PennState

ADDRESSING A CRITICAL NATIONAL NEED
Leading The Development of A Domestic Critical Minerals Supply Chain

Presented to
Chesapeake Bay Commission

By

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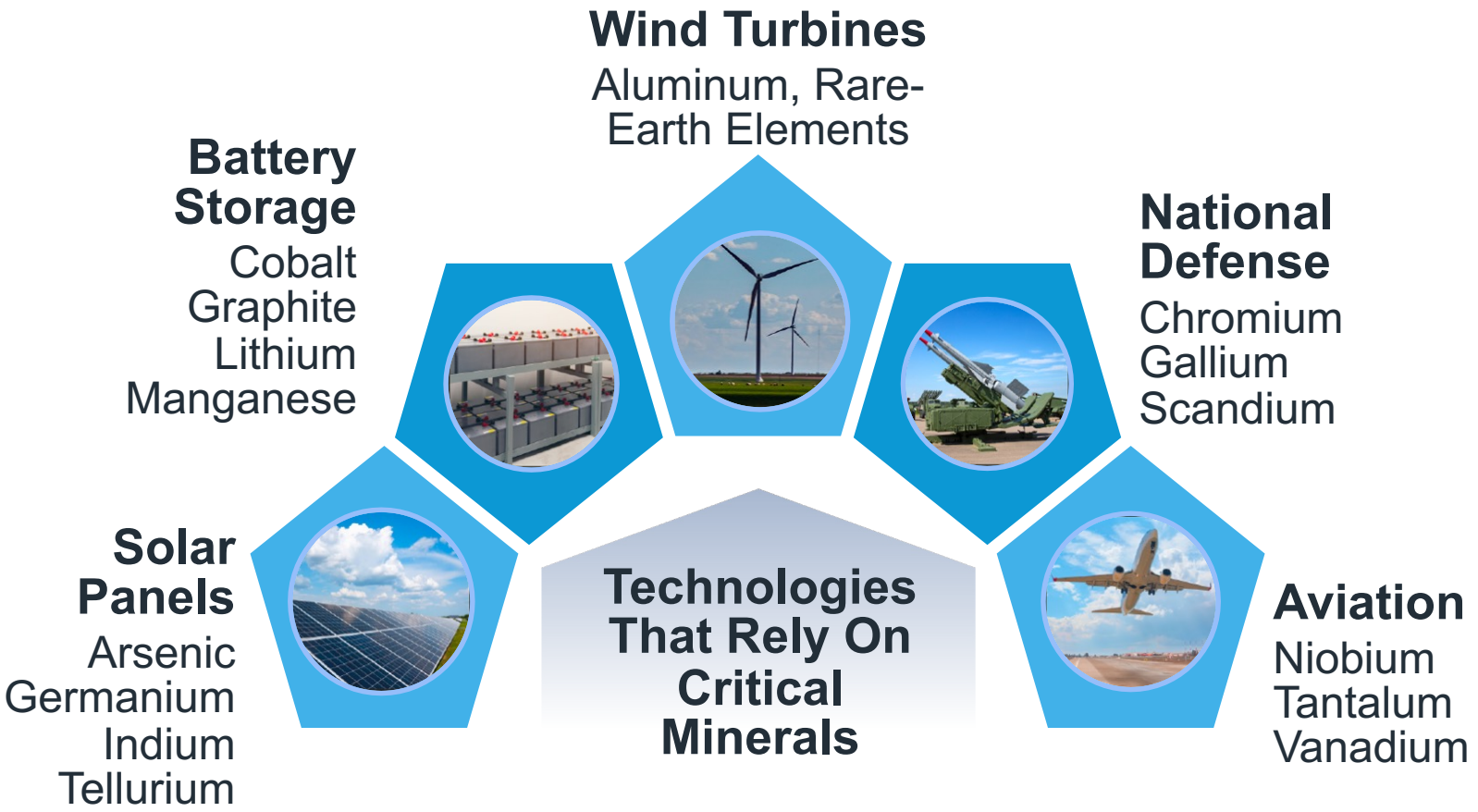
What are Critical Minerals?

Energy Act of 2020 defines critical minerals as elements that are:

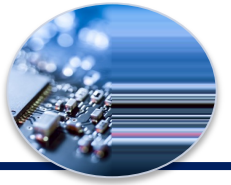
- *Essential to the **economic or national security** of the United States;*
- *Have a supply chain that is **vulnerable** to disruption; and*
- *Serve **an essential function** in the manufacturing of a product*

These minerals play a vital role in:

- *Strengthening our **national defense** and*
- ***Ensuring access to the everyday essentials of modern life**, including computers, cell phones, batteries, electric vehicles, and solar panels*



Why Penn State?



Penn State's Center for Critical Minerals (C2M)

Penn State is home to the premier university-led center for critical minerals in the nation

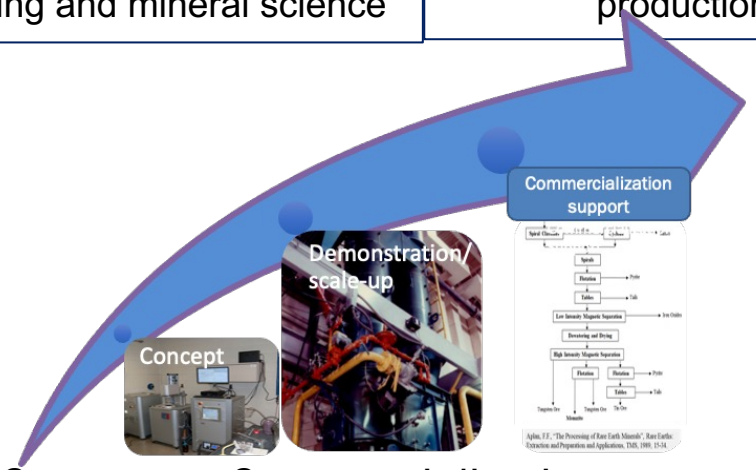
Penn State has a unique and distinguished history in mining and mineral science

Unparalleled Faculty Expertise

Pioneering research

Registered IP patents for extraction processes

Leader in synthetic graphite research for battery production



- Concept to Commercialization support

Federally Sponsored Research

Leads the Consortium to Assess Northern Appalachia Resource Yield (CANARY)

Nationally recognized leader in safe extraction, processing, and recycling of CMs from secondary sources like mine waste and acid mine drainage

Leads multiple large research projects at the DOE and NSF representing over $2.3M in Federal funding since 2020

Partner in the DoE Sponsored Critical Minerals Institute

Industry Partnerships

Annual host of the Power and Mineral Industrial Stakeholder Group (PMISG)

Home to Innovation Park

Partnerships with industry leaders in CMs which include:

The Pennsylvania Coal Alliance, USA Rare Earth, PENNCARA Energy, Materia, Texas Mineral Resources Corp., Energy Fuels, American Resources Corporation, Lithium America's and CHZ Technologies

Grand Challenges to be addressed by Center for Critical Minerals (C^2M)

- Develop the science required to establish additional rare earth and critical minerals production capacity and reserve base in the U.S., reducing imports from sensitive countries.
- Support industrial partners to commercialize the science and technology for revenue and economic development sources in the Commonwealth of PA.
- Mitigate environmental concerns from energy and mineral industry wastes and the production of value-added critical materials for national security.
- Create engaged scholarship opportunities for students, train a well-equipped workforce, and broaden employment opportunities in PA.

PennState

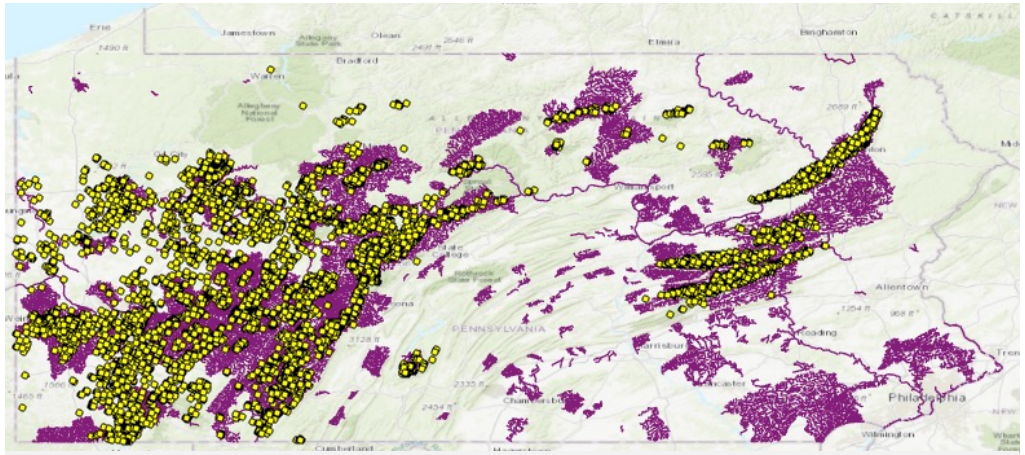
Economic revitalization and environmental restoration

PENNSYLVANIA'S UNTAPPED POTENTIAL

Pennsylvania and Secondary Critical Mineral Resources

Abandoned Mine Drainage (AMD) is one of the largest sources of stream impairment in Pennsylvania. Billions of gallons of AMD impair over 5,500 miles of streams within the Commonwealth. - ***PA DCED***

Drs. Klima and Pisupati sampling
AMD sludge from a pond in Central PA



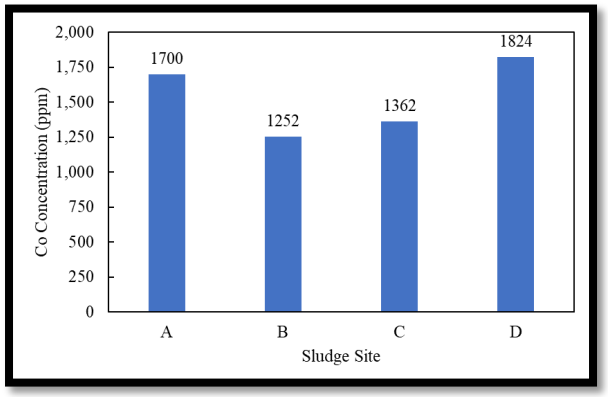
Purple poly-lines - rivers that have pollution levels higher than state-acceptable levels
Yellow poly-points - locations of abandoned mines

Potential Environmental Benefits from Production:

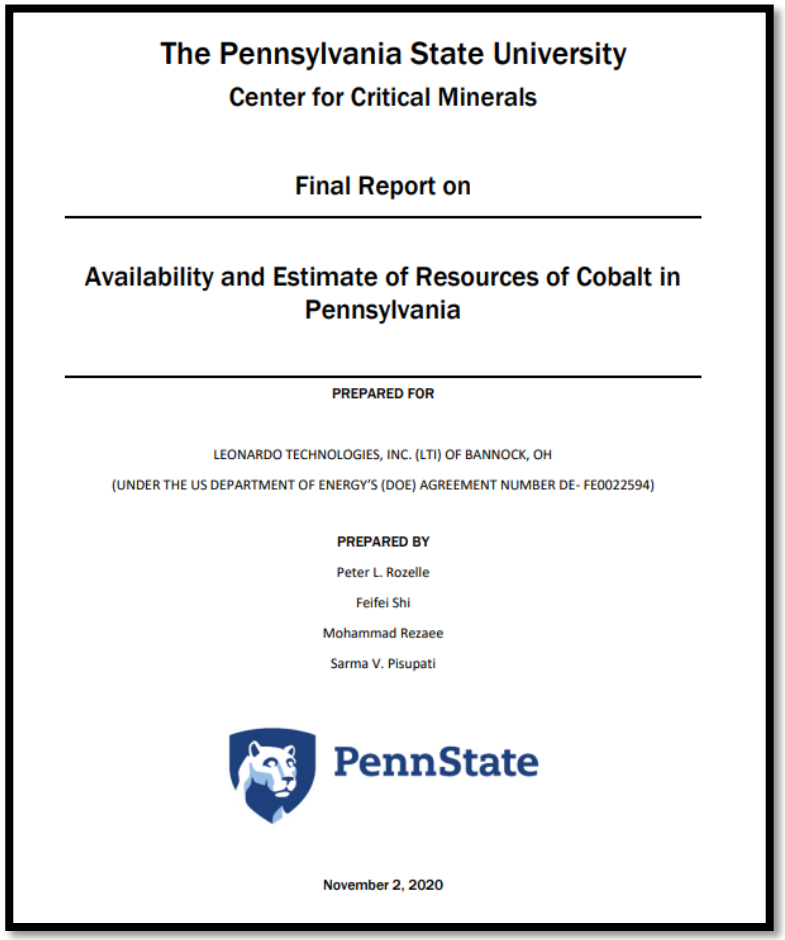
- Remining and Reclamation of Abandoned Mined Lands
- Remediation of Acid Mine Drainage
- Reclamation of Mineral Processing and Metallurgical Waste Dumps

Photo: Courtesy
Rosebud Mining Company

PSU C²M report on Cobalt Resources in PA



- There is significant cobalt potential in unconventional resources such as metal mine byproducts and acid mine drainage treatment sludges.
- A cobalt- and manganese-bearing zone has been found in the coal measures of Pennsylvania with a cobalt grade roughly equivalent to commercial ores.



The Pennsylvania State University

Center for Critical Minerals

Final Report on

Availability and Estimate of Resources of Cobalt in Pennsylvania

PREPARED FOR

LEONARDO TECHNOLOGIES, INC. (LTI) OF BANNOCK, OH

(UNDER THE US DEPARTMENT OF ENERGY'S (DOE) AGREEMENT NUMBER DE- FE0022594)

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PennState

November 2, 2020

PENNSYLVANIA AS A CENTER FOR CRITICAL MINERALS SUPPLY CHAIN

Pennsylvania's unique geological characteristics and location in the Appalachian basin make the Commonwealth an integral part of the national strategy to accelerate production from unconventional and secondary sources.

Coal Mining History

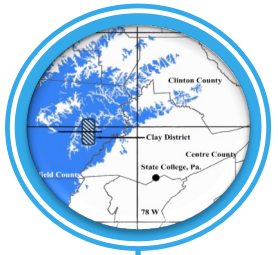
PA's history of coal mining represents an unparalleled opportunity to utilize coal refuse by extracting cobalt and manganese

Coal Byproducts

PA has some of the largest coal ash waste sites in the country containing cobalt and manganese

Marcellus Shale

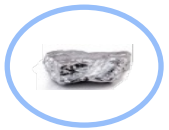
The Marcellus Shale is the largest natural gas field in the country containing highly concentrated lithium



Mercer Clay Bed

The Mercer Clay Bed contains significant amounts of lithium

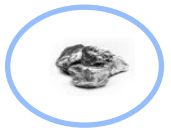
Examples of Critical Minerals Extracted from Coal Waste



Cobalt

Lithium

Rare Earths



Manganese

Battery Storage

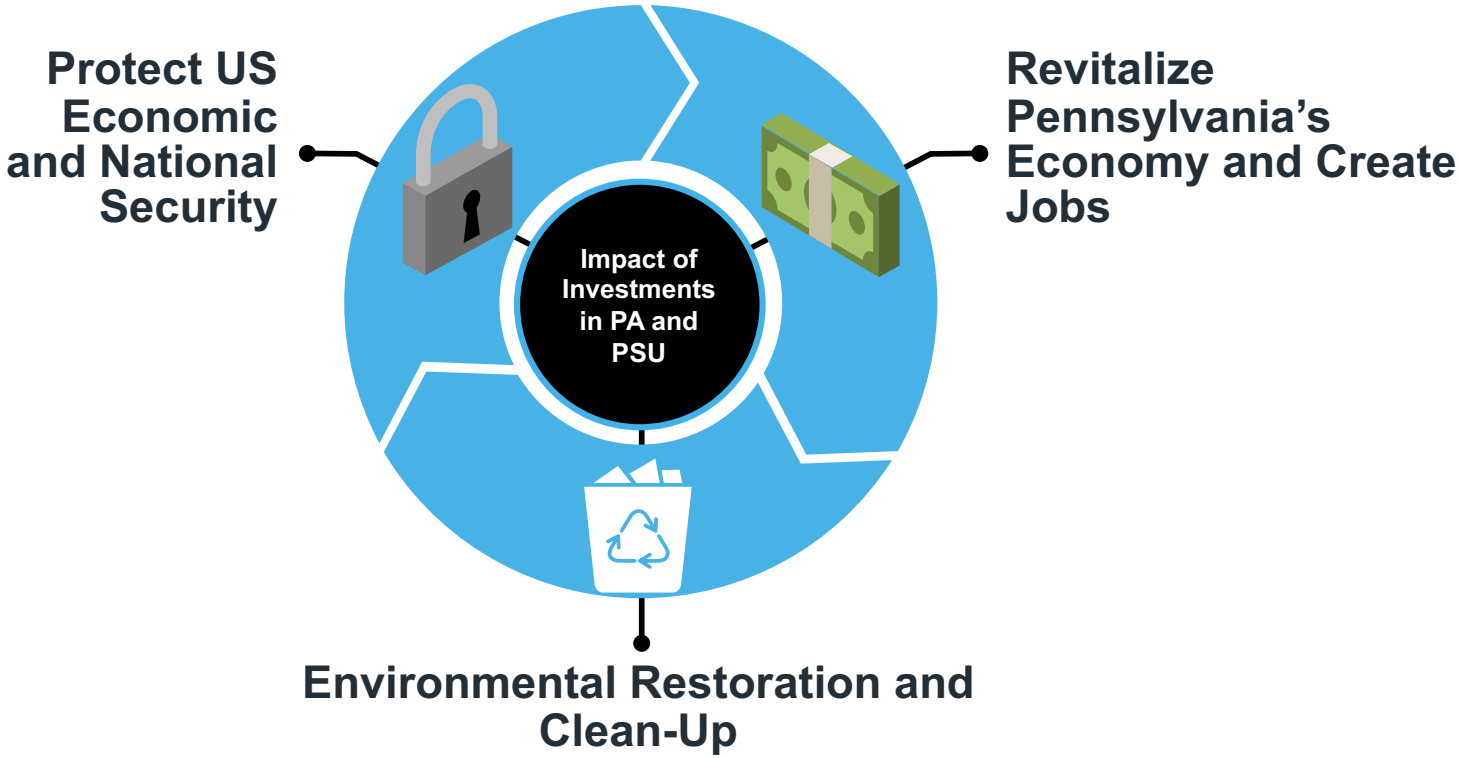
National Defense

Aviation

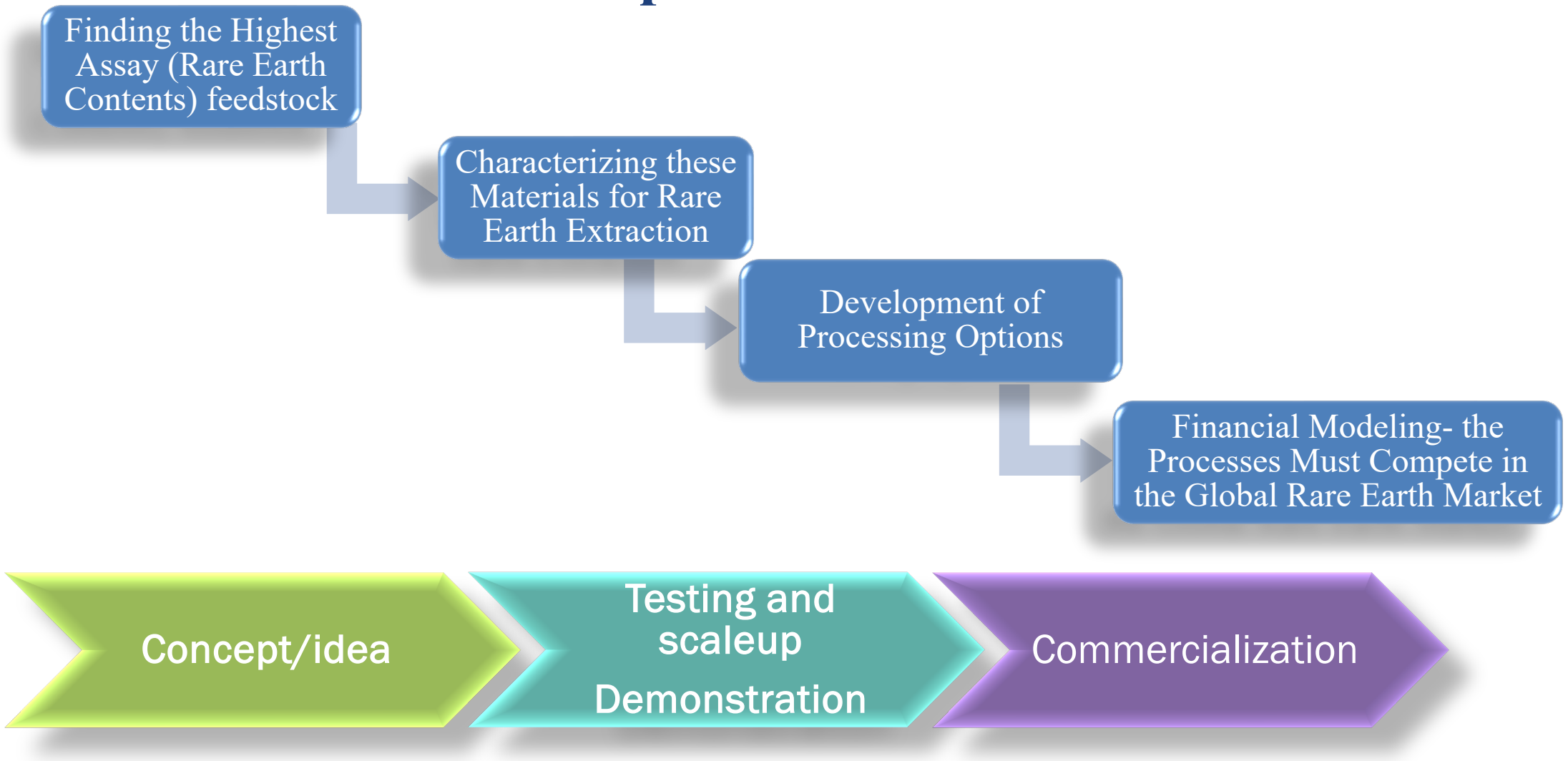
Smartphones

A “WIN-WIN-WIN” FOR THE COMMONWEALTH AND THE COUNTRY

Extracting critical minerals from energy-based waste products benefits Pennsylvania and the nation.



The Challenge: Develop Domestic Rare Earth Production Capabilities



PSU C²M is examining wide range of feedstocks and secondary resources

- Traditional Ores
- Coal Based and/or Associated Materials
- Over burden/ Under clays
  - working with Private sector and DOE – delivered separated elements to DOE
- Acid Mine Drainage and Sludge-
  - *Very high concentration resource – Working with PADEP and private industry*
- E-waste recovery from US Department of Defense Electronic Waste
  - *working with CHZ Inc., funded by REMADE Institute and EERE/DOE*
- Fly ash and power industry wastes
  - *Power and Mineral Industrial Stake Holders group*
- Mine Tailings

Our approach has been multi-metal recovery to make it economically viable to compete in global markets

PSU with partners Separated REEs from Coal based feedstock

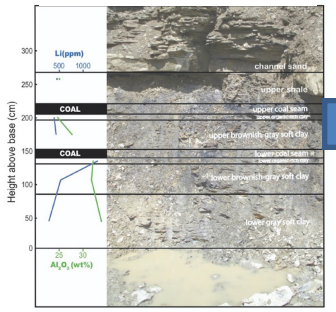
Development of Processing Options

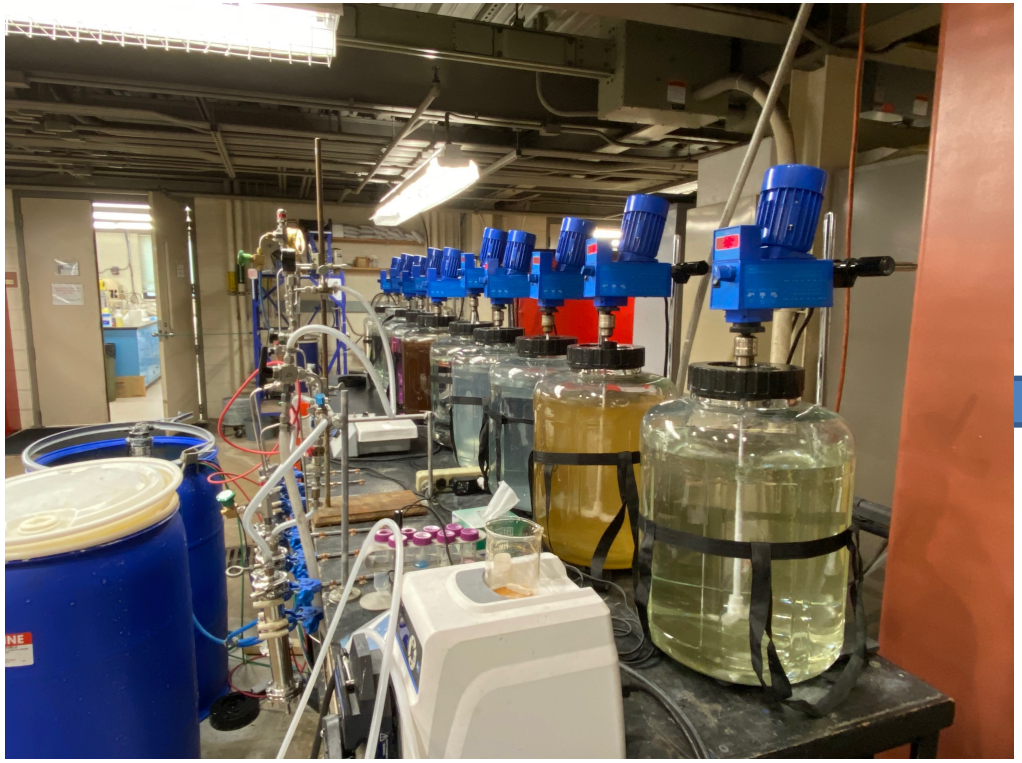
Penn State has developed a patent-pending multi-metal extraction process

Acid Mine Drainage

Acid Mine Drainage Sludge

Mercer Clay





Part 3- CUL Energy Institute

- >90% Lithium
- >90% Iron
- >95% Aluminum
- >95% Mixed REEs
- >96% Cobalt
- >95% Manganese

Current DEP Method

Expensive Chemical

AMD

Water

Sludge

Discharge into streams

PENN STATE Method

Inexpensive, Environmentally Friendly Chemical

AMD

pH 3

pH 5

pH 6-7

pH 7

Discharge into streams

Iron 90%

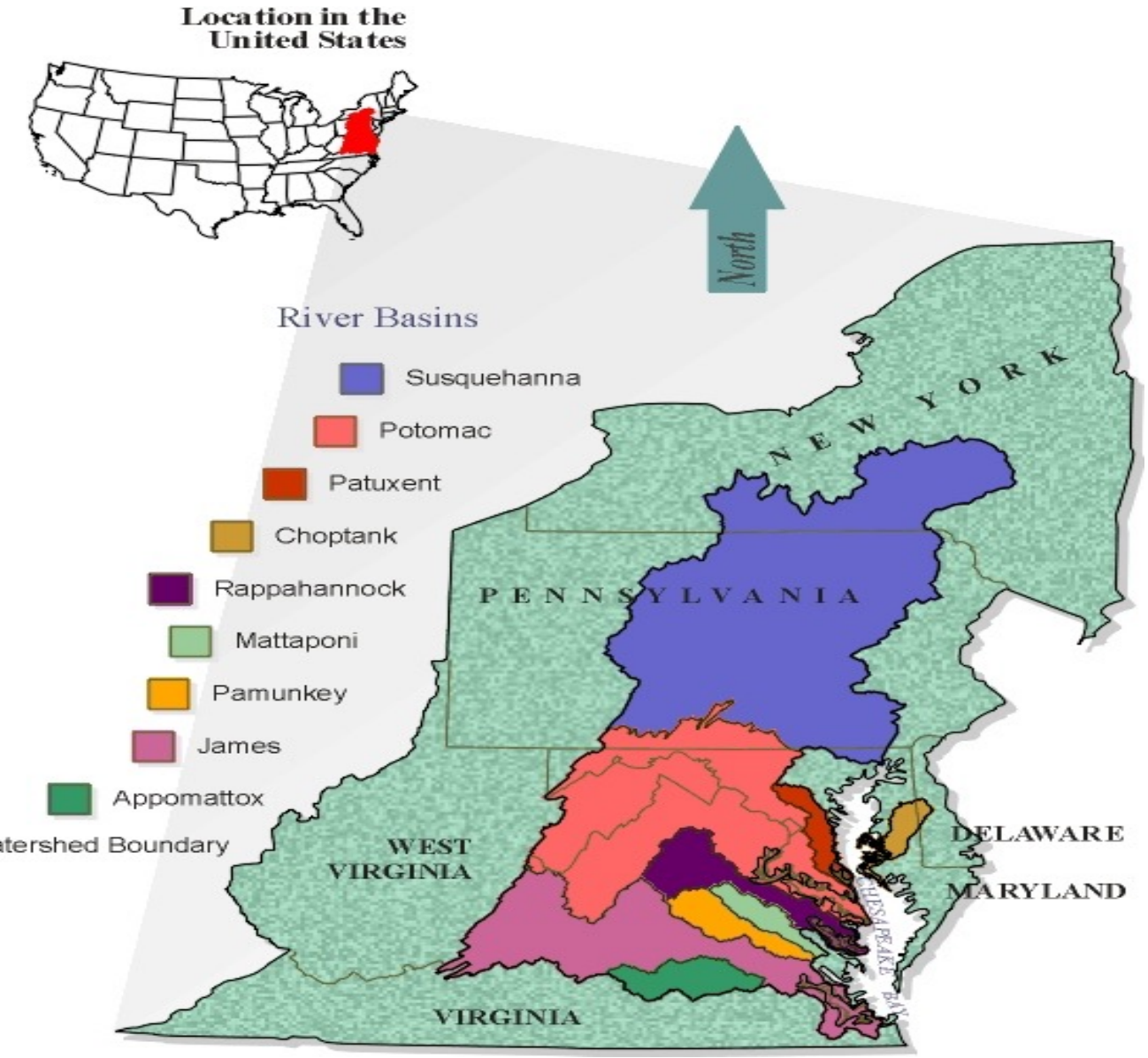
Aluminum 90%

REE 90%

Cobalt and Manganese 90%

REE and CM Potential

CHESAPEAKE BAY



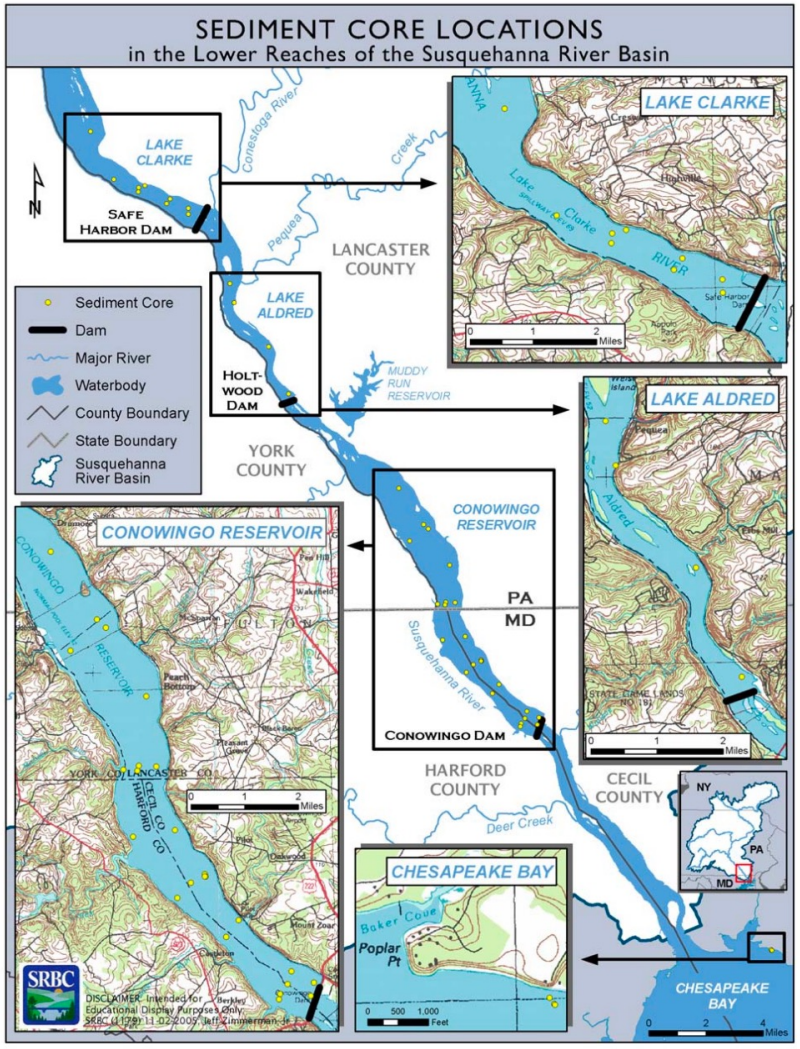
Location of Chesapeake Bay watershed and major river basins (usgs.gov)

Study on Sediments

- COMPREHENSIVE ANALYSIS OF THE SEDIMENTS RETAINED BEHIND HYDROELECTRIC DAMS OF THE LOWER SUSQUEHANNA RIVER.

PARAMETERS MEASURED ON BED SEDIMENTS

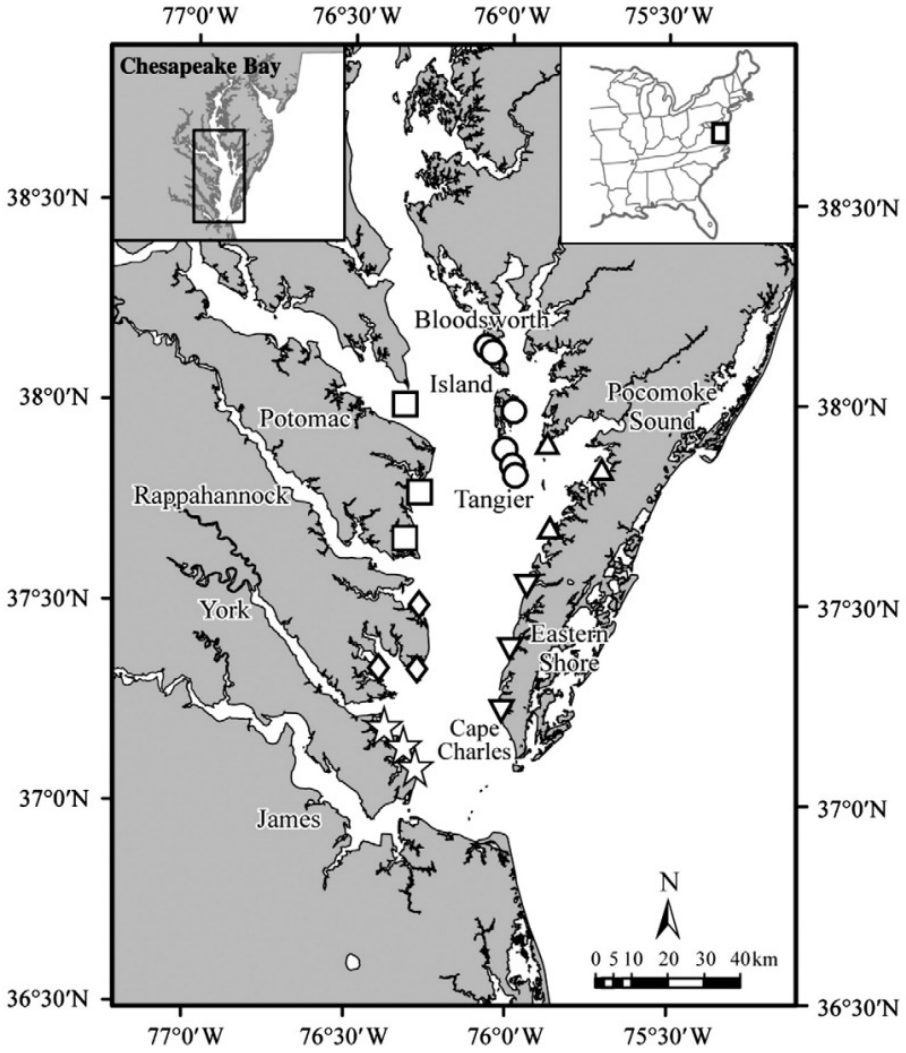
- Maryland Geological Survey
  - Physical Description
  - X-rays of whole core, and Photographs of split cores
  - Grain Size,
  - Water Content Coal Content Nutrients (total) - C, N, P, S
  - Metals (total) - Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn
- University of Maryland
  - Metals - Ag, As, Cd, Hg, Pb, Se
  - Radio-isotopes
  - Trace Organic Compounds (PAH's, PCB's, other priority pollutants)
- US Geological Survey (four stations)
  - Phosphorus Speciation

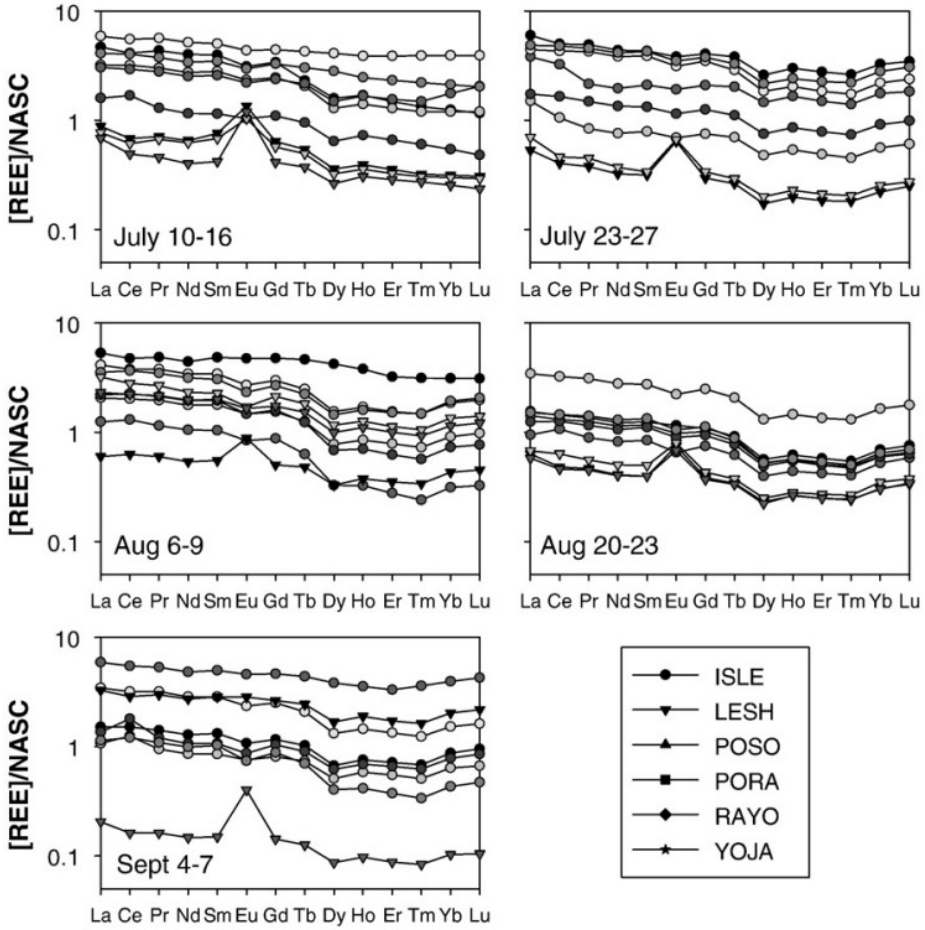


Sediment Core Sites Behind the Hydroelectric Dams on the Lower Susquehanna River and Upper Chesapeake Bay

Hill et al., "Characterization of Bed Sediment Behind the Lower Three Dams on the Susquehanna River" CBC and PADEP Publication 239 February 28, 2006

REE in sediments showed spatial heterogeneity, both laterally and longitudinally.





Hannigan, et al., Chemical Geology 272 (2010) 20–30

Takeaways

- Coal is a major component of the system
- Reduced sulfur concentration average 0.129% → Lower Acidity
- All of the metals were within the range of Northern main stem Chesapeake Bay levels.
- High silver (Ag) concentrations were found at depth
- Overall organic contaminant concentrations were comparable to those found in the Upper Chesapeake Bay
- Processes occurring in estuaries modify the abundance, species, and flux of trace elements, including the rare earth elements (REE; La to Lu), delivered by rivers to the ocean.

Questions?

Thank You!