structural origin. The lengths range from 7.25 to 24 km (4.5 to 15 mi) within the county. However, some lineaments extend for many kilometers outside of the mapped area.

There are two major sets of Landsat lineaments in Erie County. They are oriented approximately northwest-southeast and northeast-southwest. The vectors of the dominant set average 329° and those of the secondary set average 49°. The 329° set approximately coincides with the average regional dip of mapped subsurface beds. The 49° set generally corresponds to regional subsurface strike.

A detailed structural interpretation on the top of the Queenston Formation shows that some of the northwest lineaments locally coincide with dip reversals and other anomalies. This mapped horizon is the base of the Lower Silurian Medina Group which is currently the principal gas-producing reservoir in this region.

Lineaments which have a tectonic origin are surface expressions of faults and other structural disturbances which probably affected the crystalline basement and were repeatedly reactivated during the deposition of overlying beds.

Extensional fractures (fracture traces) interpreted from enlarged aerial photographs are abundant. The fracture traces are found in the surface lineament zones as well as in areas between lineaments. These fractures, at depth, can locally enhance the porosity and permeability of reservoir beds which, normally, are classified as "tight formations."

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Patch Reef Modeling—A Comparison of Devonian and Recent Examples

In reef research, models have been developed to define variations in the lithic and biotic development of facies. Walker and Alberstadt, and Hoffman and Narkiewicz developed models for growth of ancient reef communities. Although these models form a solid foundation by which patch reefs can be classed and zoned, they are neither complete nor accurate for all reef types. A comparison was made of Lower Devonian patch reefs from the Appalachian basin of New York, New Jersey, and Pennsylvania, and Holocene examples from the Bahamas and Florida Keys to identify the structure, orientation, community variability, and succession of the reef biofacies. The complexion and genesis of the carbonate lithofacies were also studied. Results show similarities; these include the size, areal distribution, 3-D geometry, wave-resistance potential, lateral sequences of facies, sedimentary textures and structures, vertical zonation explained by growth from low-energy to high-energy regimes, biotic diversity, growth habit and form, and postmortem alteration. Thus, when used in conjunction with the traditional models, the recent can serve as the basis for a general model which include most patch reef types. However, these models should not be used as explicit analogs for all Phanerozoic reefs. Knowing and understanding the limitations of these comparative studies are essential to a fuller comprehension of the potential for variations which exist within and between the traditional models.

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History of Displacement Along Ste. Genevieve Fault Zone, Southwestern Illinois

The Ste. Genevieve fault zone extends eastward from Missouri across the Mississippi River into Jackson County, Illinois, about 75 mi (120 km) southeast of St. Louis. Outcrop studies have dated movement along portions of the zone as pre-Middle Devonian, post-Mississippian, and post-Pennsylvanian. Present displacement is down to the north and east with throw ranging up to 3,000 ft (915 m). However, pre-Middle Devonian movement was down to the south and west.

The present upthrown block shows no evidence of vertical movement during the Cambrian and Ordovician. Nor is there any indication that the fault zone was part of the northern border of the Reelfoot basin, where earliest Paleozoic sediments infilled an aulacogen at the northern end of the Mississippi embayment.

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Structural History of Southern Illinois and Upper Mississippi Embayment

Early crustal failure produced deep grabens which filled with fluvial and marine sediments. Subsequent growth faulting during the Paleozoic deepened these troughs, allowing deposition of thick sedimentary sequences in the Reelfoot basin and Rough Creek graben. Uplift of the Pascola arch closed the Illinois basin to the south, and erosion along the arch removed much of the sedimentary record.

Subsidence of the Mississippi embayment area allowed deposition of southward thickening continental and marine sediments. Subsequent erosion has produced the present-day areal distribution of geologic units.

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Stratigraphic Traps and Deposition of Aux Vases and Uppermost Ste. Genevieve Formations (Mississippian), Southern Illinois

A basin-wide subsurface and outcrop study of the Aux Vases Sandstone was undertaken to determine the source of the sandstone, the regional extent of producing zones, the nature of its stratigraphic traps, and reservoir characteristics. The Aux Vases marks the transition from the predominantly carbonate deposits of the Valmeyeran to the clastic dominated Chesterian.

The Aux Vases in southwestern Illinois is composed of fine-grained, subangular to rounded sandstone commonly occurring in massive sand bodies 50 to 200 ft (15 to 60 m) thick. Many of these sand bodies are fluid-saturated and porous, but are not petroleum reservoirs. The eastern and central parts of the Illinois basin, where the Aux Vases is usually less than 30 ft (9 m) thick, are the major producing areas.

The overlying Renault Limestone separates the Aux Vases from lower Chesterian sands, forming a cap for many stratigraphic traps in the Aux Vases. The most common type of stratigraphic trap in the Aux Vases occurs in thin, shaly and silty sands overlying the Joppa Member of the Ste. Genevieve Limestone ("Aux Vases Lime"). Previous work has indicated that these are tidally influenced sands deposited on a platform of Ste. Genevieve oolitic limestone or grainstone. These Aux Vases platform sandstones grade laterally into either oolite, grainstone, or silty, shallow-marine shale. The best production comes from "permeability pods," where good porosity (15 to 20%) coincides with permeabilities in excess of 100 md.

Another type of stratigraphic trap occurs in a 4 to 10-ft (1 to 3 m) thick oolitic zone, in the lower part of the Joppa Member, usually separated from the Aux Vases by less than 10 ft (3 m) of dense limestone. When this oolite is loosely cemented, permeabilities are in excess of 200 md, resulting in excellent initial production (sometimes in excess of 1,000 bbl of oil/day).

Study results indicate a western source for the Aux Vases. The thickest accumulations of sand occur in the southwestern part of Illinois and display western cross-bedding. The amount of sand decreases and the amount of limestone increases in the producing part of the basin.

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Comparison of Organic-Rich Shales of Pennsylvanian Age in Indiana with New Albany Shale

Abundant black organic-rich shales occur in rocks of Pennsylvanian age in southwestern Indiana. They have not been well characterized except for a few thin intervals in small areas, the best example being at the abandoned Mecca Quarry in west-central Indiana. Although these shales are thinner and less widespread than the organic-rich shales of the New Albany Shale (Devonian and Mississippian age) they warrant characterization because of their accessibility during strip mining of underlying coals.

Organic-rich shales of Pennsylvanian age contain up to 44% organic carbon and might be considered potential oil shales. Carbon to hydrogen ratios in these shales are similar to those in the New Albany. Relatively high concentrations of certain metals occur in shales of both ages, especially where phosphate is abundant, and sulfur values for both shales

range from < 1 to 6%. Sulfur values are much higher for thin pyrite-rich units. Siderite nodules are common in Pennsylvanian shales, but little siderite is found in the New Albany. Dolomite, commonly ferroan, and calcite in a variety of forms are the dominant carbonates in the New Albany. Some Pennsylvanian shales may contain large fossils or mica flakes, but such coarse-grained features are uncommon in the New Albany Shale.

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Geothermal Gradients in Mississippi Embayment

A statistical analysis of bottom-hole temperatures from oil and gas wells in the northern Mississippi embayment suggests that the geothermal gradient below a depth of 1 km is low (22.2°C/km) and for the New Madrid seismic zone, it is even lower (15.7°C/km). These data support the tentative conclusion of Swanberg et al that ground-water convection is the source of near-surface heat in shallow water wells of the region. Research by Mitchell et al had suggested a high geothermal gradient in the crust and upper mantle beneath the New Madrid seismic zone as a plausible explanation for the lower than average compressional wave velocities observed there. Warmer than normal wells in the northern Mississippi embayment are scattered at random and may be attributed to random error in the data. Deep wells in the southern Mississippi embayment are substantially hotter than wells at a comparable depth farther north. The regional geothermal gradient below a depth of 1 km from northern Louisiana to central Mississippi is 26.9°C/km. From central Mississippi to central Alabama, the geothermal gradient (23.1°C/km) is comparable to that of the northern Mississippi embayment.

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Field Investigations in Arkansas Valley Seismic Swarm Area

Field and air photo investigation of the Arkansas Valley seismic swarm area in 1982 resulted in the detection of a northeast-trending lineament which dissects the swarm region and may be indicative of the fault which is the source of the recent seismicity. The linear coincides with the alignment of portions of several drainage systems along much of its length, and in other places it is defined by escarpments a few feet high. The possible relationship of the linear to local and regional structures and seismicity will be discussed. Additional features consisting of ground cracks, sinks, and a relatively fresh-appearing scarp in the vicinity of a known fault in the swarm area will also be discussed. This study was funded by the Arkansas Geologic Commission and the Geology Department of Southern Illinois University.

STRUNK, KEVIN L., and LAWRENCE L. MALINCONICO, JR., Southern Illinois Univ., Carbondale, IL, and W. JOHN NELSON and DONALD K. LUMM, Illinois State Geol. Survey, Champaign, IL

Structural Relationships Between Cottage Grove and Shawneetown Fault Systems, Southeastern Illinois, as Inferred from Gravity Data

Gravity measurements, extensive field mapping, and drill hole data have been used to determine the structural relations between the Cottage Grove and Shawneetown fault systems of southeastern Illinois.

The Cottage Grove structure is an east-west-trending, right-lateral wrench fault which extends across southern Illinois. The Shawneetown fault is the western extension of the Rough Creek fault system of Kentucky and consists of several high-angle reverse and normal faults. Both fault systems are part of Heyl's 38th Parallel lineament; however, the relation between them has been obscured by Pleistocene lacustrine and fluvial sedimentation.

Over 400 new gravity stations, with approximate 0.5 km (0.3 mi) spacing, were occupied in eastern Saline and western Gallatin Counties. The data were reduced to the Bouguer values, contoured, and selected profiles were two-dimensionally modeled. The new data, in conjunction with coal mine, drill hole and field mapping data, suggest an eastward extension and bifurcation of the Cottage Grove system. The northern segment continues eastward, dying out just west of the north-south Wabash Valley fault system. The southern segment trends southeastward, possibly merging with the Shawneetown fault system in a complexly faulted zone.

The use of gravity data in conjunction with other structural information may provide a useful tool for defining structure obscured by unconsolidated deposits in southern Illinois and other parts of the Illinois basin.

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Correlation of Fractural Reservoir Productivity with Fracture Intersection Quadrants

Higher success rates for discovery of gas and oil in naturally fractured reservoirs can be achieved by correlating discoveries and productivities with fracture intersection quadrants. These fracture intersection quadrants are formed by the intersection of the two predominant fracture directions. Higher success rates in a particular quadrant appear to be related to greater fracture density resulting from the downdip extensions of the fractures in the stratigraphic zone of interest. Plunge of the intersection should be considered to insure that the drill hole penetrates the projected intersection within the stratigraphic zone of interest.

Observations in Kentucky have shown success rates can be improved three-fold when drilling in the most favorable quadrant as opposed to the least favorable quadrant, and when the drill hole is located a proper distance from the fault intersection to allow for the downdip projection to the zone of interest.

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Tectonic History of Mississippi Embayment and Surrounding Areas

Recently published U.S. Geological Survey gravity and magnetic maps constitute powerful tools for interpreting the tectonic nature and history of the northern part of the Mississippi embayment. Perhaps the most striking feature of the maps is a set of alternating, roughly coincident gravity and magnetic anomalies that bear northeastward and extend from the northwestern edge of the embayment to Alabama. Positive anomalies in this set are viewed, using the model of McKensie, as zones of stretching, thinning, and subsidence of the continental lithosphere. Gradients between positive and negative anomalies may mark the position of listric faults, which blocked out grabens and horsts within the basement rocks, forming a low-relief crustal mosaic.

This mosaic was jostled by the Ouachita collision during the Late Pennsylvanian. A horst on the northwestern flank of the embayment was pushed slightly northeastward and uplifted at its northeastern end to form the Pascola arch. Potential field maps provide no evidence that the Pascola arch connected the Ozark and Nashville domes. Older structures athwart the region trend of the mosaic, such as the Ste. Genevieve and Rough Creek faults, were reactivated as thrust faults up on their southern sides. In the Early Permian, alkalic dikes were intruded in the region of the Illinois Mineral District providing the earliest evidence of a lens of low velocity mantle rock beneath the embayment. Radiometric dates suggest alkalic igneous activity peaked in the Cretaceous.

In this scenario, the Reelfoot region evolved from a broad complex graben to a true rift during the late Paleozoic. Mesozoic igneous events and present seismicity suggest that the Reelfoot is not a dying rift; it is instead being born.

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Drowned Barrier Bar and Tidal Inlet Sequences in Buckner-Sesser-Valier Fields, Franklin County, Illinois

Nearly 400 electric logs, using spontaneous potential and resistivity curves, were analyzed in a study of the Aux Vases Formation in the Buckner-Sesser-Valier fields of Franklin County, Illinois. Subsurface mapping procedures incorporated data from core descriptions, scout tickets, and electric logs in constructing structure maps on marker beds directly above and below the formation, and isopachs of producing and nonproducing sandstones within the formation.

Three lithofacies were recognized in the Aux Vases Formation; in ascending order they are: Facies A, a thin, nonproductive calcareous