Regional Characterization of Coal Resources in the U.S. Gulf Coast

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Abstract

There is increasing interest in extracting critical minerals (CM), including rare earth elements (REE), from coals in the United States to address the overreliance on imported REE. The U.S. Gulf Coast and the Williston basins are the two major lignite-bearing basins within the country. Recent REE and CM studies of the lignite in these basins have indicated that the coals may be a viable source material for REE and CM extraction. To evaluate in-place coal as a potential source of REE and CM, the coal resources need to be quantified. This study presents the results of a regional analysis of the U.S. Gulf Coast lignite and bituminous coal resources that might be available as potential sources of REE and CM. The resource analysis used kriging methods to develop isopleth maps of cumulative coal thickness throughout the region using data from 31,181 drill holes and other data points. The estimated total coal resource in the Gulf Coast is about 83 billion metric tons in the upper 90 m (~ 300 ft) of the subsurface. Texas accounted for 40 percent (32 billion metric tons) of the total resource, followed by Mississippi (24 %, 20 billion metric tons), Louisiana (14 %, 12 billion metric tons), Tennessee (10 %, 8.5 billion metric tons), and Arkansas (6 %, 5.1 billion metric tons). The remaining states each accounted for less than 5 percent of the total resource. Georgia had the smallest resource estimated at 7 million metric tons. Here we report the first known state-wide lignite resource estimates for Georgia, Kentucky (820 million metric tons), and Missouri (1,800 million metric tons). A comparison of the results of this study with those of previous Gulf Coast and Williston Basin resource studies is difficult because each study used different data sources, assessment methodologies, overburden depths, and qualifying coal thicknesses. Coal-power electric generation has sharply decreased in past decades and mining of these coals for CM and REE could provide additional co-products such as activated carbon and other uses such as fertilizer (soil enhancer).

Introduction

Extracting critical minerals (CM), including rare earth elements (REE), from coal and coal byproducts in the United States (U.S.) is one potential method that can help to reduce an overreliance on imports from China (Scott and Kolker, 2019; Garside, 2023). To address this issue, the U.S. Department of Energy, National Energy Technology Laboratory, Carbon Ore, Rare Earth and Critical Minerals (CORE-CM) Initiative, was designed to assess the potential of coal and coal byproducts to supply CM in 13 regions throughout the U.S. (Mullen, 2023). The mission of the CORE-CM initiative is to develop economic, competitive, sustainable domestic REE-CM supplies to support the clean energy transition and economic and national security (Mullen, 2023).

REE are essential for many different sectors, including technology (for example computers), transportation (for example electric vehicles), and renewable energy (for example wind turbines) (U.S. Geological Survey, 2022, a,b). Examples of conventional sources of REE in the U.S. include minerals such as bastnäsite and monazite extracted from carbonatites at Mountain Pass (California), the Bear Lodge Deposit (Wyoming), and the Lemhi Pass Deposit (Montana-Idaho border) (Castor, 2008; Long and others, 2010; Moore and others, 2015; Wang and others, 2020). Mountain Pass was a major producer of REE in the 1980s and 1990s but closed in response to environmental concerns (Castor, 2008). Placer deposits of REE represent another potential source, such as the monazite alluvial placers near Boise, Idaho (Sengupta and Van Gosen, 2016). Other unconventional REE sources being examined in the U.S. include coal and coal byproducts and acid mine drainage residues (Scott and Kolker, 2019; Li and Zhang, 2022; Mullen, 2023;), mine tailings (Sarker and others, 2022), geothermal brines (Stringfellow and Dobson, 2021), and industrial waste and byproducts (Binnemans and others, 2013).

Limited studies to date indicate there are variable concentrations of REE in coals and coal by-products (for example Park and others, 2020; Honaker and others, 2019; Hower and others, 2020, 2023; Middleton and others, 2020; Zhang and others, 2020). Concentrations of REE + Yttrium (REE+Y) range from 11 to 411 ppm (dry coal basis) in central Appalachian bituminous coals, including the Fire Clay coal (Hower and others, 2020). Localized high concentrations of REE have been found in North Dakota lignites (up to 2,570 ppm REE+Y + scandium [Sc], dry coal basis) (Murphy and others, 2023). Hower and others (2023) identified elevated concentrations of REE in lignite samples from the Gibbons Creek and San Miguel coal mines in Texas. The highest REE+Y+Sc concentrations were found in the Gibbons Creek mine (n=15, 40 to 4,082 ppm, mean 1,033 ppm, median 694 ppm; dry coal basis) (Hower and others, 2023; Scanlon and others, in press).

To evaluate in-place coal as a potential source of REE, the coal resources need to be quantified for the area of interest. A national coal resource assessment of about 60 coal beds indicates that over 1.5 trillion metric tons of coal remained in the United States (Ruppert and others, 2002). The coals in the United States vary in rank from lignite in the Gulf Coast and Williston basins to subbituminous coals in Powder River Basin and the Rocky Mountain Region, and bituminous coals in the Appalachian Basin and some interior U.S. basins (East, 2023). Warwick (2011) estimated coal resources near active mining areas in the southeastern U.S. Gulf

Coastal Plain totaled about 88 billion metric tons in the shallow subsurface (≤152 m, or ≤500 ft). A review of previous U.S. Gulf Coastal Plain coal resource studies that used various assessment parameters are summarized in table 1. There have been no previous coal resources assessments that span the entire Gulf Coastal Plain region. The purpose of this study was to evaluate the regional Gulf Coastal Plain coal resources that might be available as potential sources of REE and CM.

Background Geology of the Gulf Coast

The geology of the southeastern U.S. Gulf Coastal Plain region (Gulf Coast) (figs. 1, 2) has been intensively studied for energy and other resources, including those for coal, oil, natural gas, aggregates, and water resources (Buursink and others, 2018; Dubiel and others, 2007, 2011; Langer, 2002; Warwick and others, 2011b; Warwick, 2022; Williamson and others, 1990). Extensive deep drilling, geophysical logs, and seismic surveys provide a comprehensive understanding of the tectonic evolution and subsurface geology of the Gulf Coast (Ewing and Lopez, 1991; Bird and others, 2011). Coal resource maps in the vicinity of surface mines provide detailed information on coal thickness and overburden depths (Warwick and others, 2011b). Regional evaluations of the paleo-depositional environments of the coal-bearing units have been conducted over decades (for example Fisher and McGowan, 1967; Kaiser and others, 1980; Breyer, 1991; Warwick and others, 2011b). Gulf Coast coal beds are concentrated in fluvio-deltaic units of the Cretaceous Olmos Formation, and the Paleocene-Eocene Midway, Wilcox, Claiborne, and Jackson Groups (Fisher and McGowan, 1967; Kaiser and others, 1980; Breyer, 1991; Warwick and others, 2011a) (figs. 2, 3).

Table 1. Some previous coal resource studies of the U.S. Gulf Coastal Plain.
[TX, Texas; —, no data]

State and area	Depth (m)	Coal bed thickness (m)	Billion short tons	Billion metric tons	Reference
Alabama	≤610	≥0.76	2	1.8	Daniel (1973); Averitt (1975)
Alabama (Alabama-Tombigbee rivers)	≤76	0.76 to 1.5	0.6	0.5	Self and others (1978)
Alabama (Alabama-Tombigbee rivers)	>76 to 152	≥1.5	4.1	3.7	Self and others (1978)
Alabama	≤61	≥0.9	1.4	1.3	Luppens (1979, 1980)
Alabama	≤76	0.76 to 1.5	1.6	1.5	Tolson (1985)
Alabama	>76 to 1,830	≥1.5	4.7	4.3	Tolson (1985)
Arkansas	---	≥0.76	0.35	0.32	Hanley (1960); Averitt (1975)
Arkansas	≤61	≥0.9	2.5	2.2	Luppens (1979, 1980)
Arkansas	≤45.7	---	9	8.2	Prior and others (1985)
Louisiana	≤61	≥0.9	1.1	1.0	Luppens (1979, 1980)
Louisiana (Sabine)	≤152	≥0.46	1.1	1.0	Warwick (2011)
Mississippi	≤61	≥0.9	5	4.5	Luppens (1979, 1980)
Mississippi	---	---	5	4.5	Thieling and others (2009)
Kentucky (western)	---	≤0.9	0.00005	0.000045	Olive (1971)
Tennessee (western)	≤61	≥0.9	1.0	0.9	Luppens (1979, 1980)
Texas	0 to ≥ 27.4	---	7.1	6.4	Perkins and Lonsdale (1955)
Texas	≤61	variable	10.4	9.4	Kaiser (1974)
Texas	>61 to 1,524	variable	100.0	90.7	Kaiser (1974)
Texas	≥6.1 to ≤61	≥0.9	23.3	21.2	Kaiser and others (1980)
Texas	>61 to 610	≥1.5	34.8	31.6	Kaiser and others (1980)
Texas	≤61	≥0.9	11.5	10.4	Luppens (1979, 1980)
Texas	≤152	≥0.76	47.0	42.6	Kaiser (1996)
Texas (Sabine)	≤152	≥0.46	72.0	65.3	Warwick (2011)
Texas (Sabine)	>152 to ≤610	≥0.46	78.0	70.8	Warwick (2011)
Texas (northeast, Wilcox Group)	≥61 to 610	≥1.5	5.6	5.0	Kaiser (1990)
Texas (northeast)	≤152	≥0.46	16.0	14.5	Warwick (2011)
Texas (east-central)	≥61 to 610	≥0.6	37.2	33.8	Ayers and Lewis (1985)
Texas (east-central)	≤152	≥0.46	7.7	7.0	Warwick (2011)
Texas (Claiborne Group, south TX)	≤76.2	≥0.36	0.1	0.1	Mapel (1967)
Texas (Olmos Formation, south TX)	≤76.2	≥0.36	0.5	0.5	Mapel (1967)

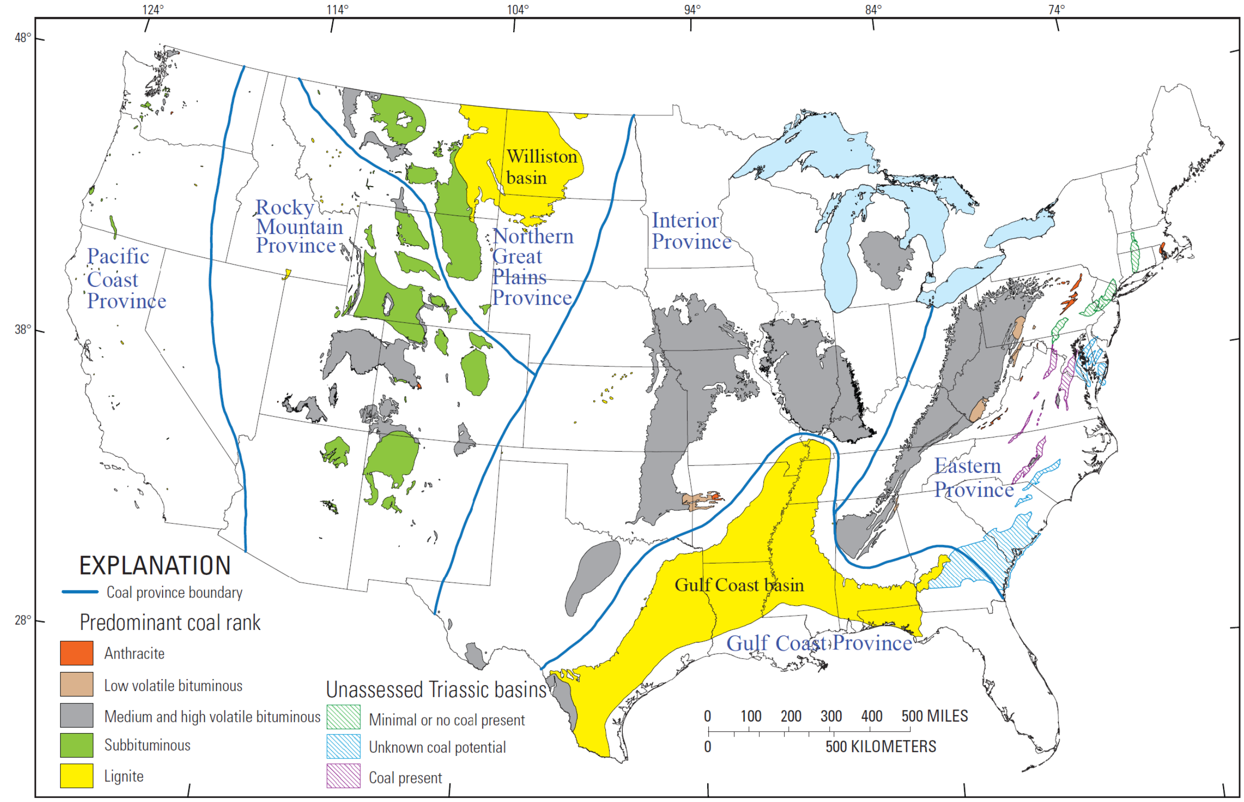

Figure 1. Map showing the coalfields of the conterminous United States. Modified from East (2012).

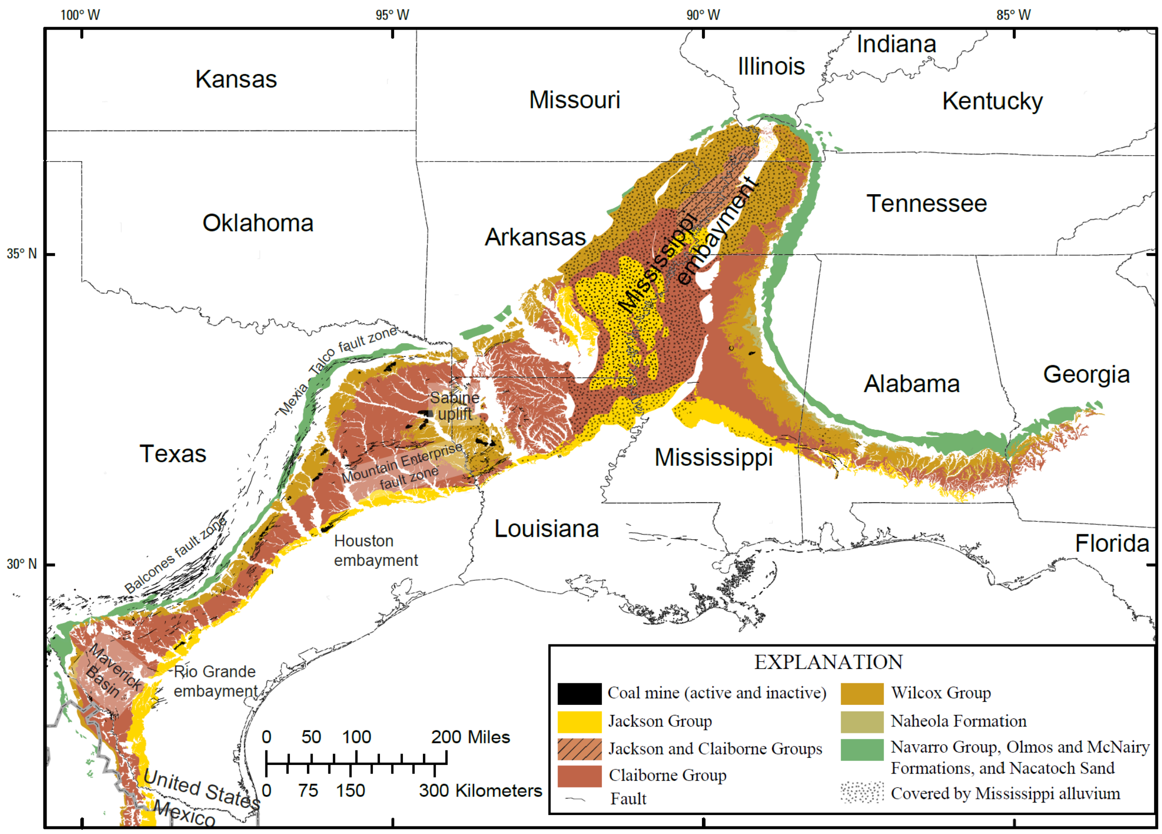

Figure 2. Map showing structural features, locations of outcrops of primary coal-bearing units and coal mine locations in the U.S. Gulf Coastal Plain and Mississippi embayment. Geology from Stose and Ljungstedt (1932), Fisk (1944), Ewing and Lopez (1991), Warwick and others (1997), Schruben and others (1994), and Page and others (2005). Gulf Coastal Plain fault traces from Dicken and others (2007), Nicholson and others (2007a,b), and Stoeser and others (2007). Geology outside the Gulf Coastal Plain and Mississippi embayment is not shown. Figure modified from Warwick (2022).

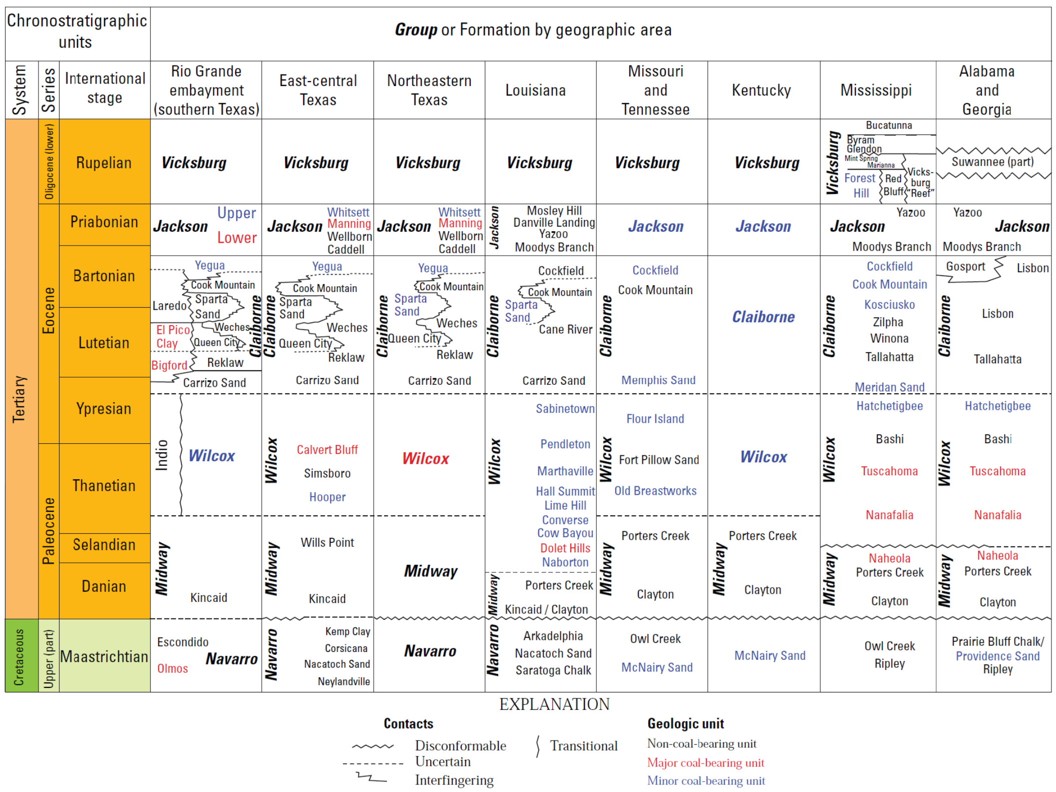

Figure 3. Correlation diagram showing stratigraphic nomenclature of Upper Cretaceous and Paleocene–Eocene coal-bearing and associated strata for the U.S. Gulf Coastal Plain and the Mississippi embayment. Group names are in bold and italic; text color indicates the degree to which a geologic unit is coal bearing. From Warwick (2022).

Depositional Environments

The coal-bearing strata in the Gulf Coast (fig. 2) were deposited in a variety of settings, and the coal ranks range from lignite to medium and high volatile bituminous (Warwick and others, 2011b). The primary coal-bearing areas of this region are along the north-northwestern margin of the Gulf Coast where coal deposits are found in Upper Cretaceous, Paleocene, and Eocene coastal, deltaic, and fluvial sediments (Fisher and McGowan, 1967; Ayers and Lewis, 1985; Kaiser, 1990; Breyer, 1991; Warwick and others, 1997).

Coal-bearing strata extend over much of the Gulf Coast area but regional stratigraphic relationships and depositional settings are poorly defined. Coal is currently mined from the Wilcox and Jackson groups (fig. 2) in the northern Gulf Coast. In Texas, the coal zones were mined underground until the late 1920s (Evans, 1974). The Paleocene–Eocene Wilcox Group crops out across most of the Gulf Coast coal-bearing region and has the greatest amount of known coal resources (Warwick and others, 2011b) (figs. 2, 3). The Wilcox Group is about 300 m (1,000 ft) thick in the subsurface near the outcrop areas and thickens downdip to thousands of meters offshore (Warwick and Crowley, 1995; Warwick, 2011, 2017, 2022). The northern (updip) parts of the Wilcox Group contain fluvial and deltaic coal-bearing facies, whereas the southern (downdip) parts of the basin contain siliciclastic shelf and marine facies. In Texas, lignite is mined from the upper part of the Wilcox Group; whereas, in Louisiana and Mississippi, lignite is mined from the lower part. Individual Wilcox Group coal beds are generally less than 4.6 m (15 ft) thick, and most coal mines produce from several beds (Warwick and others, 2011b).

The deltaic Claiborne Group overlies the Wilcox Group and contains minor coal resources (Breyer, 1991) (figs. 2, 3). In southern Texas, bituminous coals that have a texture and composition similar to those of cannel coals (cannel-like) were mined at the surface from the Claiborne Group (Evans, 1974; Warwick and Hook, 1995; Warwick and others, 1997). These coal zones extend into northern Mexico (Flores Galicia, 1991).

The deltaic Jackson Group overlies the Claiborne Group across the entire Gulf Coastal Plain. The Jackson Group is divided into several formal and informal units across the States where it is present (Breyer, 1991; Barnes, 1992) (fig. 3). Lignite zones in the Jackson Group have been mined in central Texas and are currently mined from surface mines in southern Texas (Warwick and others, 1996, 1997; Hook and others, 2011b, c).

Structural Setting

The U.S. Gulf Coast strata dip into a generally circular structural and topographic depression (basin) that formed during the break-up of Pangaea in the late Triassic (Bird and others, 2011). The basin is filled with up to 15 km of sediments that range from Late Triassic to Holocene (Ewing, 1991). In Texas, there are two major embayments: the Houston embayment in the north and the Rio Grande embayment in the south (fig. 2). Major faults in the coal-bearing areas include the Mexia - Talco fault zone (fig. 2). The Mexia - Talco fault zone forms a narrow graben trending north-northeast across the Wilcox outcrop belt and may cause locally varying thicknesses of the Wilcox Group coals (Warwick and others, 2011b). Within the Sabine Uplift, the east trending Mountain Enterprise fault zone has almost 200 m (656 ft) of displacement (Ewing, 1991). Local structure in the Gulf Coast area is also impacted by salt diapirs that formed in the Jurassic salt deposits (Ewing, 1991).

Purpose and Scope

The primary objective of this study was to quantify Gulf Coast coal resources to support their assessment as a potential source of CM, including REE. Previously gathered Gulf Coast geologic data associated with resource development (coal, oil, gas, aggregates, and water) could aid in the development of coal as a feedstock for REE and CM in the region. This coal resource evaluation included data used in previous assessments of coal resources in the Gulf Coast conducted by the U.S. Geological Survey (Averitt, 1975; Warwick and others, 2011b), Texas Bureau of Economic Geology (Kaiser and others, 1980; Ayers and Lewis, 1985), Geological Survey of Alabama (Tolson, 1985), Mississippi Department of Environmental Quality, Office of Geology (Thieling and others, 2009) and others (table 1). Recently reported REE data are based on analysis of coal samples from Gulf Coast mines archived at the USGS with limited additional sampling of one mine (San Miguel) (Scanlon and others, in press). Results of REE analyses from two of the mines (San Miguel and Gibbons Creek) are described in Hower and others (2023).

Data and Methods

Data

This regional coal resource analysis was based on stratigraphic data for 31,181 data points primarily from coal exploration drill holes in the Gulf Coast (fig. 4). Most (73 %) of the drill-hole data were obtained from two primary sources, Valentine and Dennen (2012) and the USGS National Coal Resources Data System (NCRDS) online database (U.S. Geological Survey, 2023). Other data sources are provided in table 2. The dataset also includes information obtained from outcrops, cores, geophysical logs, and coal mines. The stratigraphic data from all sources were initially combined into one database and duplicate points were identified and removed. The region is dominated by lignite-rank coal, except for localized occurrences of bituminous coal along the Texas-Mexico international border (fig. 4) (refer to Warwick and Hook, 1995; Hook and others, 2011a; Warwick and others, 2011a; East, 2012).

Table 2. Sources of drill-hole and stratigraphic data used in this study.

Data source	Data type
Valentine and Dennen (2012)	Alabama, Georgia, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee drill-hole information
U.S. Geological Survey (2023)	National Coal Resources Data System (NCRDS) drill-hole and other stratigraphic data
Tagle and others (2024)	Arkansas drill-hole information
Ratchford (2011)	Arkansas drill-hole information
Prior and others (1985)	Arkansas drill-hole information
Geological Survey of Alabama	Proprietary drill-hole information and other stratigraphic data provided in 2023
Arkansas Geological Survey, Office of the State Geologist	Proprietary drill-hole information and other stratigraphic data provided in 2023
Mississippi Department of Environmental Quality, Office of Geology	Proprietary drill-hole information and other stratigraphic data provided in 2023
The University of Texas, Bureau of Economic Geology	Proprietary drill-hole information and other stratigraphic data provided in 2023

Methods

This regional coal resource analysis used kriging methods to develop an isopleth map of cumulative coal thickness throughout the Gulf Coast region using all available data (table 2, fig. 4). Advanced spatial stochastic simulation and probabilistic coal-bed assessment methods, such as those described in Olea and others (2011, 2021), Olea and Luppens (2012), Shaffer and Olea, (2023), and ASTM D8215-2 0 (2021) for single coal bed resource modeling, were not applied in this regional study because individual coal-bed correlations are not available for most of the Gulf Coast region. The Geostatistical Analyst software package of Esri ArcGIS Desktop version 10.7.1 (Esri, 2023a) was used to spatially interpolate and estimate cumulative coal thicknesses using ordinary kriging methods (Esri, 2023b). Polygon areas were hand-drawn around the various clusters of drill holes across the region and adjusted to minimize edge-effect kriging artifacts near the margins of the polygon areas (fig. 4). The total modeled area inside all polygons was about 132,000 km^2 (~51,000 mi^2) divided into three model regions: east, north, and west (figs. 4, 5, 6, 7, 8, 9). The east model (40,500 km^2; 15,600 mi^2) includes Mississippi, Alabama, and Georgia (fig. 6). The north model (16,700 km^2; 6,500 mi^2) includes southeast Missouri, western Kentucky, western Tennessee, and northeastern Arkansas (fig. 7). The west model (~75,000 km^2; ~29,000 mi^2) includes Texas, Louisiana, and southwestern Arkansas (figs. 7, 8, 9).

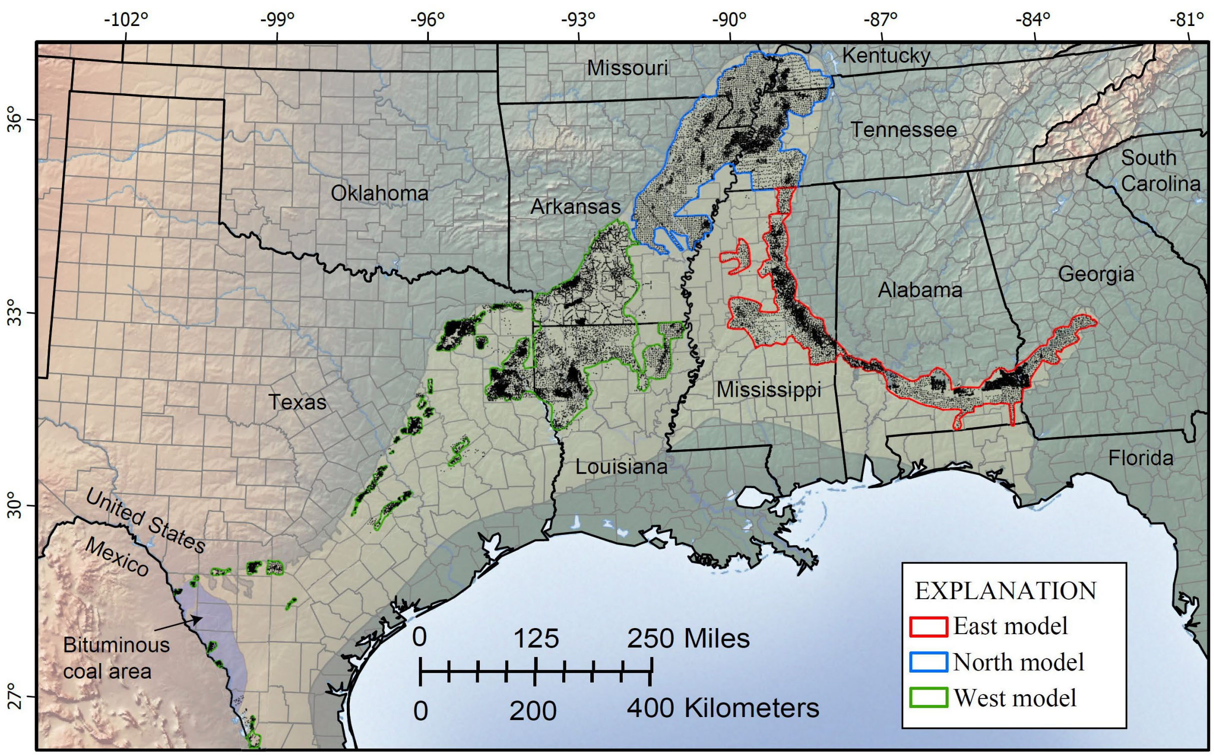

Figure 4. Locations of 31,181 data points used in this study and modeled coal resource areas in the Gulf Coastal Plain coal-bearing region (highlighted area, adapted from East, 2012). Base map, county, and state lines from Esri (2023d).

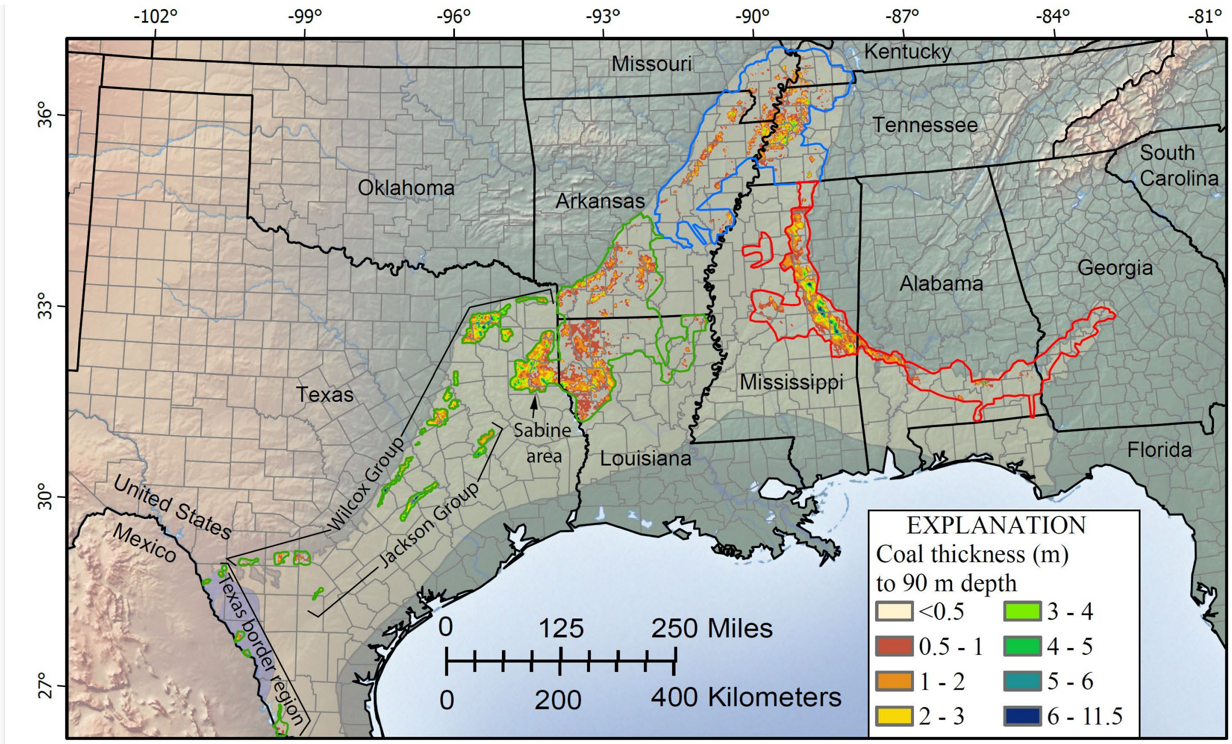

Figure 5. Gulf Coastal Plain isopleth map of cumulative coal thickness. Refer to fig. 4 for an explanation of the modeled coal resource areas (red, blue, and green lines). The Texas coal regions discussed in the text are labeled.

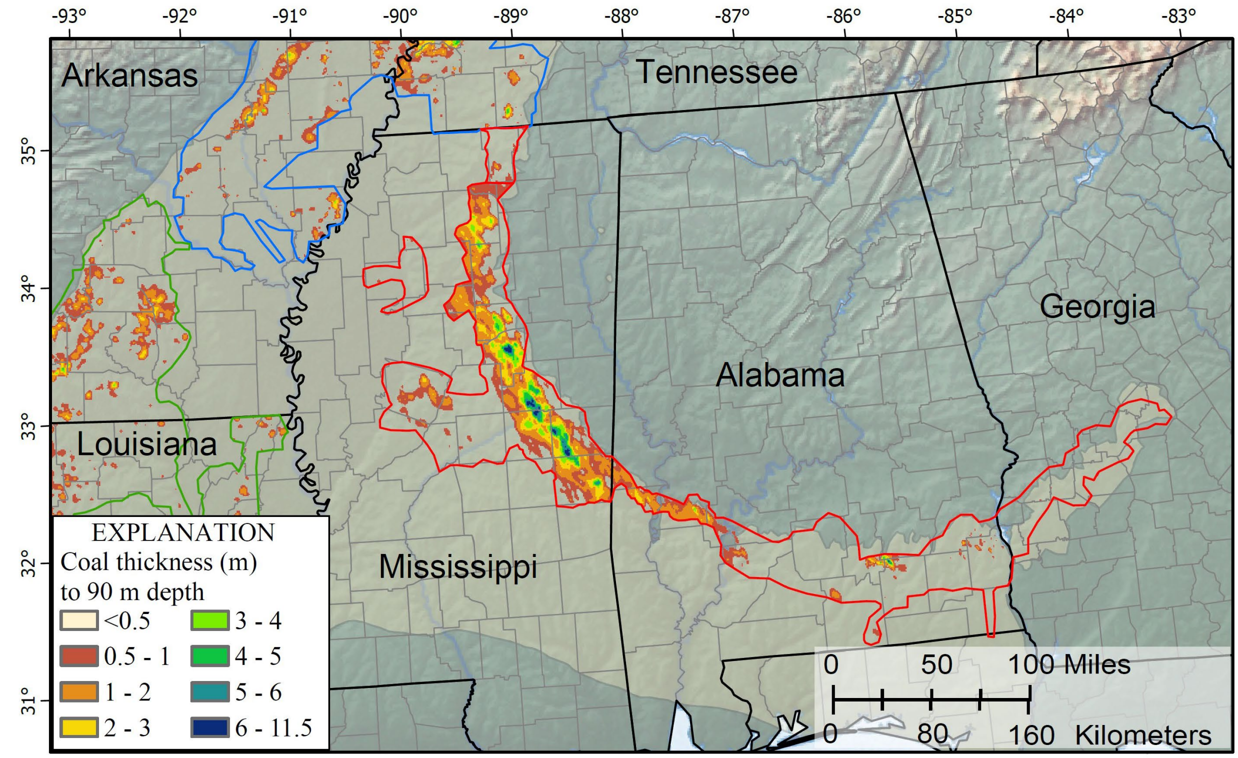

Figure 6. Isopleth map of cumulative coal thickness for the eastern modeled area (red lines).

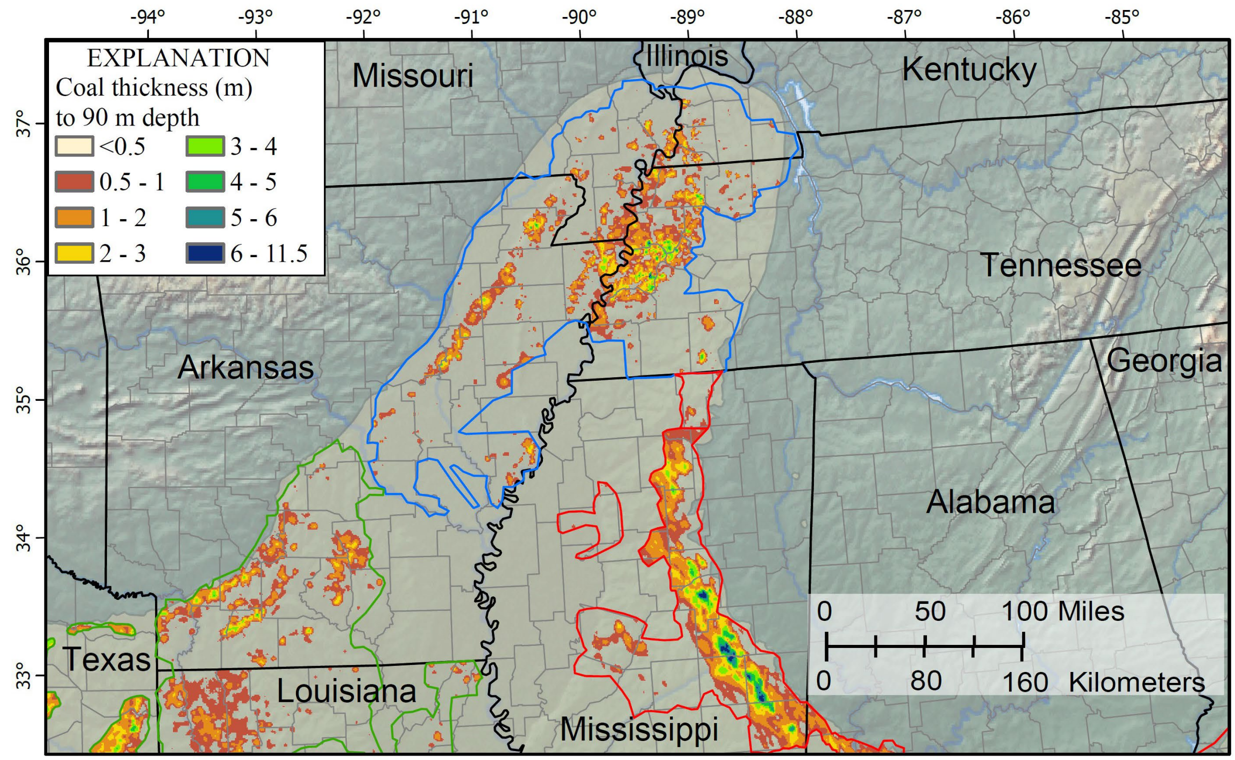

Figure 7. Isopleth map of cumulative coal thickness for the northern modeled area (blue lines).

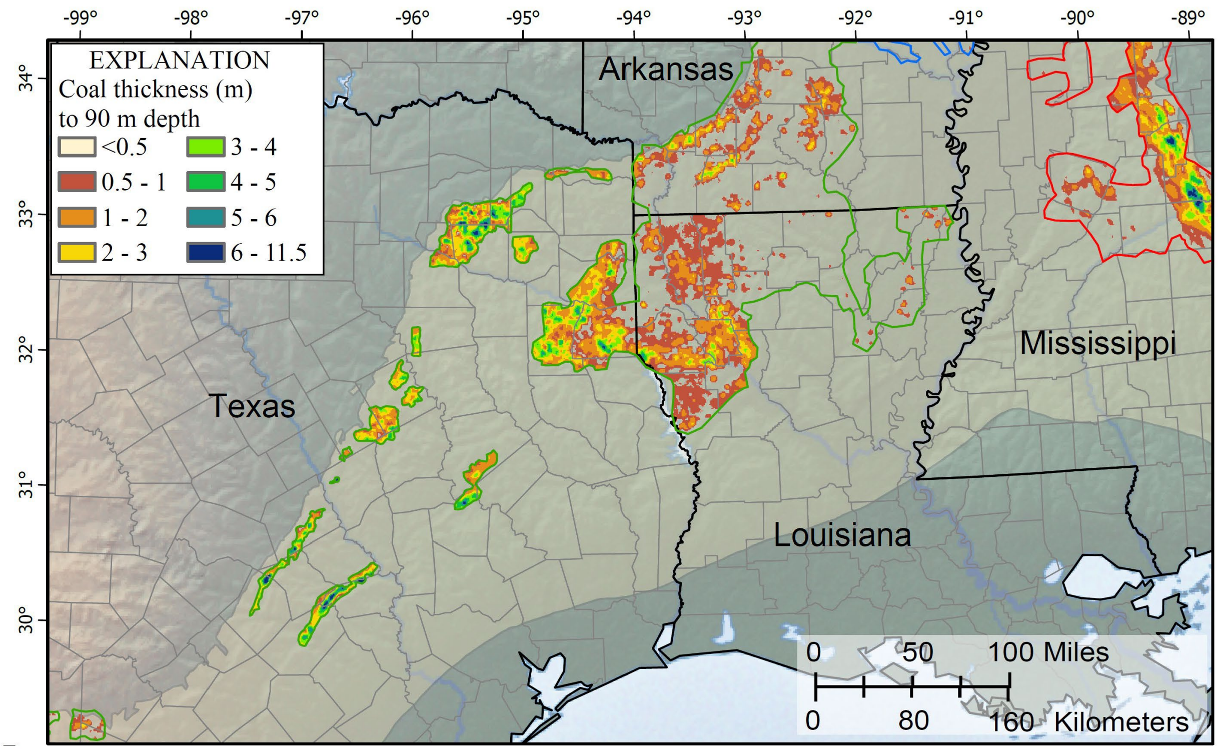

Figure 8. Isopleth map of cumulative coal thickness for the northern part of the western modeled area (green lines).

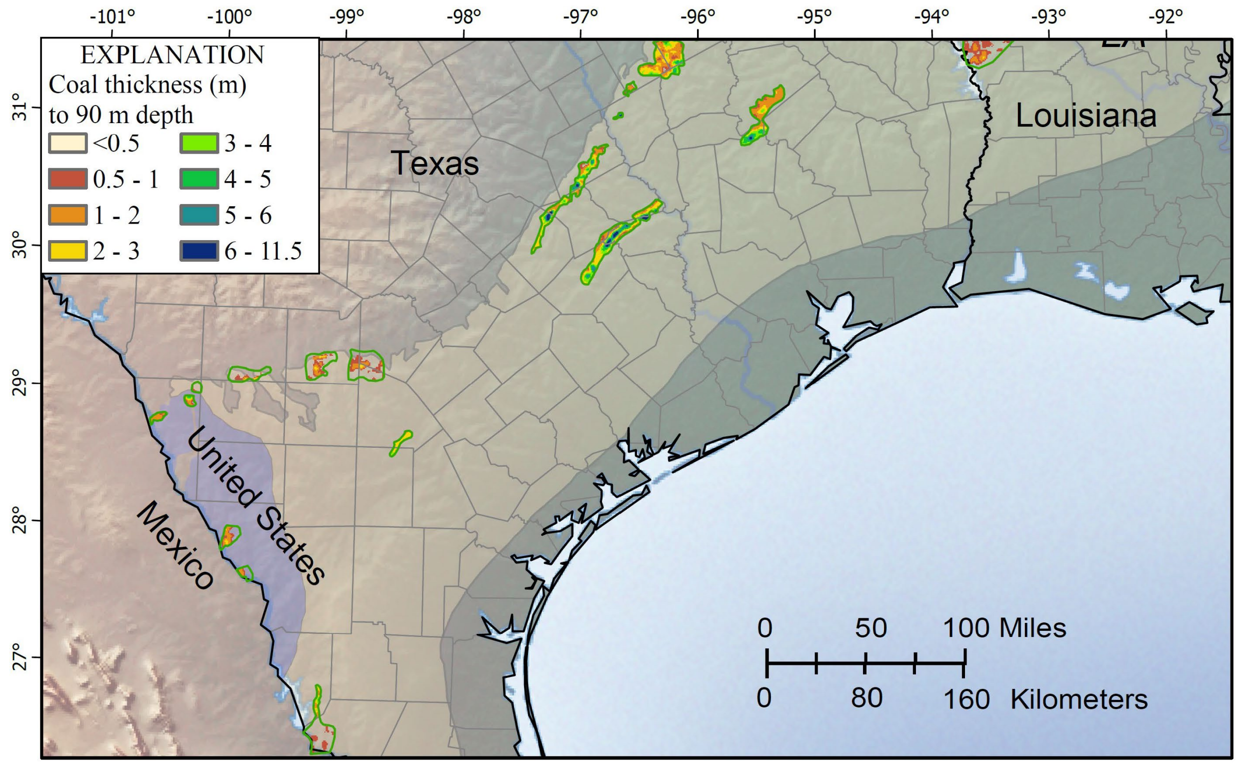

Figure 9. Isopleth map of cumulative coal thickness for the southern part of the western modeled area (green lines).

Data points in this study represent the total cumulative thickness of all coal beds between the ground surface and the lesser of either total drill-hole depth or about 90 m (~300 ft). Data extracted from the drill hole and stratigraphic information include the thicknesses and top depths for all coal beds recorded. Some drill holes did not encounter any coal beds and a total cumulative thickness of zero was assigned to such drill-hole locations. Coal thickness does not include partings. For each data point reported coal thickness was used to calculate cumulative thickness. Local conditions vary and operators generally drill no deeper than necessary to characterize coal resources based on local knowledge or information from nearby drill holes. We assume that the drill-hole data are representative of all coal resources to a depth of 90 m (300 ft).

Each modeled region was proportioned on a 1 km (0.6 mi) grid spacing. For each grid cell, estimates of cumulative total coal volumes were generated for six depths (15, 30, 45, 60, 75, and 90 m; or 50, 100, 150, 200, 250, and 300 ft). A coal bed was included in a depth category if the top of the coal was encountered above that depth. The drill-hole coal thickness data were not transformed and were de-trended using third-order polynomial fits using the automated trend model with ArcMap Geostatistics Analyst software package (Esri, 2023b). A minimum coal thickness of 0.6 m (2 ft) was used in the analysis and the thickness numbers were not rounded. Coal thickness of 0.6 m (2 ft) was selected because it represents the minimum coal thickness that may be surface minable within ~90 m (300 ft) depth from surface in the Gulf Coast.[1] Because of the reconnaissance aspects of this study, there was no effort to define surface mine stripping ratios of cumulative total overburden to cumulative total tons of coal. Volume ratios of overburden to coal, such as one to five, are commonly used by industry to define coal reserves that are economically feasible to mine (Luppens and others, 2009; Shaffer and Olea, 2023). Based on data point densities and the area of each modeled region, semi-variograms were used for the east and west regions while co-variograms were used for the north region. All models used a stable model fit, a major axis lag of 1.5 km (0.9 mi), and auto-generated azimuthal anisotropy direction and minor axis length parameters. The coal resources were estimated for a 1 km (0.6 mi) grid spacing and were summarized for each depth interval by county area and converted to total coal mass using a density of 1.29 g/cm^3 for lignite and 1.32 g/cm^3 for bituminous coal (Wood and others, 1983). All coal mass values were totaled, rounded to two significant figures, and reported in million metric tons units (1 short ton = 2,000 lb = 0.9072 metric ton) (table 3). Coal production data shown on table 3 are from U.S. Energy Informaiton Administration (2024). The associated mine mouth plants are inferred by both the coal delivery data and by simple examination of maps showing proximity of mines to the power plants.

For a discussion of the advantages and shortfalls of applying kriging methods to estimate resources, the reader can refer to Olea and others (2011, 2021). As described by Esri (2023c), if kriging errors are assumed to be normally distributed, there is a 95.5 percent probability that the actual z-value at the cell (1 km grid spacing used in this study) is the predicted raster value, plus or minus the raster standard error (equal to two times the square root of the variance).

Results

The estimated total coal resource in the Gulf Coast is about 83 billion metric tons in the upper 90 m (~ 300 ft) based on data from 31,181 drill holes and other data points (table 3). Texas accounted for 40 percent (32 billion metric tons) of the total, followed by Mississippi (24 %, 20 billion metric tons), Louisiana (14 %, 12 billion metric tons), Tennessee (10 %, 8.5 billion metric tons), and Arkansas (6 %, 5.1 billion metric tons) (fig. 10; table 3). The remaining states each accounted for less than 5 percent of the total resource. Georgia had the smallest resource estimated at 7 million metric tons. Within Texas, the Wilcox Group coals accounted for 46 percent (38 billion metric tons) of the total, followed by the Sabine area in East Texas (36 %, 30 billion metric tons), the Jackson Group (15 %, 12 billion metric tons), and the remaining Texas Border region (2 %, 1.7 billion metric tons) (fig. 5). The estimated coal resources increased approximately linearly with depth from 1.2 billion metric tons in the upper 15 m (50 ft) to about 83 billion metric tons in the upper 90 m (300 ft) (fig. 10).

[1] The Gulf Coastal Plain is generally composed of unconsolidated sediments and surface mining would likely be required for coal extraction. A maximum depth of 90 m (300 ft) depth was selected as the depth limit of this resource evaluation, even though most surface coal mine extraction occurs at depths less than 60 m (200 ft) (U.S. Energy Information Administration, 2025).

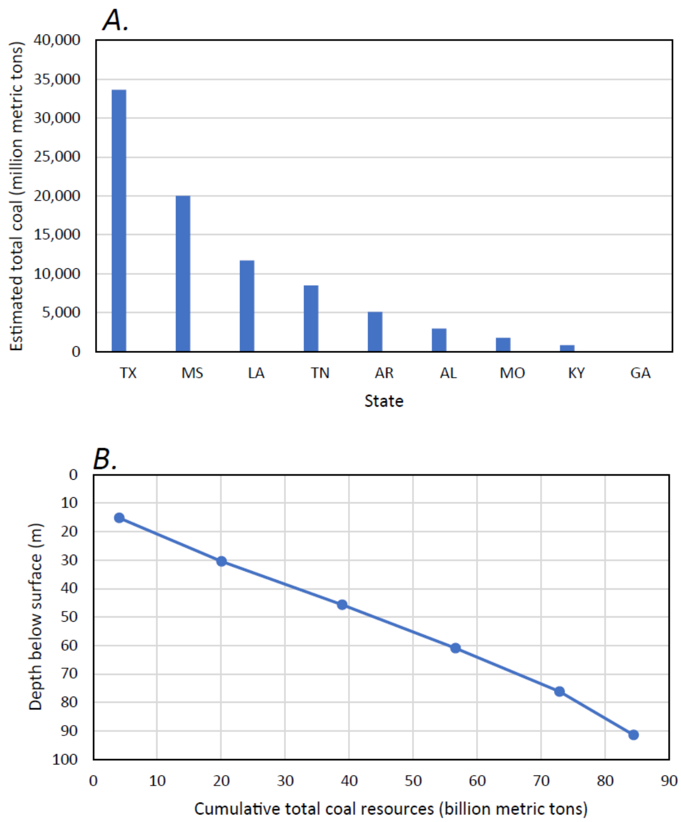

Figure 10. Plots of estimated Gulf Coast coal resources. *A*, Estimated coal resources by State. *B*, estimated coal resources by depth below the surface.

Table 3. U.S. Gulf Coastal Plain coal resource estimates.[1]

State	Percent of total coal resource	Estimated coal from surface to specified depth (million metric tons)[2]						Number of data points	Mined since 1983 (million metric tons)	Remaining (million metric tons)
		90 m	75 m	60 m	45 m	30 m	15 m			
Texas	40	34,000	30,000	24,000	18,000	9,500	1,800	11,855	1,707	32,000
Mississippi	24	20,000	17,000	14,000	9,500	5,300	1,300	3,913	62	20,000
Louisiana	14	12,000	9,400	6,700	3,900	1,400	110	5,157	111	12,000
Tennessee	10	8,500	6,900	4,400	2,600	820	160	2,386	-	8,500
Arkansas	6	5,100	4,700	4,000	3,200	1,800	310	2,895	-	5,100
Alabama	3.5	2,900	2,700	2,300	1,800	1,000	400	2,567	-	2,900
Missouri	2.1	1,800	1,300	680	180	6	3	1,049	-	1,800
Kentucky	1	820	680	530	260	80	8	626	-	820
Georgia	0	7	6	5	4	4	-	733	-	7
Total	100	84,000	73,000	57,000	39,000	20,000	4,100	31,181	1,880	83,000
Total percent									2 %	98 %

[1]All coal resource values were rounded to two significant figures, reported values may not sum to totals because of rounding.

[2] Includes only areas with ≥ 0.61 m of total coal thickness.

An estimated 1.9 billion metric tons have been mined in the region (U.S. Energy Informaiton Administration, 2024), representing about 2 percent of the total resource (table 4). Coal production increased sharply from 4 million metric tons in 1974 to 52 million metric tons in about 1990, then plateaued until about 2015, and declined sharply to 19 million metric tons in 2021 (Reedy and others, 2024). All the mines during this period were surface mines extracting coal from multiple beds. Most of the mines opened after 1974 in response to the oil crisis in the 1970s. The number of mines increased from 3 in 1972 to 15 in 1985, where it remained until 2013. In 2014, the number of mines peaked at 19, then rapidly declined in number to only 5 active mines in 2022 (U.S. Energy Informaiton Administration, 2024). The majority of the mines operated in Texas (21 lignite, 5 bituminous), with three mines in Louisiana and two in Mississippi. Most mines had associated mine-mouth power plants. The three mines in Louisiana include the Dolet Hills Lignite mine (1985 – 2020), Oxbow Lignite mine (1989 - 2009) that provided coal to the Dolet Hills power plant, and the Five Forks mine (active since 2010) that supplies raw material for conversion to activated carbon (Louisiana Economic Development, 2023). In Mississippi, the Red Hills Mine has been active since 2002, and the Liberty Mine operated from 2014 to 2017 (U.S. Energy Informaiton Administration, 2024).

Discussion

Previous coal resource estimates for the Gulf Coast region are summarized in table 1. A comparison between previous resource studies and the results of this study is difficult because each study used different data sources, assessment methodologies, overburden depths, and qualifying coal thicknesses. This study is unique because it evaluated the entire Gulf Coast coal-bearing region with one methodological approach. A general comparison of the state-wide results presented in table 1 with the results of this study (table 3) indicates the following key points:

- Georgia – No previous estimates of the lignite resources of Georgia have been found in the literature. Here we report that approximately 7 million metric tons of lignite are in place.
- Alabama – The Alabama lignite resources identified in this study (2.9 billion metric tons) are within the range of previous resource studies of 1.2 billion metric tons (Luppens, 1979, 1980) and 1.5 billion metric tons (Tolson, 1985) (tables 1, 3). However, Tolson (1985) suggests there may be significant lignite resources (4.3 billion metric tons) at depths 76 to 1,830 m. This study used a maximum depth of investigation of 90 m.
- Mississippi – Previous estimates of Mississippi coal resources are estimated to be about 4.5 billion metric tons (Luppens, 1979, 1980; Thieling and others, 2009). This study indicates there is approximately 20 billion metric tons of lignite resources at depths less than 90 m from the surface. The difference between previous and current estimates is probably due the increased number of drill holes used in the current study.
- Tennessee – There have been few studies of the lignite resources of western Tennessee. Luppens (1979, 1980) reported 1 billion metric tons of lignite might be available. This study suggests there is approximately 8.5 billion tons of lignite resources at depths less

than 90 m from the surface. As in Mississippi, this study used significantly more data points than used for previous studies.

- Kentucky – The lignite resources of western Kentucky have been poorly documented in the literature. Olive (1971), based on surficial mapping in one 1:24,000 scale quadrangle map area, suggested as much as 45,359 metric tons might be available. The results of this study, for all lignite-bearing areas of western Kentucky, suggest there may be approximately 820 million metric tons of lignite in place.
- Missouri – No previous estimates of the lignite resources of Missouri have been found in the literature. Here we report that approximately 1.8 billion metric tons of lignite are in place.
- Arkansas – Multiple lignite resource estimates have been previously reported (table 1). The approximately 5.1 billion metric tons of Arkansas lignite resource reported in this study (table 3) are within the range of previous estimates of 2 to 8 billion metric tons (Luppens 1979, 1980; Prior and others, 1985).
- Louisiana – Luppens (1979, 1980) estimated there might be 1 billion metric tons of lignite resources within Louisiana. Warwick (2011) evaluated unmined areas near active mines in Louisiana and suggested 1 billion metric tons of lignite resources remained. This study estimated state-wide resources to be 12 billion metric tons. The difference between estimates by Luppens (1979, 1980) and this study is probably due the increased number of drill hole-data points used in the current study. The resource estimates of Warwick (2011) are not State-wide and are limited to areas adjacent to active coal mining.
- Texas – Table 1 shows there have been multiple previous state-wide and regional coal (lignite and bituminous) resource assessments conducted in Texas. Note that previous assessments used various methodological approaches and data sources, so the results differ. Based on the results of this study, Texas has the largest remaining coal resources in the Gulf Coast region, totaling 32 billion metric tons (table 3).

The Gulf Coast and the Williston basin of North Dakota, Montana, and South Dakota (fig. 1) are the two major lignite-bearing basins within the United States (East, 2012). Recent REE and CM studies of the lignite in these basins have indicated that the lignite may be a viable source material for REE and CM extraction (for example, Murphy and others, 2023; Mann, 2021; Hower and others, 2023; Scanlon and others, in press). In general, individual coal beds in the Williston basin are thicker (up to 12 m or 40 ft) than coal beds in the Gulf Coast basin (up to 4.6 m or 15 ft thick) (Ellis and others, 1999; Warwick and others, 2011b). As in the Gulf Coast, lignite resource assessments in the Williston basin have variable results (table 4). Averitt (1975) suggested lignite resources in the Williston basin at depths less than 610 m (2,000 ft) and with bed thicknesses greater than 0.76 m (2.5 ft) to be as follows: Montana, 102 billion metric tons; North Dakota, 318 billion metric tons; and South Dakota, 2 billion metric tons. In a more recent study, Ellis and others (1999) estimated 69 billion metric tons of remaining coal resources were available for potential future mining in four primary coal zones that had been previously mined in western North Dakota. Murphy and others (2006) used averaged township cumulative coal thickness of lignite beds that were generally greater than 0.6 m (2 ft) thick and at depths from 6 to 122 m (20 to 400 ft) to estimate North Dakota lignite resources to be 1,157 billion metric tons. Murphy (2006) suggested North Dakota reserves at depths 6 to 46 m (20 to 150 ft) may be 22.7 billion metric tons. The Gulf Coast coal resources (83 billion metric tons, table 3) identified in this study, are comparable to the lignite reserves of North Dakota (Murphy, 2006). A regional study of coal reserves within the Gulf Coast region has not been completed.

Table 4. Some previous coal resource and reserve studies of the Williston basin.

State	Depth (m)	Coal bed thickness (m)	Billion short tons	Billion metric tons	Reference
Montana	≤914	≥0.6	112.5	102.1	Averitt (1975)
North Dakota	≤366	≥0.6	350.9	318.3	Brant (1953), Averitt (1975)
North Dakota	0 to ≥152	≥0.76	76	69	Ellis and others (1999)
North Dakota	0.6 to ≤122	≥0.6	1,275.4	1157.0	Murphy and others (2006)
North Dakota[1]	0.6 to ≤46	≥0.6	25.1	22.7	Murphy (2006)
South Dakota	≤914	≥0.6	2.2	2.0	Averitt (1975)

[1]Reserves

Conclusions

This regional study of the U.S. Gulf Coast provides an initial analysis the coal resources that might be available as potential sources of REE and CM. The resource analysis used kriging methods to develop isopleth maps of cumulative coal thickness throughout the region using data from 31,181 drill holes and other data points. The estimated total coal resource in the Gulf Coast is about 83 billion metric tons in the upper 90 m (~ 300 ft) of the subsurface. Texas accounted for 40 percent of the total, followed by Mississippi (24 %), Louisiana (14 %), Tennessee (10 %), and Arkansas (6 %). The remaining states each accounted for less than 5 percent of the total resource. Georgia had the smallest resource estimated at 7 million metric tons. Here we report the first known state-wide lignite resource estimates for Georgia, Kentucky (820 million metric tons) and Missouri (1,800 million metric tons).

A comparison between previous Gulf Coast coal resource studies and the results of this study is difficult because each study used different data sources, assessment methodologies, overburden depths, and qualifying coal thicknesses. The Gulf Coast and the Williston basin (the other major U.S. lignite region) have significate lignite resources at shallow depths (within 90 m) of the subsurface that might serve as potential sources of REE and CM. Future coal resource and reserve studies could be focused on areas within the Gulf Coast regions with elevated REE and other CM concentrations.

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