

$C_M C_S C_F C_B$

Critical Minerals in Coal Strata of the Cherokee-Forest City Basin

Franek Hasiuk, PhD



Conservation and Survey Division

Studying Nebraska and
Serving Nebraskans for 128 years

128 YRS
CSD
1893-2021

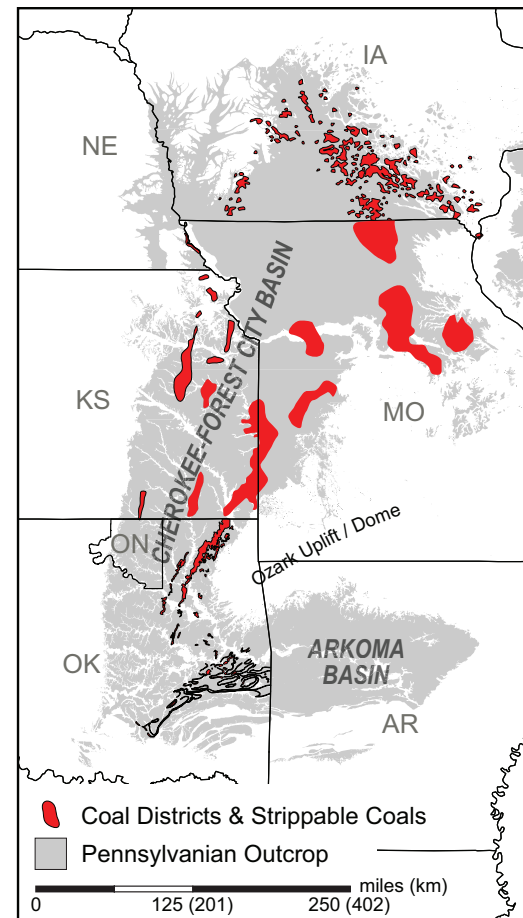


 **OSAGE**
Minerals Council

Summary

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- Five states and an Indian nation working together
- Targeting Pennsylvanian coals and associated sedimentary strata
- Testing multiple hypotheses for CM enrichment
- Aggregating data across the basin to build a new stratigraphic and structural model
- Performing CM resource assessments across the basin using geochemical data hung on new basin model



Teams and Team Members

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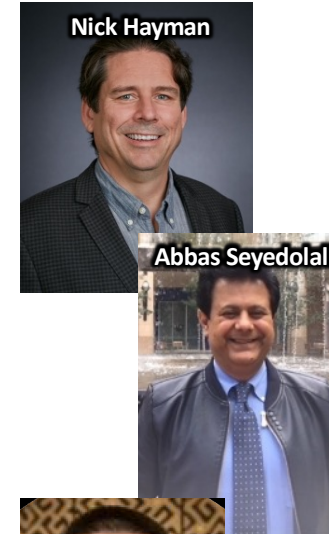
Kansas



Iowa



Oklahoma



Missouri



Osage



Nebraska



Technical Advisory Board

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- Scott Honan, NioCorp
- Clay Hartley, Phoenix Coal Company
- Rory Martin, Martin Marietta
- Bob Dawson, Iowa Dept of Transportation
- Kyle Halverson, Kansas Dept of Transportation
- Erik Blume, KU Innovation Park
- Phil Heckel, PhD, Emeritus, Univ Iowa
- Dave Newell, PhD, Emeritus, KGS

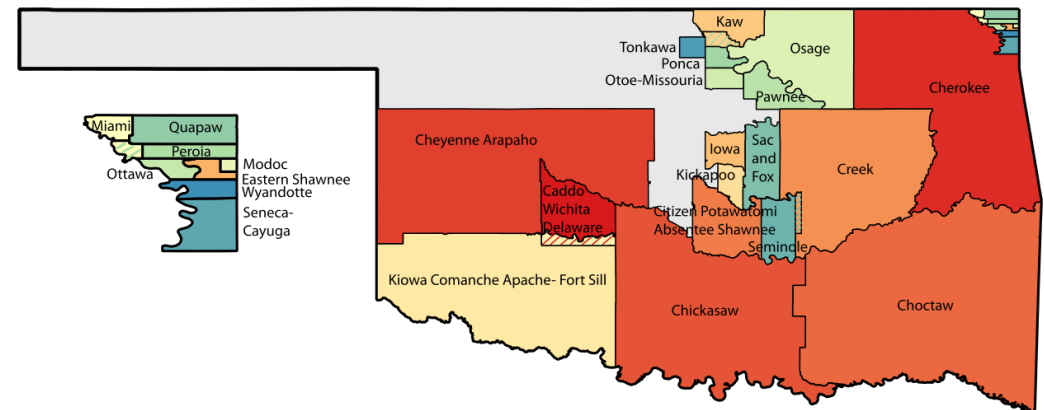


Indian Nations in basin, but not in this project

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- Kickapoo Reservation/Sac and Fox Nation Trust Land joint-use area (KS)
- Prairie Band of Potawatomi Nation Reservation (Kansas)
- Sac and Fox Nation Reservation (Kansas, Nebraska)
- Omaha Reservation (Iowa, Nebraska)
- Ponca Land Trust (Iowa, Nebraska)
- Winnebago Reservation (Iowa, Nebraska)
- Iowa Reservation (Kansas, Nebraska)

- Oklahoma Tribal Statistical Areas
→ First nations advisory council



CoreCM Initiative

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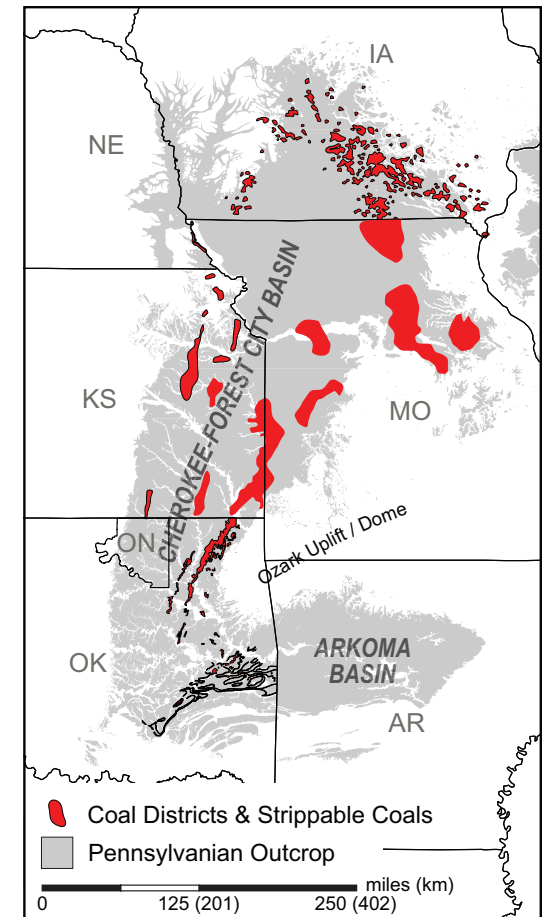
- 13 Awards



Cherokee-Forest City Basin

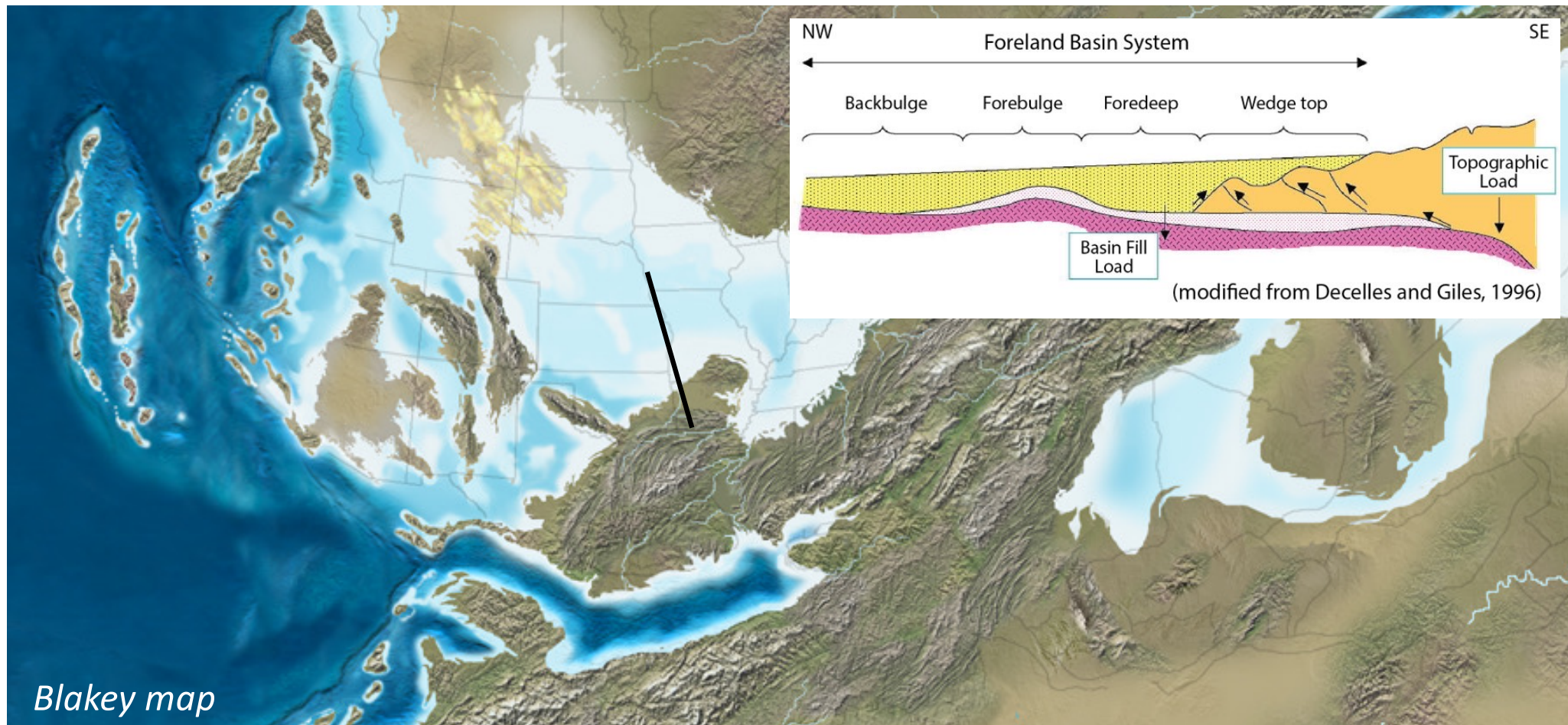
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- Stretches across several Midwestern states and Indian nations
- Legacy of coal mining and reclamation
- Close to industry



Paleo-Geography at 315 Million Years Ago

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Multiple Hypotheses for CM Enrichment

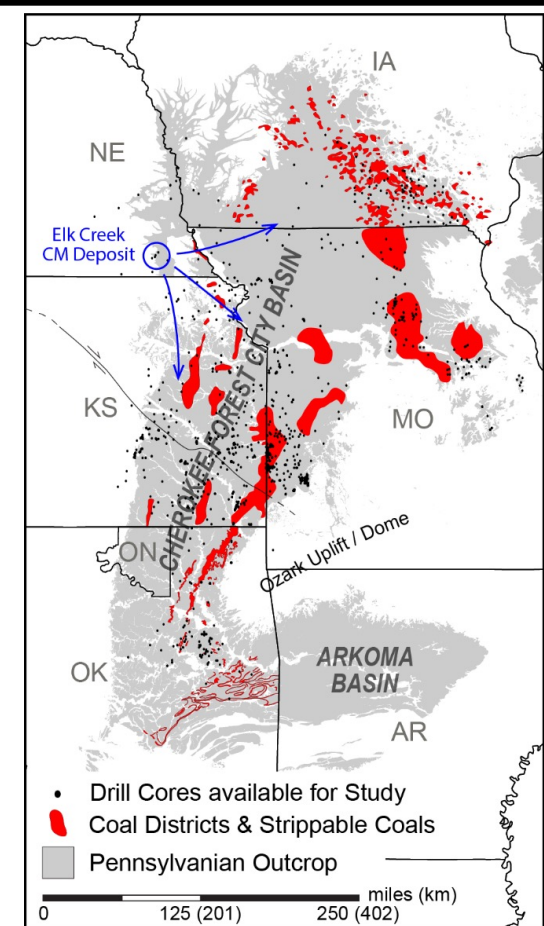
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Elk Creek is a known “world-class” CM deposit (niobium, REEs, scandium, titanium)

- Exposed to erosion during CFCB time

Multiple Working Hypotheses

1. *CM's eroded from Elk Creek and enriched in basin*
2. *Anoxic bottom waters upwelling to deposit CM's into shallower strata*
3. *Something else?*



Oil is First Found in the Mind

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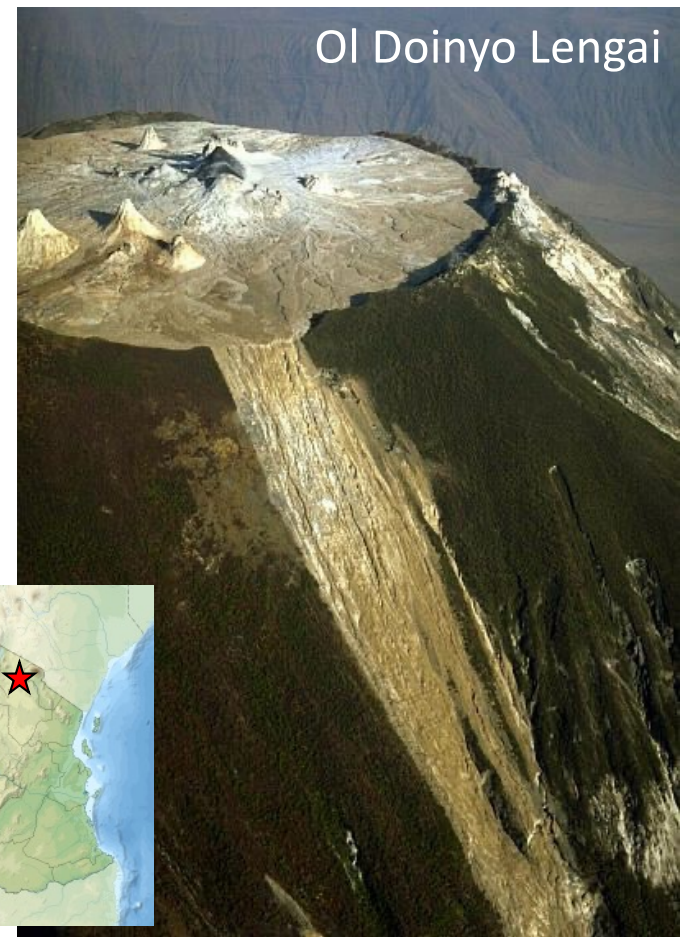
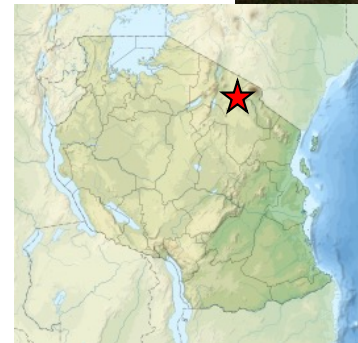
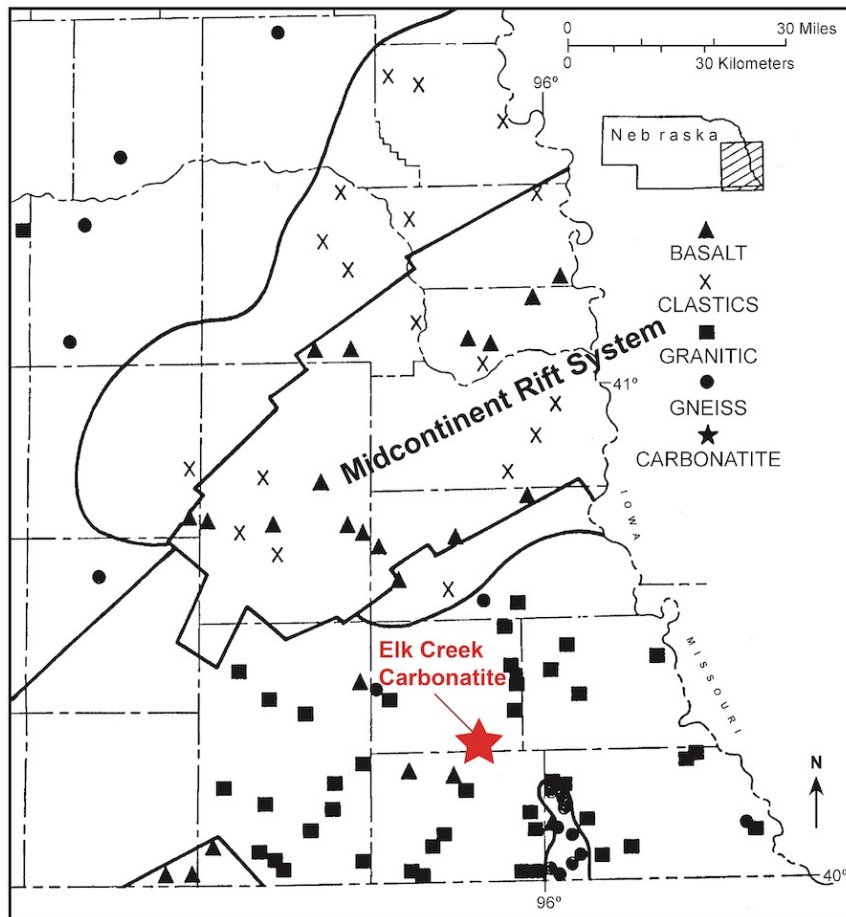


Wallace Pratt

*Petroleum Geologist,
Hat Enthusiast*

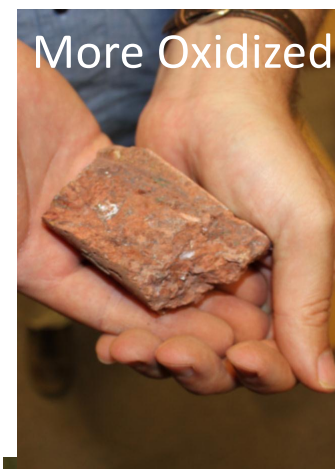
Elk Creek Carbonatite

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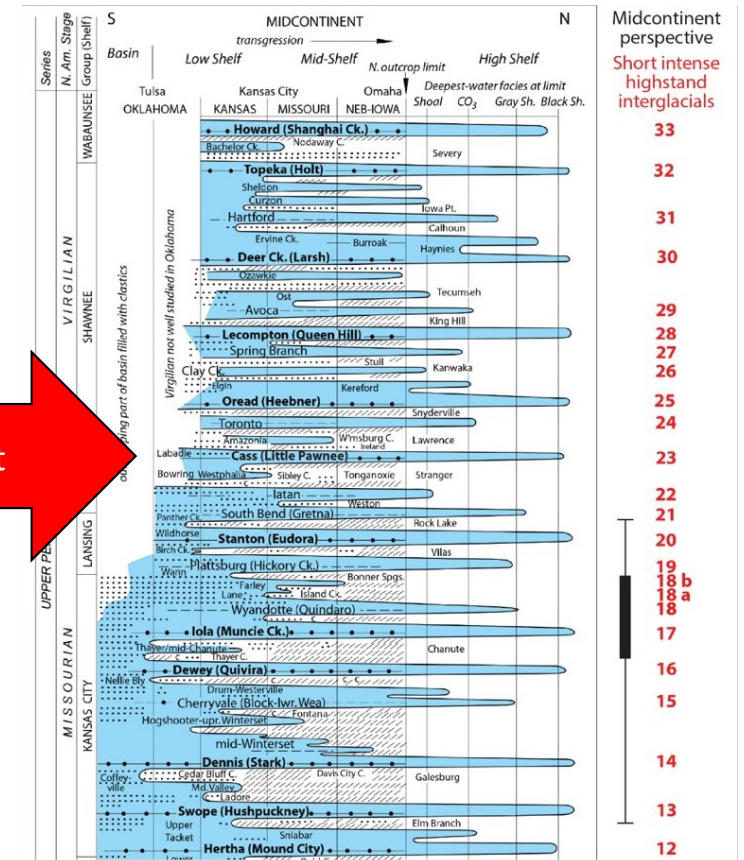
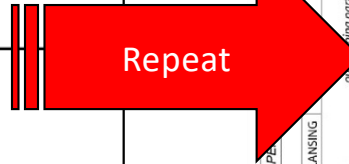
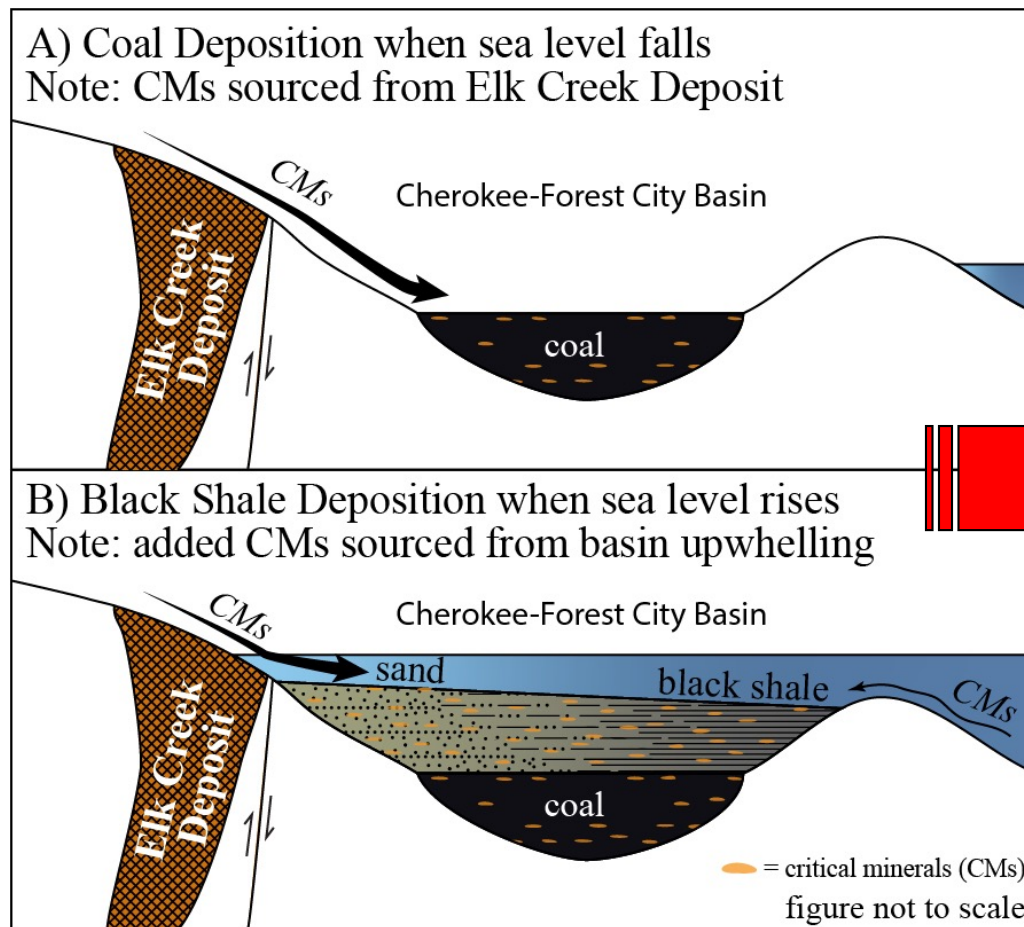
Elk Creek Carbonatite Minerals

- Rock mass is dominantly dolomite— $\text{CaMg}(\text{CO}_3)_2$
- Accessory minerals include barite (BaSO_4) and apatite group minerals (CaPO_4)
- Minerals of the pyrochlore group (usually as very small crystals) contain niobium — $(\text{Na,Ca})_2\text{Nb}_2\text{O}_6(\text{OH,F})$
- Mineral parisite and others contain REEs — $\text{Ca}(\text{Ce,Lu})_2(\text{CO}_3)_3\text{F}_2$



Upwelling is another hypothesis for CM enrichment

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Heckel, 2013; Oborny et al., 2017

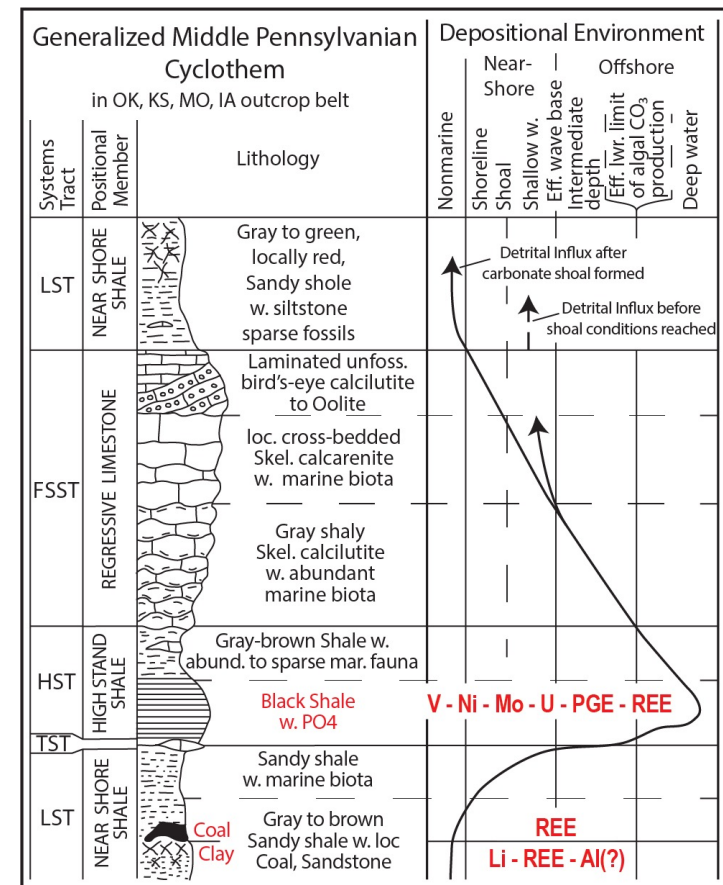
Cyclothems

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- Pennsylvanian-aged repeated cycles of sediment
- Coals/underclays and black shales are the most prospective intervals for CMs
- Adjacent intervals may provide additional resources for CM development or other industries

Generalized, repetitive stacking pattern of Pennsylvanian-aged strata within the CFCB.

Note position of critical mineral targets (coal, underlying clay, and overlying black shale) in **red**.



The Team of Teams

“Western Interior Coal Region Forum” has met
for 45 years to discuss coal issues in CFCB



29th Forum of the Coal Geologists
of the Western Interior Coal Region

Field Trip
May 25, 2005

Phoenix Coal Co. Garland Mine, Bourbon Co., KS
and
Coalbed Methane Operations of
Dart Cherokee Basin Operating Co., LLC
Montgomery Co., KS

Leaders

Lawrence L. Brady and K. David Newell—Kansas Geological Survey

With assistance from

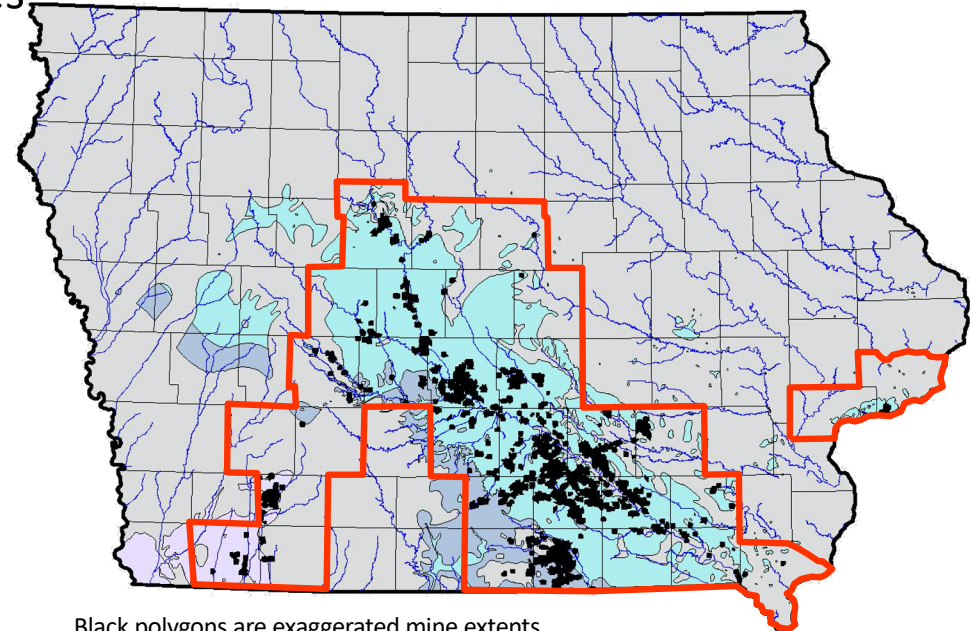
Ron Chaney (Mine Supt.)—Phoenix Coal Co., Garland Mine
Michael Murphy (District Mgr.)—Dart Cherokee Basin Operating Co.



Field Trip Guide

Iowa's Coal Mining History

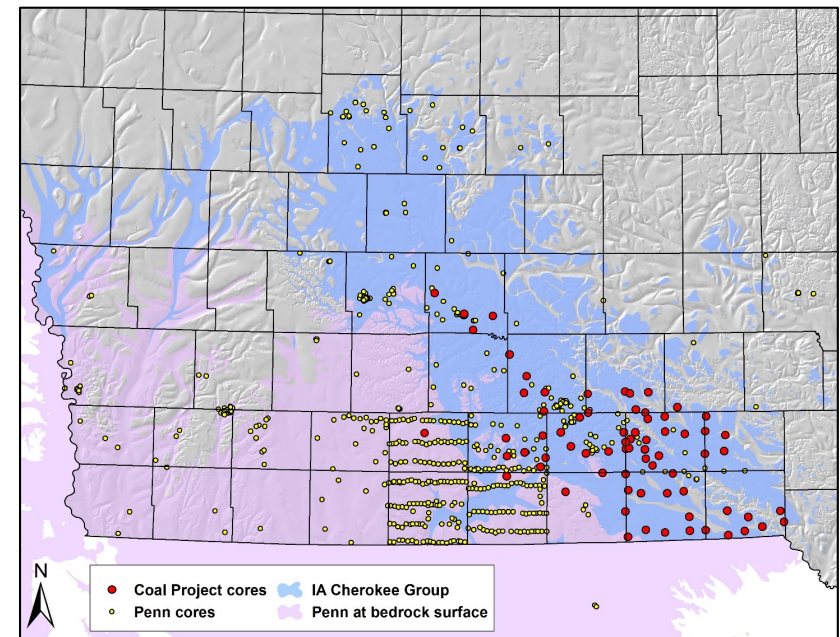
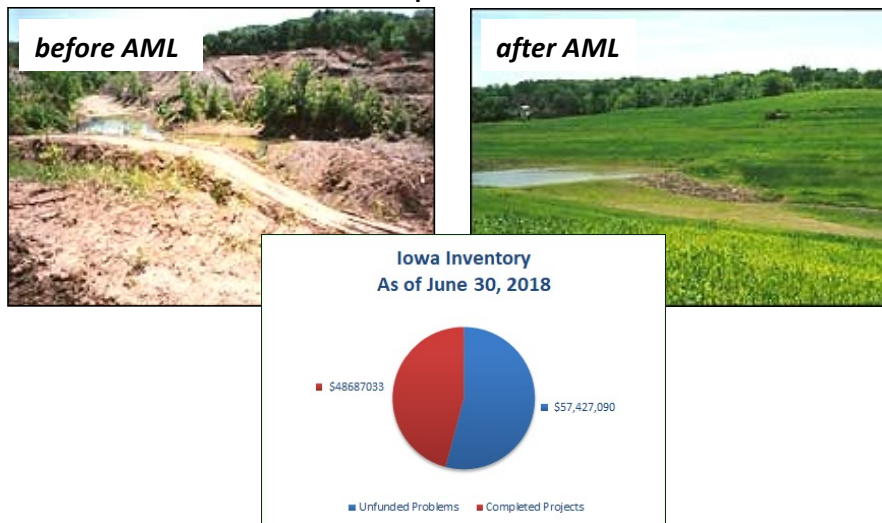
- Coal mined in Iowa from 1840's – 1994 via surface and subsurface workings
- Total estimated reserves 7.4 billion tons (some estimates up to 29 billion tons)
- 48% classified as measured, indicated in seams > 14" thick
- 56% occur in beds >28" thick in 12 counties
- < 10% of reserves have been removed
- Coal bearing region spans $\frac{1}{3}$ of the state
 - Locus of historic mining in 9 counties



Black polygons are exaggerated mine extents

Iowa Coal Data

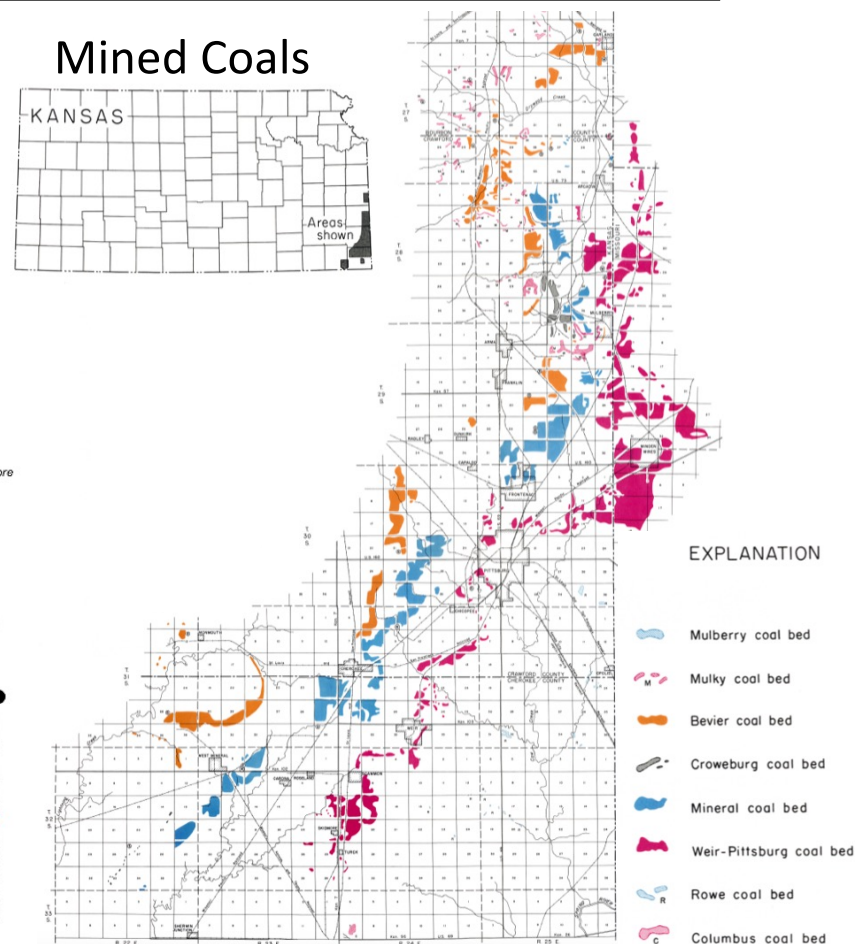
- Coal mine geodatabase – 1,619 polygons, 1,488 points
- IGS Oakdale Rock Library – 729 cores that penetrate Pennsylvanian strata
 - 88 cores from Coal Project in 1970's
- IDALS – Mines and Minerals Bureau handles Abandoned Mine Lands (AML) reclamation
 - Numerous mine waste piles remain



Kansas

- 160 years of production amounting to 300 million tons
- Peak during WWI
- High-volatile bituminous rank
- Early 2000's Coalbed Methane Project

Mined Coals

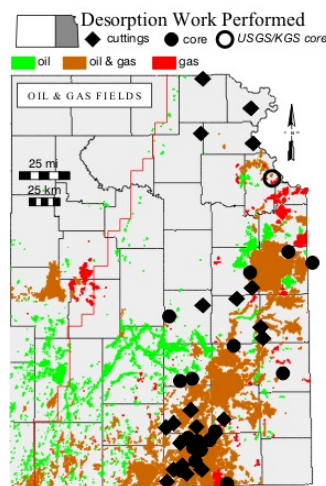


Chemical Analyses of Middle and Upper Pennsylvanian Coals from Southeastern Kansas

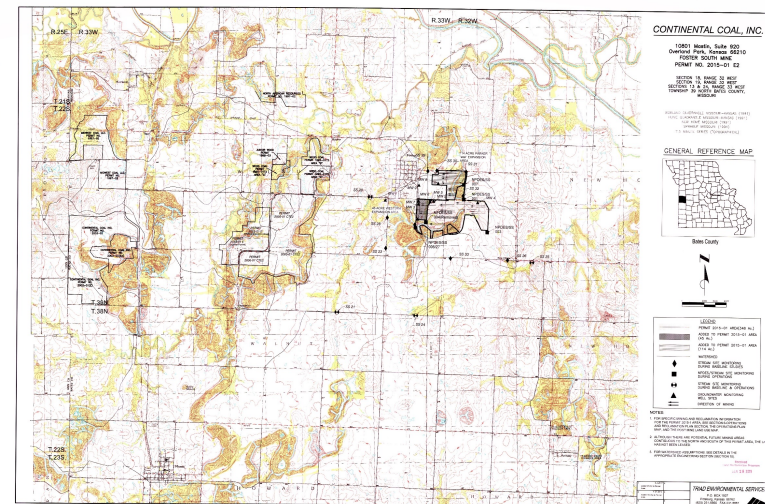
Lawrence L. Brady¹ and Joseph R. Hatch²
¹Kansas Geological Survey, 1930 Constant Avenue, Lawrence, KS 66047-3726
²U.S. Geological Survey, Box 25046, MS 939, Denver Federal Center, Denver, CO 80225-0046

Abstract

Elemental and chemical analyses and physical tests were conducted on 36 samples of Middle and Upper Pennsylvanian coals from southeastern Kansas. Concentrations of 35 minor and trace elements in these coals were statistically compared with concentrations in coals of similar rank and age from other areas in the western region of the Interior Coal Province, showing that Kansas coals have significantly higher concentrations of copper, arsenic, and lead. The zinc content in Kansas coal samples ranges from 160 to 51,000 ppm (whole-coal basis), the maximum value being the highest zinc value reported for U.S. coals. Cadmium content also has an extreme range, from less than 1.0 to 160 ppm (whole-coal basis), the maximum value being one of the highest cadmium values reported in U.S. coals. The apparent ranks of these coal samples range from high-volatile B to high-volatile A bituminous coal. Most samples of Middle Pennsylvanian coals from the major coal-mining area in Bourbon, Crawford, and Cherokee counties are high-volatile A bituminous coal. Arithmetic mean values for proximate analyses of coals (as-received basis; n = 25) show these coals to be 15.5% ash, 35.3% volatile matter, 45.9% fixed carbon, and 3.3% moisture and to have a heat of combustion of 11,910 Btu/lb. Arithmetic mean values for ultimate analyses of the coals show these coals to be 4.9% percent hydrogen, 65.3% carbon, 1.2% nitrogen, 5.5% sulfur, and 7.7% oxygen. The geometric mean values of these Kansas coals are 3.03% pyritic sulfur, 1.25% organic sulfur, and 0.2% sulfate sulfur.



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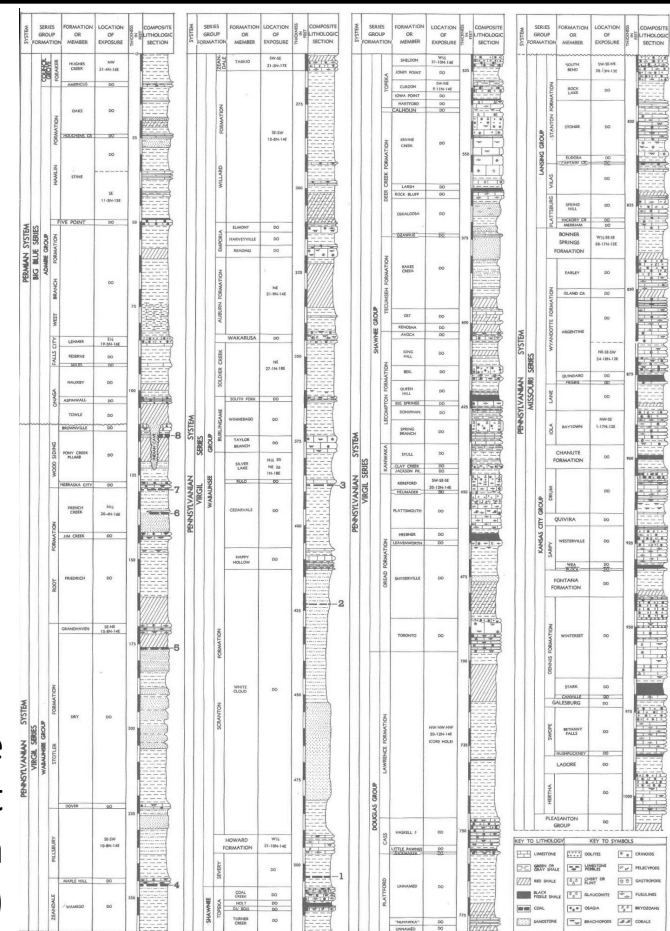


Pennsylvanian Coal in Nebraska

- Only comprehensive study of Pennsylvanian coals in Nebraska was published by Burchett in 1977
- All known Pennsylvanian coals are sub-bituminous and bituminous and they crop out only in five counties in far southeastern Nebraska
- An early-20th century mine in the Honey Creek coal (~1 m) in Nemaha County was the only truly successful coal mine in the history of Nebraska
 - All other known coals are thin (0.3 m or less)
- Burchett (1977) identified seven (7) other, thin coals in the Wabaunsee Group in outcrops in Nebraska

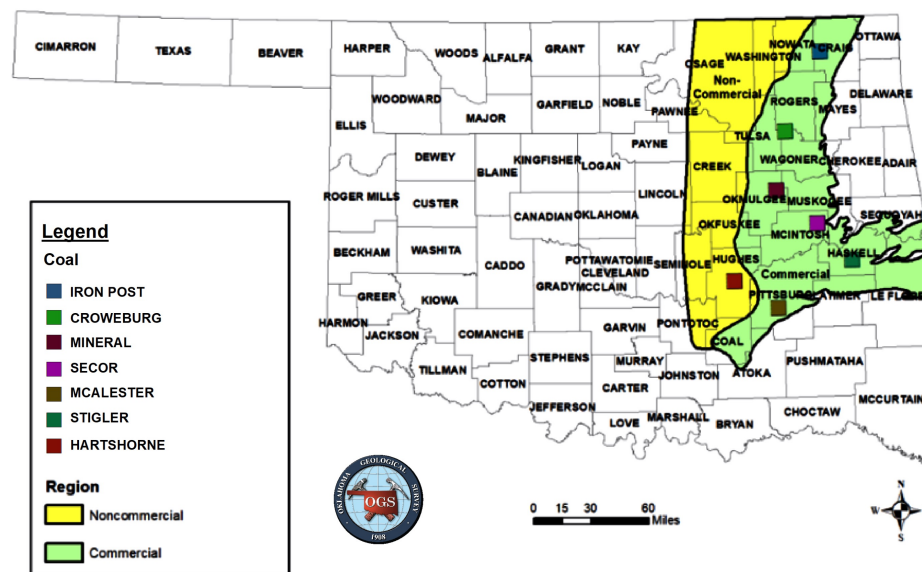


Eight coals in the
Wabaunsee Group that
crop out in SE Nebraska
(Burchett, 1977)



Oklahoma

- Assess new and existing samples from **Commercial** and **Noncommercial** coal deposits
 - Designations based on depth, stratigraphic control, etc.
- Sample a fly-ash deposit in the southeastern portion of the commercial belt, landowner permissions' pending, using a push-core tool
- Electron Microprobe analysis to verify micro-locations and mineral hosts of REE following approach of NETL group (Yang et al., 2020, Minerals)



Osage Overview – CoreCM Project



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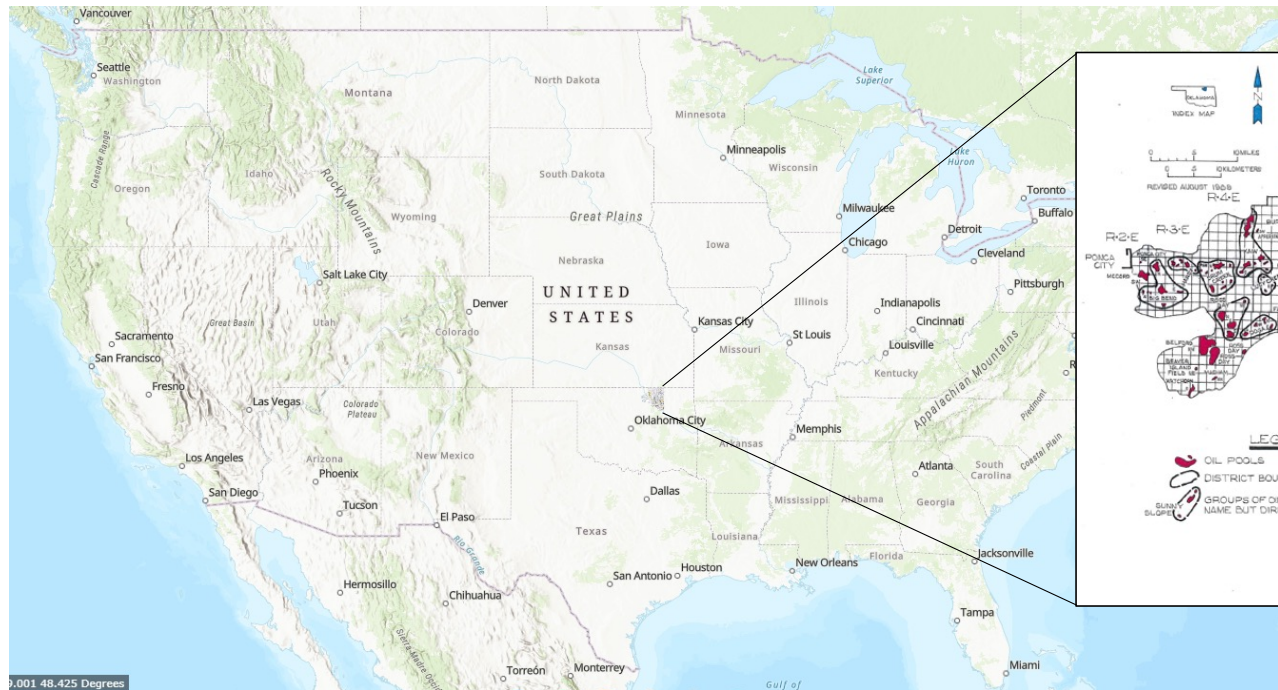
- Ceded 100 million acres to the United States
- Paid for 1.5-million-acre reservation & original survey—we previously owned—nobody wanted
- Kept minerals intact—over 1.3 billion barrels of oil have been produced along with 12 other types of income derived from mineral sources
- Current production over 11,000 BOPD & 13 BBO left
- The Osage Minerals Council created by the Osage Nation to administer and develop the Osage Mineral Estate looks to maximize tribal resource exploration and development



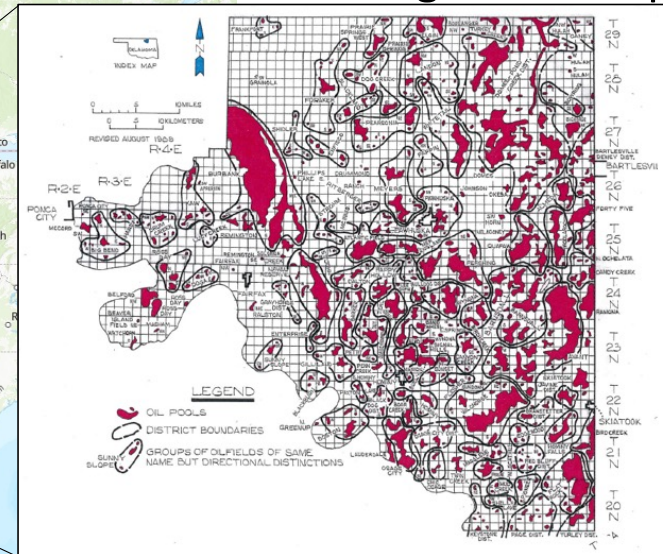
Osage Reservation – CoreCM Project



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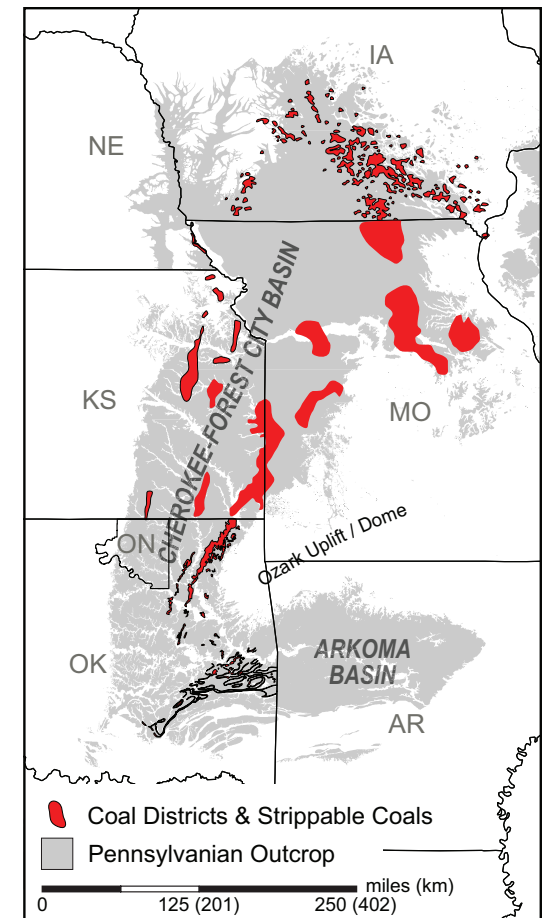
Osage Pool Map



Tasks

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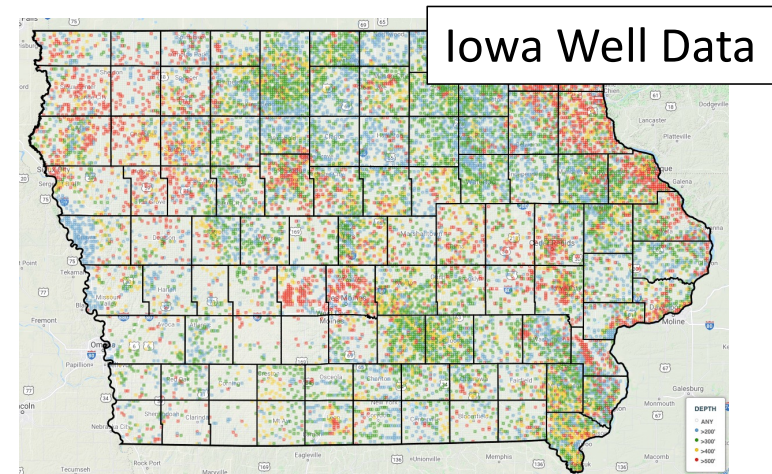
1. Deliver project on time, on budget, and safely
2. Environmental & social justice assessments
3. Geological modeling of basin resources
4. Waste stream reuse plan
5. Infrastructure, industries, and business assessment
6. Technology assessment, development and field-testing plan
7. Technology innovation center plan
8. Stakeholder outreach and education plan
9. Reporting on time



Subtask 2.1 – Data Aggregation

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- Coal-bearing sedimentary layers as well as active and abandoned mine data
 - descriptions, samples and data from outcrop and core, well log data, mine maps, and other relevant data
- Sources: USGS, EPA, State Geological Surveys, Tribal Mineral Councils, and State/Tribal regulatory data




U.S. Geological Survey
Publication




U.S. Geological Survey coal quality (COALQUAL) database; version 2.0

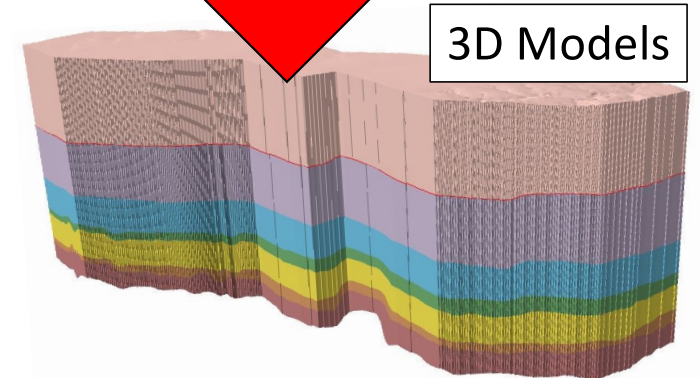
Open-File Report 97-134

By: L. J. Bragg, J.K. Oman, S. J. Tewalt, C.L. Oman, N.H. Rega, P.M. Washington, and R.B. Finkelman

<https://doi.org/10.3133/ofr97134>

 Tweet

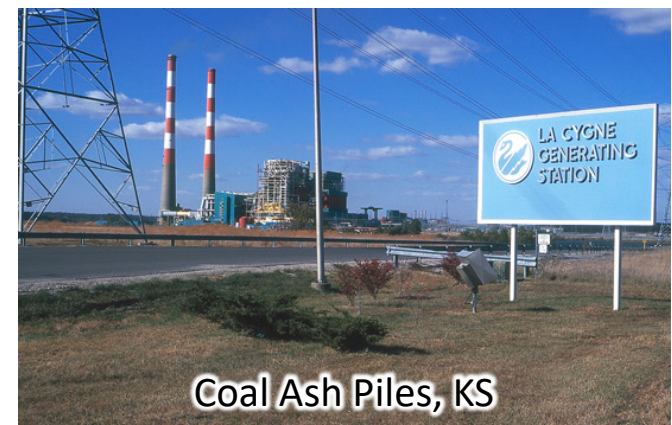
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Subtask 2.3 – CORE-CM Resource Assessments

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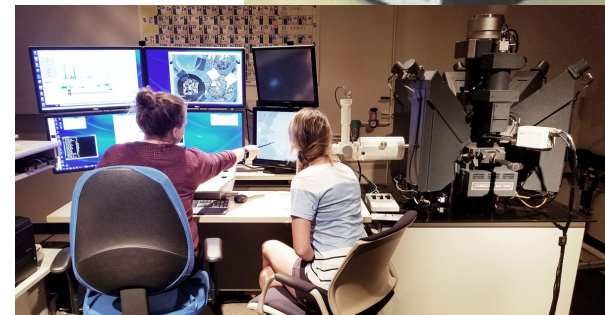
1. Coal and associated sedimentary layers
2. Combustion byproducts (e.g., Coal ash, fly ash, ponded materials)
3. Refuse (coal; other ores)
4. Acid mine drainage from coal and other ores
5. Other basin-specific resources that could enhance basin-specific economics (e.g., helium, coal-bed methane, low-alumina limestone for highway aggregates)
6. Water resources



Technical Approach

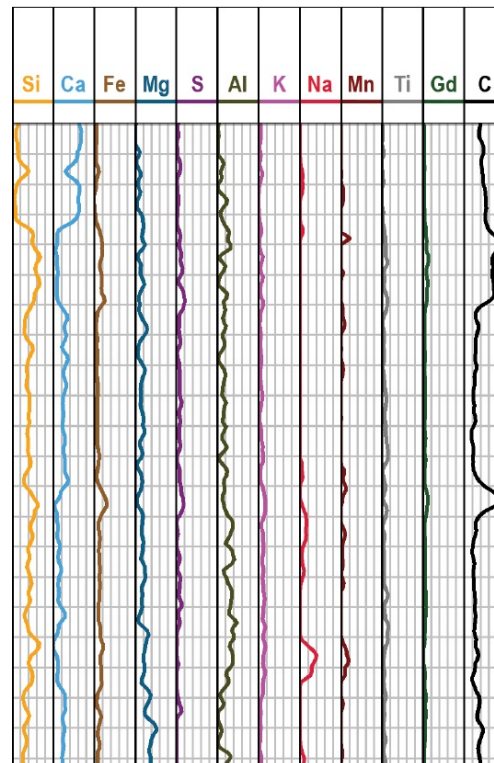
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- Correlation of strata basin-wide
 - Well logs
 - Outcrop descriptions
- Legacy Geochemical Data
- Novel Geochemical Data
 - Portable XRF analysis at IA, KS, and MO for major elements (wt% to ppm)
 - ICP-MS at University of Iowa for trace elements (ppm to ppb)
 - Electron Microprobe (EMPA) to identify host mineral phases for CMs
 - Geochemical Well Logging at select wells (next slide)

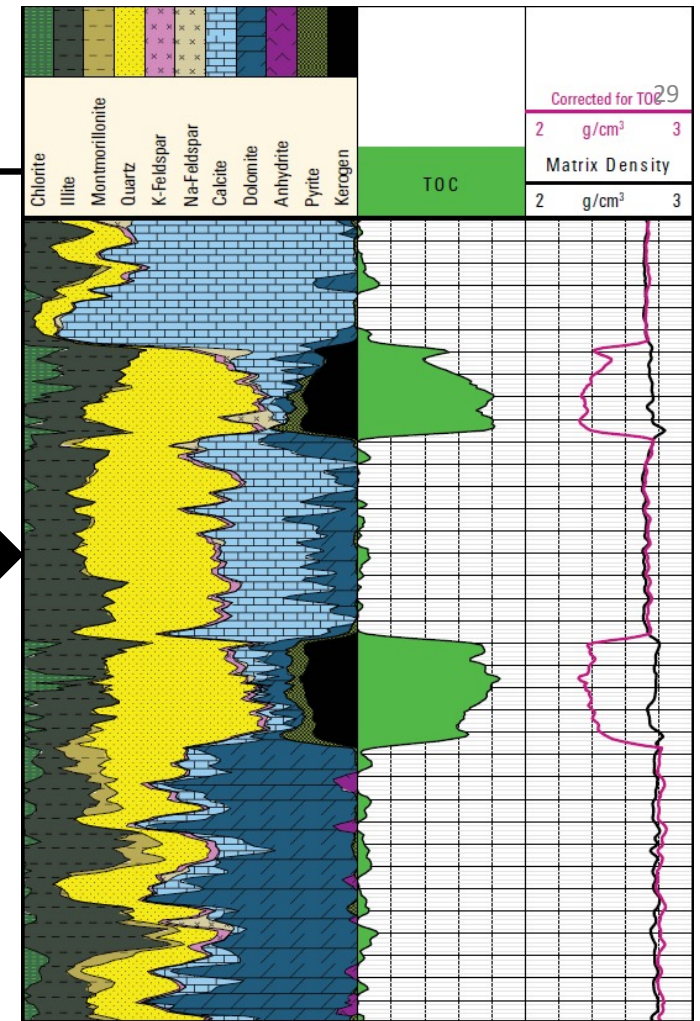


Geochemical Well Logging

- Tools designed to derive elemental contributions contained within the total measured gamma-ray energy spectrum
- Can work in both open- and case-hole environments
- Quantitative measurements of: Si, Al, Ca, Fe, Mg, S, Na, C, Mn, **Ti**, **Gd**
- Elemental concentrations can be applied to establish stratigraphic correlations
- Calibrations of downhole logs with pXRF, ICP-MS, and EMP geochemical analysis



Individual spectral yields from neutron capture are converted to elemental weight fractions

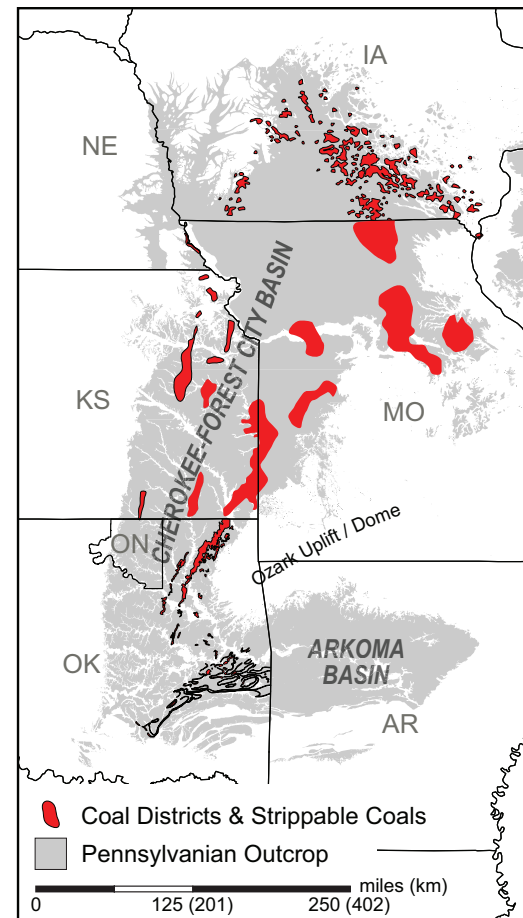


Interpretation of weight fractions determines mineralogy and matrix properties

Summary

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Backup