DEEP-BASIN COAL (LIGNITE) IN WILCOX GROUP, SABINE UPLIFT, EAST TEXAS: POTENTIAL FOR UNCONVENTIONAL COAL GAS RESOURCE DEVELOPMENT

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ABSTRACT

The Wilcox Group in the Sabine Uplift, East Texas, contains relatively large amounts of deep-basin (220- to 2,000-ft depth) coal that may in turn contain large coalbed methane resources. The objective of the proposed study is to assemble and prepare data on coal resources in the Sabine Uplift area of East Texas for inclusion in the U.S. Geological Survey National Coal Resources Data System (NCRDS). Coal occurrence and lithofacies maps created in *The Wilcox Group (Paleocene-Eocene) in the Sabine Uplift Area, Texas: Depositional Systems and Deep-Basin Lignite* (Kaiser, 1990) were digitized and converted into a Geographic Information System (GIS) format. Associated data that were derived from geophysical logs to create these maps were then compiled into a digital spreadsheet. These digital maps and data enable prediction of coal seam thickness, geometry, and continuity and, therefore, areas of potential coalbed methane resources. The distribution of the Wilcox coals is depositionally controlled, and the stratigraphic framework of the targeted horizons defines coalbed methane exploration fairways. According to available data, the highest potential for coalbed methane production and development in the Sabine Uplift, East Texas, exists in the lower Wilcox Group coal seams in Panola and Shelby Counties.

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INTRODUCTION

Interest in coalbed methane resources along the Texas Gulf Coast has increased markedly owing to rising gas prices and the availability of information pertaining to coalbed methane exploration and development. A previous report, *Defining Coalbed Methane Exploration Fairways in East-Central Texas* (Tyler and Scott, 1999) summarizes the coalbed methane potential of the Wilcox Group in East-Central Texas and provides data for inclusion in the U.S. Geological Survey National Coal Resource Database (NCRDS). As part of a continued effort to evaluate and publicize coalbed methane resources in Texas, the coal resources of the Wilcox Group in the Sabine Uplift in East Texas were studied. As in East-Central Texas, the Sabine Uplift area in East Texas (Figure 1) contains relatively large amounts of deep-basin (220- to 2,000-ft depth) coal of lignite rank that may contain large coalbed methane resources (Kaiser and others, 1980; Ayers and Lewis, 1985; Kaiser, 1990;).

Previous research in the Sabine Uplift area of East Texas has focused on coal occurrence and resource assessment (Kaiser, 1974; Kaiser and others, 1980; Kaiser, 1986; Kaiser, 1990). The distribution of the Wilcox Group coals is depositionally controlled, and the stratigraphic framework of the targeted horizons defines coalbed methane exploration fairways. For example, upper Wilcox Group coal seams in the Sabine Uplift area of East Texas occupy a flood-basin setting between paleofluvial channel complexes. Digital maps and spreadsheets of the Wilcox Group coal seams and depositional framework elements will therefore aid in establishing coal boundaries for future coalbed methane resource development.

The objective of the proposed study is to assemble and prepare data on coal resources in the Sabine Uplift area of East Texas for inclusion in the NCRDS. We will employ data from Kaiser (1990) to create the primary products of this study: (1) digital maps of location, structure, stratigraphy, and coal resources and (2) digital spreadsheets of geophysical well-log-derived data. We will also review the potential for coalbed methane in the coal-bearing seams of the Wilcox Group in the Sabine Uplift area, East Texas, by applying the coal producibility model (Tyler and others, 1997). This

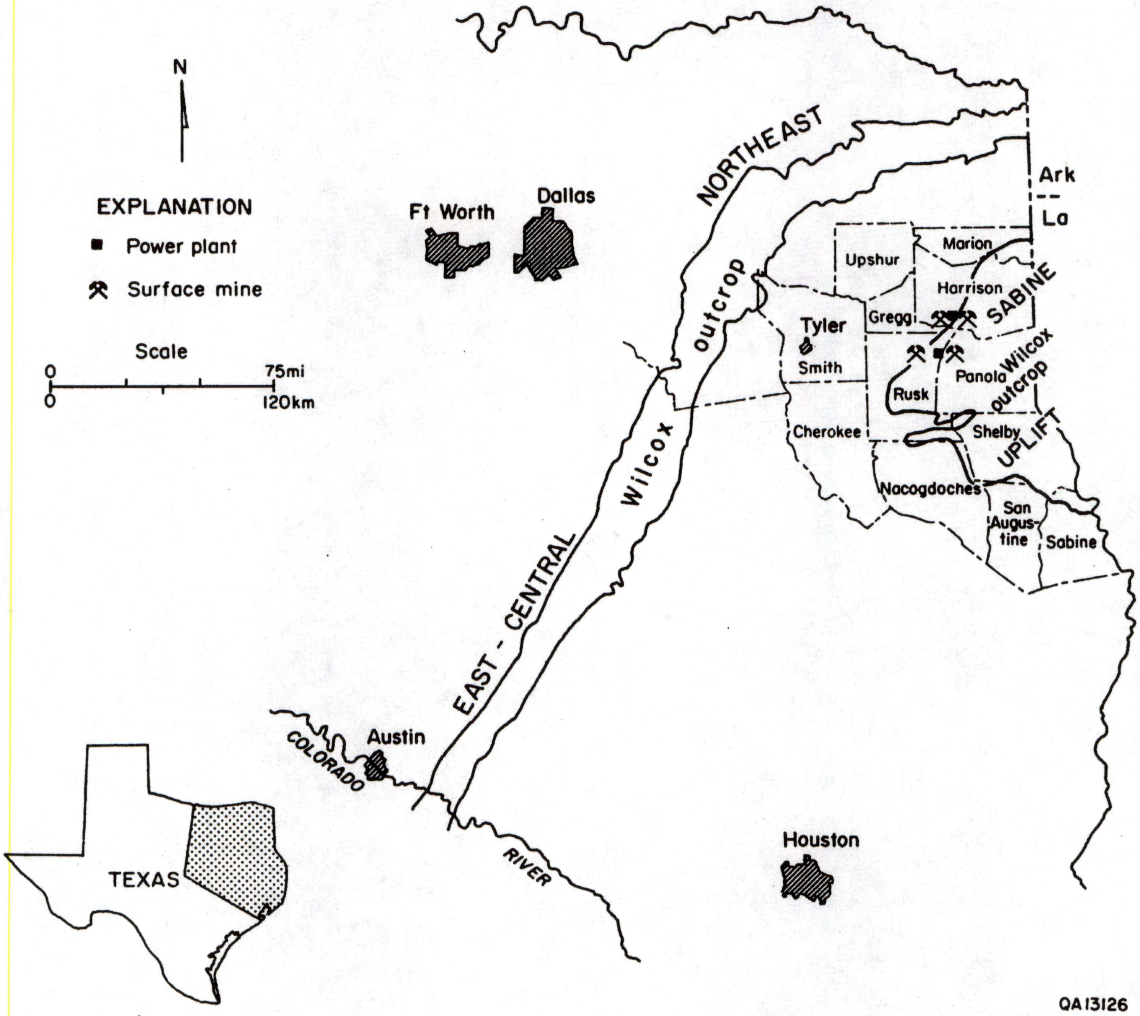

Figure 1. Location map of the Sabine Uplift area, East Texas (Kaiser, 1990).

study will comprise three parts: (1) previous investigations involving the background geology and coal resource assessment of the Sabine Uplift area, East Texas; (2) explanation of the digital maps and spreadsheets for inclusion in the NCRDS; and (3) a brief assessment of future coalbed methane production potential. This study will provide the Texas natural gas and coal industry with baseline information that may promote growth of coalbed methane production and development in the state.

PREVIOUS INVESTIGATIONS

A major energy resource in Texas providing energy since 1850, Texas coal has been researched previously in great detail. The Bureau of Economic Geology and its predecessor, the Geological Survey of Texas, published numerous reports on Texas coal resources (Dumble, 1892; Phillips, 1902, 1914; Stenzel, 1946; Stenzel and others, 1948; Perkins and Lonsdale, 1955; Fisher, 1963; Kaiser, 1974, 1990; Kaiser and others, 1980,1986; Ayers and Lewis, 1985; Fogg and others, 1991; Tyler and Scott, 1999). The depositional systems, structure, stratigraphy, hydrology, geochemistry, and resource estimates for Texas coals have been delineated in these reports. The major reference for this study, however, is the Kaiser study in 1990, *The Wilcox Group (Paleocene-Eocene) in the Sabine Uplift Area, Texas: Depositional Systems and Deep-Basin Lignite*.

Wilcox Group sediments in East Texas were derived from the Quachita Mountains to the north and northeast and were deposited as a lower Tertiary (upper Paleocene to lower Eocene) succession as much as 2,500 ft thick (Figure 2). They are informally divided into a thin, progradational (deltaic) lower unit and a thick, aggradational (fluvial) upper unit. Wilcox tectonic elements (Sabine Uplift and East Texas Basin) served to focus and receive sediment that was shaped by Wilcox bed- and mixed-load rivers into platforms and basins for peat accumulation. A channel system aggrading diagonally across the Sabine Uplift and coal seams near its crest indicates that the uplift was subsiding during Wilcox deposition, although less rapidly than the surrounding basinward areas (Kaiser, 1990).

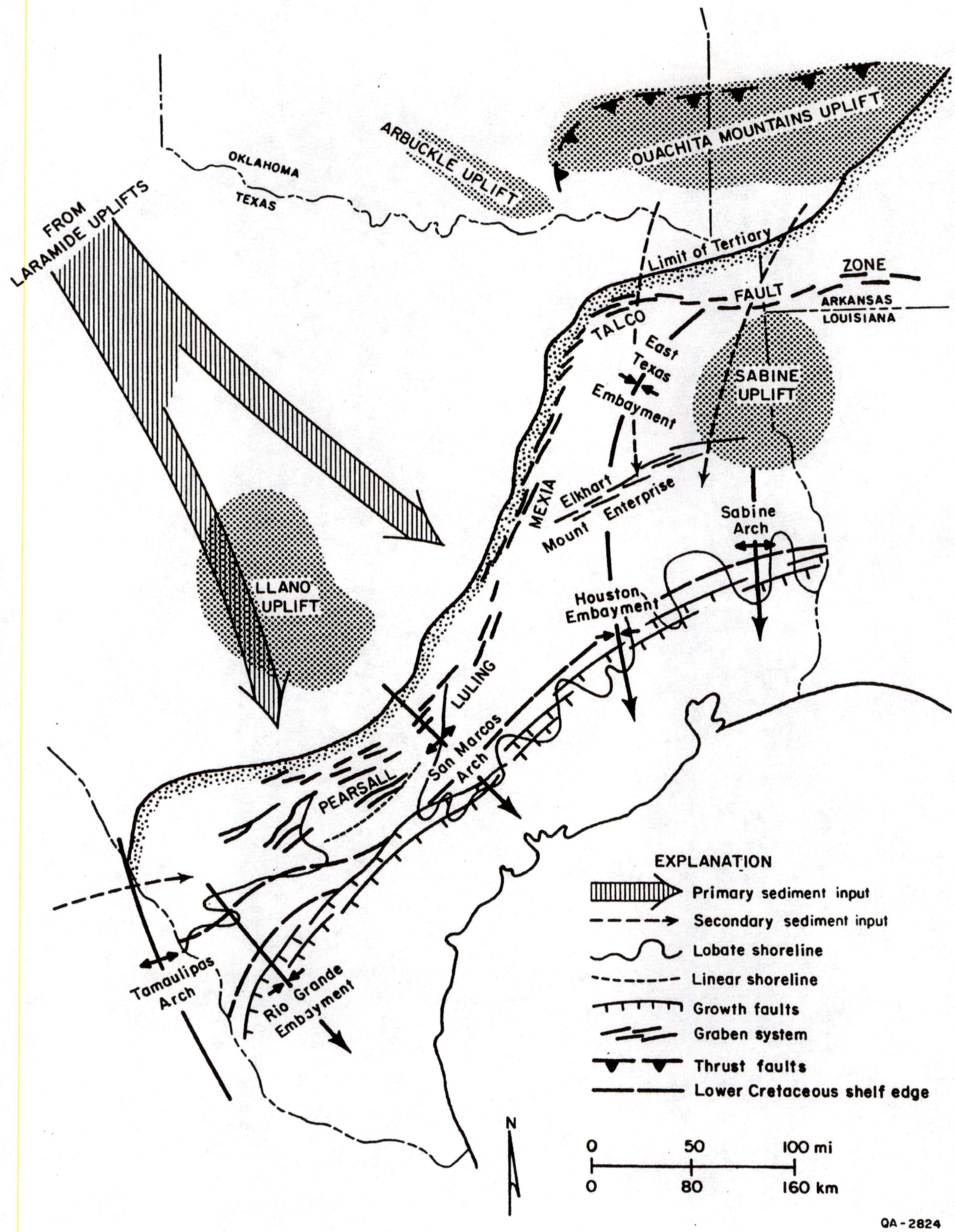

Figure 2. Regional structural elements and Wilcox Group sediment source areas (Kaiser, 1990).

In Kaiser's study (1990), coal occurrence and lithofacies maps were made from oil and gas geophysical logs obtained in the Sabine Uplift area. Coal seams were operationally defined on electric and induction logs as those beds having a sharp resistivity spike and a baseline spontaneous potential. Lithofacies mapping focused on thick sands, termed maximum and major sands, in order to establish Wilcox depositional systems. Log responses defined the maximum sand as the single thickest interval of interest, whereas a major sand was defined as any sand at least 40 ft in thickness. A maximum-sand map can be made quickly to reveal depositional systems and to predict the range of sand-body thickness and the continuity of coal seams. Because the thick sands control average hydraulic conductivity of a stratigraphic interval, moreover, the maps can become a tool for hydraulic evaluation (Fogg and others, 1991). Converting these maps and associated data that were derived from geophysical logs into a digital format forms the basis of the current study.

Coal seams at least 5 ft thick and stratigraphically restricted to facies transitions punctuating the vertical sequence are geographically limited. Thick coal seams occur in the lower Wilcox Group at the transition from marine Midway to progradational Wilcox sediments and at the top of the lower Wilcox Group transition from progradational to aggradational facies. Thick upper Wilcox Group coal seams lie primarily below the Carrizo Sand and secondarily above massive, blocky sands in the basal part of the Upper Wilcox Group at the inferred transition from dominantly bed-load (blocky sands) to mixed-load (upward-fining sequences) sedimentation (McGowen and Garner, 1970) (Figure 3).

The thickest, most laterally extensive coal seams in the deep basin lie in the lower Wilcox of Panola and Shelby Counties, having accumulated on an interdeltaic coastal plain in a sediment shadow on the south end of the Sabine Uplift. Thick coal seams in the upper Wilcox of Cherokee, Rusk, and Shelby Counties are associated with the alluvial/delta-plain transition and thick channel-fill sands. In the deep basin, small

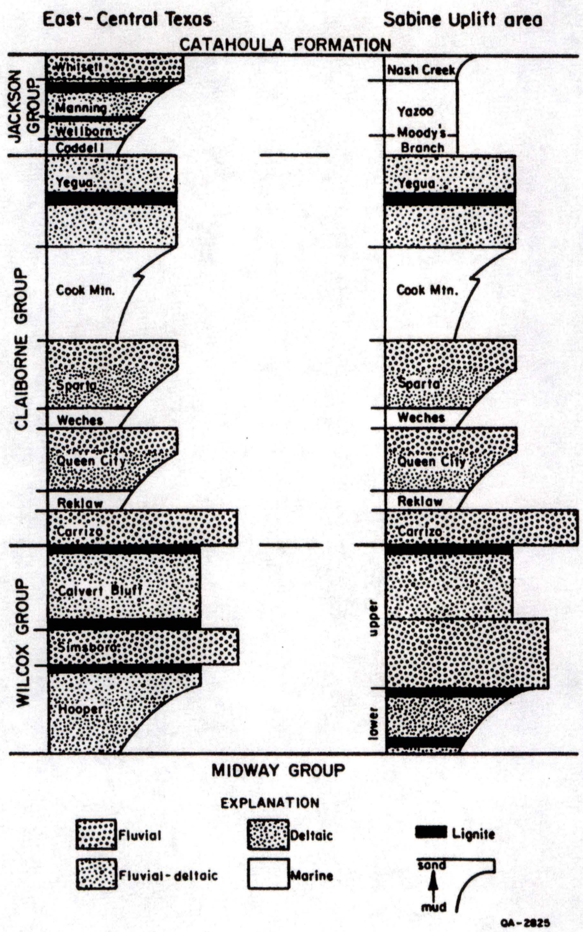

Figure 3. Lower Tertiary stratigraphy and the occurrence of coals in East Texas (Kaiser, 1990).

interchannel basins limited the lateral continuity of thick, upper Wilcox coal seams. Deep coal resources at depths less than 2,000 ft and in seams at least 5 ft thick equal approximately 5.5 billion short tons. The highest potential for deep recovery exists in coal seams in Panola and Shelby Counties (Kaiser, 1990).

Lithofacies maps reveal that depositional framework elements are elongate, channel-fill sands woven into ribbons displaying tributary patterns up paleoslope that give way basinward to distributary patterns linked across the alluvial/delta-plain transition by parallel reaches. Inferring from the size and orientation of the channel sand belts, major Wilcox Group fluvial channels must have flowed southward down the axis of the East Texas Basin and southwestward along the west flank of the Sabine Uplift. To the north, up paleoslope, the entire Wilcox Group is composed of thick alluvial cycles, and the lower Wilcox Group is absent in equivalent facies or in postdepositional alluvial downcutting (Kaiser, 1990).

DIGITAL MAPS AND SPREADSHEETS FOR INCLUSION IN NCRDS

Coal occurrence and lithofacies maps that had been made from oil and gas geophysical logs obtained in the Sabine Uplift area in Kaiser's study (1990) were digitized and converted into a Geographic Information Database (GIS) format. Associated data that were derived from geophysical logs to create these maps were compiled into a digital spreadsheet. Both the digital maps and the spreadsheet were formatted for inclusion in the NCRDS. These two tasks comprise the primary project tasks performed and form the basis for facilitating future detailed analysis of coalbed methane production and development potential.

Digital Mapping Data

Maps of location, structure, stratigraphy, and coal resources of the Wilcox Group (Paleocene-Eocene) in the Sabine Uplift area, East Texas, were compiled by Kaiser (1990). These maps were scanned and digitized with the objective of assembling and preparing data on coal resources in the Sabine Uplift area, East Texas, for inclusion in the NCRDS. Of the 16 original plates included in Kaiser's study (1990), all of the plates were scanned and 12 were digitized. These included a base map delineating the location of wells (location map), three Wilcox structure maps (base of Wilcox, structure-contour map; top of Wilcox, structure-contour map; and contact of lower and upper Wilcox, structure-contour map), six Wilcox sand maps (lower Wilcox, maximum-sand map; lower Wilcox, sand-percent map; lower Wilcox, net-sand isolith map; upper Wilcox, maximum-sand map; upper Wilcox, sand-percent map; and upper Wilcox, net-sand isolith map), and two coal-resource maps (lower Wilcox, lignite-isopleth map, and upper Wilcox, lignite-isopleth map). Plates 2, 3, 4, and 14 were not digitized because they were cross sections. These digitized maps were incorporated into an Environmental Systems Research Institute, Inc. (ESRI) ArcView GIS format for the user to readily present and analyze the digital mapping data (Figure 4). Scanned plate images and ArcView shape and database files of the digitized maps are included with this report on the provided CD.

The digital-mapping data are provided on the CD under the GIS data file directory. Within this directory reside folders containing ArcView GIS shape and database files for each plate digitized and a main project file titled ncrds.apr. Minimum hardware suggestions for installation of the ArcView GIS files include a Pentium III or greater personal computer (PC) running Windows 98, 2000, or NT. Software requirements include ESRI's ArcView GIS version 3.2a.

Installation requires copying the entire GIS data file directory to the hard drive and then opening the existing project file, ncrds.apr, within the ArcView GIS program. ArcView GIS will ask where the shape and database files are located during the initial installation of the project. Direction to the file directories that contain the shape and database files will complete the installation of the project. For simplification, all shape and database files are organized by the original plate numbers:

Plate 1: Location map
Plate 5: Base of Wilcox, structure-contour map
Plate 6: Top of Wilcox, structure-contour map
Plate 7: Contact of lower and upper Wilcox, structure-contour map

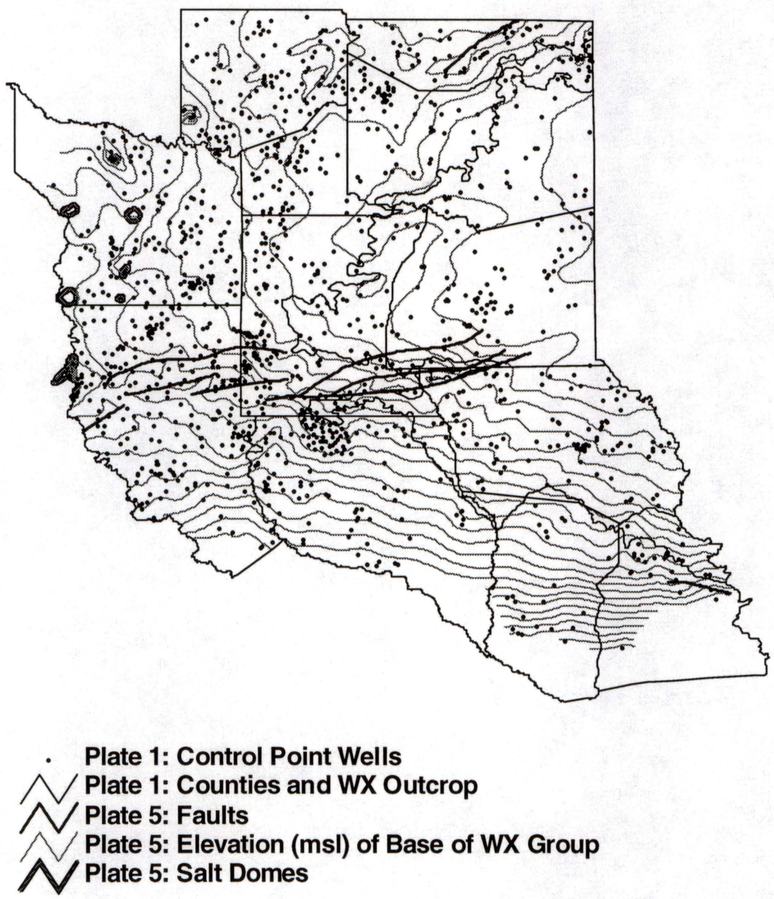

Plate 5: Base of Wilcox, structure-contour map.

Figure 4. Example of ArcView GIS representation of digital map.

Plate 8: Lower Wilcox, maximum-sand map

Plate 9: Lower Wilcox, sand-percent map

Plate 10: Lower Wilcox, net-sand isolith map

Plate 11: Upper Wilcox, maximum-sand map

Plate 12: Upper Wilcox, sand-percent map

Plate 13: Upper Wilcox, net-sand isolith map

Plate 15: Lower Wilcox, lignite-isopleth map

Plate 16: Upper Wilcox, lignite-isopleth map

Each plate folder contains the required ArcView GIS shape and database files. When the project is loaded, a view of the maps can be created by selecting desired theme items. For example, initially the project should open with the following themes selected to depict Plate 1: Location map,

Plate 1: Control Point Wells

Plate 1: Counties and WX Outcrop

When the theme is specified, moving the pointer and left-clicking on the map theme result in a table describing the theme property. For example, when the Plate 1: Control Point Wells theme is specified, moving the pointer and left-clicking on any well location result in a table describing the well name. For any other plate to be viewed, appropriate plate themes must be selected. Themes of Plate 1 serve as a base map for subsequent maps.

An advantage of representing spatial data in an ArcView GIS format is the ability to view several themes overlayed atop one another to delineate possible interrelationships among the data. New maps may be created by overlaying different data themes. The data format is also readily available for inclusion in NCRDS and may provide valuable spatial data for delineating future potential coalbed methane production and development fairways.

Digital Spreadsheet of Geophysical Well-Log-Derived Data

When compiling the maps in Kaiser (1990), we extracted data from geophysical well logs located on Plate 1. Most logs originated from the Texas Water Commission (Q prefix), whereas smaller sets (ET, PI, G, C, and M prefix) were purchased from various log libraries. Texas Energy and Natural Resources Advisory Council/Bureau of Economic Geology (TENRAC/BEG) data are also provided. Data extracted from the geophysical well logs included,

Top of the Wilcox (values in feet below sea level unless indicated by +)
Upper-lower Wilcox contact (values in feet below sea level unless indicated by +)
Base of the Wilcox (values in feet below sea level unless indicated by +)
Upper Wilcox maximum sand (ft)
Upper Wilcox net major sand (ft)
Upper Wilcox percent major sand (ft)
Lower Wilcox maximum sand (ft)
Lower Wilcox net major sand (ft)
Lower Wilcox percent major sand (ft)
Upper Wilcox resistivity of maximum sand (ohm-m)
Upper Wilcox total number of lignite seams
Upper Wilcox number of lignite seams 5 ft or thicker
Lower Wilcox total number of lignite seams
Lower Wilcox number of lignite seams 5 ft or thicker

Additional spatial data, such as county, log number, latitude, and longitude, were also compiled. Data-quality checks were conducted and resulted in several of the wells being deleted either because their well control points did not exist on the location map or no well data were present.

The data extracted from geophysical well logs were initially provided in microfiche format in Kaiser (1990). All data have been converted into a digital spreadsheet file format (Microsoft Excel and DBase IV) named Well Control Point Data and are provided with this report on the CD. The data exist within the created ArcView GIS project (ncrds.apr) as a separate table as well. This digital spreadsheet is also readily available for inclusion in the NCRDS and can be linked to the well control points in ArcView GIS.

COALBED METHANE PRODUCIBILITY

Over the past decade, on the basis of research performed in the Rocky Mountain Foreland, Western United States, and Alaska (Tyler and others, 1997), the Bureau of Economic Geology has developed a coalbed methane producibility model (Figure 5) for defining areas of prolific coalbed methane production. The coalbed methane producibility model considers all geologic and hydrologic criteria and data available. Importantly, coalbed methane producibility and resource volumes are governed by six critical factors: tectonic/structural setting, depositional systems and coal distribution, coal rank, gas content, permeability, and hydrodynamics. Exceptionally high productivity within a basin will be governed by (1) thick, laterally continuous coals; (2) adequate permeability; (3) flow of groundwater toward no-flow boundaries (regional hingelines, fault systems, facies changes, and/or discharge areas); (4) generation of secondary biogenic gases; and (5) conventional trapping along those boundaries to provide additional gas beyond that generated in situ during coalification. Understanding the dynamic interaction among these key geologic and hydrologic factors can be used to define areas that may have coalbed methane producibility (Tyler and others, 1997).

Coal beds are both the source and reservoir of methane, indicating that their distribution is critical in establishing a significant coal gas resource. Coal distribution is closely tied to tectonic, structural, and depositional setting because peat accumulation and preservation as coal require a delicately balanced subsidence rate that maintains optimal water-table levels but excludes disruptive clastic sediment influx. The depositional setting defines the substrate upon which peat growth is initiated and within which the peat swamps proliferate. Knowledge of the depositional framework and stratigraphic architecture of the Wilcox Group in the Sabine Uplift area, East Texas, provided in the digital maps of this study enables prediction of coalbed thickness, geometry, and continuity and, therefore, areas of potential coal gas resources.

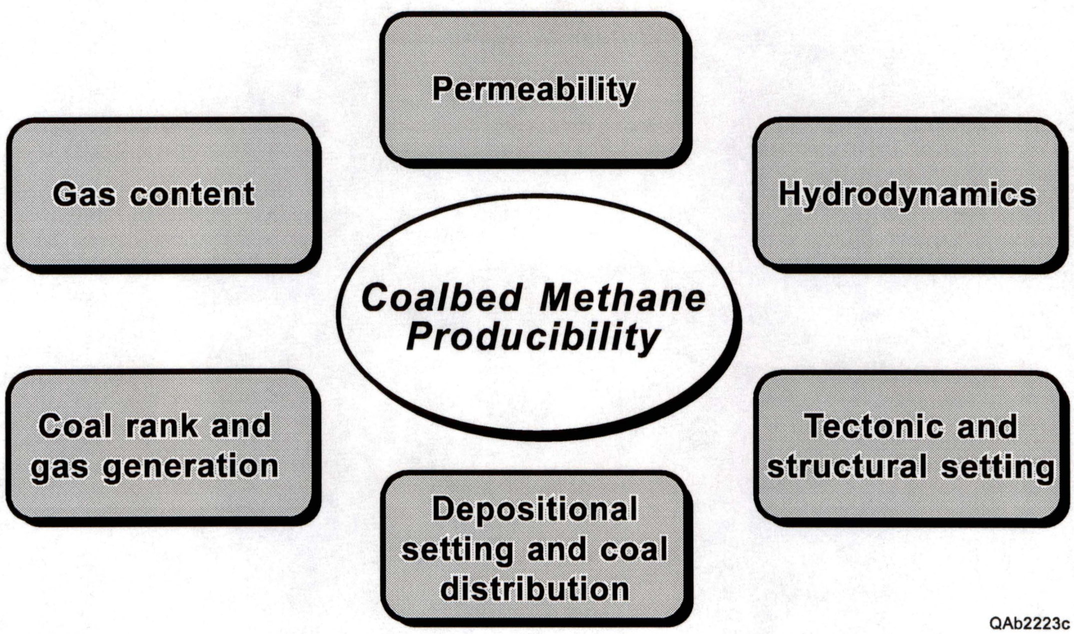

Figure 5. Coalbed methane producibility model (Tyler and others, 1997).

Coals must also reach a certain threshold of thermal maturity before large volumes of thermogenic gases can be generated. The amount and types of coal gases generated during coalification are a function of burial history, geothermal gradient, maceral composition, and coal distribution. Although higher rank coals generally have higher gas contents, gas content is not determined by coal rank alone; gas content is not fixed but changes when equilibrium conditions within the reservoir are disrupted (Scott and others, 1994).

Gas content of coals can be enhanced, either locally or regionally, by generation of secondary biogenic gases or by diffusion and long-distance migration of gases to no-flow boundaries such as structural hingelines, faults, facies variations, and compactional folds for eventual resorption and conventional trapping (Kaiser and others, 1995). Importantly, secondary biogenic gases have made a significant contribution to produced gases in the San Juan and Powder River Basins. All produced coal gases in the lower rank coals of the Powder River Basin are secondary biogenic, and more than 300 Bcf of secondary biogenic gas is estimated to have been produced in the San Juan Basin (Scott and others, 1994).

Coal rank is relatively low in the Sabine Uplift area, with most coals being lignites. However, as observed in the lower rank coals of the Powder River Basin, secondary biogenic gas may be possible. To date, analyses of the gas content and the origin of gas in the coal-bearing seams of the Wilcox Group in the Sabine Uplift area, East Texas, have not been performed.

Permeability and groundwater flow are additional controls critical to coalbed methane producibility. They are intimately related to coal distribution and depositional and tectonic/structural setting because basinward flow of groundwater through coal seams requires recharge of laterally continuous permeable coals at the basin margins. The coals, therefore, not only act as conduits for gas migration but are also commonly groundwater aquifers having permeabilities that are orders of magnitude larger than associated sandstones. In-depth analyses of the hydrology of the Wilcox Group of East Texas were performed by Kaiser and others (1986) and Fogg and others (1991).

Simple knowledge of the characteristics of the geological and hydrological controls in the coal-bearing seams of the Wilcox Group in the Sabine Uplift area, East Texas, will not lead to a conclusion about coalbed methane resources. For it is the complex interplay among these controls and their spatial relationships that governs the producibility. According to available data, the highest potential for coalbed methane production and development exists in the lower Wilcox coal seams in Panola and Shelby Counties. However, the coal-bearing seams are relatively thin and low rank, and for an accurate assessment of the future potential of coalbed methane production and development, more detailed studies are required, especially in terms of gas content and the origin of gases.

CONCLUSIONS

The objective of this cooperative project between the Bureau of Economic Geology and the U.S. Geological Survey is to provide digital data for inclusion in the NCRDS and a preliminary assessment of the coalbed methane potential of the coal-bearing seams of the Wilcox Group in the Sabine Uplift area, East Texas. Coal occurrence and lithofacies maps made from oil and gas geophysical logs obtained in the Sabine Uplift area during Kaiser's study (1990) were digitized and converted into an ArcView GIS format. Associated data that were derived from geophysical logs to create these maps were then compiled into a digital spreadsheet. These digital maps and data enable prediction of coalbed thickness, geometry, and continuity and, therefore, areas of potential coalbed methane resources. According to available data, the highest potential for coalbed methane production and development exists in the lower Wilcox coal seams in Panola and Shelby Counties. However, because of the limited scope of this project, a detailed evaluation of the future potential of coalbed methane production and development was not performed.

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