cates that such lineaments probably represent anomalous zones of increased fracture permeability about 400 ft (120 m) wide at the surface. Gas wells located near short photolineaments oriented N60°W to N30°E and especially N60°W to N0°E had significantly higher initial open flows (both before and after stimulation) than wells located near other photolineaments. Gas wells also had significantly higher initial open flows when located in high-density areas of N60°W to N30°E photolineaments. Within lineament density zones exceeding 2.0 mi/sq mi (3.2 km/2.6 sq km), 71 and 100% of randomly located gas wells would have exceeded 100 Mcf/day before stimulation and after stimulation respectively. Gas wells located near class 1 (most certain) photolineaments had higher initial open flows than wells near class 2 or 3 (less certain) photolineaments. Wells located within 0.25 mi (0.4 km) of a class 1 photolineament oriented N60°W to N30°E had significantly higher initial open flows than more distant wells. Landsat lineaments appear to be poor locations for gas wells, for they do not overlap the areas of high gas production.

Certain water-well parameters are also associated with initial gas well yield. Water wells located within areas of high initial gas flow (over 100 Mcf/day after stimulation) have significantly higher bicarbonate and nitrate concentrations than wells in areas of low gas production. Optimum sites for high-yielding gas wells would be near water wells having at least 470 mg/l bicarbonate or at least 1.75 mg/l nitrate. Initial yields before stimulation were significantly greater for gas wells near high-yielding water wells compared to gas wells near low-yielding water wells; however, this trend is probably not useful for gas exploration, for it does not apply for initial gas flows after stimulation.

BERGER, IRVING A., U.S. Geol. Survey, Reston, Va.

### Suggested Origin for Gas in Eastern Devonian Shales

Kerogen of the Chattanooga Shale in eastern Tennessee and adjacent areas is known to be of predominantly terrestrial origin. The Chattanooga Shale may be viewed as a high-ash, low-rank coal. Recent detailed studies of peat from The Everglades of Florida have led to the observation that the rate at which cellulose is degraded is reduced as the mineral content increases. Knowing of the contribution of terrestrial plant material to the sediments that later became the Chattanooga Shale (which is 75 to 85% mineral matter), we believe that those sediments probably contained an accumulation of cellulose. Slow, anaerobic degradation of that cellulose by methanogenic bacteria would be expected to result in the formation of methane that would then dissolve in other organic components of the sediment. Only in those regions where the contribution of aquatically derived organic detritus to the sediment was significant would appreciable amounts of ethane, propane, and higher gaseous hydrocarbons be expected, perhaps as products of low-temperature thermal processes.

These considerations suggest that study of the composition of kerogen in the Chattanooga Shale and its correlatives could delineate those regions of the eastern Devonian shales most likely to be the best sources of methane.

BROADHEAD, R. F., Univ. of Cincinnati, Cincinnati, Ohio, R. C. KEPFERLE, U.S. Geol. Survey, Cincinnati, Ohio, and P. E. POTTER, Univ. Cincinnati, Cincinnati, Ohio

### Gas-Bearing Ohio Shale along Lake Erie—Stratigraphy, Petrology, and Sedimentology

Increased interest in low-yield gas-bearing strata has led to reexamination of the Ohio Shale in the vicinity of Lake Erie where it has had a history of marginal commercial production for over a century.

These strata thin depositionally westward from a maximum of 2,000 ft (600 m) at the Pennsylvania border to less than 600 ft (180 m) near Sandusky where they are truncated by erosion on the Findlay arch.

Common lithotopes are black and gray shale, siltstones, and rare carbonate rocks. Black shales are most abundant in the west where gray shales and siltstones are rare. In the east, gray shales and siltstones constitute 75% of the section and the remainder is mainly black shale and minor carbonate rocks.

Thin-section petrology revealed that the black shale commonly contains, by volume, less than 20% silt-size quartz and feldspar, 30 to 60% clay and mica, and 15 to 35% organic material. Gray shale commonly contains less than 30% silt-size quartz and feldspar, 50 to 90% clay and mica, and less than 10% organic material. Much of the silt is concentrated in discrete laminae a few grains thick.

Production records are related to facies distribution to provide an exploration tool.

Cross sections and paleocurrents indicate that the Upper Devonian prodeltaic muds and turbidite siltstones were deposited episodically in a euxinic basin.

CALCAGNO, FRANK, JR., Student, Cleveland Heights, Ohio

### Fracture Pattern in Outcrop of Gas-Producing Devonian (Ohio) Shale in Northeastern Ohio

Data on more than 22,000 fracture traces within the Upper Devonian and Lower Mississippian strata exposed in northeastern Ohio reveal two pervasive fracture sets. One set, the master shear set, is a double set of fractures intersecting at an angle of 27°, with an average median orientation of N51°W. The smooth, clean fracture planes with occasional rib markings indicate that this set resulted from shear stresses. The other set, the subsidiary tensional set, consistently trends at 90° to the master shears.

These two sets may be extended as far south as central Pennsylvania and as far east as southeastern New York state, thus defining the fracture pattern of the northern Appalachian basin. The regional fracture pattern is one of a radial set of fractures (master shears) accompanied by a concentric pattern of perpendicular fractures (subsidiary tensional set).

Because of the stress conditions necessary to produce this fracture system, it is believed that the fractures were formed during two distinct structural episodes: the master shears developed during an earlier period of compressional basin formation, and the subsidiary tensional set developed during a later period of tensional relax-