structure of the crust. As the data are geographically oriented and in digital format, standard image-processing and analysis techniques can be applied. For instance, we have used a spatial filtering technique to interpolate between station locations of gravity and magnetic data to produce gray or color-coded images with continuous coverage throughout the Mid-Continent. The images contain more information than found in standard contour maps, because they can have many more contour intervals, and because they preserve local details of anomaly patterns.

As an example of applicability of these techniques, gravity images registered and overlayed with magnetic, geologic, and remote sensing data lead to the identification of a Precambrian rift structure that begins at a break in the Mid-Continent gravity high in southeast Nebraska, extends across Missouri in a northwest-southeast direction, and intersects the Mississippi Valley graben. The rift structure is about 435 mi (700 km) long and 75 to 100 mi (120 to 160 km) wide. It is expressed in gravity images as a low with a Bouguer amplitude of about -34 milligals below regional values. Some of the discrete positive magnetic anomalies in Missouri are located along the borders of the gravity low. The gravity feature cuts across a major age boundary within the Precambrian basement.

Finally, digitally enhanced thermal infrared images show a distinct alignment of linear structures with the gravity feature. The linears in some places correspond to mapped high-angle normal faults, to drape folds over relief within the Precambrian basement, and in some places, to extensions of mapped structures.

HARRIS, LEONARD D., U.S. Geol. Survey, Reston, VA

Possible Hydrocarbon Resources Beneath Blue Ridge-Piedmont Thrust Sheet

An integration of surface geologic data and subsurface seismic reflection data across the southern and central parts of the Appalachian orogene has emphasized that the fundamental structure of the orogene is a low-angle mega-thrust fault system. Documentation of this basic model began in the southern Appalachians, where seismic reflection data indicated that crystalline rocks of the Blue Ridge and Piedmont had been thrust westward burying a 50 mi (80 km) segment of Paleozoic sedimentary rocks. Recently, in a continuing effort to further define and document the regional distribution of the buried Paleozoic section, our seismic reflection studies were shifted from the southern to the central Appalachians in Virginia. Approximately 174 mi (280 km) of seismic data was acquired in a continuous profile along Interstate I-64 from the Valley and Ridge near Staunton, Virginia, eastward across the Blue Ridge, the Piedmont, and most of the coastal plain to Hampton, Virginia.

Our latest data verify the basic mega-thrust framework model by demonstrating that crystalline rocks of the Blue Ridge and Piedmont have been thrust westward burying about 30 mi (50 km) of Paleozoic sedimentary rock. Regional thermal patterns within the Appalachian orogene were disrupted by thrusting, consequently the same patterns must have existed prior to thrusting. Because thermal levels have a direct bearing on organic maturity, palinspastic restoration of these thermal patterns can be used as a general tool to assess the regional hydrocarbon potential of the area.

INEGBENEBOR, EDWARD CLIFFORD, Nigerian Natl. Petroleum Corp., Port Harcourt, Nigeria, and WILLIAM H. HARRIS,* Brooklyn College, City Univ. New York, Brooklyn, NY

Boron, Gallium, Rubidium, and Vanadium as Geochemical Indicators of Marine and Freshwater Depositional Environments: Hamilton Group (Middle Devonian), Southeastern New York

Thirty-two shale-mudstone samples collected from the Hamilton Group and previously classified on the basis of paleoenvironmental studies using geologic criteria as being of marine, brackish, or freshwater origin were analyzed for the environmental-discriminant trace elements B, Cr, Ga, Li, Ni, Rb, and V by atomic absorption spectrophotometry. The most efficient trace element discriminator used to differentiate geochemical partition of Hamilton marine from freshwater argillaceous samples was based on B vs. V, but use of other trace-element partition variables produced nearly similar results.

Considering marine and freshwater samples together, 69% of those designated on the basis of geologic criteria as either freshwater or marine were correctly classified according to the three best geochemical partition methods (B vs. V, B vs. Ga, and B vs. Ga vs. Rb). For those designated by geologic criteria as marine, partition plots of B vs. V, and B vs. Ga correctly classified 90%, and B vs. Ga vs. Rb correctly classified 95% of the samples. Only 14% of those samples geologically defined as being of freshwater origin were correctly classified based on these geochemical partition methods. The overall paleosalinity signature for the Hamilton based on geochemical partition methods is marine. The source area mountains (Acadian) at that time thus were still probably of low relief. The Hamilton probably represents a degradational delta in part with many reentrant transgressive bays, and in part a sluggishly prograding mud-dominated shoreline.

JOLLEY, RICHARD M., Univ. North Carolina, Chapel Hill, N.C.

Clearville Siltstone of Middle Devonian Mahantango Formation in Parts of Pennsylvania, Maryland, West Virginia, and Virginia

The Clearville siltstone of the Middle Devonian Mahantango Formation is an eastward-thickening and coarsening detrital clastic wedge which crops out in the Valley and Ridge province of south-central Pennsylvania, western Maryland, eastern West Virginia, and northwestern Virginia. Its west limit defines the west limit of the Mahantango Formation and can be traced in the subsurface of Cambria and Somerset Counties in Pennsylvania and in outcrop in Hardy and Mineral Counties in West Virginia.

The Clearville siltstone in the western half of its surface occurrence consists predominantly of a sequence of interbedded siltstone and mudstone which is usually directly overlain by the Pokejoy Member of the Mahantango Formation, which exists as either a calcareous, fossiliferous siltstone or an argillaceous, fossiliferous limestone. To the east, the Clearville siltstone changes to a more complex sequence of several upward-coarsening cycles, the first of which is directly overlain by a *"Spirifer" tullius* zone that correlates with the Pokejoy Member to the west.

The upward-coarsening cycles are interpreted as delta cycles, grading from prodelta mudstones and claystones near the base to medium to very thick-bedded delta front sandstones near the top of the cycles. The Pokejoy Member probably originated as an indirect result of either delta lobe abandonment or a eustatic sea-level rise following the first major phase of sedimentation of the Clearville siltstone.

The sedimentation pattern of the Clearville siltstone is marked by two lobate regions of thickening: a more northern region long referred to as the Fulton lobe, and a more southern region referred to as the Frederick lobe. In both lobes, primary sedimentation appears to have been the result of westwardly flowing turbitity currents on a gently sloping shelf with later resedimentation and physical reworking from a combination of sublittoral processes such as tidal and storm surge currents. This physical reworking, as well as biogenic reworking, is particularly evident in the Fulton lobe, where two distinct sheet sandstone facies are recognized. This and other facies comparisons suggest lower rates of sedimentation in perhaps shallower water for the Fulton lobe than the Frederick lobe during Clearville deposition.

Although very low porosity values are characteristic of the Clearville clastics, fracture porosity and thick delta front sandstone development combine in the more eastern outcrop belts to increase the potential for a hydrocarbon reservoir in the Clearville siltstone.

KEAN, WILLIAM F., Univ. of Wisconsin-Milwaukee, Milwaukee, WI

Paleomagnetism of Late Ordovician Neda Iron Ore from Wisconsin and Late Ordovician Queenston Shale from New York

The Neda iron formation is a hematite and goethite-rich oolitic ore which occurs in lens-shaped deposits on top of the Maquoketa Shale at only a few locations in the Wisconsin area. Its origin has been a puzzle for over a hundred years, but there have been suggestions that it is the westernmost extension of the Queenston Shale. Paleomagnetic studies were undertaken to see if paleopole directions from the two formations could aid in determining the origin of the Neda.

Thermal demagnetization of the Neda samples indicates the remanence is carried by hematite. Chemical demagnetization suggests the remanence is produced by the interstitial material rather than the oolites. The paleopole from 25 samples is at S 45.4°, W 48° (α 95 = 16°). This pole position is similar to Late Mississippian to Early Permian of North America rather than Late Ordovician. This suggests that the hematite in the ore was produced from dehydration of goethite during Late Mississippian time.

Queenston Shale samples from western New York were similarly measured. Thermal demagnetization indicates the remanence is carried by hematite and the pole position from 8 samples is at S 45°, W 38° (α 95 = 10°). This pole position is very similar to that of the Neda. This indicates that both formations were presumably subjected to the same post-depositional chemical changes in the late Paleozoic, but it does not conclusively show that the Neda is in fact the western extension of the Queenston. This late Paleozoic pole position has been found in almost all red sediments of Ordovician age in North America, both folded and nonfolded, which suggests that the remanence is not simply due to deformation produced by the Appalachian orogeny.

KLOC, GERALD J., State Univ. New York at Buffalo, Amherst, NY

A Local Deep Water Basin and Shoreline Model for Middle Devonian Ludlowville Formation of New York

In the Seneca Lake region, both the Ledyard and Wanakah members of the Middle Devonian Ludlowville formation have a black shale facies. This grades westward to a gray shale facies and eastward to a gray shale and siltstone facies. The black shale facies represents an anoxic basin of deeper water than the shallower water gray shale facies to the east and west. The axis of this basin trends northeast-southwest.

The Ludlowville formation from Lake Erie to the Genesee Valley has many thin argillaceous limestone beds, 1 to 4 in. (3 to 10 cm), that are useful for detailed correlation. Because these thin beds can be traced as far as 43 mi (70 km), this part of the outcrop belt probably parallels an ancient east-west shoreline. Between Genesee Valley and Seneca Lake, the inferred shoreline turns to a northeast direction parallel to the axis of the basin, and bedrock exposures display a barren, black shale facies. In these exposures the thin beds disappear. From Seneca Lake to Owasco Lake, the deeper water, black shale facies gives way to shallower water, gray shale facies with thin traceable beds. Because the thin beds disappear in the basin exposures, it becomes difficult to correlate the detailed stratigraphy of the western beds across the basin with the eastern beds. Some correlations have been made using ammonoids. The inferred northeast-trending shoreline may have circumscribed the northern end of this basin, and then turned southward to become part of the southwest-trending shoreline in eastern New York.

This basin first appeared during the deposition of the Early Devonian Helderberg Group and persisted during the deposition of the Middle Devonian Onondaga Limestone and Hamilton Group. Throughout this period, the basin axis shifted from eastern to western New York. This basin has already proven to be of economic importance as a gas producer from the Onondaga reefs that occur on its margin, and may provide other areas of economic importance.

KOCH, WILLIAM F., Waynesburg College, Waynesburg, PA

Brachiopod Community Paleoecology, Paleobiogeography, and Depositional Topography of Devonian Onondaga Limestone in Eastern North America

The lower Middle Devonian Onondaga Limestone was deposited in a northwest-southeast elongated topographic basin and on the surrounding carbonate platform. Two sedimentary cycles are present in the Onondaga. The Edgecliff represents a transgression which spread epeiric seas over much of eastern North America. During the Nedrow-Lucas regression, the interior of the platform became restricted resulting in the deposition of evaporites. The Moorehouse transgression continued through the deposition of the Tioga Bentonite, followed by pre-Speeds-Dundee regression from the craton.

Onondaga brachiopod communities, arranged from nearshore to offshore, include the Atrypid-*Megakozlowskiella*, Atrypid-*Levenea*, Chonetid, *Atlanticocoelia*, Ambocoeliid, and *Truncalosia* communities. The Onondaga-age Eastern Americas Realm is divided into the Appohimchi province in the Appalachian basin and the Michigan basin-Hudson Bay Lowland province in the midwest. The provincial assignment of the James Bay region of Ontario is uncertain; the eastern townships of Quebec are near the boundaries both of the two provinces of the Eastern Americas Realm, and of the Eastern Americas Realm and the Old World Realm.

KURESHY, A.A., Staten Island, NY

Stratigraphic Correlation of Planktonic and Larger Foraminiferal Zones

A very few areas of the sedimentary basins of the world are characterized by marine facies of clastic and non-clastic origin, which are rich in planktonic and larger foraminiferal assemblages. Pakistan is one of the countries where the Tertiary marine deposits (Paleocene to Miocene) are represented by both clastic and non-clastic facies characterized by stratigraphically restricted planktonic and larger foraminiferal species, which provide the basis for the interregional biostratigraphic correlation.

The marine clastic deposits of Paleocene to Miocene age in the Lower Indus and Baluchistan basins of Pakistan are rich in the planktonic assemblages. On the basis of the stratigraphically restricted species, 22 planktonic foraminiferal zones were delineated to mark the stratigraphic boundary of the various European stages (Kureshy, 1977). The non-clastic marine deposits of Paleocene to early Miocene age in the Lower Indus and Upper Indus basins of Pakistan, which are interbedded with clastic deposits, are rich in larger foraminifera. On the basis of the stratigraphically restricted species, ten biostratigraphic zones of the larger foraminifera are designated (Kureshy, 1978).

These assemblages are cosmopolitan in occurrence of identical geological ages. The planktonic foraminiferal zones are more widespread and have close resemblance to the Caribbean region, as compared to larger foraminiferal zones. The larger foraminifera of Pakistan have no resemblance to the Caribbean region; however, they closely resemble Middle East and Indo-Pacific regions. The