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Cover Illustration: Middle Kittanning underclay sample from Clearfield County, Pennsylvania.

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Middle Kittanning Coal Waste and Underclay as an Alternative Rare Earth Elements Feedstock

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Acronyms, Abbreviations, and Symbols

Term	Description
DOE	U.S. Department of Energy
Earth MRI	Earth Mapping Resources Initiative
EIA	U.S. Energy Information Administration
LKT	Lower Kittanning
HREE	Heavy rare earth elements
MKT	Middle Kittanning
MSHA	Mine Safety and Health Administration
NETL	National Energy Technology Laboratory
REE	Rare earth elements: The 15 lanthanides plus yttrium and scandium
REO	Rare earth oxides
UKT	Upper Kittanning
USGS	U.S. Geological Survey

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EXECUTIVE SUMMARY

In order to secure domestic sources of rare earth elements (REE) from coal related materials, there must be validation of representative feedstocks. Actively producing coal mines that target the Middle Kittanning coal seam in the Appalachian Basin were compiled. These mines were cross-referenced with publicly available geochemical data such as the U.S. Geological Survey (USGS) Earth Mapping Resources Initiative geochemical data along with samples evaluated and characterized by the National Energy Technology Laboratory (NETL). This work evaluated the extent of elevated Middle Kittanning underclay concentrations of REE in comparison to other underclay formations. Therefore, further up-scaling of research associated with the separation and extraction of REE and other critical minerals can be beneficial to utilizing domestic REE supplies for various technology sectors, to include energy, biomedical, and defense. Numerous current active mines targeting the Middle Kittanning coal seam represent a geographically significant opportunity for shared feedstocks and collaborations to further understand the role of Middle Kittanning underclay as a critical mineral feedstock.

1. APPALACHIAN BASIN FORMATION

The Appalachian Basin began forming ~480 million years ago (Ma). Within the Middle Ordovician Period (458–470 Ma) during the beginning of the Taconic Orogeny the Iapetus oceanic plate collided with the North American plate. This collision led to the Iapetus plate being subducted under the North American plate and subsequently the Appalachian Basin began to form. At this time the North American continent was located on a passive plate margin near the equator with the inland water bodies being similar to the tropical seas surrounding the continent (Ettensohn, 1985). In the eastern highlands of the continent, sediments were the parent material for future clastic deposits (Cecil et al., 1985). Current day major coal beds located in the Appalachian Basin are traced back to deposited paleosols during basin formation (Yang et al., 2020). Deposition of paleosols occurred within the Pennsylvanian Period (360–300 Ma) including vast peat mires and the associated underclay deposits (Yang et al., 2020).

The present day Appalachian Basin sedimentary sequence is found in an elongate depression stretching from central Alabama to the Adirondack Mountains in New York (Colton, 1962). The Appalachian Basin extends over 207,000 square miles and encompasses 35,000–40,000 feet of stratified rock (Colton, 1962). The Appalachian Basin covers 11 states (Alabama, Georgia, Kentucky, Maryland, New Jersey, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia) (USGS, 2021d). Two of these states (Kentucky and Ohio) have Appalachian Plateaus geology (USGS, 2021d). Two other states (Georgia and New Jersey) have Valley and Ridge geology (USGS, 2021d). The remaining seven states have both the Valley and Ridge physiographic providence as well as the Appalachian Plateaus physiographic providence present (USGS, 2021d). The Appalachian Plateaus are comprised of flat rocks with a low dip that transition to the fold and thrust topography of the Valley and Ridge province (USGS, 2021d). The Blue Ridge Mountains border the Appalachian Basin to the east (Colton, 1962). The Nashville Dome as well as the Findlay and Cincinnati arches border the Appalachian Basin on the western side (Colton, 1962). The greater (primarily Paleozoic) sedimentary rock fraction has a volume of ~510,000 cubic miles, whereas the lesser (primarily Late Precambrian) volcanic rocks have a volume of about a few thousand cubic miles (Colton, 1962).

In the Appalachian Basin, the Pennsylvanian is the younger of two subperiods of the Carboniferous Period (Hornberger et al., 2011). Within this subperiod the Allegheny Formation is located stratigraphically above the Pottsville Formation and below the Conemaugh Formation (Hornberger et al., 2011). Much of the economically mineable coal in the Pennsylvanian subperiod is located within the Allegheny Formation (Hornberger et al., 2011). As seen in Figure 1, the major coal beds in the Allegheny Formation from oldest to youngest are: Little No. 5 Block, Clarion, Lower Kittanning (LKT), Middle Kittanning (MKT), Upper Kittanning (UKT), Lower Freeport, and Upper Freeport.

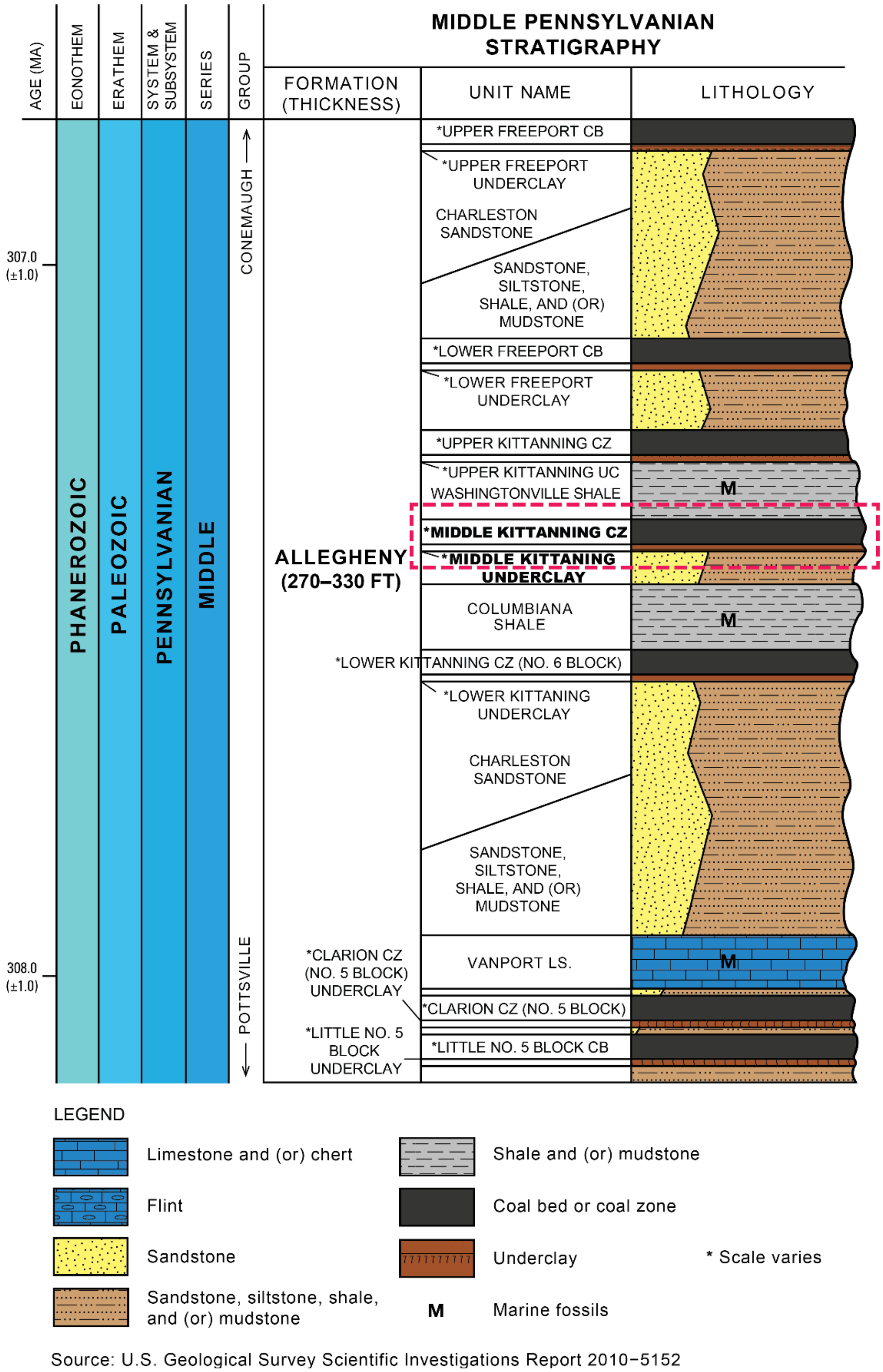

Figure 1: Appalachian Basin Middle Pennsylvanian stratigraphic column showing Middle Kittanning coal zone and Middle Kittanning underclay. Reproduction of Figure 1 from USGS Scientific Investigations Report 2010-5152 with permission from Leslie F (Jingle) Ruppert (USGS).

2. COAL RANK AND COAL BED NAME VARIATIONS

All coal begins as peat and subsequently undergoes physical and chemical changes during coalification. Coalification is a natural process that results from peat burial beneath ever deepening sediments and the resultant increases in pressure and temperature. The final rank of a coal seam is determined by the degree of coalification and the chemistry of the organic matter precursors of the coal. As a coal bed undergoes increasing degrees of coalification and the rank increases, the coal will become harder, drier, denser, and more carbon-rich.

The four major ranks (types) of coal in order of highest grade to lowest grade are: anthracite, bituminous, subbituminous, and lignite. Anthracite coal is frequently referred to as hard coal. Anthracite coal has a black luster, is brittle, has low levels of volatile matter and is comprised of a large proportion of fixed carbon. Bituminous coal often has a high heating (Btu) value and is a middle rank coal. In the U.S., bituminous coal is used in metallurgical and thermal applications. The MKT coal seam is bituminous and appears shiny, smooth, and blocky. Bituminous coal can be comprised of alternating shiny and dull thin layers. One step lower in rank is subbituminous coal, which is duller black. Subbituminous coal is primarily used in electricity production as subbituminous coal has a low heating value. The lowest grade of coal is lignite. Lignite has the lowest content of carbon and is brown. Mainly used in electricity production, lignite also has a low heating value as well as a high moisture content (USGS, 2021d).

The naming convention of a particular coal bed such as LKT and MKT can vary geographically from state to state as illustrated in the Table 1 (USGS, 2010). The UKT coal bed is only referred to as UKT in Pennsylvania, Maryland, and West Virginia (UKT coal does not occur in either Ohio or Kentucky). When investigating data related to current and past coal mining, it is important to recognize the local variations in coal bed names (USGS, 2010).

Table 1: Various Names used to Describe the LKT Coal Bed and MKT Coal Bed in Different States (USGS, 2010)

Name of Coal Bed	Various State Names for the Same Coal Bed
Lower Kittanning	LKT – Pennsylania and Maryland LKT and No. 6 Block – West Virginia LKT and Coal No. 5 – Ohio Princess No. 6 – Kentucky
Middle Kittanning	MKT – Pennsylvania and West Virginia MKT and Luke – Maryland MKT and No. 6 – Ohio Princess No. 7 – Kentucky

3. RARE EARTH ELEMENTS AND CRITICAL MINERALS

Yttrium (Y), Scandium (Sc), and the 14 naturally occurring lanthanide elements make up the rare earth elements (REE). These elements are widespread in the Earth's crust but typically exist in the Earth's crust generally in concentrations too low for their mining to be economically feasible. Modern technologies spanning various sectors (automotive, energy, defense, etc.) have been increasingly utilizing REE. This increase in demand has pushed many nations to focus on finding reliable domestic sources of REE to stabilize their short-term and long-term economic outlooks (Bauer et al., 2010). The increase in demand and price for REE mainly comes from end users including magnets, lasers, cell phones, and electronics in general with the market forecasted to reach $20 billion dollars USD by 2026 (Pulidindi and Pandey, 2017).

In 2020, REE were mined globally with main sources being the minerals: loparite, bastnasite, monazite, and the lateritic ion-adsorption clays. Domestic production of bastnasite and monazite concentrates increased from 14,000 metric tons of rare earth oxides (REO) equivalent in 2018 to 38,000 metric tons of REO equivalent in 2020. In 2020, 380 metric tons of purified REE were imported and 27 metric tons were exported. From 2016–2019, 80% of REE imports came from China, 5% from Estonia, 4% from Japan and Malaysia, and 7% from other countries. Currently, minimal amounts of REE are recovered from the recycling of lamps, magnets, and batteries (USGS, 2021c).

In addition to the recent increase in demand for REE, there has been an increase in demand for other critical minerals. One solution to the limitations stated above is the utilization of coextraction of REE and other critical minerals. Critical minerals are defined as commodities which are crucial for U.S. national security and economic growth (DOE, 2021). Three years ago, the Secretary of the Interior released a list of 35 critical minerals in the Federal Register (DOE, 2018a). Fourteen of these critical minerals are not produced domestically, while 31 of the 35 critical minerals are at least 50% reliant on importation (DOE, 2021). The 35 critical minerals are: aluminum, antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite, hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, the rare earth elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium (DOI, 2018a). The primary uses of these critical minerals are listed in Table 2 below.

Table 2: Critical Minerals and their Uses (USGS, 2020; DOI, 2018b)

Critical Minerals	Uses
Aluminum	Transportation, electrical transmission lines, packaging, consumer durables, machinery, and construction.
Antimony	Flame retardants (for toys, car and airplane seat covers, and children's clothing) and a hardened lead used in storage batteries.
Arsenic	Semi-conductors, pesticides, and preservatives for pressure treating lumber.
Barite	Petroleum industry and an aggregate in "heavy" cement.
Beryllium	Defense industries and an alloying agent in aerospace.
Bismuth	Atomic research and medications.
Cesium and Rubidium	Research and development (mainly in electronics).
Chromium	Refractories, chemicals, stainless steel, and other nonferrous alloys.
Cobalt	The military, many industries to make items such as superalloys, rechargeable battery electrodes, airbags in vehicles, drying agents, and magnets.
Fluorspar	Manufacturing process of uranium fuel, insulating foams, gasoline, aluminum, steel, and refrigerants.
Gallium	Optoelectronic devices and analog integrated circuits.
Germanium	Polymerization catalysts, night vision technologies, and fiber optics.
Graphite	Batteries, fuel cells, and high-temperature lubricants.
Hafnium and Zirconium	High temperature ceramics, nuclear control rods, and nickel-based superalloys.
Helium	Research, MRIs, and lifting agents.
Indium	Mainly used in LCD screens.
Lithium	Batteries.
Magnesium	An alloying addition to aluminum for beverage cans, the manufacturing of ceramics and steels, and liners in furnaces.
Manganese	Steelmaking, dry cell batteries, and fertilizers.
Niobium	Rocket subassemblies (steels and superalloys) and jet engine components.
Platinum Group Metals	Catalytic agents.
Potash	An agricultural fertilizer.
Rhenium	Superalloys and lead-free gasoline.
Scandium	Fuel cells and alloys.
Strontium	Ceramic magnets and pyrotechnics.
Tantalum	Solar cells, steelmaking, capacitors, and other electronics components.
Tellurium	Solar cells and steelmaking.
Tin	Alloys for steel and protective coatings.
Titanium	Alloys and as a white pigment.

Table 2 (cont.): Critical Minerals and their Uses (USGS, 2020; DOI, 2018b)

Critical Minerals	Uses
Tungsten	Wear-resistant metals, high-temperature lubricants, a substitute for lead in bullets, catalysts, and inorganic pigments.
Uranium	Primarily used in nuclear fuel.
Vanadium	Titanium alloys used in airframes and jet engines and in critical components of automobiles.

REE and critical minerals can be found across the world in many geological strata including the hard mineral deposits (e.g., bastnaesite or carbonatites) as well as in sedimentary formations (aluminosilicate-rich clays or laterites). The majority of the global heavy rare earth elements (HREE) are sourced from China's ion-absorbed clays, despite being lower grade. This diagenetic HREE enrichment in clays can also be found in other locations around the world. The weathering of REE-bearing alkaline igneous formations can lead to an accumulation of REE phosphates, oxides, or apatitic phases in adjacent strata or secondary phases. There are possible domestic REE sources based on specific geological areas located in the United States. Research has been conducted at the National Energy Technology Laboratory (NETL) to characterize various Appalachian coal, underclays, and related byproducts (Yang et al., 2020). One underclay of specific interest is the MKT underclay. MKT coal/underclay is found domestically in the Appalachian Basin (Figure 1) and the underclay is of interest due to its readily extractable REE (USGS, 2021a).

REE can accumulate in aluminosilicate-rich coal deposits as well as associated coal underclays (such as MKT coal underclay) by the weathering of REE-rich host rocks and subsequent remobilization and redeposition of REE ions from the weathering host rocks to the active layer of sediments or clay-rich soils. The aluminosilicate-rich coal/coal underclay REE enrichment process can occur over time through the accumulation of REE ions by ion-adsorption as well as in crystalline materials and REE-bearing colloids. Since the formation of the Appalachian Basin, aluminosilicate-rich clays have formed via the weathering of REE bearing igneous parent rocks (Yang et al., 2020). The REE in these igneous parent rocks exist in various adsorbed states (colloidal and exchangeable)(Yang et al., 2020).

Currently, there is interest in furthering research associated with MKT underclay due to the resource being previously characterized and having shown to have heightened concentrations (>300 ppm) of REE and associated critical minerals. Knowledge of the locations and yearly production of coal at these mines will help develop next steps of characterization of this REE source and lead to possible industry partnerships and field testing.

4. METHODS

Personal communication with state agencies and several databases listed below were used to aggregate mine data with a focus on regional REE concentrations in domestic coal. Mine data collected includes current mines targeting the MKT coal seam, mine annual production, location, mine identification numbers, permit numbers, operator, controller, mine status, and mine type. These databases include:

- U.S. Energy Information Administration (EIA, 2021a)
- U.S. Geological Survey Coal Quality Database (COALQUAL; Palmer et al., 2015)
- U.S. Department of Labor Mine Safety and Health Administration (MSHA, 2021) Mine Data Retrieval System
- U.S. Geological Survey Earth Mapping Resources Initiative (Earth MRI; USGS, 2021a)
- Pennsylvania Department of Environmental Protection bituminous coal mining reports (PADEP, 2019)
- Pennsylvania Department of Environmental Protection coal mining operations database (PASDA, 2021)
- West Virginia Geologic & Economic Survey (WVGES, 2021c)
- U.S. Geological Survey Mineral Resources Data System (MRDS; USGS, 2021b)
- Ohio Department of Natural Resources Division of Geological Survey (ODNR, 2020; Heavilin, 2021)

ArcGIS Pro was used to construct the map of active mines in the Appalachian Basin targeting the MKT coal seam.

Caveats regarding the accuracy of this list of currently active coal mines targeting the MKT coal seam include:

- Delays of approximately one year to 18 months for states to release annual reports of currently producing coal mines.
- The names of specific coal seams differ from state to state.

5. MIDDLE KITTANNING MINING OBSERVATIONS

The MKT coal seam spans five states: Pennsylvania, Maryland, West Virginia, Ohio, and Kentucky (USGS, 2010, 2021b). Of these five states, mining efforts targeting the MKT coal seam are currently occurring in Pennsylvania, West Virginia, and Ohio (PADEP, 2019; WVGES, 2021c; OHDNR, 2020; Kentucky Mine Mapping Information System, 2021). In 2019, 44 of the mines permitted to extract the MKT coal seam produced coal (Figure 2). Of these 44 mines, 6 were underground operations and 38 were surface mines. The top 5 producing mines of MKT are located in West Virginia, Ohio, and Pennsylvania (Table 3). Production at these 44 mines ranged from 601 tons to 4,274,748 tons (Appendix Table 1). Two mines produced more than 1,000,000 tons, 10 mines produced more than 100,000 tons, and 22 mines produced more than 10,000 tons.

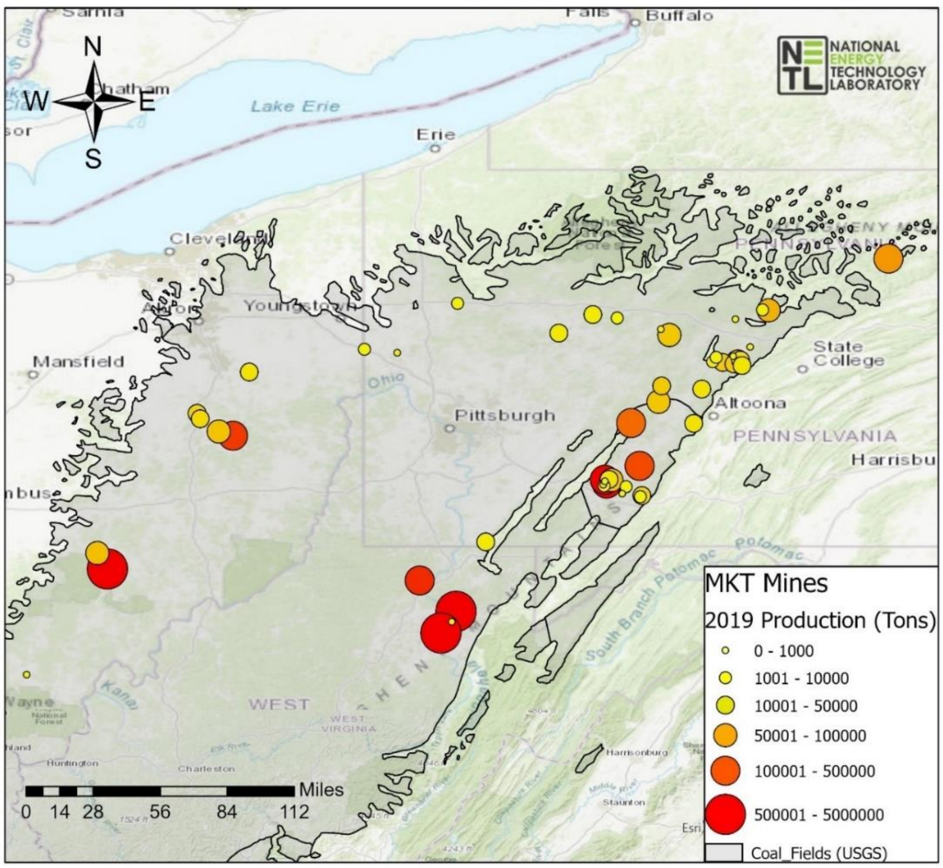

Figure 2: Map of active mines in the Appalachian Basin targeting the Middle Kittanning coal seam.

Table 3: Top Five MKT Producing Mines in 2019 (Production in Short Tons)

Mine Name	Operator	State	County	Mine Type	2019 Production (Short Tons)	2020 Production (Short Tons)
Leer Mine	ACI Tygart Valley	WV	Taylor	Underground	4,274,748	4,185,123
Sentinel Mine/Leer Mine South	Wolf Run Mining LLC	WV	Barbour	Underground	1,106,710	1,185,425
Mine Complex-#6 Mine/ Buckingham Mine No. 6	CCU Coal and Construction LLC, Buckingham	OH	Perry	Underground	829,737	162,549
North Fork	AK Coal Resources, Inc.	PA	Somerset	Underground	363,971	68,004
Acosta Deep Mine	Wilson Creek Energy LLC	PA	Somerset	Underground	362,347	112,348

Bituminous coal mining has occurred in Pennsylvania since the late 18th Century with mostly drift mines targeting the Pittsburgh coal seam ranging from anthracite to bituminous coal (PADEP, 2021). Until the 1960s, when longwall mining became more commonplace, almost all bituminous mines in the state were room-and-pillar mines (PADEP, 2021). Room-and-pillar mining is a type of underground mining where coal seams are split into rectangular or square sections by drilling tunnel-like openings into the mine (PADEP, 2021). Longwall mining is a modern type of mining where, during the development stage of the mine, rectangular blocks of coal are extracted in a constant procedure utilizing an automated cutting head advancing parallel to the coal face (Cleveland, 2015).

Currently in the southwest section of Pennsylvania, there are 21 counties with active bituminous mines that produce coal primarily for the generation of electricity and metal production (PADEP, 2021). In this southwestern region of Pennsylvania, the MKT coal seam resides within the Allegheny group (thickness of 270–330 feet) below Washingtonville shale (Figure 1). As of Jan. 1, 2020, Pennsylvania had an estimated 5% (25,990,000,000 short tons) of the demonstrated reserve base of coal in the U.S. (EIA, 2020b). This demonstrated reserve base represents the fraction of coal (both measured and indicated) in the U.S. which meets distinct mineable criteria and could be mined commercially currently or with future technologies (EIA, 2021b). The U.S. EIA defines the fraction of domestic coal that can be mined with current technologies, taking into account recovery and accessibility factors, as the estimated recoverable reserves (EIA, 2021b). As of 2019, Pennsylvania had an estimated recoverable reserve of 1,070,000,000 short tons of coal (952,000,000 short tons of which is bituminous coal) (EIA, 2020a). The location of MKT coal in relation to other coal seams in southwestern Pennsylvania (from Allegheny County, Pennsylvania, to Allegany County, Maryland) is shown in Figure 3. The cross-section in Figure 3 illustrates the key elements of the coal system and surrounding strata. It is useful for evaluating these resources within the Appalachian Basin and the span of the underclay systems respective to the coal seam.

Before coal mining started in Ohio in the early 19th Century, it is estimated that 19,200,000,000 short tons of MKT coal were located beneath the surface in the state (Wright and Erber, 2021). This estimate (calculated in 2018) was derived using GIS software as well as 5,432 thickness points at locations near or at MKT outcrops dispersed across Ohio (Wright and Erber, 2021). As of 2018, ~1,800,000,000 short tons of MKT coal have been mined in Ohio, leaving a MKT coal resource of 17,400,000,000 short tons in the state (Wright and Erber, 2021). Of the remaining MKT coal reserve, 700,000,000 short tons are surface mineable and 11,200,000,000 short tons are considered deep mineable in Harrison County and Guernsey County (Wright and Erber, 2021). Currently there are seven mines targeting the MKT (No. 6) coal seam in Ohio (ODNR, 2020; Heavilin, 2021). These are located in Perry Tuscarawas and Stark counties (ODNR, , 2020; Heavilin, 2021). Two of these mines are underground mines, while the remaining five mines are surface mines, with a production range (2019) from 19,953 short tons to 829,737 short tons (ODNR, 2020).

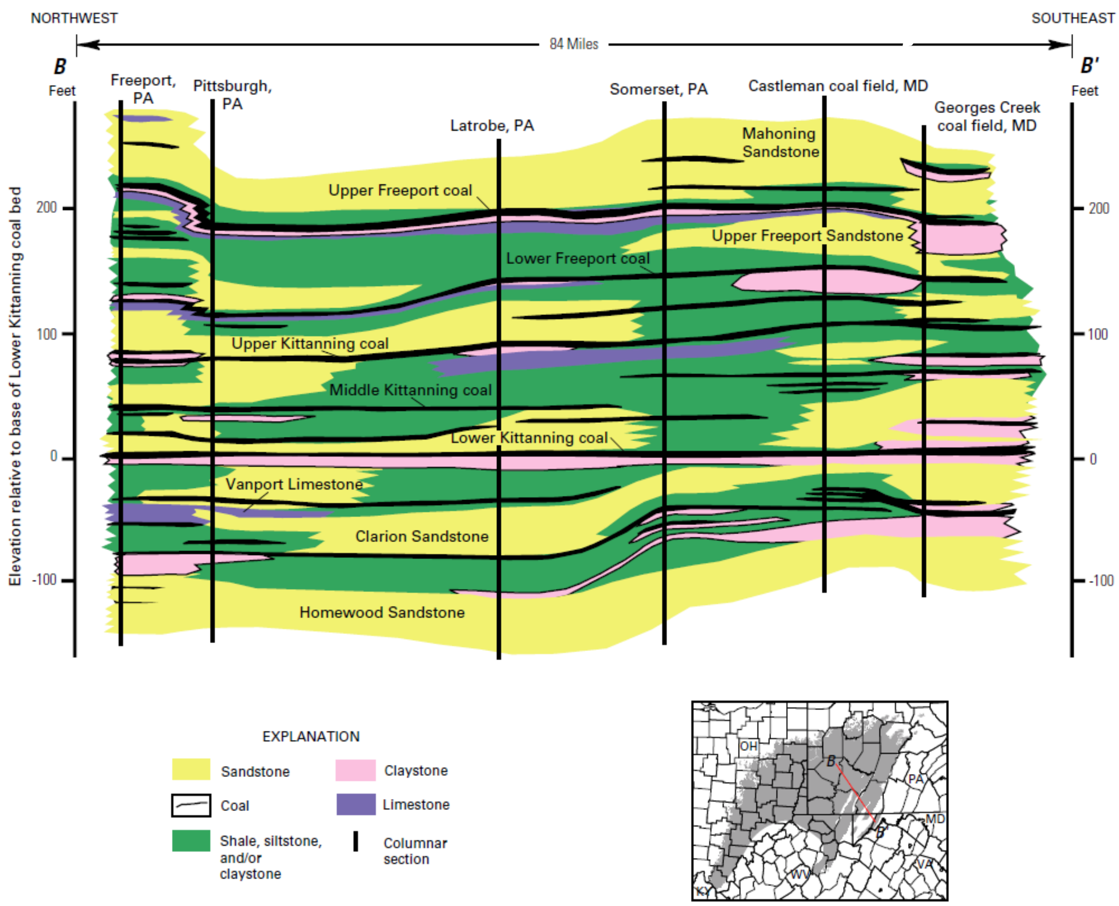

Figure 3: Cross section B-B` spanning from Allegheny County, Pennsylvania, southeast to Allegany County, Maryland. Vertical exaggeration X652. Reproduced from U.S. Geological Survey Professional Paper 1625-C Chapter E with permission from Philip Freeman (USGS).

Industrial coal mining has occurred in West Virginia since 1810 with historic peak coal production occurring in 1927 (146,088,121 short tons) and 1947 (173,653,816 short tons)(WVGES, 2021b). In 2019, 13% of coal produced in the U.S. came from West Virginia, making the state the second-largest coal producing state and the largest producer of bituminous coal in the U.S. (EIA, 2020c, 2021c). As of Jan. 1, 2020, West Virginia has an estimated 6% (30,040,000,000 short tons) of the demonstrated reserve base of coal in the U.S. (EIA, 2020b, 2021b). Of these 30,040,000,000 short tons,1,436,000,000 short tons are recoverable coal reserves (EIA, 2020a,b, 2021b). Currently there are two underground mines and one surface mine targeting MKT coal in West Virginia (WVGES, 2021a,b). In 2019, West Virginia produced 93,279,000 short tons (all of which was bituminous coal)(EIA, 2020c).

There are currently no coal mines targeting the MKT coal seam in either Kentucky or Maryland. It is estimated that 104,000,000,000 short tons (64,000,000,000 in eastern Kentucky and 40,000,000,000 in western Kentucky) existed in-place in Kentucky before mining initiated in the state (Smith and Brant, 1978; Brant 1983a,b; Brant et al., 1983a,b,c,d). In 1790, commercial coal production began in Kentucky (Kentucky Energy and Environment Cabinet Department for Energy Development and Independence, 2017). Production surpassed 100,000 short tons in 1855 and surpassed 1,000,000 short tons in 1879 (Kentucky Energy and Environment Cabinet Department for Energy Development and Independence, 2017). As of 2020, Kentucky had a demonstrated coal reserve of 28,030,000,000 short tons (EIA, 2020b). Of these 28,030,000,000 short tons, 699,000,000 short tons are currently recoverable reserves (EIA, 2020a, 2020b). As of Jan. 1, 2020, Maryland had a demonstrated reserve base of coal of 594,000,000 short tons. Of these 594,000,000 short tons, 8,000,000 short tons are currently recoverable reserves (EIA, 2020a, 2020b).

Geochemical data can be compared to current mining operation data to determine existing waste piles and potential feedstock supply. One challenge is the availability of representative geochemical data. Additionally, it is important to acknowledge the heterogeneity of REE and critical mineral concentrations in underclay. This heterogeneity exists within and between underclay seams. REE data collected by NETL combined with USGS Earth MRI data shows that Alleghany coal seams have variable REE concentrations (Yang et al., 2020; USGS, 2021a). The concentration of REE in the LKT coal seam ranged from 241 ppm to 655 ppm with an average concentration of 367 ppm. The concentration of REE in the MKT coal seam ranged from 229 ppm to 1,032 ppm with an average concentration of 420 ppm. The concentration of REE in the UKT coal seam ranged from 198 ppm to 571 ppm with an average concentration of 311 ppm. The variability of REE concentrations in a singular coal underclay between the adjacent LKT, MKT, and UKT is also shown in Figure 4.

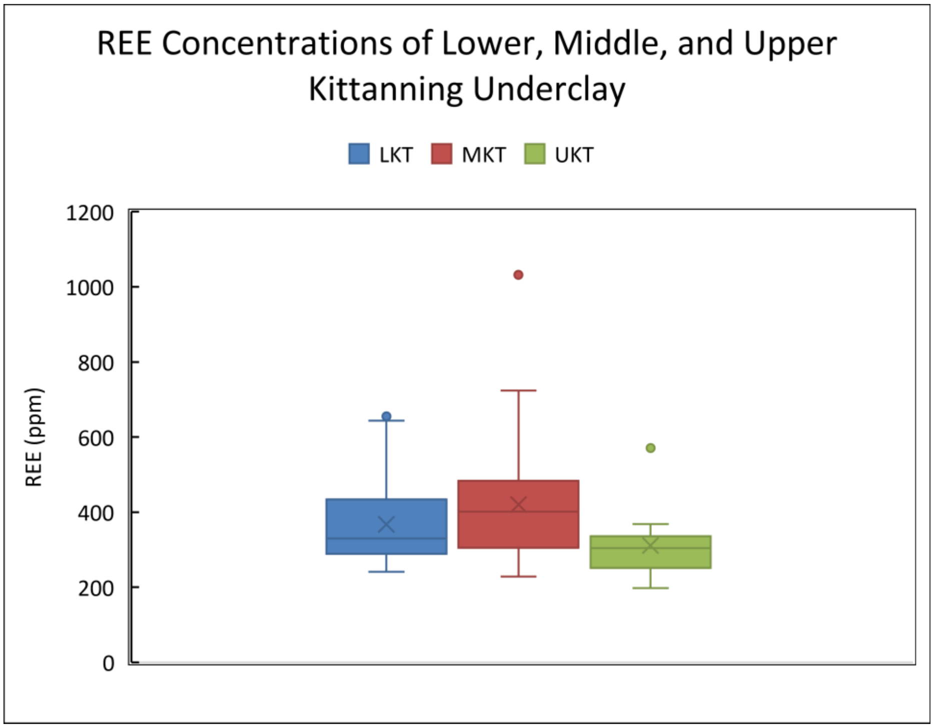

Figure 4: Box and whisker plot comparing REE concentrations of Lower Kittanning underclay, Middle Kittanning underclay, and Upper Kittanning underclay.

6. CONCLUSIONS

As demand for a domestic supply of REE and critical minerals increases, further research is needed to determine suitable feedstocks of sufficient size and extractability that can support a domestic REE supply chain. Determination of coal underclays that have the ability for economically feasible co-extraction of REE and critical minerals can help expand the amount of currently available coal refuse resources for extraction. Connecting industry partners may be found through the determination of current mines targeting the Middle Kittanning coal seam. From this research, a current list of all mines targeting the MKT coal seam is now available. It is important to note that most annual coal mine data reports are published and made publicly available in the third or fourth quarters of the following calendar year.

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APPENDIX

Table A1: Current Mines in Production Targeting the MKT Coal Seam (Production in short tons)

Mine Name	MSHA ID/*State Permit #	Operator	State	County	Latitude	Longitude	Mine Type	2019 Production (Short Tons)	2020 Production (Short Tons)
Leer Mine	4609192	ACI Tygart Valley	WV	Taylor	39.331111	-79.958611	Underground	4,274,748	4,185,123
Sentinel Mine/Leer South Mine	4604168	Wolf Run Mining LLC	WV	Barbour	39.200000	-80.049722	Underground	1,106,710	1,185,425
Mine Complex-#6 Mine/Buckingham Mine No. 6	3304526	CCU Coal and Construction LLC, Buckingham	OH	Perry	39.586880	-82.065120	Underground	829,737	162,549
North Fork	3610041	AK Coal Resources, Inc.	PA	Somerset	40.126944	-79.061389	Underground	363,971	68,004
Acosta Deep Mine	3609893	Wilson Creek Energy LLC	PA	Somerset	40.103889	-79.049722	Underground	362,347	112,348
Barrackville Refuse Pile	4609050	LP Mineral, LLC	WV	Marion	39.517222	-80.179444	Surface	234,302	170,267
Tusky Mine	3304509	Rosebud Mining Company	OH	Tuscarawas	40.393640	-81.306590	Underground	218,458	Not Available
No. 34 Hill	*56160102	Elk Resources Inc	PA	Somerset	40.210548	-78.850275	Surface	198,434	Not Available
Cochenour Ridge	*11180101	Laurel Sand & Stone Inc	PA	Cambria	40.469436	-78.901386	Surface	160,671	Not Available
Thomas Northeast	*41080101	Fisher Mining Company Processing Plant	PA	Lycoming	41.464436	-77.346386	Surface	108,052	Not Available
Lindsey Operation	*14090102	RES Coal LLC	PA	Centre	40.841381	-78.258053	Surface	81,257	Not Available
Pottersdale Mine	*17940107	River Hill Coal Co Inc	PA	Clearfield	41.151231	-78.071875	Surface	75,503	Not Available
Cannon	*D-2463	CCU Coal and Construction, LLC	OH	Perry	39.684220	-82.124660	Surface	61,616	Not Available
Ralphton Mine	*56130107	Coal Loaders Inc	PA	Somerset	40.124364	-79.021719	Surface	59,060	Not Available

Table A1 (cont.): Current Mines in Production Targeting the MKT Coal Seam (Production in short tons)

Mine Name	MSHA ID/*State Permit #	Operator	State	County	Latitude	Longitude	Mine Type	2019 Production (Short Tons)	2020 Production (Short Tons)
Midvale	*IM-0569	L & M Mineral Co.	OH	Tuscarawas	40.418580	-81.390880	Surface	56,098	Not Available
Bakerton Rod & Gun Mine	*11150103	Amerikohl Mining Inc	PA	Cambria	40.597214	-78.735553	Surface	52,739	Not Available
Marshall Ridge Operation/ Marshall Ridge #2	*17060110/ *17110107	Bell Resources Inc	PA	Clearfield	41.001670	-78.671383	Surface	51,073	Not Available
Little Beaver 2 Mine	*17980115	Junior Coal Contr Inc	PA	Clearfield	40.836936	-78.349442	Surface	47,703	Not Available
Driscoll Hollow Mine	3610258	Coal Loaders, Inc.	PA	Cambria	40.693881	-78.717497	Surface	46,496	Not Available
Ellis Opr	*14040101	RES Coal LLC	PA	Centre	40.826103	-78.280553	Surface	44,369	Not Available
Ervin	*IM-2170	Kimble Clay & Limestone Co.	OH	Tuscarawas	40.527140	-81.523760	Surface	37,007	37,007
Craighead Mine	3610272	Heritage Coal & Natural Resources LLC	PA	Somerset	40.032214	#########	Surface	35,183	Not Available
Kimble Clay & Limestone Co.	*IM-0009	Kimble Clay & Limestone Co.	OH	Tuscarawas	40.496730	-81.505160	Surface	30,550	30,550
Beaver Mine	*14940101	Junior Coal Contr Inc	PA	Centre	40.849992	-78.241664	Surface	26,156	Not Available
Sugar Run Mine	*7920101	EP Bender Coal Co Inc	PA	Blair	40.466659	-78.523330	Surface	21,672	Not Available
Pero	*D-2364	CCU Coal and Construction, LLC	OH	Stark	40.779100	-81.206900	Surface	19,953	19,953
88 Job	*11130102	EP Bender Coal Co Inc	PA	Cambria	40.675825	-78.474997	Surface	18,764	Not Available
Lohr Strip	*56150101	Fieg Bros	PA	Somerset	40.130020	-79.034108	Surface	18,582	Not Available

Table A1 (cont.): Current Mines in Production Targeting the MKT Coal Seam (Production in short tons)

Mine Name	MSHA ID/*State Permit #	Operator	State	County	Latitude	Longitude	Mine Type	2019 Production (Short Tons)	2020 Production (Short Tons)
Ridge GFCC	*140701	Junior Coal Contr Inc	PA	Centre	40.818047	-78.230831	Surface	17,003	Not Available
Shankle Mine	3610323	Reichard Contracting Inc	PA	Clarion	41.012770	-79.337219	Surface	11,332	Not Available
Wymps Gap Surface Coal Mine	3606393	Charles L Swenglish & Sons Coal Company Inc	PA	Fayette	39.750556	-79.779722	Surface	11,061	Not Available
Mayo Operation	3610256	P & N Coal Company Inc	PA	Jefferson	41.126325	-79.132219	Surface	10,550	Not Available
Kasubick Mine	*17990103	River Hill Coal Co Inc	PA	Clearfield	40.841659	-78.409164	Surface	6,518	Not Available
Berry Mine	*61120107	Ben Hal Mining Co	PA	Venango	41.193325	-79.950552	Surface	5,000	Not Available
Reese No 1 & 2 Strip	3605493	Philip Reese Coal Company Inc	PA	Clearfield	41.152778	-78.108611	Surface	4,155	Not Available
Kasubick #4	3602733	Kasubick Brothers Coal Co.	PA	Clearfield	40.866944	-78.388333	Surface	3,880	Not Available
Raushel Mine	*37020306	East Fairfield Coal Co	PA	Lawrence	40.915270	-80.512219	Surface	2,896	Not Available
Boone Mine	3610067	LCT Energy LP	PA	Somerset	40.025270	-78.844719	Surface	2,576	Not Available
Byers Mine	*56120104	Wilson Creek Energy LLC	PA	Somerset	40.089437	-79.064164	Surface	2,571	Not Available
Gray No 1 Mine	*56753048	Gray Mining Co Inc	PA	Somerset	40.084992	-78.931941	Surface	2,233	Not Available
Mohney Mine	3609887	MSM Coal Co Inc	PA	Jefferson	41.104436	-78.984719	Surface	1,373	Not Available
Hart Mine	*56100102	PBS Coals Inc	PA	Somerset	40.041659	-78.95583	Surface	893	Not Available

Table A1 (cont.): Current Mines in Production Targeting the MKT Coal Seam (Production in short tons)

Mine Name	MSHA ID/*State Permit #	Operator	State	County	Latitude	Longitude	Mine Type	2019 Production (Short Tons)	2020 Production (Short Tons)
Wells Road	*17110106	Black Cat Coal LLC	PA	Clearfield	41.037781	-78.722774	Surface	676	Not Available
McMillin Mine	3609887	Amerikohl Aggregates Inc	PA	Lawrence	40.895548	-80.314163	Surface	601	Not Available

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