In Partnership with TMRC, PSU & K-Tech

Recovery of Rare Earth Elements from Coal Mining Waste Materials

Presented by Rusty Sutterlin Ph.D (Chief Science Officer)

Pioneering technologies for the low-cost recovery of organic and inorganic building blocks from business wastes.

Goal

- Create a Profitable Business to Extract REE's from Appalachian coal overburden.
- Gather experimental data so that a self-contained, modular and portable continuous ion exchange/continuous ion chromatography (CIX/CIC) pilot plant can be built.
- Determine the economic viability of mining and processing Rare Earth elements (REEs) associated with U.S. Appalachian coal deposits.
- The final goal is to purify three REEs to an industrial purity that is salable.

Inventure

Partners

- Inventure (Lead) – Tuscaloosa, Al
  - Rusty Sutterlin, Ph.D
- TMRC (Sub) – Rockport, Tx
  - Dan Gorski
- Penn State (Sub) – University Park, Pa
  - Sarma Pisupati, Ph.D.
- K-Tech (Sub) – Lakeland, Fl
  - Wes Berry

Inventure

Simplified Work Flow

- TMRC in collaboration with Jeddo Coal acquires the feedstock.
- PSU does physical beneficiation pretreatment and leaching of the feedstock.
- Inventure and K-Tech do an ion exchange extraction of the REEs. This results in a concentrated REE solution. The REE solution is separated into the individual elements at high purity using ion chromatography.
- TMRC works with buyers of the REEs

Inventure

TMRC
Texas Mineral Resources Corp

Texas Mineral Resources Corp.

TMRC's Role is divided into six basic tasks:

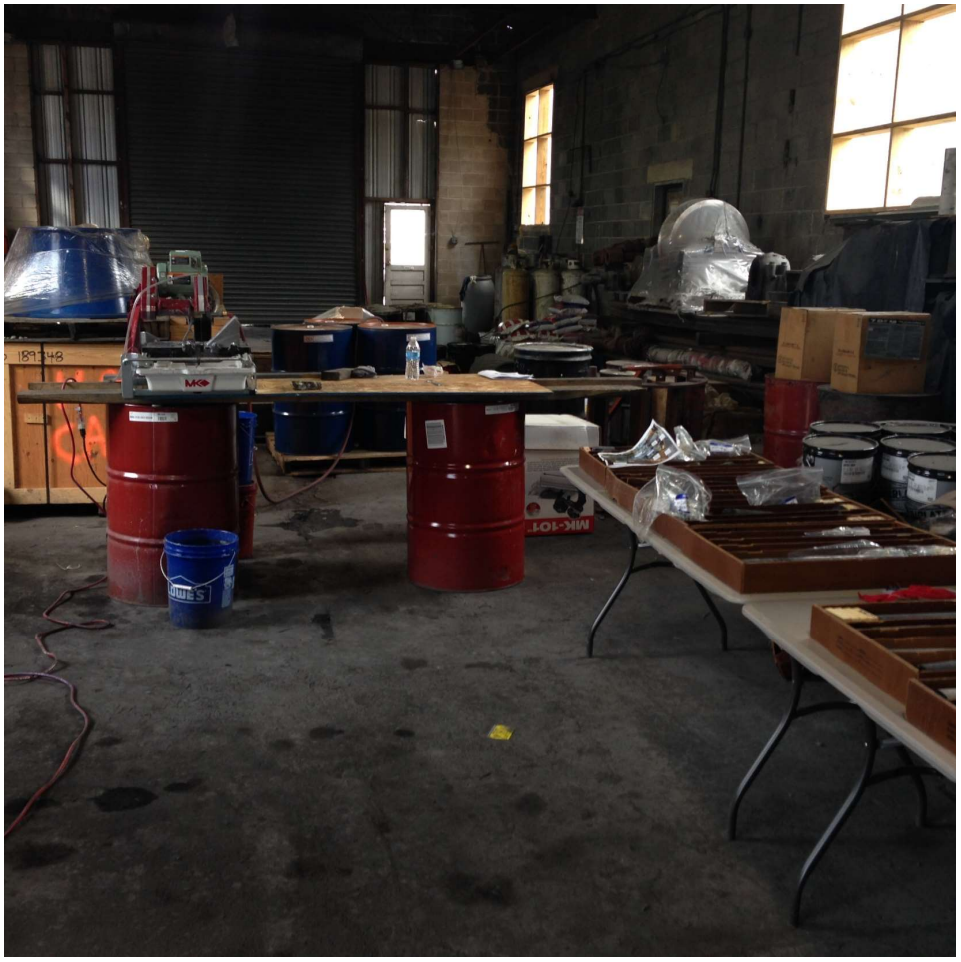
1. Collect the mine samples from the primary site at the Jeddo Coal Company's Upper Lehigh No. 5 deposit and from alternate sites within the Jeddo properties and from other alternate sites in western PA. We also will evaluate and attempt to understand the geology of these occurrences.
2. Define the size and grade of the resource at the various areas.
3. Working with other participants, design a preliminary mine plan.
4. Working with other participants design a preliminary physical and hydrometallurgical section of the processing plant.
5. Draft a preliminary economic analysis.

Jeddo Coal Co. Drill Core

In 2013 Jeddo Coal Co. conducted an extensive diamond drilling program at five of their properties. All the core is warehoused at their mine-site along with all the log data.

We have selected one of these core holes, Eckley North No. 2, to detail sample in order to gain understanding of the geologic controls of these REE occurrences.

Core Sawing and Logging Setup



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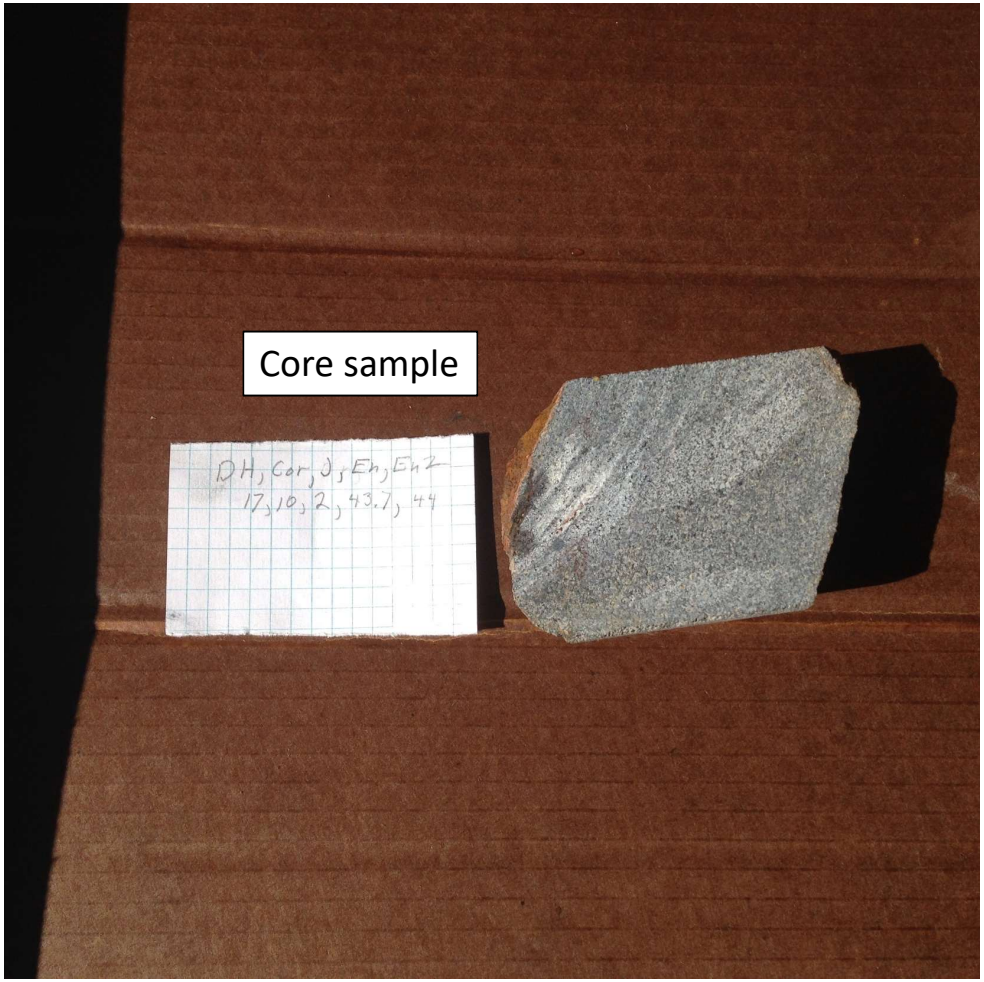
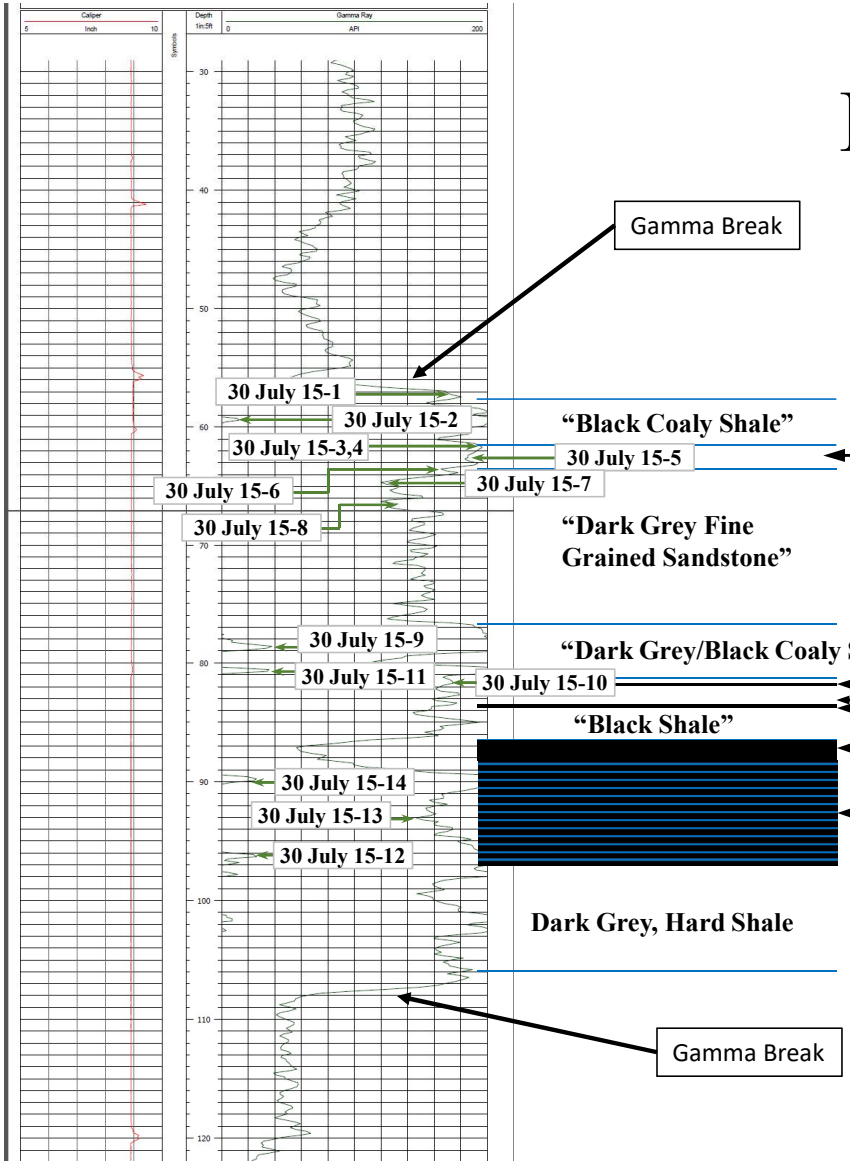


Eckley North No. 2



Gamma Break

30 July 15-1

30 July 15-2

30 July 15-3,4

30 July 15-5

30 July 15-6

30 July 15-7

30 July 15-8

"Black Coaly Shale"

"Grey, Fine Grained Sandstone"

"Dark Grey Fine Grained Sandstone"

30 July 15-9

30 July 15-11

30 July 15-10

"Dark Grey/Black Coaly Shale and Shaley Coal"

"Coal"

"Carbonaceous Shale/Shaley Coal"

"Black Shale"

"Coal" "Coal"

30 July 15-14

30 July 15-13

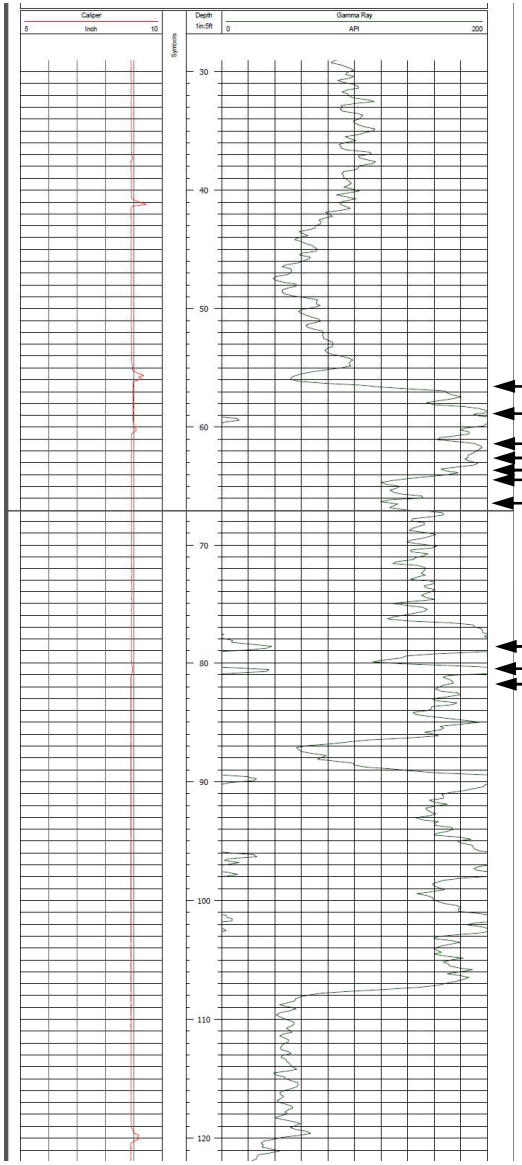
30 July 15-12

Shale and Coal

Dark Grey, Hard Shale

Gamma Break

Eckley North No. 2



56.5’, 409 PPM REE

59’, 401 PPM REE

61.25’, 401 PPM REE

62.5’, 338 PPM REE

63.33’, 417 PPM REE

64.5’, 173 PPM REE

66.5’, 233 PPM REE

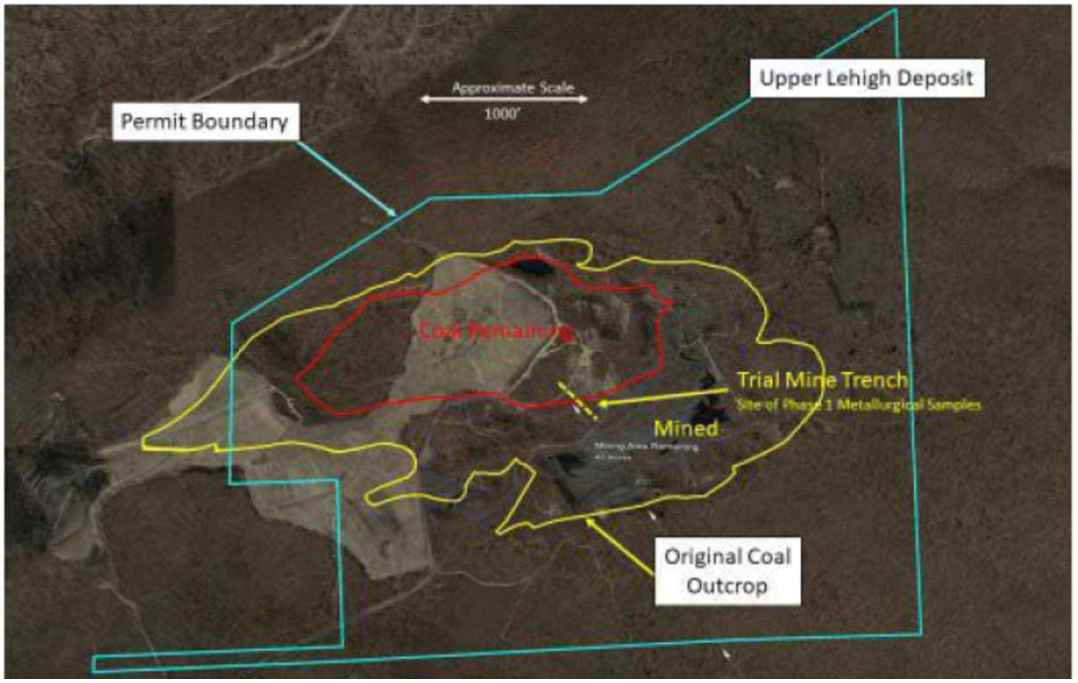
78.67’, 401 PPM REE

80.5’, 409 PPM REE

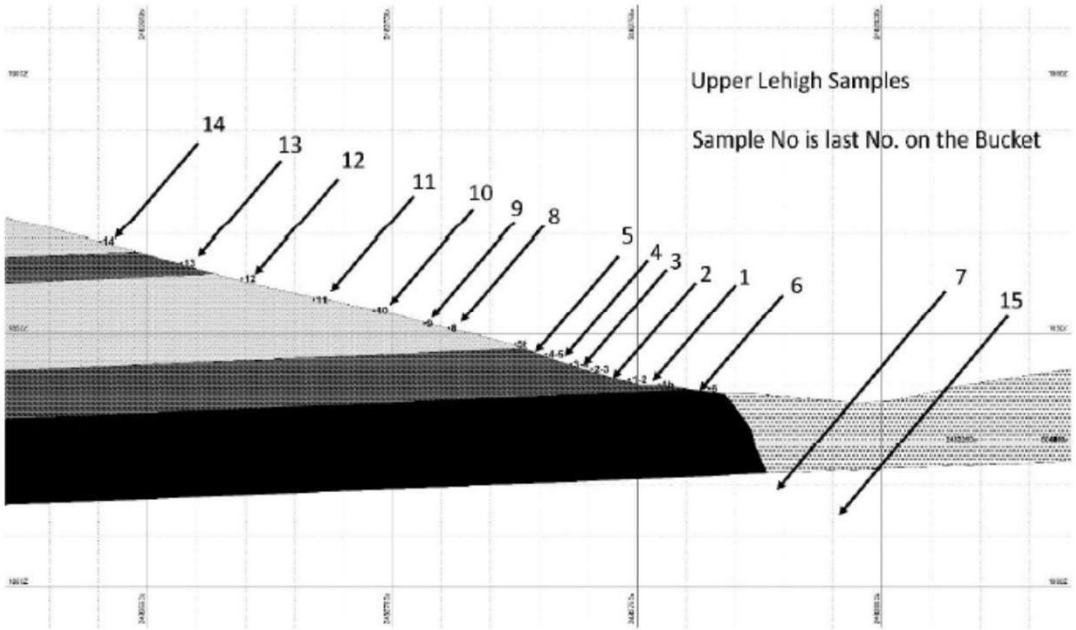
81.5’, 233 PPM REE

Upper Lehigh No. 5

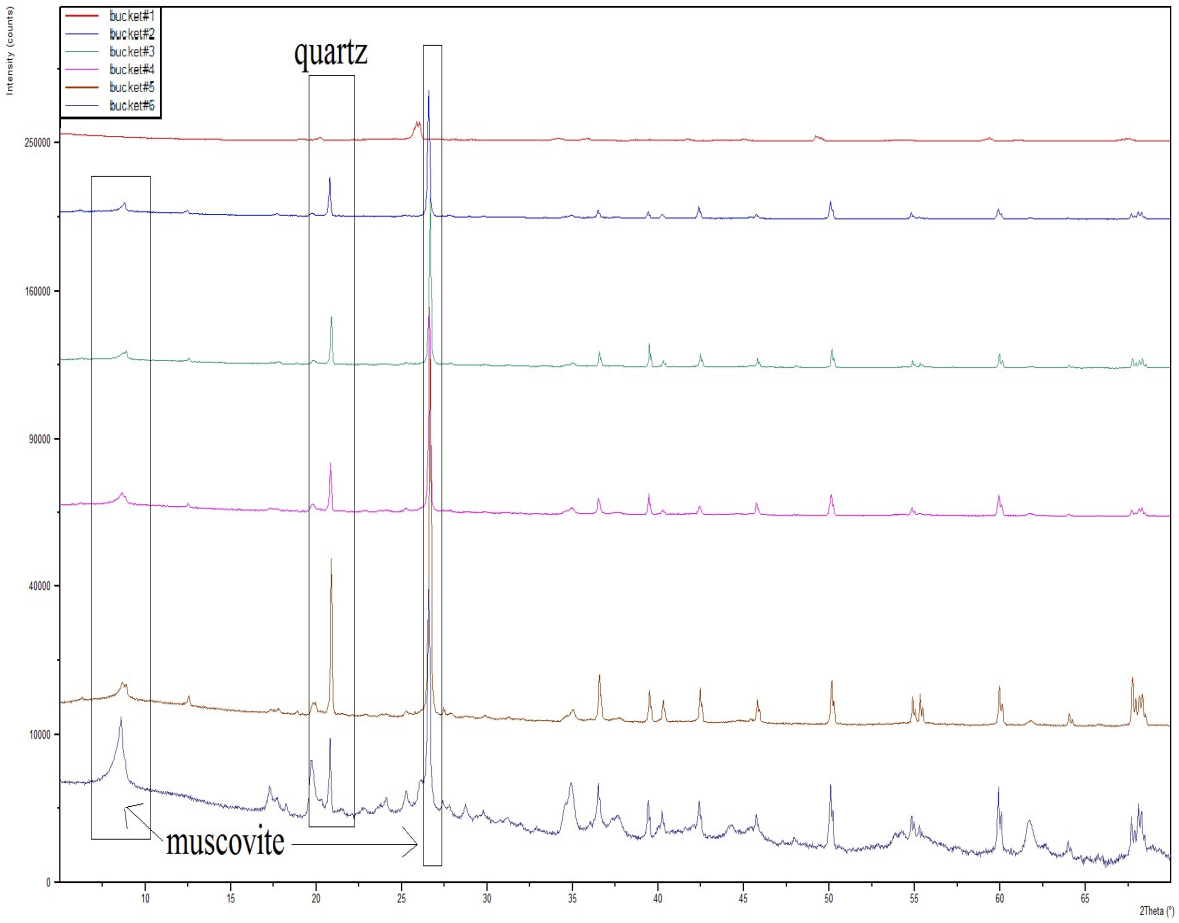
The rock section exposed in the trial mine trench at Upper Lehigh No. 5 will be measured and detail sampled. Metallurgical samples have been collected from this site and delivered to Penn state for further evaluation.



Upper Lehigh No. 5



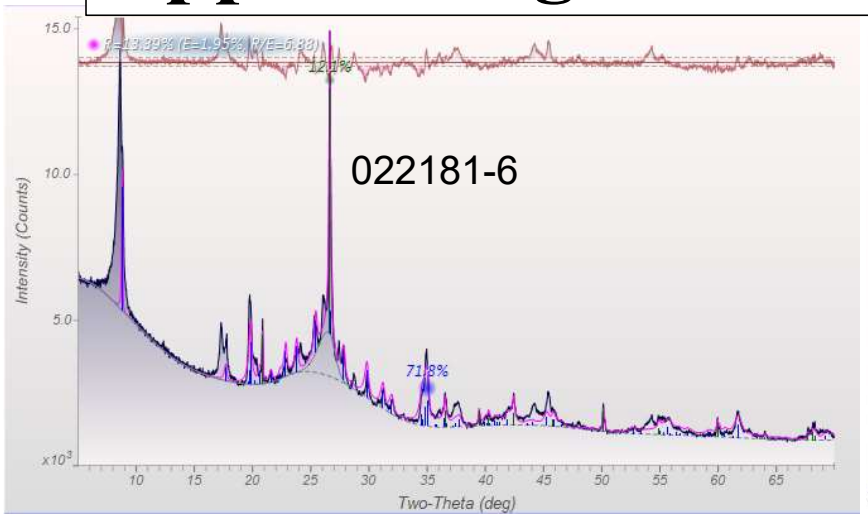
Upper Lehigh No. 5 - Bucket Sample 1-6 XRD

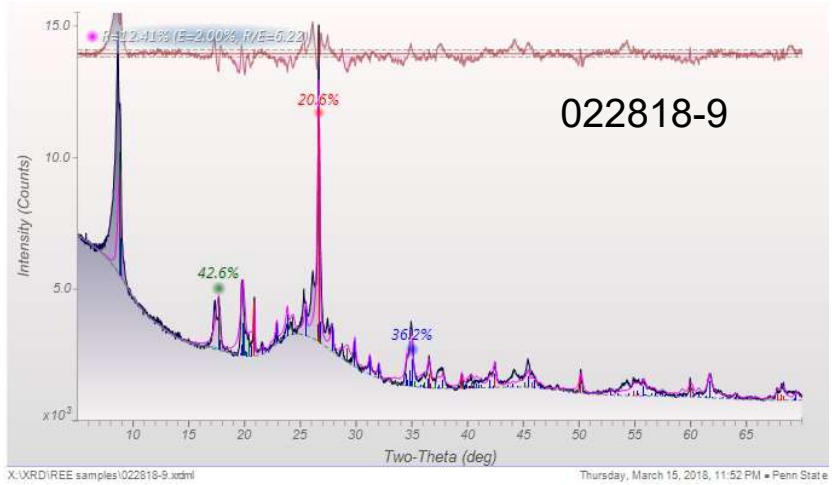


Sample	Amorphous (wt%)	Quartz (wt%)	Muscovite (wt%)	Kaolinite (wt%)
1	36 (uncertain)	22	0	0
2	7	72	16	Little to none
3	8	68	19	Little to none
4	2	56	Uncertain	7 (uncertain)
5	1	70	20	Little to none
6	6	32	54	Little to none

- Aluminosilicates have been shown in the literature to have a high positive correlation with total REE content.
- In these samples, the major aluminum silicate phases are muscovite and kaolinite.
  - Sample 1 has little to no aluminum silicate phases, thus unlikely to contain high REE values
  - Sample 6 has the highest, and can be a potential suitable candidate to optimize leaching efficiency

Upper Lehigh No. 5 – Grab Samples XRD





Sample	Muscovite	Quartz	Amorphous	Other Al Si
022818-1	53%	11%	35%	Maybe
022818-2	No peak @9, none	Maybe a little	15%	76.4% (orthoclase)
022818-4	66%	31.5%	2.6%	Unlikely
022818-6	72%	12%	16%	Unlikely
022818-9	63%	20.6%	0.6%	
022818-10	6.5%	Very little	93.5%	

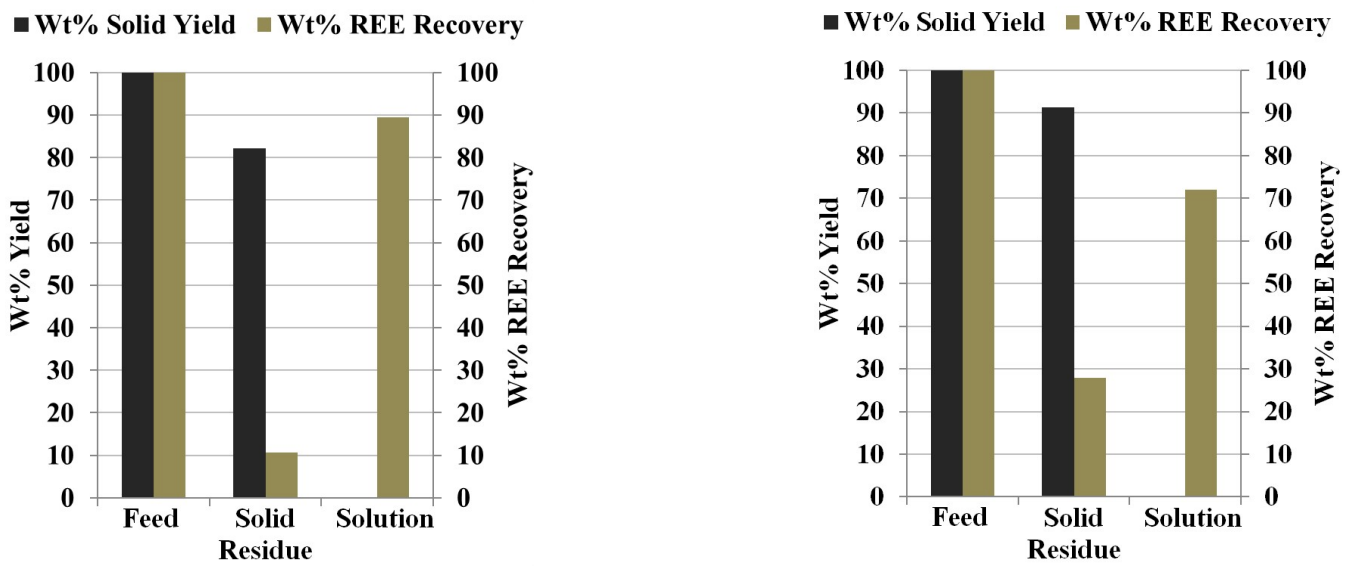
PSU
Penn State University

PSU Tasks

- ***Task 1.0*** *– Literature Review of Chemical Processing Approaches*
  - Focus on ion-exchange methods and the corresponding extraction conditions and results
- ***Task 2.0*** *– Sample Characterization and Sample Selection*
  - Determine the concentrations of REEs in each sample. Depending on the sample, crushing and sieving methods will be used to produce material of sufficient fineness for REE analysis.
- ***Task 3.0*** *– Physical Processing of Selected Samples*
  - Additional processing of the candidate samples will be carried out (separation, grinding to increase surface area) to prepare material for chemical processing.
- ***Task 4.0*** *- REE Extraction and Enrichment via Chemical Processing*
  - A systematic study on the effect of: a) type lixiviant (e.g., ammonium sulfate, ammonium acetate); b) extraction time (e.g., 30, 60, 120 minutes); c) lixiviant concentration (e.g., 0.5, 1.0, 2.0 M); d) pH (e.g., 4, 7); e) operating pressure (e.g., 1, 4, 8 atm); and f) particle top size (-0.15, -0.45, -0.01 mm) will be studied

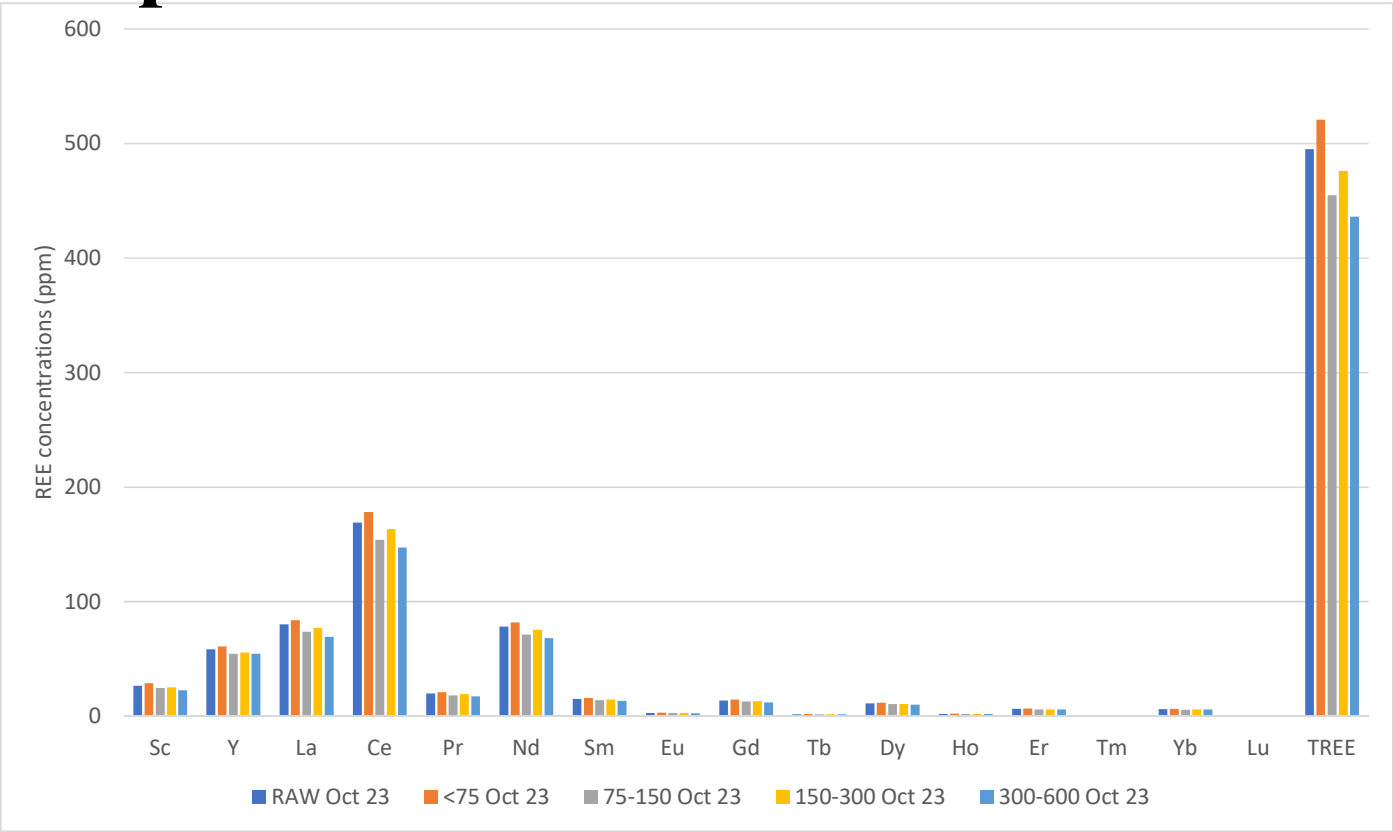
PSU Prior Tests

Previous results at PSU indicated that a significant fraction of the contained REE's in materials associated with the Upper Kittanning coal bed are extractable using an ammonium sulfate solution as lixiviant



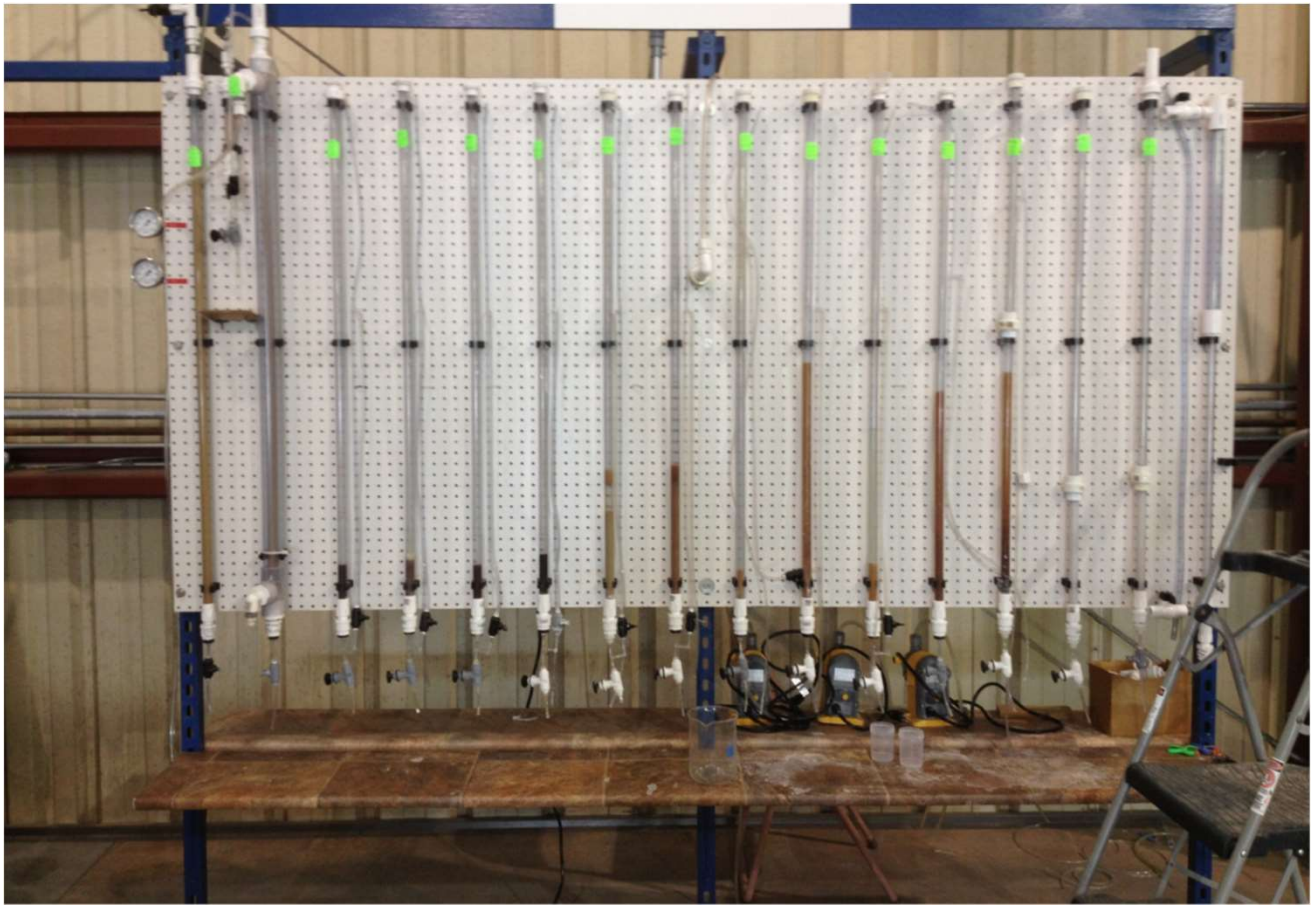
Solid Residue Yield and REE Recovery to Solution, Samples A and B, 700 by 100 micron fraction, 1 hour in Ammonium Sulfate Solution

Total REE concentration and distributions for various particle size fractions of Oct23 sample.



K-Tech & Inventure
(Separations using Chromatography)

Chromatography Test Bench

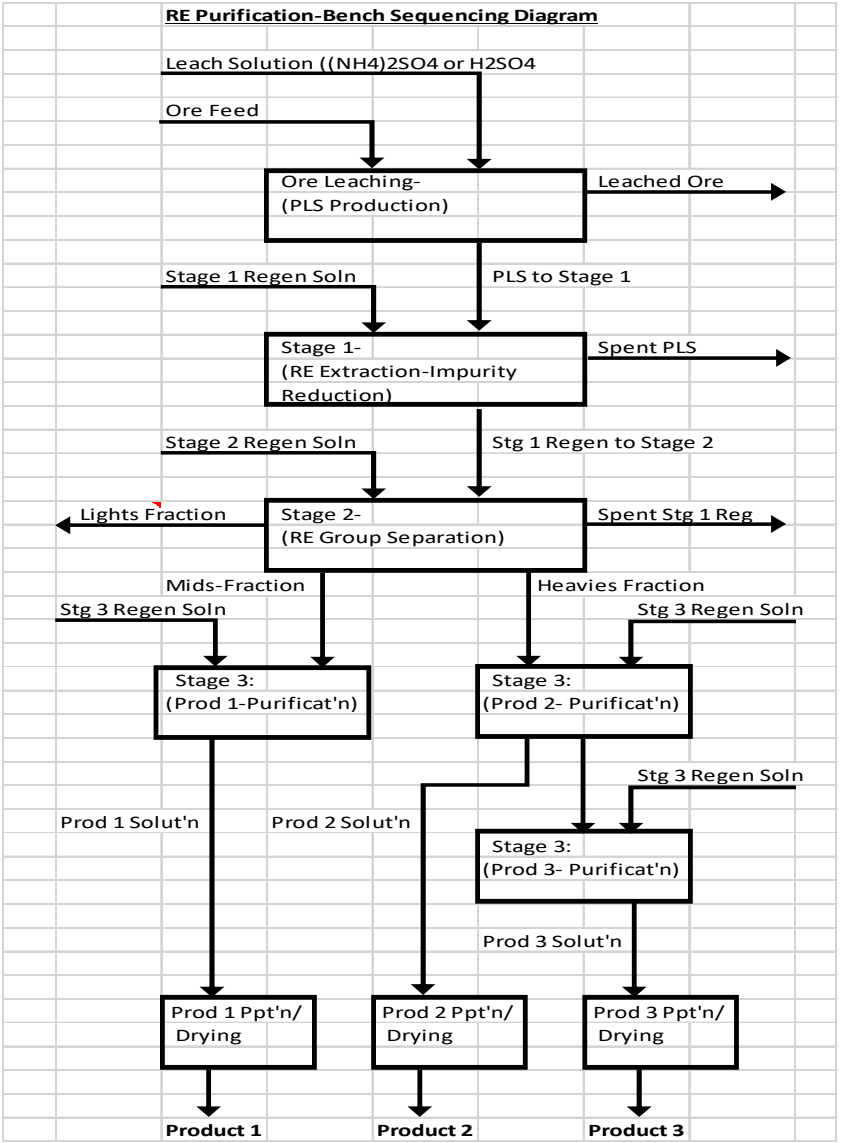


Chromatography Test Bench

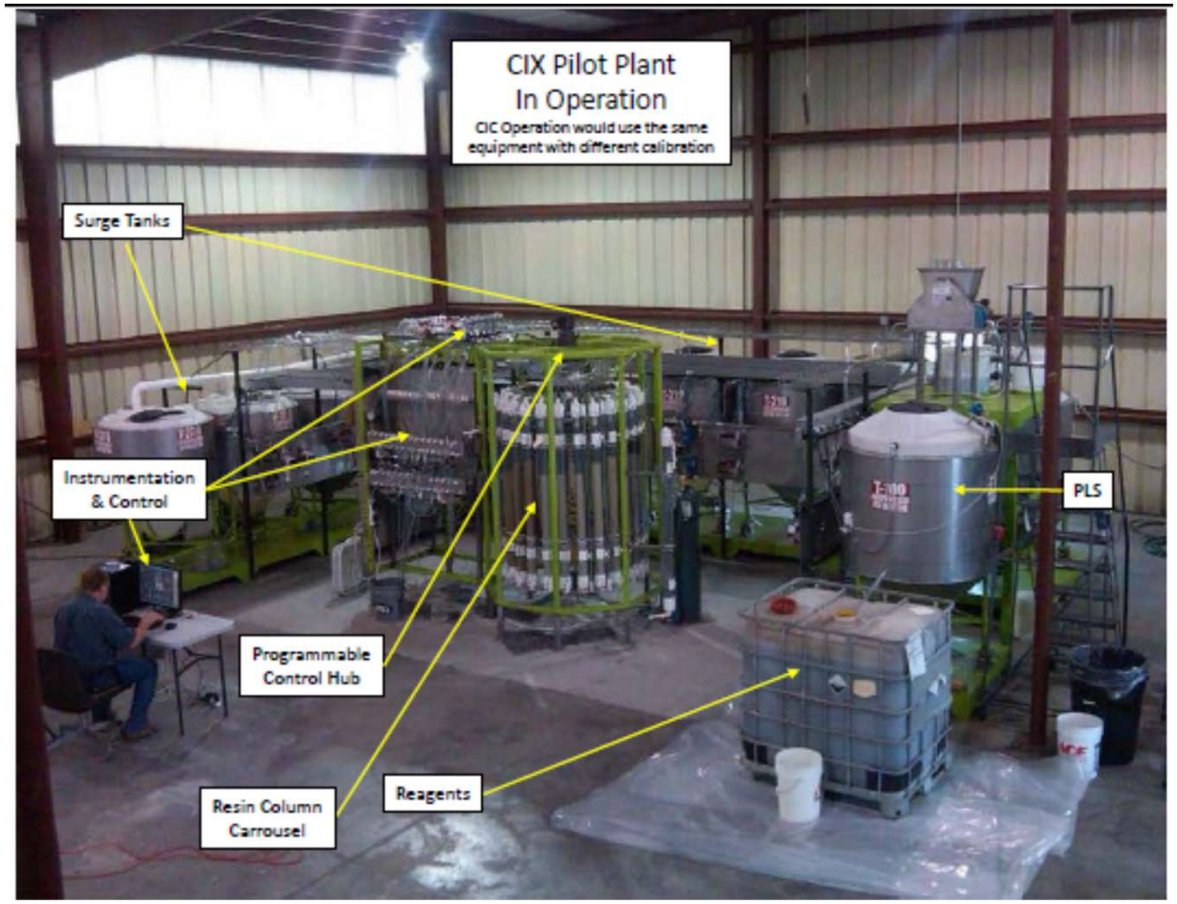
The general bench testing set-up is shown. To illustrate the concept, 3 RE products are shown to be the target materials from the testing.

The operational nature of the CIC systems is such that solutions can be run in a campaign fashion due to the relatively fast response time of the CIC systems and the ability to change reagent ratios quickly.

In this manner, a single CIC system could process more than one feed solution using a campaign approach wherein one solution is processed for a period of time to produce product and inventory.



Phase 2 Goal
Continuous Chromatography Pilot Plant



Phase 2 Goals

- Work will be performed at the Jeddo Coal site.
- A skid mounted continuous chromatography system will be operated onsite.
- Creating a profitable technology
- Create other spin off related technologies and other non coal related sources of REE's