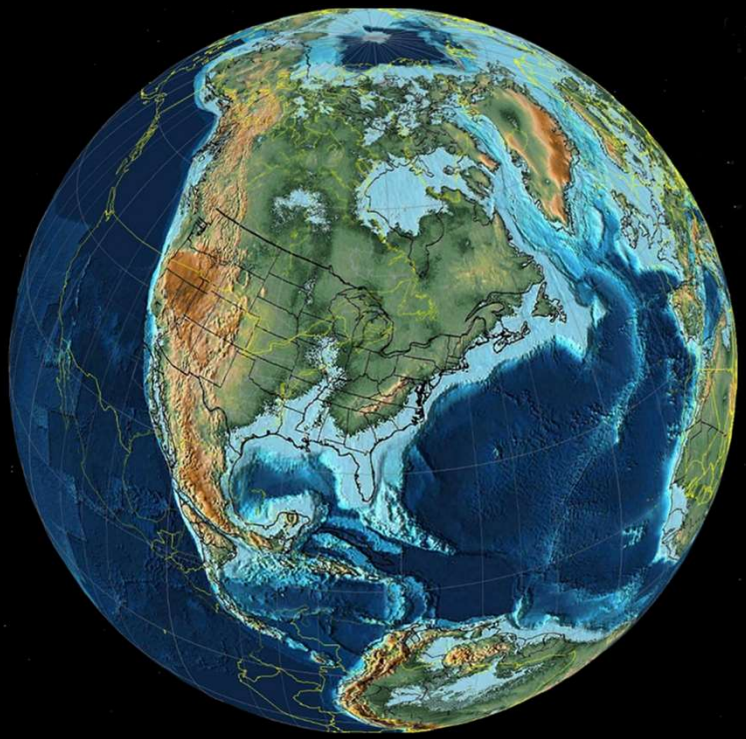
Developing a geo-data science driven method to assess REE's in coal related strata

Kelly Rose, PhD, NETL

April, 2018



Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY

Project Goals

To develop an assessment methodology for **systematically predicting REE concentrations in coal and coal-related strata** that…

https://www.explorenature.org/center-event/x-marks-spot-irvine-scavenger-hunt/

- Is based off known **mechanisms** that result in concentration of REEs in coal & coal related strata
- Can be used to identify **areas** with ***higher REE prospectivity***
- Can be used to constrain whether REE concentrations and volumes suggest **viability** **of** ***commercial extraction*** in priority US coal bearing basins

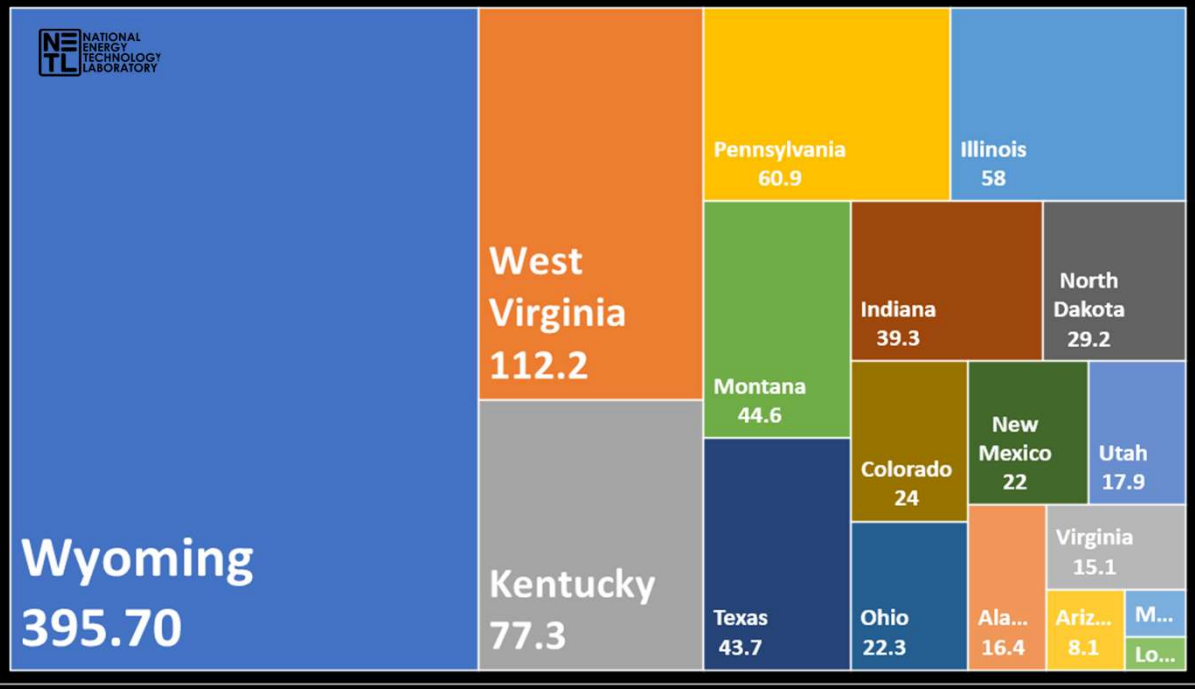
There is the risk that existing data on REE occurrences in different regions/coal types & ages is insufficient and that prior data collection efforts were biased

Inadequate and/or inappropriate data, could result in missed opportunities

Where are REE enriched coals likely to be a viable commodity?

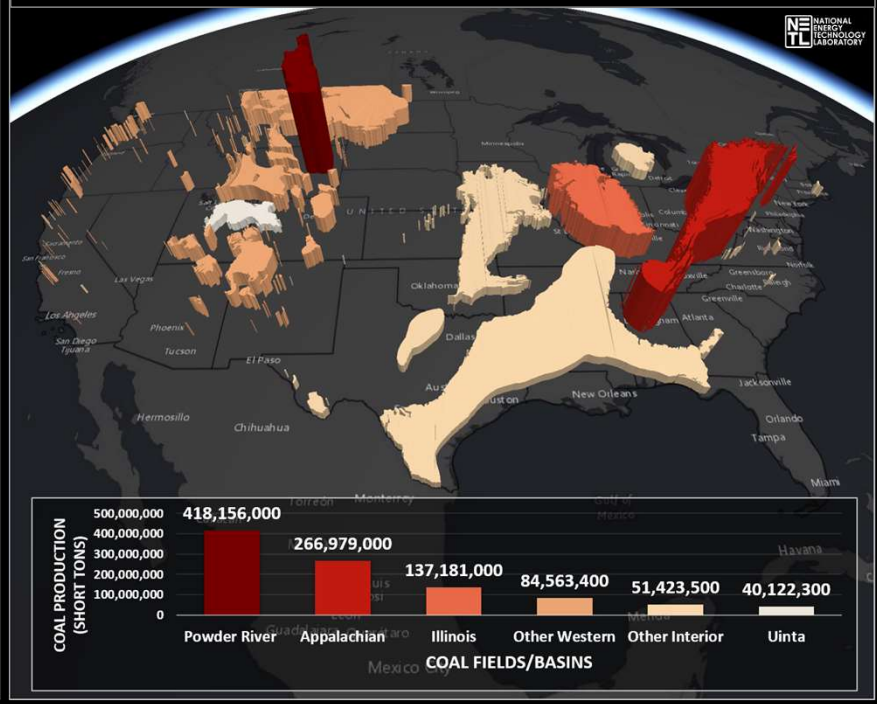
How may these resources vary?

MILLIONS OF SHORT TONS OF COAL PRODUCED BY STATE (2014)



Data sources: Energy Information Administration (EIA) state level data (2015)

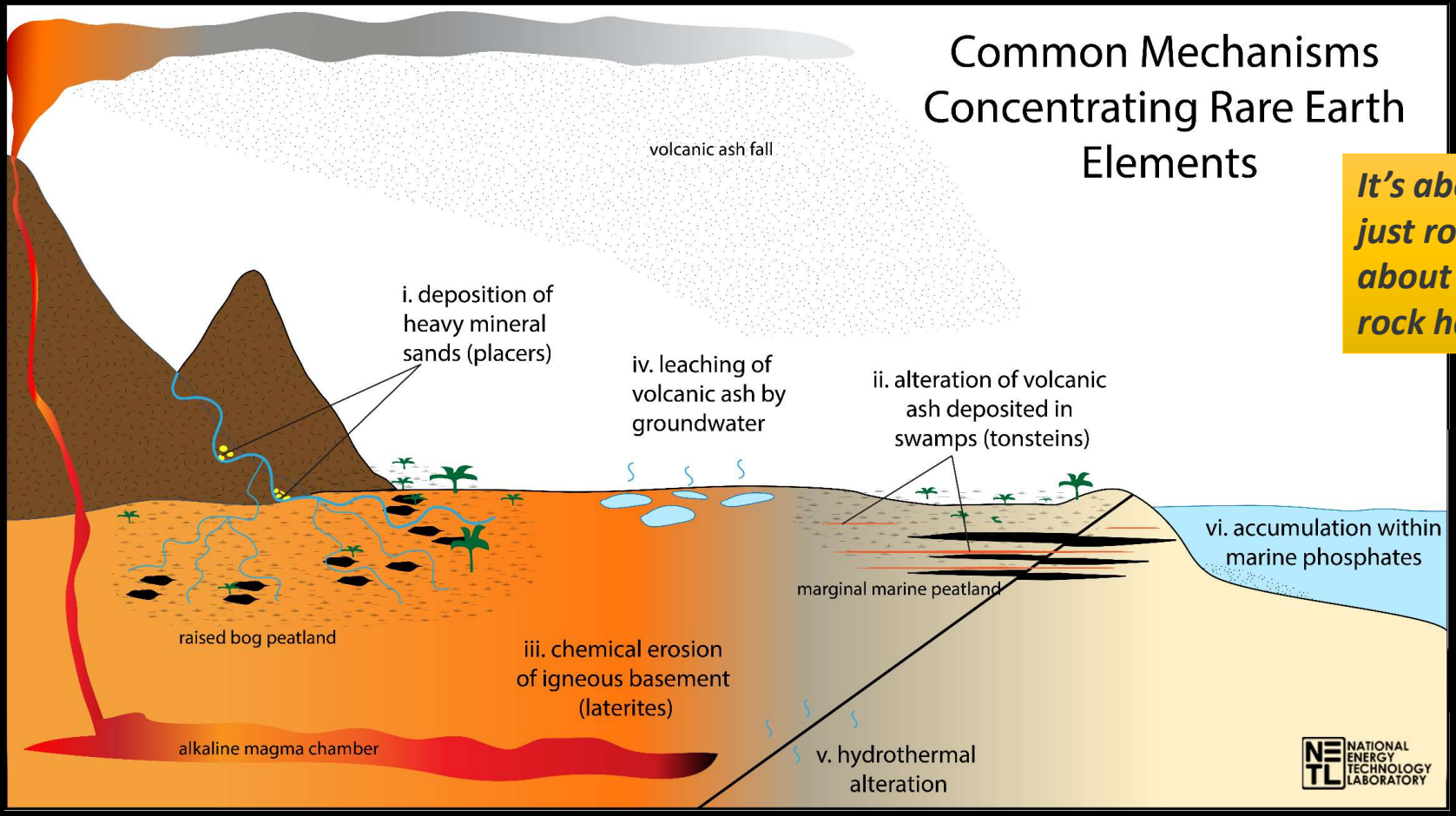
SHORT TONS OF COAL PRODUCED BY FIELDS AND BASINS (2014)



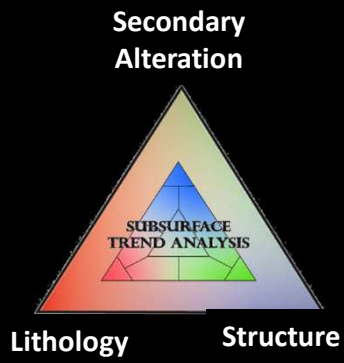
Data Source: EIA

What are the mechanisms of REE enrichment in coal & coal-related strata?

Not all coals are created equal…



It's about more than just rock type…it's about the history the rock has experienced



Where and when are REEs enriched in coal and coal-related strata?

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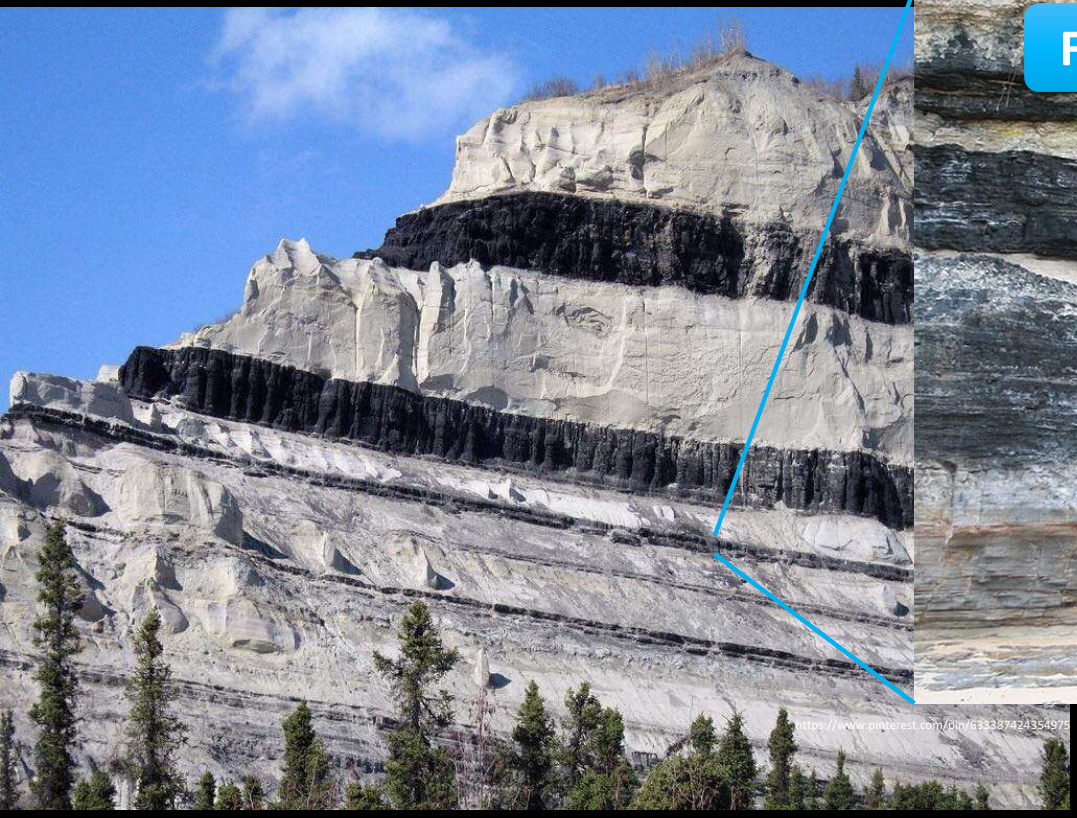
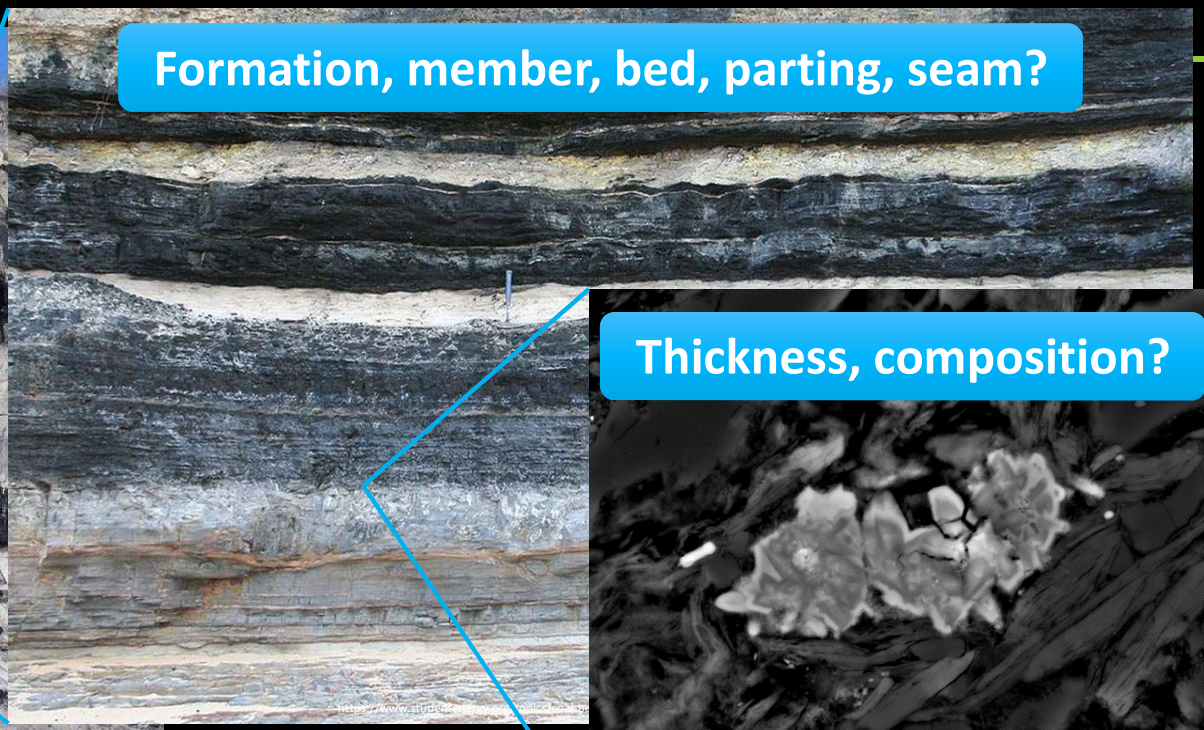
Region, basin, outcrop, depth/time?

…All of these scales are relevant!



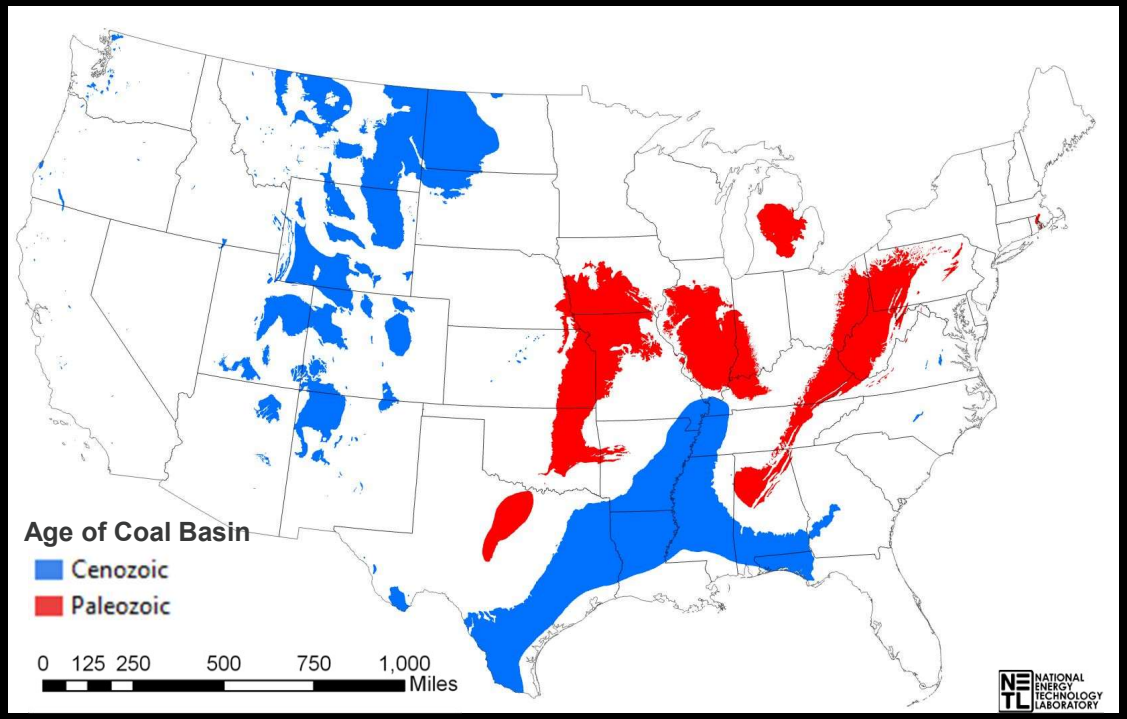
Formation, member, bed, parting, seam?

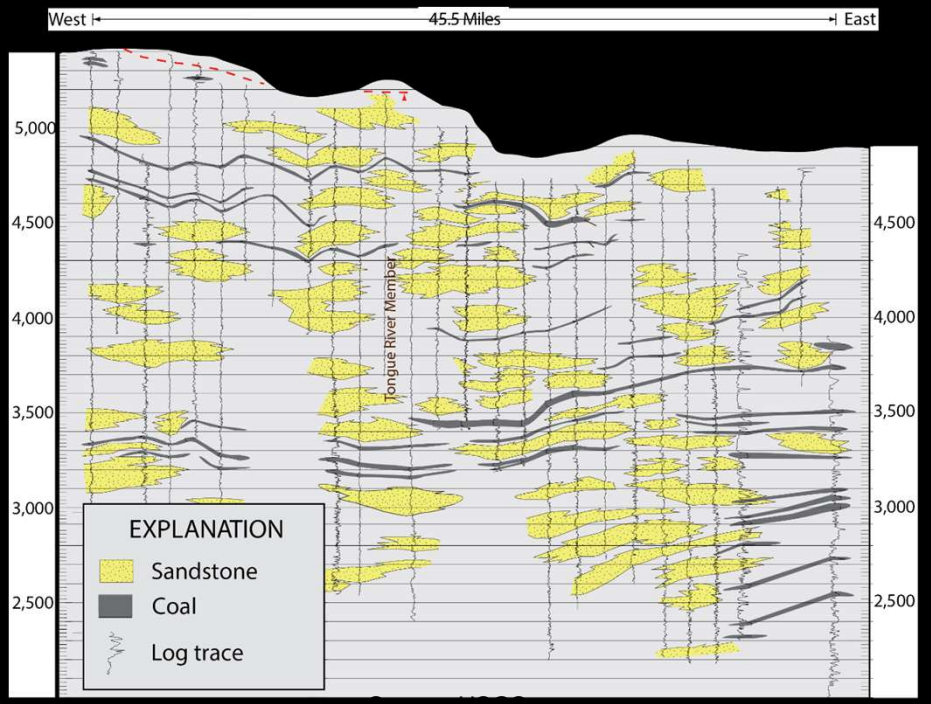


Thickness, composition?

Devil's in the Details…

- Not all coal basins are created equal
- Subsurface complexity results in 3D heterogeneity

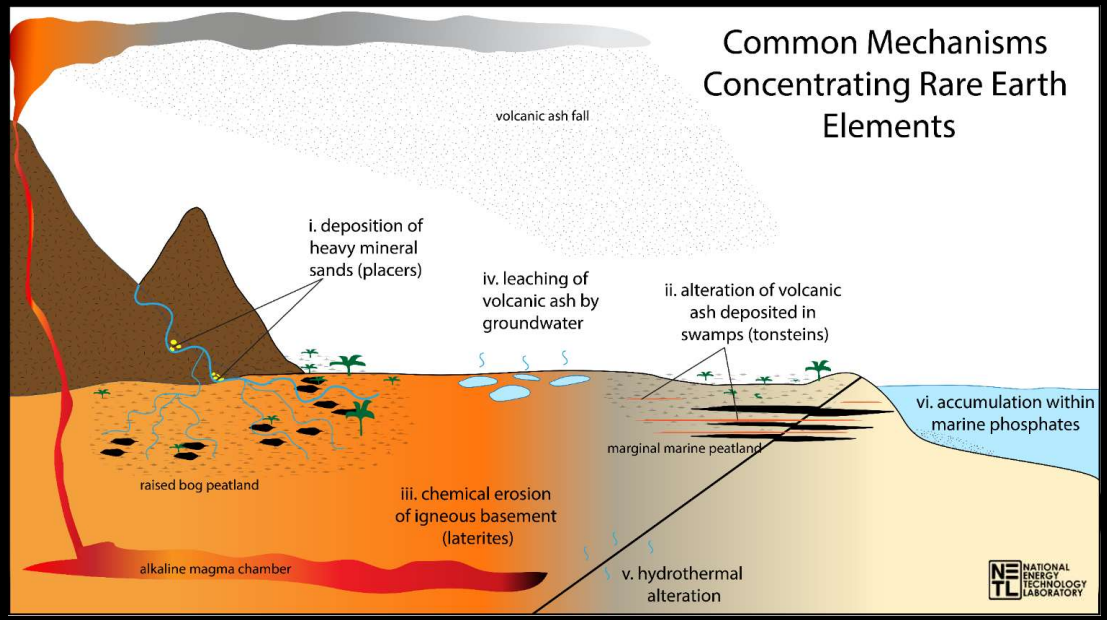




Challenge: Assessment method must address different REE Coal Enrichment Mechanisms

Step 1 - Knowledge Review

- **Comprehensive review of >100 publications**
- **Focused on better understanding the occurrence of REE's in sedimentary systems and the geological factors that influence the distribution of REE's in coal deposits**



Key takeaways

1. **REE concentrations more likely** to increase if host strata is spatially and temporally **proximal to REE-rich volcanic sources** or **REE-rich bedrock**
2. Post-depositional **geologic history** of the coal basins **influences concentration mechanisms**
3. Coal **depositional environment is important**
   - Freshwater vs. marine setting can impact concentration mechanisms
4. **Type and abundance of coal forming plants vary through geological time and space**
   - Coal depositional environments changed with geological evolution of plants and tectonic environment

REE Distributions in coal-bearing strata depend on Time and Space

- Evolution of coal-forming plants
- Coal basin history
- Mechanisms of REE enrichment
- Proximity of basins to REE volcanic sources
- KEY: spatial-temporal gaps in REE sample data

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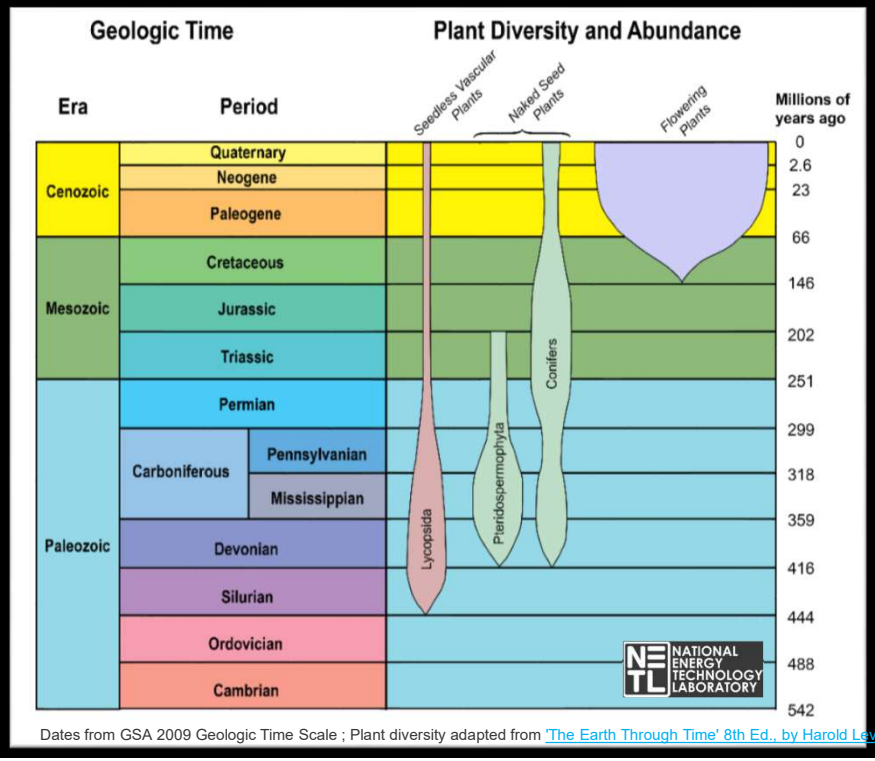
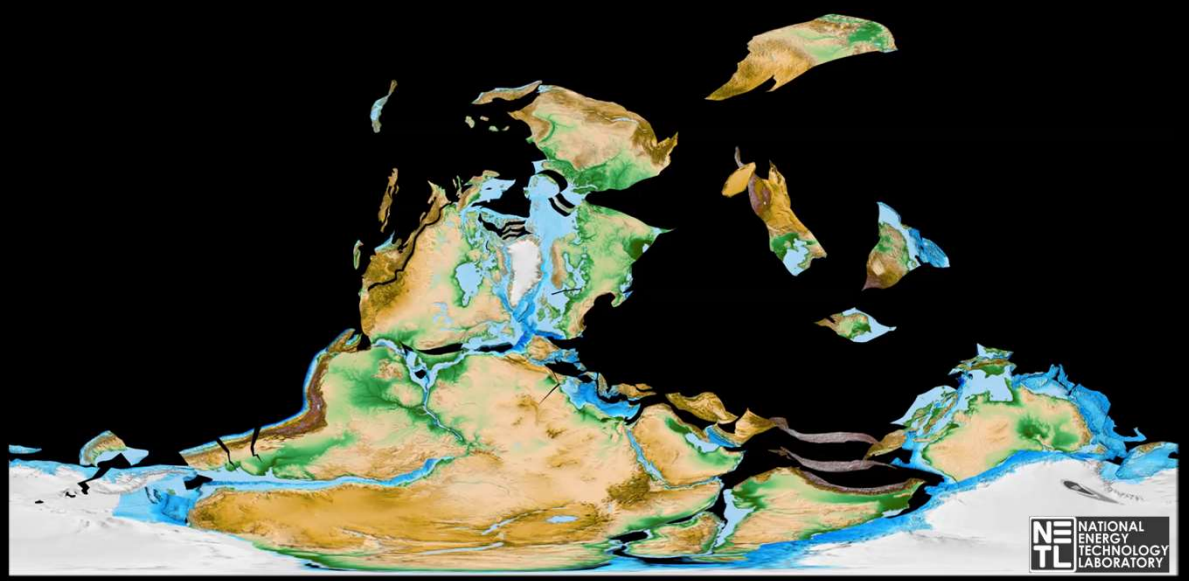
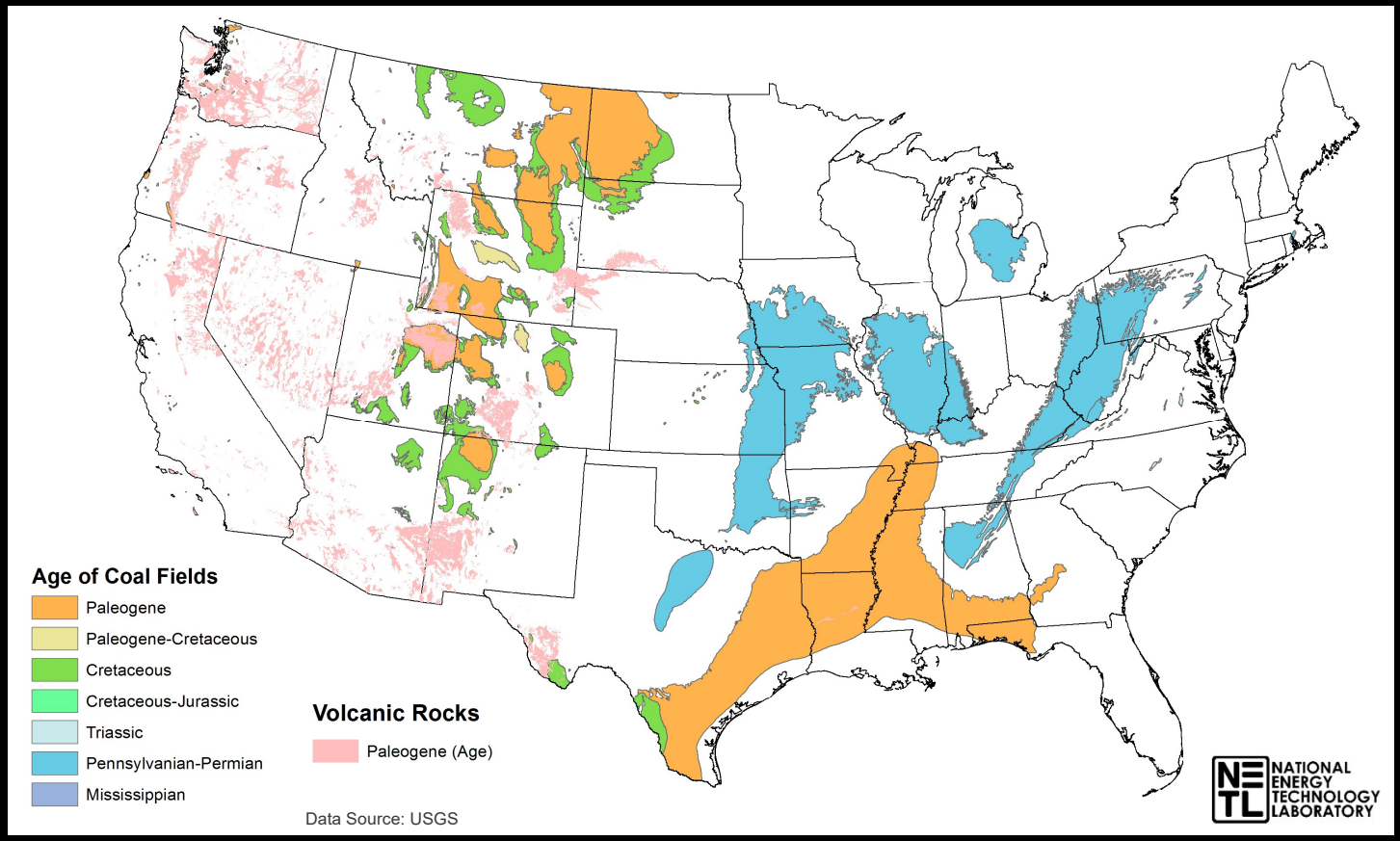


Dates from GSA 2009 Geologic Time Scale ; Plant diversity adapted from 'The Earth Through Time' 8th Ed., by Harold Levin

Configuration of continents through time (323 MYA to present)



US Coal Fields and Paleogene-aged Volcanic Rocks



Note relative proximity of Western US Coal basins to volcanism during times of deposition (i.e., basins located near volcanic rocks of similar age)

Depositional environment of Paleogene coal fields

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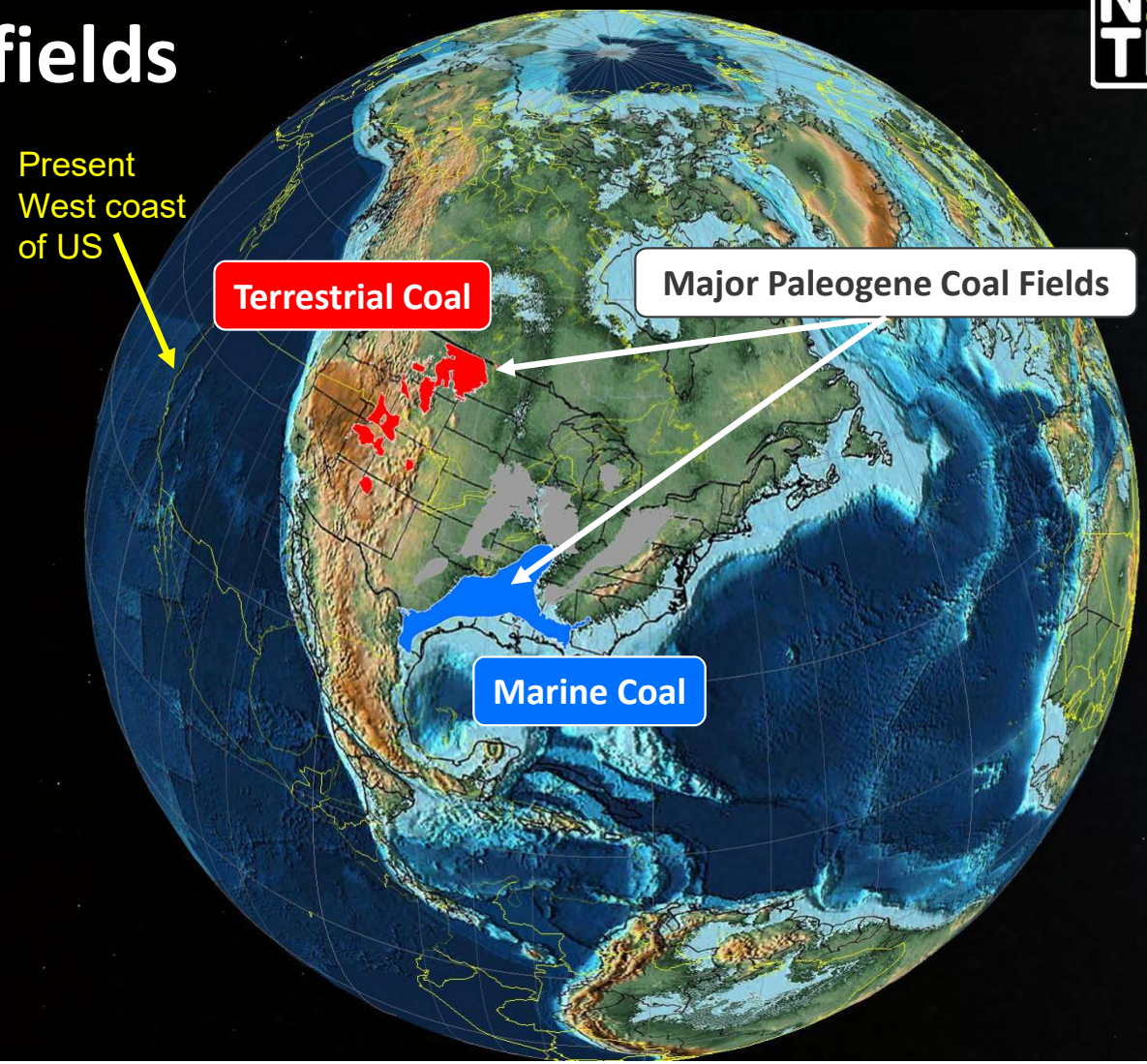
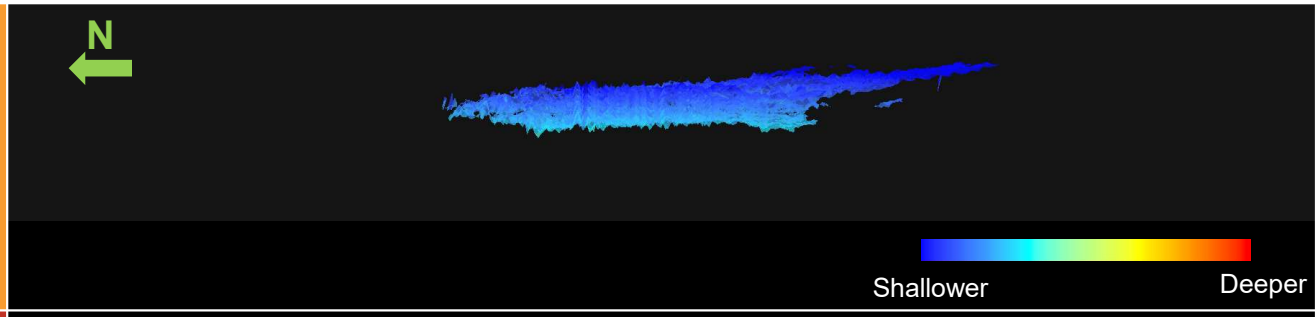
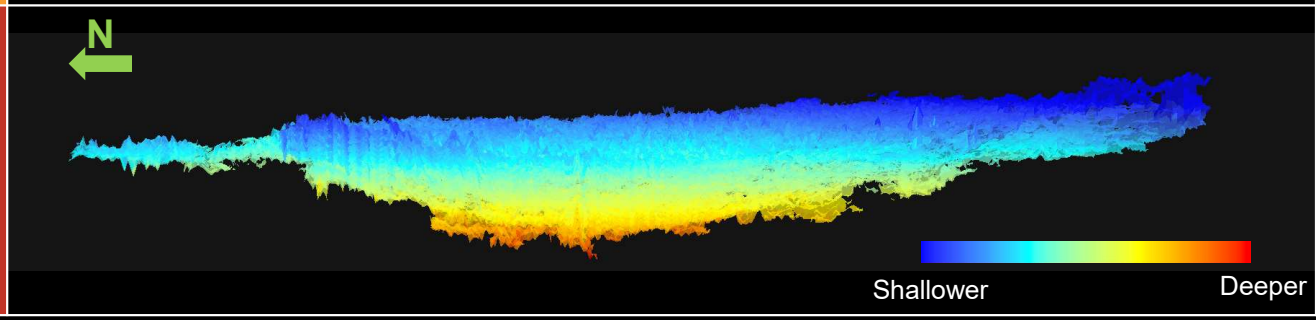
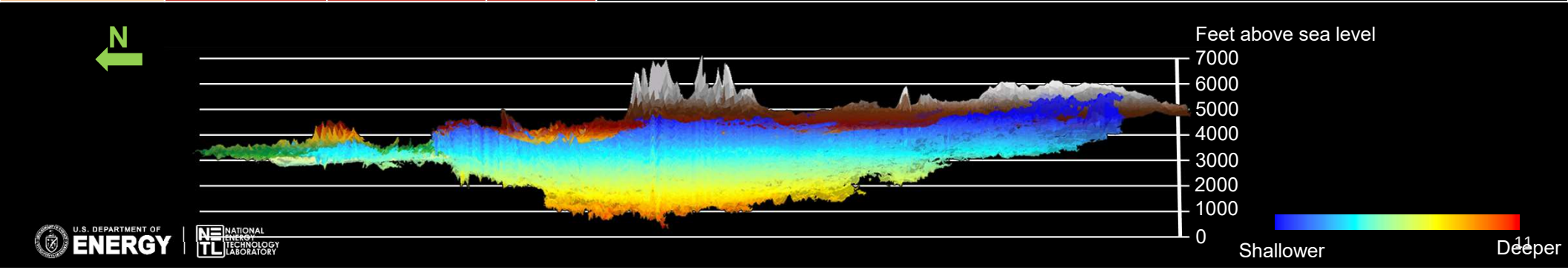
Era	Period	Millions of years ago
		0
Cenozoic	Quaternary	2.6
	Neogene	23
	Paleogene	66
Mesozoic	Cretaceous	146
	Jurassic	202
	Triassic	251
Paleozoic	Permian	299
	Carboniferous: Pennsylvanian	318
	Carboniferous: Mississippian	359
	Devonian	416
	Silurian	444
	Ordovician	488
	Cambrian	542



Period	Epoch	Formation	# of coal beds	3D Visualization by depth (10X vertical exaggeration)
Paleogene	Eocene	Wasatch	7	
	Paleocene	Fort Union	40	



Challenge: Integrate and Evaluate "Big" Datasets

Key Points

- **Mixed/multiple data sources**
- **Inconsistent scale of data**
- **Homogenized samples lose vertical resolution of resource enrichment**
- **Managing large database**
- **Incomplete records within datasets (e.g., different analyses for related samples)**

The **inherent complexity** of these systems & data resources, coupled with **heterogeneous** and **ambiguous** data, provide **unique challenges** when trying to assess and predict REE distributions and occurrences in sedimentary, coal related strata

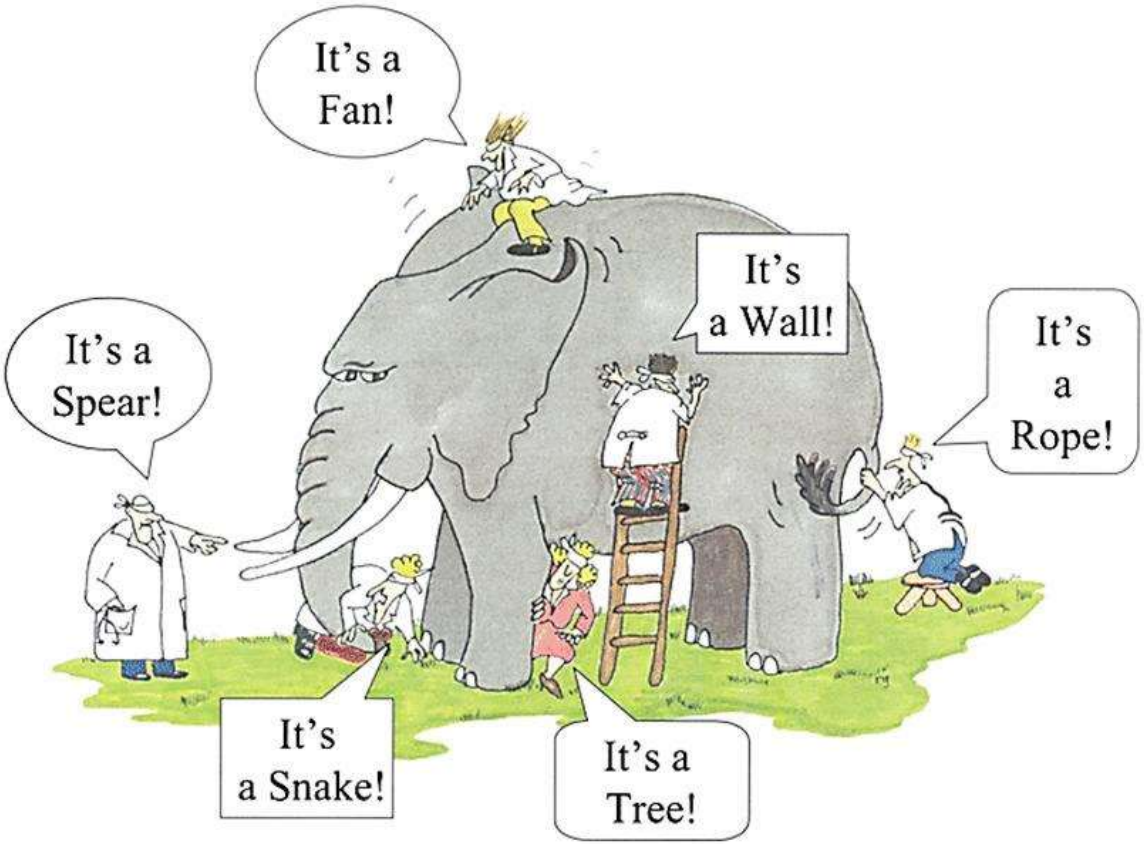
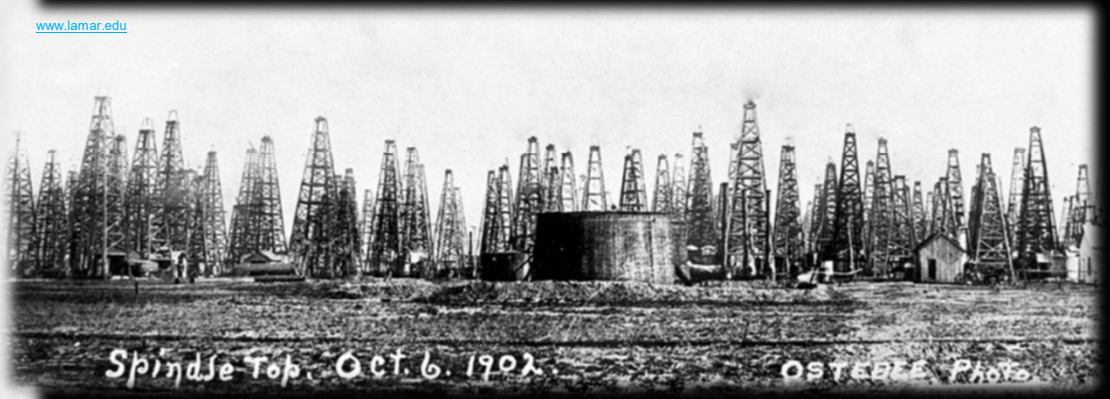


Image from G. Renee Guzlas (available at http://shreddedbyscience.com/six-blind-men-one-elephant-and-an-educated-guess/)

Systematic Assessments Work

Oil & Gas Exploration, 1900's



Random grab samples & "probing" are costly

Systematic, geoscience founded, methods & models are key to **efficient & effective** natural resource exploration

Approach: Developing a REE Coal Assessment Method

Two main components

1. *Geological Characterization*

Criteria to inform where conditions most favorable for REE-enrichment of coals

- **Geological data** (cores, well logs, coalbed depth/thickness; USGS US-STRAT, USGS CRAs, surficial geology)
- **Geochemical data** (coal and other samples; USGS CoalQual, NUREsed, NGS, and NGD)
- Existing information/data for **known REE occurrences** (USGS bedrock deposits)
- **Coal basin geohistory** to identify potential enrichment mechanisms (e.g., syndepositional volcanism)

2. *Spatial/Volumetric Assessment*

Tools used to assess REE coal spatial extent and assess REE coal resource potential

- **Geostatistical analysis** of geological/geochemical data to identify spatial patterns/anomalies in both regional and local scale (cluster and or hot spot analyses)
- Seam-based **geometry calculations** using core data, other geological data (generate circular cross sections? 3D model?)
- Local/regional **coal production history**

Approach: Developing a REE Coal Assessment Method

Component 1

1. Geological Characterization

Criteria to inform where conditions most favorable for REE-enrichment of coals.

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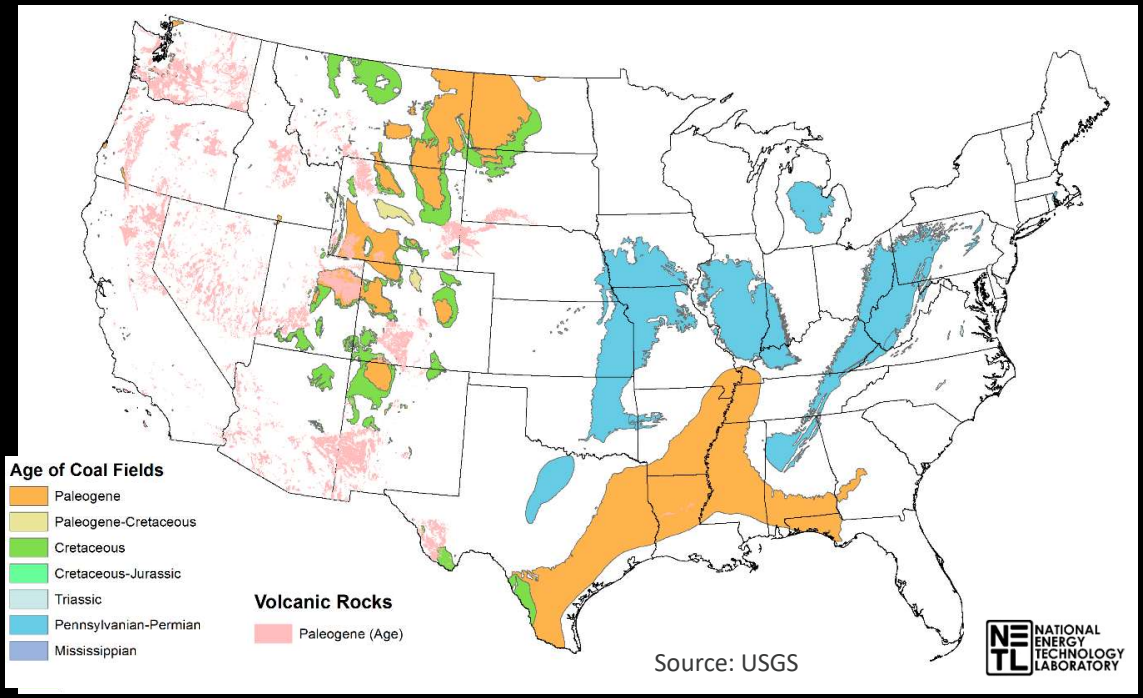


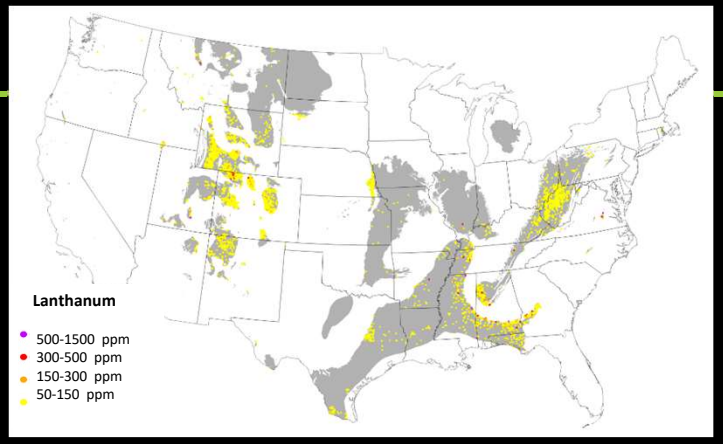
Approach: Developing a REE Coal Assessment Method

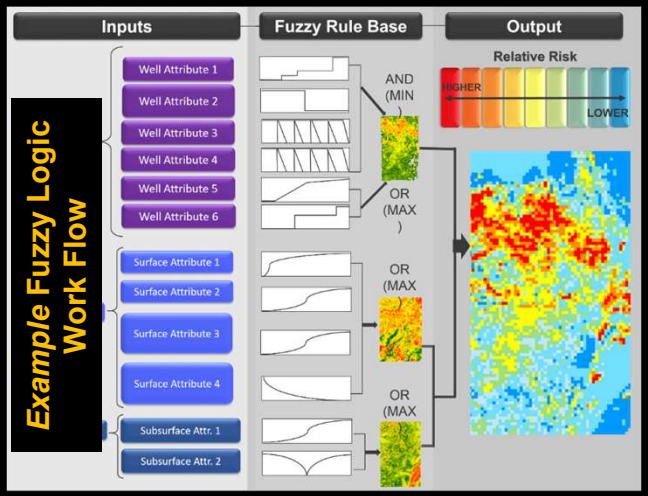
Component 2

2. Spatial/Volumetric Assessment

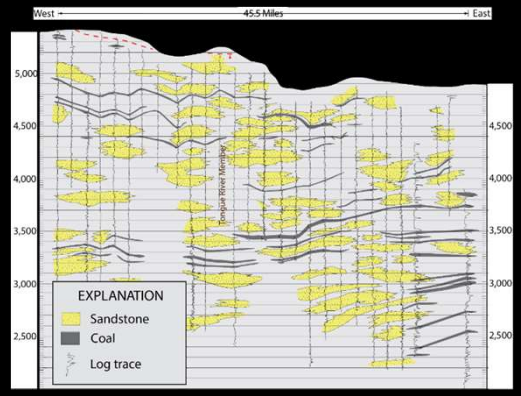
To assess REE coal spatial extent and assess REE coal resource potential

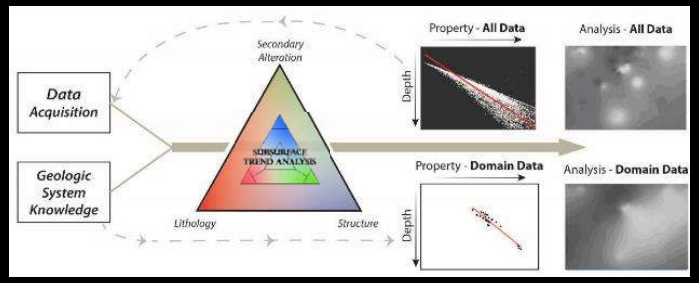
- **Geostatistical analysis** of geological/geochemical data to identify spatial patterns/anomalies in both regional and local scale (cluster and or hot spot analyses)
- Seam-based **geometry calculations** using core data, other geological data (generate circular cross sections? 3D model?)
- Local/regional **coal production history**
- Advanced computing approaches





Bauer et al in prep



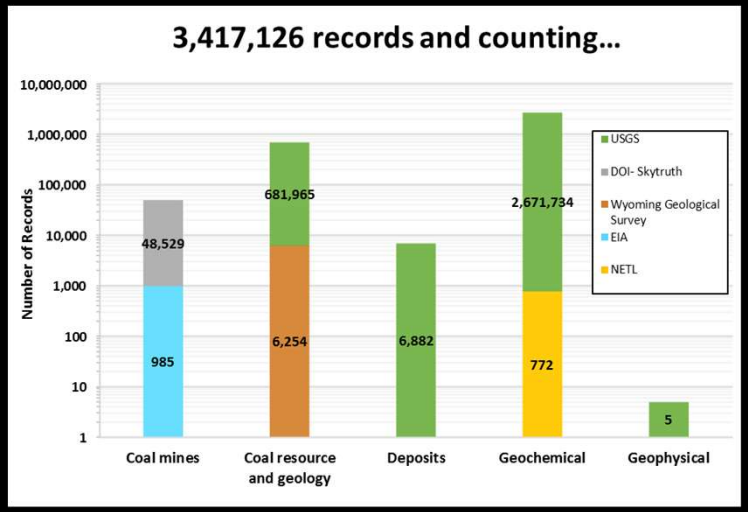


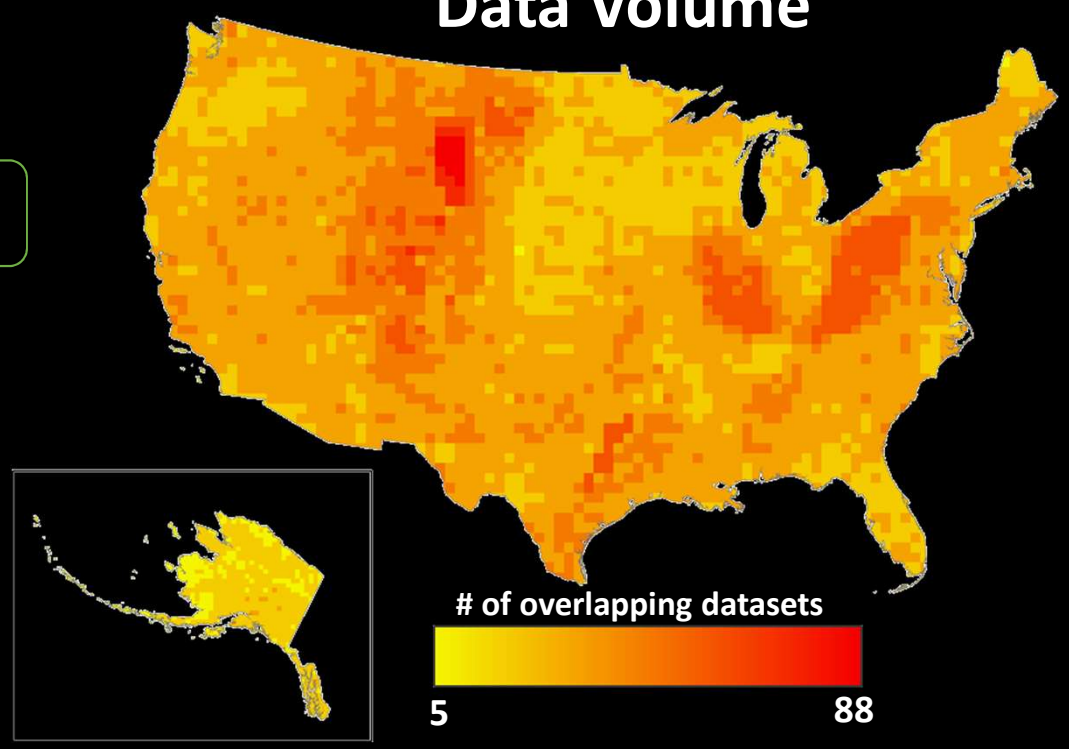
Rose 2015

Challenge: Compile and Evaluate Field Datasets

From NETL, USGS, EIA, State Geological Surveys, etc

- Compiled database of over 200 publicly available, basin- and national-scale spatial datasets
- Determined relationships between REE concentrations and distributions
- Identified critical information gaps and **future data needs** for testing of resource assessment method





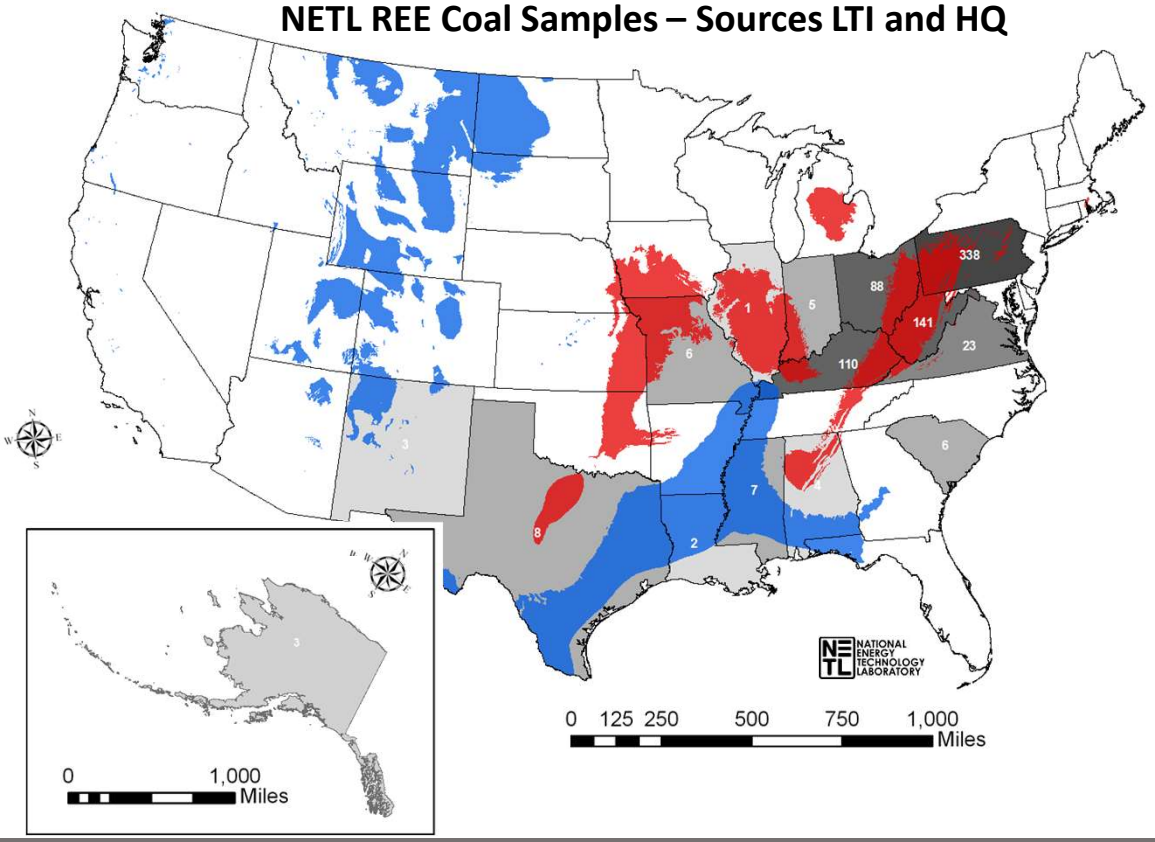
Challenge: Data Gaps & Scale of Data

Key Points

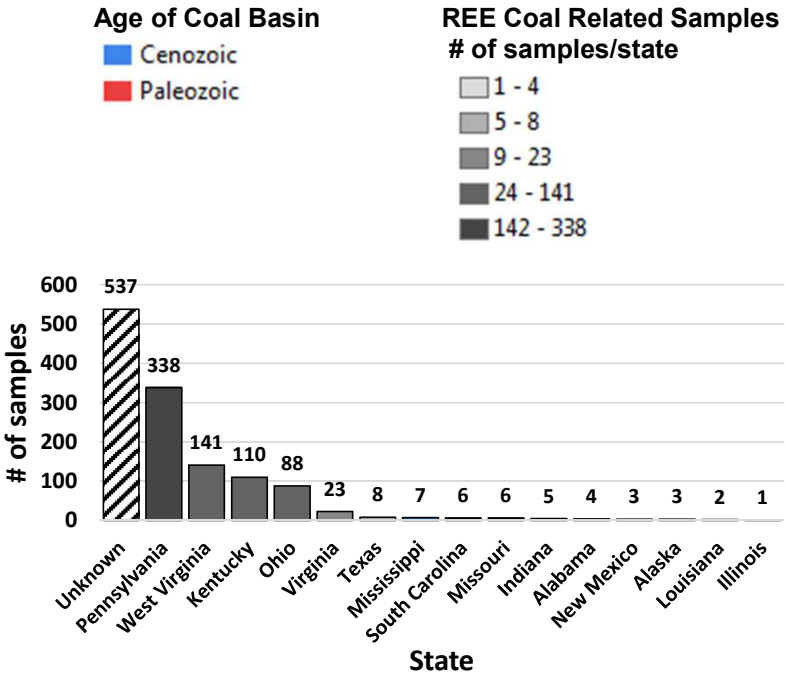
- **Sample collection biases (over or underrepresented coal fields)**
- **Precision of spatial location data**
- **REE resource may be independent of coal quality**
  - High REE potential may occur in marginally economic coal fields
- **Selective mining of high concentration resources may require vertical (depth) constraints**
- **REE resource may be concentrated in mine reject piles**
  - (not in CoalQual data)

Challenge: Regional Data Gaps

Paleozoic vs. Cenozoic Coals

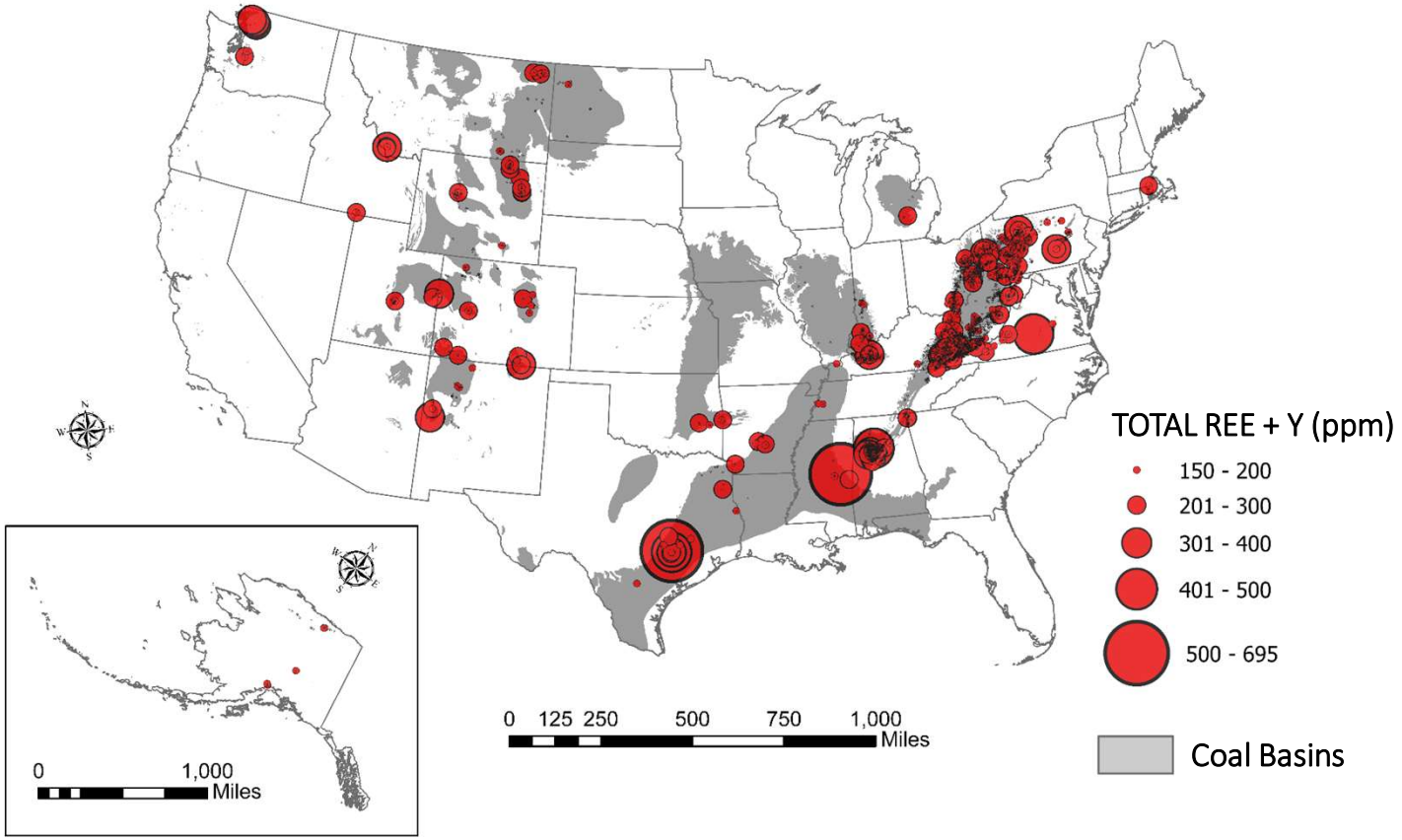


- 514 samples from LTI
- 768 samples from NETL-HQ (**258 available on EDX**)
- **Total = 772 samples**



Challenge: Regional Data Gaps

USGS CoalQual Data – Total REE + Y (>150 ppm)

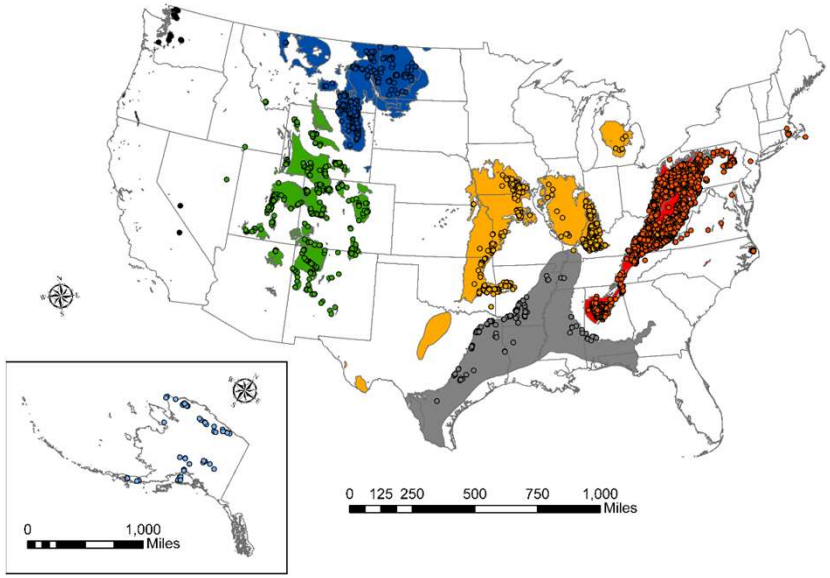


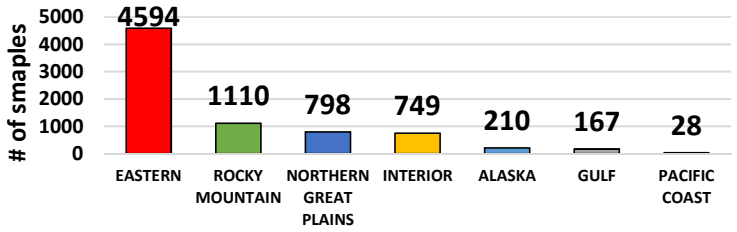
KEY POINTS

- High REE measured in coal basins nationwide
- **Highest values observed in data sparse regions**

Need better sample data to support predictions

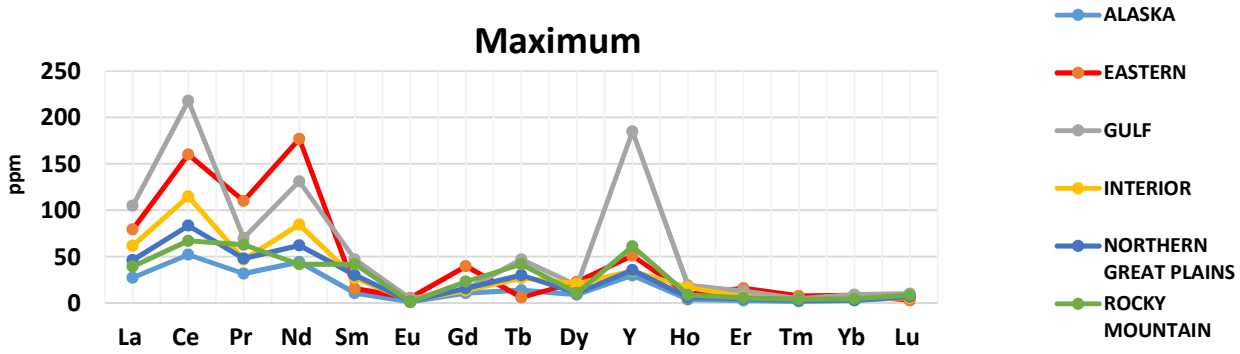
USGS CoalQual Data example





KEY POINTS

- **Samples vertically homogenized** (averaged) across coal seams
- Own their own, these measurements are not enough
  - Need to integrate measured information with other measurements and contextual information to inform prediction



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REE Sample Data

What is needed?

- **Sample ID**
  - Unique ID, Project ID, Lab ID, Stratigraphic ID (CoalQual), API #
- **Sample Description**
  - Material, Sample Type (hand sample, drill core, fly ash, etc.)
  - Seam Name, Seam Thickness, Stratigraphic Association
  - Sample Status
- **Geolocation Information**
  - Lat./Long., UTM, Depth
- **Site Characteristics**
  - Site Name, Lithology of Adjacent Rock
- **Collection Information**
  - Name of Collector, Date Collected, Date Analyzed, Date and Reference for Analyses Published
- **Chemical Analysis Information (if available)**
  - Lab Name, Analysis Technique, Sample Prep Method, Alteration, Other Significant Mineralogy, Trace Element Conc., Oxide Conc., REY Conc., Vitrine Reflectance
- **Other Metadata**
  - Contact Info, Links to Data (if published)

Need for a more **systematic**, consistent REE coal/sed **sample acquisition, analytical & database curation approach**

What's the value of data?

- Use data/information to build a more complete picture
- In this era of big data… each small piece helps complete the "puzzle"
- More data/information = more accurate R&D, analysis and predictions

Data image from: http://successflow.co.uk/blog/2015/11/27/data-is-the-new-oil-but-do-you-have-the-resources-to-refine-it/
Darth Vader meme from: https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwjz74Ppw-_XAhUs8IMKHbD-DGIQjhwIBQ&url=https%3A%2F%2Fmemegenerator.net%2Finstance%2F65615215%2Fdarth-vader-if-you-only-knew-the-power-of-data&psig=AOvVaw1hC87vj7bHefAdUm4Qrdc5&ust=1512448477268414:

https://edx.netl.doe.gov

Underpinned by A Virtual Library & Laboratory for Energy Science

- Virtualizing team analytics
- Continued innovations to connect DOE FE affiliated researchers to online resources (tools, data, etc)
- Increasing # of tools and apps for use in team workspaces
- **In development since 2011**

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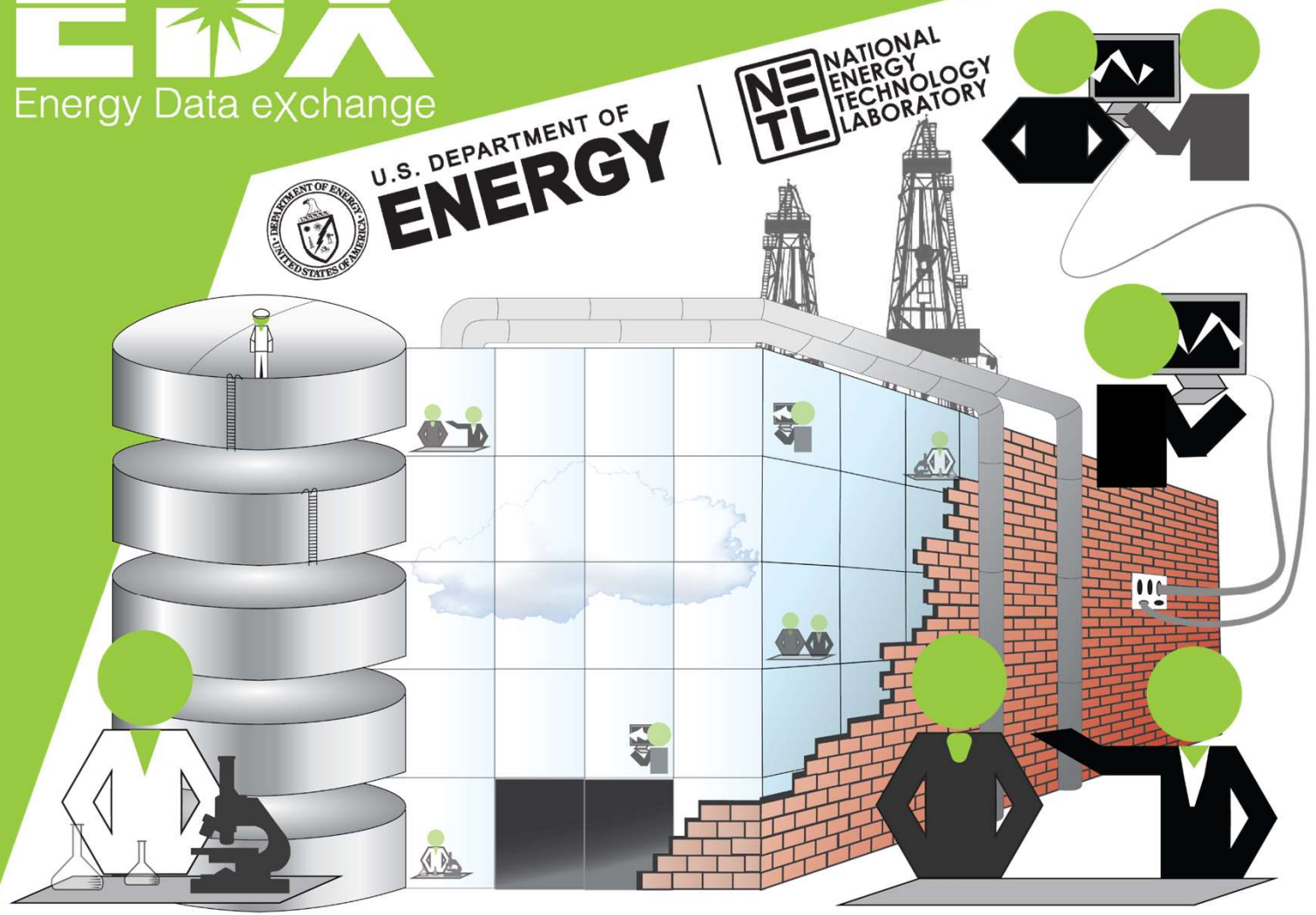
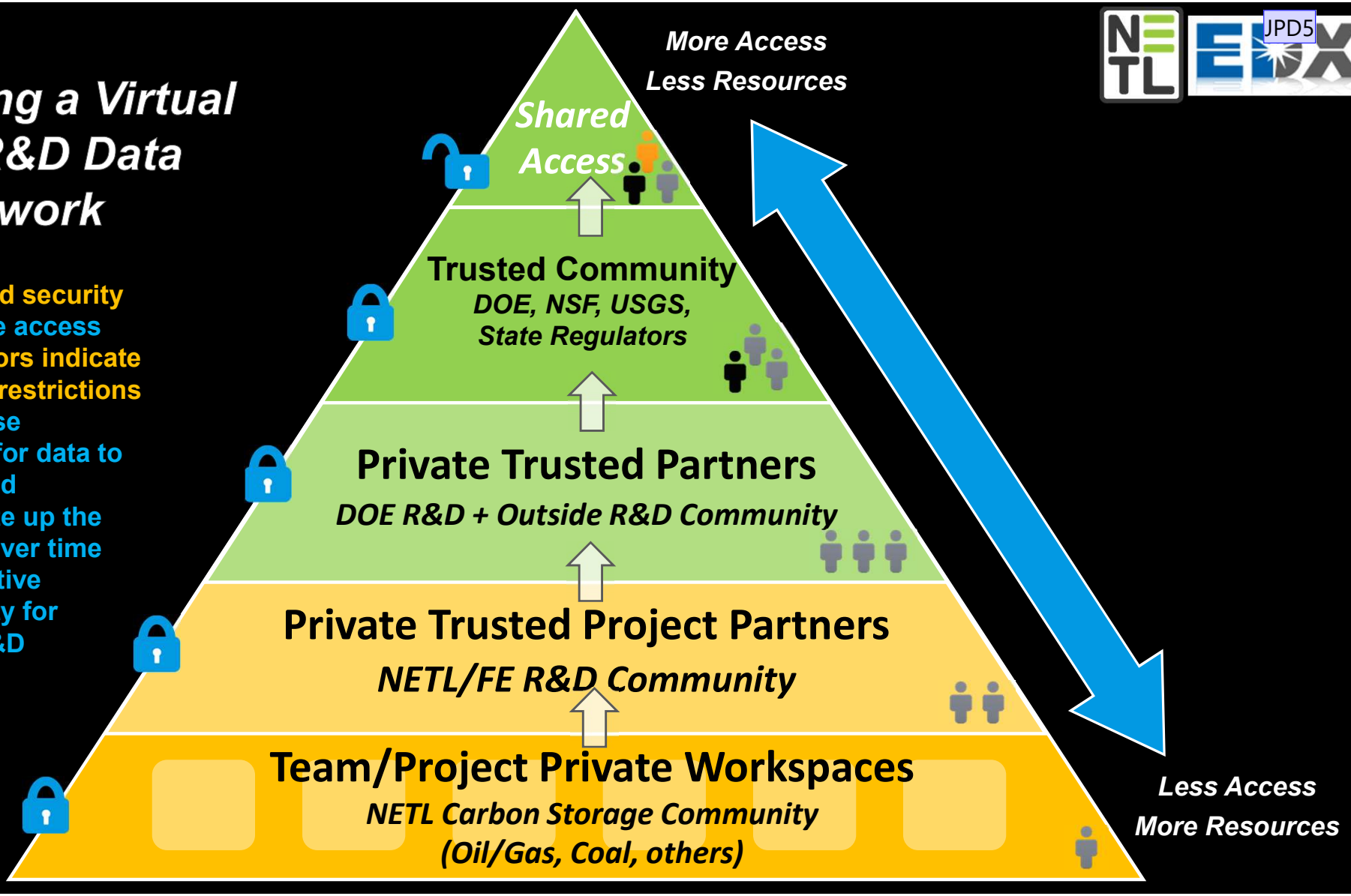
EDX
Energy Data eXchange



Building a Virtual DOE R&D Data Framework

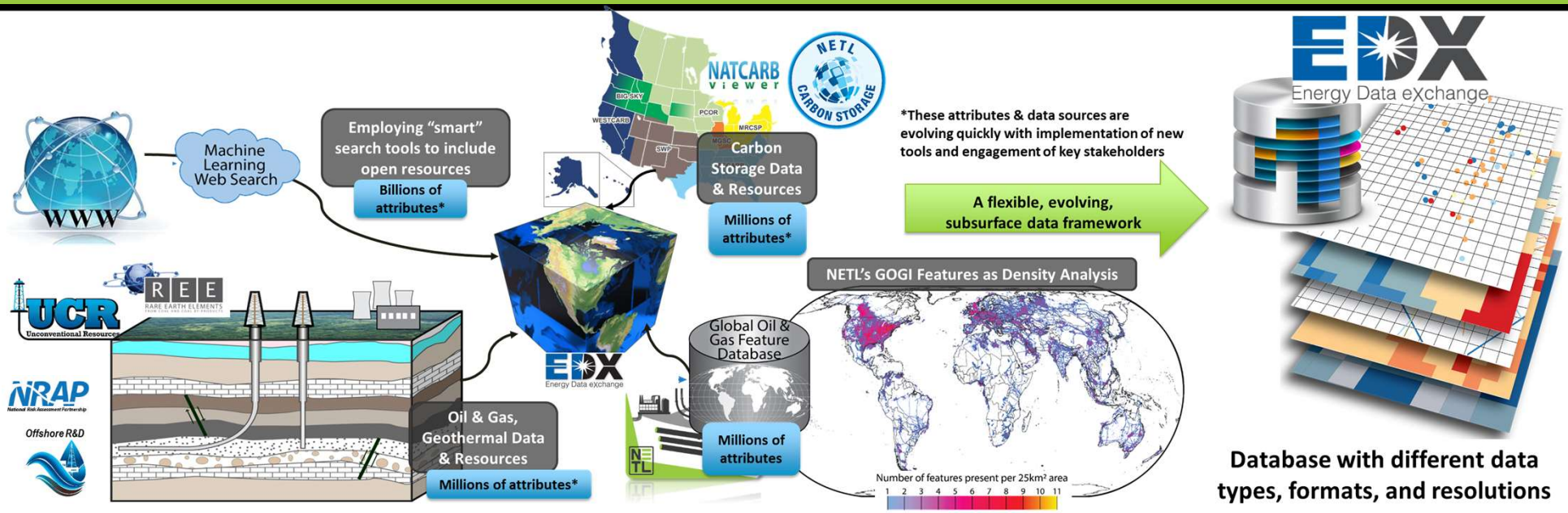
- Role based security to manage access
- Contributors indicate "license" restrictions on data use
- Potential for data to mature and matriculate up the pyramid over time
- Collaborative community for energy R&D



Slide 25

JPD5 Add EDX Logo.
Jennifer P. DiGiulio, 7/7/2017

Advanced Data Computing & Tools to develop a Virtual FE R&D Data Framework



Combination of advanced, big data driven, tools & capabilities, hosted **via <u>private</u> side of EDX** to **build a virtual data system for DOE FE** researchers:

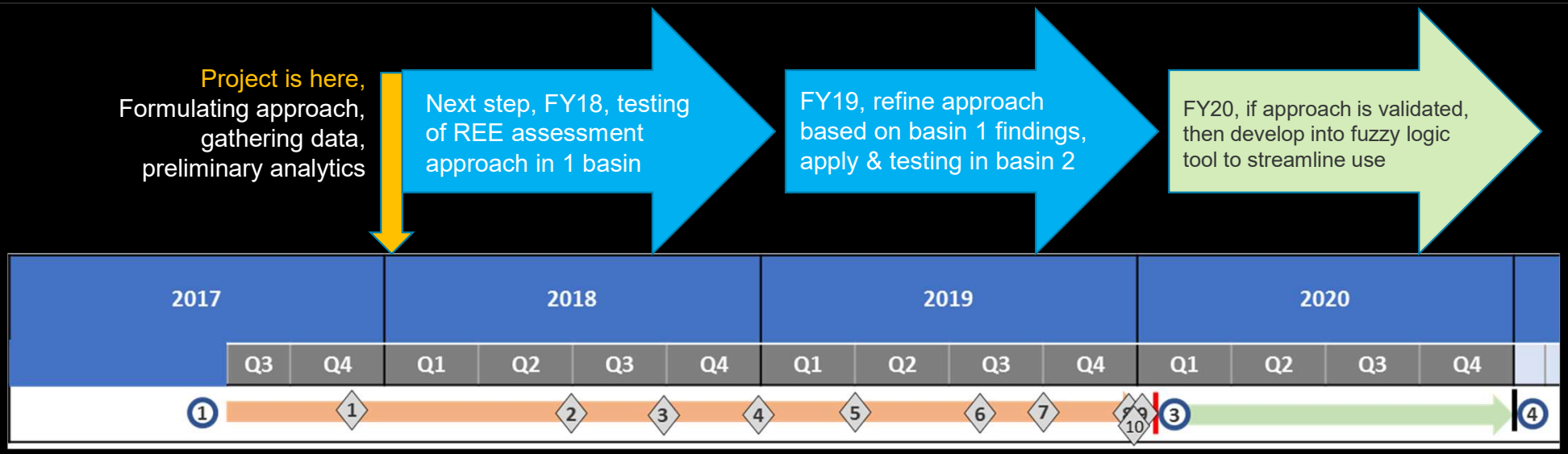
- **Federating** with billions of open-source, online data sets
- Offering data through **EDX Geocube,** a spatial data tool, or via **direct search on EDX**
- Gradually **identifying key data gaps**, and **filling** in the U.S. subsurface data puzzle.

Rose, K., Baker, D.V. "Vic", Bauer, J., Dehlin, M., Jones, T.J., and Rowan, C., 2017, Working Smarter Not Harder – Developing a Virtual Subsurface Data Framework for US Energy R&D, invited talk, American Geophysical Union Annual Meeting, **<u>IN035. Increasing the bandwidth of imaging-data-to-research pipelines, AGU Fall 2017 Meeting</u>**

Ongoing collaboration/coordination

- **Connected with several REE science teams at Idaho National Laboratory, and University of Wyoming**
  - pursued studies related to REE and geothermal systems, including in relation to oil and gas field's produced waters
  - potential to explore other prospecting techniques to help drive out year assessments and technology development...
- **Univ. of Wyoming Carbon Management Institute –Subcontract to collect vertically constrained core material through Powder River Basin Wyodak Core. Including-high gamma ray section**
  - To Date, 50 samples have been ashed and await analysis
  - Continued discussions and potential samples to be collected with industry partners of the Carbon Management Institute
- **USGS**
  - Preliminary discussions with Dr. Ruppert at the USGS (Appalachian Basin-Coal) regarding the coordination and collaboration of our efforts with their CRA methodologies
  - We decided it was appropriate to discuss a MOU for this effort to facilitate exchange of samples and USGS coalbed assessment maps
  - Peter Warwick (POC Gulf lignite), Brian Schaffer (POC for Powder River Basin)

Ongoing Efforts



- Test and demonstrate method in select basins
- Help determine if REE concentrations and volumes support commercial extraction in priority U.S. coal bearing sedimentary basins

Next steps

- Gather and evaluate relevant data for initial assessment of priority basin(s)
- Continue collaboration with geochemistry experts at NETL and the U. of Wyoming to provide validation/calibration field data for PRB
- Incorporate Subsurface Trend Analyses in the assessment approach
- Prepare and publish catalog of data aligned in REE coal assessment needs
  - Integration into Geocube tool hosted on EDX for public access

Building a Geo-Data Science Method to Predict Coal REE Prospectivity

NATIONAL ENERGY TECHNOLOGY LABORATORY

Geo-Data Science Team:

- *Geochemistry* - Scott Montross & Burt Thomas
- *Geology* - Emily Cameron, Gabe Creason, Jenny DiGuilio
- *Geostatistics, GIS, Geology* - Devin Justman, Roy Miller & Kelly Rose
- *Data/Database Scientist* – *Mike Sabbatino*

Thank you

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