THE NEW ALBANY SHALE GAS PLAY IN SOUTHERN INDIANA

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ABSTRACT

The New Albany Shale (Devonian and Mississippian) in Indiana is mostly brownishblack organic-rich shale with lesser greenish-gray shale. The formation is 100 to 140 feet thick in southwest into the Illinois Basin, where it attains a thickness of more than 360 feet in Posey County.

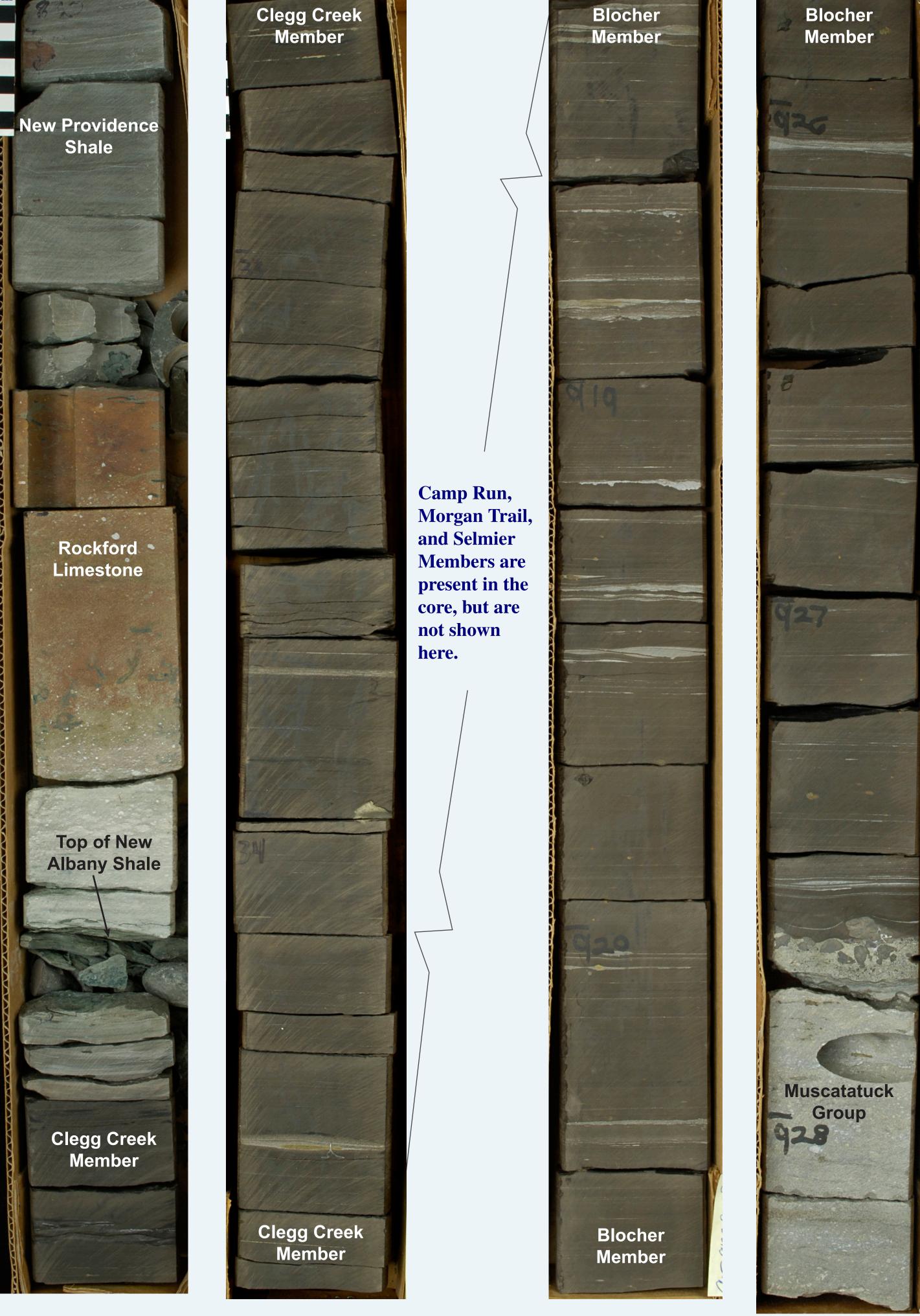
Gas production from New Albany Shale began in when interest waned in favor of more lucrative and production rates generally range from 20 to 450

MCFGPD. In the past 2 years, Daviess County and surrounding areas have become the focus of New Albany exploration after the El Paso Production No. 2-10 Peterson horizontal discovery well was rumored to have tested 1.3 MMCFGPD at an approximate measured depth of 2,200 feet.

New Albany production is mostly from the organicrich Clegg Creek Member. Gas compositions (C₁-C₄ and CO₂) and carbon and hydrogen isotopic signatures indicate that both purely thermogenic and mixed thermogenic and biogenic gases are produced from the New Albany. Produced water ranges from brine to water diluted through recharge by modern precipitation; the brine zones contain primarily thermogenic gas and the diluted water zones contain gas of mixed thermogenic and biogenic origin.

PARTIAL CORE OF NEW ALBANY SHALE

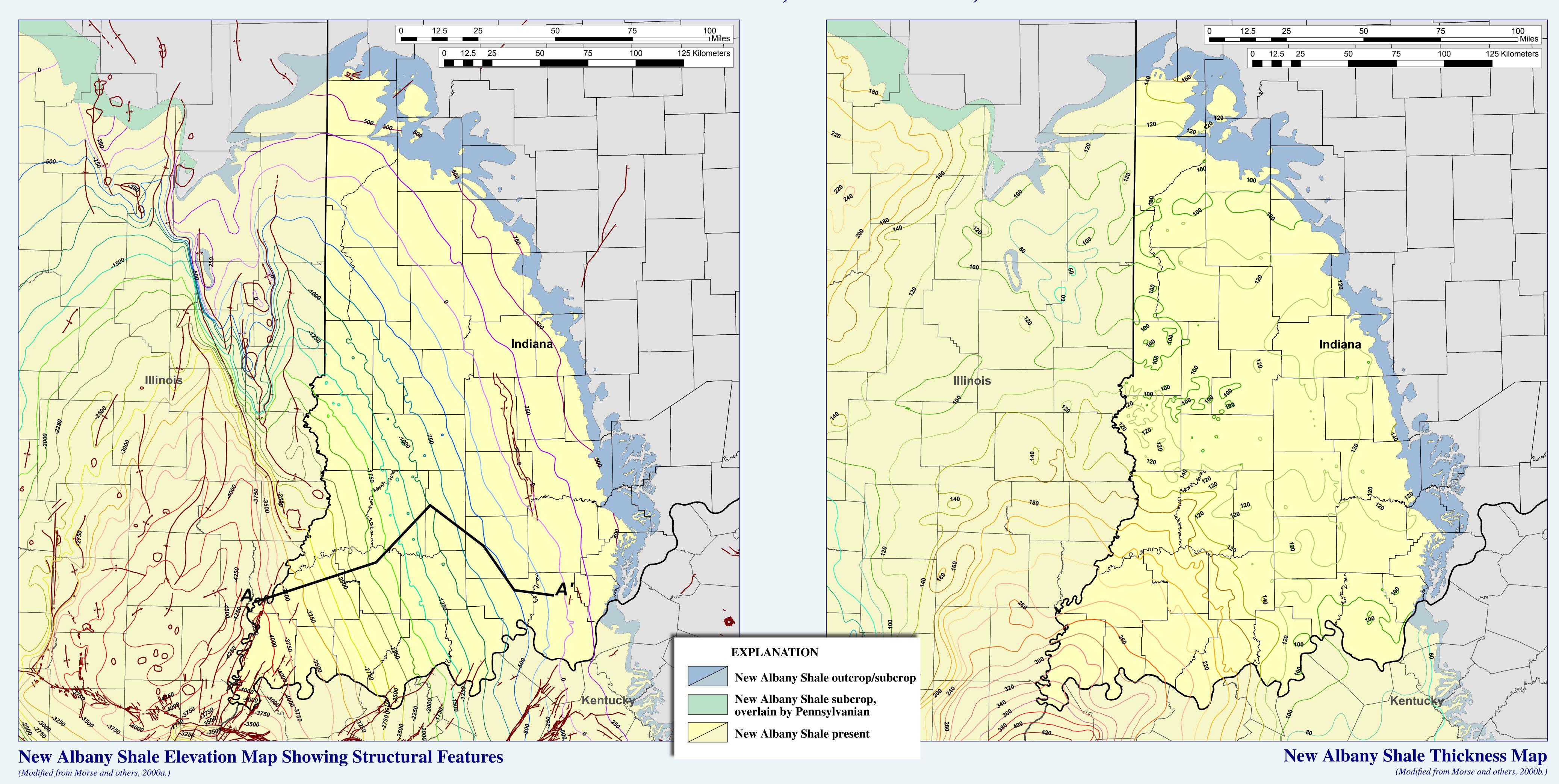
Jet/LaVanway Chinn Harrison County 157491 (Gamma-ray log is shown on stratigraphic cross section)

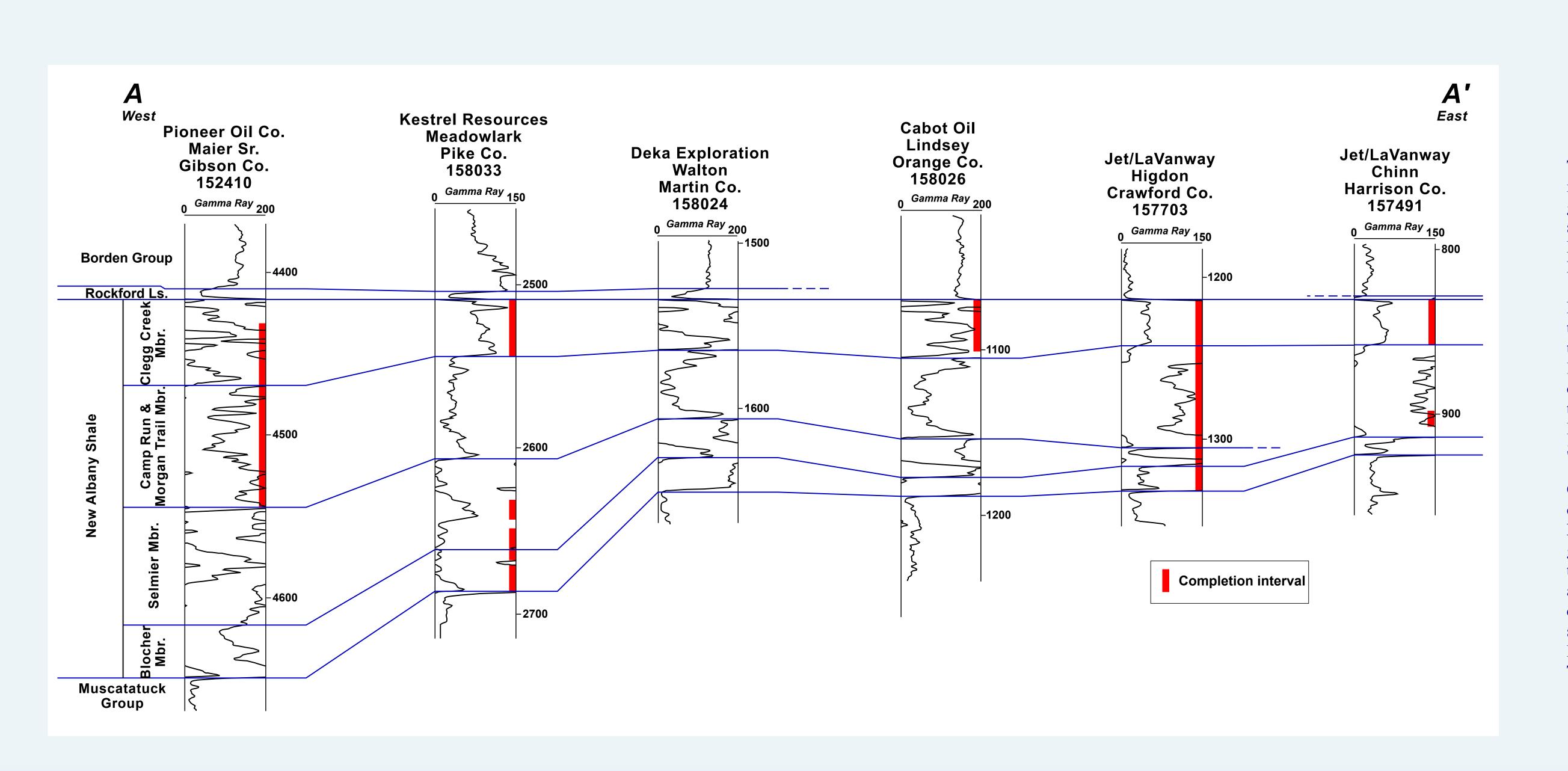


Core of the New Providence Shale (Mississippian), Rockford Limestone (Mississippian), and upper part of the Clegg Creek Member of the New Albany Shale (Devonian and Mississippian).

Core of the lower part of the Blocher Member of the New Albany Shale and the upper part of the Muscatatuck Group (Devonian).

NEW ALBANY SHALE STRUCTURE, THICKNESS, AND STRATIGRAPHY





New Albany Shale Stratigraphic Cross Section with Member Correlations

The New Albany Shale (Devonian and Mississippian) in Indiana

The Selmier Member consists predominantly of greenish-gray is characterized by brownish-black organic-rich shale with lesser to olive-gray shale with small amounts of brownish-black shale, greenish-gray shale. The formation is 100 to 140 feet thick in dolomite, limestone, and thin beds of quartzose sandstone. TOC southeastern Indiana and dips and thickens to the southwest into the ranges from 0.4 to 2.3 percent when the member is observed in the Illinois Basin, where it attains a thickness of more than 360 feet in southeastern Indiana cores (Hasenmueller and Leininger, 1987); Posey County (Hasenmueller, 1982; Morse and others, 2000a, b). TOC for the member averages 4.5 percent in Sullivan County.

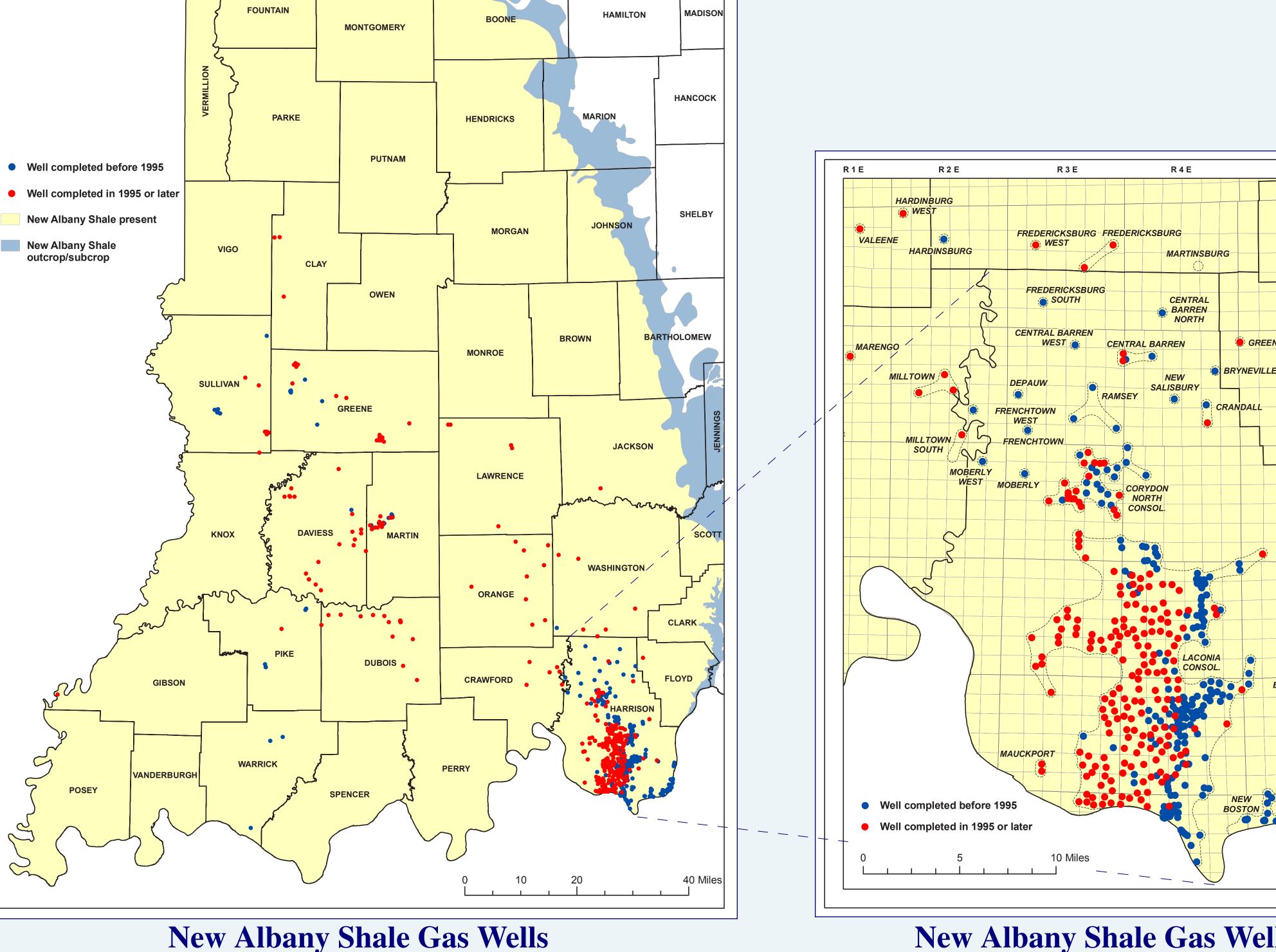
the east-west stratigraphic cross section. The uppermost member, brownish-black to grayish-black organic shale with carbonate the Clegg Creek Member, consists of brownish-black finely laminated shale. Hasenmueller and Leininger (1987) reported total southeastern Indiana cores (Hasenmueller and Leininger, 1987); organic carbon (TOC) values ranging from 10.4 to 13.7 percent for TOC in the Sullivan County core is 5.36 percent. the Clegg Creek Member from ten cores located in six southeastern Sullivan County in southwestern Indiana is 9 percent.

On the cross section, the Camp Run and Morgan Trail Members of the New Albany Shale are undifferentiated. The Camp Run **Member** is characterized by interbedded brownish-black and shale with TOC ranging from 4.4 to 7.2 percent in southeastern Indiana. The TOC for the undifferentiated Camp Run and Morgan Trail interval in the Sullivan County core is 5.4 percent.

Four intervals within the New Albany Shale are differentiated on The **Blocher Member**, the basal member, consists of calcareous laminae and beds. TOC ranges from 7.2 to 9.4 percent in the

Indiana counties. The average TOC for the interval in a core from All the wells on the cross section are reported as New Albany Shale gas wells completed from 1994 to 1997; the completion intervals are denoted in red on each gamma-ray log. New Albany Shale gas production is predominantly from the organic-rich Clegg Creek Member. In addition to production from the New Albany Shale, the Pioneer Oil Company Maier Sr. well in Gibson County also greenish-gray shale and an organic carbon content ranging from 5.1 produces oil and gas from the Mississippian St. Louis, Salem, and to 6.7 percent in the cores from southeastern Indiana (Hasenmueller Harrodsburg Limestones and the Devonian Muscatatuck Group and Leininger, 1987). The underlying **Morgan Trail Member** carbonates. The completion rate for this well was 10 BOPD and 17 contains brownish-black to olive-black finely laminated siliceous MCF. No completion rates were reported for the other gas wells.

NEW ALBANY SHALE PRODUCTION



Southwestern Indiana

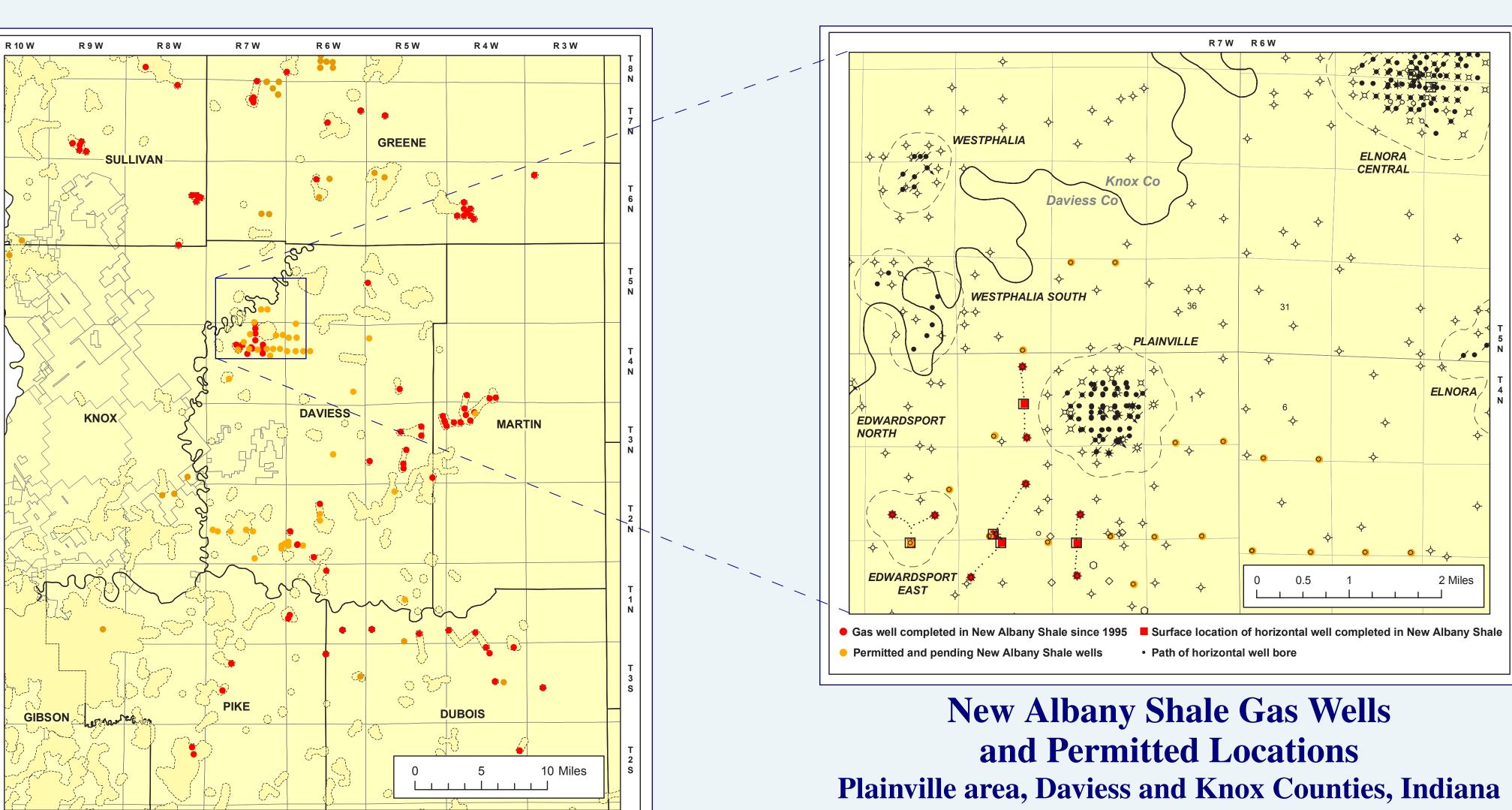
Development of the New Albany Shale as a producing unconventional gas reservoir in Indiana began over 100 years ago in Harrison and Martin Counties. Development was renewed within the last decade and is associated with the application of directional drilling technology (horizontal and multi-lateral completions). Activity has been centered in Harrison and Daviess Counties. (Modified from Zuppann and others, 2006.)

surrounding counties, Indiana. Irregular forms are the outlines of existing

oil and gas fields (dominantly conventional oil production from Chesterian

sands and oolite bodies). (Modified from Zuppann and others, 2006.)

New Albany Shale Gas Wells Harrison County, Indiana Map showing completed New Albany Shale gas wells and fields in the Harrison County, Indiana, area. (Modified from Zuppann and others, 2006.)



Enlargement of northwestern Daviess County showing distribution of recent (and ongoing) development. Wells completed to date are horizontal on 320-acre spacing. Some contain multilateral completions (Modified from Zuppann New Albany Shale Gas Wells and Permitted Locations Daviess and surrounding counties, Indiana Map showing recent New Albany Shale development in Daviess and

FRACTURE ORIENTATIONS

EXPLANATION For this map, joints are defined as fractures or partings in rock having little or no discernible displacement. compasses. The accuracy of measuremen with a compass, particlarly in quarries faces were the only joints that could be one measurement on the equal-area rose diagrams shown on this map. The number arcs is shown by the area of each bar of

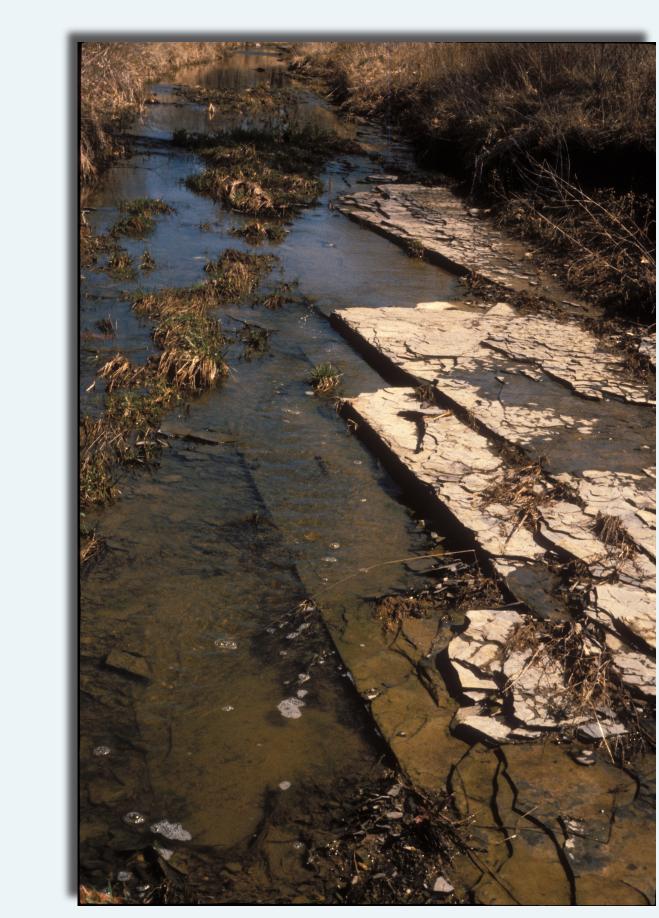
Map of Indiana Showing Directions of Bedrock Jointing

From Ault, 1989b

Calcite-filled fracture in a New Albany Shale core from Phegley #1 well in Sullivan County.

Characteristics of New Albany Shale Fractures

Natural fractures are abundant in the New Albany Shale. Much of the shale is brittle and exhibits close-spaced joints that reflect regional stress. Induced fractures are likely to mimic the natural systems. On outcrop, prominent joints tend east-northeast at 76° to 78°, are nearly vertical, and are spaced 1½ to 6 feet apart. Local variations in direction and spacing are associated with reefs, faults, and other geologic structures. Fractures in cores can differ in direction from those in outcrops and are often occluded by secondary mineralization, mostly carbonates or pyrite. Joints do not trend in the same direction as lineaments or known faults (see Ault, 1989a, b, and Carr, 1981).



Dominant east-west fractures in New Albany Shale near Henryville in Clark County.



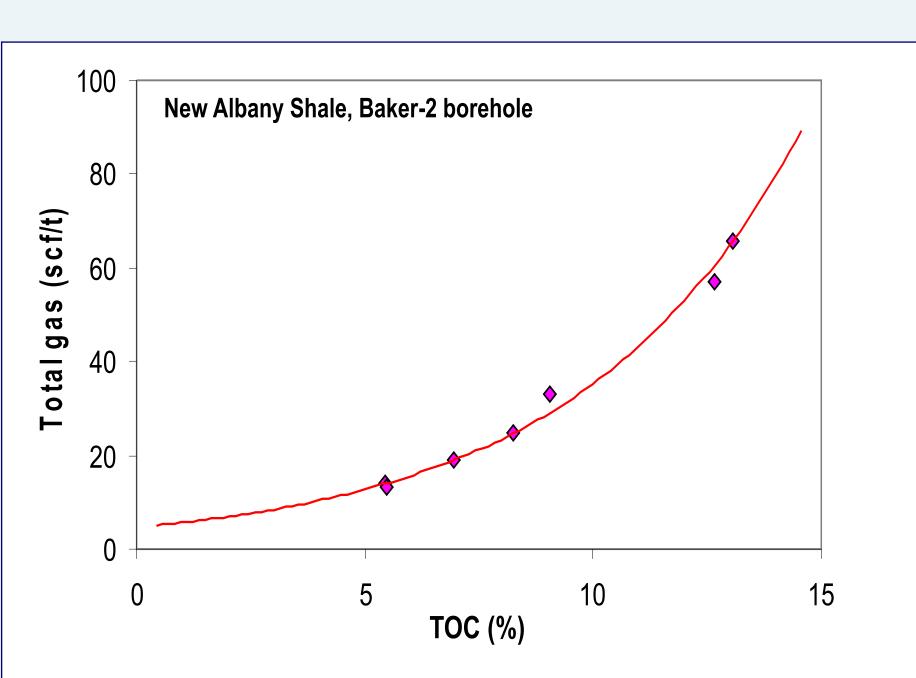
Closely spaced New Albany Shale fractures along the Ohio River west of New Albany in Floyd County.



Vertical joints showing dominant east-west trending joints and secondary north-south joints in weathered New Albany Shale at the North Vernon Quarry in Jennings County.

GAS GEOCHEMISTRY

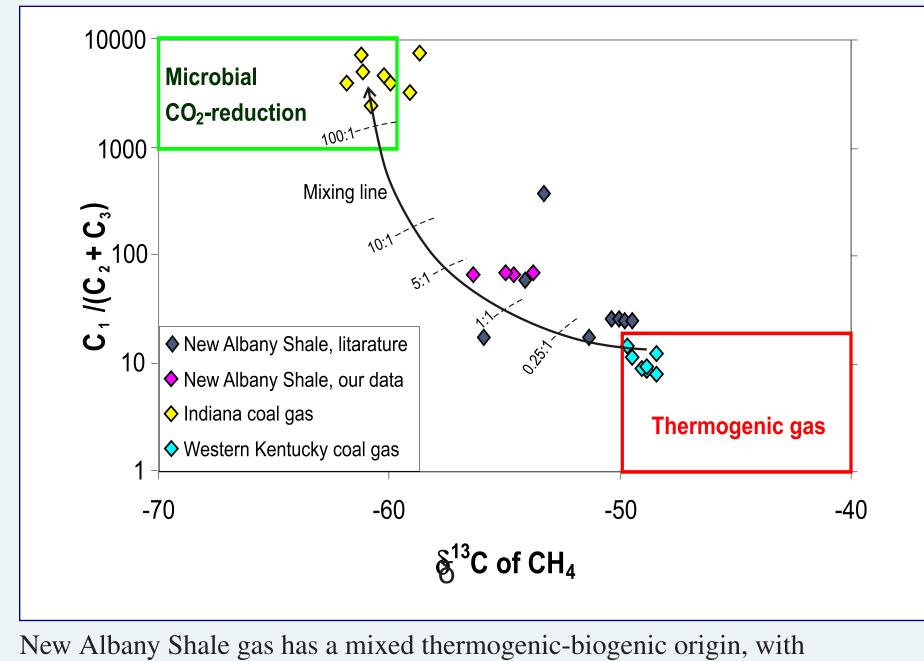
It has been suggested that gas origin of the New Albany Shale in the Illinois Basin relates to water characteristics (Walter and others, 2001) such that thermogenic gas occurs in areas without freshwater recharge, whereas mixed thermogenic-microbial gas occurs in zones of localized recharge of modern meteoric water.



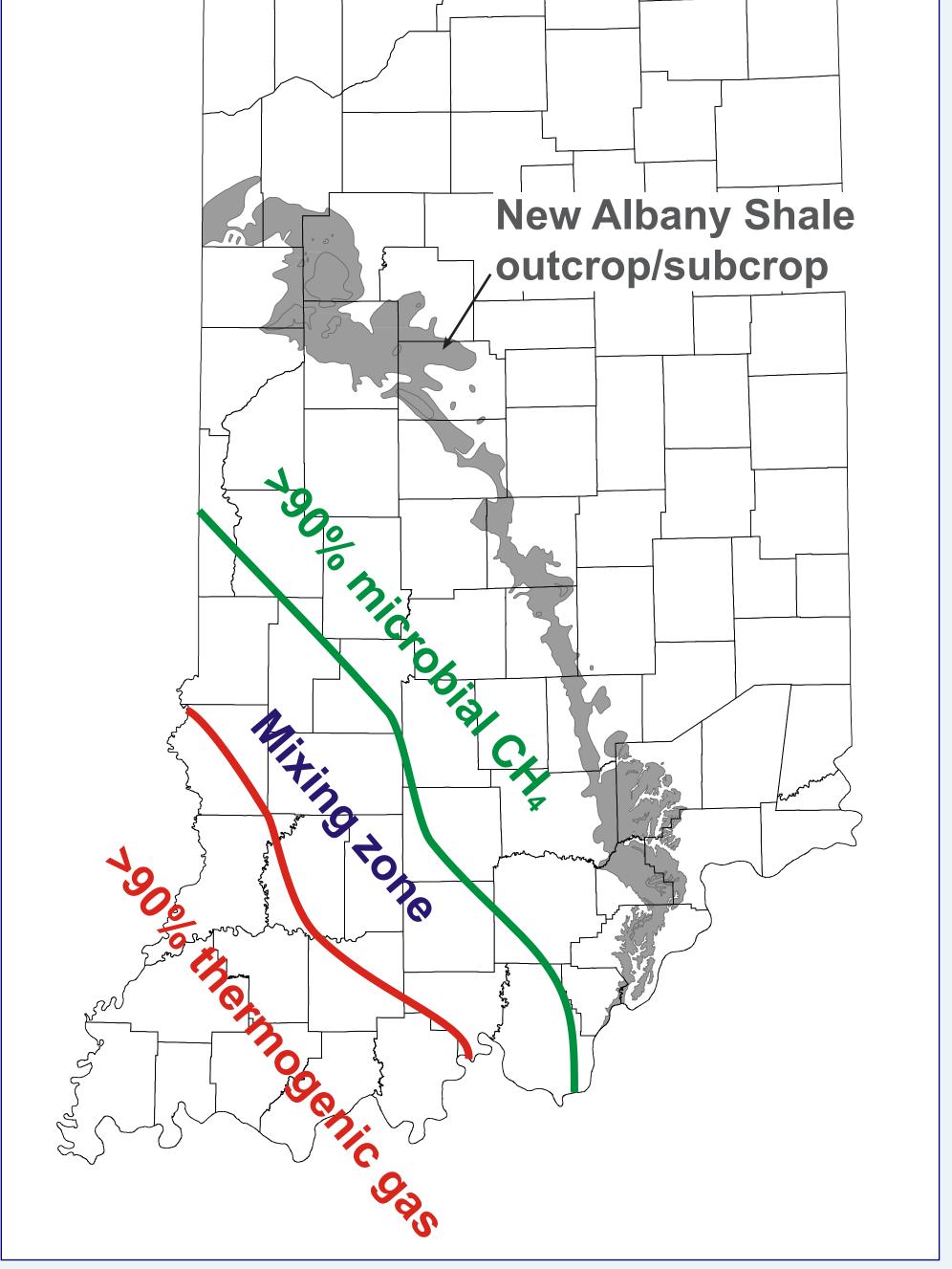
composition of New Albany shale from Indiana suggests dominant mixed thermogenic-biogenic gas origin, with the thermogenic gas dominating over biogenic gas. The presence of secondary microbial methane is documented by lower ¹³C value and lower contributions of ethane and propane, compared to the thermogenic end member. At present, we do not have enough gas composition and isotopic data, but we expect to see a progression from thermogenic to mixed thermogenic/ biogenic gas as illustrated on the map

Compiled molecular and isotopic

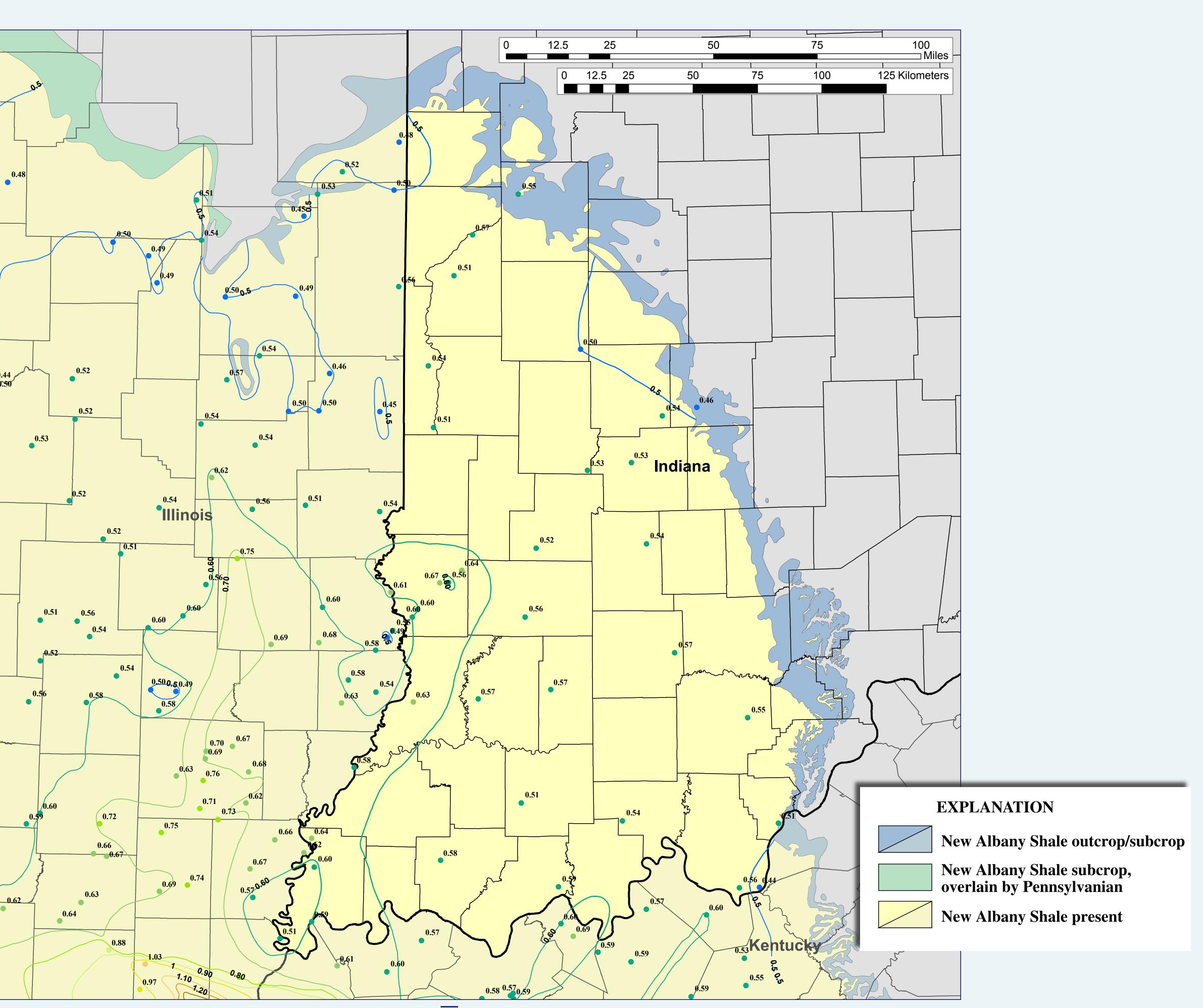
Gas content in the New Albany Shale varies, generally increasing when TOC content increases.



thermogenic gas dominating over biogenic gas.

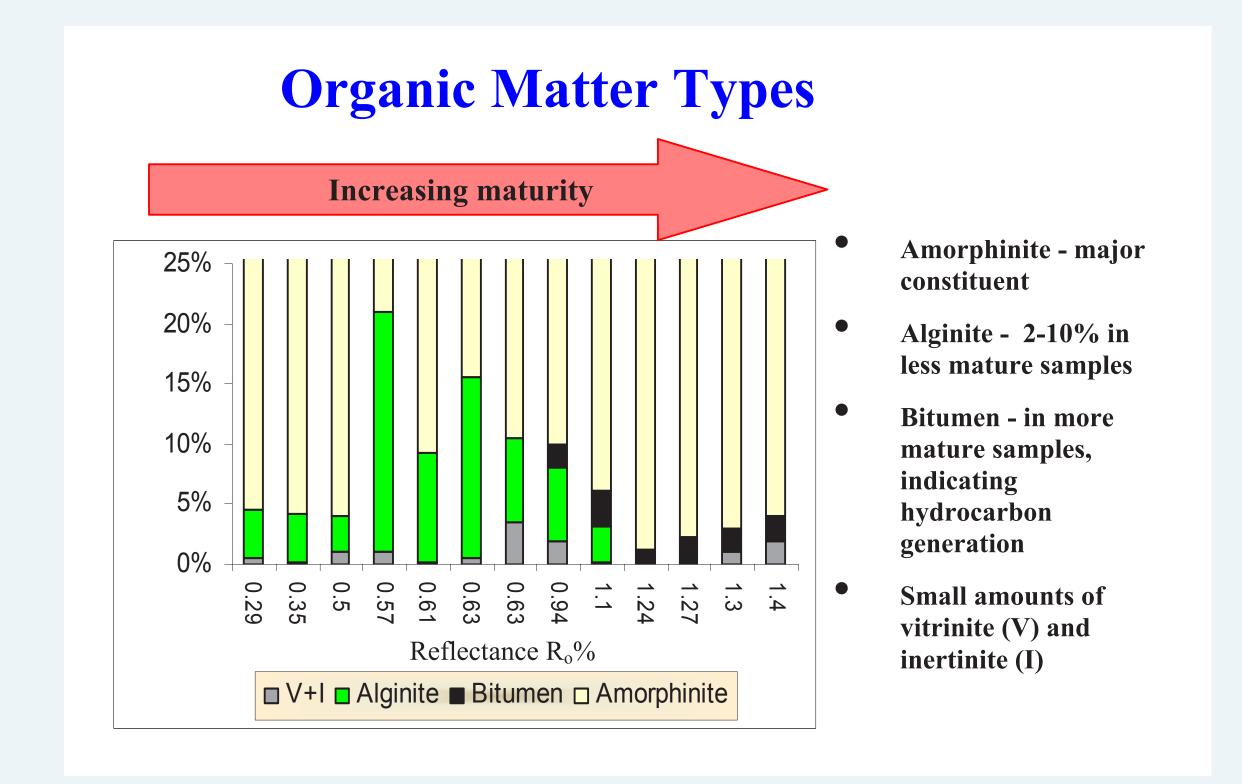


Map showing generalized regions of microbial and thermogenic gas in the New Albany Shale of Indiana.

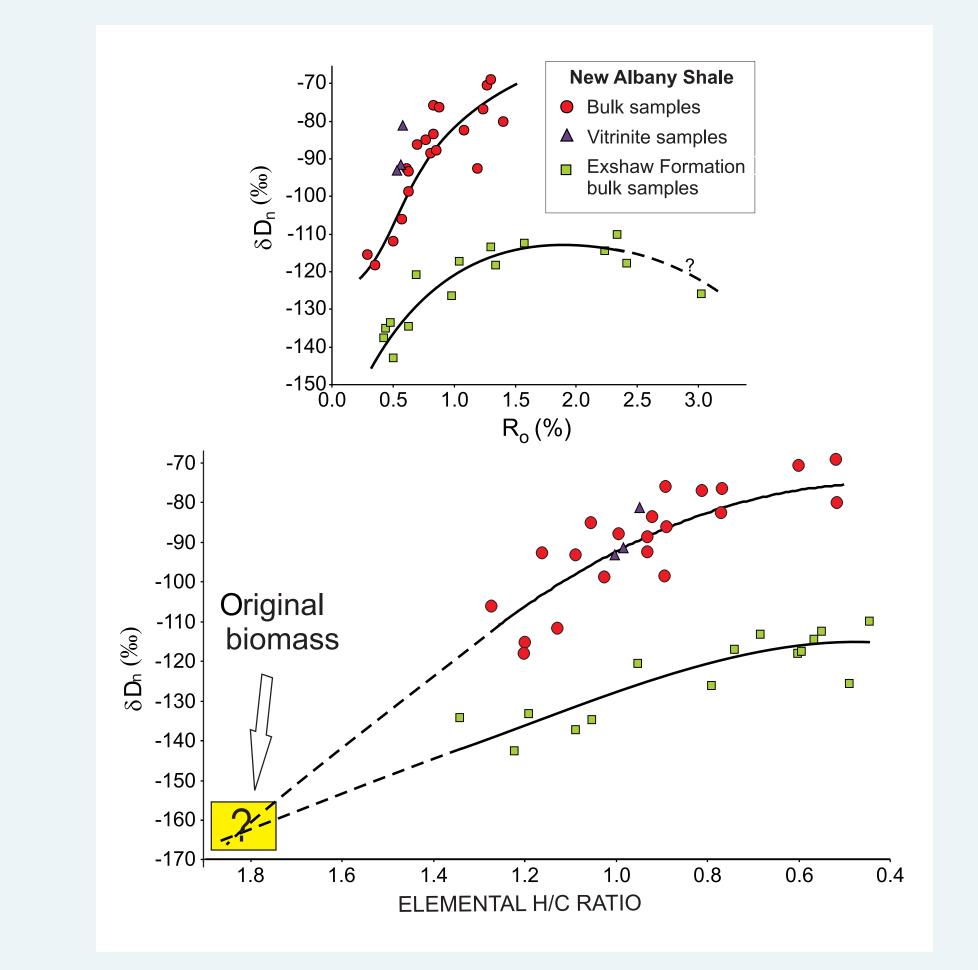


New Albany Shale Vitrinite Reflectance ($\% \overline{R}_0$) Map (Modified from Morse and others, 2000.)

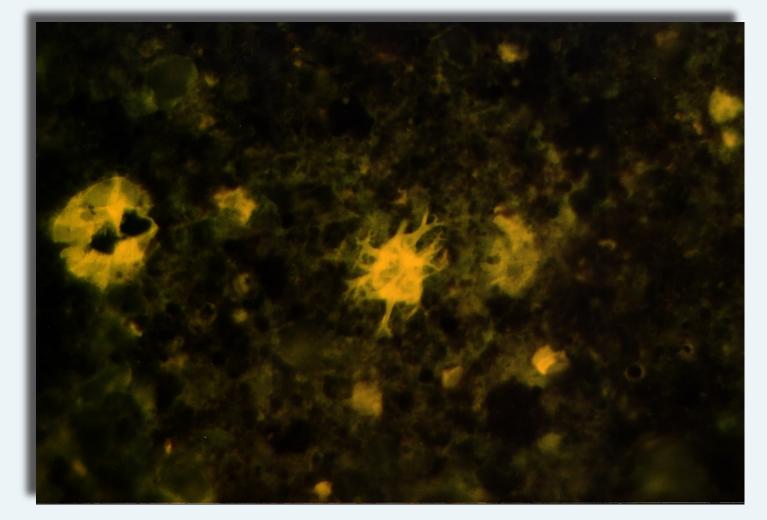
SOURCE ROCK CHARACTERIZATION



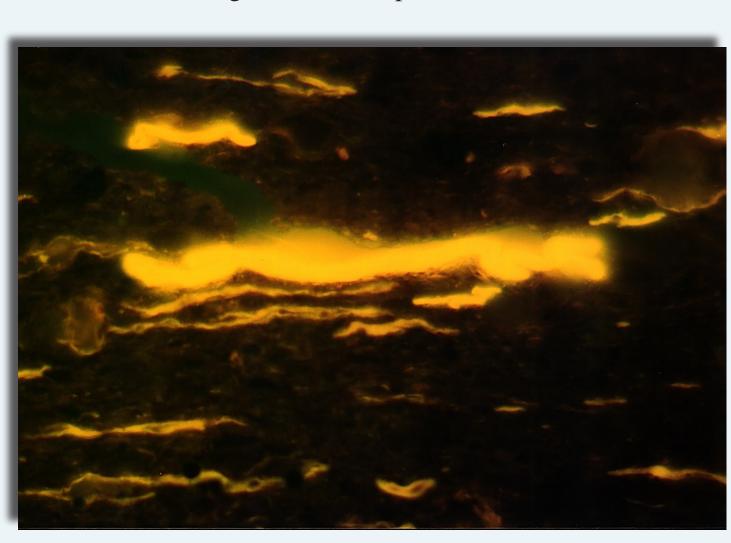
Organic matter types — Amorphous organic matter (amorphinite) is the dominant organic matter type in the New Albany Shale. Alginite can be locally abundant in less mature samples. Terrestrial organic matter—vitrinite and inertinite—is sporadic. In higher maturity samples, solid bitumen is present, indicating hydrocarbon generation from kerogen (Lis, 2006).



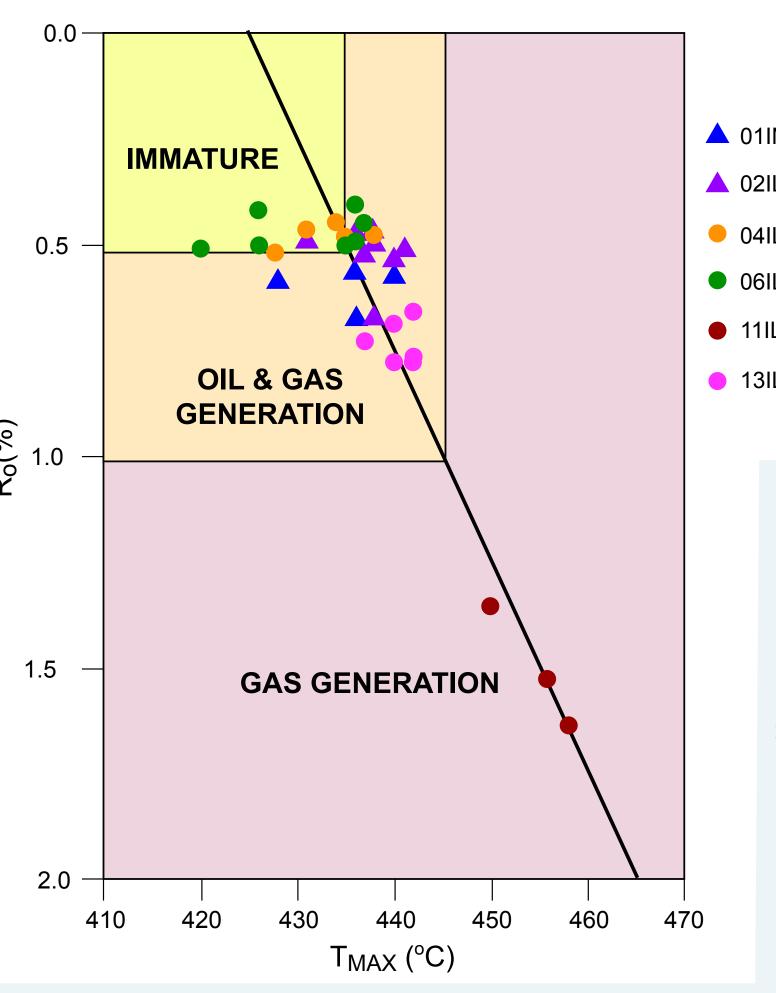
Isotopic composition of organic matter — Hydrogen isotopic composition (δD_n values) of nonexchangeable organic hydrogen in New Albany Shale expresses an overall trend towards less negative values with increasing thermal maturity, from -115 % to -69%. There is a good correlation between isotopic values and H/C ratio (Lis, 2006).



Photomicrograph showing acritarch (yellow body in the center) and other, probably algal, fluorescing material in a sample of New Albany Shale. (Fluorescent light, oil immersion, the longer axis of the photo is 240 micrometers.)



Photomicrograph showing abundance of algal material (yellow fluorescing bodies) in a sample of New Albany Shale. (Fluorescent light, oil immersion, the longer axis of the photo is 240 micrometers.)



△ 01IN - Energy Res. No. 1, Phegley Farms, Sullivan County, Indiana △ 02IL - Tri Star Prod. No. 1, Lancaster, Effingham County, Illinois 04IL - Northern Illinois Gas No. 1 RAR, Henderson County, Illinois 06IL - Northern Illinois Gas No. 1 MAK, Tazewell County, Illinois 11IL - Rector & Stone No. 1 MO Portland Cement, Hardin County, Illinois 13IL - Jenkins No. 1 Simpson, Wayne County, Illinois

Graph showing Rock-Eval® T_{MAX} versus mean random vitrinite reflectance (\bar{R}_0). Petroleum generation begins at $T_{MAX} = 435^{\circ}C$ (Peters, 1986) and is indicated in some New Albany Shale samples with \bar{R}_0 values between 0.41 and 0.50 percent. The sloping line represents the linear regression of the data and has the equation T_{MAX} =19.65 R_o + 424.6. T_{MAX} data are for core samples (Chou and others, 1991). Modified from Comer and others (1994) and Hasenmueller and Comer (2000).

gen isotopic exchangeability in Paleozoic marine kerogens (type-II): Bloom-

Morse, D. G., Comer, J. B., and Nuttall, B. C., 2000, Map showing mean random

in the Illinois Basin, in Hasenmueller, N. R., and Comer, J. B., eds., GIS

compilation of gas potential of the New Albany Shale in the Illinois Basin:

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pilation of gas potential of the New Albany Shale in the Illinois Basin: Gas

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of gas potential of the New Albany Shale in the Illinois Basin: Gas Research

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vitrinite reflectance (R₂) for New Albany Shale (Devonian and Mississippian)

ington, Indiana University Department of Geological Sciences Ph.D. disserta-

CONCLUSIONS

The New Albany Shale is an active unconventional gas play in Indiana. The formation is present throughout the southwestern part of the state and ranges in thickness from 100 feet near the outcrop to more than 360 feet in Posey County where the elevation of the top of the New Albany Shale is more than 4,000 feet below sea level.

The majority of New Albany Shale gas wells completed in the last decade are in Harrison County, where depth of producing intervals varies from 500 to 1,100 feet and production rates generally range from 20 to 450 MCFGPD. Recently, Daviess County and surrounding areas have become the focus of New Albany exploration after the El Paso Production No. 2-10 Peterson horizontal discovery well was rumored to have tested 1.3 MMCFGPD at an approximate measured depth of 2,200 feet.

Clegg Creek Member is the dominant producing interval, but completions in other zones have added to the total gas production. Thermogenic and mixed thermogenic and biogenic gases are produced from the New Albany Shale and produced water ranges from brine to water diluted through recharge by modern precipitation. The brine zones contain primarily thermogenic gas and the diluted water zones contain gas of mixed thermogenic and biogenic origin.

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