>3
Eureka Area A	CX-00093	9E+03	0	0E+00	4E+04	0	0E+00	7E+03	0	0E+00	
Eureka Area B	CX-00083	9E+03	0	0E+00	4E+04	0	0E+00	9E+03	0	0E+00	
Eureka Area C	CX-00072	4E+04	1	4E+04	2E+05	0	0E+00	2E+04	0	0E+00	
				4E+03			**8E+03**			**0E+00**	

ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-eq
s/g = structures per gram

APPENDIX C.2. Between-Replicate Evaluation of Libby City Pit FBAS Soil Results

Location	Sample ID	Total LA									
		FBAS Replicate #1 (ESATR8)			FBAS Replicate #2 (Hygeia)			FBAS Replicate #3 (EMSL04)			Replicates that are statistically different
		Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	
Libby City Pit	FM-00013	2E+04	0	0E+00	3E+04	1	3E+04	2E+04	3	6E+04	
	FM-00014	9E+04	10	9E+05	9E+04	16	1E+06	2E+05	1	2E+05	1>3 2>3
	FM-00015	9E+04	19	2E+06	9E+04	18	2E+06	1E+05	4	4E+05	1>3 2>3
	FM-00016	9E+04	12	1E+06	9E+04	19	2E+06	1E+05	9	9E+05	
	FM-00017	5E+04	7	3E+05	9E+04	20	2E+06	5E+04	1	5E+04	1<2 1>3 2>3
	FM-00018	5E+04	16	8E+05	9E+04	6	6E+05	5E+04	3	1E+05	1>3
	FM-00019	5E+04	5	2E+05	9E+04	10	9E+05	1E+05	3	3E+05	1<2
	FM-00020	5E+04	7	3E+05	9E+04	4	4E+05	5E+04	5	2E+05	
			mean:	**3E+05**			**6E+05**			**3E+05**	

ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/g = structures per gram

APPENDIX C.2. Between-Replicate Evaluation of Libby City Pit FBAS Soil Results (cont.)

Location	Sample ID	PCME LA									
		FBAS Replicate #1 (ESATR8)			FBAS Replicate #2 (Hygeia)			FBAS Replicate #3 (EMSL04)			Replicates that are statistically different
		Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	
Libby City Pit	FM-00013	8E+03	0	0E+00	1E+04	0	0E+00	8E+03	0	0E+00	
	FM-00014	4E+04	13	5E+05	4E+04	15	6E+05	6E+04	0	0E+00	1>3 2>3
	FM-00015	4E+04	16	6E+05	4E+04	14	5E+05	4E+04	8	3E+05	
	FM-00016	4E+04	7	3E+05	4E+04	19	7E+05	4E+04	6	2E+05	1<2 2>3
	FM-00017	2E+04	9	2E+05	4E+04	15	6E+05	2E+04	1	2E+04	1<2 1>3 2>3
	FM-00018	2E+04	10	2E+05	4E+04	2	7E+04	2E+04	3	6E+04	
	FM-00019	2E+04	8	2E+05	4E+04	6	2E+05	4E+04	3	1E+05	
	FM-00020	2E+04	7	1E+05	4E+04	2	7E+04	2E+04	6	1E+05	
				1E+05			**1E+05**			**1E+05**	

ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast micros
s/g = structures per gram

APPENDIX C.1. Between-Replicate Evaluation of 2011 Libby Borrow Source FBAS Soil Results

Borrow Source	Event	Sample ID	Total LA									
			FBAS Replicate #1 (Hygeia)			FBAS Replicate #2 (RESI)			FBAS Replicate #3 (EMSL27*)			Replicates that are statistically different
			Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	
Boothman Pit	Event 1	EX-30112	3E+04	3	9E+04	9E+04	0	0E+00	2E+04	0	0E+00	
	Event 2	EX-30118	2E+04	4	6E+04	9E+04	6	5E+05	5E+04	1	5E+04	1<2 2>3
	Event 3	EX-30125	2E+04	6	9E+04	4E+04	7	3E+05	5E+04	0	0E+00	1<2 2>3
Noble Ranch House Pit #1	Event 1	EX-30469	3E+04	2	6E+04	2E+04	3	6E+04	3E+04	0	0E+00	
	Event 2	EX-30472	3E+04	1	3E+04	2E+04	4	9E+04	2E+04	0	0E+00	
	Event 3	EX-30475	9E+04	3	3E+05	9E+04	3	3E+05	5E+04	1	5E+04	
Fink Pit	Event 1	EX-30479	9E+04	0	0E+00	9E+04	5	4E+05	1E+05	0	0E+00	1<2 2>3
	Event 2	EX-30482	9E+04	4	4E+05	7E+04	2	1E+05	5E+04	3	1E+05	
	Event 3	EX-30485	9E+04	2	2E+05	5E+04	7	3E+05	1E+05	0	0E+00	
Feller Pit	Event 1	EX-30489	9E+04	11	1E+06	4E+04	50	2E+06	9E+04	9	8E+05	1<2 2>3
	Event 2	EX-30492	3E+04	7	2E+05	3E+04	51	1E+06	5E+04	0	0E+00	1<2 1>3 2>3
	Event 3	EX-30495	9E+04	6	6E+05	9E+04	19	2E+06	9E+04	6	5E+05	1<2 2>3
Valley View Pit (Eureka, MT)	Event 1	EX-30459	3E+04	0	0E+00	4E+04	0	0E+00	1E+04	0	0E+00	
	Event 2	EX-30460	9E+04	0	0E+00	7E+04	0	0E+00	9E+04	0	0E+00	
	Event 3	EX-30461	9E+04	0	0E+00	9E+04	0	0E+00	5E+04	0	0E+00	
				mean:	**2E+05**			**5E+05**			**1E+05**	

ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/g = structures per gram

**Replicate #3 for samples EX-30489 and EX-30495 were analyzed by ESATR8*

APPENDIX C.1. Between-Replicate Evaluation of 2011 Libby Borrow Source FBAS Soil Results (cont.)

Borrow Source	Event	Sample ID	PCME LA									
			FBAS Replicate #1 (Hygeia)			FBAS Replicate #2 (RESI)			FBAS Replicate #3 (EMSL27*)			Replicates that are statistically different
			Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	
Boothman Pit	Event 1	EX-30112	1E+04	3	4E+04	4E+04	0	0E+00	1E+04	0	0E+00	
	Event 2	EX-30118	6E+03	3	2E+04	4E+04	8	3E+05	2E+04	0	0E+00	1<2 2>3
	Event 3	EX-30125	6E+03	5	3E+04	2E+04	2	4E+04	2E+04	1	2E+04	
Noble Ranch House Pit #1	Event 1	EX-30469	1E+04	0	0E+00	6E+03	1	6E+03	1E+04	0	0E+00	
	Event 2	EX-30472	1E+04	0	0E+00	9E+03	2	2E+04	9E+03	0	0E+00	
	Event 3	EX-30475	4E+04	4	1E+05	4E+04	1	4E+04	2E+04	1	2E+04	1>3
Fink Pit	Event 1	EX-30479	4E+04	0	0E+00	3E+04	2	5E+04	4E+04	0	0E+00	
	Event 2	EX-30482	4E+04	4	1E+05	3E+04	1	3E+04	2E+04	1	2E+04	1>3
	Event 3	EX-30485	4E+04	3	1E+05	2E+04	2	4E+04	4E+04	0	0E+00	
Feller Pit	Event 1	EX-30489	4E+04	8	3E+05	4E+04	1	4E+04	4E+04	5	2E+05	1>2
	Event 2	EX-30492	1E+04	8	1E+05	3E+04	13	3E+05	2E+04	0	0E+00	1<2 1>3 2>3
	Event 3	EX-30495	4E+04	2	7E+04	4E+04	5	2E+05	4E+04	5	2E+05	
Valley View Pit (Eureka, MT)	Event 1	EX-30459	1E+04	0	0E+00	1E+04	0	0E+00	5E+03	0	0E+00	
	Event 2	EX-30460	4E+04	0	0E+00	3E+04	0	0E+00	4E+04	0	0E+00	
	Event 3	EX-30461	4E+04	0	0E+00	2E+04	0	0E+00	2E+04	0	0E+00	
					6E+04			**7E+04**			**3E+04**	

ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/g = structures per gram

APPENDIX C.4. Between-Replicate Evaluation of the 2012 Troy Background Study Soil Results

Location	Sample ID	Total LA									
		FBAS Replicate #1 (Hygeia*)			FBAS Replicate #2 (EMSL27)			FBAS Replicate #3 (ESATR8)			Replicates that are statistically different
		Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	
Shannon Flats, East	TK-00011	1E+05	1	1E+05	2E+04	0	0E+00	9E+04	0	0E+00	
Garrison Road, County Gravel Pit	TK-00027	5E+05	0	0E+00	2E+04	0	0E+00	5E+05	0	0E+00	
Airport Gravel Pit	TK-00031	9E+04	0	0E+00	2E+04	0	0E+00	2E+05	3	7E+05	1<3 2<3
East Side Road Forest Service #2	TK-00039	9E+04	5	5E+05	4E+04	0	0E+00	5E+05	6	3E+06	1>2 1<3 2<3
Cornwell Gravel Pit	TK-00043	5E+05	0	0E+00	5E+04	0	0E+00	5E+05	0	0E+00	
			mean:	**1E+05**			**0E+00**			**7E+05**	

ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equivalent
s/g = structures per gram

**Filter replicate #1 for sample TK-00011 was analyzed by EMSL22*

APPENDIX C.4. Between-Replicate Evaluation of the 2012 Troy Background Study Soil Results (cont.)

Location	Sample ID	PCME LA									
		FBAS Replicate #1 (Hygeia*)			FBAS Replicate #2 (EMSL27)			FBAS Replicate #3 (ESATR8)			Replicates that are statistically different
		Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	Sensitivity (1/g)	No. of Structures	Conc. (s/g)	
Shannon Flats, East	TK-00011	4E+04	0	0E+00	9E+03	0	0E+00	4E+04	1	4E+04	
Garrison Road, County Gravel Pit	TK-00027	2E+05	0	0E+00	9E+03	0	0E+00	2E+05	1	2E+05	2<3
Airport Gravel Pit	TK-00031	4E+04	0	0E+00	9E+03	0	0E+00	9E+04	2	2E+05	2<3
East Side Road Forest Service #2	TK-00039	4E+04	8	3E+05	2E+04	0	0E+00	2E+05	1	2E+05	1>2
Cornwell Gravel Pit	TK-00043	2E+05	0	0E+00	2E+04	0	0E+00	2E+05	1	2E+05	
				6E+04			**0E+00**			**2E+05**	

ID = identification
LA = Libby amphibole asbestos
PCME = phase contrast microscopy-equiv
s/g = structures per gram