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Coal Gas Resource Potential of Cretaceous and Paleogene Coals of the Gulf of Mexico Coastal Plain (including a review of the activity in the Appalachian and Warrior basins)[1]

By Peter D. Warwick[2], F. Clayton Breland, Jr.[3], M. Edward Ratchford[4], and Paul C. Hackley[2]

Abstract

The primary focus of this presentation is on the coal gas resource potential of Lower Cretaceous and Wilcox Group (Paleocene-Eocene) coals of the Gulf Coastal Plain. In addition, a brief review of the coalbed methane exploration activity and resources of the Appalachian and Black Warrior basin is provided.

Recent investigations conducted by Federal, State, and industry organizations suggest that significant coalbed gas resources may exist in the lower Trinity Group and Hosston Formation (both Lower Cretaceous), Midway Group (Paleocene), and Wilcox Group (Paleocene-Eocene) of the Gulf of Mexico Coastal Plain. Drill records from Arkansas and Louisiana indicate that there are Cretaceous coal beds greater than 10 ft thick at depths of 1,500- 6,000 ft suitable for coalbed gas development. Vitrinite reflectance obtained from Cretaceous coal cuttings at these depths indicates that Ro_{max} equals up to 0.53%. Available data from conventional oil and gas wells in Louisiana indicate that upper, middle, and lower Wilcox Group coal zones have potential for coalbed gas accumulations and similar data from Texas, Arkansas, Mississippi, and Alabama indicate that gas may be present in coal beds of the lower and middle sections of the Wilcox. In addition, gas accumulations may occur in the coal beds of the upper part of the Midway Group in Mississippi and Alabama. Public data from several wells completed in Wilcox Group coal zones in north-central Louisiana indicate that initial production ranges from 7 to 122 thousand cubic feet (MCF) of gas per day and that production of saline water ranges from 0 to 550 barrels (bbls) per day.

In Louisiana, the depth to the targeted Wilcox coal beds ranges from 1,500 to 5,000 ft, and individual coal beds have a maximum thickness of about 20 ft. The thickest coal beds tend to be in the lower Wilcox coal zone and cumulative coal thickness can exceed 100 ft. Although geochemical and petrographic data from Wilcox Group coals from across the region indicate that the coal beds are lignite in rank at depths less than 350 ft, they reach a rank

[1] Modified from Warwick and others (2004); and unpublished short course notes from Short Course 8: Advances in coalbed methane exploration and development: A review of coalbed methane potential and opportunities in North America, American Association of Petroleum Geologists Annual Meeting, Dallas, TX, April 18, 2004; and Coalbed methane resources in the Southeast, Petroleum Technology Transfer Council, Central Gulf Region, Short Course, Lafayette, LA, June 8, 2004

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of subbituminous B, or greater, at depths of approximately 5,000 ft. Preliminary gas isotope data indicate that Wilcox coal gas originated from the microbial reduction of CO2 and that in some places, these gases may be mixed with migrated thermal gases. Proximity to salt dome structures or buried Late Cretaceous igneous intrusions and associated geothermal heat flow may be important exploration tools for finding coal beds with elevated rank and potentially increased gas content. More data are needed to better characterize and assess the coalbed gas potential for the Cretaceous coal beds in this region.

Current coal gas production in the Black Warrior basin is primarily located in Tuscaloosa, Jefferson, and Walker counties, Alabama. More than 1.5 trillion cubic feet (Tcf) of coal gas has been produced from the Black Warrior basin. In the Appalachian basin, current coal gas production is primarily located in southwestern Virginia and the adjacent part of southern West Virginia, and in northern West Virginia and adjacent parts of southwestern Pennsylvania. Cumulative coal gas production from the Appalachian basin is approximately 0.5 Tcf.

Acknowledgements

The U.S. Geological Survey and the Louisiana Geological Survey have Cooperative Research and Development Agreements with Devon SFS Operating, Inc., EnerVest Management Partners, Ltd., and Harvest Gas Management, L.L.C. Results of this research, which are currently proprietary, will be published in the near future. Cooperative research with these companies has led to a better understanding of the coal gas potential of the Gulf Coastal region. The Dolet Hills Mining Company provided access for mine coal sample collection and International Paper provided assistance in locating information on Cretaceous coal samples, and well logs from Arkansas.

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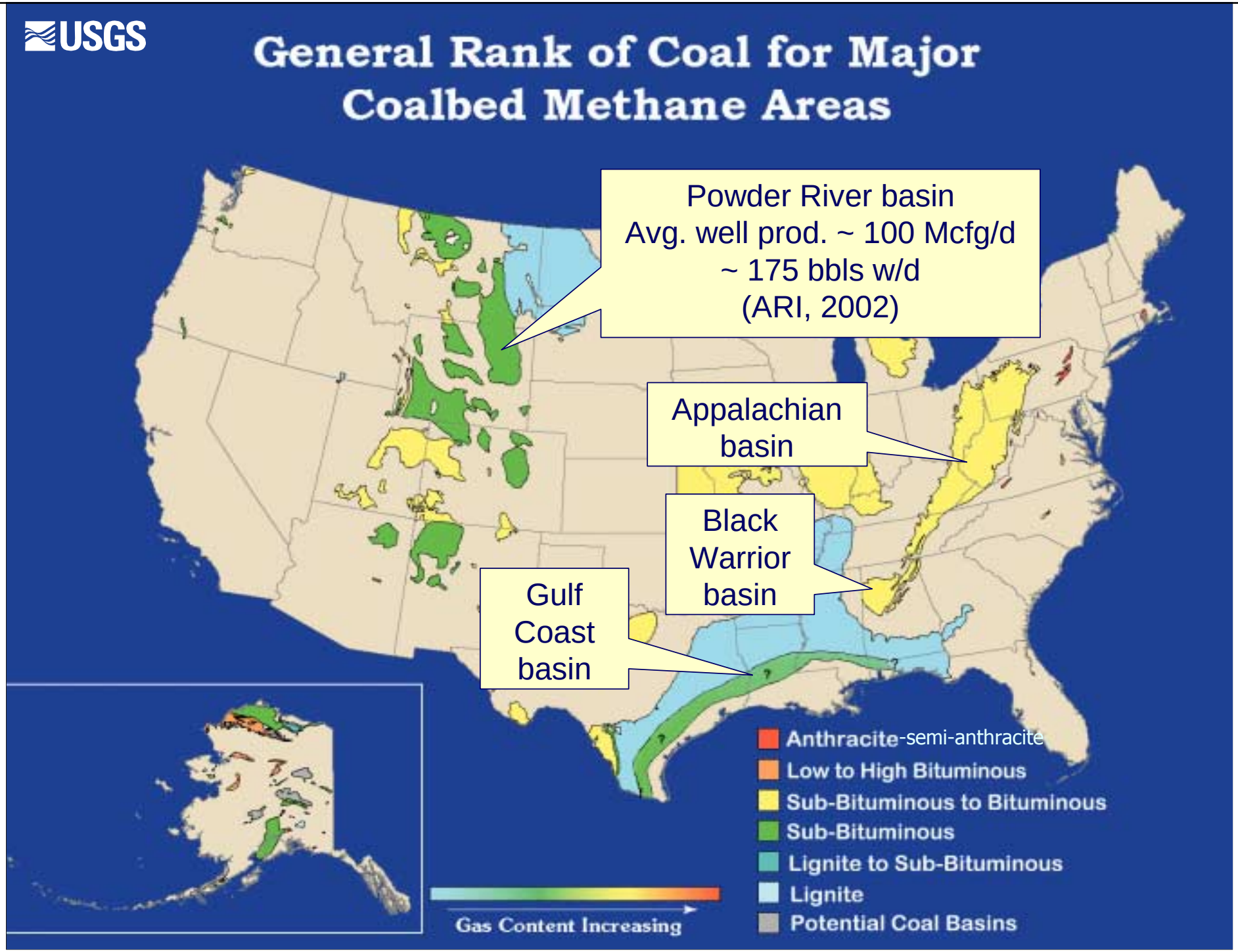
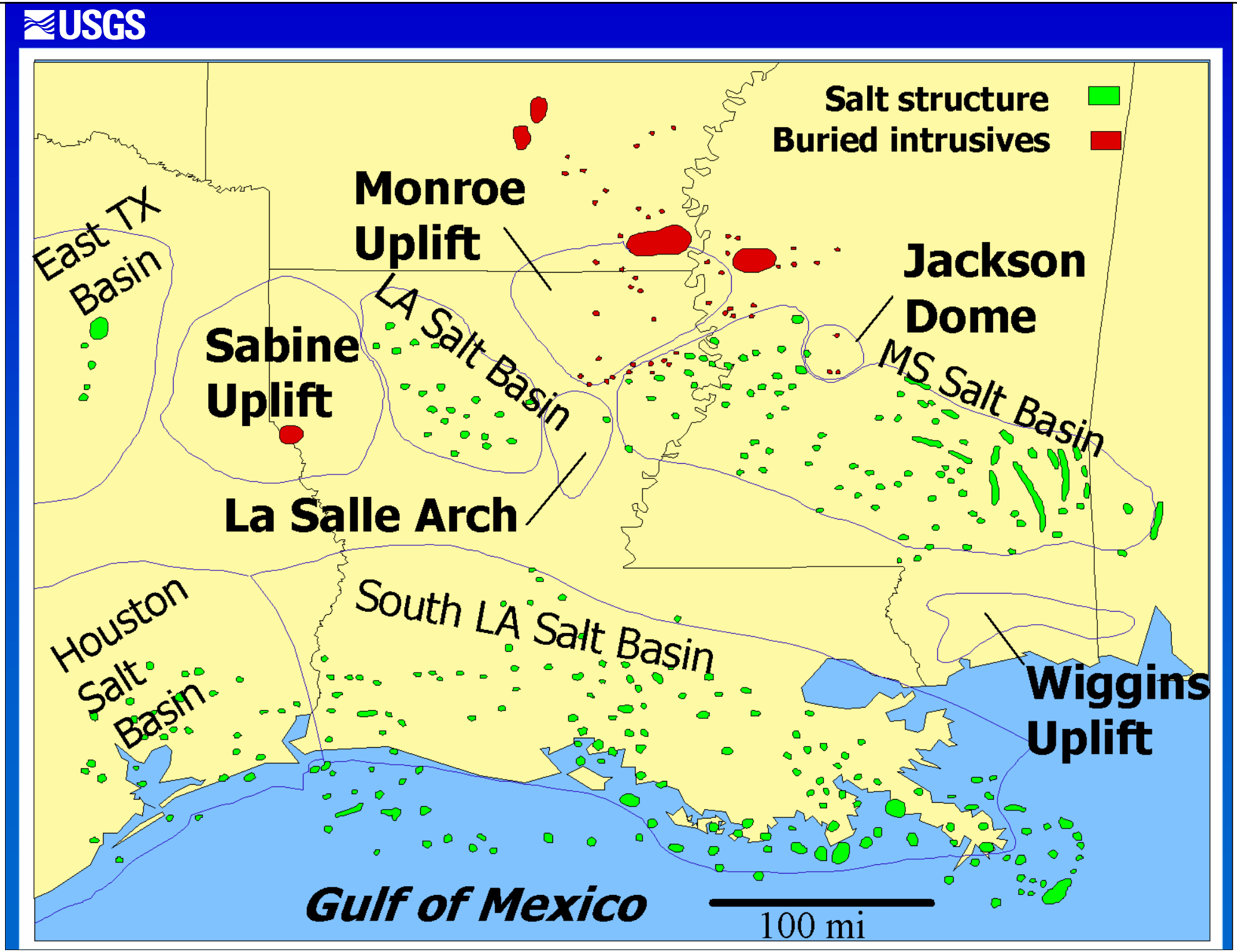
Outline

- Subsurface Cretaceous coals of AR-LA
  - unrecognized coal and CBM potential
- An update on the CBM activity in Tertiary Wilcox coals of north LA and coal gas potential for other areas
  - Stratigraphy
  - Hydrogeology
  - Exploration/Production
  - Gas Chemistry
- A review of coal gas activity and resources in the Appalachian and Warrior basins

Outline of presentation. CBM = coalbed methane.



General rank of coal for major coalbed methane areas in the United States. Note that the rank of Gulf Coast coals increase with depth to sub-bituminous or greater. For later comparison to the Gulf Coast area, average coal gas and water production data are provided for the Powder River basin (Advanced Resources International [ARI], 2002). Note the location of the Appalachian and Black Warrior basins.



Major structural features (outlined in blue) of the Louisiana region of the Gulf Coast basin. Modified from Ewing and Lopez (1991).

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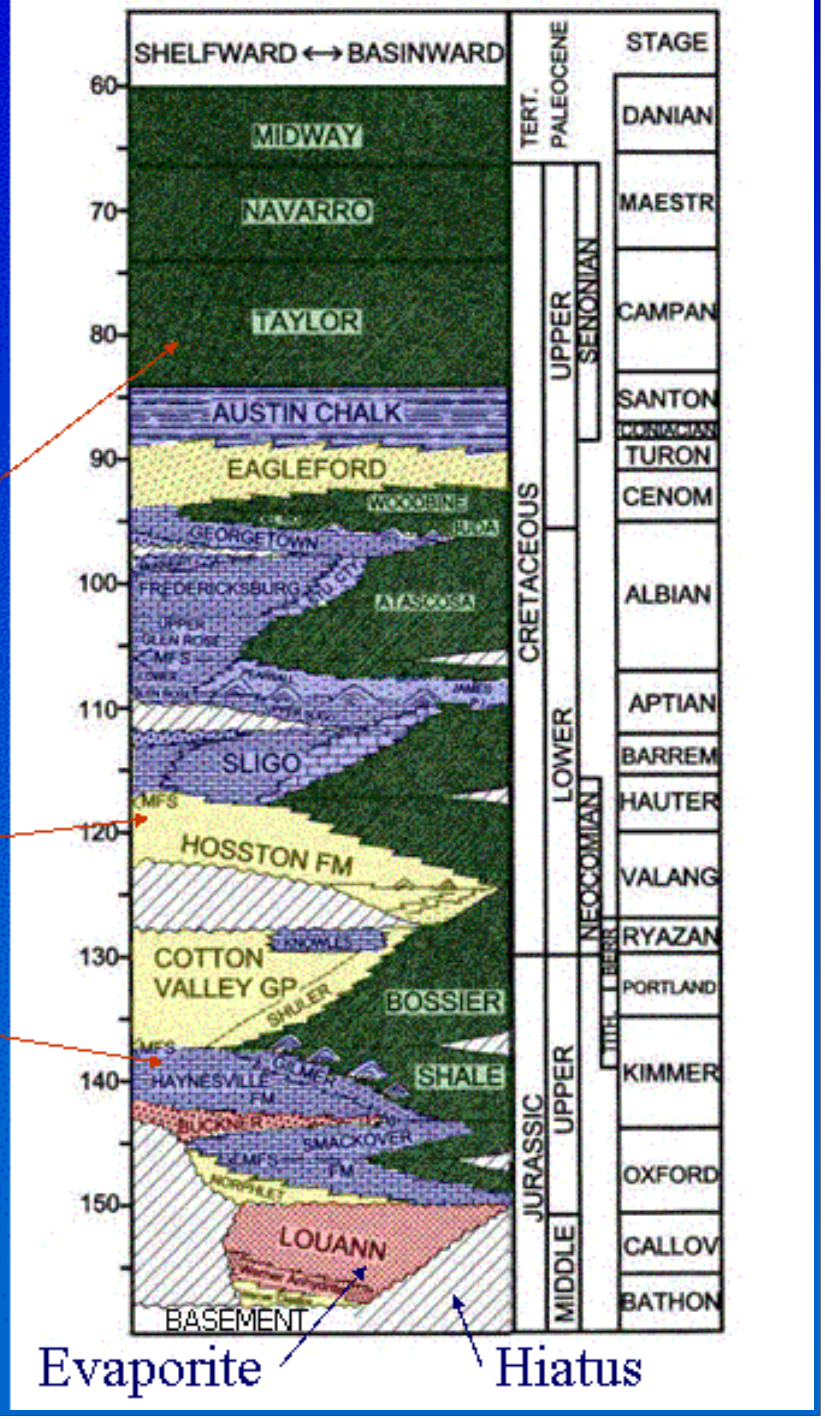
Generalized Jurassic and Cretaceous stratigraphy of the northwestern part of Gulf Coastal Plain

Mudstone

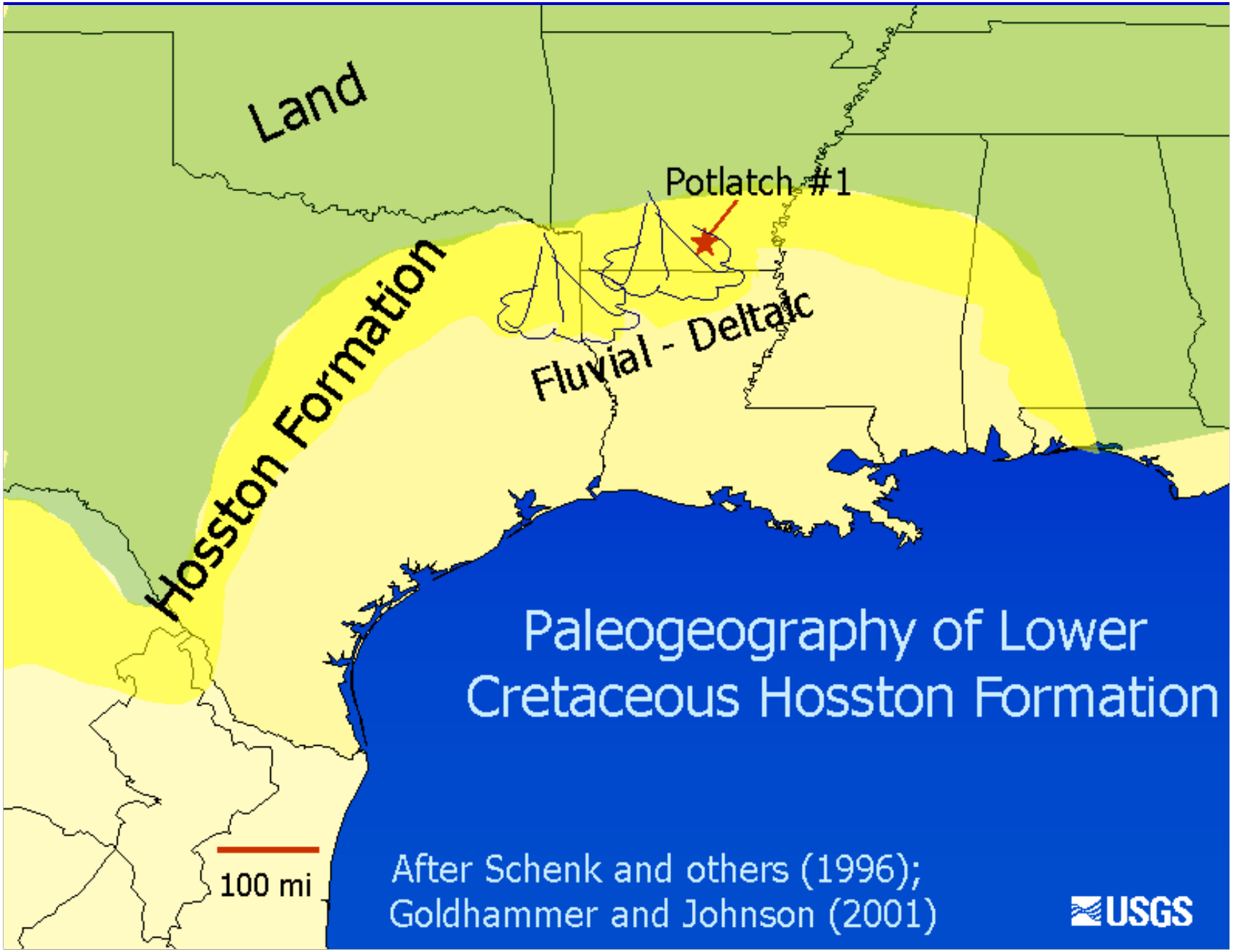
Siliciclastic rock

Carbonate rock

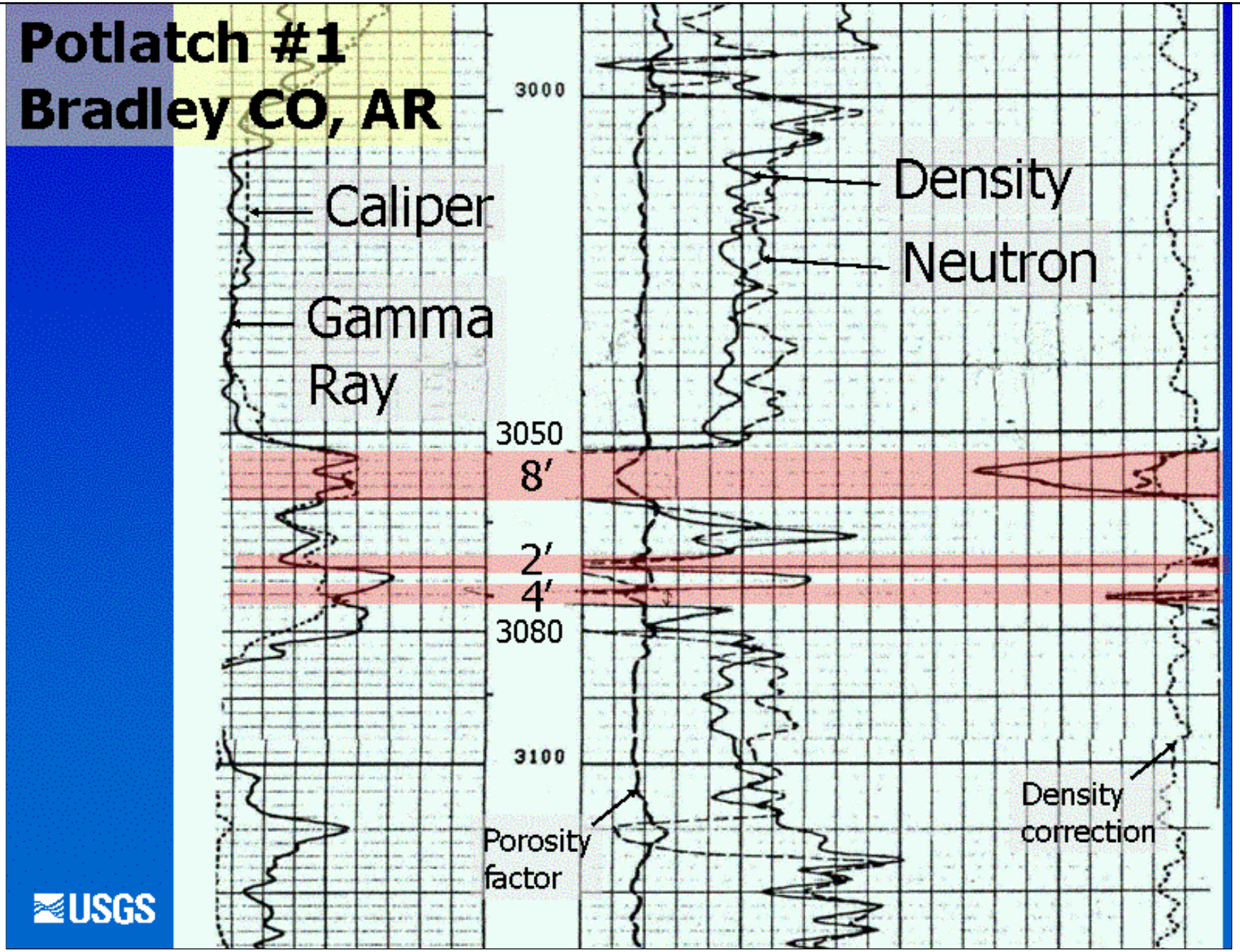
From Goldhammer and Johnson (2001)



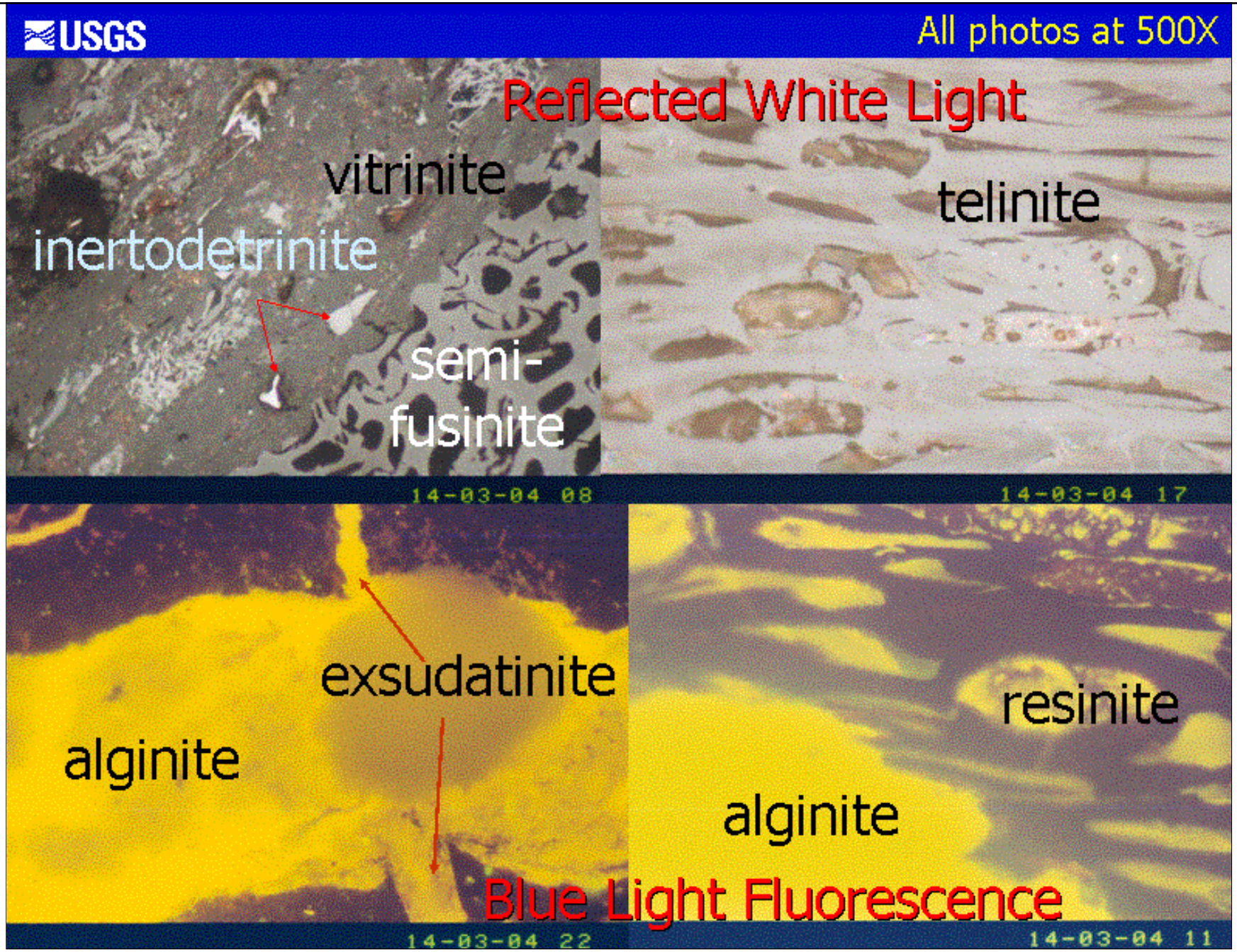
Generalized Jurassic and Cretaceous stratigraphy of the northwestern part of Gulf Coastal Plain. Note the location of the Lower Cretaceous Hosston Formation clastic wedge. Modified from Goldhammer and Johnson (2001).



Paleogeographic map of the Lower Cretaceous Hosston Formation clastic wedge. Adapted from Schenk and others (1996) and Goldhammer and Johnson (2001). Note the location of the fluvial-deltaic depositional environments proposed by Goldhammer and Johnson (2001) for northern Louisiana and southern Arkansas. These were potentially good environments for peat (coal) accumulation. The star indicates the location of the Potlatch #1 well in southern Arkansas. The mud log from the Potlatch #1 well reported coal cuttings from intervals within and near the Hosston Formation. There are other wells in northern Louisiana that report the occurrence of coal cuttings in the Lower Cretaceous section (Jim York, personal communication, 2003).



Portion of the caliper, gamma ray, density, and neutron well logs from the Potlatch #1 well (API # 03011100770000) in Bradley County, Arkansas. The red shaded area indicates the probable coal intervals with interpreted thicknesses. Depths are in feet. Coal cuttings were recovered from the following intervals 3050-3060 ft, 3060-3070 ft, and 3070-3080 ft. The mud log from this well reported other coal intervals from 3440-3460 ft and 3470-3480 ft. Regional correlations with other well logs indicate that the Potlatch #1 coal intervals are within, or are associated with, the Hosston Formation (or lower Trinity Group and Travis Peak Formation of Haley, 1993).

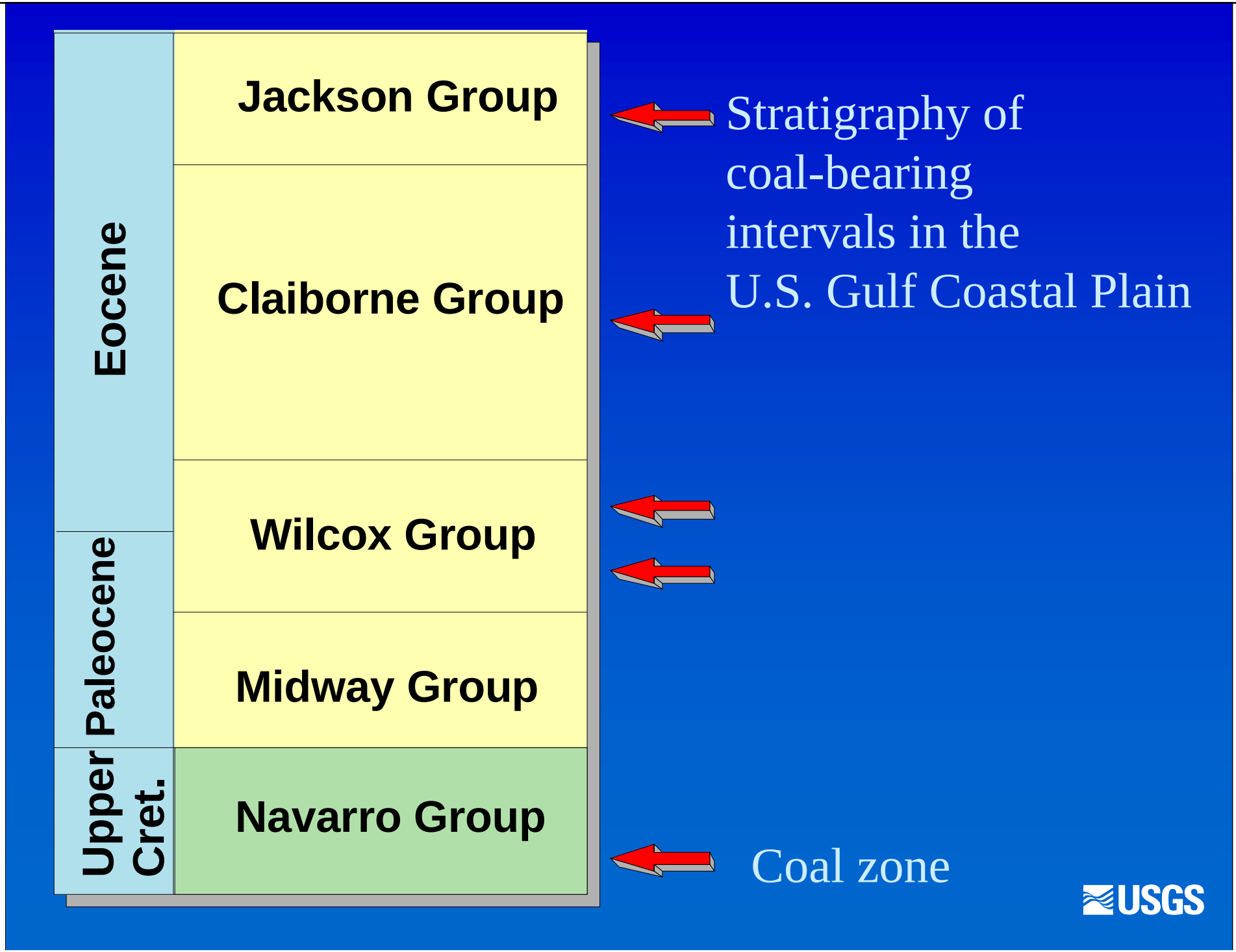


Photomicrographs of coal cuttings from the Potlatch #1 well. Photo 14-03-04 08: Vitrinite groundmass with inertodetrinite in the upper left and semifusinite showing remnant cell structures in the lower right of the photomicrograph; sample from the 3050-3060 ft interval, 500X magnification in reflected white light. Photo 14-03-04 17: Telinite showing well preserved cell structures; sample from the 3060-3070 ft interval, 500X magnification in reflected white light. Photo 14-03-04 22: Alginite with exsudatinite filling cracks; sample from the 3070-3080 ft interval, 500X magnification in blue light fluorescence. Photo 14-03-04 11: Alginite and resinite filling cell structures; sample from the 3060-3070 ft interval, 500X magnification in blue light fluorescence.

Potlatch #1, Bradley Co., AR

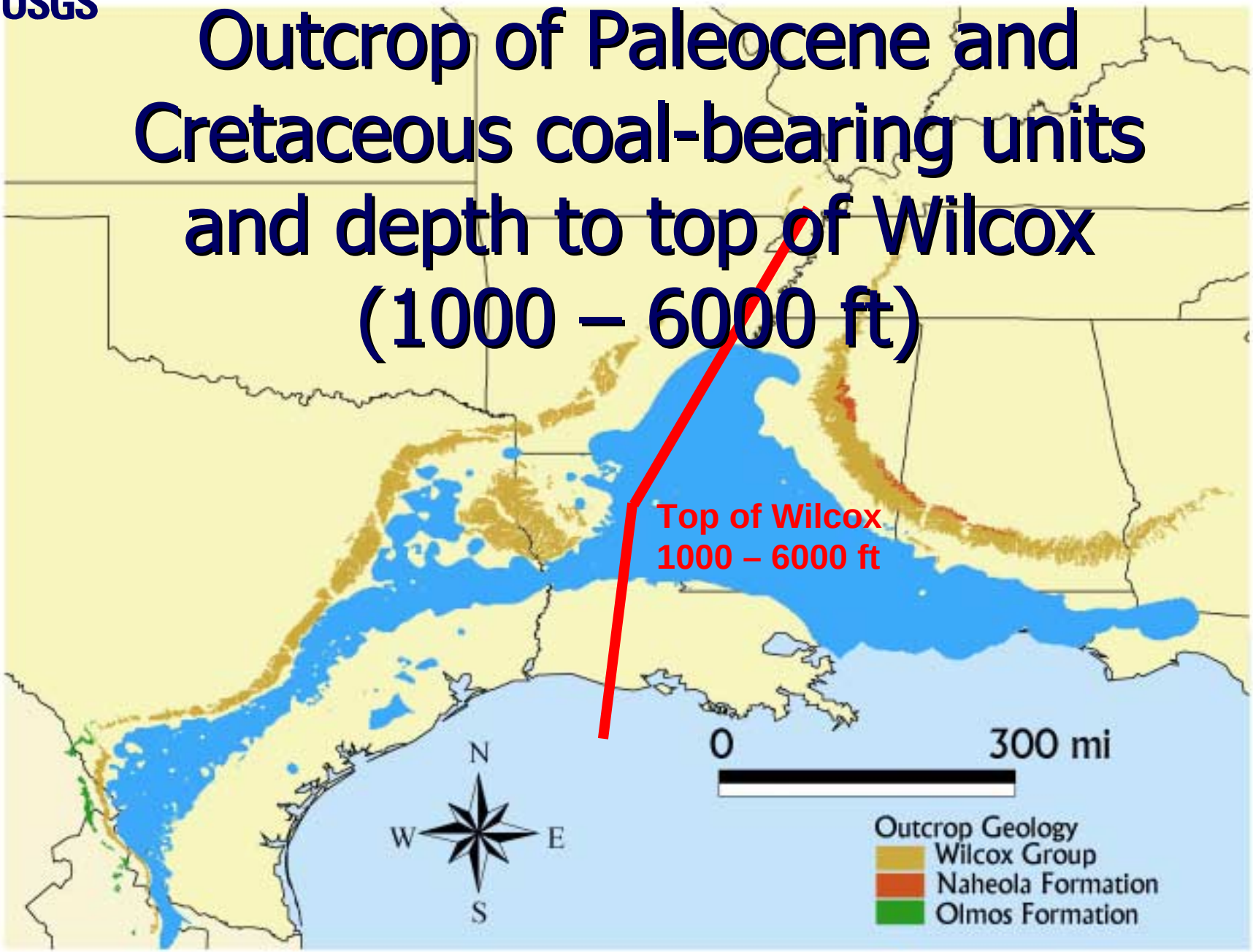
- Three coal zones recognized in the Trinity - Hosston Fm. (Travis Peak)
- Depths range from 3050 – 3500 ft
- About 20 ft cumulative coal with individual beds up to 8 ft thick
- Ro_{max} at 3050-3080 ft at 0.53 % (hvCb)
- Coal zone extends into northeastern LA
- Reports of Upper Cretaceous coals in MS & AL (Brown, 1907; Monroe and others, 1946)

Summary of findings for Cretaceous age coal from Arkansas and neighboring states. hvCb = high volatile C bituminous.

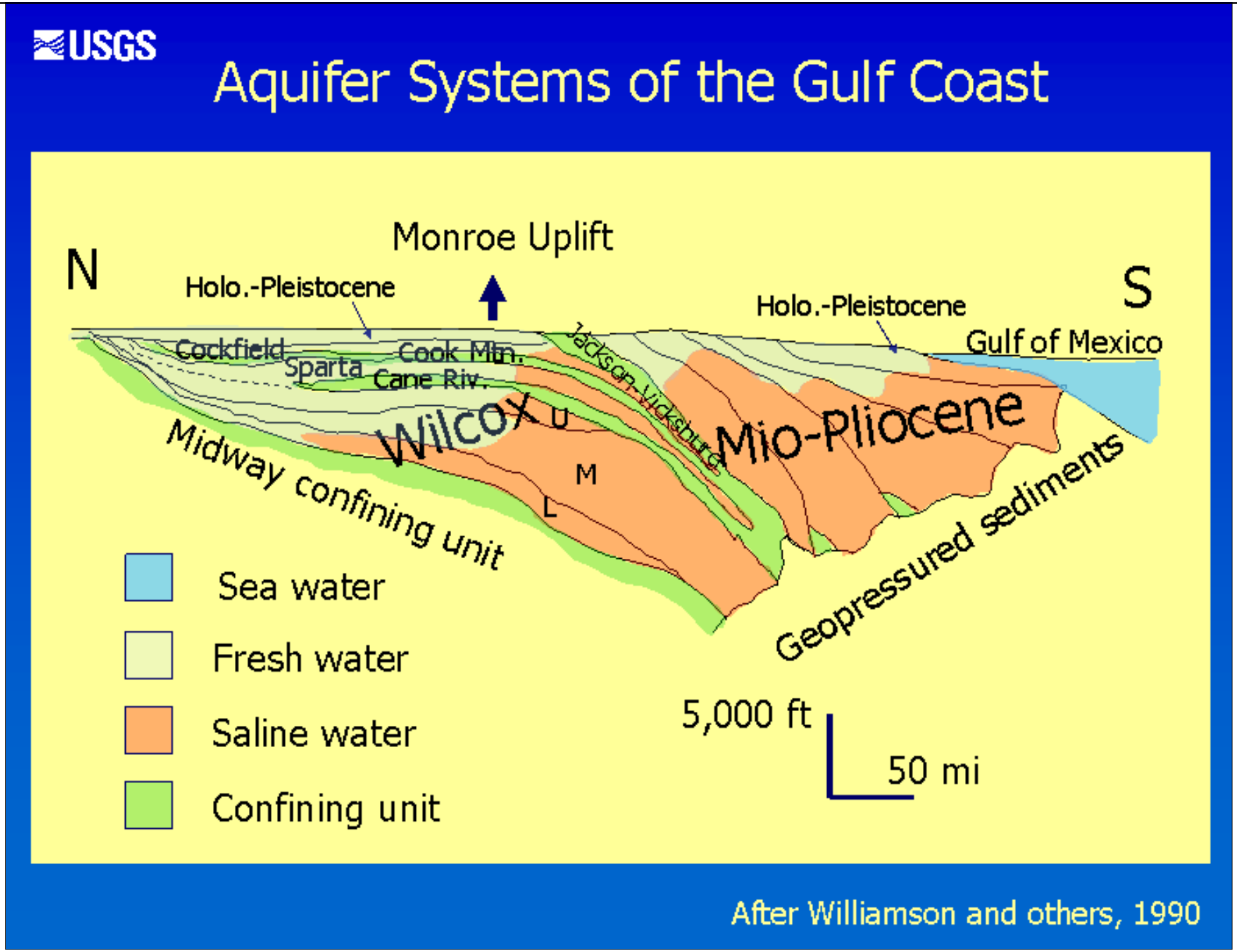


Generalized coal-bearing stratigraphy of the upper Cretaceous, Paleocene and Eocene of the Gulf Coastal Plain. From Warwick and others (2000b).

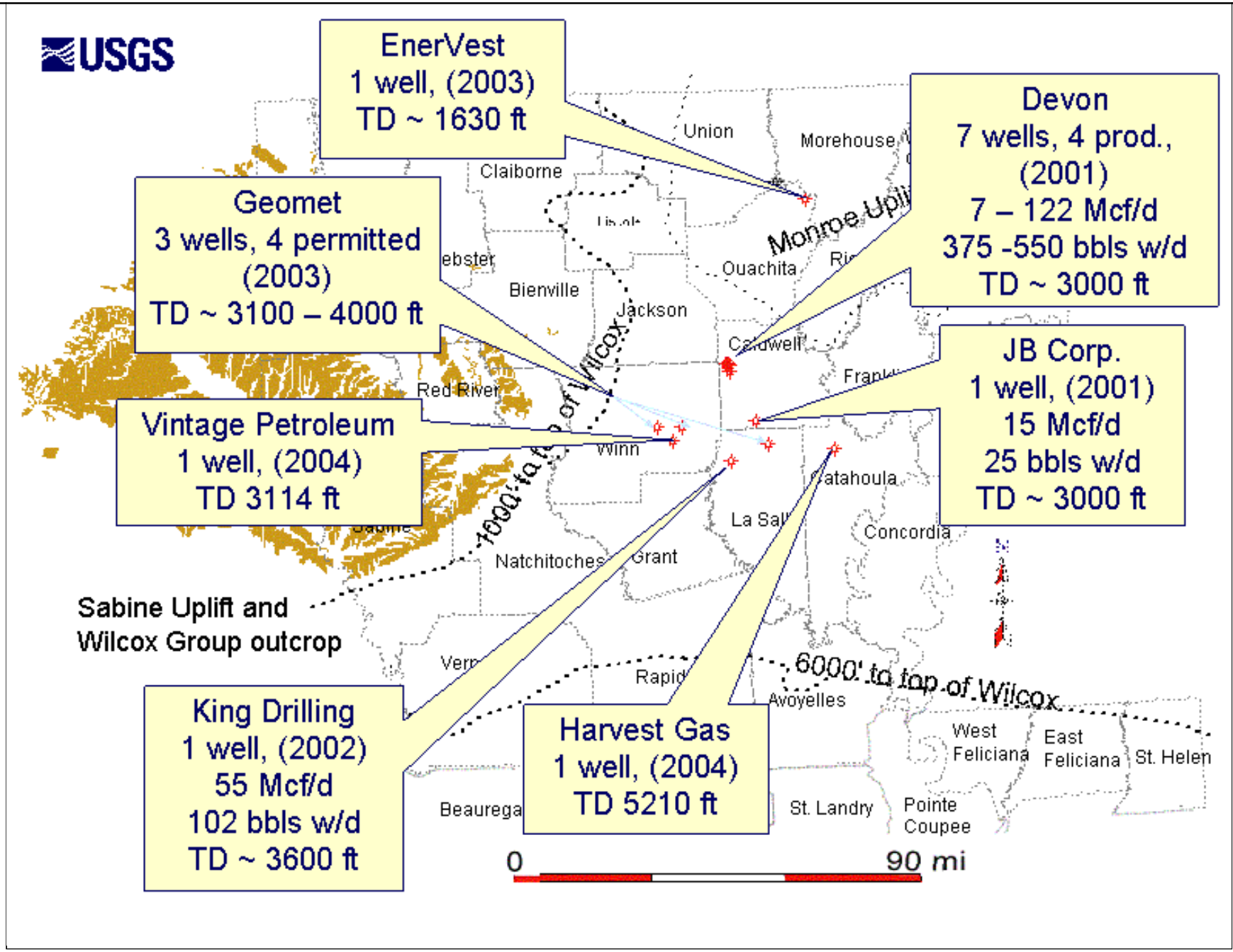
Outcrop of Paleocene and Cretaceous coal-bearing units and depth to top of Wilcox (1000 – 6000 ft)



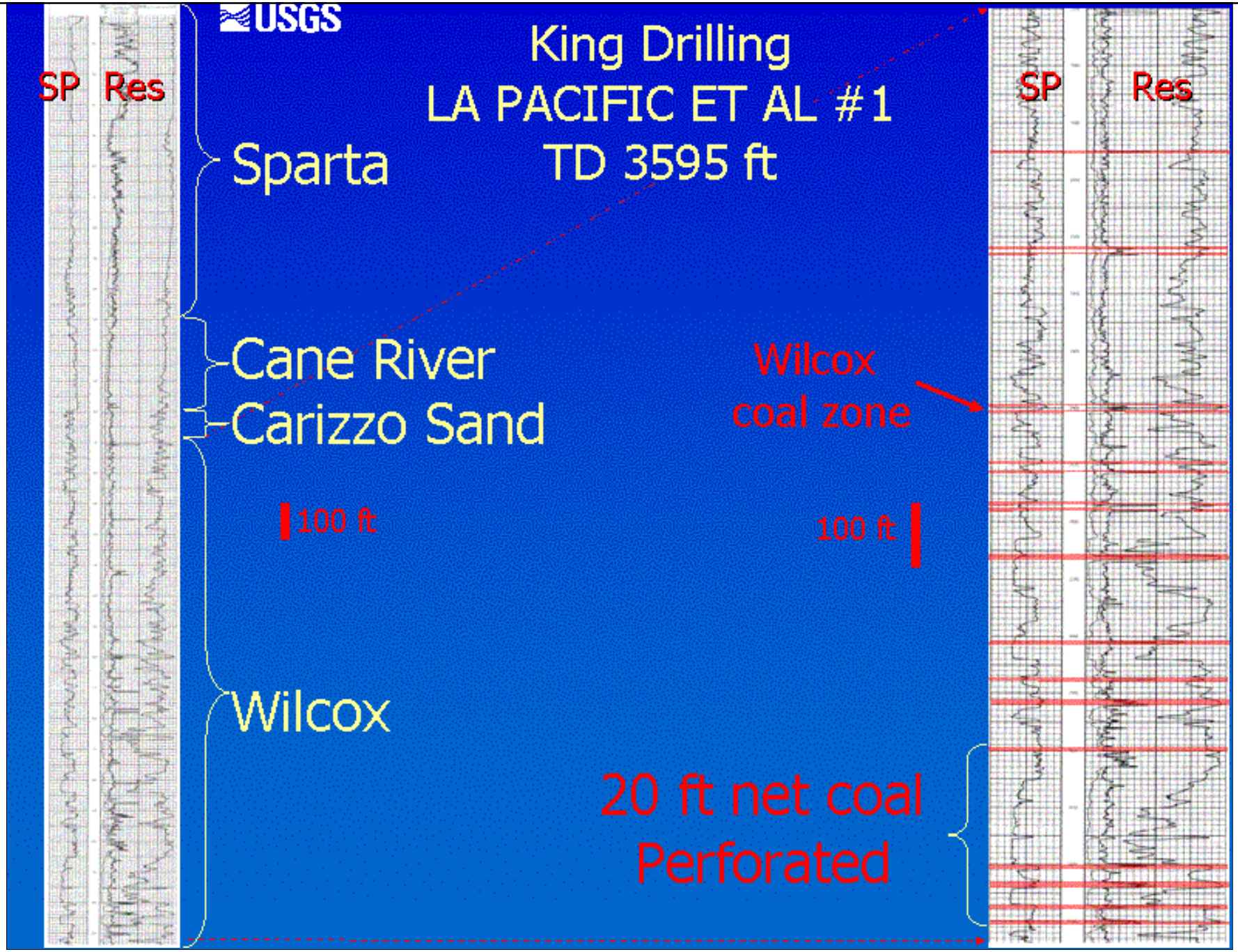
Outcrop of Paleocene and Cretaceous coal-bearing units in the Gulf Coastal Plain. The area shaded dark blue shows the area where the depth to the top of the Wilcox Group ranges from 1000 to 6000 ft. The heavy solid red line is the line of section on the next illustration. Modified from Barker and others (2000).



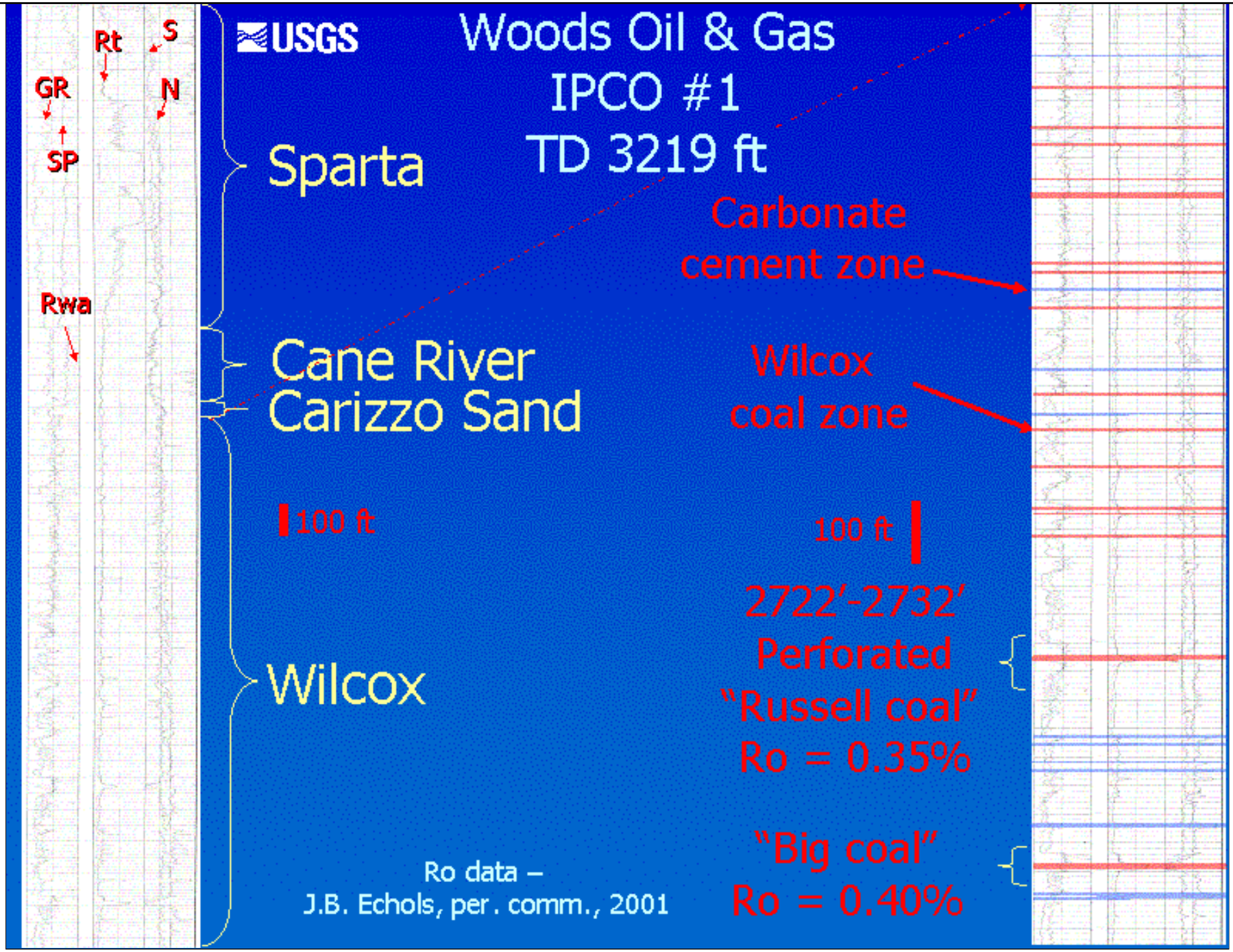
Generalized cross section showing the major Tertiary aquifers and confining units in the Mississippi Embayment and southern Louisiana. Note that much of the aquifer systems are filled with saline water derived from groundwater interaction with salt diapers (Huff and Hanor, 1997). Geopressured sediments are found at depth. Diagram modified from Williamson and others (1990). Holo. = Holocene; Mio = Miocene; L = Lower; M = Middle; U = Upper.



Review of coal bed methane (CBM) drilling activity in northern Louisiana since 2001. Approximately 15 wells have been drilled specifically for coal bed gas exploration or production. Boxes indicate company name, number of wells drilled or producing (prod.), year of first well (in parentheses), initial production of gas and water (if available), and total depth (TD) of the wells. Dotted lines indicate 1,000 to 6,000 ft depth range to the top of the Wilcox Group. Well data from Louisiana Department of Natural Resources Strategic Online Natural Resources Information System [http://sonris-www.dnr.state.la.us/www_root/sonris_portal_1.htm].



Example of well log stratigraphy and coal intervals (shaded in red) in the King Drilling LA Pacific Et Al #1 well in La Salle Parish, Louisiana. Note that there are multiple coal zones in the Wilcox and that the thickest coal beds tend to be in the lower part of the Wilcox. The log on the right is the expanded Wilcox part of the log on the left. On well logs consisting only of spontaneous potential (SP) and resistivity (Res), coal beds are hard to distinguish from limestone beds. Well data from Louisiana Department of Natural Resources Strategic Online Natural Resources Information System [http://sonris-www.dnr.state.la.us/www_root/sonris_portal_1.htm].



Example of well log stratigraphy with coal (shaded in red) and limestone (shaded in blue) intervals in the Woods Oil and Gas (John B. Company), IPCO #1 well in Caldwell Parish, Louisiana. Note that the thickest coal beds are in the lower part of the Wilcox. The log on the right is the expanded Wilcox part of the log on the left. On well logs that include gamma ray (GR), sconic (S), and neutron (N), coal and limestone beds are easily distinguished. Formation density curves are also very useful for coal identification. Well data from Louisiana Department of Natural Resources Strategic Online Natural Resources Information System [http://sonris-www.dnr.state.la.us/www_root/sonris_portal_1.htm]. SP = spontaneous potential; Rwa = apparent formation water resistivity, Rt = resistivity. Ro data from J.B. Echols, personal communication, 2001.

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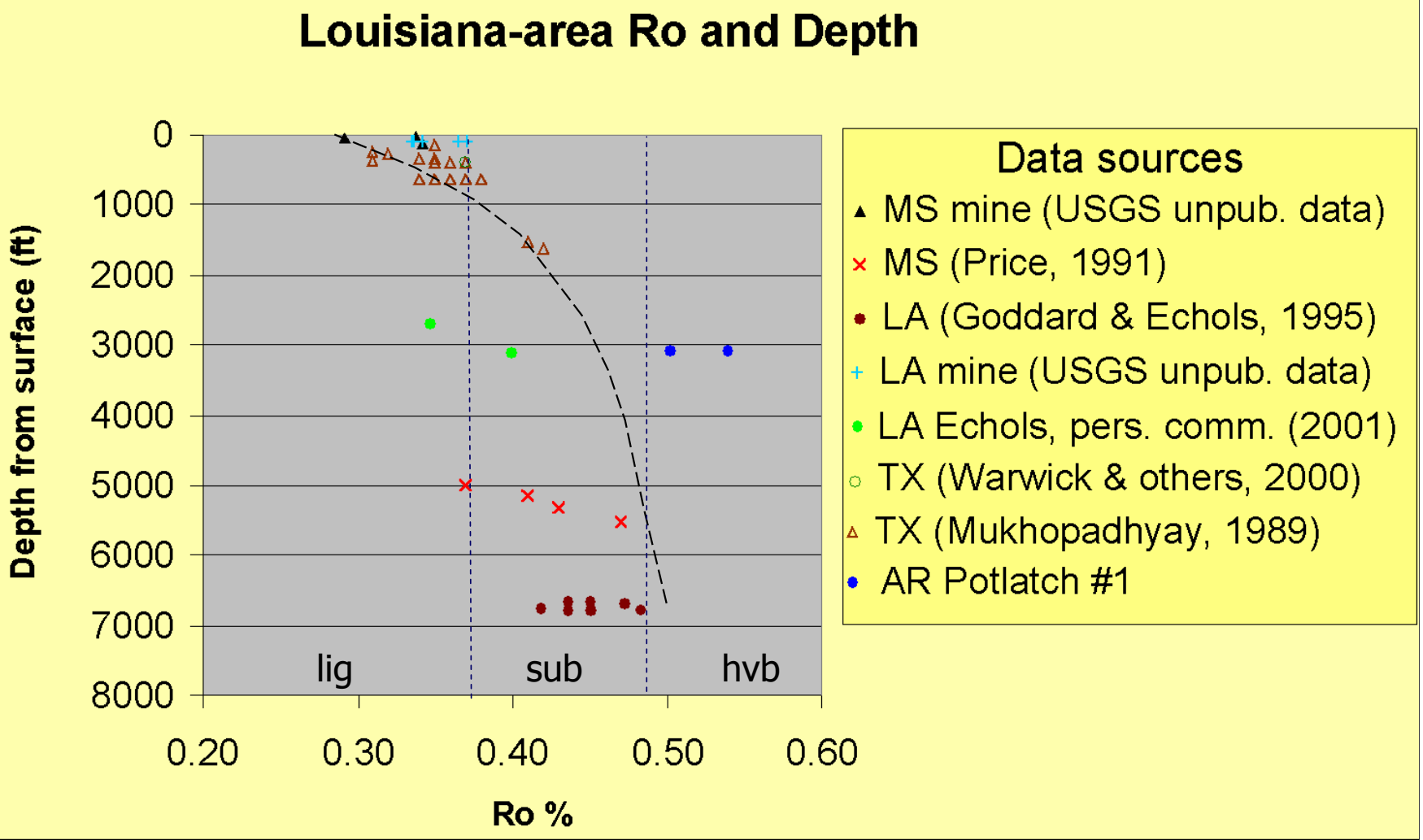
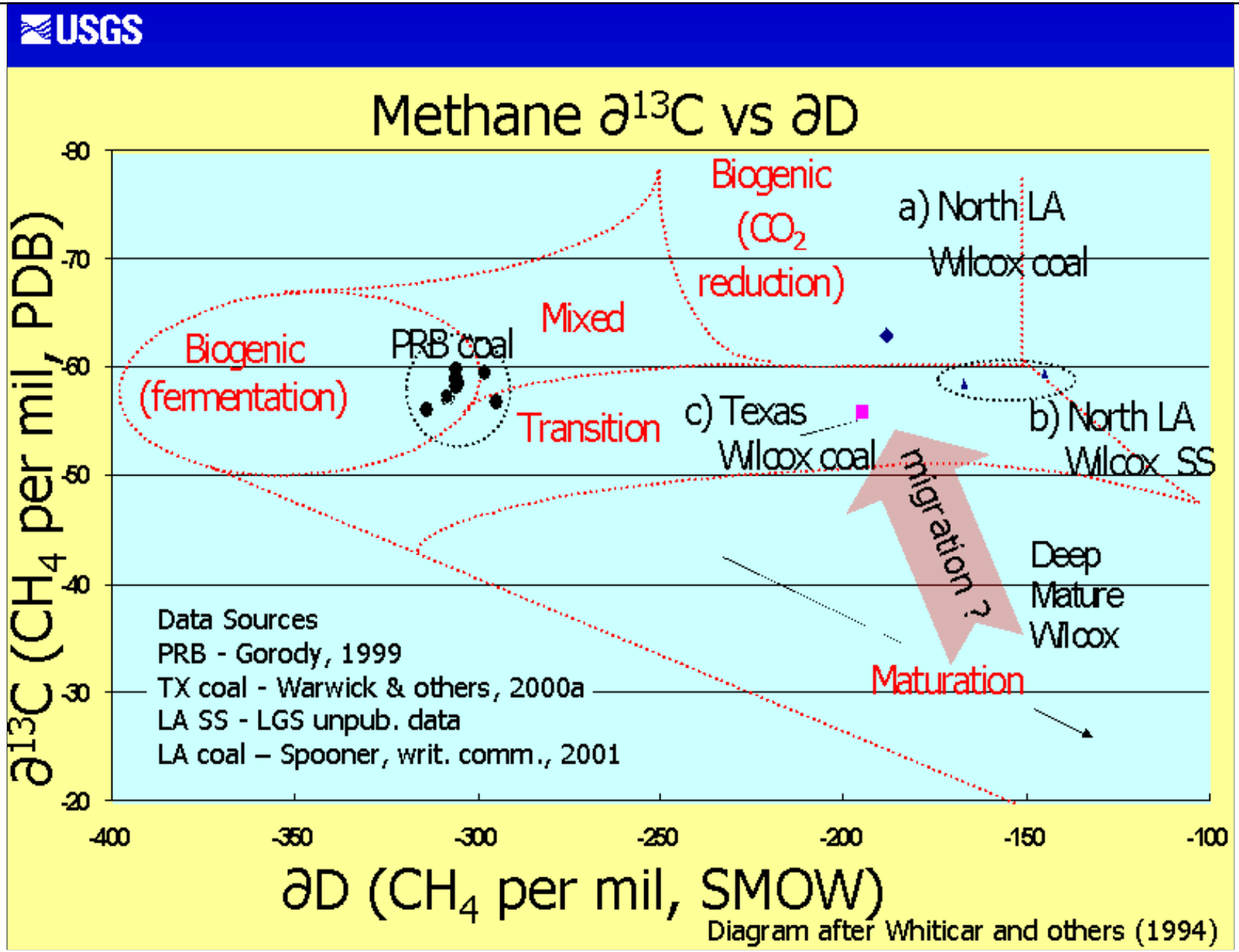


Plot of public coal reflectance data (Ro %) against depth for the Louisiana area. Vertical dashed lines indicate approximate boundaries between lignite (lig), subbituminous (sub), and high-volatile bituminous (hvb) coal ranks. A dashed best-fit line (exponential) is plotted that illustrates the approximate change of rank with depth. The trend line is based on public and confidential data. The wide scatter in the data may reflect variable heat flow rates and associated maturity in different parts of the basin. Sample states are indicated for each data set. Potlatch #1 data are from this report. Unpub. = unpublished.



Plot of the isotopic values of carbon (C) and hydrogen (D) with fields showing the origin of gases after Whiticar and others (1994). For reference, Powder River (PRB) coals primarily plot in the biogenic fermentation field. Wilcox coal gas from north Louisiana (a) plots within the biogenic CO_2 reduction field, whereas gas collected from conventional Wilcox sandstone reservoirs (b) falls within (near) the transition zone between biogenic and mature thermogenic gases. Coal gas collected from a shallow (380 ft) well in northeast Texas also (c) plots within the transition zone indicating that these gases may have originated from mixing of mature gases and gases with a biogenic, CO_2 reduction origin. The red arrow indicates the proposed migration direction and mixing pathway of thermal gas. Sources of data for the PRB = Gorody (1999); North Louisiana Wilcox coal = Harry Spooner, written communication, 2001; north Louisiana Wilcox conventional sandstone (SS) reservoir gas = unpublished (unpub.) Louisiana Geological Survey (LGS) data; Texas Wilcox coal = Warwick and others (2000b). PDB = Pee Dee Belemnite; SMOW = standard mean ocean water.

Photograph of coal fractures and cleats in the Oxbow Lignite mine in northwestern Louisiana.

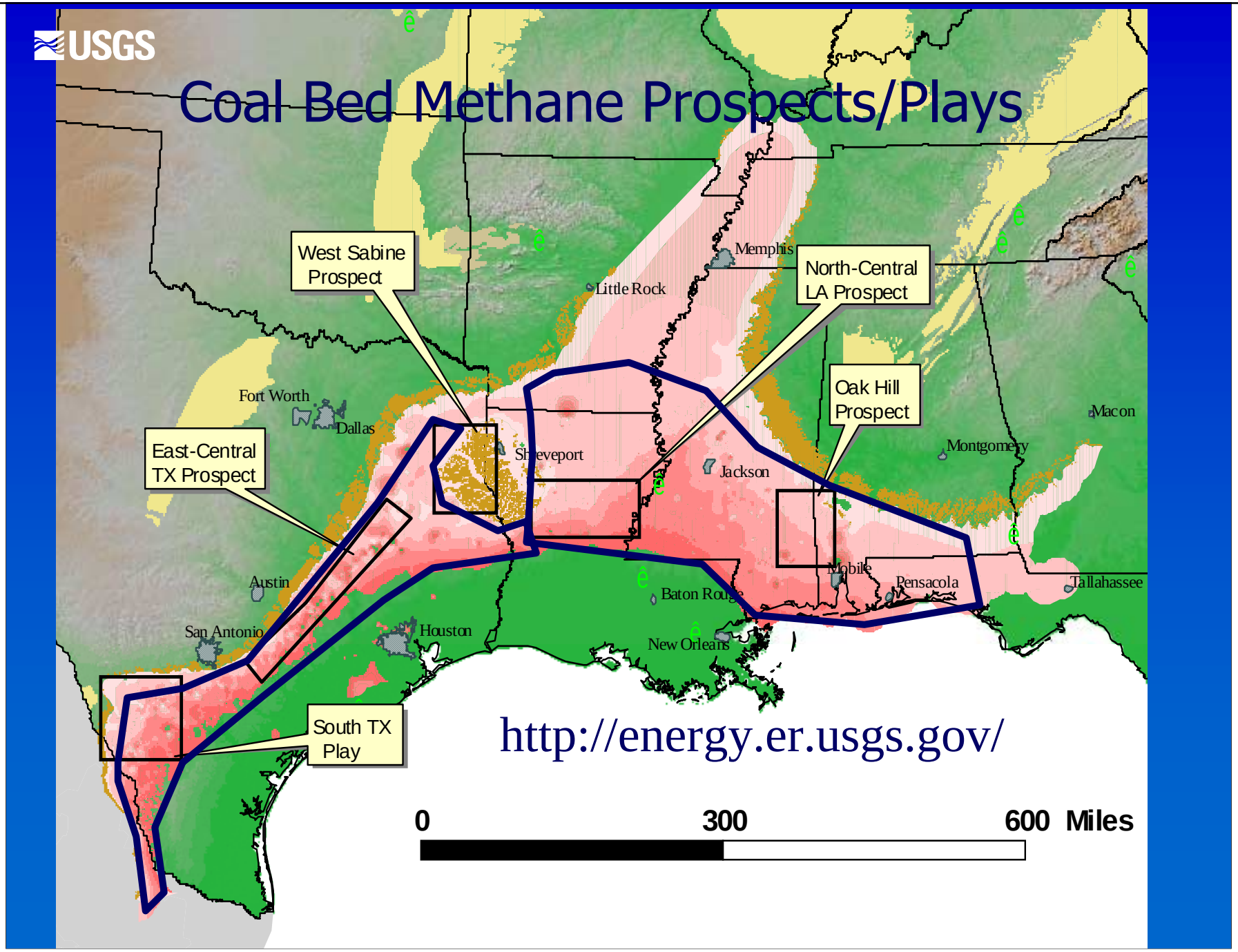
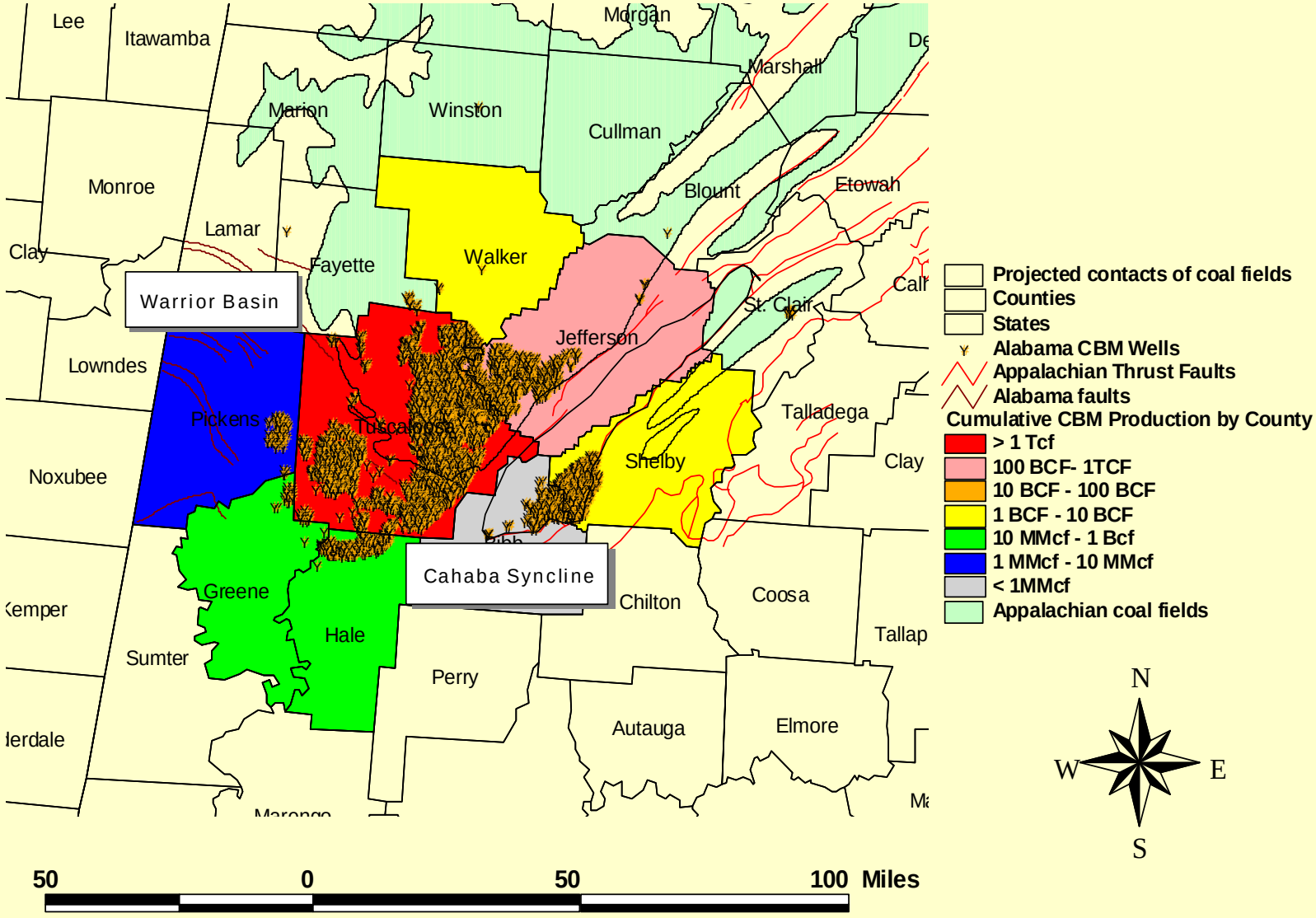


Diagram from Warwick and others (2002) which indicates potential coalbed methane prospects and plays (boxes). Based on the current coal gas exploration efforts in north Louisiana and the occurrence of bituminous Cretaceous coal in southern Arkansas, the potential exploration areas have been expanded as indicated by the heavy blue lines. Red shaded areas illustrate the depth to the top of the Wilcox Group, and ranges from 500 ft (light red) to 6000 ft (dark red). Outcrop of the Wilcox is indicated by the orange color and yellow indicates the location of other coal-bearing basins. Base map after Barker and others (2002).

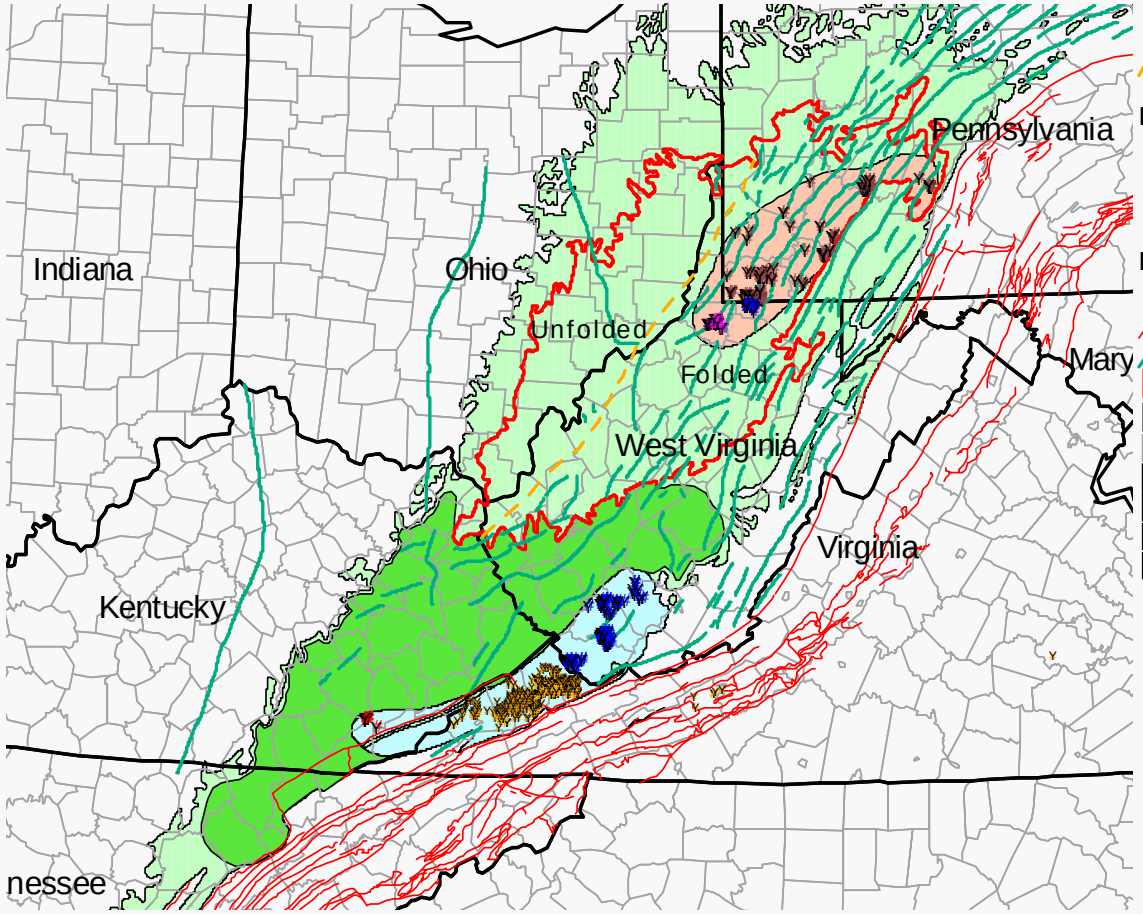
Alabama Coal Fields, Showing Cumulative Production by County, 2000



Milici, written communication, 2004

Map of Alabama coal fields and coalbed gas production areas. Cumulative gas production (CBM) by county is indicated by color fill. For an estimate of the remaining coal gas resources of the Black Warrior basin see Hatch and others (2003). Illustration from Milici, written communication, 2004.

CBM Fairways, Northern and Central Appalachian Basin



Milici, written communication, 2004

USGS coal gas (CBM) assessment map of northern and central Appalachian basin coal fields and coalbed gas production fields. For an estimate of the remaining coal gas resources of the Appalachian basin see Milici and others (2003). MPS = Minimum Petroleum System; AU = Assessment Unit. Illustration from Milici, written communication, 2004.

Conclusions

- Cretaceous coals of the northern Gulf Coastal plain should be evaluated for their CBM potential

- Wilcox coals contain saline water; initial gas isotope data indicates that Wilcox coal gas originated from biogenic reduction of CO_2; coal rank increases to near hvCb with depth

- Early production data from Wilcox coals indicate that there is a potential resource of coal-bed gas underlying a large area in the Gulf Coastal Plain

- There is potential for enhanced coal-bed methane production and CO_2 storage in the Gulf Region. This may includes the possibility of methane generation from reduction of introduced CO_2

Conclusions. CBM = coalbed methane; hvCb = high volatile C bituminous.

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