Identification and Characterization of Coal and Coal By-Products Containing High Rare Earth Element Concentrations

Northern and Central Appalachia Coal Basins

Final Report

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TABLE OF CONTENTS

LIST OF PHOTOGRAPHS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1.0 INTRODUCTION

Rare earth elements as defined for the scope of this project are rare earth elements plus yttrium and scandium (REE+Y+Sc) are strategically important metals to the United States since their unique magnetic, phosphorescent, and catalytic properties are essential in the manufacturing of numerous products for defense, medical technology and consumer electronics such as high-strength magnets, high performance batteries, alloys, glass, ceramics, catalysts and other applications. REE+Y+Sc's include a group of fifteen chemically similar lanthanide elements, plus scandium and yttrium with similar properties. The Department of Energy (DOE) has been investigating the economic feasibility of recovering REE+Y+Sc's from domestic U.S. coal and coal by-products. Tetra Tech Inc. (Tetra Tech) was engaged by the DOE's National Energy Technology Laboratory (NETL) to collect and characterize REE+Y+Sc-bearing samples of coal and coal associated materials in West Virginia and Pennsylvania that lie in the northern and central Appalachian coal basins. Tetra Tech partnered with the West Virginia Geological and Economic Survey (WVGES) and the Pennsylvania Department of Environmental Protection's Bureau of Abandoned Mine Reclamation (PaBAMR) in this project. The WVGES has a long history of investigating the State's coal resources. PaBAMR is responsible for reclaiming Pennsylvania abandoned mines and has access to many coal resources.

Prior research has indicated that REE+Y+Sc's accumulate via chemical and physical processes in clays and near coal/clay interfaces in the eastern US coal basins. Some of the coals also contain elevated concentrations of REE+Y+Sc's. If it can be demonstrated that economically viable sources of REE+Y+Sc may be present in coal and/or its associated rocks and waste products, the reliance on foreign sources of REE+Y+Sc's can be minimized. Currently the United States imports 100 % of REE+Y+Sc's consumed. This totals approximately 17,000 metric tons per year. At present approximately 90% of the US REE+Y+Sc supply is provided by China. Developing a domestic source of REE+Y+Sc production would lessen the US dependence on a single source foreign supply. In identifying a source from domestic coal and associated materials an additional revenue stream may be available for current and future coal mining operations. Further, in most mining operations, the extraction and amassing of the commodity represents the bulk of the mining expense. When REE+Y+Sc's are concentrated in coal waste rock, the additional expense of mining the REE+Y+Sc's would likely be low, as the coal is already being mined, whether or not the REE+Y+Scs are utilized. Based on this scenario, the grade of REE+Y+Sc required for profitable exploitation would most likely be lower than that of a traditional REE+Y+Sc mine not associated with coal. To characterize the coal resources for REE+Y+Sc content the Tetra Tech team initially screened and sampled coals and coal associated materials that were considered to have a high probability of containing high REE+Y+Sc contents in West Virginia and Pennsylvania.

WVGES has an abundance of coal analytical data included in their Coal Bed Mapping Program (CBMP) data set. Coal quality data in the CBMP data sets include records of coal analyses for over 50,000 discrete samples. Many of these samples are still available in the WVGES storage files near Morgantown, WV. Selected samples were re-tested by our team for REE+Y+Sc Content. These samples include coal, in seam non coal materials, the roof, and floor materials. Based on the REE+Y+Sc data available from this data set, Tetra Tech and WVGES selected expected high REE+Y+Sc content areas for field sampling and testing in both the Northern and Central Appalachia coal fields in West Virginia.

In previous work, two distinct diapirs (an upward intrusion of rock into overlying materials, often resulting in a dome shaped structure) were identified in the Northern Appalachian basin in central Pennsylvania. There appeared to be an association with igneous materials from diapirs, and other igneous activity found in or adjacent to coal basins that contained elevated levels of REE+Y+Sc's. Therefore sites near these diapirs were selected for sampling to evaluate whether this relationship exists and if so, whether it can be used to screen for significant REE+Y+Sc concentrations. Pennsylvania Bureau of Abandoned Mine Reclamation (PaBAMR) has access to numerous abandoned mine lands in the area and provided Tetra Tech access to sample the appropriate coal seams and associated materials where available. Private coal interests also provided access to sampling in this vicinity as well as other locations in the Pennsylvania bituminous coal field. Additional sampling was conducted in both Pennsylvania and West Virginia to correlate findings within coal seams and similar geologic settings and where approvals from owners were obtained.

2.0 BACKGROUND

Tetra Tech's has previously conducted REE+Y+Sc research, most notably, for the *Assessment of Rare Earth Elemental Contents in Select United States Coal Basins* (Bryan et al, 2015) with Leonardo Technologies Inc., which developed methods for predicting where high concentrations of REE+Y+Sc's exist, defining controls and occurrences of REE+Y+Sc averages over total coal seams and providing quantitative estimates of REE+Y+Sc resources based on geostatistics. This previous experience, in addition to the team's extensive work in the geographical region, provided Tetra Tech's team with a strong understanding of the potential locations for REE+Y+Sc sampling in this project.

3.0 FIELD AND LAB METHODOLOGY

3.1 SAMPLING PROCEDURE

The purpose of this project was to sample coal and coal related materials to characterize Northern and Central Appalachian coal resources having REE+Y+Sc's. Finding and describing areas of the coal basin that have a minimum concentration of 300 parts per million (ppm) REE+Y+Sc's as the material is removed from the ground, with no processing other than drying was the goal. Coal and coal-related materials are defined as run-of-mine coal; roof rock; overburden; shale/clay partings; mine floor underclays/shales; coal preparation plant refuse; etc.; and other coal-like materials as mined.

3.1.1 Sample Collection

The Tetra Tech team used the USGS "Field Description and Sampling of Coal Beds" by James M. Schopf, 1960, Geological Survey Bulletin 1111-B, procedure to collect samples for each location. Separate samples taken included the coal benches, roof and floor rock, partings, and any other higher ash lithotypes (bone, bony coal, laminated coal, and coaly shale intervals). In addition to the physical samples taken, each exposure was, described in detail, and the geographic coordinates of each sample were recorded via GPS (surface samples). For underground samples collected in active mines, latitude and longitude were obtained for each sampling point from the operator. Sample sizes collected were small, typically 2-4 pounds and placed in one gallon-sized zip lock style plastic bags. All samples were double bagged and a unique identification was written on the outside of each bag. An example of a sample location can be found in Photograph 1.

Photograph 1 - Example of Sample Location

Figure 1 shows the approximate boundary or transition between the northern and central basins. All samples taken to the north of the boundary are logged in Northern Appalachia, and all samples taken to the south of that route are identified as Central Appalachia samples.

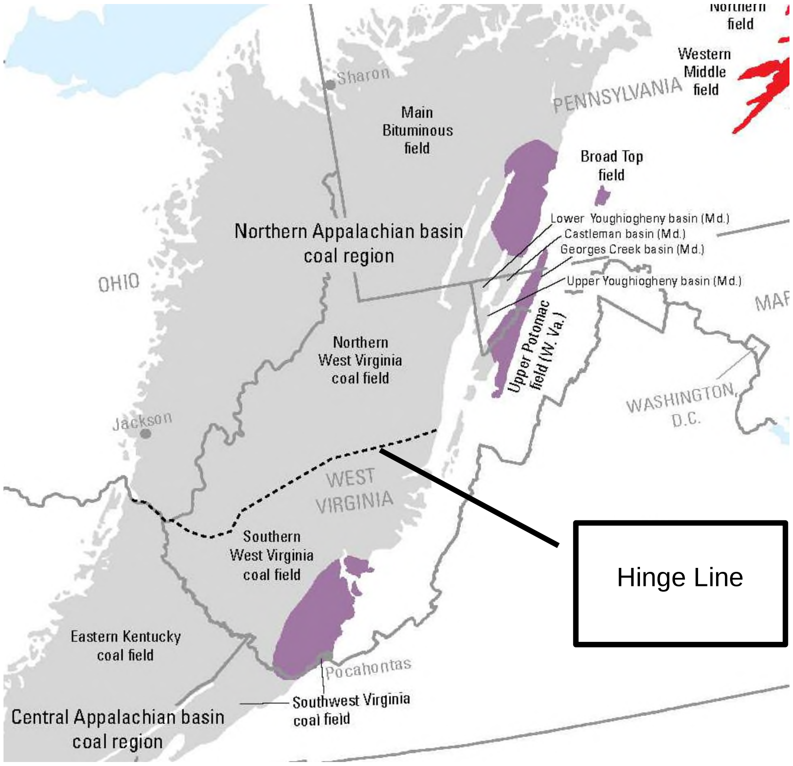


Figure 1 - Appalachian Boundaries (Rupert et Al, 2015) Dashed Line Shows Approximate Boundary between Northern and Central Appalachian Coal Basins

3.1.1.1 Sample Nomenclature

Each sample collected for analysis was assigned a unique sample tracking number and labeled. This number consisted of a two-segment alphanumeric code.

The alphanumeric sample tracking number used for samples is as follows:

Site Identifier: NA = Northern Appalachian

Sample: 001

An example of a sample identification would be "NA-012" which is sample number 12 collected from the Northern Appalachian Basin.

For samples provided by WVGES were identified as WVA-#### to signify samples provided from their extensive coal geologic archives, or WVGS-#### for samples collected from the field by WVGES staff for this project.

In many instances multiple samples were collected at one location, as a result alphanumeric location numbers were assigned at each sampling location. It is possible for multiple samples to be recorded under one location number.

The alphanumeric location number used was follows:

Region Identifier: A = Appalachia

Location: 001

An example follows in Table 1:

Table 1 - Location Name Example

Location	
Appalachia	A
Site	001
Sample	NA-012, NA-013, NA-014

3.1.1.2 Sample Shipping and Analysis

All samples were placed in one gallon-sized zip lock bags and placed in appropriate shipping containers. A completed COC form, placed in a zip lock bag, was included with each sample shipment. The samples were shipped to Nexus Geo, LLC of Thorton, Colorado for sample preparation. Once the samples were prepared they were sent to Dr. Javier Seravalli at the Spectrographic and metabolomics Laboratory at the University of Nebraska, Lincoln (UN-L) for the final analysis of REE+Y+Sc by Inductively Coupled Plasma Mass Spectrometry (ICP-MS).

Photograph 2 - Example of Sample Packaging

3.1.2 Quality Assurance/Quality Control

Quality Assurance/Quality Control (QA/QC) procedures applicable to this project included the following:

- Documentation for samples through chain-of-custody reports;
- Collection of field duplicate samples

A split of select field collected samples was processed as a field duplicate and analyzed by the laboratory for the same parameters as the associated geologic sample. Results of the duplicate analyses were used to evaluate precision, including variability in sample preparation and analysis. Duplicate samples were submitted at a frequency of 1 per 20 samples as per the USGS **“**Quality Assurance and Quality Control of Geochemical Data: A Primer for the Research Scientist” (Geboy, 2011).

Chain-of-Custody (COC)

To ensure the integrity of samples from collection through analysis, an accurate written record of possession and handling of the sample was completed. The chain-of-custody procedure began at the time of sample collection. The owner of the sample was considered anyone who is responsible for the sample. A sample was under custody if any of the following conditions applied

- It is in the owner’s actual possession.
- It is in the owner’s view, after being in his/her physical possession.
- It was in the owner’s possession and was locked or sealed to prevent tampering.
- It is in a secure area.

Custody documentation is designed to provide documentation of preparation, handling, storage, and shipping of samples collected. This documentation is referred to as the chain-of-custody form. When in shipment the sample will be sealed with a custody seal until it is transferred to its new owner.

Prior to shipment or relinquishing samples to the laboratory, the chain-of-custody form was checked for completeness and accuracy. The number of samples in the shipment container was checked against the number of samples indicated on the chain-of-custody form.

3.2 CHARACTERIZATION PLAN

The raw material collected in the field required processing and treatment prior to submittal to the ICP-MS analysis at the laboratory at the UN-L. The samples underwent cataloging, grinding, weighing, ashing, and extraction. The extract from each sample was submitted for ICP-MS analysis to determine rare earth elements. Data obtained from the lab analysis was provided to the owner that provided samples or sampling location.

3.2.1 Sample Preparation Steps

Nexus provided sample preparation and concentration services for this contract. Nexus followed the sample preparation and concentration procedures used to prepare samples for total REE+Y+Sc analysis by ICP-MS as outlined below.

3.2.2 Grinding

Field samples collected ranged from two to four pounds. These samples were delivered to Nexus in their entirety. Approximately one half of the sample was split and subjected to grinding in a rotary hammer mill. A small portion of raw sample was submitted to the mill first and then discarded. This is commonly referred to as the “pre-contamination” step and reduces cross contamination from previous ground samples. The remainder of the split was reduced to powder of approximately < 200 mesh. The remaining uncrushed split of the sample was retained and cataloged for the duration of the project as a back-up should additional testing be required.

3.2.3 Ashing

Ashing was carried out in an electric muffle furnace equipped with a proportional-integral/derivative/temperature controller in a well ventilated area. A working carbon monoxide monitor was present in the laboratory during all ashing. Proper personal protective equipment such as insulated gloves, apron, and eye-wear was used by the operator. Heated samples were only removed utilizing metal tongs of adequate length. The furnace is equipped with an automatic cut-off switch that is activated when the door is open.

3.2.3a Weighing: A weighed 35 to 50 gram split of the ground sample was ashed in an electric muffle furnace following the temperature recommendations as stated in ASTM D4503-08. In this procedure, a sample is placed in a pre-weighed ceramic crucible with a ceramic cover.

3.2.3b Pre-Heating: The crucible was then placed in a furnace preheated to 300°C.

3.2.3c Heating: The temperature was then increased to 550°C by the end of one hour. Held sample temperature at 550°C for a minimum of 5 hours.

3.2.3d Calculations: When calculating the percent ash in the sample, the following formula was applied:

$$\text{Ash in sample, \%} = [(A-B)/C] \times 100$$

When calculating mass loss percentage of the sample, the following formula was applied:

$$\text{Mass Loss in sample, \%} = 100 - \text{Ash \%}$$

Where: A = weight of crucible, cover, and ash residue in grams

B = weight of empty crucible and cover in grams, and

C = weight of pre-ashed sample used in grams

If the mass loss was less than 25 %, the non-ashed sample was processed in accordance with Section 3.2.4.1. If mass loss was greater than 25%, the ashed sample was processed in accordance with Section 3.2.4.2.

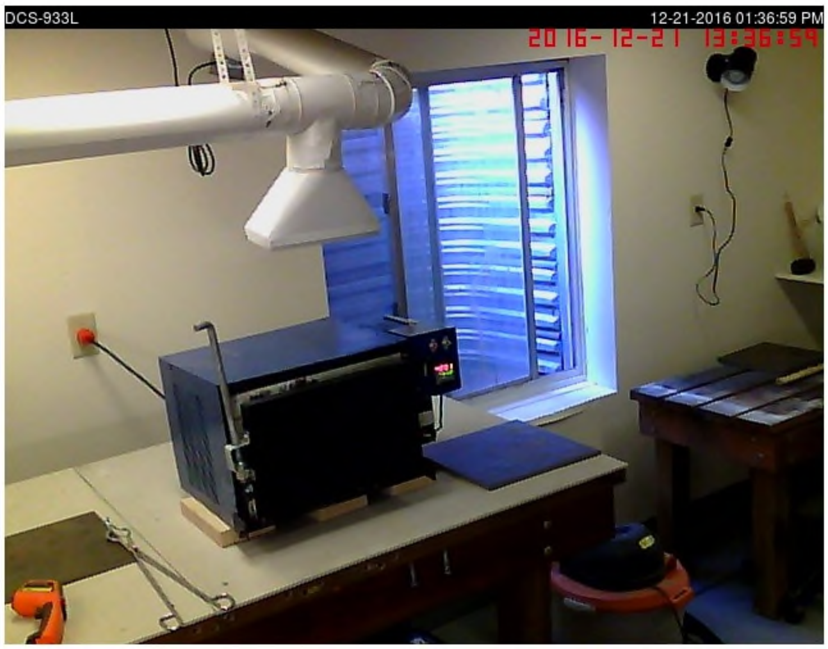
3.2.4 Alkali Fusion Solubilization or Multi-Acid Digestion

Nexus utilized alkali fusion methods to dissolve the REE+Y+Sc in collected samples prior to submitting the material to the UN-L ICP-MS laboratory. This method is described below.

3.2.4.1 Alkali Fusion Solubilization

This method can be employed for a large number of samples for analysis by X-ray fluorescence (XRF), inductively coupled plasma (ICP), and other analytical techniques and followed ASTM D4503-08 procedures. Borate fusion is a widely used sample preparation method in which an oxidized sample is dissolved in molten flux at temperatures of around 1050°C.

Samples were mixed with a flux of lithium metaborate ($LiBO_2$, m.p. ~845°C). The sample/flux mixture was heated until the flux is disintegrated or is solubilized, yielding a melt that was homogeneous at the atomic level and was dissolved in HNO_3 or HCl for ICP analysis.



Photograph 3 - Samples Undergoing Lithium Metaborate Fluxing in Graphite Crucibles in a Muffle Furnace

3.2.4.2 Multi-Acid Digestion

The coal and coal related materials analyzed was ashed as described in Section 3.2.3 of this plan. As a back-up method for sample preparation, the ash would be subjected to a multi-acid digestion as defined in ASTM D 6357-11, in the event that fluxing proved to be inadequate. Under the plan the ash would be subjected to a multi-acid digestion as defined in ASTM D6357-11. This method would utilize an initial digestion with Aqua regia followed by the addition of HF (hydrofluoric acid). Upon completion, the sample would be re-dissolved in 1% HNO_3 (nitric acid). Ash samples would be digested and diluted to 50 ml before being submitted to the UN-L lab for ICP-MS analysis. All digestions would be performed under the fume hood. The analyst wore the proper PPE such as safety googles, chemical resistant gloves, lab coat, and a chemical filter mask. Fluxing, however proved to be effective and therefore, multi-acid digestion has not been applied to the samples in the study.

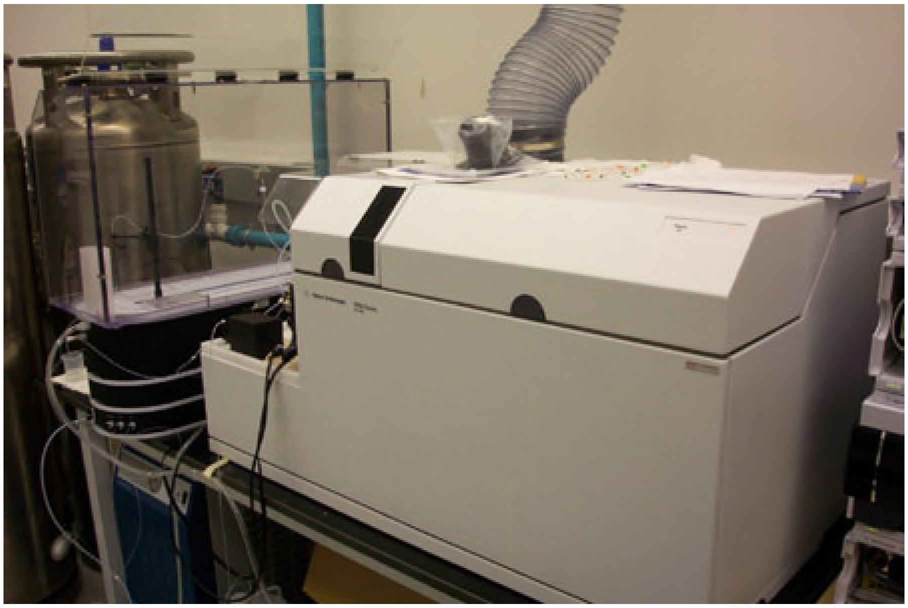
Nexus preparation laboratory is shown in Photograph 4 and 5.

Photograph 4 - Nexus Preparation Laboratory

Photograph 5 - Nexus Preparation Laboratory

3.2.1 ICP-MS Analysis and Data Integrity

REE data was generated utilizing ICP-MS analysis on a unit housed and operated by the Spectroscopy and Biophysics Core at the University of Nebraska, Lincoln, NE. Photograph 6 shows the Argillent 7500cx system in use at the lab.



Photograph 6 - ICP-MS Instrument – Spectroscopy and Biophysics Core
University of Nebraska, Lincoln

As part of the quality control and assessment of data integrity, NEXUS included "blind duplicates" to the lab to check precision of the lab and the methods employed. A duplicate sample generally was submitted for every 20 samples. In addition, the ICP-MS lab injected every sample at least 2 times to maintain a check on instrument precision. NEXUS also included a sample of the Iron Hill Carbonatite from the Powderhorn area of Colorado with each batch to check on the accuracy of the analytical run. As reported by Van Gosen, 2008, the median value for total REE from the Carbonatite Dikes was 3,079 ppm and for Cerium, 1,410 ppm. His analysis was conducted at the SGM Mineral Resources of Toronto, Canada utilizing inductively coupled plasma-atomic emission spectroscopy (ICP-AES). NEXUS utilized ICP-MS, but found the results to be comparable, at least to the level that they could ascertain that the University of Nebraska Lab values were in agreement with the published values. NEXUS, based on 22 individual ICP-MS analyses calculated a median Powderhorn sample value of 3,456.9 ppm total REE and a median value of 1,617 ppm for cerium.

Whenever the laboratory noted a decrease in instrument sensitivity, they would perform the required maintenance to retune the machine and then re-inject the samples. On two occasions, (January, 2017 and December, 2017) the lab did not identify the decrease in sensitivity. However, as NEXUS had included the Powderhorn sample, it was possible to normalize the lab's reported results after the fact by comparing the individual REE values from the reported Powderhorn sample and adjusting the individual REE values of all the samples based on the ratio of the calculated medians from all valid Powderhorn analyses to the batch Powderhorn sample.

4.0 SITE SELECTION

This section presents a condensed discussion of Appalachian coal stratigraphy studied in this report. A full length discussion is contained in Appendix B.

4.1 BASIN DISCUSSION

Pennsylvanian coal fields of Pennsylvania and West Virginia, and by default the entire Appalachian basin, have been divided into an older southern, low-sulfur field known as Central Appalachia Coal Basin and the younger, northern, high-sulfur field known as Northern Appalachia Basin based on regional variations in coal quality, rank, and age (Figure 1). The older, southern coal field comprises mainly Early and Middle Pennsylvanian-aged strata whereas the northern coal field comprises mainly uppermost Middle and Late Pennsylvanian (and earliest Permian) strata. The hinge lines separate the southern and northern coal fields (Figure 1).

4.1.1 Pennsylvania Coal Basins

The main bituminous coal field of the Northern Appalachian basin extends north from the hinge line in central West Virginia into western Pennsylvania (Figure 1). The same general sequence of coal bearing rocks shown in the stratigraphic column in Figure 2, is with some minor exceptions, also indicative of the coal geology of Pennsylvania. The two states use the same nomenclature for many of the key marker beds, but differ in some details, and some minor beds are present in one state but absent from the other. Many of the commercially important coal beds in the Northern Appalachian basin can be traced and correlated over large distances, which promotes consistent regional characterization. Ruppert et al (2014) provide discussion and a stratigraphic sequence correlation chart across the Appalachian coal region that shows the similarity in sequence and nomenclature across northern West Virginia, Maryland and western Pennsylvania. Depositional settings and structural features, such as folding, are also similar across the northern basin. Therefore the discussion of geologic conditions and influence on REE deposition and occurrence is applicable across the northern Appalachian basin.

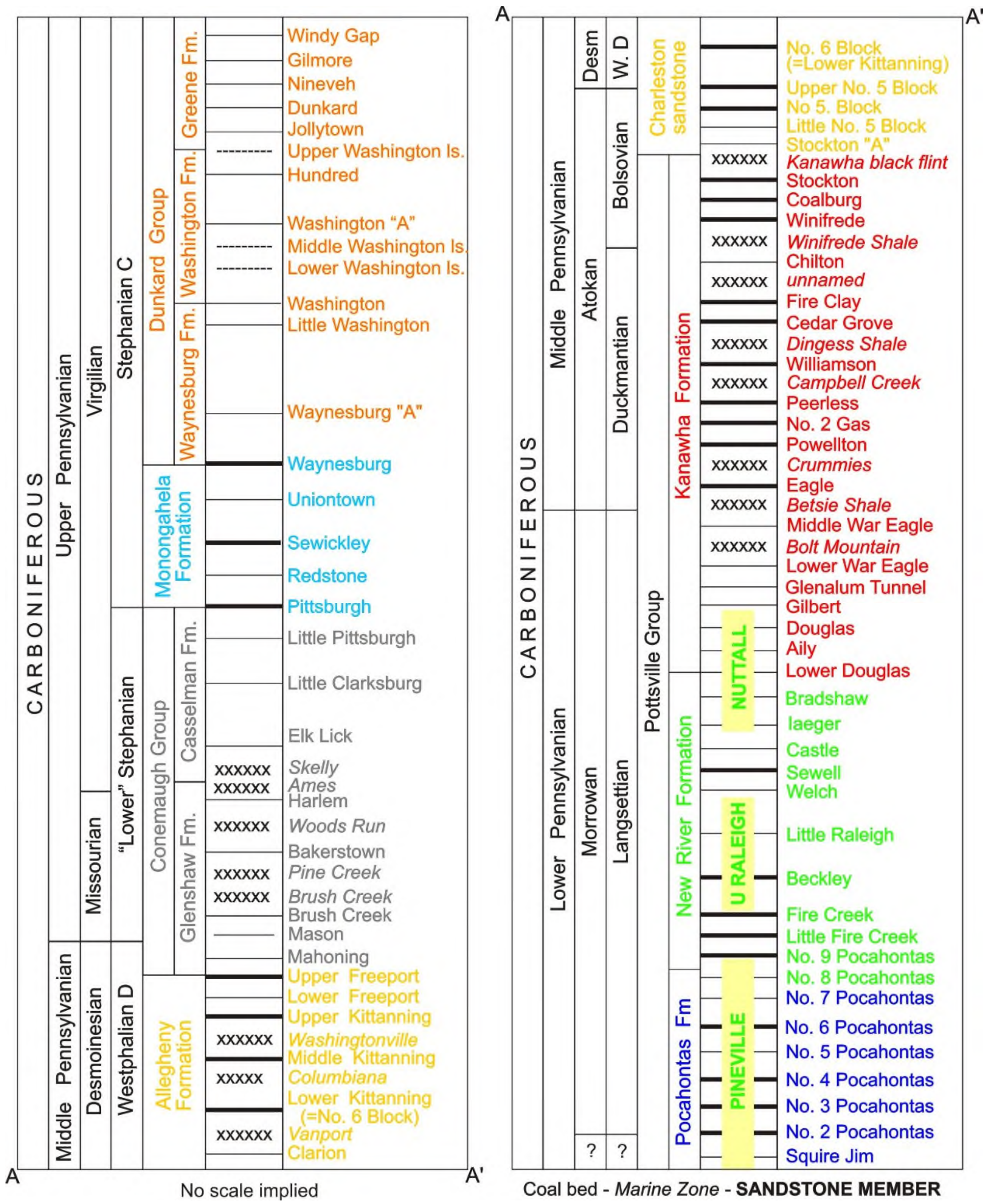


Figure 2 - Stratigraphic column of Pennsylvanian coal beds, marine zones, and other units

Subsidence in the Appalachian region associated with mountain building to the south and east provided space for the accumulation of coal-bearing rocks that thin to the northwest. Thickness trends in the basin fill suggest that only part of the original sequence of rocks is preserved. Some rocks were uplifted and subsequently removed by erosion. The relevant coal bearing stratigraphy is summarized in figure 2 for the northern and southern fields using West Virginia nomenclature.

4.1.2 Southern West Virginia Coal Field

The rocks of the southern coal field are mainly assigned to the coal-bearing Pottsville Group. In areas of maximum development in southern West Virginia, the Pottsville Group reaches a preserved thickness of approximately 1250 m (4000 feet) and is subdivided into the Lower Pennsylvanian Pocahontas and New River formations and the Lower and Middle Pennsylvanian Kanawha Formation (Figure 2). The Pottsville thins northward to approximately 110 m (350 feet) thick in northernmost West Virginia.

Pocahontas Formation: The Pocahontas formation consists of sandstones with lesser amounts of siltstones, shales, mudstones, and coal beds deposited in a series of coalescing delta lobes and associated coastal plain facies. Regionally, the Pocahontas Formation thins north and northwestward from a maximum thickness of approximately 215 m in southern West Virginia and adjacent areas, wedging out in approximately 48 km (Englund 1974, Englund and Thomas 1990). Pocahontas Formation coal beds are generally low and mid-volatile bituminous in rank and have been widely mined for metallurgical purposes. The Pocahontas Nos. 2, 3, 4, and 6 and associated splits contain the main original resources with the Poca No. 3 being the most aerially widespread and heavily mined. Available REE values suggest generally variable background concentrations with no target areas located.

New River Formation: The Lower Pennsylvanian New River Formation (Figure 2) extends upward from the base of the Pocahontas No. 8 coal bed to the base of the Lower Douglas (?) coal bed of Hennen and Teets (1919) (Arndt 1979, Englund 1979), reaching a maximum preserved thickness of over 305 m (1000 feet) in its southern outcrop area and thinning to the north and west. The New River Formation consists of quartz rich sandstones with lesser amounts of siltstones, shales, mudstones, and coal beds. In many areas thick, lenticular quartz rich sandstones are prominent. The New River Formation thins rapidly to the north and northwest until in northern parts of the Appalachian region it is absent or unrecognizable.

Coal beds are generally mid-volatile bituminous in rank and have been widely mined for steam generation and metallurgical purposes. The Fire Creek, Beckley and Sewell beds contain the largest original resources and have been widely mined. Significant original resources were also present in the Little Fire Creek, Welch, and Iaeger beds. Investigated samples contain varying background concentrations of REEs and no special target areas identified.

Kanawha Formation: The Lower (as defined in Blake et al., 2002) and Middle Pennsylvanian Kanawha Formation is a coal-bearing sequence of sandstones, siltstones, shales, and mudstones with minor occurrences of siderite, limestone, and flint clay (Figure 2). A maximum preserved thickness of more than 613 m is present in southern West Virginia (Arkle *et al*. 1979, Blake *et al*. 1989, Blake 1992, Blake *et al*. 1996). The base of the Kanawha Formation is placed at the base of the Lower Douglas coal bed of Hennen and Teets (1919) and the upper contact of the Kanawha Formation at the top of the Kanawha Black Flint of White (1891).

The Kanawha Formation contains numerous coal beds and range in rank from mid-volatile bituminous in the lower part of the formation in the more southern parts of its occurrence to high-volatile A bituminous over the majority of its area. The formation contains a large number of economically minable coal beds historically comprising approximately 40% of West Virginia's original coal resources and, until recently, approximately 50% of its annual production. Kanawha Formation coal is mined for metallurgical purposes and as low sulfur compliance steam coal. Many Kanawha coal beds occur in multiple bed zones with frequent splits and merges. Widely mined coal beds include the Douglas, Gilbert, Glenalum Tunnel, Lower War Eagle, Middle War Eagle, Eagle (and splits), Powellton (and splits), No. 2 Gas, Peerless, Williamson, Cedar Grove, Fire Clay, the Chilton zone, the Winifred zone, the Coalburg zone, and the Stockton zone. A widespread volcanic ash (tonstein) is found in the Fire Clay coal across southern West Virginia, Virginia, Kentucky, and Tennessee. Published analyses for the Fire Clay in Kentucky (Hower, et al., 1999, 2016), and for this report, indicate elevated REE concentrations associated with the tonstein. Data generated during this study agree with this finding. Variable levels of REEs have been identified for other coals, but, other than the well-documented Fire Clay and associated volcanic ash, REE concentrations are not overly attractive.

4.1.3 Northern Coal Field

Allegheny Formation: The Middle Pennsylvanian (northern) Allegheny Formation consists of sandstones, mudrocks, and coal beds with minor amounts of thin, non-marine limestones. Calcareous material occurs in the upper part of the formation and is notably absent in the lower part. Numerous aerially-widespread and widely mined coal beds are present in the Allegheny Formation (Figure 2). Beds within specific zones can split apart as much as 50-60 feet, making regional correlations tentative. Widely mined coal beds include the Lower, Middle, and Upper Kittannings and the Upper Freeport and Mahoning. The Clarion and Lower Freeport have also been exploited, but to a lesser extent along with Brookville and Mercer Coals which represent the top portion of the Pottsville Formation. Associated with the Allegheny coals are a distinctive lithology consisting of high kaolinitic clay beds (flint clays), frequently brecciated. These coal beds have been mined for refractory purposes and brick making. Analyses from various Allegheny coals, partings, and floors, including the brecciated flint clays, suggest the possibly of sporadic REE economic resources, but the results are unfinished as of this writhing.

Conemaugh Group: The Middle and Upper Pennsylvanian Conemaugh Group extends from the top of the Upper Freeport coal bed to the base of the Pittsburgh coal bed (Figure 2). Coal beds in the Conemaugh Group are thin, impure, and areally-restricted. The Bakerstown coal is the only Conemaugh coal with significant original resources. Minor resources have been exploited from the Brush Creek, Harlem, and Elk Lick coals (Figure 2). Coal quality is generally poor with relative high ash yield and high sulfur content. Available REE data show mainly background, although variable, levels. No specific targets areas were identified.

Monongahela Formation: The Upper Pennsylvanian Monongahela Formation extends upward from the base of the Pittsburgh coal bed to the base of the Waynesburg coal bed. Strata include non-marine limestone, sandstones, mudstones/shales, and coal beds. The non-marine limestones dominate the section below the Uniontown coal bed. Excluding the aerially widespread Pittsburgh seam, Monongahela coal beds tend to be aerially restricted. Coal quality varies, with sulfur yield relatively high compared to older coals. Widely mined coals include the Pittsburgh, Redstone, and Sewickley. As with most coal beds in the Appalachian region, REE concentrations are rarely above background, with no high-concentration targets identified.

Dunkard Group: The Dunkard Group is variably subdivided into the Waynesburg, Washington, and Greene formations (Figure 2) and contains all strata above the base of the Waynesburg coal bed in the Appalachian region (Berryhill *et al.* 1971). The strata consist of sandstones, shales, nonmarine limestones and coal beds. Excluding the Waynesburg, coal beds are generally thin, and unimportant and only the Waynesburg, Waynesburg "A" and Washington coal (zones) contain any potential resources. Analyses have not identified any areas with significant REE contents significantly above background levels.

4.2 SAMPLE LOCATION

4.2.1 West Virginia Sampling

Tetra Tech's plan was to first screen the WVGES sample archives to identify potential elevated concentrations of REE+Y+Sc's in not only coal seams but in associated geologic materials (partings, roof and floor). Elevated concentrations of REE+Y+Sc for this report is defined as concentrations above 300 ppm. The WVGES has 2,500,000 discrete stratigraphic records and coal quality data from over 50,000 discrete samples in their archives. Our plan was to test many samples to determine which seams and which location had the best opportunity to find higher concentration. These initial screening samples were based upon our knowledge from the previous report – i.e. that dirtier coals had higher concentrations of REE+Y+Sc and associated materials such as under clays in the coal floor, roof shales and partings seem to have a higher probability of finding REE+Y+Sc than the associated coal seams. The personal knowledge gained from WVGES staff also added to our team's plan. Thus 86 samples, representing 21 coal seams and multiple locations, in the WVGES archives of samples were selected for analysis. These samples were comprised of bench samples or full channel samples, generally with separate parting, roof and/or floor samples. Several of the samples were comprised of six inch increment samples that were combined into representative bench samples. It should be noted that the USGS base of REE+Y+Sc samples for West Virginia used in Tetra Tech's 2015 report largely came from data arrived from testing of this same sample set. However, that data base only tested coal and not the roof, floor or partings, even though that material was available. In West Virginia 86 screening samples were submitted form the archives. Please see Table 2.

Table 2 - Summary of Screening Samples

Basin	# Samples	# Samples +300 ppm	% of sample +300 ppm
Northern Appalachia	24	13	54%
Central Appalachia	62	13	21%

In Northern Appalachia 5 of the 13 samples (38%) of +300 ppm REE+Y+Sc were associated with Lower Kittanning in Webster County, WV. An additional 2 samples (15%) were associated with the Pittsburgh Coal in Marshall County, WV.

In Central Appalachia 4 of the 13 samples (31%) of +300 ppm REE+Y+Sc were associated with the Little Chilton in Boone County, WV. Another 3 of 13 samples (23%) were from the Fire Clay seam in Kanawha County, WV. Combined these samples makeup 54% of the 300+ ppm samples, are in adjacent seams in Kanawha Formation which is known to have tonstein present in both the Fireclay and Little Chilton seams.

Based on the results of the screening the team agreed that the Pittsburgh Seam in northwest West Virginia and the Lower/Middle Kittanning in northeast West Virginia appeared to have the best opportunity in the West Virginia area of the Northern Appalachian coal basin to have coal or coal associated rocks that have consistent values at or above 300 REE+Y+Sc. The Fire Clay and Little Chilton coal seams in Central Appalachia, and associated strata were also thought, based on the data, to have potential to contain REE+Y+Sc's at concentrations of greater than 300 ppm. The team's industry contacts arranged for an access to currently operating mines in these seams for sample collection.

In West Virginia the following coal seams were targeted:

<u>Northern Appalachia</u>

- The Pittsburgh coal seam in Marshall, Ohio and Wetzel Counties, WV has a large future production potential due to its large reserve base and our screening indicated a relatively high REE+Y+Sc sample test results (in Marshall County).

- The Middle and Lower Kittanning coal seams in Barbour, Upshur, and Webster Counties, WV also has ample reserves to support future coal production. Screening sample results in these seams showed high REE+Y+Sc concentrations.

<u>Southern Appalachia</u>

- The Fire Clay and Little Chilton coal seams in Kanawha, Boone, and Logan Counties, WV screening sample results showed, a high REE+Y+Sc potential in previous research reported in Tetra Tech's 2015 report (Bryan, et al 2015). The Kentucky Geologic Survey has reported that the Fire Clay coal seam in Kentucky has a high REE+Y+Sc content due to igneous activity which occurred during its formation.

Since we have observed tonsteins and volcanic ashes within the Fire Clay and Little Chilton coal seams, they were also screened as expected high REE+Y+Sc content.

4.2.2 Pennsylvania Sampling

The Pennsylvania bituminous coal region lies totally in the Northern Appalachian coal basin. The coal seams in Pennsylvania are the same coal seams located in northern West Virginia. Thus, our team selected to assess whether the REE+Y+Sc potential being investigated in northern West Virginia would carry over in Pennsylvania. Thus the following coal seams were targeted:

<u>Northern Appalachia</u>

- The Pittsburgh coal seam in Washington and Greene Counties, PA. This seam still has a large production potential.
- The Lower Kittanning coal seam in Somerset, Cambria, Clearfield, Centre, and Clinton Counties, PA still has a large future production potential. In addition, the previous research in Tetra Tech's 2015 report (Bryan, et al 2015) reported that the Lower Kittanning underclay's have the potential to exceed 300 ppm REE+Y+Sc.
- The Lower Kittanning Coal Seam had 8 of 16 screening samples (50%) of the strata exceed 300 ppm in Clinton and Clearfield counties, PA.

Even though the above discussed coal seams were targeted other coal seams and several sludge ponds were also sampled when easily available during our sampling events so that a clearer understanding of the relationship of REE+Y+Sc content with shales, clays and seam partings could be reported.

Appendix A shows the locations of all the study samples that have REE+Y+Sc data results. The symbols on this map represent a single location which may contain multiple samples (e.g., roof, coal, partings, floor, etc.) collected at that location.

5.0 RESULTS AND DISCUSSION

This is a final report Tetra Tech has collected 500 distinct samples in northern and central Appalachia. Analytical results and associated sample identification information were combined in a master spreadsheet and sorted and summarized by the following criteria:

1. Material Type
2. Coal basin: Northern Appalachia, and Southern Appalachia
3. Location (County)
4. Samples or sites displaying greater than 300 ppm concertation Total REE+Y+Sc (TREE)

As defined by DOE/NETL the project will examine light and heavy rare earth elements, plus Yttrium (Y) and Scandium (Sc). The grouping is as follows:

- Light Rare Earth Elements: Scandium (Sc), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodynium (Nd), Samarium (Sm), Europium (Eu), and Gadolinium (Gd)
- Heavy Rare Earth Elements: Yttrium (Y), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yb), and Lutetium (Lu)

For the discussion of the results the following are defined as Total REE+Y+Sc (TREE), Light REE plus Scandium (LREE) and Heavy REE plus Yttrium (HREE)

Table 3 shows the distribution and summary information on samples collected and categorized. The Northern Appalachian samples were collected from sites in Pennsylvania and West Virginia from surface and underground mine operations and from sites administered by the states agencies that manage abandoned mined land sites. The Lower and Middle Kittanning coal seams and associated materials were the most frequent sample sources in Northern Appalachia. The Fire Clay coal seam and associated materials are the most frequent samples in the central Appalachian basin. Drawings of the sample locations with their overall results can be found in Drawings 1 through 3 in Appendix A.

Table 3 - Summary of Sample Distribution of Materials

Basin	Number Samples	Counties Sampled	Coal Seams	Material Types
Northern Appalachia	371 (78>300 ppm TREE)	20 (West Virginia 11) Pennsylvania 9)	20	Roof, Floor, Parting, Coal, Channel sample, Coal Refuse
Central Appalachia	129 (24>300 ppm TREE)	10 (West Virginia)	15	Roof, Floor, Parting, Coal, Channel samples
Total	**500 (102 >300 ppm TREE)**	**30**	**35**	

Eighty-five (85) samples had concentrations exceeding 300 ppm total TREE. Fifty-four (54), were in the Northern Appalachian Basin (NAPP). About 26% of samples in the Central Appalachian basin (CAPP) had TREE concentrations exceeding 300 ppm. The distribution of TREE in concentration categories are shown for Northern and Central Appalachia in figures 3 and 4, respectively.

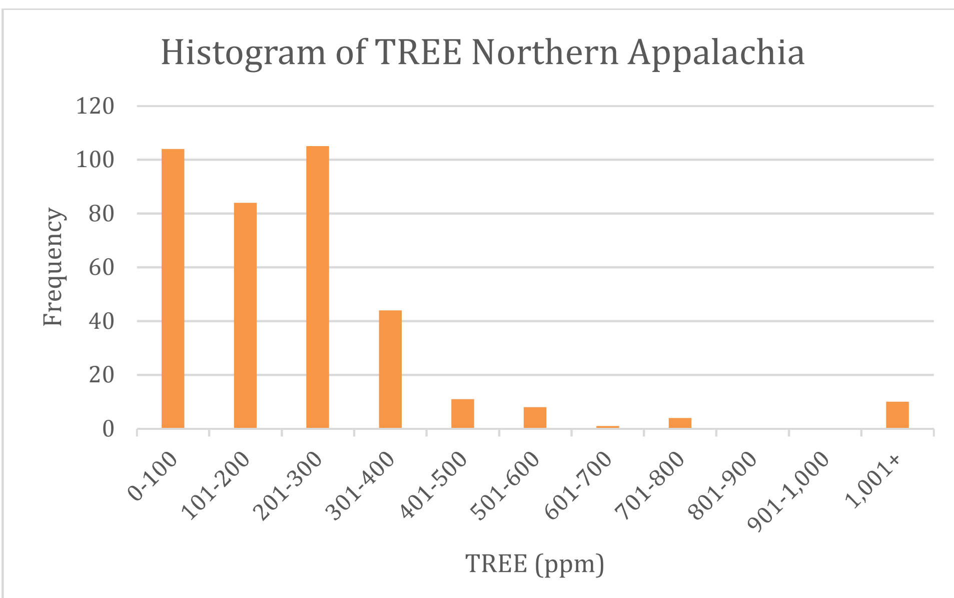


Figure 3 - Distribution of TREE Sample Concentrations, Northern Appalachia

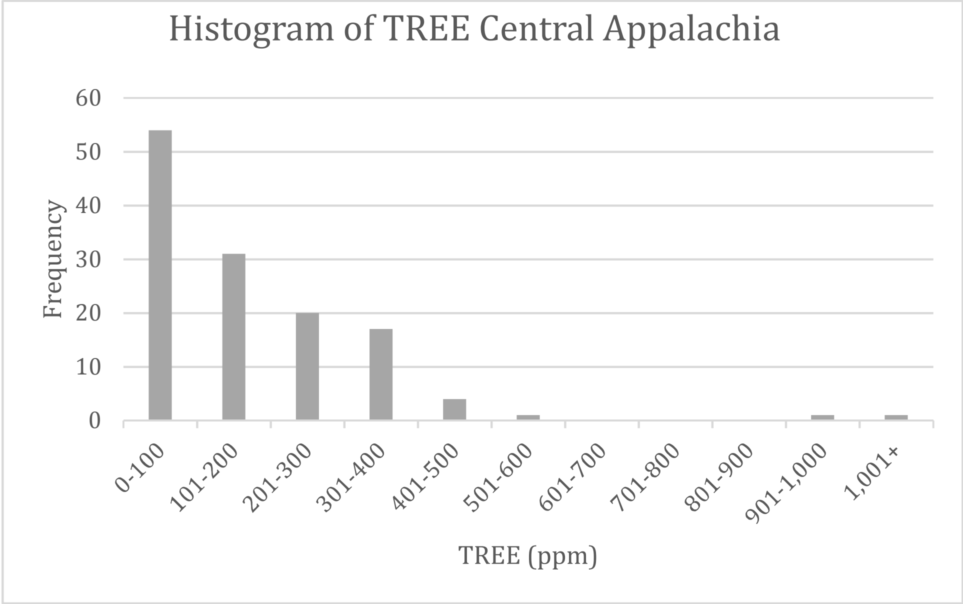


Figure 4 - Distribution of TREE Concentration, Central Appalachia

In both basins, a majority of samples reported were found to be less than 300ppm TREE. In each basin a small number of samples exceed 500 ppm TREE giving a skewed appearance to the bar charts.

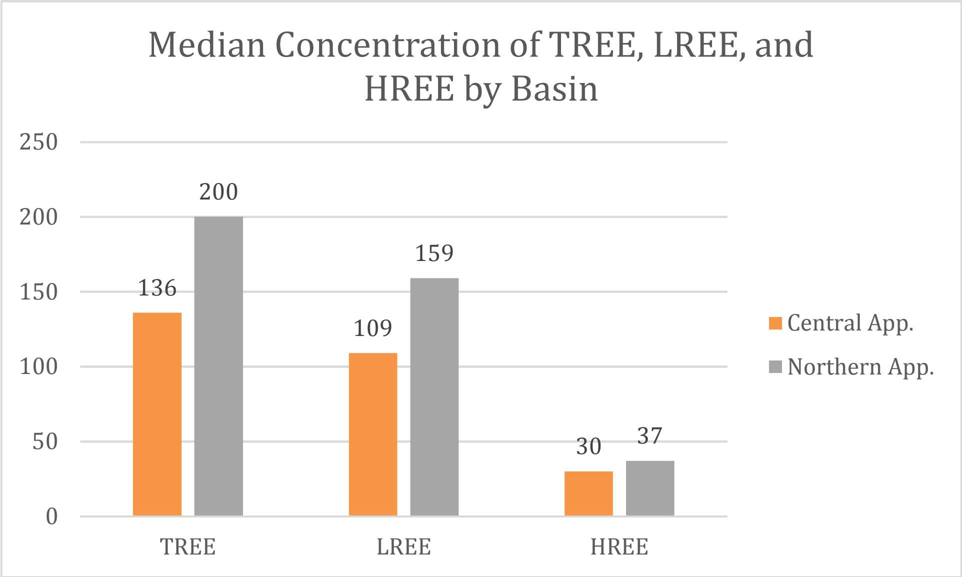


Figure 5 - Median Concentration of TREE, LREE and HREE for All Samples and by NAPP and CAPP

Figure 5 summarizes concentrations for all samples, and by NAPP and CAPP. Values shown are medians to represent central tendency of the data. A small increment of samples contain high concentrations of REE+Y+Sc's and these samples skew the data. TREE data for the CAPP are also skewed by a small number of high concentrations.

Figure 5 shows that the NAPP samples typically contain greater concentrations of REE+Y+Sc, mostly as light REE's than the CAPP. With respect to elements comprising HREE, the basins exhibit similar typical concentrations

Figures 6 and 7 show median concentrations of individual elements LREE and HREE for all samples and for each coal basin. Cerium (Ce), Lanthanum (La) and Neodymium (Nd) are the most abundant LREE elements. Dysprosium (Dy), Erbium (Eu) and Ytterbium (Yb) are the most abundant HREE elements. HREE element concentrations are lower than LREE, and with smaller differences between the basins, typically about 0.5 ppm or less.

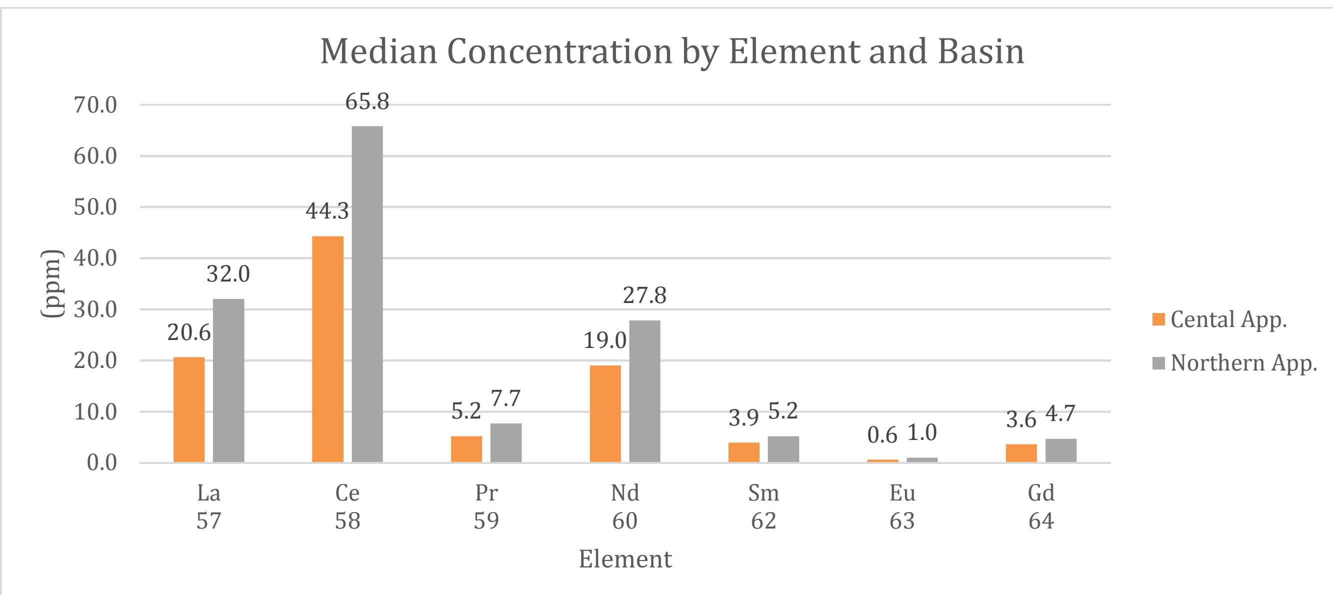


Figure 6 - Median Concentration of Individual LREE Elements for All Samples, and by NAPP and CAPP

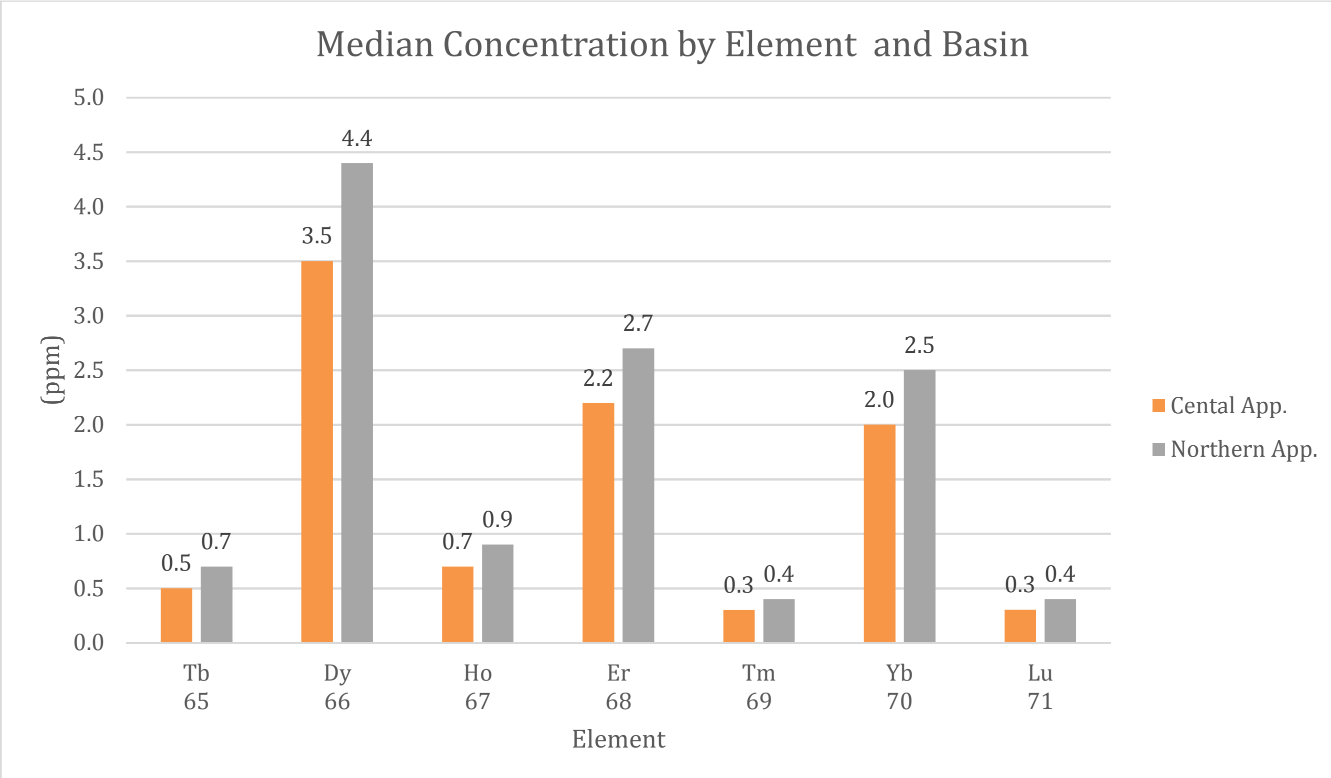


Figure 7 - Median Concentration of Individual HREE Elements for All Samples, and by NAPP and CAPP

Sample data was subdivided into NAPP and CAPPs, and then sorted and summarized for TREE and Light to Heavy Ratio for the variables of county, associated coal seam, and material type. Summary data was compiled for each sorted subset including number of samples (N), mean or average concentration, median, minimum and maximum reported values. The sorted subsets are summarized in Table 4 through Table 15 in the following sections.

The following sections contain preliminary observations on the sorted data.

5.1 REE+Y+SC DISTRIBUTION BY COUNTY

Tables 4 and 5 contain summary data by county for the NAPP. Sampling was conducted for nine counties in Pennsylvania that are mainly associated with the Kittanning coals and surrounding rocks (Allegheny formation) and in possible proximity to igneous source materials. Typical or median TREE ranged from about 200 to 430 ppm in Centre, Clinton, Clearfield and Somerset counties, Pennsylvania. Most of the individual samples exceeding 300 ppm in NAPP occur in these counties.

Table 4 - Summary TREE Concentration (ppm) by Sampled County, NAPP

County	State	N	Mean	Median	Minimum	Maximum
Barbour	WV	54	200	181	9	1,076
Cambria	PA	1	513	513	513	513
Centre	PA	58	210	219	12	478
Clearfield	PA	96	431	195	9	6,081
Clinton	PA	48	240	229	13	755
Fayette	PA	6	200	222	21	235
Forrest	PA	4	210	225	72	316
Grant	WV	8	350	139	24	1,851
Harrison	WV	1	24	24	24	24
Marion	WV	1	22	22	22	22
Marshall	WV	23	139	125	2	329
Monogalia	WV	25	189	202	42	187
Randolph	WV	5	68	62	58	93
Somerset	PA	18	204	209	20	565
Tucker	WV	2	45	45	42	48
Upshur	WV	3	66	60	26	111
Washington	PA	3	89	76	55	136
Webster	WV	7	401	495	70	554
Westmoreland	PA	2	307	307	294	320
Wetzel	WV	6	68	54	14	162
Total		371	263	200	2	6,081

Sampling in West Virginia was focused in eleven counties, and two sections associated with the Pittsburgh and Kittanning coal seams. Webster County reported the highest concentrations with a median of nearly 400 ppm TREE. Samples associated mainly with the Pittsburgh coal in Monongalia, Marshall and Wetzel counties had typical TREE of less than 100 to about 190 ppm TREE.

Table 5 - Summary of NAAP Low to High Ratio by County

County	State	N	Mean
Barbour	WV	54	4.5
Cambria	PA	1	1.4
Centre	PA	58	4.3
Clearfield	PA	96	6.4
Clinton	PA	48	4.5
Fayette	PA	6	4.3
Forrest	PA	4	4.7
Grant	WV	8	3.9
Harrison	WV	1	4.4
Marion	WV	1	1.5
Marshall	WV	23	4.8
Monongalia	WV	25	4.5
Randolph	WV	5	5.1
Somerset	PA	18	4.6
Tucker	WV	2	4.4
Upshur	WV	3	4.1
Washington	PA	3	1.7
Webster	WV	7	5.5
Westmoreland	PA	2	5.7
Wetzel	WV	6	3.7
Total		371	5.0

Sampling in the CAPP was in ten counties and are shown in Tables 6 and 7. Boone County reported the largest concentrations, with a median 228 ppm of TREE, based on 20 samples. The remaining four focus counties had median TREE of about 178 (Mingo), 184 (Raleigh) 151 (Logan) and 177 (Kanawha) ppm.

Table 6 - Summary TREE Concentration (ppm) by Sampled County, CAPP

County		N	Mean	Median	Minimum	Maximum
Boone	WV	20	228	238	34	420
Fayette	WV	1	128	128	128	128
Kanawha	WV	27	177	78	17	1,384
Logan	WV	32	151	102	4	923
McDowell	WV	1	20	20	20	20
Mingo	WV	35	178	162	19	508
Nicholas	WV	1	181	181	181	181
Raleigh	WV	10	184	137	13	402
Webster	WV	1	166	166	166	166
Wyoming	WV	1	19	19	19	19
Total		129	176	136	4	1,384

Table 7 - Summary Light to Heavy Ratio by Sampled County, CAPP

County	State	N	Mean
Boone	WV	20	4.8
Fayette	WV	1	6.0
Kanawha	WV	27	3.8
Logan	WV	32	3.8
McDowell	WV	1	3.4
Mingo	WV	35	3.6
Nicholas	WV	1	3.8
Raleigh	WV	10	4.0
Webster	WV	1	3.2
Wyoming	WV	1	4.0
Total		129	3.9

5.2 REE+Y+SC DISTRIBUTION BY COAL SEAM

Tables eight and nine summarize NAPP concentration data, sorted by associated coal seam. The NAPP coals, in general, contain more mineral matter than coals in the central basin and might therefore have greater potential to sequester TREEs. Twenty coal seams are represented in the northern Appalachian basin sampling, including the Pittsburgh and Kittanning seam. The latter represent the bulk of current and anticipated future production in this basin. Materials identified with Lower Kittanning and Lower Freeport coals report median TREE of 329 and 208 ppm respectively. The Pittsburgh coal, based on 41 samples, has TREE of about 134 ppm.

Table 8 - TREE Concentration (ppm) by Associated Coal Seam, NAPP

Associated Coal Seam/Zone/Seam	N	Mean	Median	Minimum	Maximum
Bakerstown	1	42	42	42	42
Brookville	18	240	238	74	478
Clarion	5	212	164	126	382
Freeport	1	1,851	1,851	1,851	1,851
Harlem	5	73	58	14	134
Little Clarksburg	1	36	36	36	36
Lower Freeport	19	208	224	14	409
Lower Kittanning	144	379	232	9	6,081
Lower Mercer	2	121	121	60	181
Mahoning	11	176	177	18	353
Mercer	1	723	723	723	723
Middle Kittanning	43	180	148	13	1,074
Pittsburgh	41	134	169	1	387
Sewell	1	58	58	58	58
Sewell B	1	62	62	62	62
Sewickley	2	286	286	270	302
Upper Freeport	42	175	170	10	572
Upper Kittanning	6	141	141	25	240
Upper Mercer	5	147	115	76	244
Waynesburg	4	236	231	83	400
Unknown	18	259	253	138	432
Total	371	263	200	2	6,081

Table 9 - Summary NAAP Low to High Ratio by Seam

Associated Coal Seam/Zone/Seam	N	Mean
Bakerstown	1	4.6
Brookville	18	3.7
Clarion	5	4.0
Freeport	1	1.2
Harlem	5	4.2
Little Clarksburg	1	2.8
Lower Freeport	19	4.7
Lower Kittanning	144	5.9
Lower Mercer	2	4.6
Mahoning	11	4.7
Mercer	1	3.5
Middle Kittanning	43	4.4
Pittsburgh	41	4.3
Sewell	1	5.0
Sewell B	1	6.6
Sewickley	2	4.7
Upper Freeport	42	4.3
Upper Kittanning	6	3.9
Upper Mercer	5	4.0
Waynesburg	4	5.0
Unknown	18	5.1

Tables 10 and 11 show summary concentration data sorted by associated coal seam for the CAPP. A total of 15 coal seams are represented, mostly from the Kanawha formation. The coals are stratigraphically below and chronologically older than the coals in the NAPP. The Fire Clay coal seam was a focused target for sampling, based on the identification of tonsteins (volcanic ash falls) associated with this seam. However, the reported median TREE of 76 samples is about 179 ppm.

Table 10 - TREE (ppm) by Associated Coal Seam, CAPP

Associated Coal Seam/Zone/Seam	N	Mean	Median	Minimum	Maximum
Bens Creek	4	190	200	24	337
Cedar Grove	4	272	285	98	420
Chilton	6	120	115	19	723
Coalburg	1	171	171	171	171
Fire Clay	76	179	145	4.1	1,384
Fire Creek	1	20	20	20	20
Glenalum Tunnel	3	267	360	74	366
Little Chilton	11	182	136	27	381
Lower Kittanning	1	84	84	84	84
Lower Winifred	1	107	107	107	107
Middle Kittanning	8	129	137	32	222
Middle War Eagle	6	180	120	13	402
No.2 Gas	4	197	194	61	339
Stockton	2	163	163	140	185
Williamson	1	118	118	118	118
Total	129	176	136	4	1,384

Table 11 - Summary CAAP Low to High Ratio by Coal Seam

Associated Coal Seam/Zone/Seam	N	Mean
Bens Creek	4	4.1
Cedar Grove	4	4.5
Chilton	6	4.3
Coalburg	1	4.4
Fire Clay	76	3.7
Fire Creek	1	3.4
Glenalum Tunnel	3	4.5
Little Chilton	11	5.3
Lower Kittanning	1	3.0
Lower Winifred	1	6.3
Middle Kittanning	8	3.7
Middle War Eagle	6	3.9
No.2 Gas	4	4.4
Stockton	2	3.2
Williamson	1	3.3
Total	129	3.9

5.3 TREE BY MATERIAL TYPE

Rare earth concentration data, sorted by material type, is summarized for the NAPP in tables 12 and 13 and in boxplots in figure 8. The greatest concentrations are found in floor (260 ppm), parting (275 ppm) and roof rocks (221 ppm). These rocks by virtue of their depositional setting and subsequent weathering often contain substantial amounts of clay minerals. Clays, especially kaolinite, may sequester TREEs. Coal samples contain only about one third the concentration of TREE's compared to the roof, floor and parting materials.

Table 12 - TREE (ppm) by Material Type, NAPP

Sample Type	N	Mean	Median	Minimum	Maximum
Bench	1	83	83	83	83
Bone	3	174	166	74	284
Channel	26	91	62	10	345
Coal	94	98	61	2	755
Core	26	296	266	131	1,074
Dike	1	197	197	197	197
Floor	101	260	237	20	723
Paleosol	1	214	214	214	214
Parting	31	275	247	36	554
Refuse	6	113	118	20	185
Roof	360	221	224	22	716
Sludge	21	1,358	1215	55	6,081.0
Total	371	263	200	2	6,081

Table 13 - Summary NAAP Low to High by Sample Type

Sample Type	N	Mean
Bench	1	4.7
Bone	3	4.3
Channel	26	4.5
Coal	94	4.1
Core	26	5.0
Dike	1	4.2
Floor	101	4.4
Paleosol	1	3.6
Parting	31	5.2
Refuse	6	4.6
Roof	60	4.5
Sludge	21	13.3
Total	371	5.0

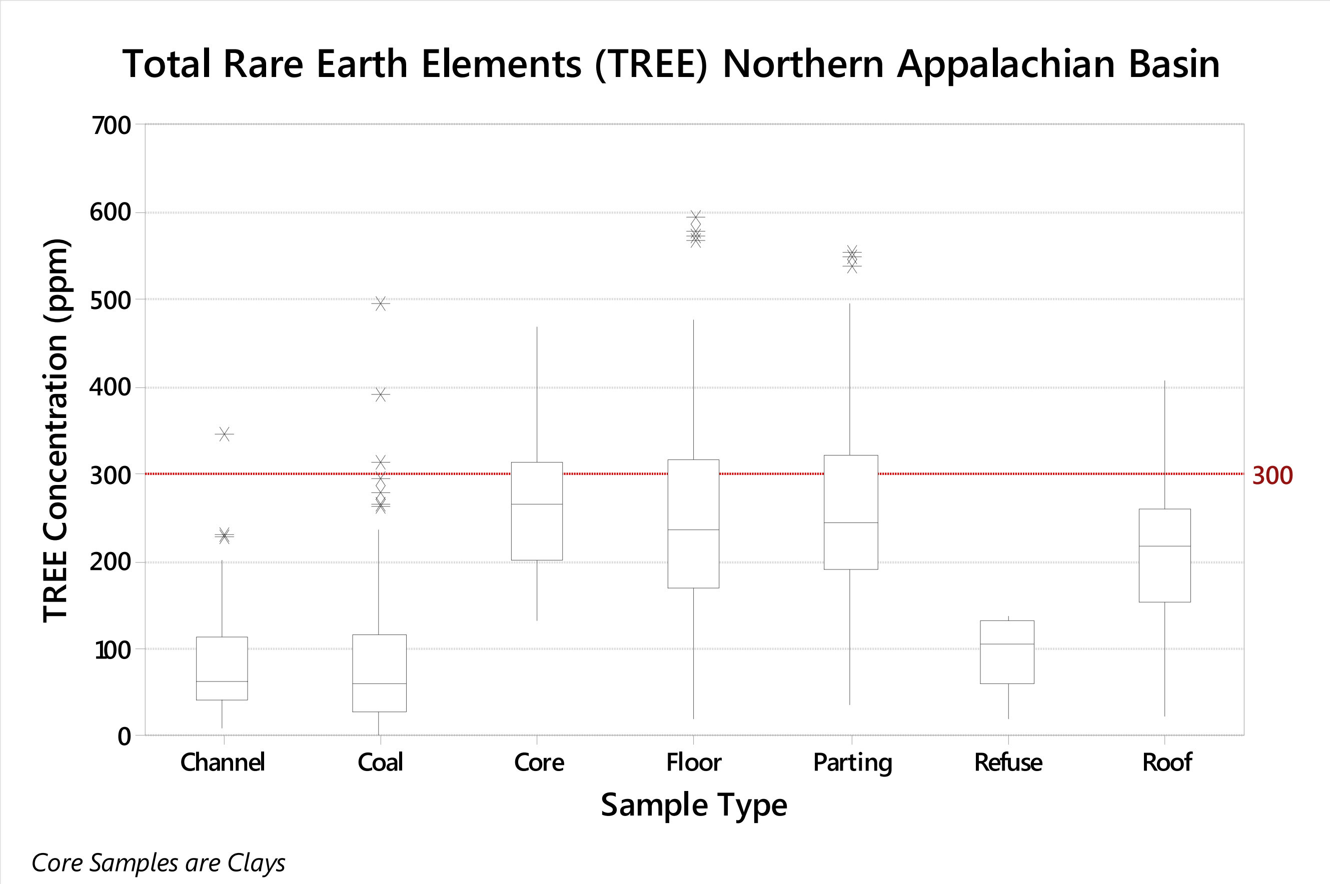


Figure 8 - Boxplot TREE NAPP by Material Type

TREE concentration data, sorted by material type, is summarized for the CAPP in tables 14 and 15 and shown in figure 9. The distribution is similar to that found in the northern basin. The greatest concentrations are in floor (284 ppm), roof (278 ppm) and parting (268 ppm) rocks. Coals typically contain about 15 to 20% of the concentrations in the surrounding rocks.

Table 14 - TREE (ppm) by Material Type, CAPP

Sample Type	N	Mean	Median	Minimum	Maximum
Bench	2	65	65	36	94
Bone	1	923	923	923	923
Channel	45	122	83	17	1,384
Coal	36	105	65	4	508
Floor	11	284	270	129	420
Parting	16	268	273	66	422
Roof	15	278	300	136	414
Tonstein	3	263	278	191	321
Total	129	176	136	4	1,384

The CAPP, like the NAPP, exhibits the largest rare earth concentrations, not in the coals themselves, but in the rocks adjacent to the coals. Figure 10 also shows a relatively small range of TREE concentration in the “Floor” samples in comparison to Parting and Roof materials.

Table 15 - Summary CAAP Low to High Ratio by Sample Type

Sample Type	N	Mean
Bench	2	4.0
Bone	1	6.2
Channel	45	3.7
Coal	36	3.1
Floor	11	5.0
Parting	16	4.7
Roof	15	4.5
Tonstein	3	5.4
Total	129	3.9

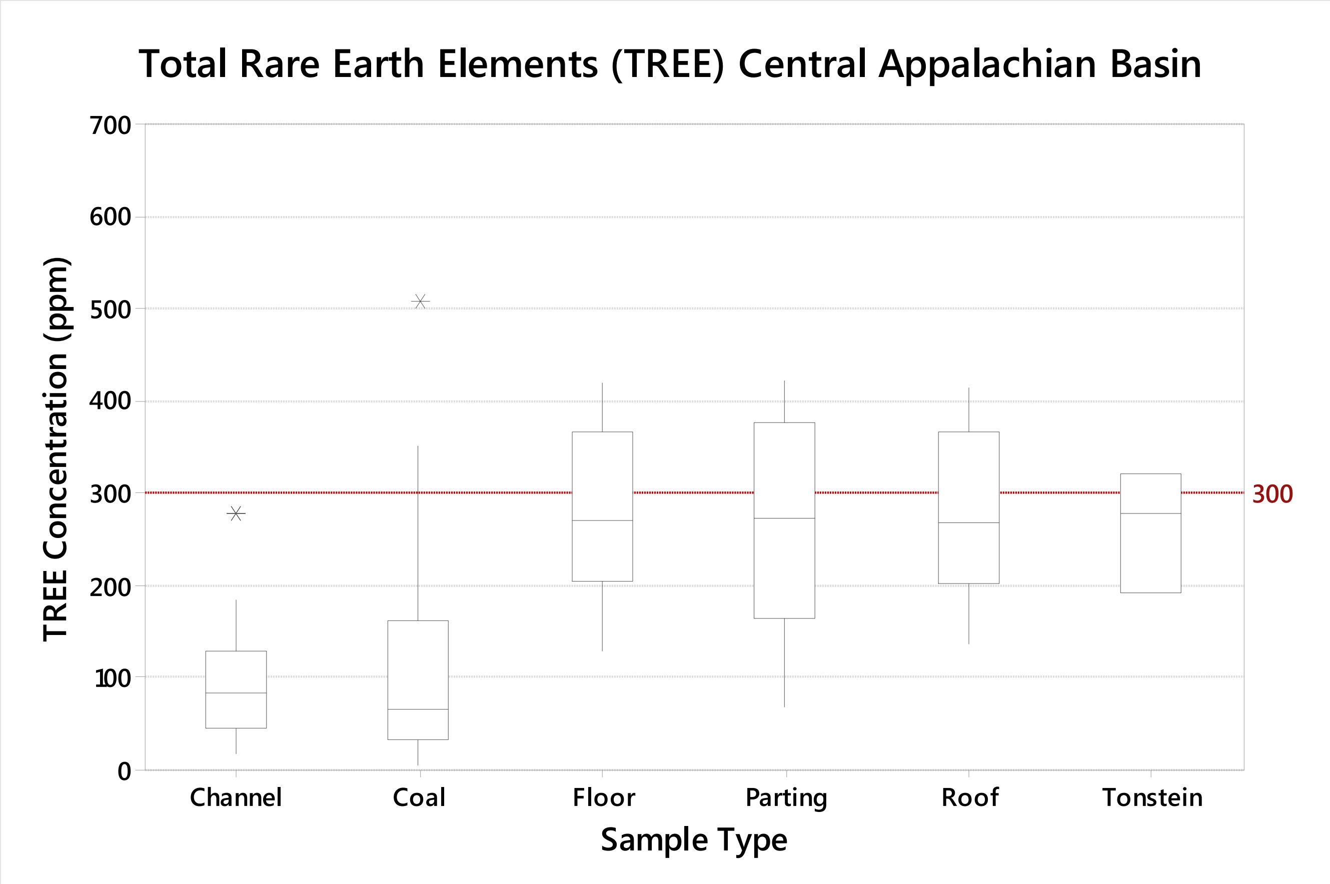


Figure 9 - Box Plot TREE CAPP by Material Type

5.4 DISCUSSION OF RESULTS

Tables 16 and 18 provides information on all sampling areas in Northern and Central Appalachia respectively that contained TREE concentrations exceeding 300 ppm. The 300 ppm was a criterion set by DOE to identify sources with potential for further examination and study. Data in Tables 16 and 18 includes information for coals and associated strata. Mine water treatment sludge samples are grouped separately

Tables 17 and 19 provide a summary of occurrence by associated coal seam and by county for samples in Northern and Central Appalachia. Mine water treatment sludge samples were not included in this data because they were not included in the original scope of work but were utilized as an indicator of the presence of TREE The results received were notable

One of the higher concentrations identified in the study area was a three county area in central Pennsylvania (Clearfield, Centre, and Clinton counties). Out team collected 34 strata samples with TREE greater than 300 ppm. Another 13 mine water treatment system samples (sludges) indicated greater than 300 ppm TREE levels. Table 16 shows the distribution of host strata with elevated TREE levels. Floor material, and predominantly clays, were the most common source of high TREE levels with 51% of all samples over 300 ppm within the coal strata. Table 17 shows the occurrence of samples over 300 ppm by associated coal seam and by county. For Northern Appalachia the Lower Kittanning coal had 48% of all samples collected over 300 ppm, with Middle Kittanning coal coming in second with 17% of the samples. Clinton County had the highest percentage of +300 ppm TREE samples with 25%. The combination of Clearfield, Centre, and Clinton counties had 54% of elevated TREE samples. The only other county in Northern Appalachia in double digits was Barbour County in northern West Virginia with 17%. It must, however, be pointed out that this information is based on relatively small data base.

The abundance of samples reporting greater than 300 ppm, coupled with a relatively large number of active mining operations, and an improving metallurgical coal market suggests this area should be evaluated in more detail. In Northern Appalachia the data clearly points to further examination of the floor material of the Allegheny Group geologic formation, more specifically the Lower and Middle Kittanning seams in the Clearfield, Centre and Clinton county area.

Table 16 - Summary of Locations with TREE Samples Greater than 300 PPM - NAPP

			For sample +300 ppm TREE										
Northern App.	State	No. Samples	Coal Seams	Roof	Coal/Core	Parting	Floor	Sludge	No. +300 ppm	% +300 ppm	Avg.	Median	Max.
Barbour	WV	54	LK, MK		9		2		11	20%	421	352	1,074
Cambria	Pa	1	LK					1	1	100%	513	513	513
Centre	Pa	58	MK, LK	1	1		7		9	16%	388	375	513
			Cl, Br										
Clearfield	Pa	80	Mercer, LK	1			8		9	11%	409	328	723
(Strata)			UF, Mahoning										
Clearfield	Pa	16	LK					13	13	81%	1,940	1,215	6,081
(Sludge)													
Clinton	Pa	48	LK	4	3	1	8		16	33%	428	347	755
Fayette	Pa	6	Pitt				1		1	17%	363	363	363
Forrest	PA	4	LK				1		1	25%	316	316	316
Grant	WV	8	UF					1	1	13%	1,851	1,851	1,851
Marshall	WV	23	Pitt.	1		1			2	9%	315	315	329
Monongalia	WV	25	LF, Pitt.	1	1	3	1		6	24%	364	366	409
			Sew, Way										
Somerset	Pa	18	LK				2		2	11%	490	490	565
Webster	WV	7	LK			4	1		5	71%	507	536	554
Westmoreland	Pa	2	LK				1		1	50%	320	320	320
		Occurrence by Strata		8	14	9	32	15	78				
			Percentage	10%	18%	12%	**41%**	19%					

* See Table 17 for full coal seam names

Table 17 - TREE 300+ Occurrence by Seam and Strata- NAPP

Occurrence by Seam (Strata Only)

	Number	%
Waynesburg (Way)	1	2%
Sewickley (Sew)	1	2%
Pittsburgh (Pitt)	4	6%
Mahoning	1	2%
Upper Freeport (UF)	5	8%
Lower Freeport (LF)	3	5%
Middle Kittanning (MK)	11	17%
Lower Kittanning (LK)	**30**	**48%**
Clarion (Cl)	1	2%
Brookville (Br)	5	8%
Mercer	1	2%
	63	100%

Occurrence by County (Strata Only)

	Number	%
Barbour	11	17%
Centre	**9**	**14%**
Clearfield	**9**	**14%**
Clinton	**16**	**25%**
Fayette	1	2%
Forrest	1	2%
Marshall	2	3%
Monongalia	6	10%
Somerset	2	3%
Webster	5	8%
Westmoreland	1	2%
	63	100 %

In the Central Appalachia, five counties reported samples with greater than 300 ppm TREE. As shown in Table 18, most of the samples represent partings (40%), followed by roof (28%), floor (20%), and coal (12%). Table 19 shows the elevated TREE materials are associated with the Fire Clay coal seam (44%), Little Chilton seam (16%), and the Cedar Grove, #2 Gas, Bens Creek, Middle War Eagle, and Glenalum Tunnel seams (8% each seam). The coal bearing rocks of the Central Appalachians are chronologically older than the Northern Appalachians by 25 million years and exhibited a different distribution of TREE’s, predominantly occurring in the partings and roof.

Table 19 illustrates that Boone County WV had the highest number of samples (10) over 300 ppm TREE, or 40%. The ten elevated samples were spread over four coal seams and distributed between the roof, partings, and floor. The sample were found in the Little Chilton (roof, parting, and floor), Cedar Grove seam (roof and floor), #2 Gas (roof and parting), and Glenalum Tunnel (roof and floor). The roof accounted for 50% of the samples, 30% of the samples were floor, and 20% were partings.

The Fire Clay coal seam had the highest number of occurrences at 11 or 44% of the elevated samples. It was the only coal seam to exceed 300 ppm TREE in Kanawha, Logan, and Mingo counties. The high readings were predominantly associated with the partings (64%), the coal (27%), and in the roof (9%).

The Fire Clay coal seam in Kanawha, Logan, and Mingo counties was a target seam and area for this study. The Fire Clay had shown high TREE concentrations in previous research, but our sampling did not find the anticipated result in the three county area sampled. We collected ninety four (94) samples, with only eleven (11) of them (12%) exceeding 300 ppm TREE.

The highest TREE we observed in Central Appalachia was a Fire Clay channel sample in Kanawha County with 1,384 ppm TREE. It is however, suggested that future sampling be conducted to better define the potential resource. Our suggestion for additional research would be Boone County in various seams, and Kanawha County in the Fire Clay seam.

Table 18 - Summary of Locations with TREE Samples Greater than 300 PPM - CAPP

			For sample +300 ppm TREE										
	State	No. Samples	Coal Seams	Roof	Coal/Core	Parting	Floor	Sludge	No. +300 ppm	% +300 ppm	Avg.	Median	Max.
Boone	WV	20	Little Chilton, #2 Gas	5		2	3		10	50%	356	238	420
			Cedar Grove										
			Glenalum Tunnel										
Kanawha	WV	27	Fire Clay		2	2			4	15%	636	78	1,384
Logan	WV	32	Fire Clay			2			2	6%	637	637	932
Mingo	WV	35	Fire Clay	1	1	3			5	14%	388	396	508
Raleigh	WV	10	Middle War Eagle	1		1	2		4	40%	366	365	402
			Bens Creek										
		Occurrence by Strata		7	3	10	5	0	25				
			Percentage	9%	4%	**13%**	6%	0%					

Table 19 - TREE 300+ Occurrence by Seam and Strata- CAPP

Occurrence by Seam

	Count	%
Little Chilton	4	16%
Fire Clay	**11**	**44%**
Cedar Grove	2	8%
#2 Gas	2	8%
Bens Creek	2	8%
Middle War Eagle	2	8%
Glenalum Tunnel	2	8%
	25	100%

Occurrence by County

	Count	%
Boone	**10**	**40%**
Kanawha	4	16%
Logan	2	8%
Mingo	5	20%
Raleigh	4	16%
	25	100%

5.3 CLEARFIELD COUNTY PA FAULTING

Samples in central Pennsylvania specifically in the Clearfield, Centre, and Clinton County area appear to consistently show elevated TREE values. These samples were obtained in a portion of the Allegheny Plateau adjacent to the Pennsylvania Salient which shows an increase in fault-fracture density and possibly lines up with ancient mid-ocean transform faults. Because these samples show higher TREE content, one must question whether deep seated fluids associated with the tectonic development of the region are in part responsible for their presence. A review of the geology and geophysical makeup of the basement may hold important answers to this question. Figure 12 illustrates the faulting in the Clearfield, Centre, and Clinton county area.

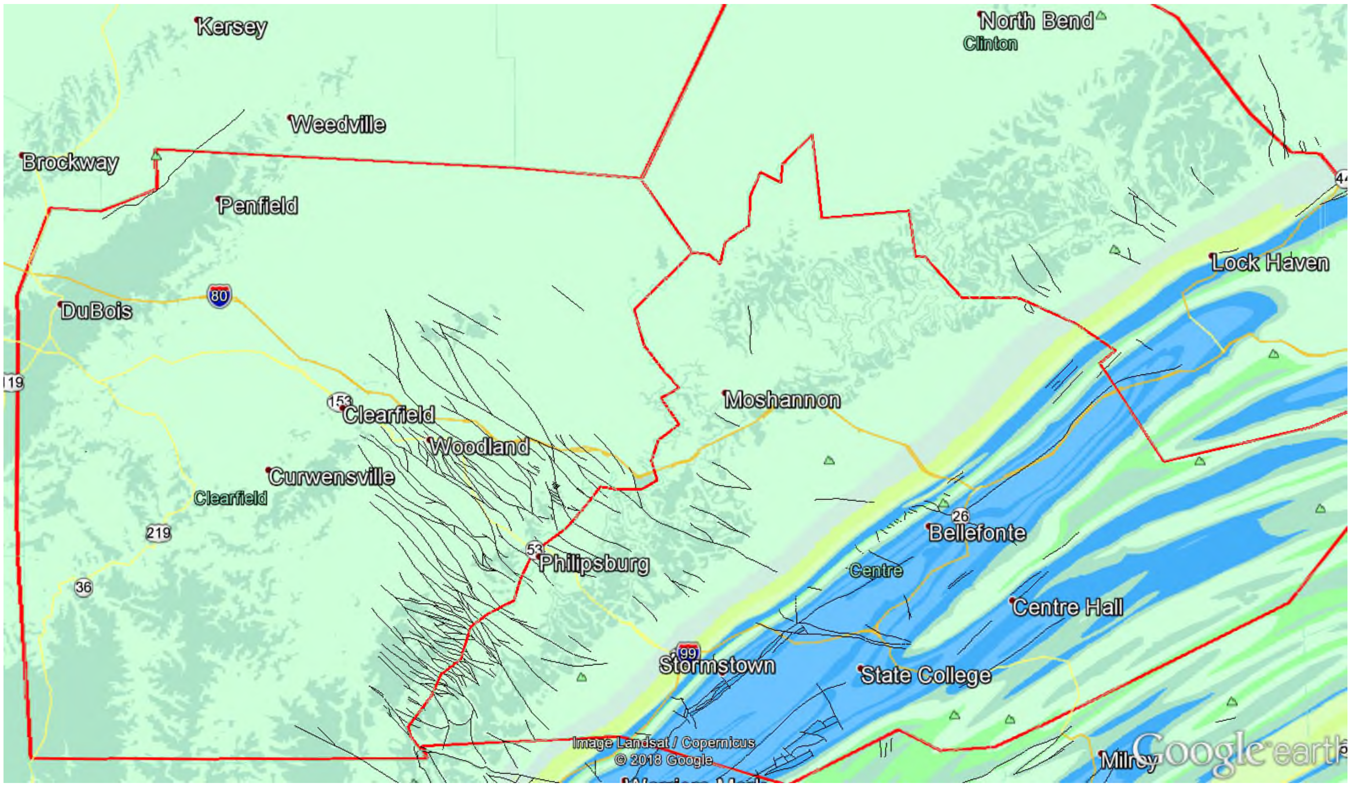


Figure 12 - Faulting in Clearfield, Centre, and Clinton Counties (USGS, 2005)

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 DIFFICULTIES AND OBSTACLES

Sampling access was also often an issue. Future work could be facilitated with a more concerted effort between Tetra Tech and possibly DOE in obtaining permission for sampling access in future studies. Outcrop and highwall sampling was available from most of the active mining operations we contacted, but access to cores, other than those in the WVGES archives, was limited. Funding for core drilling would help to solidify the data set, and give greater understanding to the distribution of REE's in the coal fields.

6.2 FUTURE RESEARCH NEEDS/OPPORTUNITIES

6.2.1 Additional Sampling

Under this contract we identified rare earth elements in Northern and Central Appalachia. The best and most consistent results were achieved in the Northern Appalachian counties of Clearfield, Centre, and Clinton. The best and most consistent coal seam identified was the Lower Kittanning, and the Middle Kittanning, and the most consistent strata was the floor material. While these results are very encouraging, there needs to be much more sampling conducted to begin to form a demonstrated reserve package that could be further developed.

Although not contiguous with the above-mentioned counties, Barbour County in northern West Virginia had some encouraging results. Additional sampling is also recommended for the Lower and Middle Kittanning seams in the region.

Additional sampling would also be useful to further determine the source material and better understand the REE distribution in Kanawha and Boone counties in southern West Virginia. The distribution of the Fire Clay seam REE's are not understood, although the highest strata TREE sample in Northern or Central Appalachia was collected from the Fire Clay seam in Kanawha county. Additional sample collection would be beneficial.

6.2.2 Write Methodology

This contract was focused on coal and coal associated rare earth elements, and subsequently coal sampling and analysis methodology was adopted. Utilizing an X-ray fluorescence (XRF) gun as a screening tool gave us an insight to what to expect from the ICP-MS analysis. We were initially disappointed in the correlation between the two testing means, but came to realize it was due to laboratory procedures. Ashing the samples at coal analysis standards, both time and temperature, proved to significantly lower the rare earth elements retained in the sample. We believe the rare earth elements were being mobilized by the ammonia being driven off in the ashing process. The result was that rare earth elements were going out the exhaust flue of the muffle furnace being used to ash the samples.

We immediately revised our sample preparation procedure to incorporate lower temperatures and shorter ashing times, and the correlation between the XRF and ICP-MS improved significantly. The initial samples were reprocessed, and the updated results incorporated in the data set.

Another source of rare earth elements modestly explored under this contract was acid mine drainage (AMD) iron precipitate. Precipitate samples taken proved to be a good source of rare earth elements, and this product is exclusively associated with coal mines in the areas investigated. This precipitate, even in its “dry” state consists of approximately 85% water. This physical condition does not fall under any of the coal field or laboratory methodologies for testing.

Specification and methodologies should be developed to evaluate rare earth elements from different materials so that the same standards for sample collection, laboratory processing, and reporting of rare earth element content are used by all preforming this work.

Due to some to the unique properties of the rare earth elements we suggest specifications be written with cooperation from other federal agencies such as United States Geologic Survey (USGS), the American Society of Testing Materials (ASTM). We also would encourage inclusion of the state geologic agencies such as West Virginia Geologic and Economic Survey (WVGES), the Pennsylvania Geologic Survey (PaDCNR), and the Colorado Geologic Survey (CGS).

6.2.3 Reserve Methodology

The USGS Coal Assessment Program criteria for estimating coal reserves should be used as a model for preforming a methodology for collecting and analyzing REE data and estimating reserves

At this point in time we are still low in the Rare Earth Resource Triangle, as illustrated in Figure 13. We have identified that rare earth elements are present in some coals and associated strata in concentration of 300 ppm and higher. We are identifying the coal seam and geographic areas in which these resources are located, and as such are currently identifying reserves. Additional sampling and expansion of the knowledge base, development of sampling and laboratory standards, development of mineral processing methods and economics are needed so we can develop rare earth resource and industry domestically.

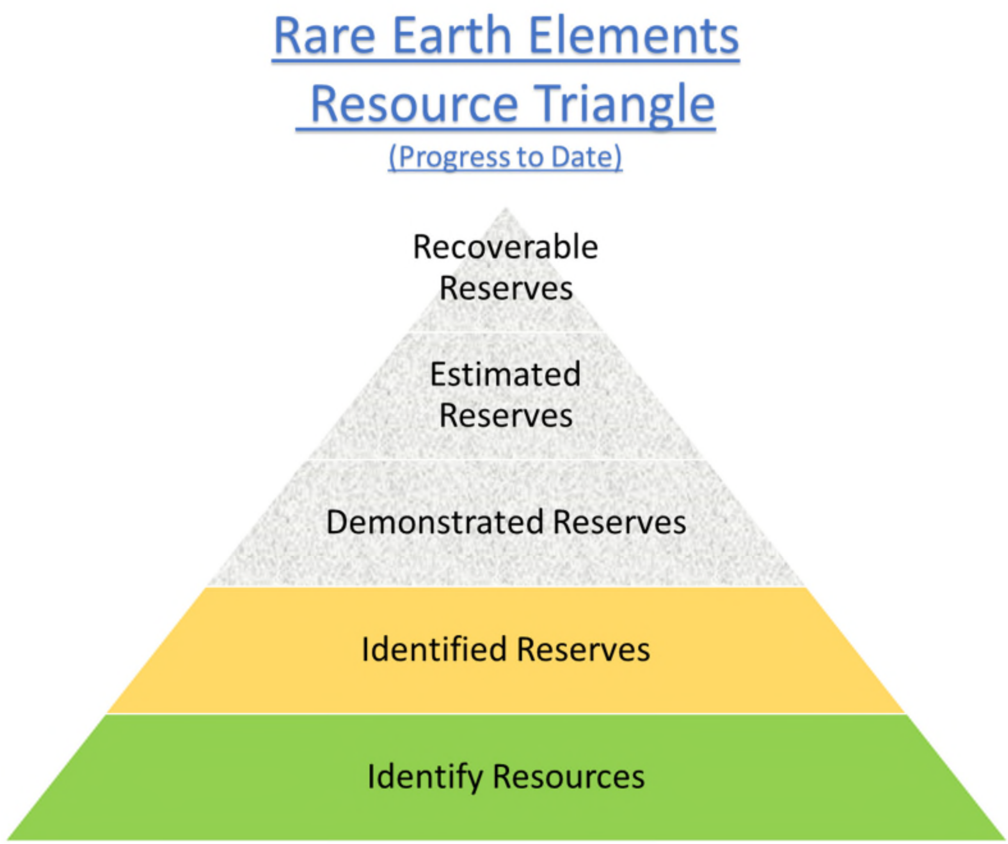


Figure 13 - REE Resource Triangle

6.2.4 Mining Recovery

The recovery of high concentrations of rare earth elements in specific sections of the coal strata by selective mining should be investigated and demonstrated to the mining industry. Once the REE's are identified, modifications to the mining cycle and/or the coal preparation plant can be made to effectively recover the rare earths.

Many rare earth elements are related to the minerals in coal. In coal preparation plants, minerals are rejected in order to produce clean coal products that meet an ash specification. It is important to understand the balance of minerals and rare earth elements (REEs) in coal preparation plants and in acid mine drainage treatment facilities to:

- optimize the production of rare earth elements or, potentially, other minerals and elements, such as alumina, from the coal minerals and
- evaluate the potential for value-added products.

Knowing the amounts of the elements produced on a daily, weekly, or annual basis will allow the calculation of the potential production of these elements and value-added products. This will be the basis for developing true case studies for economic analyses related to the production of REEs from coal. This allows the current coal production to be considered in the analysis.

Selecting one or two coal preparation plants that process coal seams containing relative high REEs, researchers would sample and analyze all coal and refuse streams within said preparation plant(s) to produce a mass balance for all components. Streams could then be selectively targeted for further enrichment of REEs and/or other minerals/elements in applied, practical coal/mineral processing circuits.

In addition, acid mine drainage treatment facilities would be targeted from the same seams associated with the treatment of refuse from the coal preparation plant(s). The acid mine drainage would be sampled and analyzed similarly to determine the potential for further enrichment of REEs or other elements (iron, for example) in the acid mine drainage.

Researchers will gather capital and operating costs from the coal preparation plants and acid mine drainage treatment facilities. With the material balances and information on costs from these facilities, the calculation of the production costs for all products—clean coal, REEs, and other value-added products—can be made. This will determine the economic viability of the production of REEs and other products from targeted high REE coals.

6.2.5 Mineralogical/Geochemical Residence of REE's

This study by Tetra Tech characterized total, light and heavy rare earth concentrations in coals and associated sedimentary rocks. The specific geochemical residence of the sampled REE's was not part of this study and is unknown. REE's may be present as

- Components of mineral phases including some halides, carbonates, oxides and silicates
- Ion adsorbed on clays or oxides
- Rarely, minerals composed principally of REE's

The geochemical residence of REE's directly affects the choice of extractive techniques and ease and efficiency recovery of REE's. Extraction of REE's adsorbed on clays may be effected by simple leaching processes, while recovery from the matrix of a solid mineral can require more aggressive extraction. A useful next step in REE studies would be an investigation of the mechanisms (adoption or mineral matrix) sequestering REE's in sedimentary rocks identified as having potentially significant concentration of REE. The mineralogical and geochemical residence studies would guide bench top scale evaluations of extraction methods for optimum recovery.

6.2.6 Critical Metals

On December 20, 2017, the White House issued a "Presidential Executive Order on a Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals". A Draft List of 35 critical minerals was issued by the Department of Interior in February, 2018 as a first result.

In addition to the work reported here on REE assays, Tetra Tech has separately conducted XRF tests on selected samples, for elements on Interior's Critical Minerals list. These elements are used in a variety of applications, including electronics, gas turbine superalloys, and defense applications. Some highlights are as follows:

- Antimony- exceeding 500 ppm
- Cobalt- exceeding 1,000 ppm
- Niobium- exceeding 500 ppm
- Strontium- exceeding 5,000 ppm
- Vanadium- exceeding 800 ppm

Aluminum is also on the Interior list, and as has been the case with other DOE-funded work related to the coal measures, some samples have elevated aluminum contents (reported as Al_2O_3).

When added to the REE concentrations, the additional critical minerals found in some samples can result in significant composite contained-mineral values. This in turn suggests that multiple product recovery operations would have significantly improved commercial prospects, as compared with REE production alone, and would create an accelerated pathway to commercial REE production from these materials.

It is suggested that future research be completed to evaluate the critical metals resource available in the areas investigated within this report.

6.3 CLOSURE

Rare Earth elements have been identified at levels in excess of 300 ppm in both the Northern and Central Appalachia basins. The Northern Appalachia Basin, which is located in northern West Virginia and Pennsylvania, had sixty three (63) strata samples above the 300 ppm threshold, high TREE's being found primarily in the floor material, 51% of the +300 ppm strata samples, with 22 % of the samples coming from the coal seams. Partings and roof represented 14% and 13% of the +300 ppm strata samples respectively.

The highest occurrence of the +300 ppm samples were found in central Pennsylvania in Clearfield, Centre, and Clinton counties. A second area of high concentration was observed in Barbour County West Virginia. Both of these areas had high concentrations found primarily in the Lower and Middle Kittanning coal seams.

There were twenty five (25) samples of +300 ppm TREE in the Central Appalachia basin which is located in southern West Virginia. Eleven (11) of the twenty five (25), or 44% of the samples above 300 ppm TREE were from the Fire Clay seam located in Kanawha, Logan, and Mingo counties in West Virginia. Another ten (10) of the twenty five (25) were in four seams located in Boone County West Virginia. The distribution of the REE's in the strata was different than that of the Northern Appalachia. The most frequent occurrence was in the partings (40% of the +300 ppm samples), followed by the roof material at 28%. The area south of Charleston West Virginia encompassing southern Kanawha, Boone, Logan, and Mingo counties had the highest concentration of +300 ppm readings.

Both Northern and Central Appalachia Basins offer opportunities for additional sample collection to build a better understanding of the rare earth reserves. Northern Appalachia has more +300 ppm samples and more consistent geologic distribution of rare earths, but Central Appalachia higher concentrations of rare earths from coal seam samples. Additional work in needed to understand the depositional characteristics of rare earth elements within the coal strata matrix.

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APPENDIX A - DRAWINGS

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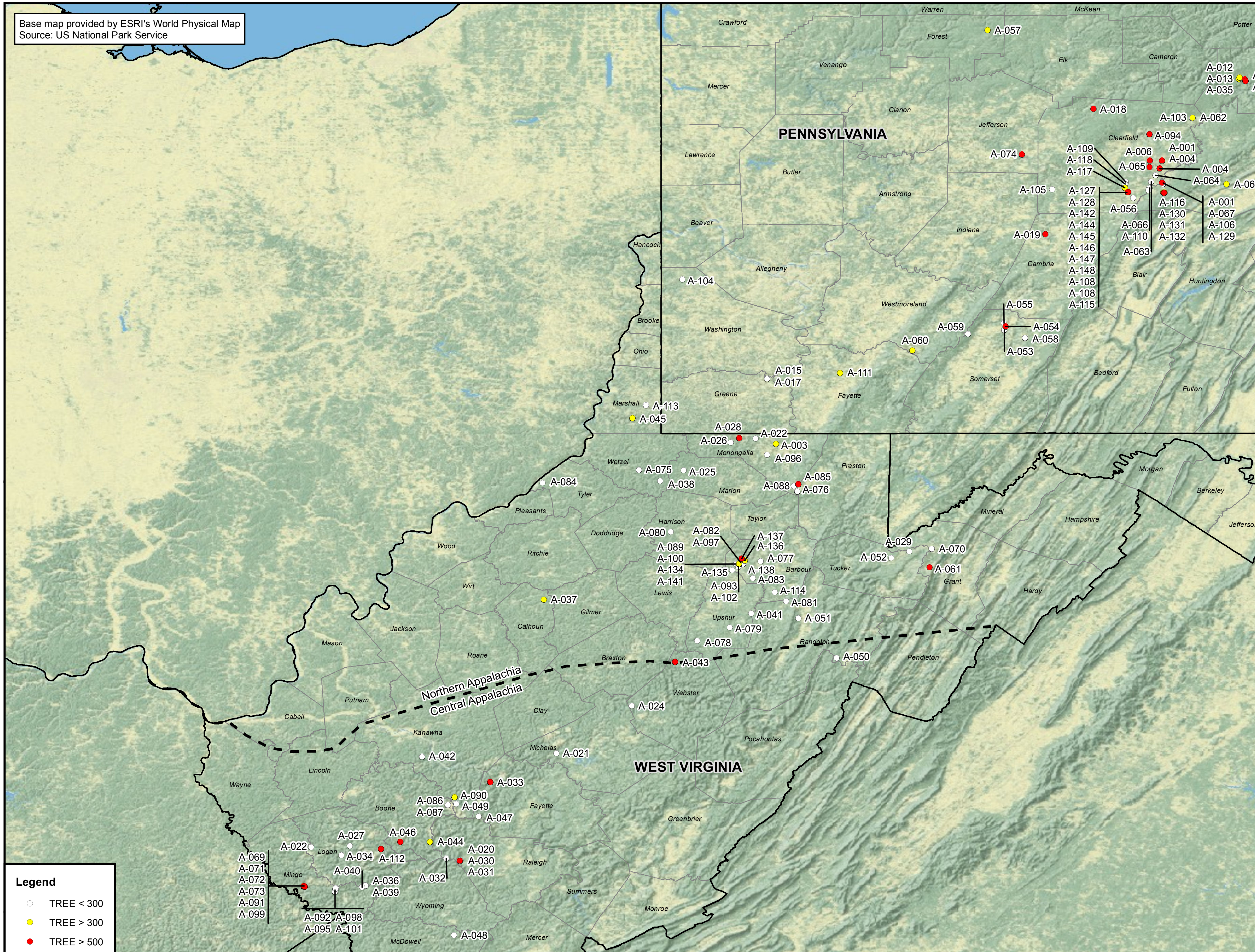

TETRA TECH

SAMPLE LOCATIONS
NORTH AND CENTRAL APPALACHIA

U.S. DEPARTMENT OF ENERGY,
NATIONAL ENERGY TECHNOLOGY LABORATORY
PENNSYLVANIA AND WEST VIRGINIA

DRAWN BY: S. PAXTON 10/12/17
CHECKED BY: K. PUGH 04/30/18
APPROVED BY: F. WOOD 04/30/18

CONTRACT NUMBER: 212G-PB-00467

DRAWING NUMBER
1

REVISION
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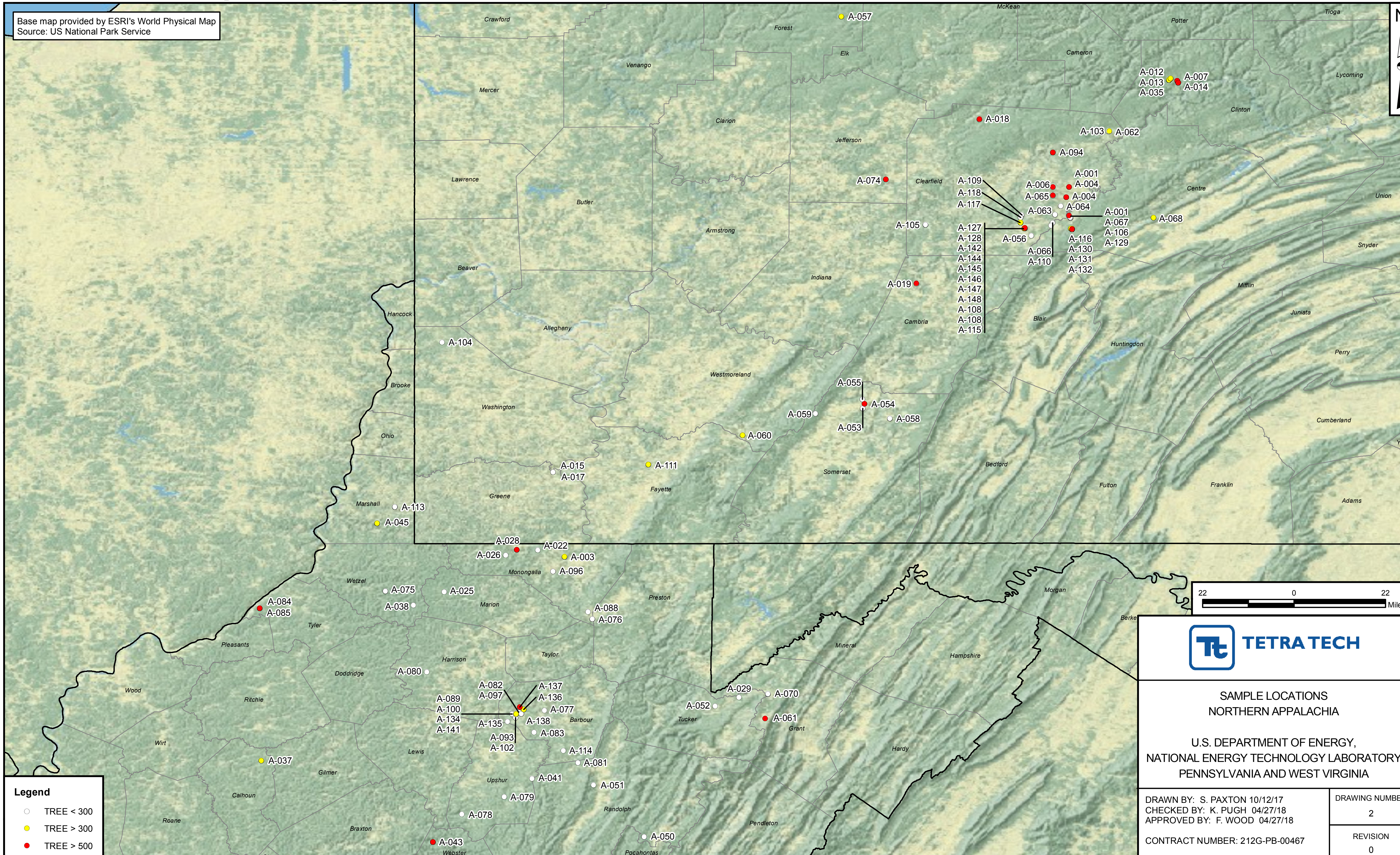

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APPENDIX B – GEOLOGIC DESCRIPTION

Introduction

Late Paleozoic paleogeographic reconstructions show North America and Europe united in a single landmass (Laurussia) positioned with its southern boundary sub-parallel to, and a few degrees south of, the paleoequator (Scotese and McKerrow, 1990; Scotese, 2002). Through the Pennsylvanian Laurussia moved northward through the wet tropics. The Appalachian-Variscan Orogeny began as Laurussia and Gondwana collided obliquely during the Carboniferous (Hatcher, 2002). In response to orogenic thrust loading, a series of foreland basins extended eastward along the paleoequator from the North American Midcontinent into eastern Europe (Euramerica), generally referred to as the Euramerican Pennsylvanian tropical or paleoequatorial coal belt (Wagner, 1984, 1993) (Figure 1). The Appalachian Basin was between the North American craton to the north and the rising orogeny to the south. These equatorial basins shared a common climatic history as demonstrated by their common paleoflora (e.g. Blake et al., 2002) and the widespread development of minable coal resources. The Late Paleozoic Ice Age is recorded in the basin fills by the repetitious eustatic (allocyclic rather than autocyclic) transgressive-regressive cycles, termed cyclothems in North America (e.g. Wanless and Shepard, 1936; Heckel, 1994) or "marine zones" (see Blake et al., 1992, Beuthin and Blake, 2004 for discussion on "marine zone") that have been correlated across Euramerican foreland fills (see discussion in Blake et al., 2002).

As Earth entered Glacial Stage II of the Late Paleozoic Ice Age (Isbell et al., 2003), large volumes of water were sequestered in growing Gondwanan high-latitude glaciers (Veevers and Powell, 1987; Frankes et al., 1992; Crowell, 1999; Isbell et al., 2003; Fielding et al., 2008 and papers therein), lowering global sea levels and subaerially-exposing large parts of the continental shelf. Lowered sea level and increased influx of clastics eroded from the rising east-west oriented Appalachian-Variscan mountains resulted in a switch from Middle Mississippian carbonates (Greenbrier Limestone) to Late Mississippian clastics (Mauch Chunk Group) in the Appalachian region. The Late Mississippian clastics of the Appalachian region were deposited under a semi-arid paleoclimate (Blake et al., 2009 and references therein) based on the presence of well-developed paleovertisols frequently with paleocaliches, and the lack of the coal beds that formed under the subsequent Pennsylvanian everwet climate. In contrast to the Late Mississippian semi-arid paleoclimate, Early Pennsylvanian sediment (Pottsville Group) was deposited under tropical wet to everwet conditions (Cecil et al., 1985; Cecil, 2003; Cecil and Dulong, 2003). Paleogeographic reconstructions for the Early Pennsylvanian show North America drifting northward towards the paleoequator out of the desert belt into the tropics (Scotese and McKerrow, 1990). Rain-water fed, raised peats (ombrogenous) formed under the tropical everwet climate and terrestrial, non-coal Pennsylvanian rocks are shades of gray with no greenish or reddish tints and generally contain abundant plant-derived organic material.

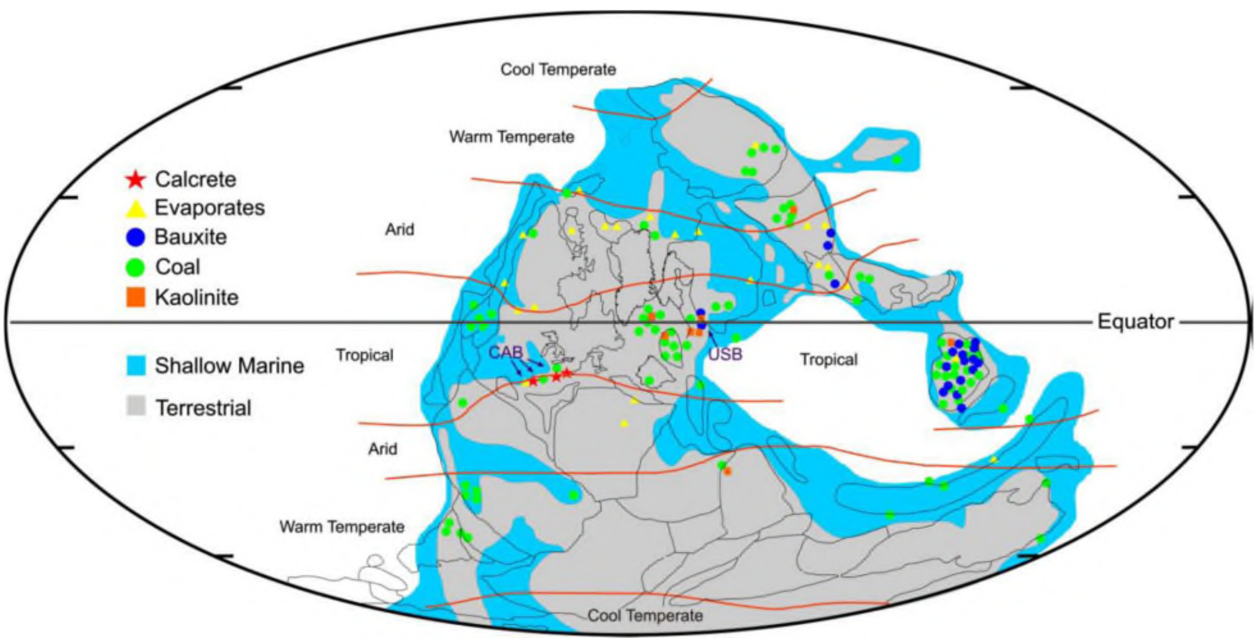

Figure l. Continental configuration for the early Namurian (Late Mississippian: Serpukhovian), approximately 325 million years ago. Paleoclimate proxies used to produce the map are shown to constrain paleoclimate belts. Euramerica is a belt located a few degrees south of the paleoequator and extending approximately between the Central Appalachian Basin (CAB) and the Upper Silesian Basin (USB). Notice the cluster of dry climate proxies in the vicinity of the CAB and the predominance of wet climate proxies in the eastern Euramerican USB. The CAB is positioned farther south of the paleoequator than the USB. Adapted from Scotese, 2002 in Blake et al., 2009.

Appalachian Basin

Pennsylvanian coal fields of West Virginia, and by default the entire Appalachian basin, have been divided into an older southern, low-sulfur field and the younger, northern, high-sulfur field based on regional variations in coal quality, rank, and age (Figure 2). The older, southern coal field comprises mainly Early and Middle Pennsylvanian-aged strata whereas the northern coal field comprises mainly uppermost Middle and Late Pennsylvanian (and earliest Permian) strata. Subsidence in the Appalachian region associated with orogeny to the south and east provided accommodation space for the accumulation of a northwest-thinning, coal-bearing clastic wedge that progressively onlapped north-northwestward onto the North American craton during the Early and Middle Pennsylvanian (Arkle, 1974; Donaldson, 1974; Donaldson and Shumaker, 1981; Donaldson and Eble, 1989, 1991). Thickness trends of within the basin fill suggest that only the distal part of the original clastic wedge is preserved: the thicker proximal portion of the fill was uplifted during later stages of the Appalachian Orogeny and subsequently removed by erosion. The hinge line, better referred to as a "hinge area or zone", separates the southern and northern coal fields, located in the area where the cratonic margin resisted rapid subsidence and is perhaps the position of a forebulge formed in response to crustal loading to the east and south. Clearly, the two basins formed under different subsidence and climatic regimes, to be discussed below.

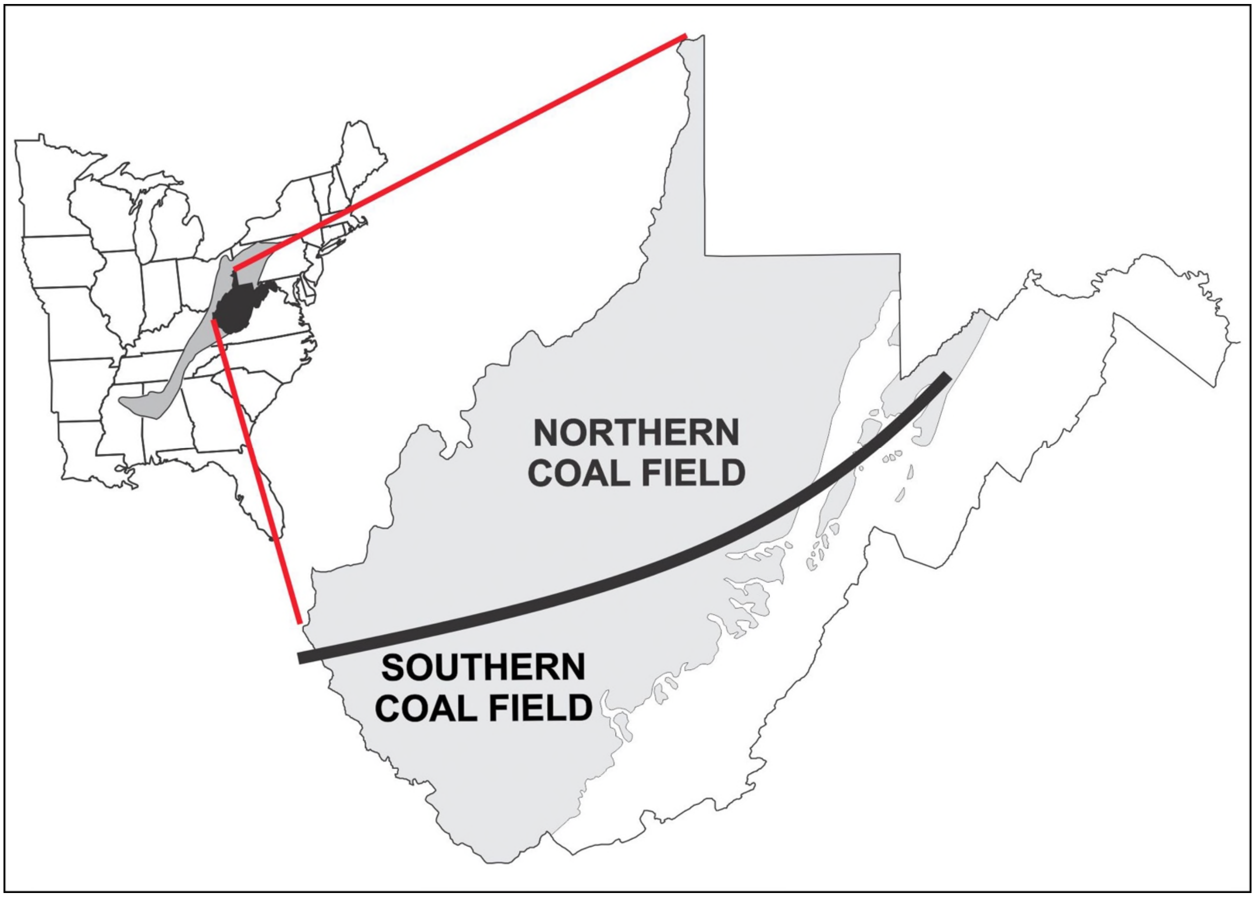

Figure 2. Pennsylvanian coal fields of the West Virginia portion of the Appalachian Basin, and the line between the major coal fields that also marks a zone of change in the thickness of the Pennsylvanian Pottsville Formation/Group. Adapted from Blake, 1997.

Lithostragraphy

Appalachian Basin lithostratigraphy originally was developed in the late 1800s and early 1900s in various States as workers sought to define their rock sequences within geographically separate areas. As a result, different States use different Formation and Bed terminology. Fortunately for this study, the nomenclature currently in use in West Virginia will suffice as there is no overlap with adjacent States with different nomenclatures (Figure 3). In the northern Appalachian region, there is some confusion and disagreement between Pennsylvanian and West Virginia over which bed is the Middle Kittanning and which is the

Lower Kittanning. As these seams comprise a group of distinct benches that variously spilt and merge across the basin, this minor disagreement is of little consequence.

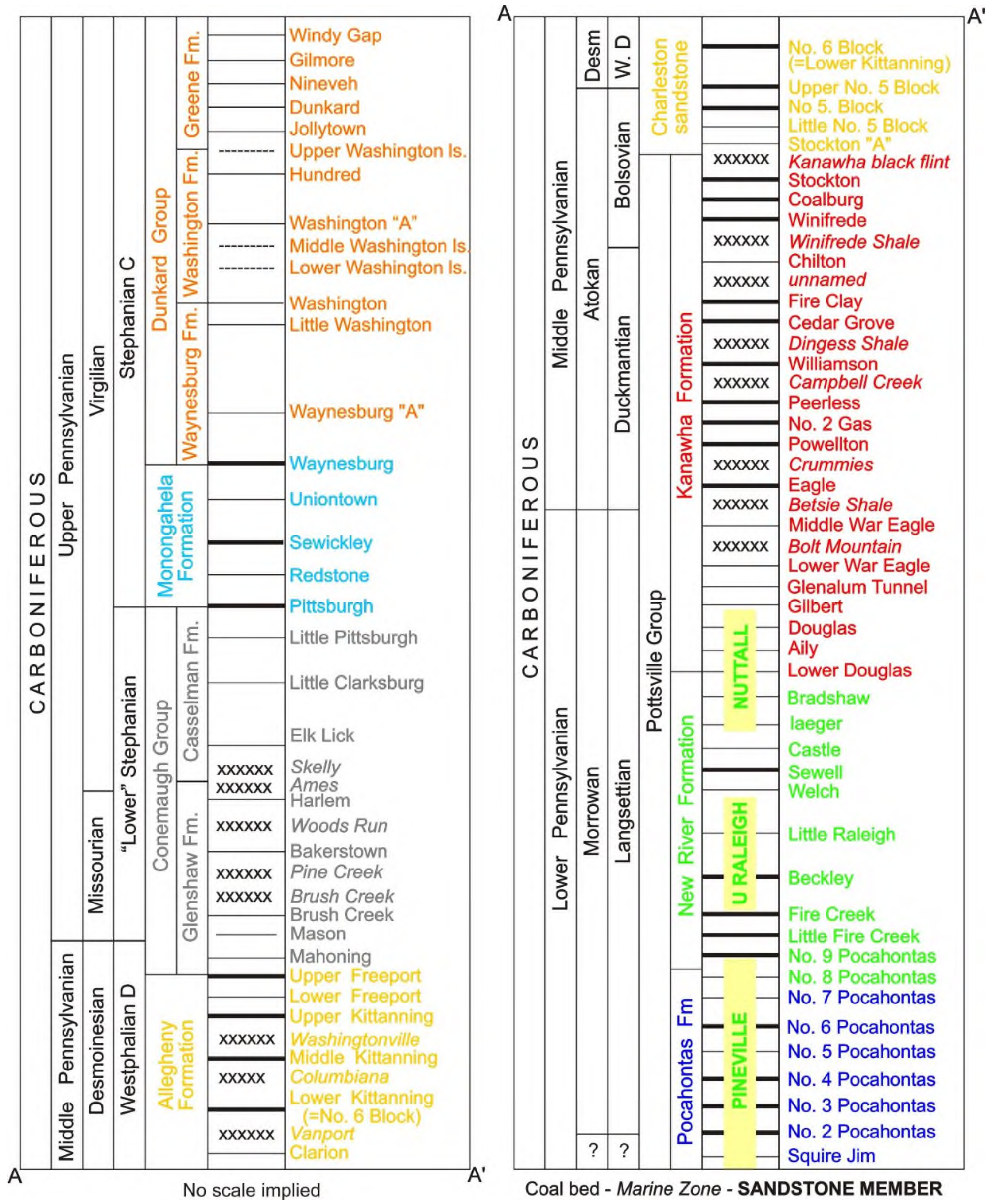

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Figure 3. Stratigraphic column of Pennsylvanian coal beds, marine zones, and other units mentioned in the text. Pennsylvanian litho- and chronostratigraphy recognized by the West Virginia Geological and Economic Survey. Taken from Blake et al., 2002. No scale implied

Southern West Virginia Coal Field

The rocks of the southern coal field ae mainly assigned to the coal-bearing Pottsville Group. In areas of maximum development in southern West Virginia, the Pottsville Group reaches a preserved thickness of approximately 1250 m (4000 feet) and is subdivided into the Lower Pennsylvanian Pocahontas and New River formations and the Lower and Middle Pennsylvanian Kanawha Formation (Figure 3). The Pottsville thins northward to approximately 110 m (350 feet) thick in northernmost West Virginia. Glacioeustatic marine zones are intercalated throughout the mainly terrestrial, coal-bearing Kanawha Formation (Blake et al., 1994). The Pottsville thins dramatically north of the hinge line and loses its defining characteristics, and across the Northern Appalachian region the Pottsville is generally afforded formational rank (Blake et al., 2002). The much discussed Miss-Penn unconformity (e.g. Blake and Beuthin, 2008 and references therein) occurs between the underlying Mauch Chunk Formation and the Pottsville Formation spanning at least the middle and upper Namurian of western European chronostratigraphy. Currently, this unconformity is attributed to a large drop in sea level related to an increase in Gondwanan glaciation (see discussion in Blake and Beuthin, 2008). In addition, the scale of the unconformity increases generally northward from southern West Virginia across the hinge line as accommodation space was limited due to slow subsidence of the North American cratonic margins.

Pocahontas Formation: Englund (1974) and Englund and Thomas, (1990) interpret the Lower Pennsylvanian Pocahontas Formation (Figure 3) as fluvial-deltaic sandstones with lesser amounts of siltstones, shales, mudstones, and coal beds deposited in a series of coalescing delta lobes and associated coastal plain facies. Peat accumulated on the topographically positive, sand-rich, abandoned delta lobes. More recently, Blake and Beuthin (2008) envision a broad, low-lying valley draining southward towards Alabama's Warrior Basin. Regionally, the Pocahontas Formation thins north and northwestward from a maximum thickness of approximately 215 m in southern West Virginia and adjacent areas, wedging out in approximately 48 km (Englund 1974, Englund and Thomas 1990). The lower formation contact is placed at the base of the lower sandstone member (Englund 1974), but in some areas the lower formation contact is problematical. Blake and Beuthin (2008) applied a sequence stratigraphic model to the lower formation contact (=Mississippian-Pennsylvanian Subsystemic Boundary), envisioning the presence of an unconformity associated with a paleovalley incised during the eustatic sea level drop associated with the onset of Glacial Stage II (discussed above). In areas where the upper part of the Pocahontas has not been truncated by Early Pennsylvanian (sub-New River Formation) erosion, the upper formation contact is placed arbitrarily at the base of the Pocahontas No. 8 coal bed (Englund, 1979). Early Pennsylvanian erosion progressively truncated the Pocahontas Formation north-northwestward, a thinning trend possibly enhanced by nondeposition. This regional unconformity is located at the base of the Pineville Sandstone Member of the overlying New River Formation (Chesnut 1988, 1992, Englund and Thomas 1990) (Figure 3). Marine influence in noncoal strata are rare, but nonmarine bivalves have been found associated with the Pocahontas Nos 3 and 6 coal beds (unpublished data). Pocahontas Formation coal beds are generally low and mid-volatile bituminous in rank and have been widely mined for metallurgical purposes. The Pocahontas Nos. 2, 3, 4, and 6 and associated splits contain the main original resources with the Poca No. 3 being the most aerially widespread and heavily mined. Available REE values suggest generally variable background concentrations with no target areas located.

New River Formation: The Lower Pennsylvanian New River Formation (Figure 3) extends upward from the base of the Pocahontas No. 8 coal bed to the base of the Lower Douglas (?) coal bed of Hennen and Teets (1919) (Arndt 1979, Englund 1979), reaching a maximum preserved thickness of over 305 m (1000 feet) in its southern outcrop area and thinning to the north and west. Blake (1997; Blake et al., 2002) correlated this bed with the Gilbert coal be of southernmost West Virginia. The New River Formation consists of sublithic to lithic arenites with lesser amounts of siltstones, shales, mudstones, and coal beds.

In many areas thick, lenticular quartzose sandstone bodies are prominent and are unconformable with underlying beds. Paleocurrent data indicate a general northwest transportation direction from low-grade metamorphic highlands to the southeast for the lithic sandstones and a south-southwest transport direction from the stable craton towards the southern Appalachian region for the quartzose sandstones (Arkle 1974, Horne 1979, Houseknecht 1980, Donaldson and Shumaker 1981, Chesnut 1992, 1993, 1994; Archer and Greb 1995). Blake and Gillespie (1994) and Blake (1997) suggested that the New River Formation, as defined, has a diachronous top due to miscorrelations of coal beds in the overlying Kanawha Formation (Figure 3). The New River Formation thins rapidly to the north and northwest until in northern parts of the Appalachian region it is absent or unrecognizable due to loss of key beds, nondeposition, and/or erosion. In the northern areas where the New River Formation is unrecognizable or absent, Middle Pennsylvanian (Kanawha Formation equivalent) strata are in contact with older Upper Paleozoic (Upper Devonian to Upper Mississippian) strata.

Limited diversity trace fossil assemblages are locally common in marine-influenced sequences of sandy shales to very fine-grained, frequently lenticular- to flaser-bedded, lower to middle estuarine facies. Invertebrate body fossils, consisting of long-lived forms with little biostratigraphic utility, have been reported from five zones in the New River Formation (summarized in Blake 1997).

Coal beds are generally mid-volatile bituminous in rank and have been widely mined for steam generation and metallurgical purposes. The Fire Creek, Beckley and Sewell beds contain the largest original resources and have been widely mined. Significant original resources were also present in the Little Fire Creek, Welch, and Iaeger beds. Investigated samples contain varying background concentrations of REEs and no special target areas identified.

Kanawha Formation: The Lower (as defined in Blake et al., 2002) and Middle Pennsylvanian Kanawha Formation is a coal-bearing sequence of sandstones, siltstones, shales, and mudstones with minor occurrences of siderite, limestone, and flint clay (Figure 3). At least 14 brackish to normal marine zones have been identified, many of which occur across the entire central Appalachian region and are considered glacioeustatic in origin (Rice *et al*. 1987, Chesnut 1991, 1992, 1993, Blake *et al*. 1994, Blake 1997). A maximum preserved thickness of more than 613 m is present in southern West Virginia (Arkle *et al*. 1979, Blake *et al*. 1989, Blake 1992, Blake *et al*. 1996). The base of the Kanawha Formation is placed at the base of the Lower Douglas (?) coal bed of Hennen and Teets (1919) and the upper contact of the Kanawha Formation at the top of the Kanawha Black Flint of White (1891).

The Kanawha Formation contains numerous coal beds and range in rank from mid-volatile bituminous in the lower part of the formation in the more southern parts of its occurrence to high-volatile A bituminous over the majority of its area. The formation contains a large number of economically minable coal beds historically comprising approximately 40% of West Virginia's original coal resources and, until recently, approximately 50% of its annual production. Kanawha Formation coal is mined for metallurgical purposes and as low sulfur compliance steam coal. Many Kanawha coal beds occur in multiple bed zones with frequent splits and merges. Widely mined coal beds include the Douglas, Gilbert, Glenalum Tunnel, Lower War Eagle, Middle War Eagle, Eagle (and splits), Powellton (and splits), No. 2 Gas, Peerless, Williamson, Cedar Grove, Fire Clay, the Chilton zone, the Winifrede zone, the Coalburg zone, and the Stockton zone. A widespread volcanic ash (tonstein) is found in the Fire Clay coal across southern West Virginia, Virginia, Kentucky, and Tennessee. Published analyses for the Fire Clay in Kentucky (Hower, et al., 1999, 2016), and for this report, indicate elevated REE concentrations associated with the tonstein. Data generated during this study agree with this finding. Another tonstein has been found locally in the Williamson coal bed bear Oceana, West Virginia, but this tonstein seems to be of limited aerial extent and REE analyses for the Williamson coal deliver unspectacular concentrations. Generally the lower Kanawha coal beds, below the Betsie Shale Member (Figure 3) are relatively thin and mined for metallurgical purposes. Middle Kanawha coal, between the Betsie and Winifrede Shale Member, are mined for steam and metallurgical purposes. Benches within the Winifrede coal zone have been widely mined for metallurgical and steam purposes. The high inertinite content present in most of the Coalburg and Stockton benches render them unsuitable for metallurgical purposes. Variable levels of REEs have been identified, but, other than the well-documented Fire Clay and associated volcanic ash, REE concentrations are not overly attractive.

Charleston Sandstone (southern Allegheny Formation): Although still not completely clear, late Middle Pennsylvanian traditional stratal relationships between the southern and northern coal fields have been misunderstood. Most early work incorrectly equated the Charleston Sandstone of Campbell and Mendenhall (1896) with the Allegheny Formation of more northern areas (e.g. Arndt 1979). The "Charleston Sandstone" nomenclature is not recognized by the West Virginia Geological and Economic Survey as a confusing name that is not recognized outside a small area around Charleston, West Virginia, where sandstones from several formations have serendipitously stacked due to post-deposition erosion. This unit is not identifiable outside this limited area and is of no practical use. In central and southern West Virginia, the southern West Virginia Allegheny Formation is thick with numerous economic coal beds, whereas, the Allegheny Formation is thin and coal beds, when present, are thin, lenticular, and few in number. In the more northern part of the foreland basin the situation is reversed with the Charleston Sandstone being thin to absent. Palynomorph analysis suggests the No. 6 Block coal bed (southern West Virginia usage) correlates with the Lower Kittanning coal bed (Allegheny Formation of northern areas) (Figure 3) (Peppers 1996). Arkle (1974) postulated the presence of a nearly unrecognizable unconformity at the top of the Charleston Sandstone based on subtle changes in mudrock weathering characteristics and sandstone mineralogy. Additional, quartz pebbles return to the sandstones after an absence since the New River Formation. The renewed presence of quartz pebbles suggest a change in source area or uplift of proximal parts of the foreland and recycling of New River sands. Analyses of the relevant macroflora (Blake et al., 2002) also suggests the presence of a minor unconformity encompassing the upper Bolsovian and lower Austurian (Westphalian D of Figure 3) at this level, although the macroflora from the No. 5 and Upper No. 5 Block coals are poorly studied. The widespread occurrence of kaolinitic paleosols (brecciated flint clays) above this level and above thought to represent lateritic weathering of coastal plains exposed to tropical weathering during glacioeustatic sea level lowstands lends credible support for a climatic shift occurring within this interval.

The southern West Virginia Allegheny Formation is dominated by thick, multistoried fluvial sandstones and coal beds. Mutli-benched coals tend to be thick, although aerially discontinuous with common splitting and merging. Resource loss is locally common due to post deposition channeling. Widely mined coals include the No. 5 Block and the Upper No. 5 Block (Figure 3). These coals are high, although variable, in inertinite content, frequently making much of this resource unsuitable for metallurgical purposes. Locally, the high inertinite content results in a very hard coal with low Hardgrove grindability indexes rendering these resources mainly useful as “lump” coal, being too hard for pulverization in modern coal-fired power plants. The “5 Blocks” do not seem likely candidates for REE exploitation.

Northern Coal Field

The Middle Pennsylvanian (northern) Allegheny Formation consists of sandstones, mudrocks, and coal beds with minor amounts of thin, non-marine limestones. Calcareous material occurs in the upper part of the formation as calcareous nodules or calcrete in paleosols or in discrete beds, beginning with the Johnstown (Cement) Limestone and associated paleosol. Calcareous material is notably absent below this level. In addition, the mudrocks become noticeably “green” beginning at this level compared to older strata. These two factors suggest the presence of a climate change occurring at the level of the Johnstown Limestone. Intercalated marine zones in the bottom half of the Allegheny Formation in the northern Appalachian region of Ohio, western Pennsylvania, and West Virginia's northern panhandle allow correlation with the more marine sections of the Interior basins on the North American mid-Continent (e.g. Heckel 1994). Sandstones are generally lithic arenites and commonly contain cm-scale or smaller quartz pebbles. Quartz arenites are present locally. In contrast to the thick, multistoried sandstones found south of the hinge line, Allegheny sandstones tend to be more aerially restricted and seem to exhibit lateral accretion rather than vertical stacking, suggesting less accommodation space (=slower subsidence) to the north. Allegheny coals tend to occur in zones of coal and carbonaceous shales. Numerous aerially-widespread and widely mined coal beds are present in the Allegheny Formation (Figure 3). Beds within specific zones can split apart as much as 50-60 feet, making regional correlations tentative. Widely mined coal beds include the Lower, Middle, and Upper Kittannings and the Upper Freeport and Mahoning. The Clarion and Lower Freeport have also been exploited, but to a lesser extent. Associated with the Allegheny coals are a distinctive lithology consisting of high kaolinitic clay beds (flint clays), frequently brecciated. These coal beds have been mined for refractory purposes and brick making. Analyzes from various Allegheny coals, partings, and floors, including the brecciated flint clays, suggest the possibly of sporadic REE economic resources, but the results are unfinished as of this writhing.

Conemaugh Group: The Middle and Upper Pennsylvanian Conemaugh Group extends from the top of the Upper Freeport coal bed to the base of the Pittsburgh coal bed (Figure 3). These contacts follow long-established tradition in North America of placing formation contacts at geographically-widespread, economically-important coal beds: contacts difficult to locate in the absence of the designated coal bed. The basal part of the Conemaugh Group from the top of the Upper Freeport upward a variable interval towards the Brush Creek coal bed is lithologically indistinguishable from the subjacent Allegheny

Formation and contains a Middle Pennsylvanian macroflora. Somewhere between the Upper Freeport and Brush Creek coal beds, and slightly above the "Mahoning" level, commonly occurs a brecciated flint clay bed, often associated with non-marine limestone beds. Red beds first occur at this level and continue upwards through the younger Appalachian formations. Red beds are unknown below this level and do not occur in the subjacent Allegheny Formation. This is also a distinct macrolforal break at this level, represent a hiatus of controversial duration (Blake et al., 2002; Falcon-Lang et al., 2011). This is a better position for the Allegheny-Conemaugh contact as there is a striking change in the Conemaugh above this level; the section being dominated by abundant, well-developed red paleosols with features suggestive of development under relatively dry to seasonally-dry climatic conditions such as calcareous soil nodules and vertic structures (Cecil *et al*. 1994, Joeckel 1995).

Coal beds in the Conemaugh Group are thin, impure, and areally-restricted, reflecting the impact of climate on peat accumulation. During the Conemaugh times, water table position was one main factor controlling peat formation and accumulation in contrast to the importance of an everwet climate in controlling peat formation in the lower series (White 1931, Cecil *et al*. 1985, 1994, Cecil 1990). Intercalated marine zones are stratigraphically important for intrabasinal and continental correlations (Heckel 1994). The Bakerstown coal is the only Conemaugh coal with significant original resources, but resource depletion is a serious issue. Minor resources have been exploited from the Brush Creek, Harlem, and Elk Lick coals (Figure 3). Coal quality is generally poor with relative high ash yield and high sulfur content. Available REE data show mainly background, although variable, levels. No specific targets areas were identified.

Monongahela Formation: The Upper Pennsylvanian Monongahela Formation extends upward from the base of the Pittsburgh coal bed to the base of the Waynesburg coal bed. Different regional stratigraphies disagree with the formational contact, placing it either at the base of the top of the Waynesburg coal zone.

WVGES generally uses the top of the Waynesburg as the formational contact, but bows herein to neighboring usages. Pennsylvania to the north subdivide the Monongahela, elevating it to Group status. The onset of Pittsburgh peat accumulation marks a return to wetter climates compared to the underlying Conemaugh Group: generally the calcareous paleovertisols are absent. Strata include nonmarine limestone, sandstones, mudstones/shales, and coal beds. The non-marine limestones dominate the section below the Uniontown coal bed. Megafloras are most commonly associated with various coal beds.

Excluding the aerially widespread Pittsburgh seam, Monongahela coal beds tend to be aerially restricted. Coal quality varies, with sulfur yield relatively high compared to older coals. Widely mined coals include the Pittsburgh, Redstone, and Sewickley. As with most coal beds in the Appalachian region, REE concentrations are rarely above background, with no high-concentration targets identified.

Dunkard Group: The Dunkard Group is variably subdivided into the Waynesburg, Washington, and Greene formations (Figure 3) and contains all strata above the base of the Waynesburg coal bed in the Appalachian region (Berryhill *et al.* 1971). The strata consist of sandstones, shales, nonmarine limestones and coal beds. The limestones do not dominate the section as in the underlying Monongahela Formation; thick, fluvial sandstones of limited aerial extent are more common. Excluding the Waynesburg, coal beds are generally thin, and unimportant and only the Waynesburg, Waynesburg “A” and Washington coal (zones) contain any potential resources. The double-benched Waynesburg is quite thick and widely mined by stripping in north-central regions in West Virginia. Waynesburg is fairly high in ash and only suitable for steam generation. The clayey middle parting in the Waynesburg is difficult to remove during beneficiation, making underground mining unfeasible. The Waynesburg “A” coal bed has been mined locally with the underlying Waynesburg, although it is unminable in its own right. For tax purposes and resource estimations, WVGES has removed the Washington from West Virginia’s resource base.

Analyses have not identified any areas with significant REE contents significantly above background levels. None of the numerous named coals in the middle and upper Dunkard were analyzed for this study.

Peat Formation

An important question that needs to be answered is how rare earth elements (REE) are introduced into the coal through the peat-forming environment. There are only two possible mechanisms. First, the REEs are present in the original substrate that the peat-forming plants grew on and was taken up by the plants as part of their nutrient intake. Or, the REEs can be introduced secondarily into the peat environment with clastics washed onto the peat by surface floods or through an air-fall mechanism, either as in-blown dust, dust washed from the atmosphere by precipitations, or as volcanic ash deposited on the surface of the peat body. These mechanisms will be briefly addressed below after peat-formation is discussed. There is still the issue with a concentrating mechanism that would increase REE content beyond background levels.

In order for a coal-forming peat to accumulate to any appreciable thickness, several criteria must be simultaneously met (Diessel, 1992). First, the substrate on which the peat accumulates must be nearly flat and at or just below the persistent, regional water table, generally sea level in the Appalachian foreland. Water depth at the site of peat accumulation must be shallow enough for plants to grow in situ but deep enough that the plant debris accumulates under water in anoxic conditions where oxidation and decay are retarded or prevented. The surface water in the peat-forming environment may be marine, brackish or fresh, but fresh water of moderately low pH is best for preventing decay by microbes and preserving the peat (Stach et al., 1982). The low pH and anoxic conditions are maintained as partial decay of dead plant material uses oxygen and releases organic acids. The higher pH associated with brackish or marine waters is less toxic to consumers of organic materials. Water entering the swamp should be largely sediment-free, as the peat-forming environment should accumulate only peat. For this discussion, sediment refers to both clastic particles and dissolved ions. For example, after deposition, partial coalification, loss of water content, and compaction, a peaty deposit originally containing 10% clastic sediments may result in the formation of a carbonaceous rock with 90% minerals and only 10% coaly materials (Cecil et al., 1982). For peat to accumulate to significant thickness, ~~a~~ the water table must be maintained very close to the peat-air interface so that as the plants continue to grow and die, and the organic material is preserved under water. These conditions require slow, continuous subsidence of the substrate or a gradual rise in sea level. As long as these conditions are met over a thousands of years, a low moor or planar topogenous peat accumulates from flora best adapted to those conditions. Due to their low topographic profile, planar “swamps,” are subject to a number of factors that influence the composition (quality) of the resultant coal. Fluctuations in clastic sediment input due to streams periodically flooding the peat surface introduces clastic sediments that result in high mineral (ash) content. In addition, the input of fresh waters raise the pH of the peat waters, allowing for increased biotic decomposition, decreasing future coal quality (Stach et al., 1982). As Carboniferous peats accumulated on a broad coastal plain, episodic inundations of planar peats by brackish and marine water, providing a ready source of energy to sulfur-fixing bacteria, increasing the peat’s sulfur content (Casagrande, 1987). These waters also raise the pH of the peat interstitial water, encouraging consumers to degrade the abundant organic material. Short to moderate-term fluctuations in water availability is another factor that impacts the quality of planar peats. Prolonged droughts due to fluctuating climatic conditions can subaerially expose the peat, drying it out and exposing the organic material to microbial attack or destruction by fire. Changes in subsidence rates also interferes with peat accumulation. Cessation of subsidence exposes the peat to the dangers of drying previously discussed, allowing impure coal (bone) partings to form. Clastics can be introduced forming widespread clastic partings. Increases in subsidence drown the peat-forming environments, resulting in deposition of clastic sediment.

Low moor planar swamps are the norm in today's temperate and subtropical climates. Good examples are the Snuggedy swamp of South Carolina, the Okefenokee Swamp of Georgia, and the Everglades of Florida, although these examples are developing under different tectonic settings than occurred in the Appalachian region during the Pennsylvanian. Under current climates and the proper tectonic settings, the annual rainfall and resulting surface water influx is adequate to maintain these swamps for thousands of years. Many Pennsylvanian age coals of the Appalachian region formed wholly or in part in topogenous swamps. The extensive Pittsburgh coal is one example of a topogenous peat accumulation.

Tropical equatorial climates exhibit very high annual rainfall, high humidity and high temperatures. Under these ever-wet, tropical conditions, the source of water into the swamps is largely from rainfall (ombrotrophic: solely rainfall fed) (Diessel, 1992). The high annual rainfall infiltrates into the peat and slowly moves through the peat, exiting the swamp through the peat. This constant movement of relatively pure rainwater through the peat prevents mineral-laden ground water to filter back into the peat. As a result, a perched water table forms which allows additional peat to accumulate above the local stream or sea level. These "domed" ombrogenous peat swamps are common in regions of the tropics such as Borneo where the peat may attain thicknesses greater than 50 feet in only 6,000 years (Anderson, 1964). .Because of their elevated nature these ombrogenous peats are very low in mineral matter (ash) and are often subjected to extensive oxidation caused, not only by fire, but through the actions of fungi and prolonged exposure to oxygenated rain water.

During the Middle Pennsylvanian (upper Kanawha through "southern" Allegheny formations: Winifrede through Upper 5 Block coals: Figure 3) West Virginia was situated a few degrees south of the paleoequator within the equatorial belt and the peat that formed many of these coals accumulated under ombrotrophic, ever-wet, rain-forest conditions (Boucot et al., 2013). These coals generally began as low moor swamps, but due to the ever-wet climate, developed into domed swamps producing low ash "splint" coals rich in oxidized plant materials. Because of the austere, nutrient-poor conditions in the uppermost part of the domed peat, splint coals formed from tough, resistant remnants of the original plants in the form of oxidized materials (inertinites) and spores (liptinites). These coals can be difficult to mine because of their hardness and combust very poorly in modern power plants.

Because of differing rates of subsidence or sea level rise and differing time scales for peat accumulation, most West Virginia coal swamps did not develop into "domed" swamps, but only attained an "elevated" swamp profile between a classic low-moor configuration and a fully-developed domed peat. These coals, from the Lower Pennsylvanian Pocahontas coals through the Middle Kanawha Formation, formed "elevated" swamps under high rainfall conditions that were ideal to produce high quality coals rich in the original "woody" plant materials (vitrinite) and low in mineral matter (ash) and sulfur.

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APPENDIX C - RESULTS

Dry Ash Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																						
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)															Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-001	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	1,215.2	685.4	529.8	1.3	40.1	326.6	64.0	206.5	35.0	172.8	64.5	18.1	84.3	14.6	84.5	15.5	42.1	5.9	35.3	5.4	11.9	15.1
A-001	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	2,876.7	1,787.2	1,089.5	1.6	10.4	772.4	316.4	626.0	93.9	418.5	116.8	32.1	173.0	26.2	141.8	26.9	66.7	8.0	41.1	6.5	3.5	7.1
A-004	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	2,623.6	1,288.3	1,335.3	1.0	27.8	908.5	122.7	389.8	64.5	337.2	119.7	34.5	192.1	32.1	181.1	35.2	92.2	11.9	64.3	10.0	10.6	16.9
A-004	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	2,471.0	1,207.1	1,263.9	1.0	33.5	872.8	116.0	364.8	60.5	312.7	110.3	31.7	177.4	29.5	166.4	32.3	83.8	10.9	58.8	9.4	17.8	15.8
A-004	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	1,479.3	762.1	717.2	1.1	10.9	475.4	79.8	237.0	38.7	197.3	69.1	19.8	109.5	17.9	102.5	20.0	52.1	6.6	36.8	5.9	2.1	8.2
A-004	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	4,753.5	2,416.7	2,336.8	1.0	98.1	1,612.5	241.2	741.4	115.5	613.3	209.8	57.4	340.1	54.9	305.8	60.0	155.1	20.0	112.1	16.4	44.8	33.8
A-009	Floor	Northern Appalachia	Lower Kittanning	PA	Clearfield	156.6	129.7	26.9	4.8	18.5	18.2	26.7	53.2	5.9	19.1	3.1	0.6	2.6	0.5	3.1	0.7	2.0	0.3	1.9	0.3	9.7	3.0
A-017	Sludge	Northern Appalachia	Pittsburgh	PA	Washington	76.2	33.3	42.9	0.8	7.8	32.8	2.9	8.0	1.3	6.6	2.1	0.6	4.0	0.7	3.9	0.9	2.2	0.4	1.4	0.4	11.7	2.9
A-018	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	630.9	335.1	295.7	1.1	32.4	178.6	27.9	93.3	15.8	79.4	29.5	8.5	48.4	8.6	49.6	9.5	25.0	3.3	18.5	2.8	10.8	6.5
A-019	Sludge	Northern Appalachia	Lower Kittanning	PA	Cambria	512.8	295.6	217.2	1.4	36.9	161.6	35.7	110.7	11.9	56.5	14.7	3.8	25.4	3.8	23.3	4.8	12.8	1.6	8.4	1.1	44.3	1.7
A-021	Channel	Central Appalachia	Fire Clay	WV	Nicholas	180.5	142.9	37.7	3.8	18.8	26.7	28.0	56.1	6.4	23.3	4.9	0.9	4.5	0.7	4.1	0.9	2.3	0.3	2.2	0.3	11.2	5.5
A-022	Channel	Central Appalachia	Fire Clay	WV	Logan	68.3	47.4	20.9	2.3	6.1	15.8	8.4	17.9	2.2	8.4	1.9	0.4	2.0	0.3	1.9	0.4	1.2	0.2	1.0	0.1	3.5	1.6
A-022	Channel	Central Appalachia	Fire Clay	WV	Logan	82.6	56.9	25.6	2.2	7.7	19.3	10.0	21.6	2.5	9.8	2.3	0.5	2.5	0.4	2.3	0.5	1.4	0.2	1.3	0.2	5.3	1.6
A-022	Bench	Northern Appalachia	Waynesburg	WV	Monongalia	83.3	68.8	14.5	4.7	7.9	10.3	14.3	28.2	3.2	10.9	2.1	0.4	1.8	0.3	1.5	0.3	0.9	0.1	0.9	0.1	3.5	1.1
A-024	Channel	Central Appalachia	Fire Clay	WV	Webster	166.2	126.9	39.3	3.2	16.7	28.4	25.8	49.7	5.7	19.9	4.0	0.9	4.0	0.7	3.7	0.9	2.5	0.4	2.3	0.3	11.5	2.7
A-026	Channel	Northern Appalachia	Upper Kittanning	WV	Monongalia	226.2	189.5	36.7	5.2	12.3	26.5	42.7	79.5	8.9	34.3	6.3	1.2	4.3	0.6	3.7	0.8	2.3	0.3	2.1	0.3	5.5	4.6
A-027	Channel	Central Appalachia	Fire Clay	WV	Logan	105.2	77.3	27.9	2.8	8.9	20.8	15.2	30.0	3.5	13.4	2.9	0.6	2.9	0.5	2.5	0.6	1.6	0.3	1.4	0.2	5.3	1.8
A-028	Channel	Northern Appalachia	Waynesburg	WV	Monongalia	202.0	164.7	37.2	4.4	17.7	26.6	33.3	66.9	7.6	27.9	5.4	1.1	4.8	0.7	3.9	0.8	2.3	0.4	2.1	0.3	8.8	2.8
A-030	Coal	Central Appalachia	Middle War Eagle	WV	Raleigh	32.0	26.7	5.3	5.0	2.2	3.7	5.7	11.1	1.2	4.6	0.9	0.2	0.8	0.1	0.6	0.1	0.4	0.1	0.3	0.1	1.4	0.7
A-033	Channel	Central Appalachia	Fire Clay	WV	Kanawha	40.9	30.4	10.5	2.9	3.4	7.6	5.9	11.8	1.5	5.4	1.1	0.2	1.1	0.2	1.1	0.2	0.7	0.1	0.6	0.1	1.5	4.8
A-033	Channel	Central Appalachia	Fire Clay	WV	Kanawha	60.1	31.3	28.7	1.1	3.1	21.4	5.2	11.6	1.5	5.9	1.7	0.3	2.0	0.4	2.6	0.6	1.7	0.2	1.5	0.2	0.8	2.4
A-033	Channel	Central Appalachia	Fire Clay	WV	Kanawha	78.0	54.0	24.0	2.2	2.3	17.5	9.2	22.3	2.9	11.3	2.9	0.3	2.7	0.4	2.7	0.5	1.5	0.2	1.1	0.1	1.3	1.1
A-033	Channel	Central Appalachia	Fire Clay	WV	Kanawha	45.0	25.5	19.5	1.3	3.5	15.2	4.0	9.2	1.2	4.5	1.3	0.2	1.6	0.2	1.6	0.4	1.0	0.1	0.9	0.1	1.4	0.7
A-033	Channel	Central Appalachia	Fire Clay	WV	Kanawha	28.9	15.5	13.4	1.2	2.1	10.3	2.9	5.6	0.7	2.5	0.6	0.2	0.9	0.2	1.1	0.2	0.8	0.1	0.6	0.1	0.5	0.3
A-033	Channel	Central Appalachia	Fire Clay	WV	Kanawha	1,384.1	1,289.6	94.4	13.7	20.6	64.3	259.6	595.6	70.8	263.2	42.1	9.9	27.8	3.1	14.4	2.4	5.5	0.6	3.8	0.5	37.9	6.5
A-034	Channel	Central Appalachia	Cedar Grove	WV	Logan	98.2	74.4	23.8	3.1	7.2	17.2	13.6	30.3	3.5	13.0	3.1	0.6	3.0	0.5	2.5	0.5	1.4	0.2	1.3	0.2	5.3	1.7
A-035	Channel	Central Appalachia	No.2 Gas	WV	Logan	61.4	49.5	11.9	4.1	6.3	8.7	10.3	19.7	2.1	7.9	1.5	0.3	1.4	0.2	1.2	0.2	0.7	0.1	0.7	0.1	3.6	0.9
A-035	Channel	Central Appalachia	Williamson	WV	Logan	118.0	90.4	27.6	3.3	6.7	20.0	17.6	37.3	4.5	16.6	3.7	0.7	3.4	0.5	2.9	0.6	1.7	0.3	1.4	0.2	3.8	1.0
A-036	Channel	Central Appalachia	Fire Clay	WV	Mingo	173.8	122.2	51.6	2.4	14.7	37.3	22.3	46.7	5.9	21.9	5.1	0.7	5.0	1.0	5.1	1.2	3.1	0.6	2.8	0.5	14.3	3.3
A-042	Channel	Central Appalachia	Stockton	WV	Kanawha	140.1	105.8	34.3	3.1	36.1	21.6	13.7	29.6	4.3	13.5	3.6	1.4	3.7	1.3	3.5	1.4	2.4	1.1	2.1	1.0	32.7	2.8
A-044	Channel	Central Appalachia	No.2 Gas	WV	Boone	88.2	65.3	23.0	2.8	8.8	16.8	12.1	24.8	3.0	10.9	2.7	0.5	2.5	0.4	2.2	0.5	1.4	0.2	1.2	0.2	5.2	2.5
A-045	Channel	Northern Appalachia	Pittsburgh	WV	Marshall	229.7	216.8	12.9	16.8	3.5	8.5	43.4	99.6	12.2	44.6	7.3	1.6	4.5	0.5	2.2	0.3	0.8	0.1	0.5	0.1	5.5	0.9
A-045	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	201.3	160.1	41.2	3.9	19.0	29.1	33.2	63.8	7.1	25.7	5.4	1.0	5.0	0.7	4.4	1.0	2.7	0.4	2.6	0.4	5.7	2.6
A-046	Channel	Central Appalachia	Coalburg	WV	Boone	170.8	138.9	31.9	4.4	16.4	22.3	29.3	55.9	6.3	22.2	4.3	0.8	3.6	0.6	3.5	0.7	2.2	0.3	2.1	0.3	7.6	2.2
A-046	Coal	Central Appalachia	Glenalum Tunnel	WV	Boone	74.0	59.8	14.2	4.2	4.1	10.1	13.3	25.3	2.8	10.1	2.0	0.4	1.8	0.3	1.6	0.3	0.8	0.1	0.8	0.1	2.6	1.2
A-046	Channel	Central Appalachia	Cedar Grove	WV	Boone	175.6	140.8	34.8	4.0	14.2	25.0	28.7	56.3	6.6	24.6	5.1	0.9	4.4	0.6	3.7	0.8	2.2	0.3	2.0	0.3	8.0	3.7
A-049	Bench	Central Appalachia	Fire Clay	WV	Boone	36.1	29.1	7.0	4.2	2.2	4.9	6.2	11.7	1.4	5.3	1.1	0.2	1.0	0.2	0.9	0.2	0.5	0.1	0.4	0.1	1.0	1.0
A-049	Bench	Central Appalachia	Fire Clay	WV	Boone	93.8	74.2	19.6	3.8	3.2	14.1	15.8	32.5	3.9	13.4	2.8	0.2	2.3	0.4	2.2	0.4	1.2	0.2	1.0	0.1	4.2	1.4

Dry Ash Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-058	Floor	Northern Appalachia	Lower Kittanning	PA	Somerset	20.0	16.5	3.4	4.8	1.7	2.1	3.1	6.7	0.8	3.0	0.6	0.2	0.6	0.1	0.4	0.1	0.3	0.1	0.2	0.1	1.4	0.4
A-061	Sludge	Northern Appalachia	Freeport	WV	Grant	1,851.2	1,001.7	811.5	1.2	108.2	631.8	105.4	322.5	46.4	238.8	69.7	16.4	94.4	14.2	77.0	15.1	38.3	4.9	26.6	3.8	30.6	7.3
A-066	Refuse	Northern Appalachia	Lower Kittanning	PA	Clearfield	184.9	152.2	29.5	5.2	8.0	22.4	35.8	66.1	7.2	27.0	4.3	0.7	3.3	0.3	2.9	0.4	1.6	0.1	1.7	0.1	1.5	1.8
A-069	Coal	Central Appalachia	Fire Clay	WV	Mingo	128.95	95.09	33.87	2.81	3.21	21.78	18.57	41.26	4.95	18.37	4.07	0.54	4.12	0.68	4.41	0.97	2.73	0.40	2.56	0.34	7.11	3.13
A-069	Coal	Central Appalachia	Fire Clay	WV	Mingo	62.47	43.49	18.99	2.29	1.93	12.47	7.55	17.92	2.23	9.11	2.09	0.33	2.33	0.40	2.43	0.53	1.43	0.20	1.33	0.20	2.16	1.26
A-071	Parting	Central Appalachia	Fire Clay	WV	Mingo	396.24	231.63	164.61	1.41	28.64	119.42	42.43	88.39	10.51	39.67	9.33	1.70	10.95	2.19	15.37	3.53	10.83	1.62	10.22	1.42	27.22	12.70
A-072	Coal	Central Appalachia	Fire Clay	WV	Mingo	176.68	91.98	84.69	1.09	12.83	65.69	12.03	32.10	4.32	17.84	5.00	1.23	6.63	1.14	7.23	1.57	4.43	0.60	3.52	0.51	6.49	2.92
A-073	Coal	Central Appalachia	Fire Clay	WV	Mingo	33.71	21.60	12.12	1.78	1.44	8.52	4.31	8.43	1.05	4.07	0.96	0.19	1.15	0.19	1.29	0.29	0.86	0.14	0.72	0.10	1.39	0.38
A-073	Coal	Central Appalachia	Fire Clay	WV	Mingo	70.05	38.21	31.84	1.20	2.78	21.79	5.67	14.47	1.92	7.74	1.99	0.59	3.05	0.55	3.64	0.82	2.43	0.35	2.03	0.23	1.64	0.94
A-075	Coal	Northern Appalachia	Pittsburgh	WV	Wetzel	61.06	42.51	18.55	2.29	8.12	15.33	7.11	15.37	1.64	7.01	1.48	0.13	1.64	0.03	1.51	0.13	0.81	0.00	0.87	0.00	0.13	0.84
A-075	Coal	Northern Appalachia	Pittsburgh	WV	Wetzel	161.53	128.00	33.53	3.82	23.76	25.66	22.60	46.39	5.52	21.75	4.01	0.63	3.34	0.39	3.13	0.49	1.93	0.07	1.79	0.07	4.99	1.90
A-075	Coal	Northern Appalachia	Pittsburgh	WV	Wetzel	47.29	34.10	13.19	2.58	4.54	10.62	5.81	13.12	1.47	6.71	1.27	0.10	1.07	0.00	1.27	0.10	0.67	0.00	0.70	0.00	0.00	0.87
A-075	Coal	Northern Appalachia	Pittsburgh	WV	Wetzel	29.79	24.44	5.35	4.57	3.14	4.70	4.64	9.83	1.06	4.45	0.71	0.00	0.60	0.00	0.60	0.00	0.22	0.00	0.22	0.00	0.00	0.11
A-075	Coal	Northern Appalachia	Pittsburgh	WV	Wetzel	14.20	10.75	3.46	3.11	0.00	3.70	2.42	5.22	0.48	2.59	0.35	0.00	0.14	0.00	0.28	0.00	0.03	0.00	0.07	0.00	0.00	0.00
A-076	Coal	Northern Appalachia	Middle Kittanning	WV	Monongalia	56.31	43.72	12.59	3.47	2.86	10.86	7.39	18.21	2.18	9.86	1.80	0.10	1.32	0.00	1.16	0.03	0.42	0.00	0.35	0.00	0.00	0.13
A-076	Coal	Northern Appalachia	Middle Kittanning	WV	Monongalia	73.03	51.64	21.39	2.41	4.90	17.59	6.71	20.57	2.69	11.45	2.59	0.25	2.47	0.16	1.90	0.25	0.92	0.00	0.70	0.00	0.16	0.32
A-076	Coal	Northern Appalachia	Middle Kittanning	WV	Monongalia	265.08	233.98	31.10	7.52	15.43	23.53	60.70	99.15	10.26	37.59	5.41	1.00	4.43	0.39	3.49	0.46	1.76	0.06	1.37	0.03	0.15	0.88
A-076	Coal	Northern Appalachia	Middle Kittanning	WV	Monongalia	50.48	36.36	14.13	2.57	2.36	11.40	9.80	14.94	1.33	5.41	1.15	0.09	1.27	0.06	1.36	0.12	0.67	0.00	0.70	0.00	0.00	0.12
A-077	Channel	Northern Appalachia	Middle Kittanning	WV	Barbour	71.77	54.21	17.57	3.09	6.94	14.51	10.10	21.23	2.37	9.89	1.72	0.22	1.75	0.09	1.56	0.14	0.72	0.00	0.66	0.00	0.17	0.28
A-078	Channel	Northern Appalachia	Lower Mercer	WV	Upshur	60.04	49.21	10.83	4.54	8.36	9.12	9.37	19.53	2.00	7.91	0.98	0.11	0.96	0.00	0.93	0.00	0.39	0.00	0.39	0.00	0.42	0.28
A-083	Channel	Northern Appalachia	Middle Kittanning	WV	Barbour	78.83	60.83	18.00	3.38	13.50	14.60	10.15	20.68	2.46	9.83	1.93	0.27	2.01	0.13	1.66	0.19	0.83	0.00	0.70	0.00	0.54	0.40
A-084	Channel	Northern Appalachia	Upper Kittanning	WV	Monongalia	57.74	40.95	16.78	2.44	6.88	14.01	7.38	15.65	1.68	6.81	1.24	0.10	1.22	0.00	1.29	0.12	0.74	0.00	0.73	0.00	0.06	0.38
A-085	Coal	Northern Appalachia	Lower Freeport	WV	Monongalia	113.61	98.17	15.44	6.36	3.78	11.75	17.39	40.23	5.22	23.28	4.39	0.67	3.20	0.19	2.02	0.19	0.77	0.00	0.67	0.00	0.86	1.06
A-085	Coal	Northern Appalachia	Lower Freeport	WV	Monongalia	223.37	179.33	44.04	4.07	22.35	33.70	31.38	69.85	8.43	34.48	6.44	1.19	5.21	0.63	4.56	0.74	2.23	0.15	1.91	0.12	3.96	4.08
A-086	Channel	Central Appalachia	Middle Kittanning	WV	Boone	129.29	105.80	23.49	4.50	16.70	18.81	20.22	40.63	4.50	17.27	3.21	0.50	2.77	0.22	2.23	0.28	1.10	0.00	0.94	0.00	2.89	1.45
A-087	Channel	Central Appalachia	Lower Kittanning	WV	Boone	84.17	62.87	21.30	2.95	10.25	18.22	12.48	24.44	2.60	9.81	1.63	0.19	1.46	0.06	1.53	0.13	0.82	0.00	0.67	0.00	0.62	0.50
A-088	Channel	Northern Appalachia	Middle Kittanning	WV	Monongalia	45.43	32.55	12.87	2.53	6.16	10.01	4.21	11.17	1.40	6.59	1.40	0.18	1.43	0.03	1.43	0.12	0.76	0.00	0.67	0.00	0.12	0.37
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	63.99	34.80	29.20	1.19	8.94	21.39	4.03	10.06	1.19	6.32	1.96	0.24	2.04	0.27	3.08	0.53	1.96	0.13	1.75	0.08	0.00	2.84
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	29.65	22.80	6.85	3.33	1.13	5.93	4.35	9.60	1.10	5.04	0.71	0.03	0.84	0.00	0.79	0.00	0.21	0.00	0.18	0.00	0.00	0.73
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	65.69	56.38	9.31	6.05	3.32	7.70	13.08	24.58	2.63	9.67	1.71	0.21	1.17	0.03	0.96	0.06	0.39	0.00	0.42	0.00	0.00	0.45
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	17.08	14.59	2.50	5.84	0.00	3.19	4.17	7.39	0.66	2.66	0.23	0.00	0.16	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	66.54	47.46	19.08	2.49	7.30	15.06	6.68	16.79	2.04	9.94	2.18	0.28	2.25	0.17	2.01	0.21	0.97	0.00	0.80	0.00	0.35	0.38
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	34.30	26.22	8.08	3.25	1.74	6.79	4.92	10.65	1.25	5.82	0.84	0.00	1.00	0.00	0.93	0.00	0.42	0.00	0.26	0.00	0.00	0.06
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	59.02	33.58	25.45	1.32	4.83	19.46	4.52	11.33	1.29	7.42	1.70	0.27	2.21	0.20	2.72	0.37	1.56	0.00	1.16	0.00	0.00	2.82
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	95.29	59.72	35.57	1.68	13.29	27.69	9.94	19.91	2.40	9.88	1.82	0.28	2.22	0.22	2.92	0.52	2.06	0.09	1.97	0.09	1.72	3.20
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	107.64	33.11	74.53	0.44	7.52	60.85	3.81	9.18	1.12	6.37	1.87	0.32	2.91	0.40	5.22	0.97	3.60	0.29	2.91	0.29	0.00	2.09
A-091	Coal	Central Appalachia	Fire Clay	WV	Mingo	232.81	173.35	59.45	2.92	8.28	41.23	31.47	76.16	9.02	33.57	7.13	0.65	7.07	1.14	6.73	1.42	4.14	0.59	3.68	0.53	7.38	4.08
A-091	Coal	Central Appalachia	Fire Clay	WV	Mingo	33.23	24.66	8.57	2.88	0.64	5.73	4.69	10.90	1.30	4.99	0.95	0.16	1.03	0.19	0.98	0.24	0.61	0.11	0.61	0.11	0.77	0.32

Dry Ash Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-094	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	383.4	223.9	159.5	1.4	6.6	106.9	25.8	78.3	11.6	57.0	16.9	4.5	23.2	3.7	21.9	4.5	11.5	1.5	8.3	1.3	7.4	3.7
A-094	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	364.1	208.1	156.1	1.3	4.6	104.0	23.5	72.4	11.0	53.8	16.0	4.3	22.3	3.6	21.7	4.4	11.5	1.5	8.1	1.3	6.3	3.0
A-094	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	1,162.4	674.8	487.6	1.4	37.7	340.3	76.5	231.7	32.7	166.4	49.0	12.6	68.3	10.7	60.7	12.4	32.1	4.2	23.8	3.3	43.1	10.7
A-095	Channel	Central Appalachia	Little Chilton	WV	Logan	59.64	51.28	8.36	6.13	2.76	4.75	10.09	21.77	2.68	10.06	1.83	0.45	1.62	0.24	1.41	0.27	0.72	0.13	0.72	0.13	5.26	1.33
A-096	Coal	Northern Appalachia	Pittsburgh	WV	Barbour	10.14	7.83	2.31	3.39	0.84	1.47	1.75	2.90	0.38	1.29	0.28	0.07	0.31	0.07	0.28	0.07	0.17	0.03	0.14	0.07	0.52	0.28
A-098	Coal	Central Appalachia	Fire Clay	WV	Mingo	130.48	99.36	31.12	3.19	2.83	22.30	18.50	44.31	5.37	19.82	4.24	0.38	3.93	0.66	3.61	0.72	1.85	0.25	1.51	0.22	3.42	2.64
A-098	Coal	Central Appalachia	Fire Clay	WV	Mingo	50.64	32.80	17.85	1.84	0.89	11.86	5.84	13.78	1.75	6.85	1.58	0.23	1.89	0.34	2.06	0.49	1.46	0.23	1.23	0.17	2.03	1.23
A-099	Coal	Central Appalachia	Fire Clay	WV	Mingo	149.31	113.48	35.83	3.17	2.72	22.74	22.74	50.07	6.00	22.00	4.66	0.52	4.77	0.78	4.92	1.01	2.95	0.41	2.65	0.37	6.49	4.47
A-100	Channel	Northern Appalachia	Little Clarksburg	WV	Barbour	35.86	26.51	9.34	2.84	2.21	5.67	4.49	10.22	1.31	5.36	1.18	0.28	1.46	0.26	1.41	0.31	0.77	0.10	0.72	0.10	2.10	1.18
A-102	Channel	Northern Appalachia	Upper Freeport	WV	Barbour	10.05	7.93	2.12	3.74	0.58	1.42	1.42	3.37	0.41	1.45	0.32	0.06	0.32	0.06	0.23	0.06	0.12	0.06	0.12	0.06	0.29	0.12
A-103	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	252.6	154.2	98.4	1.6	20.2	62.6	9.4	38.3	7.1	41.9	16.1	3.9	17.3	2.5	14.6	2.5	7.2	0.9	7.1	0.9	0.0	2.8
A-103	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	226.0	140.7	85.3	1.6	23.4	55.3	9.3	35.5	6.4	35.6	13.3	3.1	14.1	2.0	12.1	2.1	6.2	0.8	6.1	0.7	0.0	2.2
A-111	Coal	Northern Appalachia	Pittsburgh	PA	Fayette	96.2	72.1	24.1	3.0	6.0	17.3	13.5	29.2	3.5	13.3	2.9	0.7	3.0	0.4	2.7	0.5	1.5	0.2	1.2	0.2	2.5	1.1
A-111	Floor	Northern Appalachia	Pittsburgh	PA	Fayette	362.7	254.1	108.6	2.3	24.6	76.5	35.2	89.5	12.8	56.8	15.1	3.7	16.5	2.5	14.1	2.6	6.7	0.9	4.7	0.7	8.0	4.4
A-112	Coal	Central Appalachia	Fire Clay	WV	Logan	66.5	38.2	28.3	1.3	5.4	20.8	6.2	13.2	1.8	6.7	2.0	0.7	2.3	0.6	2.4	0.7	1.7	0.5	1.3	0.4	3.3	1.1
A-112	Coal	Central Appalachia	Fire Clay	WV	Logan	45.5	21.3	24.2	0.9	1.4	18.0	3.5	7.7	1.0	4.2	1.3	0.3	1.9	0.3	2.3	0.5	1.5	0.2	1.3	0.2	0.0	0.3
A-112	Coal	Central Appalachia	Fire Clay	WV	Logan	48.4	36.6	11.8	3.1	2.0	9.1	8.1	15.4	1.8	6.5	1.4	0.2	1.2	0.2	1.1	0.2	0.6	0.1	0.5	0.1	0.9	0.3
A-112	Coal	Central Appalachia	Fire Clay	WV	Logan	29.6	23.2	6.4	3.6	0.7	4.1	4.4	10.4	1.2	4.6	0.9	0.1	0.9	0.1	0.9	0.2	0.5	0.1	0.4	0.1	0.9	0.4
A-112	Coal	Central Appalachia	Fire Clay	WV	Logan	234.3	199.6	34.7	5.8	15.4	23.7	43.6	86.9	9.5	32.9	5.6	1.0	4.6	0.7	4.0	0.8	2.5	0.3	2.2	0.3	10.2	2.9
A-112	Coal	Central Appalachia	Middle Kittanning	WV	Logan	32.0	19.1	12.9	1.5	4.2	9.4	2.3	5.7	0.8	3.1	1.2	0.3	1.5	0.2	1.5	0.3	0.8	0.1	0.5	0.1	0.4	0.4
A-112	Coal	Central Appalachia	Middle Kittanning	WV	Logan	222.1	135.3	86.8	1.6	63.4	60.3	14.6	28.3	3.4	13.7	4.3	1.2	6.3	1.4	9.6	2.0	6.1	0.8	5.8	0.8	6.3	4.4
A-113	Roof	Northern Appalachia	Pittsburgh	WV	Marshall	252.3	203.0	49.3	4.1	4.6	35.2	43.6	96.7	10.3	34.4	6.6	0.6	6.2	0.9	5.5	1.1	3.2	0.4	2.6	0.4	4.2	2.8
A-113	Parting	Northern Appalachia	Pittsburgh	WV	Marshall	36.3	29.1	7.2	4.0	3.7	4.6	4.9	11.3	1.4	5.2	1.1	0.2	1.2	0.2	1.0	0.2	0.6	0.1	0.5	0.1	2.1	0.7
A-113	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	38.0	22.1	15.8	1.4	2.3	11.2	5.1	7.1	0.9	4.0	1.0	0.3	1.4	0.3	2.1	0.4	0.9	0.1	0.7	0.1	0.9	0.4
A-113	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	14.4	11.2	3.2	3.5	0.6	2.0	2.3	4.7	0.6	2.1	0.4	0.1	0.5	0.1	0.4	0.1	0.3	0.1	0.2	0.1	0.9	0.2
A-113	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	18.6	15.3	3.3	4.6	1.4	2.2	3.2	6.4	0.7	2.5	0.5	0.1	0.5	0.1	0.4	0.1	0.2	0.1	0.2	0.1	1.7	0.2
A-113	Parting	Northern Appalachia	Pittsburgh	WV	Marshall	125.1	100.2	24.8	4.0	9.5	17.1	21.1	42.7	4.7	16.3	2.9	0.6	2.6	0.4	2.7	0.6	1.7	0.3	1.7	0.3	5.4	1.5
A-113	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	12.6	10.6	2.1	5.1	0.4	1.2	2.2	4.5	0.5	2.1	0.4	0.1	0.4	0.1	0.3	0.1	0.2	0.1	0.1	0.0	0.4	0.2
A-113	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	40.2	32.5	7.7	4.2	4.4	5.3	5.5	12.9	1.5	5.8	1.1	0.2	1.0	0.2	0.9	0.2	0.5	0.1	0.4	0.1	1.6	0.5
A-113	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	5.3	4.5	0.7	6.1	0.2	0.5	1.0	2.0	0.2	0.7	0.1	0.1	0.2	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1
A-113	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	1.4	1.1	0.2	4.6	0.2	0.2	0.2	0.4	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A-127	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	301.1	236.0	65.2	3.6	28.5	47.2	46.5	92.1	10.4	41.5	7.9	1.7	7.3	1.1	6.8	1.4	4.1	0.6	3.5	0.4	6.5	2.0
A-132	Coal	Northern Appalachia	Lower Kittanning	PA	Centre	48.7	42.1	6.5	6.4	2.1	4.6	8.8	18.7	2.0	8.0	1.3	0.2	1.0	0.1	0.8	0.1	0.4	0.1	0.4	0.0	0.8	0.4
A-132	Coal	Northern Appalachia	Lower Kittanning	PA	Centre	389.3	322.0	67.4	4.8	27.2	47.1	68.4	138.7	14.5	52.6	9.6	2.1	8.9	1.2	7.4	1.6	4.7	0.6	4.2	0.5	11.8	4.9
A-134	Coal	Northern Appalachia	Harlem	WV	Barbour	57.5	44.5	12.9	3.5	5.0	8.4	7.0	16.9	2.2	8.1	3.1	0.5	1.7	0.3	2.1	0.4	1.0	0.2	0.5	0.0	3.0	13.6
A-134	Coal	Northern Appalachia	Harlem	WV	Barbour	30.6	24.8	5.8	4.3	2.0	3.7	4.6	10.4	1.2	4.4	0.9	0.2	1.0	0.2	0.8	0.2	0.5	0.1	0.4	0.1	1.6	0.6

Dry Ash Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																						
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-134	Coal	Northern Appalachia	Harlem	WV	Barbour	14.2	11.5	2.8	4.2	0.7	1.7	2.2	4.7	0.5	2.2	0.5	0.1	0.5	0.1	0.4	0.1	0.2	0.1	0.2	0.0	0.9	0.4
A-134	Coal	Northern Appalachia	Upper Freeport	WV	Barbour	24.8	20.0	4.8	4.2	1.3	3.6	4.1	8.6	1.0	3.6	0.7	0.1	0.7	0.1	0.5	0.1	0.3	0.1	0.2	0.0	0.3	0.3
A-138	Core	Northern Appalachia		WV	Barbour	168.4	129.0	39.3	3.3	13.0	28.3	24.8	50.8	6.1	22.3	5.0	1.2	5.9	0.9	4.6	0.9	2.3	0.3	1.8	0.3	6.0	7.1
A-141	Coal	Central Appalachia	Fireclay	WV	Logan	26.1	19.2	7.0	2.7	1.3	5.8	3.4	8.1	0.9	3.8	0.8	0.0	0.8	0.0	0.8	0.0	0.3	0.0	0.3	0.0	0.0	0.3
A-141	Coal	Central Appalachia	Fireclay	WV	Logan	73.6	24.7	48.9	0.5	4.1	33.6	4.0	8.5	1.0	4.1	1.2	0.0	1.9	0.3	4.4	0.9	3.8	0.5	4.8	0.6	0.0	3.4

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-001	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	6,081.0	3,754.1	2,326.9	1.6	74.1	1,649.4	615.0	1,287.9	188.6	897.9	249.3	67.4	374.0	55.5	300.3	56.3	140.4	17.7	93.6	13.6	44.2	21.2
A-003	Floor	Northern Appalachia	Pittsburgh	WV	Monongalia	387.1	310.4	76.7	4.0	7.0	49.0	59.4	130.1	17.2	68.2	14.0	2.7	11.8	1.8	10.8	2.1	6.2	0.9	5.2	0.9	5.4	2.5
A-003	Sludge	Northern Appalachia	Pittsburgh	WV	Monongalia	100.4	81.2	19.2	4.2	2.8	12.3	16.9	34.2	4.2	16.3	3.2	0.7	2.9	0.5	2.5	0.5	1.5	0.2	1.4	0.3	2.0	1.1
A-006	Floor	Northern Appalachia	Mercer	PA	Clearfield	722.5	561.6	160.9	3.5	80.9	105.3	119.0	216.0	23.6	85.5	16.6	3.8	16.3	3.1	18.3	4.3	12.6	2.0	13.0	2.3	67.2	16.4
A-007	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	715.8	600.6	115.2	5.2	61.7	74.9	112.9	243.6	27.6	110.5	21.5	4.3	18.4	2.5	14.8	3.1	8.8	1.3	8.3	1.5	56.8	8.9
A-007	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	214.4	180.5	33.9	5.3	28.6	23.1	36.6	69.0	7.2	27.9	5.4	1.1	4.7	0.6	4.2	0.8	2.5	0.3	2.1	0.2	34.8	2.8
A-007	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	312.8	264.6	48.2	5.5	36.2	31.9	52.3	102.7	11.4	44.0	9.0	1.8	7.2	1.1	6.1	1.3	3.6	0.5	3.3	0.5	45.1	4.5
A-007	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	294.2	242.0	52.2	4.6	32.1	35.6	47.9	96.1	10.4	39.4	7.5	1.6	7.0	1.0	6.2	1.2	3.7	0.4	3.6	0.5	38.1	3.6
A-007	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	103.8	89.0	14.8	6.0	21.9	10.3	14.6	30.6	3.3	13.1	2.5	0.5	2.3	0.3	2.0	0.3	1.0	0.1	0.8	0.1	30.9	1.1
A-007	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	459.9	367.0	92.9	3.9	49.3	62.1	70.3	143.4	16.4	63.0	11.4	2.2	10.9	1.6	10.5	2.2	7.0	0.9	7.4	1.1	51.8	6.9
A-007	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	591.8	494.1	97.7	5.1	49.5	64.9	97.8	200.4	23.3	90.0	16.8	2.8	13.4	1.9	11.8	2.3	7.0	1.0	7.7	1.1	55.9	7.9
A-007	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	577.1	459.0	118.1	3.9	49.8	77.8	91.2	184.5	21.5	81.0	14.6	3.0	13.4	2.3	13.4	3.1	8.9	1.7	9.1	1.8	53.1	8.6
A-009	Roof	Northern Appalachia	Lower Kittanning	PA	Clearfield	295.5	246.0	49.5	5.0	21.3	33.7	45.2	105.5	11.8	43.8	9.1	1.7	7.5	1.1	6.4	1.2	3.2	0.5	2.9	0.4	9.4	2.3
A-012	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	327.8	258.4	69.4	3.7	10.3	44.7	46.4	105.1	13.6	55.4	12.8	2.8	12.0	1.8	10.4	2.0	5.2	0.7	4.0	0.7	7.9	3.8
A-012	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	284.7	225.3	59.5	3.8	7.1	37.6	44.0	94.9	11.8	46.0	9.9	2.3	9.3	1.4	8.5	1.6	4.8	0.7	4.2	0.7	7.2	5.2
A-012	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	231.0	188.9	42.1	4.5	7.5	26.8	39.9	81.5	9.8	35.7	7.0	1.5	6.0	0.9	5.8	1.1	3.3	0.5	3.2	0.6	6.0	3.2
A-012	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	67.4	57.1	10.3	5.5	2.6	6.7	12.6	24.8	3.0	10.6	1.8	0.4	1.4	0.2	1.3	0.3	0.8	0.1	0.8	0.2	2.8	0.7
A-012	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	13.2	11.4	1.8	6.4	1.0	1.1	2.5	4.7	0.6	2.0	0.4	0.1	0.3	0.0	0.2	0.0	0.2	0.0	0.2	0.0	3.3	0.1
A-012	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	122.6	102.0	20.6	4.9	2.8	13.1	26.3	44.6	4.9	17.0	3.1	0.6	2.7	0.4	2.7	0.5	1.6	0.3	1.6	0.3	3.2	1.8
A-012	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	33.2	27.0	6.1	4.4	2.1	3.9	5.8	11.5	1.3	4.7	0.8	0.2	0.7	0.1	0.7	0.1	0.4	0.1	0.5	0.1	2.8	0.5
A-012	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	27.1	22.4	4.7	4.7	1.8	2.8	5.0	9.4	1.1	3.7	0.7	0.1	0.7	0.1	0.6	0.1	0.4	0.1	0.4	0.1	3.8	0.5
A-012	Parting	Northern Appalachia	Lower Kittanning	PA	Clinton	321.1	248.7	72.4	3.4	10.3	47.8	55.7	105.5	12.8	46.4	8.9	1.6	7.5	1.2	8.2	1.8	5.8	0.9	5.6	1.1	7.8	4.0
A-012	Parting	Northern Appalachia	Lower Kittanning	PA	Clinton	245.1	193.2	51.9	3.7	13.8	33.2	42.2	79.4	9.7	34.9	6.5	1.3	5.5	1.0	6.4	1.4	4.2	0.7	4.3	0.7	10.3	3.8
A-012	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	188.6	157.7	31.0	5.1	12.0	19.7	35.2	65.4	8.0	27.6	4.9	0.9	3.7	0.6	3.8	0.8	2.5	0.4	2.6	0.5	10.0	4.2
A-012	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	226.0	187.2	38.8	4.8	9.5	25.4	42.2	79.4	9.6	34.0	6.4	1.1	5.0	0.8	5.0	1.0	3.0	0.4	2.7	0.5	6.7	2.4
A-012	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	314.3	263.5	50.8	5.2	12.3	32.5	59.7	110.4	13.6	49.1	9.3	1.8	7.4	1.1	6.7	1.3	3.9	0.6	3.9	0.8	9.8	4.0
A-012	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	312.1	259.0	53.2	4.9	11.5	34.0	57.6	108.9	13.4	48.9	9.4	1.9	7.5	1.2	7.1	1.5	4.2	0.7	3.9	0.7	8.3	3.4
A-012	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	316.7	259.1	57.6	4.5	11.8	36.8	55.9	108.7	13.5	49.4	9.5	2.0	8.3	1.3	7.7	1.5	4.6	0.7	4.2	0.7	8.3	3.7
A-013	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	303.8	248.5	55.3	4.5	11.3	35.5	51.3	104.8	12.9	48.3	9.7	2.1	8.2	1.3	7.3	1.4	4.4	0.6	4.0	0.7	7.9	3.2
A-013	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	357.9	280.0	77.9	3.6	10.2	50.2	53.9	115.7	14.4	58.1	12.6	3.0	12.0	1.9	11.1	2.1	5.9	0.8	5.0	0.9	7.8	4.2
A-013	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	217.5	176.2	41.3	4.3	6.3	25.3	34.0	74.3	9.2	36.1	7.6	1.7	7.1	1.0	6.1	1.2	3.4	0.5	3.2	0.5	7.4	3.9
A-013	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	235.2	196.2	39.0	5.0	7.0	24.8	39.6	83.6	10.1	39.4	8.2	1.7	6.5	1.0	5.5	1.1	3.0	0.4	2.6	0.5	5.5	4.6
A-013	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	138.1	112.7	25.3	4.4	4.4	15.8	25.4	48.7	5.8	20.4	4.0	0.9	3.2	0.5	3.5	0.7	2.1	0.3	2.1	0.4	6.0	2.4
A-013	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	29.1	23.9	5.1	4.7	1.2	3.3	5.1	10.2	1.2	4.5	0.9	0.2	0.7	0.1	0.7	0.1	0.4	0.1	0.4	0.0	3.3	0.3
A-013	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	56.3	46.0	10.3	4.5	3.3	6.8	10.0	19.1	2.2	7.9	1.7	0.3	1.5	0.2	1.3	0.3	0.7	0.1	0.7	0.1	3.1	0.8
A-013	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	65.4	53.5	11.9	4.5	2.1	7.6	11.7	23.0	2.7	9.8	1.9	0.4	1.8	0.3	1.7	0.3	1.0	0.1	0.7	0.2	2.0	0.9
A-013	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	353.3	282.8	70.5	4.0	9.6	44.6	69.2	121.6	14.7	50.3	8.5	1.8	7.2	1.2	8.2	1.8	6.0	1.0	6.6	1.2	12.5	6.5
A-013	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	209.9	165.5	44.4	3.7	11.7	29.2	37.1	67.8	8.2	29.3	5.7	1.1	4.6	0.8	5.2	1.2	3.4	0.5	3.5	0.7	8.3	3.1

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-014	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	102.9	81.8	21.1	3.9	5.2	12.9	15.2	33.6	4.1	16.2	3.6	0.7	3.2	0.5	3.1	0.6	1.8	0.3	1.7	0.3	9.2	1.3
A-014	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	67.0	56.0	11.0	5.1	2.0	6.8	10.6	24.0	2.9	11.2	2.5	0.6	2.1	0.3	1.7	0.3	0.9	0.2	0.8	0.1	4.7	0.6
A-014	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	100.6	83.2	17.4	4.8	2.7	11.3	16.3	35.4	4.3	17.3	3.6	0.7	2.7	0.4	2.2	0.5	1.3	0.2	1.3	0.3	2.9	0.7
A-014	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	86.7	65.0	21.7	3.0	15.2	8.5	9.4	19.8	3.3	9.8	2.9	1.6	2.9	1.5	2.8	1.6	2.3	1.4	2.1	1.4	21.3	2.9
A-014	Roof	Northern Appalachia	Lower Kittanning	PA	Clinton	73.6	58.4	15.2	3.8	2.5	9.5	11.5	25.0	3.0	11.4	2.3	0.5	2.1	0.3	2.0	0.4	1.2	0.2	1.2	0.2	3.0	0.9
A-014	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	72.0	56.9	15.1	3.8	1.8	9.8	12.7	24.5	2.9	10.9	1.9	0.4	1.8	0.3	1.9	0.4	1.1	0.2	1.2	0.3	2.4	1.2
A-014	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	27.3	22.9	4.4	5.2	2.5	2.7	4.3	9.3	1.1	4.1	0.8	0.2	0.7	0.1	0.6	0.1	0.3	0.1	0.4	0.2	3.0	0.4
A-014	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	754.6	517.8	236.8	2.2	11.1	159.9	85.0	180.3	29.6	127.8	34.9	8.7	40.3	6.1	33.6	6.2	16.1	2.0	11.2	1.8	8.6	4.8
A-014	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	181.0	151.0	30.0	5.0	7.3	19.4	36.1	64.9	7.4	25.6	4.8	1.0	3.8	0.6	3.8	0.8	2.3	0.4	2.3	0.4	7.3	2.9
A-014	Parting	Northern Appalachia	Lower Kittanning	PA	Clinton	247.4	194.5	52.9	3.7	8.4	33.1	45.2	82.8	9.9	35.1	6.3	1.2	5.6	1.0	6.6	1.4	4.6	0.7	4.7	0.8	9.0	4.3
A-014	Parting	Northern Appalachia	Lower Kittanning	PA	Clinton	212.1	167.1	45.0	3.7	8.4	29.0	37.4	68.0	8.5	31.9	6.3	1.3	5.4	0.9	5.6	1.2	3.6	0.6	3.5	0.7	6.9	3.9
A-014	Parting	Northern Appalachia	Lower Kittanning	PA	Clinton	231.1	191.7	39.3	4.9	9.9	23.4	43.3	80.3	9.7	35.3	6.8	1.2	5.2	0.9	5.6	1.1	3.4	0.5	3.7	0.6	14.1	5.7
A-014	Coal	Northern Appalachia	Lower Kittanning	PA	Clinton	493.6	412.4	81.1	5.1	7.3	47.7	80.0	179.5	22.3	86.4	18.2	3.7	15.1	2.5	14.2	2.5	6.6	1.0	5.9	0.8	7.5	6.2
A-014	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	339.9	271.4	68.5	4.0	16.4	43.2	59.4	110.8	13.5	50.1	9.8	2.2	9.0	1.4	9.1	1.9	5.6	0.8	5.5	0.9	19.0	8.7
A-014	Floor	Northern Appalachia	Lower Kittanning	PA	Clinton	237.2	185.3	52.0	3.6	10.0	32.9	40.2	77.6	9.5	34.7	6.3	1.3	5.7	1.0	6.6	1.4	4.2	0.7	4.4	0.8	7.3	4.2
A-015	Sludge	Northern Appalachia	Pittsburgh	PA	Washington	55.4	23.0	32.4	0.7	0.8	24.5	2.4	6.7	1.2	6.3	1.7	0.6	3.4	0.5	3.4	0.7	1.8	0.2	1.1	0.2	1.6	3.0
A-016	Parting	Northern Appalachia	Sewickley	WV	Monongalia	302.1	253.5	48.6	5.2	10.5	29.8	51.9	105.2	13.4	51.2	10.4	2.1	8.8	1.3	7.6	1.4	4.0	0.6	3.4	0.6	9.1	3.7
A-018	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	785.4	516.8	268.6	248.1	1.1	47.7	161.2	20.8	69.9	10.9	55.9	20.3	5.9	37.2	6.4	36.6	7.5	19.5	2.3	13.1	3.4	3.7
A-020	Channel	Central Appalachia	Bens Creek	WV	Raleigh	24.0	17.7	6.3	2.8	1.1	4.6	3.7	7.2	0.8	3.4	0.7	0.1	0.6	0.1	0.6	0.1	0.4	0.1	0.4	0.0	1.0	0.7
A-025	Channel	Northern Appalachia	Lower Kittanning	WV	Marion	21.7	13.0	8.7	1.5	1.0	6.0	1.9	4.3	0.6	2.8	0.7	0.2	1.4	0.2	1.1	0.2	0.6	0.1	0.5	0.1	1.0	0.3
A-028	Parting	Northern Appalachia	Waynesburg	WV	Monongalia	260.0	224.0	36.0	6.2	14.8	23.6	46.8	94.3	11.0	40.6	8.2	1.6	6.8	0.9	4.8	1.0	2.6	0.4	2.4	0.3	11.2	2.8
A-028	Parting	Northern Appalachia	Waynesburg	WV	Monongalia	400.2	330.9	69.3	4.8	26.3	46.2	70.8	141.4	15.9	56.3	10.3	1.8	8.2	1.4	8.3	1.7	5.1	0.8	5.1	0.7	25.0	5.9
A-029	Channel	Northern Appalachia	Upper Freeport	WV	Tucker	47.7	38.7	8.9	4.3	3.5	6.2	7.8	15.9	1.8	6.8	1.4	0.2	1.2	0.2	1.0	0.2	0.6	0.1	0.5	0.1	2.4	0.7
A-030	Roof	Central Appalachia	Middle War Eagle	WV	Raleigh	203.6	169.3	34.3	4.9	11.8	22.6	36.2	70.1	8.3	30.6	6.0	1.2	5.0	0.7	4.2	0.9	2.6	0.4	2.5	0.4	10.1	7.6
A-030	Coal	Central Appalachia	Middle War Eagle	WV	Raleigh	35.8	25.0	10.8	2.3	1.7	7.8	4.7	10.0	1.2	5.0	1.1	0.2	1.3	0.2	1.2	0.2	0.6	0.1	0.6	0.1	6.6	0.8
A-030	Parting	Central Appalachia	Middle War Eagle	WV	Raleigh	393.4	330.4	63.0	5.2	22.1	41.3	68.7	136.6	16.9	60.9	12.8	2.2	10.3	1.6	8.4	1.6	4.7	0.7	4.2	0.6	20.9	8.6
A-030	Coal	Central Appalachia	Middle War Eagle	WV	Raleigh	12.8	7.8	5.0	1.5	0.5	3.7	1.7	2.8	0.4	1.4	0.4	0.1	0.5	0.1	0.5	0.1	0.3	0.0	0.3	0.0	0.2	0.4
A-030	Floor	Central Appalachia	Middle War Eagle	WV	Raleigh	402.4	328.8	73.5	4.5	22.0	49.5	67.9	135.2	16.5	61.7	12.7	2.4	10.5	1.6	9.2	1.8	5.3	0.8	4.8	0.7	16.0	3.8
A-031	Roof	Central Appalachia	Bens Creek	WV	Raleigh	337.1	279.1	57.9	4.8	26.2	38.4	56.2	112.7	13.3	50.0	10.1	1.9	8.7	1.3	7.3	1.5	4.2	0.6	4.0	0.6	16.4	5.5
A-031	Coal	Central Appalachia	Bens Creek	WV	Raleigh	70.9	57.7	13.2	4.4	4.4	9.3	12.4	24.0	2.8	10.1	2.1	0.4	1.7	0.2	1.4	0.3	0.9	0.1	0.8	0.1	3.9	1.3
A-031	Seat	Central Appalachia	Bens Creek	WV	Raleigh	329.8	269.6	60.1	4.5	22.4	39.7	59.4	111.5	13.0	46.6	8.4	1.4	7.0	1.1	7.3	1.5	4.7	0.7	4.5	0.6	14.7	3.4
A-032	Channel	Central Appalachia	Chilton	WV	Wyoming	19.0	15.2	3.8	4.0	1.4	2.6	3.2	6.3	0.7	2.6	0.4	0.1	0.5	0.1	0.5	0.1	0.3	0.1	0.2	0.0	3.0	0.3
A-033	Parting	Central Appalachia	Fire Clay	WV	Kanawha	386.4	330.3	56.1	5.9	16.0	36.7	76.7	146.6	16.1	54.7	10.6	1.1	8.5	1.3	7.8	1.5	4.0	0.6	3.7	0.5	35.4	7.4
A-033	Parting	Central Appalachia	Fire Clay	WV	Kanawha	421.7	354.4	67.4	5.3	17.1	44.4	79.2	158.6	17.5	59.6	11.9	1.1	9.5	1.6	9.1	1.8	4.8	0.7	4.4	0.6	59.8	7.4
A-033	Channel	Central Appalachia	Fire Clay	WV	Kanawha	276.2	232.1	44.1	5.3	6.5	28.7	49.9	107.7	11.7	39.9	8.4	0.7	7.1	1.1	6.3	1.2	3.2	0.5	2.7	0.4	15.4	6.5
A-033	Channel	Central Appalachia	Fire Clay	WV	Kanawha	113.3	87.3	26.0	3.4	5.9	17.6	20.1	36.1	4.2	15.4	2.7	0.5	2.4	0.4	2.8	0.6	1.9	0.3	2.1	0.3	4.9	1.7
A-037	Coal	Northern Appalachia	Middle Kittanning	WV	Barbour	147.5	121.3	26.2	4.6	9.0	17.9	26.7	50.9	5.8	20.7	4.0	0.8	3.5	0.5	3.1	0.7	1.8	0.3	1.6	0.3	6.1	1.7
A-037	Seat	Northern Appalachia	Middle Kittanning	WV	Barbour	323.5	276.3	47.2	5.9	22.2	31.1	65.2	116.4	13.1	44.4	7.6	1.4	5.9	0.9	5.8	1.2	3.5	0.6	3.6	0.6	17.3	5.5
A-038	Channel	Northern Appalachia	Middle Kittanning	WV	Wetzel	91.7	78.0	13.7	5.7	4.0	9.1	17.0	34.0	3.9	14.1	2.5	0.4	2.1	0.3	1.8	0.4	1.0	0.1	0.9	0.2	4.5	1.1
A-039	Channel	Central Appalachia	Little Chilton	WV	Mingo	27.2	22.9	4.3	5.4	0.9	2.9	5.3	10.1	1.1	3.9	0.8	0.1	0.6	0.1	0.5	0.1	0.3	0.1	0.2	0.1	1.6	0.4
A-040	Channel	Central Appalachia	Little Chilton	WV	Mingo	34.5	28.6	5.9	4.9	0.9	4.0	6.7	12.6	1.4	5.0	1.0	0.2	0.9	0.1	0.7	0.1	0.4	0.1	0.4	0.1	1.4	0.5
A-041	Channel	Northern Appalachia	Middle Kittanning	WV	Upshur	25.9	20.5	5.4	3.8	1.6	3.8	4.4	8.4	1.0	3.5	0.8	0.1	0.6	0.1	0.6	0.1	0.4	0.1	0.3	0.0	0.8	0.3
A-042	Parting	Central Appalachia	Stockton	WV	Kanawha	184.9	142.2	42.7	3.3	7.5	29.6	31.4	61.7	7.0	24.7	4.8	0.9	4.3	0.7	4.5	1.0	3.0	0.5	3.0	0.5	12.4	2.7
A-043	Parting	Northern Appalachia	Lower Kittanning	WV	Webster	553.6	500.2	53.4	9.4	25.4	34.1	118.2	227.1	23.8	79.1	13.5	2.6	10.5	1.4	7.2	1.4	4.0	0.6	4.2	0.6	28.8	7.4
A-043	Parting	Northern Appalachia	Lower Kittanning	WV	Webster	547.3	457.2	90.1	5.1	25.9	58.2	100.3	197.2	22.4	82.1	15.6	2.8	10.9	1.8	11.3	2.4	7.1	1.1	7.1	1.1	34.4	11.2
A-043	Parting	Northern Appalachia	Lower Kittanning	WV	Webster	536.1	468.7	67.4	6.9	24.8	43.1	101.6	200.8	22.6	84.0	18.3	3.4	13.1	1.6	9.0	1.8	5.3	0.8	5.1	0.7	35.5	9.3

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-043	Parting	Northern Appalachia	Lower Kittanning	WV	Webster	403.2	338.5	64.7	5.2	18.6	41.2	64.7	143.0	16.8	64.5	15.9	2.5	12.4	1.7	9.2	1.8	4.9	0.7	4.4	0.7	28.9	9.2
A-043	Parting	Northern Appalachia	Lower Kittanning	WV	Webster	495.7	422.4	73.3	5.8	24.0	49.1	91.8	181.2	20.7	74.4	15.7	2.4	12.3	1.7	9.5	1.8	5.1	0.7	4.7	0.7	31.7	8.3
A-043	Floor	Northern Appalachia	Lower Kittanning	WV	Webster	202.8	158.5	44.3	3.6	7.2	30.3	30.9	65.8	7.9	31.0	7.3	1.5	6.9	1.0	5.6	1.1	2.9	0.4	2.7	0.4	6.4	2.5
A-043	Channel	Northern Appalachia	Lower Kittanning	WV	Webster	69.7	51.8	18.0	2.9	6.6	12.2	11.0	20.3	2.2	7.7	1.7	0.4	1.9	0.4	2.3	0.5	1.3	0.2	1.0	0.1	2.7	1.8
A-044	Parting	Central Appalachia	No.2 Gas	WV	Boone	338.6	286.5	52.1	5.5	17.6	33.9	67.0	121.0	14.1	49.7	8.5	1.5	7.1	1.0	6.4	1.4	3.9	0.6	4.2	0.5	21.7	4.1
A-044	Roof	Central Appalachia	No.2 Gas	WV	Boone	299.8	252.3	47.6	5.3	24.2	30.8	50.7	101.0	12.1	45.6	9.2	1.8	7.6	1.1	6.2	1.2	3.7	0.6	3.5	0.5	15.9	7.1
A-044	Floor	Central Appalachia	Little Chilton	WV	Boone	363.0	308.1	54.9	5.6	17.2	36.2	69.4	132.2	15.2	54.2	10.0	1.7	8.2	1.1	6.7	1.4	4.2	0.7	4.1	0.5	14.3	3.8
A-044	Parting	Central Appalachia	Little Chilton	WV	Boone	324.0	277.9	46.0	6.0	19.2	30.9	56.2	112.6	13.6	53.9	11.8	2.1	8.5	1.1	5.9	1.2	3.1	0.4	3.0	0.4	12.6	3.6
A-044	Roof	Central Appalachia	Little Chilton	WV	Boone	380.8	317.0	63.8	5.0	19.4	42.4	65.2	132.2	15.8	59.6	12.1	2.2	10.5	1.5	8.4	1.6	4.4	0.7	4.2	0.6	15.0	3.8
A-044	Roof	Central Appalachia	Little Chilton	WV	Boone	314.5	268.2	46.3	5.8	22.1	30.6	56.5	109.5	13.1	48.4	9.4	1.7	7.5	1.0	6.0	1.2	3.3	0.5	3.3	0.5	17.5	5.0
A-044	Channel	Central Appalachia	Little Chilton	WV	Boone	33.9	28.4	5.4	5.2	2.8	3.8	6.0	11.8	1.3	4.5	0.9	0.1	0.8	0.1	0.6	0.1	0.4	0.1	0.3	0.0	3.2	0.5
A-045	Roof	Northern Appalachia	Pittsburgh	WV	Marshall	268.8	223.6	45.2	4.9	18.6	30.3	47.7	93.9	10.7	38.2	7.3	1.3	5.8	0.9	5.4	1.2	3.4	0.5	3.2	0.4	11.6	4.3
A-045	Roof	Northern Appalachia	Pittsburgh	WV	Marshall	329.1	271.3	57.9	4.7	23.0	38.7	55.4	111.9	13.0	47.6	9.7	2.0	8.7	1.3	7.2	1.4	4.2	0.6	3.8	0.5	18.8	4.5
A-045	Parting	Northern Appalachia	Pittsburgh	WV	Marshall	120.1	102.0	18.0	5.7	7.9	12.0	22.6	44.1	4.7	16.9	2.9	0.5	2.4	0.4	2.1	0.4	1.4	0.2	1.4	0.2	5.8	1.4
A-045	Parting	Northern Appalachia	Pittsburgh	WV	Marshall	239.4	195.0	44.4	4.4	15.6	30.0	44.4	83.2	9.1	31.5	5.7	1.0	4.6	0.8	4.8	1.1	3.3	0.5	3.3	0.5	11.2	3.1
A-045	Parting	Northern Appalachia	Pittsburgh	WV	Marshall	301.5	238.7	62.8	3.8	17.6	42.7	54.4	102.8	11.3	38.8	6.8	1.3	5.8	1.0	6.5	1.5	4.6	0.7	5.0	0.8	14.8	4.4
A-045	Floor	Northern Appalachia	Pittsburgh	WV	Marshall	168.8	133.7	35.1	3.8	11.0	24.6	27.6	55.2	6.3	23.7	4.8	0.9	4.3	0.7	3.9	0.8	2.2	0.3	2.1	0.3	6.8	2.3
A-046	Channel	Central Appalachia	Lower Winifrede	WV	Boone	106.7	92.1	14.7	6.3	5.0	9.6	20.6	40.0	4.5	16.0	3.0	0.6	2.5	0.3	1.9	0.4	1.1	0.2	1.1	0.2	6.2	1.3
A-046	Floor	Central Appalachia	Glenalum Tunnel	WV	Boone	365.9	304.6	61.2	5.0	25.6	41.1	63.5	125.6	14.7	54.5	10.6	1.8	8.3	1.2	7.5	1.6	4.4	0.7	4.2	0.6	15.2	4.7
A-046	Roof	Central Appalachia	Glenalum Tunnel	WV	Boone	360.1	290.9	69.2	4.2	19.4	46.3	60.3	120.0	14.5	53.5	10.7	2.2	10.1	1.5	8.7	1.8	5.0	0.7	4.6	0.7	14.4	4.3
A-046	Floor	Central Appalachia	Cedar Grove	WV	Boone	420.3	357.7	62.6	5.7	20.7	40.9	78.9	151.1	17.9	65.1	12.2	2.1	9.7	1.4	7.8	1.7	4.8	0.7	4.6	0.7	17.4	4.4
A-046	Roof	Central Appalachia	Cedar Grove	WV	Boone	393.6	330.1	63.5	5.2	31.5	42.7	67.4	133.7	15.8	57.9	11.8	2.2	9.7	1.4	7.9	1.5	4.5	0.6	4.2	0.6	20.5	8.0
A-047	Channel	Central Appalachia	Little Chilton	WV	Fayette	127.8	109.5	18.4	6.0	5.5	12.1	23.6	46.9	5.5	20.0	4.1	0.7	3.1	0.5	2.4	0.5	1.3	0.2	1.3	0.2	5.7	1.9
A-048	Coal	Central Appalachia	Fire Creek	WV	McDowell	19.6	15.1	4.4	3.4	1.4	3.1	3.2	6.1	0.7	2.6	0.5	0.1	0.4	0.1	0.5	0.1	0.3	0.1	0.3	0.0	1.9	0.5
A-050	Channel	Northern Appalachia	Sewell	WV	Randolph	58.3	48.6	9.8	5.0	1.0	6.6	11.3	21.6	2.4	8.6	1.7	0.4	1.6	0.2	1.3	0.2	0.7	0.1	0.6	0.1	1.8	0.7
A-050	Channel	Northern Appalachia	Sewell B	WV	Randolph	62.2	54.0	8.2	6.6	4.4	5.6	13.0	22.9	2.5	8.1	1.6	0.3	1.2	0.2	1.2	0.2	0.5	0.1	0.4	0.1	4.2	0.5
A-051	Channel	Northern Appalachia	Lower Kittanning	WV	Randolph	66.7	56.3	10.4	5.4	3.8	7.1	11.7	24.2	2.7	9.9	1.9	0.3	1.6	0.2	1.3	0.3	0.7	0.1	0.6	0.1	3.0	0.9
A-052	Channel	Northern Appalachia	Bakerstown	WV	Tucker	42.0	34.5	7.6	4.6	2.1	5.3	7.4	14.7	1.7	6.0	1.2	0.3	1.2	0.2	0.9	0.2	0.5	0.1	0.4	0.1	1.8	0.4
A-053	Roof	Northern Appalachia	Lower Kittanning	PA	Somerset	62.0	50.4	11.7	4.3	2.0	7.1	10.1	21.9	2.6	9.9	1.9	0.3	1.6	0.2	1.6	0.3	1.0	0.2	1.0	0.2	3.0	0.9
A-053	Floor	Northern Appalachia	Lower Kittanning	PA	Somerset	293.9	240.7	53.3	4.5	20.3	33.1	56.6	102.9	11.2	40.2	7.7	1.7	7.1	1.1	7.2	1.5	4.5	0.7	4.5	0.7	14.9	7.6
A-053	Coal	Northern Appalachia	Lower Kittanning	PA	Somerset	82.2	63.0	19.1	3.3	4.9	11.5	11.1	24.9	3.0	12.3	2.9	0.7	3.2	0.5	3.0	0.6	1.6	0.2	1.4	0.2	5.5	2.2
A-053	Floor	Northern Appalachia	Lower Kittanning	PA	Somerset	218.6	171.3	47.4	3.6	18.0	31.1	34.3	70.1	8.1	28.5	5.6	1.3	5.5	1.0	5.5	1.3	3.5	0.7	3.5	0.7	12.2	3.4
A-054	Roof	Northern Appalachia	Lower Kittanning	PA	Somerset	260.7	211.6	49.1	4.3	22.9	34.2	41.0	84.6	10.0	37.5	7.4	1.6	6.6	1.0	5.9	1.1	3.2	0.5	2.8	0.4	9.2	4.7
A-054	Floor	Northern Appalachia	Lower Kittanning	PA	Somerset	414.9	364.8	50.1	7.3	32.4	33.9	76.9	156.4	16.9	58.9	11.2	2.6	9.4	1.2	6.2	1.2	3.5	0.5	3.2	0.5	15.2	4.3
A-055	Roof	Northern Appalachia	Lower Kittanning	PA	Somerset	58.0	45.6	12.4	3.7	3.1	8.7	9.3	19.3	2.3	8.4	1.6	0.3	1.3	0.2	1.3	0.2	0.8	0.1	0.8	0.1	1.9	0.6
A-055	Floor	Northern Appalachia	Lower Kittanning	PA	Somerset	200.3	151.5	48.7	3.1	17.9	34.0	30.9	59.9	7.0	24.9	4.9	1.0	5.0	0.9	5.3	1.1	3.3	0.5	3.1	0.5	8.9	2.9
A-056	Roof	Northern Appalachia	Clarion	PA	Clearfield	233.6	193.1	40.5	4.8	20.0	27.9	37.2	77.6	9.3	34.9	6.9	1.4	5.8	0.9	5.0	1.0	2.6	0.4	2.4	0.4	8.3	2.4
A-056	Floor	Northern Appalachia	Clarion	PA	Clearfield	126.2	103.1	23.1	4.5	9.2	13.6	23.8	43.1	4.7	16.3	2.8	0.6	2.7	0.5	3.1	0.7	2.2	0.3	2.3	0.4	12.2	3.6
A-057	Roof	Northern Appalachia	Lower Kittanning	PA	Forrest	72.2	58.3	13.8	4.2	5.0	9.2	11.5	24.4	2.9	10.4	2.0	0.4	1.7	0.3	1.6	0.4	1.0	0.2	1.0	0.2	3.1	0.7
A-057	Floor	Northern Appalachia	Lower Kittanning	PA	Forrest	316.2	271.5	44.7	6.1	21.5	30.6	56.1	114.5	13.5	49.8	8.8	1.6	5.8	0.8	5.1	1.1	3.1	0.5	3.1	0.5	14.2	4.4
A-057	Floor	Northern Appalachia	Lower Kittanning	PA	Forrest	185.9	149.1	36.8	4.1	11.8	23.6	34.1	63.9	7.0	23.2	4.1	0.9	4.1	0.7	4.7	0.9	2.9	0.5	3.1	0.5	9.0	3.1
A-057	Floor	Northern Appalachia	Lower Kittanning	PA	Forrest	264.25715	216.153	48.1038	4.493	14.759	29.92779	51	96.1355	10.59	35.93	6.328	1.409	5.837	1.075	6.171	1.381	3.994	0.701	4.143	0.712	15.59	5.523
A-058	Roof	Northern Appalachia	Lower Kittanning	PA	Somerset	166.4	142.0	24.4	5.8	8.5	13.8	28.7	59.4	7.2	27.3	5.2	1.2	4.5	0.7	3.9	0.8	2.2	0.3	2.3	0.4	10.2	2.5
A-058	Roof	Northern Appalachia	Lower Kittanning	PA	Somerset	22.4	15.9	6.5	2.4	1.8	3.0	2.4	5.7	0.9	2.9	0.8	0.4	1.0	0.4	0.9	0.4	0.6	0.3	0.6	0.3	3.1	0.8

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																						
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)															Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-058	Roof	Northern Appalachia	Lower Kittanning	PA	Somerset	175.9	137.2	38.8	3.5	19.7	26.2	26.6	54.0	6.1	21.2	4.3	0.9	4.4	0.7	4.4	1.0	2.8	0.5	2.8	0.5	9.6	3.2
A-058	Bone	Northern Appalachia	Lower Kittanning	PA	Somerset	284.3	226.3	58.0	3.9	17.5	40.3	48.3	94.9	10.8	39.4	7.5	1.5	6.5	1.0	6.4	1.3	4.0	0.6	3.8	0.6	9.8	2.7
A-058	Coal	Northern Appalachia	Lower Kittanning	PA	Somerset	232.4	191.2	41.2	4.6	20.4	28.1	38.0	77.0	9.1	33.2	6.4	1.3	5.7	0.8	4.9	1.0	2.9	0.4	2.6	0.4	9.1	2.2
A-059	Roof	Northern Appalachia	Lower Kittanning	PA	Somerset	222.5	180.1	42.4	4.2	16.8	29.5	36.0	72.9	8.7	31.9	6.4	1.4	5.9	0.8	4.9	1.0	2.8	0.4	2.6	0.4	7.7	2.9
A-059	Floor	Northern Appalachia	Lower Kittanning	PA	Somerset	177.7	132.0	45.7	2.9	15.4	31.8	28.8	52.8	6.0	20.7	3.8	0.8	3.8	0.7	4.7	1.1	3.2	0.5	3.3	0.5	8.7	3.0
A-060	Roof	Northern Appalachia	Lower Kittanning	PA	Westmoreland	294.3	241.4	52.9	4.6	20.9	36.5	48.2	98.8	11.9	43.7	8.8	1.7	7.3	1.1	6.2	1.3	3.6	0.5	3.3	0.5	9.7	2.5
A-060	Floor	Northern Appalachia	Lower Kittanning	PA	Westmoreland	319.7	278.6	41.1	6.8	32.0	26.1	59.5	112.3	11.9	42.3	9.2	2.2	9.2	1.1	5.5	1.1	3.1	0.5	3.1	0.5	14.3	3.9
A-062	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	391.0	281.0	110.0	2.6	39.6	84.4	45.2	104.5	12.3	52.4	11.6	2.4	13.0	1.8	10.6	1.9	5.7	0.6	4.4	0.5	8.8	2.5
A-063	Roof	Northern Appalachia	Lower Kittanning Rider	PA	Clearfield	165.7	135.4	30.3	4.5	10.7	18.4	27.1	55.9	6.7	24.4	4.9	1.1	4.7	0.7	4.4	0.9	2.6	0.4	2.5	0.4	10.5	2.7
A-063	Coal	Northern Appalachia	Lower Kittanning Rider	PA	Clearfield	260.8	218.1	42.7	5.1	19.3	29.2	43.6	89.9	10.7	38.9	7.9	1.6	6.3	0.9	5.2	1.0	2.9	0.4	2.7	0.4	10.3	2.6
A-063	Floor	Northern Appalachia	Lower Kittanning Rider	PA	Clearfield	56.0	121.2	41.0	3.0	14.4	28.3	23.3	45.2	5.3	20.3	4.8	1.7	6.4	0.9	5.8	0.9	2.5	0.3	2.0	0.3	5.2	2.4
A-063	Roof	Northern Appalachia	Lower Kittanning Rider	PA	Clearfield	236.3	193.0	43.4	4.4	22.5	29.7	37.9	77.2	8.9	33.1	6.3	1.4	5.7	0.9	5.1	1.0	3.0	0.5	2.8	0.4	9.0	3.0
A-063	Coal	Northern Appalachia	Lower Kittanning Rider	PA	Clearfield	9.8	5.8	4.0	1.4	0.0	3.7	1.0	2.8	0.3	1.4	0.1	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A-063	Floor	Northern Appalachia	Lower Kittanning Rider	PA	Clearfield	247.3	206.6	40.6	5.1	43.0	29.6	37.4	73.0	8.7	34.5	5.4	0.9	3.9	0.7	3.7	0.8	2.4	0.4	2.6	0.4	8.2	2.4
A-064	Roof	Northern Appalachia	Middle Kittanning	PA	Clearfield	87.8	66.6	21.1	3.2	11.7	15.1	13.3	25.0	2.7	9.9	1.9	0.4	1.8	0.3	2.1	0.5	1.4	0.2	1.3	0.2	5.6	1.7
A-064	Coal	Northern Appalachia	Middle Kittanning	PA	Clearfield	80.7	62.7	17.9	3.5	7.9	14.3	11.7	24.9	2.8	11.8	1.7	0.2	1.8	0.1	1.8	0.2	0.8	0.0	0.9	0.0	1.1	0.6
A-064	Floor	Northern Appalachia	Middle Kittanning	PA	Clearfield	220.5	178.8	41.7	4.3	26.5	28.9	34.4	70.3	8.1	28.6	5.1	1.0	4.8	0.8	4.7	0.9	2.8	0.4	2.7	0.4	10.1	3.9
A-065	Floor	Northern Appalachia	Lower Kittanning	PA	Clearfield	461.7	377.2	84.5	4.5	66.3	61.8	70.1	140.2	16.3	61.8	11.6	2.0	8.9	1.3	8.6	1.7	4.9	0.6	5.0	0.5	20.0	6.1
A-066	Refuse	Northern Appalachia	Lower Kittanning	PA	Clearfield	105.8	84.7	17.8	4.7	6.8	13.9	17.9	36.0	4.0	15.2	2.4	0.4	2.1	0.2	1.7	0.2	1.0	0.0	0.9	0.0	2.4	0.8
A-066	Refuse	Northern Appalachia	Lower Kittanning	PA	Clearfield	130.1	103.9	19.3	5.4	25.3	15.1	17.9	36.8	3.8	14.8	2.8	0.4	2.1	0.2	1.7	0.3	1.0	0.0	0.9	0.0	5.7	1.3
A-066	Refuse	Northern Appalachia	Lower Kittanning	PA	Clearfield	19.5	14.9	3.9	3.8	3.1	3.6	2.5	5.4	0.5	2.4	0.4	0.0	0.4	0.0	0.3	0.0	0.1	0.0	0.1	0.0	0.6	0.1
A-066	Refuse	Northern Appalachia	Lower Kittanning	PA	Clearfield	100.6	83.6	17.1	4.9	5.7	9.8	17.5	35.8	4.2	14.9	2.7	0.6	2.4	0.4	2.4	0.6	1.6	0.3	1.6	0.3	6.7	2.2
A-067	Roof	Northern Appalachia	Middle Kittanning	PA	Centre	248.8	205.2	43.6	4.7	21.2	30.3	39.5	82.0	9.7	36.6	7.6	1.6	7.0	1.0	5.3	1.0	2.8	0.4	2.4	0.4	8.6	5.5
A-067	Parting	Northern Appalachia	Middle Kittanning	PA	Centre	171.1	128.5	37.8	9.8	28.9	28.0	28.4	55.5	5.9	22.6	3.9	0.7	3.5	0.4	3.4	0.6	2.2	0.2	2.0	0.2	2.9	1.9
A-067	Coal	Northern Appalachia	Middle Kittanning	PA	Centre	17.9	14.7	2.8	5.2	2.1	2.5	2.7	5.9	0.6	2.7	0.3	0.0	0.3	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.3	0.1
A-067	Floor	Northern Appalachia	Middle Kittanning	PA	Centre	235.3	193.2	42.1	4.6	14.5	26.2	34.0	79.2	9.5	36.8	8.6	2.2	8.5	1.2	6.4	1.3	3.3	0.5	2.9	0.4	12.5	3.1
A-068	Floor	Northern Appalachia	Clarion	PA	Centre	382.4	302.6	71.2	4.3	13.7	52.4	67.4	129.3	14.5	56.1	10.1	2.1	9.4	1.1	7.3	1.3	4.2	0.4	4.0	0.4	3.3	5.3
A-068	Roof	Northern Appalachia	Clarion	PA	Centre	153.6	123.5	30.1	4.1	10.7	17.9	23.1	49.9	6.1	22.8	4.9	1.2	4.8	0.9	4.3	1.1	2.5	0.5	2.4	0.5	10.2	2.6
A-068	Coal	Northern Appalachia	Clarion	PA	Centre	164.4	112.3	46.1	2.4	20.9	36.4	19.3	40.6	4.5	18.7	3.8	0.6	3.8	0.5	3.9	0.7	2.2	0.2	2.0	0.2	4.1	1.9
A-069	Roof	Central Appalachia	Fire Clay	WV	Mingo	162.42	112.42	50.00	2.25	13.33	36.01	20.66	44.84	5.20	19.08	4.21	0.70	4.40	0.73	4.98	1.10	3.26	0.48	3.00	0.44	11.61	2.20
A-069	Parting	Central Appalachia	Fire Clay	WV	Mingo	302.78	254.89	47.89	5.32	12.25	32.27	49.53	112.85	13.40	48.12	9.71	0.64	8.39	1.25	6.69	1.22	3.15	0.42	2.57	0.32	40.82	7.94
A-069	Coal	Central Appalachia	Fire Clay	WV	Mingo	153.97	119.66	34.31	3.49	3.06	21.63	23.04	52.57	6.48	23.91	4.99	0.47	5.14	0.79	4.83	1.02	2.75	0.43	2.51	0.35	6.63	2.87
A-069	Floor	Central Appalachia	Fire Clay	WV	Mingo	295.36	244.34	51.03	4.79	27.51	35.15	47.03	98.89	11.64	42.31	8.23	1.60	7.12	1.04	6.01	1.18	3.47	0.52	3.23	0.42	10.07	2.71
A-070	Coal	Northern Appalachia	Upper Freeport	WV	Grant	24.24	19.48	4.75	4.10	0.92	2.89	3.57	7.94	0.97	4.16	0.80	0.24	0.89	0.12	0.71	0.18	0.41	0.06	0.32	0.06	0.89	0.35
A-070	Parting	Northern Appalachia	Upper Freeport	WV	Grant	294.26	245.58	48.68	5.04	20.43	33.48	46.17	101.94	12.18	45.37	9.09	1.96	8.43	1.09	5.93	1.16	3.16	0.44	2.98	0.44	11.92	3.02
A-070	Coal	Northern Appalachia	Upper Freeport	WV	Grant	86.91	68.41	18.50	3.70	22.59	14.76	7.96	19.84	2.33	11.31	2.11	0.32	1.95	0.10	1.82	0.22	0.96	0.00	0.73	0.00	0.58	1.41
A-070	Parting	Northern Appalachia	Upper Freeport	WV	Grant	274.64	235.53	39.10	6.02	18.93	27.07	50.26	101.40	11.06	39.31	7.10	1.40	6.08	0.84	4.52	0.92	2.55	0.41	2.43	0.36	12.18	3.32
A-070	Coal	Northern Appalachia	Upper Freeport	WV	Grant	52.23	37.35	14.88	2.51	7.85	10.45	5.30	12.59	1.58	6.35	1.58	0.34	1.77	0.30	1.69	0.38	0.98	0.15	0.86	0.08	1.95	0.75
A-070	Parting	Northern Appalachia	Upper Freeport	WV	Grant	190.71	160.43	30.28	5.30	16.72	19.81	33.57	67.58	7.57	26.17	4.34	0.85	3.63	0.58	3.57	0.77	2.34	0.38	2.44	0.38	13.35	3.07
A-070	Coal	Northern Appalachia	Upper Freeport	WV	Grant	23.59	17.82	5.77	3.09	2.09	4.11	3.21	7.05	0.85	3.06	0.66	0.15	0.74	0.08	0.62	0.15	0.39	0.08	0.31	0.04	0.58	0.31
A-071	Coal	Central Appalachia	Fire Clay	WV	Mingo	507.81	387.51	120.30	3.22	15.70	85.25	77.14	172.51	20.02	71.11	14.77	1.64	14.62	2.23	13.47	2.83	7.81	1.08	6.74	0.89	14.59	8.82
A-071	Tonstein	Central Appalachia	Fire Clay	WV	Mingo	190.55	162.25	28.30	5.73	4.64	16.22	32.20	71.78	8.69	32.31	6.54	0.59	5.50	0.89	5.10	0.93	2.47	0.34	2.04	0.31	43.94	4.96
A-072	Parting	Central Appalachia	Fire Clay	WV	Mingo	155.78	121.66	34.12	3.57	13.13	24.59	24.89	49.64	5.70	20.04	3.86	0.72	3.67	0.52	3.41	0.72	2.16	0.33	2.13	0.26	6.55	1.60
A-074	Roof	Northern Appalachia	Lower Kittanning	PA	Somerset	221.8	183.9	37.9	4.9	12.9	25.5	35.6	76.0	9.3	35.3	7.0	1.6	6.3	0.9	5.0	1.0	2.6	0.4	2.3	0.3	7.4	5.0

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-074	Floor	Northern Appalachia	Lower Kittanning	PA	Somerset	565.4	522.0	43.4	12.0	26.1	30.1	102.5	223.7	27.0	107.0	22.2	3.5	10.1	1.0	5.3	1.0	2.7	0.4	2.5	0.3	11.9	3.2
A-076	Coal	Northern Appalachia	Middle Kittanning	WV	Monongalia	42.10	37.33	4.76	7.84	4.03	4.06	8.45	15.80	1.52	5.97	0.81	0.08	0.68	0.00	0.58	0.00	0.21	0.00	0.24	0.00	0.00	0.21
A-076	Coal	Northern Appalachia	Middle Kittanning	WV	Monongalia	74.03	51.71	22.33	2.32	7.76	18.35	7.81	19.54	2.34	9.73	2.20	0.23	2.10	0.19	1.97	0.22	0.92	0.00	0.78	0.00	1.36	0.67
A-076	Coal	Northern Appalachia	Middle Kittanning	WV	Monongalia	47.99	35.49	12.50	2.84	3.79	10.89	5.20	14.46	1.76	7.50	1.39	0.15	1.25	0.02	1.05	0.05	0.39	0.00	0.29	0.00	0.00	0.05
A-076	Channel	Northern Appalachia	Middle Kittanning	WV	Monongalia	61.87	48.21	13.66	3.53	6.48	11.14	9.17	18.79	2.23	8.62	1.35	0.12	1.47	0.06	1.38	0.12	0.64	0.00	0.53	0.00	0.18	0.41
A-079	Channel	Northern Appalachia	Lower Kittanning	WV	Upshur	111.44	87.96	23.48	3.75	12.70	18.20	16.33	34.56	3.91	15.24	2.37	0.45	2.40	0.22	2.26	0.33	1.26	0.00	1.17	0.03	2.90	0.98
A-080	Channel	Northern Appalachia	Pittsburgh	WV	Harrison	24.02	19.56	4.45	4.39	2.19	4.57	4.13	8.34	0.78	3.55	0.36	0.00	0.31	0.00	0.32	0.00	0.06	0.00	0.11	0.00	0.00	0.00
A-081	Coal	Northern Appalachia	Middle Kittanning	WV	Randolph	92.23	77.33	14.90	5.19	8.99	12.04	15.91	31.39	3.45	13.52	2.03	0.27	1.76	0.05	1.38	0.12	0.70	0.00	0.72	0.00	0.93	0.42
A-081	Coal	Northern Appalachia	Middle Kittanning	WV	Randolph	59.95	45.86	14.09	3.25	8.80	11.16	7.31	16.31	1.84	8.26	1.56	0.25	1.53	0.13	1.38	0.18	0.67	0.02	0.55	0.00	1.45	0.40
A-082	Channel	Northern Appalachia	Upper Kittanning	WV	Barbour	25.35	18.50	6.86	2.70	2.63	4.94	3.19	6.99	0.85	3.32	0.72	0.13	0.68	0.13	0.68	0.13	0.46	0.07	0.39	0.07	0.72	0.39
A-082	Channel	Northern Appalachia	Upper Mercer	WV	Barbour	115.43	94.10	21.33	4.41	11.61	14.03	18.31	37.63	4.19	15.67	3.14	0.66	2.90	0.48	2.69	0.57	1.59	0.24	1.50	0.24	5.92	2.00
A-085	Channel	Northern Appalachia	Lower Freeport	WV	Monongalia	345.02	287.54	57.48	5.00	39.57	44.08	52.03	110.02	13.20	53.15	10.66	1.76	7.14	0.85	5.62	0.91	2.98	0.24	2.61	0.20	7.52	4.37
A-085	Roof	Northern Appalachia	Lower Freeport	WV	Monongalia	408.52	356.75	51.77	6.89	67.30	36.64	65.20	132.29	16.13	58.77	9.51	1.36	6.20	0.82	5.78	1.00	3.31	0.33	3.55	0.34	18.17	11.22
A-085	Parting	Northern Appalachia	Lower Freeport	WV	Monongalia	338.72	276.25	62.47	4.42	40.24	47.63	50.14	107.03	12.35	48.74	9.01	1.46	7.29	0.93	6.05	1.04	3.21	0.31	3.01	0.28	10.51	4.44
A-085	Floor	Northern Appalachia	Lower Freeport	WV	Monongalia	280.45	238.73	41.72	5.72	37.23	32.24	47.12	90.88	10.58	39.87	7.03	1.19	4.83	0.50	3.96	0.57	1.95	0.16	2.13	0.22	8.07	3.39
A-089	Channel	Northern Appalachia	Lower Mercer	WV	Barbour	181.19	148.37	32.82	4.52	16.97	21.55	30.02	59.68	6.83	24.21	5.02	1.05	4.58	0.69	4.14	0.87	2.40	0.36	2.44	0.36	10.14	3.38
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	276.13	239.68	36.45	6.58	28.76	26.38	47.37	96.47	11.49	43.17	6.95	1.11	4.37	0.51	3.86	0.65	2.38	0.20	2.27	0.20	10.13	3.57
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	183.98	153.09	30.89	4.96	18.30	23.70	28.28	59.94	7.16	29.03	5.40	0.90	4.07	0.43	3.04	0.50	1.61	0.10	1.41	0.10	3.77	2.06
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	59.33	43.64	15.70	2.78	2.76	12.01	8.06	17.78	2.26	9.45	1.66	0.15	1.52	0.06	1.61	0.21	0.95	0.00	0.98	0.00	3.33	0.83
A-090	Channel	Central Appalachia	Fire Clay	WV	Kanawha	42.97	28.87	14.09	2.05	4.45	20.11	5.10	11.29	1.27	5.06	0.79	0.03	0.89	0.00	1.03	0.03	0.55	0.00	0.38	0.00	0.00	0.21
A-090	Coal	Central Appalachia	Fire Clay	WV	Kanawha	163.15	134.29	28.86	4.65	11.27	20.11	26.37	53.80	6.66	27.41	4.86	0.57	3.35	0.38	3.32	0.47	2.08	0.09	2.24	0.16	5.24	1.64
A-090	Coal	Central Appalachia	Fire Clay	WV	Kanawha	352.02	304.12	47.91	6.35	45.99	35.83	59.23	118.04	13.47	51.22	8.52	1.38	6.25	0.74	4.80	0.81	2.64	0.28	2.53	0.28	13.41	4.31
A-091	Floor	Central Appalachia	Fire Clay	WV	Mingo	253.30	212.71	40.60	5.24	22.91	27.51	41.82	86.52	10.15	37.06	6.98	1.29	5.98	0.86	4.83	0.99	2.84	0.43	2.78	0.36	9.03	2.51
A-092	Coal	Central Appalachia	Chilton	WV	Mingo	19.25	15.01	4.24	3.54	0.72	2.78	3.12	6.27	0.72	2.84	0.59	0.12	0.62	0.09	0.56	0.12	0.28	0.06	0.28	0.06	0.81	0.37
A-092	Floor	Central Appalachia	Chilton	WV	Mingo	235.11	195.34	39.77	4.91	25.54	27.34	38.76	79.07	8.91	31.34	5.66	1.08	4.98	0.75	4.51	0.95	2.71	0.41	2.71	0.41	10.67	2.54
A-093	Coal	Northern Appalachia	Upper Mercer	WV	Barbour	75.98	60.25	15.73	3.83	6.73	9.68	10.75	24.54	2.81	10.47	2.19	0.48	2.28	0.39	2.22	0.51	1.32	0.23	1.18	0.20	4.53	1.49
A-095	Roof	Central Appalachia	Little Chilton	WV	Logan	136.03	111.88	24.15	4.63	11.07	16.40	22.92	45.99	5.37	19.00	3.50	0.72	3.32	0.50	2.78	0.58	1.69	0.29	1.62	0.29	5.51	1.80
A-095	Floor	Central Appalachia	Little Chilton	WV	Logan	204.80	162.93	41.87	3.89	16.17	27.82	32.95	65.66	7.92	28.85	5.34	1.03	5.01	0.79	5.07	1.09	3.03	0.49	3.09	0.49	11.32	2.70
A-096	Coal	Northern Appalachia	Upper Mercer	WV	Barbour	87.29	69.39	17.90	3.88	6.73	10.77	13.00	28.00	3.30	12.50	2.67	0.63	2.57	0.43	2.63	0.53	1.60	0.23	1.47	0.23	5.20	1.70
A-097	Floor	Northern Appalachia	Upper Mercer	WV	Barbour	244.28	199.76	44.52	4.49	22.05	30.15	47.86	89.44	8.30	24.11	3.56	0.65	3.79	0.72	5.10	1.05	3.23	0.52	3.27	0.49	14.73	8.43
A-097	Paleosol	Northern Appalachia	Upper Mercer	WV	Barbour	214.09	167.62	46.47	3.61	20.09	32.58	37.01	67.64	7.26	24.84	4.78	1.05	4.95	0.80	4.78	1.05	3.10	0.49	3.21	0.45	12.45	3.21
A-098	Roof	Central Appalachia	Fire Clay	WV	Mingo	235.44	172.42	63.03	2.74	10.22	45.97	36.27	72.37	8.59	30.90	6.48	1.17	6.41	1.04	6.58	1.37	3.84	0.55	3.22	0.46	7.29	2.21
A-098	Channel	Central Appalachia	Fire Clay	WV	Mingo	87.59	58.83	28.76	2.05	3.65	16.95	10.38	22.64	2.91	11.90	3.16	0.43	3.74	0.70	4.60	0.94	2.60	0.38	2.29	0.31	10.58	9.69
A-098	Parting	Central Appalachia	Fire Clay	WV	Mingo	243.08	198.35	44.73	4.43	16.15	30.35	39.00	86.93	9.78	33.52	6.57	0.58	5.82	0.95	5.69	1.19	3.07	0.44	2.69	0.34	45.75	3.92
A-098	Parting	Central Appalachia	Fire Clay	WV	Mingo	140.50	111.06	29.44	3.77	6.16	17.05	22.07	47.37	5.70	20.11	4.60	0.46	4.60	0.78	5.02	0.95	2.61	0.39	2.31	0.33	29.57	4.66
A-098	Floor	Central Appalachia	Fire Clay	WV	Mingo	128.69	108.77	19.92	5.46	7.36	11.55	23.19	46.20	5.43	19.51	3.31	0.64	3.13	0.51	2.99	0.64	1.79	0.28	1.84	0.32	9.48	2.85
A-099	Roof	Central Appalachia	Fire Clay	WV	Mingo	414.14	354.72	59.42	5.97	34.40	41.11	74.04	146.80	16.84	60.14	11.10	2.05	9.35	1.28	6.88	1.39	3.97	0.61	3.69	0.50	14.51	3.69
A-099	Roof	Central Appalachia	Fire Clay	WV	Mingo	207.02	144.90	62.12	2.33	15.88	43.88	25.42	58.52	6.87	25.54	5.71	0.99	5.97	1.03	6.53	1.46	4.16	0.60	3.95	0.52	18.93	3.26
A-099	Tonstein	Central Appalachia	Fire Clay	WV	Mingo	320.98	277.11	43.87	6.32	11.82	29.18	55.22	124.60	14.56	51.58	10.15	0.77	8.41	1.24	6.54	1.14	2.80	0.40	2.30	0.27	42.67	7.48
A-101	Roof	Central Appalachia	Chilton	WV	Mingo	202.78	168.29	34.49	4.88	12.30	21.39	33.66	69.77	8.40	31.38	6.12	1.17	5.49	0.83	4.87	1.00	2.87	0.45	2.66	0.41	10.47	3.52
A-101	Coal	Central Appalachia	Chilton	WV	Mingo	26.28	17.19	9.09	1.89	2.53	6.59	2.90	6.23	0.73	2.96	0.70	0.20	0.93	0.13	0.93	0.20	0.57	0.07	0.53	0.07	0.50	0.70
A-101	Parting	Central Appalachia	Chilton	WV	Mingo	220.20	191.05	29.15	6.55	21.26	19.71	39.41	78.72	8.94	31.62	5.50	1.08	4.52	0.61	3.44	0.67	2.09	0.34	1.99	0.30	8.71	3.51
A-104	Refuse	Northern Appalachia	Pittsburgh	PA	Washington	136.3	106.6	29.7	3.6	23.7	23.0	19.6	38.0	4.2	16.0	2.4	0.5	2.3	0.2	2.5	0.4	1.6	0.1	1.8	0.1	4.3	1.4
A-105	Roof	Northern Appalachia	Lower Freeport	PA	Clearfield	182.6	150.0	32.6	4.6	17.2	22.4	28.9	59.3	7.0	26.5	5.4	1.1	4.6	0.7	3.9	0.8	2.2	0.3	2.1	0.3	6.6	1.6

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-105	Roof	Northern Appalachia	Lower Freeport	PA	Clearfield	206.5	174.9	31.6	5.5	9.6	17.9	33.8	74.1	8.9	34.4	6.7	1.4	6.0	0.9	5.1	1.0	2.9	0.4	2.8	0.4	12.5	3.7
A-105	Coal	Northern Appalachia	Lower Freeport	PA	Clearfield	61.9	48.4	13.5	3.6	4.6	10.0	9.5	19.4	2.2	8.6	1.8	0.4	1.8	0.3	1.4	0.3	0.7	0.1	0.7	0.1	1.6	0.6
A-105	Coal	Northern Appalachia	Lower Freeport	PA	Clearfield	75.4	56.4	19.0	3.0	11.1	13.4	11.6	20.4	2.3	7.4	1.4	0.7	1.5	0.3	2.0	0.4	1.3	0.2	1.2	0.2	4.0	2.8
A-105	Floor	Northern Appalachia	Lower Freeport	PA	Clearfield	283.2	239.1	44.2	5.4	26.1	30.0	49.7	98.2	10.9	38.6	7.1	1.5	7.0	1.0	5.4	1.1	3.0	0.5	2.8	0.4	11.7	4.2
A-106	Roof	Northern Appalachia	Middle Kittanning	PA	Centre	136.6	109.7	26.9	4.1	9.6	16.2	20.5	44.2	5.3	20.3	4.4	1.0	4.5	0.7	4.1	0.9	2.3	0.3	2.1	0.3	7.9	4.1
A-106	Roof	Northern Appalachia	Middle Kittanning	PA	Centre	168.8	132.0	36.8	3.6	15.9	23.3	24.0	51.6	6.0	22.6	5.1	1.2	5.7	0.9	5.2	1.0	3.0	0.4	2.6	0.4	9.1	6.4
A-106	Coal	Northern Appalachia	Middle Kittanning	PA	Centre	278.9	214.7	64.2	3.3	50.6	49.7	37.5	75.2	8.3	31.3	5.8	1.0	4.9	0.6	5.3	1.0	3.5	0.4	3.3	0.3	8.8	3.3
A-106	Coal	Northern Appalachia	Middle Kittanning	PA	Centre	34.7	27.8	6.8	4.1	2.0	4.2	5.5	11.6	1.3	5.1	1.1	0.2	1.0	0.2	1.0	0.2	0.6	0.1	0.5	0.1	2.1	0.7
A-106	Floor	Northern Appalachia	Middle Kittanning	PA	Centre	164.4	138.0	26.3	5.2	12.1	16.1	27.2	58.1	6.7	24.4	4.5	1.0	4.1	0.7	3.7	0.8	2.3	0.4	2.1	0.4	10.8	3.2
A-106	Roof	Northern Appalachia	Middle Kittanning	PA	Centre	341.75331	285.275	56.4784	5.051	42.625	41.23174	49.09	107.771	13.06	51.51	10.51	1.993	8.726	1.103	6.482	1.084	3.231	0.329	2.709	0.31	12.267	6.443
A-106	Roof	Northern Appalachia	Middle Kittanning	PA	Centre	250.5662	209.693	40.8736	5.13	24.969	29.00858	35.92	81.1276	9.708	40.16	8.744	1.698	7.367	0.895	5.301	0.78	2.502	0.184	2.043	0.161	6.9997	5.783
A-107	Roof	Northern Appalachia	Mahoning	PA	Clearfield	274.5	223.9	50.6	4.4	22.4	34.3	43.5	91.7	10.7	39.8	7.8	1.4	6.6	1.0	6.4	1.2	3.5	0.5	3.1	0.5	10.7	3.4
A-107	Coal	Northern Appalachia	Mahoning	PA	Clearfield	18.3	15.1	3.2	4.7	0.9	1.9	3.0	6.2	0.8	2.9	0.6	0.1	0.6	0.1	0.5	0.1	0.3	0.0	0.2	0.0	1.1	0.4
A-107	Floor	Northern Appalachia	Mahoning	PA	Clearfield	125.4	102.3	23.0	4.4	5.2	13.4	19.5	39.8	5.3	21.9	4.8	1.1	4.7	0.7	3.9	0.7	2.0	0.3	1.8	0.3	6.9	3.8
A-107	Floor	Northern Appalachia	Mahoning	PA	Clearfield	100.6	82.5	18.1	4.5	5.1	10.5	16.2	34.7	4.2	15.8	3.1	0.6	2.8	0.5	2.6	0.6	1.7	0.3	1.7	0.3	6.0	1.9
A-107	Roof	Northern Appalachia	Mahoning	PA	Clearfield	352.5	292.2	60.3	4.8	54.8	45.1	49.7	107.1	12.6	50.6	9.2	1.3	6.9	0.9	6.0	1.1	3.3	0.3	3.2	0.4	10.9	3.5
A-108	Roof	Northern Appalachia	Upper Freeport	PA	Clearfield	244.9	201.5	43.4	4.6	21.7	29.8	40.1	81.1	9.6	35.1	6.9	1.3	5.8	0.9	5.1	1.0	2.9	0.4	2.8	0.4	9.1	2.2
A-108	Coal	Northern Appalachia	Upper Freeport	PA	Clearfield	36.9	26.3	10.6	2.5	0.4	8.8	4.8	11.4	1.4	6.0	1.1	0.1	1.0	0.0	1.0	0.1	0.4	0.0	0.3	0.0	0.0	0.0
A-108	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	282.2	234.9	47.2	5.0	8.4	28.9	44.1	94.7	12.1	49.1	11.6	2.9	12.1	1.6	8.2	1.5	3.5	0.5	2.7	0.4	8.8	3.0
A-109	Roof	Northern Appalachia	Middle Kittanning	PA	Clearfield	199.0	156.8	42.2	3.7	15.0	28.0	29.0	62.9	7.7	28.5	6.0	1.3	6.4	0.8	5.8	1.1	2.9	0.4	2.7	0.4	7.1	3.4
A-109	Roof	Northern Appalachia	Middle Kittanning	PA	Clearfield	259.5	214.7	44.8	4.8	22.1	31.5	42.8	87.3	10.2	37.2	7.2	1.6	6.2	0.9	5.1	1.0	2.9	0.4	2.6	0.4	8.8	2.3
A-109	Coal	Northern Appalachia	Middle Kittanning	PA	Clearfield	13.8	9.2	4.6	2.0	1.0	3.0	1.3	3.4	0.5	1.8	0.5	0.1	0.5	0.1	0.6	0.1	0.3	0.1	0.3	0.1	1.1	0.3
A-109	Floor	Northern Appalachia	Middle Kittanning	PA	Clearfield	179.6	156.0	23.6	6.6	12.4	13.5	32.3	68.8	7.7	25.9	4.4	0.8	3.7	0.6	3.5	0.8	2.2	0.4	2.3	0.4	13.1	4.0
A-110	Sludge	Northern Appalachia	Lower Kittanning	PA	Clearfield	226.2	179.3	46.9	3.8	24.8	33.5	31.9	67.0	8.6	33.7	6.9	1.1	5.4	0.7	5.0	1.0	3.2	0.3	2.9	0.3	7.6	2.4
A-111	Coal	Northern Appalachia	Pittsburgh	PA	Fayette	20.9	16.6	4.3	3.8	2.1	3.1	3.5	6.7	0.7	2.6	0.5	0.1	0.5	0.1	0.5	0.1	0.3	0.0	0.3	0.0	0.8	0.2
A-111	Parting	Northern Appalachia	Pittsburgh	PA	Fayette	208.1	174.0	34.1	5.1	14.3	23.8	38.6	73.8	8.2	29.1	5.0	1.0	4.0	0.6	3.8	0.8	2.3	0.3	2.2	0.3	7.9	2.2
A-111	Roof	Northern Appalachia	Pittsburgh	PA	Fayette	274.4	230.0	44.4	5.2	20.2	29.9	44.4	96.0	11.1	41.5	8.1	1.6	7.2	1.0	5.5	1.1	3.1	0.5	2.9	0.4	12.5	3.3
A-111	Parting	Northern Appalachia	Pittsburgh	PA	Fayette	235.1	201.9	33.2	6.1	13.2	22.7	44.9	88.1	9.9	33.9	6.2	0.9	4.8	0.8	3.7	0.9	2.7	0.4	1.8	0.4	10.9	2.6
A-112	Parting	Central Appalachia	Fire Clay	WV	Logan	351.4	287.4	64.1	4.5	12.9	44.4	62.8	131.5	14.7	48.4	8.5	1.4	7.3	1.5	7.0	1.6	4.2	0.9	3.7	0.8	17.4	2.6
A-112	Tonstein	Central Appalachia	Fire Clay	WV	Logan	278.2	223.9	54.3	4.1	10.0	35.9	41.8	98.5	11.8	43.0	8.9	0.8	9.1	1.3	7.8	1.5	3.8	0.5	2.9	0.4	37.2	7.4
A-112	Bone	Central Appalachia	Fire Clay	WV	Logan	922.5	793.6	128.9	6.2	19.9	84.3	159.0	344.9	42.4	159.8	34.5	3.9	29.2	3.9	19.7	3.3	8.5	1.1	7.0	1.0	26.0	7.7
A-112	Floor	Central Appalachia	Fire Clay	WV	Logan	270.0	224.4	45.5	4.9	18.9	31.1	49.4	92.4	10.7	38.6	7.2	1.1	6.2	0.9	5.5	1.1	3.2	0.5	2.9	0.4	10.3	3.2
A-112	Floor	Central Appalachia	Middle Kittanning	WV	Logan	189.9	158.1	31.8	5.0	22.2	20.8	35.9	65.2	6.5	20.7	3.5	0.7	3.4	0.6	3.8	0.8	2.4	0.4	2.5	0.4	12.9	3.1
A-112	Parting	Central Appalachia	Middle Kittanning	WV	Logan	66.0	53.8	12.2	4.4	6.7	7.7	10.7	21.4	2.5	8.7	1.7	0.4	1.6	0.3	1.7	0.3	1.0	0.2	0.9	0.2	4.5	1.4
A-112	Coal	Central Appalachia	Middle Kittanning	WV	Logan	54.4	41.7	12.7	3.3	5.8	9.3	7.2	15.9	1.9	7.2	1.6	0.4	1.6	0.2	1.4	0.3	0.7	0.1	0.6	0.1	1.9	0.6
A-112	Parting	Central Appalachia	Middle Kittanning	WV	Logan	145.2	118.4	26.8	4.4	7.8	16.0	23.5	50.2	5.8	21.5	4.5	0.9	4.1	0.7	3.9	0.8	2.3	0.4	2.3	0.4	9.4	2.7
A-112	Roof	Central Appalachia	Middle Kittanning	WV	Logan	195.4	164.2	31.2	5.3	12.9	21.1	33.6	68.3	8.1	30.1	5.6	1.1	4.7	0.7	3.9	0.8	2.2	0.3	2.0	0.3	7.0	2.0
A-113	Coal	Northern Appalachia	Pittsburgh	WV	Marshall	30.1	23.5	6.6	3.5	3.4	4.4	3.9	8.7	1.0	4.5	0.9	0.2	1.0	0.1	0.9	0.2	0.4	0.1	0.4	0.1	1.0	1.1
A-113	Parting	Northern Appalachia	Pittsburgh	WV	Marshall	226.3	190.5	35.9	5.3	19.1	24.9	40.5	79.2	8.8	30.9	5.9	1.2	4.8	0.7	4.1	0.8	2.4	0.4	2.2	0.4	9.8	2.1
A-113	Bone	Northern Appalachia	Pittsburgh	WV	Marshall	74.2	58.6	15.6	3.8	5.3	10.4	12.1	24.9	2.8	9.7	1.8	0.4	1.6	0.3	1.7	0.4	1.2	0.2	1.2	0.2	3.4	1.1
A-113	Floor	Northern Appalachia	Pittsburgh	WV	Marshall	268.7	223.4	45.2	4.9	19.1	31.6	48.3	93.8	10.4	37.0	7.3	1.3	6.2	0.9	5.3	1.0	2.9	0.4	2.7	0.4	10.3	2.6
A-113	Dike	Northern Appalachia	Pittsburgh	WV	Marshall	197.1	159.3	37.9	4.2	13.9	26.5	32.4	65.9	7.7	27.8	5.4	1.1	5.0	0.7	4.4	0.9	2.4	0.4	2.2	0.3	7.3	3.6
A-114	Parting	Northern Appalachia	Sewickley	WV	Monongalia	270.2	218.8	51.4	4.3	23.6	35.8	42.6	87.8	10.3	38.1	8.0	1.6	6.7	1.0	5.9	1.2	3.3	0.5	3.1	0.5	9.4	3.0
A-115	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	231.0	191.3	39.7	4.8	17.8	26.5	37.2	79.4	9.2	33.7	6.4	1.5	6.0	0.9	5.0	1.0	2.8	0.4	2.8	0.4	9.9	2.2

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-116	Roof	Northern Appalachia	Lower Kittanning	PA	Centre	217.0	189.6	27.4	6.9	8.4	15.7	35.6	81.6	10.4	40.7	6.9	1.2	4.8	0.7	4.2	0.9	2.6	0.4	2.5	0.4	10.4	2.2
A-117	Roof	Northern Appalachia	Lower Kittanning	PA	Clearfield	155.5	131.7	23.8	5.5	6.6	14.2	25.9	56.1	6.7	25.7	5.0	1.1	4.5	0.6	3.7	0.8	2.0	0.3	1.9	0.3	7.3	1.9
A-117	Coal	Northern Appalachia	Lower Kittanning	PA	Clearfield	10.2	8.0	2.3	3.5	0.6	1.7	1.5	3.0	0.4	1.7	0.4	0.1	0.3	0.0	0.2	0.0	0.1	0.0	0.1	0.0	0.1	0.1
A-117	Parting	Northern Appalachia	Lower Kittanning	PA	Clearfield	175.5	141.9	33.6	4.2	16.6	20.8	28.6	57.9	6.7	23.1	4.1	0.8	4.1	0.7	4.5	1.0	2.8	0.4	2.9	0.4	13.0	4.4
A-117	Coal	Northern Appalachia	Lower Kittanning	PA	Clearfield	40.1	29.8	10.3	2.9	2.4	7.1	5.2	11.2	1.5	6.1	1.5	0.3	1.6	0.2	1.3	0.3	0.7	0.1	0.5	0.1	1.6	0.5
A-117	Parting	Northern Appalachia	Lower Kittanning	PA	Clearfield	186.3	158.8	27.5	5.8	13.2	16.5	33.4	67.0	7.9	27.8	4.6	0.9	4.0	0.6	3.9	0.8	2.4	0.3	2.4	0.4	11.1	3.0
A-117	Parting	Northern Appalachia	Lower Kittanning	PA	Clearfield	172.5	143.4	29.1	4.9	12.1	19.6	32.3	62.6	6.8	22.3	3.4	0.7	3.2	0.5	3.3	0.7	2.1	0.3	2.2	0.3	8.5	2.2
A-117	Coal	Northern Appalachia	Lower Kittanning	PA	Clearfield	26.4	14.0	12.4	1.1	0.6	9.7	1.3	4.7	0.8	3.8	1.2	0.3	1.3	0.2	1.2	0.2	0.6	0.1	0.4	0.1	0.0	0.1
A-117	Floor	Northern Appalachia	Lower Kittanning	PA	Clearfield	310.7	226.9	83.7	2.7	11.9	52.5	41.2	86.3	10.5	41.3	11.9	3.7	20.1	2.8	14.3	2.5	5.9	0.8	4.4	0.6	14.1	4.3
A-117	Roof	Northern Appalachia	Lower Kittanning	PA	Clearfield	295.64518	244.968	50.6776	4.834	16.727	34.88418	48.41	104.058	12.23	44.78	9.185	1.868	7.713	1.118	6.269	1.231	3.396	0.467	2.901	0.41	10.161	2.816
A-118	Roof	Northern Appalachia	Lower Kittanning	PA	Centre	239.0	194.3	44.7	4.3	23.1	30.9	37.3	77.4	9.1	33.4	6.6	1.4	5.9	0.9	5.3	1.1	3.0	0.5	2.7	0.4	8.5	3.1
A-118	Roof	Northern Appalachia	Upper Kittanning	PA	Centre	239.5	194.4	45.1	4.3	20.5	32.2	38.1	80.5	9.0	32.9	6.4	1.3	5.7	0.8	5.0	1.0	2.8	0.4	2.5	0.4	7.8	2.0
A-118	Coal	Northern Appalachia	Upper Kittanning	PA	Centre	78.0	61.7	16.3	3.8	4.5	9.7	11.2	24.7	3.0	12.2	2.7	0.6	2.8	0.5	2.5	0.5	1.4	0.2	1.4	0.2	5.2	2.4
A-118	Floor	Northern Appalachia	Upper Kittanning	PA	Centre	216.2	179.0	37.2	4.8	23.6	24.2	35.6	69.4	8.6	30.1	5.4	1.1	5.2	0.8	4.7	1.0	2.8	0.5	2.8	0.5	11.5	2.9
A-118	Roof	Northern Appalachia	Lower Freeport	PA	Centre	207.0	168.4	38.6	4.4	21.5	26.6	33.2	65.6	7.9	28.7	5.4	1.1	4.9	0.8	4.5	0.9	2.7	0.4	2.4	0.4	8.3	2.1
A-118	Bone	Northern Appalachia	Lower Freeport	PA	Centre	165.6	139.1	26.5	5.3	12.7	16.9	27.6	58.6	6.5	23.9	4.6	1.0	4.3	0.6	3.6	0.8	2.0	0.3	2.0	0.3	8.1	2.5
A-118	Coal	Northern Appalachia	Lower Freeport	PA	Centre	13.6	11.4	2.2	5.2	0.5	1.6	2.3	5.1	0.6	2.2	0.4	0.1	0.3	0.0	0.3	0.0	0.1	0.0	0.1	0.0	0.2	0.1
A-118	Floor	Northern Appalachia	Lower Freeport	PA	Centre	200.3	170.4	30.0	5.7	19.4	20.4	37.4	71.0	7.9	26.5	4.3	0.7	3.2	0.6	3.4	0.7	2.1	0.3	2.2	0.3	10.3	3.2
A-127	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	321.5	255.2	66.3	3.8	36.6	46.9	47.2	103.4	10.5	40.6	8.0	1.6	7.1	1.2	7.0	1.5	4.6	0.6	3.9	0.5	9.3	2.6
A-127	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	167.7	137.6	30.1	4.6	10.5	17.9	28.1	57.5	6.9	24.9	4.6	0.9	4.1	0.7	4.2	0.9	2.7	0.4	2.7	0.4	9.9	2.3
A-127	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	275.2	218.6	56.6	3.9	22.3	40.3	43.8	86.2	10.4	39.5	7.9	1.7	6.9	1.1	6.2	1.3	3.5	0.6	3.1	0.5	8.6	2.4
A-127	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	182.4	144.8	37.7	3.8	10.3	23.4	27.5	59.2	7.2	27.3	6.0	1.4	6.0	0.9	5.4	1.1	3.1	0.5	2.9	0.4	8.7	2.4
A-127	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	189.9	154.5	35.4	4.4	13.2	22.9	28.9	63.4	7.6	28.7	5.9	1.3	5.6	0.8	4.6	0.9	2.8	0.4	2.6	0.4	8.2	2.4
A-127	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	312.4	245.2	67.2	3.7	31.5	48.6	49.5	99.5	10.5	39.4	6.9	1.4	6.5	1.0	6.6	1.4	4.6	0.6	3.8	0.5	7.7	2.3
A-128	Floor	Northern Appalachia	Lower Freeport Rider	PA	Clearfield	195.8	155.5	40.4	3.9	22.0	28.2	31.0	60.2	6.6	25.6	4.8	0.9	4.4	0.6	4.4	0.9	2.9	0.4	2.6	0.3	5.4	2.0
A-128	Floor	Northern Appalachia	Lower Freeport Rider	PA	Clearfield	128.9	105.9	23.1	4.6	9.7	14.2	21.3	42.9	5.2	19.2	3.6	0.7	3.3	0.5	3.1	0.7	2.0	0.3	2.1	0.3	7.0	2.1
A-128	Floor	Northern Appalachia	Lower Freeport Rider	PA	Clearfield	220.5	170.4	50.1	3.4	20.2	34.9	32.8	67.7	7.7	29.2	5.9	1.3	5.6	0.9	5.6	1.2	3.6	0.5	2.9	0.4	5.7	2.2
A-128	Floor	Northern Appalachia	Lower Freeport Rider	PA	Clearfield	294.6	224.3	70.2	3.2	26.9	51.5	43.9	88.8	9.7	38.1	8.0	1.5	7.5	1.2	7.0	1.5	4.3	0.6	3.7	0.5	6.7	2.0
A-129	Roof	Northern Appalachia	Lower Kittanning	PA	Centre	224.7	186.0	38.7	4.8	19.5	26.5	36.8	75.4	8.8	32.6	6.2	1.3	5.4	0.8	4.7	0.9	2.6	0.4	2.4	0.4	7.9	2.9
A-129	Coal	Northern Appalachia	Lower Kittanning	PA	Centre	51.4	37.8	13.6	2.8	7.2	9.9	6.8	13.6	1.6	5.9	1.2	0.3	1.3	0.2	1.2	0.3	0.9	0.1	0.7	0.1	2.6	1.1
A-129	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	240.8	201.5	39.3	5.1	22.3	27.5	40.6	82.9	9.3	33.5	6.1	1.3	5.5	0.8	4.3	0.9	2.7	0.4	2.4	0.3	9.5	3.2
A-129	Roof	Northern Appalachia	Lower Kittanning	PA	Centre	127.76146	105.479	22.2827	4.734	11.36	14.19976	20.54	42.8906	5.025	18.06	3.714	0.692	3.204	0.473	2.949	0.619	1.784	0.291	1.748	0.218	6.4081	1.566
A-129	Coal	Northern Appalachia	Lower Kittanning	PA	Centre	12.382304	6.39526	5.98705	1.068	2.2043	4.218147	0.762	1.66005	0.218	0.816	0.245	0.082	0.408	0.109	0.626	0.163	0.408	0.054	0.354	0.054	0.3538	0.272
A-129	Parting	Northern Appalachia	Lower Kittanning	PA	Centre	204.10893	165.407	38.7016	4.274	14.235	23.59116	32	69.3264	8.111	29.18	5.721	1.245	5.586	0.909	5.452	1.144	3.298	0.538	3.298	0.471	16.255	5.385
A-129	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	114.16879	90.4586	23.7102	3.815	8.4581	13.37407	16.36	36.3626	4.494	17.03	3.418	0.956	3.378	0.584	3.625	0.763	2.305	0.343	2.38	0.336	9.328	3.957
A-129	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	162.5928	133.443	29.1503	4.578	11.701	17.17322	28.97	56.3105	6.412	22.06	3.851	0.663	3.483	0.645	3.98	0.884	2.672	0.405	2.911	0.479	14.999	3.501
A-129	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	296.48893	248.275	48.2141	5.15	21.982	33.63894	52.3	103.307	11.42	42.83	7.901	1.691	6.842	0.939	5.614	1.146	3.303	0.399	2.84	0.334	7.7187	3.329
A-130	Roof	Northern Appalachia	Brookville	PA	Centre	271.7	213.9	57.8	3.7	26.5	40.7	40.7	84.1	9.4	37.1	7.5	1.5	7.1	1.1	6.5	1.4	3.9	0.5	3.3	0.4	6.7	2.4
A-130	Coal	Northern Appalachia	Brookville	PA	Centre	98.8	79.9	19.0	4.2	6.9	13.3	16.4	34.1	3.6	13.5	2.4	0.5	2.4	0.4	2.1	0.5	1.4	0.2	1.1	0.1	2.8	1.2
A-130	Coal	Northern Appalachia	Brookville	PA	Centre	83.4	67.7	15.7	4.3	8.1	11.4	13.6	28.1	2.8	10.6	2.0	0.4	1.9	0.3	1.7	0.3	1.0	0.1	0.7	0.1	2.1	0.8
A-130	Floor	Northern Appalachia	Brookville	PA	Centre	289.6	204.9	84.7	2.4	24.3	60.8	44.7	83.0	8.6	31.8	5.4	1.1	6.0	1.1	8.1	1.8	6.0	0.7	5.5	0.7	11.9	4.3
A-130	Floor	Northern Appalachia	Brookville	PA	Centre	161.0	119.2	41.9	2.8	19.5	30.8	25.2	45.6	4.7	17.0	3.1	0.6	3.3	0.5	3.7	0.9	2.8	0.4	2.5	0.3	6.2	1.9
A-130	Floor	Northern Appalachia	Brookville	PA	Centre	220.6	170.7	49.9	3.4	27.8	35.4	32.8	65.7	7.3	26.8	5.1	0.9	4.5	0.8	5.1	1.1	3.5	0.5	3.1	0.4	7.8	3.0
A-130	Floor	Northern Appalachia	Brookville	PA	Centre	324.4	264.1	60.2	4.4	44.7	42.4	53.8	101.3	10.6	39.2	7.2	1.4	5.9	1.0	6.0	1.4	4.2	0.6	4.1	0.5	10.3	4.2

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-130	Floor	Northern Appalachia	Brookville	PA	Centre	247.2	202.1	45.1	4.5	28.6	31.7	40.3	82.6	8.8	31.3	5.2	1.0	4.3	0.7	4.9	1.0	3.2	0.4	2.9	0.4	6.7	2.3
A-130	Floor	Northern Appalachia	Brookville	PA	Centre	477.6	386.1	91.6	4.2	26.1	61.8	71.6	161.6	18.1	75.4	16.0	3.0	14.3	2.1	11.8	2.4	6.5	0.9	5.4	0.7	9.3	3.4
A-130	Floor	Northern Appalachia	Brookville	PA	Centre	356.7	268.0	88.7	3.0	28.5	64.4	52.9	106.8	11.8	45.9	9.7	2.0	10.4	1.6	9.5	2.0	5.5	0.7	4.4	0.5	7.2	2.5
A-131	Roof	Northern Appalachia	Brookville	PA	Centre	228.4	181.5	46.9	3.9	25.0	33.5	34.4	71.0	7.7	30.4	5.9	1.2	5.7	0.8	5.1	1.0	3.1	0.4	2.6	0.3	5.3	2.0
A-131	Coal	Northern Appalachia	Brookville	PA	Centre	94.9	78.4	16.5	4.7	5.0	9.9	16.0	33.3	3.9	14.0	2.9	0.6	2.5	0.4	2.4	0.5	1.4	0.2	1.5	0.2	6.7	1.6
A-131	Coal	Northern Appalachia	Brookville	PA	Centre	73.4	59.0	14.4	4.1	5.7	10.5	12.0	25.0	2.7	9.8	1.8	0.4	1.7	0.2	1.5	0.3	0.9	0.1	0.8	0.1	1.2	0.6
A-131	Floor	Northern Appalachia	Brookville	PA	Centre	199.6	132.8	66.8	2.0	16.1	48.6	28.7	53.5	5.5	20.1	3.9	0.8	4.2	0.8	6.1	1.4	4.5	0.6	4.2	0.5	5.8	2.9
A-131	Floor	Northern Appalachia	Brookville	PA	Centre	150.1	107.8	42.3	2.6	14.9	28.9	22.0	42.6	4.6	16.3	3.0	0.8	3.6	0.7	4.4	1.1	3.2	0.5	3.2	0.4	8.2	2.4
A-131	Floor	Northern Appalachia	Brookville	PA	Centre	291.6	234.1	57.5	4.1	30.6	40.8	46.3	95.5	10.3	37.4	6.7	1.2	6.1	1.0	6.2	1.3	3.9	0.5	3.4	0.4	8.2	2.7
A-131	Floor	Northern Appalachia	Brookville	PA	Centre	381.4	312.8	68.6	4.6	22.0	47.8	61.9	132.2	14.5	57.6	11.6	2.3	10.7	1.5	8.2	1.6	4.6	0.6	3.8	0.4	6.2	2.3
A-131	Floor	Northern Appalachia	Brookville	PA	Centre	364.1	286.2	78.0	3.7	30.0	56.0	56.2	115.8	12.9	49.9	9.9	1.9	9.6	1.4	8.4	1.8	5.1	0.7	4.1	0.5	7.9	2.7
A-132	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	277.3	219.2	58.1	3.8	26.3	42.2	47.2	90.5	9.6	34.0	5.5	0.9	5.2	0.9	5.6	1.3	3.8	0.5	3.4	0.4	6.3	2.5
A-132	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	279.0	230.2	48.9	4.7	24.4	35.7	52.3	98.7	10.1	34.6	4.8	0.8	4.4	0.7	4.6	1.0	3.1	0.4	3.0	0.3	6.5	2.1
A-132	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	293.4	247.1	46.3	5.3	31.8	33.7	48.5	98.7	10.6	42.6	8.1	1.5	5.3	0.7	4.6	1.0	3.1	0.4	2.6	0.3	7.6	2.1
A-132	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	225.7	174.1	51.6	3.4	26.1	36.3	34.6	67.7	7.5	27.4	4.8	1.0	4.9	0.9	5.3	1.2	3.7	0.5	3.3	0.4	9.2	2.5
A-132	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	346.2	261.4	84.9	3.1	32.5	62.0	45.2	101.3	11.7	47.0	10.5	2.1	11.0	1.6	9.0	1.9	5.2	0.6	4.0	0.5	6.4	3.5
A-132	Floor	Northern Appalachia	Lower Kittanning	PA	Centre	236.9	183.3	53.5	3.4	20.2	36.8	34.4	73.3	8.3	32.8	6.5	1.3	6.5	1.0	6.0	1.2	4.1	0.5	3.4	0.5	7.5	3.0
A-133	Core	Northern Appalachia	Middle Kittanning	WV	Barbour	289.4	226.2	63.3	3.6	24.2	44.0	47.8	93.8	10.2	35.5	6.8	1.4	6.6	1.1	6.7	1.5	4.4	0.7	4.3	0.6	9.0	3.0
A-133	Core	Northern Appalachia	Middle Kittanning	WV	Barbour	131.2	98.7	32.4	3.0	7.0	20.0	18.4	39.8	4.9	18.7	4.2	1.0	4.8	0.8	4.5	0.9	2.7	0.4	2.6	0.4	5.9	2.3
A-133	Core	Northern Appalachia	Middle Kittanning	WV	Barbour	257.6	190.7	66.9	2.9	16.8	46.2	31.0	72.6	9.1	37.3	10.2	2.4	11.5	1.6	8.2	1.6	4.3	0.6	3.8	0.5	10.1	3.5
A-133	Core	Northern Appalachia	Middle Kittanning	WV	Barbour	1074.4	687.8	386.6	1.8	17.7	281.5	118.8	237.2	39.3	167.7	42.1	10.6	54.4	7.9	44.1	8.8	22.2	3.0	16.8	2.2	7.5	33.3
A-133	Core	Northern Appalachia	Middle Kittanning	WV	Barbour	224.1	190.6	33.5	5.7	11.6	20.1	45.1	85.5	9.1	29.5	4.6	0.9	4.2	0.7	4.5	1.0	3.1	0.5	3.2	0.5	13.7	2.7
A-133	Core	Northern Appalachia	Middle Kittanning	WV	Barbour	289.9	237.0	52.9	4.5	20.9	37.2	48.0	99.6	11.5	41.1	7.8	1.5	6.6	1.0	5.8	1.2	3.5	0.5	3.3	0.5	11.3	2.5
A-133	Core	Northern Appalachia	Middle Kittanning	WV	Barbour	306.1	243.9	62.1	3.9	20.9	43.3	49.0	101.3	11.9	43.5	8.1	1.6	7.6	1.2	7.0	1.5	4.2	0.6	3.8	0.6	10.4	3.2
A-133	Core	Northern Appalachia	Middle Kittanning	WV	Barbour	468.4	431.1	37.4	11.5	13.4	21.2	87.5	177.6	22.7	98.1	19.6	3.2	8.9	1.0	5.3	1.2	3.7	0.6	3.8	0.6	12.7	5.5
A-134	Core	Northern Appalachia		WV	Barbour	253.4	219.7	33.7	6.5	13.0	21.5	43.2	91.0	11.8	46.2	8.0	1.3	5.4	0.8	4.5	0.9	2.7	0.4	2.5	0.4	9.0	2.6
A-134	Core	Northern Appalachia		WV	Barbour	253.5	216.1	37.4	5.8	19.4	24.4	42.4	87.8	10.9	42.6	6.8	1.2	4.9	0.7	4.6	1.0	2.9	0.4	2.9	0.4	10.7	3.2
A-134	Core	Northern Appalachia		WV	Barbour	307.2	264.7	42.5	6.2	23.4	28.9	57.7	113.0	13.0	43.9	6.8	1.4	5.5	0.8	4.9	1.0	3.0	0.4	2.9	0.4	12.3	3.8
A-134	Core	Northern Appalachia		WV	Barbour	241.6	203.5	38.2	5.3	19.3	26.3	46.3	86.8	9.7	31.3	4.9	1.0	4.2	0.7	4.2	0.9	2.7	0.4	2.6	0.4	8.8	2.6
A-134	Core	Northern Appalachia		WV	Barbour	358.9	313.9	45.0	7.0	32.0	30.7	65.7	135.6	15.0	50.4	7.7	1.5	6.1	0.9	5.1	1.1	3.2	0.5	3.1	0.4	15.3	3.6
A-134	Roof	Northern Appalachia	Harlem	WV	Barbour	134.2	111.0	23.3	4.8	7.3	13.5	21.6	45.7	5.7	21.3	4.3	1.0	4.1	0.6	3.7	0.8	2.1	0.3	2.1	0.3	8.1	3.9
A-134	Floor	Northern Appalachia	Harlem	WV	Barbour	127.0	103.5	23.5	4.4	12.9	15.6	19.0	41.1	4.9	17.8	3.4	0.8	3.4	0.6	2.8	0.6	1.6	0.3	1.6	0.3	6.5	2.2
A-134	Roof	Northern Appalachia	Upper Freeport	WV	Barbour	257.6	195.0	62.6	3.1	18.8	43.7	33.1	77.8	9.5	37.1	8.2	1.8	8.8	1.3	7.2	1.5	4.0	0.6	3.7	0.6	11.1	15.1
A-134	Coal	Northern Appalachia	Upper Freeport	WV	Barbour	26.9	21.9	4.9	4.5	2.4	3.5	4.1	8.8	1.0	3.9	0.9	0.2	0.7	0.1	0.5	0.1	0.3	0.1	0.3	0.1	1.1	0.3
A-134	Coal	Northern Appalachia	Upper Freeport	WV	Barbour	30.7	24.8	5.9	4.2	1.6	3.5	4.6	10.3	1.2	4.7	1.1	0.3	1.0	0.2	0.9	0.2	0.5	0.1	0.5	0.1	2.1	0.9
A-134	Coal	Northern Appalachia	Upper Freeport	WV	Barbour	97.6	74.8	22.7	3.3	8.2	16.6	14.9	29.5	3.4	13.0	2.6	0.6	2.6	0.4	2.4	0.5	1.4	0.2	1.1	0.2	4.1	1.5
A-134	Floor	Northern Appalachia	Upper Freeport	WV	Barbour	73.8	59.6	14.3	4.2	3.4	9.1	12.9	25.4	3.0	10.7	2.1	0.4	1.8	0.3	1.9	0.4	1.2	0.2	1.1	0.2	4.1	1.0
A-134	Coal	Northern Appalachia	Lower Kittanning	WV	Barbour	8.9	5.9	2.9	2.0	1.3	2.0	0.8	2.0	0.3	0.9	0.3	0.1	0.4	0.1	0.3	0.1	0.2	0.1	0.2	0.0	0.5	0.2
A-134	Roof	Northern Appalachia	Lower Kittanning	WV	Barbour	218.2	185.0	33.2	5.6	18.3	22.8	38.3	77.7	8.8	30.9	5.5	1.0	4.5	0.7	3.8	0.8	2.3	0.3	2.2	0.3	7.7	2.3
A-134	Floor	Northern Appalachia	Lower Kittanning	WV	Barbour	352.3	307.8	44.6	6.9	23.1	28.1	60.9	131.5	15.6	55.9	10.7	1.8	8.3	1.2	6.3	1.3	3.4	0.6	3.2	0.5	21.5	6.8
A-135	Core	Northern Appalachia		WV	Barbour	180.8	154.8	26.0	6.0	8.5	14.7	34.1	67.0	7.8	28.0	4.5	0.8	4.0	0.7	4.0	0.9	2.5	0.4	2.5	0.4	10.3	3.7
A-136	Core	Northern Appalachia		WV	Barbour	138.0	113.8	24.2	4.7	8.3	14.4	24.2	47.5	5.6	20.3	3.8	0.7	3.3	0.6	3.4	0.7	2.2	0.4	2.2	0.4	10.2	2.2
A-136	Core	Northern Appalachia		WV	Barbour	309.9	225.3	84.6	2.7	13.5	52.7	37.0	82.9	10.9	46.0	13.2	3.5	18.3	2.8	14.2	2.6	6.1	0.9	4.5	0.7	12.7	4.9
A-136	Core	Northern Appalachia		WV	Barbour	373.7	297.7	76.0	3.9	26.9	53.2	56.6	118.0	14.3	54.9	11.7	2.8	12.5	1.8	9.3	1.8	4.7	0.6	3.9	0.6	12.4	3.3
A-137	Core	Northern Appalachia		WV	Barbour	326.9	242.4	84.5	2.9	27.6	57.8	33.4	85.7	11.9	52.9	14.4	2.9	13.7	1.9	11.0	2.1	5.6	0.8	4.8	0.7	12.9	6.4

Dry Mass Basis - Sampling Material Identification and Characterization

		Researcher Field Sampling Data Inputs				Primary Elemental Identification Technique																					
		Origin of the Sample and Description				Elements (ppm)						Lanthanides (ppm)														Actinides (ppm)	
Location ID	Sample Type	Coal Basin	Associated Coal Bed/Zone/Seam	State	County	TREE	LREE	HREE	L/H Ratio	Sc 21	Y 39	La 57	Ce 58	Pr 59	Nd 60	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Th 90	U 92
A-137	Core	Northern Appalachia		WV	Barbour	158.7	106.3	52.4	2.0	27.8	34.2	16.3	34.9	4.1	14.5	3.4	0.8	4.6	1.0	6.5	1.4	4.1	0.7	4.0	0.5	12.5	5.1
A-137	Core	Northern Appalachia		WV	Barbour	431.9	370.9	61.0	6.1	32.4	42.7	68.3	154.5	19.8	75.2	11.2	1.9	7.5	1.1	6.7	1.4	4.1	0.6	3.8	0.5	14.1	5.8
A-138	Core	Northern Appalachia		WV	Barbour	220.4	189.8	30.6	6.2	16.6	18.2	39.1	80.6	9.5	32.8	5.7	1.2	4.2	0.9	3.8	1.1	2.6	0.7	2.6	0.7	14.9	3.6
A-138	Core	Northern Appalachia		WV	Barbour	290.8	250.3	40.5	6.2	22.8	27.9	53.5	105.8	11.9	42.4	7.2	1.5	5.1	0.8	4.4	0.9	2.8	0.5	2.7	0.5	12.5	2.9
A-138	Core	Northern Appalachia		WV	Barbour	207.4	177.8	29.6	6.0	13.7	17.5	37.2	76.8	8.8	30.2	5.4	1.3	4.4	0.8	3.8	1.0	2.6	0.6	2.7	0.5	13.7	2.9
A-138	Core	Northern Appalachia		WV	Barbour	158.5	136.8	21.7	6.3	12.2	13.8	28.1	57.1	6.7	23.9	4.6	1.0	3.1	0.4	2.6	0.6	1.8	0.3	1.9	0.3	9.3	1.7
A-138	Core	Northern Appalachia		WV	Barbour	273.8	227.6	46.2	4.9	26.9	31.5	46.8	93.9	10.6	37.2	6.1	1.2	4.9	0.8	5.2	1.1	3.3	0.5	3.4	0.5	10.7	2.0
A-141	Coal	Central Appalachia	Fireclay	WV	Logan	27.7	19.9	7.8	2.5	1.6	6.2	4.3	8.4	0.9	3.4	0.6	0.0	0.7	0.0	0.8	0.0	0.4	0.0	0.4	0.0	0.0	0.4
A-141	Coal	Central Appalachia	Fireclay	WV	Logan	4.1	3.7	0.4	8.9	0.2	0.7	0.8	1.7	0.1	0.7	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A-141	Coal	Central Appalachia	Fireclay	WV	Logan	205.1	175.1	30.1	5.8	18.0	20.9	38.1	71.9	8.3	28.7	5.4	0.9	3.8	0.4	3.5	0.6	2.1	0.2	2.2	0.2	8.0	2.5
A-141	Parting	Central Appalachia	Fireclay	WV	Logan	222.9	189.2	33.7	5.6	19.3	23.2	41.8	77.1	9.0	31.1	5.8	0.9	4.2	0.6	3.9	0.7	2.4	0.3	2.4	0.3	7.6	2.3
A-141	Coal	Central Appalachia	Fireclay	WV	Logan	189.1	154.0	35.1	4.4	13.7	24.8	32.0	62.3	7.5	28.1	5.3	0.8	4.2	0.5	3.8	0.7	2.3	0.3	2.5	0.2	5.5	4.5
A-142	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	173.1675	144.478	28.6893	5.036	8.1541	16.40814	28.69	59.9746	7.389	28.66	5.458	1.065	5.092	0.799	4.593	0.932	2.696	0.399	2.463	0.399	10.717	2.529
A-142	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	160.71791	130.188	30.5301	4.264	8.8771	18.26408	25.91	54.1924	6.538	24.65	4.648	0.93	4.439	0.72	4.439	0.9	2.699	0.42	2.669	0.42	8.5472	2.159
A-142	Floor	Northern Appalachia	Upper Freeport	PA	Clearfiled	235.13434	187.705	47.4294	3.958	21.41	32.37801	38.21	72.5442	7.847	33.14	6.446	2.013	6.096	0.554	6.096	1.108	3.588	0.379	2.888	0.438	10.034	2.888
A-143	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	162.62497	135.026	27.5992	4.892	9.3659	16.30369	26.84	57.3448	6.678	24.72	4.705	0.976	4.401	0.694	4.141	0.846	2.45	0.39	2.385	0.39	9.6695	2.103
A-143	Floor	Northern Appalachia	Upper Freeport	Pa	Clearfield	194.41808	155.811	38.6073	4.036	12.517	23.4082	28.72	63.6139	7.83	29.78	6.096	1.3	5.96	0.975	5.554	1.219	3.305	0.542	3.116	0.488	10.458	2.926
A-143	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	278.39707	225.277	53.1196	4.241	28.278	37.04185	43.95	91.2333	10.43	36.85	6.746	1.419	6.368	0.977	5.99	1.261	3.499	0.536	3.373	0.441	10.971	3.152
A-144	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	571.65202	520.421	51.2307	10.16	13.556	30.79449	101.2	231.791	28.4	108.2	18.32	4.431	14.57	1.814	8.919	1.589	3.964	0.542	3.16	0.449	20.361	3.908
A-144	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	164.69869	134.868	29.8303	4.521	10.624	18.43046	27.55	55.868	6.676	24.26	4.591	0.976	4.325	0.688	4.103	0.865	2.506	0.399	2.484	0.355	9.559	1.974
A-144	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	185.27253	148.299	36.9736	4.011	14.415	24.17698	28.53	60.8977	7.081	25.39	5.463	1.214	5.311	0.809	4.805	1.012	2.782	0.405	2.58	0.405	8.3456	2.023
A-145	Roof	Northern Appalachia	Mahoning	PA	Clearfield	177.09169	146.027	31.0645	4.701	10.81	18.26453	27.56	60.0799	7.425	27.74	5.851	1.158	5.405	0.861	4.603	1.039	2.792	0.505	2.524	0.475	12.681	3.118
A-145	Floor	Northern Appalachia	Mahoning	PA	Clearfield	183.52863	152.973	30.5552	5.006	10.087	18.46457	30.85	64.9545	7.688	28.91	5.027	0.953	4.501	0.723	4.435	0.92	2.628	0.394	2.596	0.394	9.5937	3.154
A-145	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	327.69985	271.832	55.8676	4.866	33.563	38.46055	53.23	111.096	12.67	44.64	7.985	1.624	7.027	1.091	6.494	1.304	3.833	0.532	3.673	0.479	13.388	4.019
A-145	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	156.47278	128.096	28.3764	4.514	8.0862	17.36597	25.42	53.5898	6.415	23.87	4.744	1.044	4.923	0.716	4.148	0.895	2.387	0.358	2.178	0.328	8.2951	2.745
A-145	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	125.56641	102.086	23.4802	4.348	6.5049	13.5568	19.89	42.6434	5.118	19.4	3.907	0.84	3.79	0.586	3.633	0.781	2.149	0.352	2.11	0.313	8.4974	2.032
A-146	Roof	Northern Appalachia	Mahoning	PA	Clearfield	153.88296	125.365	28.5179	4.396	8.6299	17.18887	24.9	52.2059	6.179	23.26	4.617	1.03	4.546	0.746	4.226	0.852	2.415	0.355	2.379	0.355	7.9907	2.024
A-146	Floor	Northern Appalachia	Mahoning	PA	Clearfield	149.69949	123.358	26.3416	4.683	9.1823	15.89678	23.99	50.732	6.112	23.56	4.562	0.947	4.275	0.631	3.816	0.803	2.324	0.344	2.181	0.344	9.0962	2.554
A-146	Coal	Northern Appalachia	Upper Freeport	PA	Clearfield	66.033132	54.2329	11.8002	4.596	3.0873	6.689071	10.81	22.7428	2.847	9.982	2.264	0.446	2.058	0.343	1.921	0.412	1.063	0.172	1.029	0.172	4.185	1.441
A-146	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	118.99846	96.0702	22.9283	4.19	6.642	13.68256	19.55	39.3473	4.756	17.77	3.666	0.77	3.56	0.531	3.348	0.691	2.072	0.319	1.966	0.319	7.7313	2.258
A-147	Roof	Northern Appalachia	Mahoning	PA	Clearfield	208.48744	172.716	35.7718	4.828	11.497	20.92554	32.72	71.3303	8.639	33.36	7.039	1.536	6.591	0.981	5.717	1.109	3.221	0.469	2.901	0.448	12.073	3.008
A-147	Floor	Northern Appalachia	Mahoning	PA	Clearfield	193.2071	160.079	33.128	4.832	10.323	19.87679	31.5	66.9658	8.045	30.32	6.004	1.272	5.65	0.858	4.969	1.035	2.869	0.414	2.692	0.414	10.264	2.514
A-147	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	127.48975	106.47	21.0193	5.065	7.3842	11.74609	22.81	44.5115	5.186	18.51	3.675	0.859	3.538	0.584	3.297	0.687	2.026	0.309	2.026	0.343	10.304	2.61
A-148	Floor	Northern Appalachia	Upper Freeport	PA	Clearfield	247.95266	185.854	62.0983	2.993	16.688	41.19693	33.16	71.6816	8.702	33.82	8.509	2.148	11.15	1.625	8.895	1.652	4.268	0.551	3.442	0.468	10.244	2.589