

generation of accurate computer-enhanced images or maps. Problems related to diurnal variations and solar storms at high magnetic latitude are largely overcome because changes in the total magnetic field do not significantly affect the magnetic gradient. Analysis of an experimental survey, covering 4,418 line km (2,745 line mi), suggests that the Marsh Creek anticline in the Arctic National Wildlife Refuge is prospective for oil and/or gas. Additional magnetic anomalies were also identified. Although the effect of permafrost on epigenetic processes has not been investigated, the data suggest that special purpose aeromagnetic surveying may be a useful and relatively inexpensive way to explore for oil and gas in this hostile environment.

DORNING, KEN J., Pallab Research, Sheffield, England

Applied Biostratigraphy in Paleozoic Exploration

Integration of data from the palynological analysis of acritarchs and chitinozoa, together with conodont data, provides biostratigraphic results in all environments from wide carbonate platform, inner and outer shelf, basin margin, to deep basin sediments.

This integrated data is of great value in Paleozoic exploration biostratigraphy, in particular where microspore and calcareous microfossil data are inadequate. The acritarch data are of prime importance as the numerous, diverse assemblages provide a refined biostratigraphy of shelf and basin margin sediments worldwide; the chitinozoa are of particular value in deep basin areas, whereas the conodonts are of value in carbonate platform areas.

Identification of basin margins and basin subsidence can be gained by the preservation and known environmental distribution of selected acritarchs and chitinozoa. Sediment source areas can be identified using recycled palynomorphs. Thermal maturation based on vitrinite reflectance cannot be applied to pre-Silurian rocks; in the Paleozoic visual kerogen analysis including acritarch and chitinozoa colors, together with conodont coloration and organic pyrolysis provides the data on organic thermal maturation and source rock oil and gas potential.

DOROBEK, STEVEN L., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA

Regional Cathodoluminescent Cement Zonation Related to Upland-Sourced Paleo-aquifers: Devonian Helderberg Carbonates and Clastics, Central Appalachians

Cathodoluminescent zonation in shallow burial calcite cements of the Keyser and New Creek Limestones (lower Helderberg Group, Upper Silurian-Lower Devonian) in Virginia, West Virginia, and Maryland can be mapped regionally. Regional distribution of cement zones coincides with the distribution of easterly derived sandstone tongues within the carbonate sequence. In southwestern Virginia, calcite cements in limestones subjacent and laterally equivalent to the Clifton Forge and Healing Springs Sandstones show cathodoluminescent zonation of nonluminescent (earliest cement) to bright to dull or subzoned dull (last shallow burial cement). Nonluminescent cements are Mn^{2+} and Fe^{2+} poor and precipitated from oxidizing meteoric pore fluids; bright cement (Mn^{2+} -rich) reflects more reducing pore fluids; dull cement (Fe^{2+} -rich) precipitated from most reducing shallow to deeper burial pore fluids. Nonluminescent-bright-dull zonation grades abruptly into correlative subzoned dull cement downdip from sandstone tongues. Further downdip, subzoned dull cement grades into dull (nonzoned) cement. Limestone adjacent

to the Elbow Ridge Sandstone (West Virginia and Maryland) lacks nonluminescent and bright cement but has subzoned dull cement that grades into dull cement westward. Clear rim cement on scattered pelmatozoan grains in the Clifton Forge, Healing Springs, and Elbow Ridge Sandstones have complexly zoned nonluminescent and bright cements. Quartz grains have pressure-solved contacts and are cemented by dull luminescent, deep burial cement. Predominance of deep burial Fe-rich cement in sandstone indicates that they remained "open" during shallow burial diagenesis and that sandstone tongues acted as conduits for oxidizing meteoric ground waters recharged from tectonic highlands. Downdip from sandstone tongues, subzoned dull and nonzoned dull cements precipitated from reducing meteoric ground waters distant from subareal recharge areas. Precipitation of shallow burial zoned cements ceased when recharge areas were buried by thick Devonian clastics (Ridgeley Sandstone, Huntersville Chert, Millboro Shale) or when burial removed the sediments from the effects of upland sourced meteoric ground waters. Final porosity occlusion in the limestone is by deep burial, clear, Fe-rich calcite cement (dull luminescence), Fe-rich "saddle dolomite," silica cement, and rare fluorite. This study emphasizes the importance of (1) tectonic uplands as recharge areas for aquifers involved in cementation; (2) potential of inter-layered sandstones in carbonate sequences to act as permeable conduits for meteoric ground waters because they are less susceptible to calcite cementation than associated lime grainstones; and (3) documenting regional cathodoluminescent zonation of porosity-occluding shallow burial calcite cements in potential reservoir facies prior to hydrocarbon migration.

DOTSEY, PETE, Stephen F. Austin Univ., Nacogdoches, TX

A Petrologic Examination of Some Resedimented, Coarse-Grained, Clastic Intervals in Ouachita Mountains, Arkansas

Several resedimented, coarse-grained clastic intervals exist in the strata of the Ouachita Mountains. A petrologic examination of selected units in the basal Stanley Shale, the Arkansas Novaculite, and the Missouri Mountain Shale yields information pertaining to provenance, transportation, and deposition.

Twenty-five coarse-grained units sampled are categorized as massive sandstone, pebbly sandstone, clast-supported conglomerate, and matrix-supported conglomerate. Samples exhibit grading, imbrication, and stratification indicative of mass flow and fluidal flow-transport processes. Sedimentary rock fragments are the predominant clasts, with chert being the primary constituent. Other major constituents are detrital quartz, rip-up clasts, and shale fragments, of which the latter show signs of soft-sediment deformation. A metasedimentary source area is inferred. Paleoflow direction, estimated to be to the south and southwest, was ascertained by orientation of imbricated clasts and channel cuts.

A vertical sequence change from a matrix-supported conglomerate to a bimodal, clast-supported conglomerate, both of which exhibit channeling, to a massive sandstone occurs at one locality. This fining-upward sequence is due to a change in source area, which may be the result of tectonism and/or glacio-eustatic sea-level fluctuations.

DOUGLAS, ROBERT G., Univ. Southern California, Los Angeles, CA

Foraminifera as Paleobathymetric Indicators

Benthic foraminifera are one of the principal means of inter-

preting the bathymetry of ancient depositional environments. With the advent of geohistory methods that require quantitative paleodepth data, greater importance has been placed on benthic foraminifera as paleodepth indicators. The purpose of this symposium is to review some of the problems and prospects offered by our current state-of-knowledge.

Widely used foraminiferal paleodepth indicators include faunal trends (species abundance, species diversity, test composition, planktonic to benthic ratios) and species depth limit (e.g., UDL) based upon distributional studies of modern benthic microfaunas. The application of such ecologic approaches in the interpretation of fossil data relies on three assumptions that have received little attention: that modern distributional patterns are analogous to those of the past; that homeomorphs of modern taxa had similar ecological adaptation; and that the depth habitats of modern species were the same in the past. The first appears sound, but growing evidence suggests that the latter two require revision.

From the study of foraminiferal ecology it is clear that species distribution is unrelated to bathymetry per se but coincides with water-mass, sediment, and nutrient boundaries in the ocean. Because such boundaries vary within the oceans, few, if any, modern species are actually isobathyal (same upper depth limit) outside of limited regions. Paleobathymetric models calibrated in terms of modern species are probably less precise than originally presumed. During the Cenozoic, climatic fluctuations produced major changes in water-mass distribution, sediment patterns and oceanic productivity that, in turn, caused shifts in the depth distribution of many deep sea species. How bathyal assemblages in continental margins responded to these environmental changes remains an unanswered question in foraminiferal paleobathymetry. Also unclear is the paleobathymetry of fossil assemblages, for which there are no direct modern analogs such as the agglutinated assemblages found in Cretaceous and early Tertiary time.

Despite current problems, benthic foraminiferal paleobathymetric approaches are basically sound and as benthic faunal responses to climatic-oceanographic changes are better understood, benthic foraminifera will be even more useful indicators of environment.

DOWNES, JOHN W., Univ. Arkansas, Fayetteville, AR

Significance of Carbonate-Clastic Shoaling Cycles in Mississippian of Northern Arkansas

Shoaling-upward carbonate shelf cycles are known to occur in many parts of the world and throughout the geologic record. A typical shoaling carbonate cycle begins with deep-shelf, interbedded, lime mudstones and shale. These are succeeded by open-shelf bioclastic packstones and grainstones, and finally in many places by oolite, the latter representing the culmination of the shoaling process. Subsequent cycles repeat this basic pattern. When correlated across a shelf, the cycles are thought to represent the episodic progradation of a carbonate sand platform that built up to wave base, subsided, and built up again.

Upper Mississippian (Chesterian) strata in northern Arkansas consist of alternating limestones and shales that include a set of shoaling-upward cycles. These cycles, occurring within the dominantly carbonate Pitkin Formation, differ from the pattern described above in that they contain a significant terrigenous component. This material exists both as fissile black shale within lower-cycle lime mudstone, and as quartz sand admixed within upper-cycle oolite grainstones. This dual occurrence is thought to be related to movement of the shoreline that accompanied the repeated outbuilding of a carbonate platform. At the beginning

of a cycle, the shoreline was distinct from the deeply submerged shelf and lime and terrigenous mud accumulated in a quiet-water setting. Thickness and facies analysis of the Pitkin indicate an east-west trending shelf with a shoreline located in southern Missouri, perhaps curving south around the Ozark uplift. Eastward increase in shale percentage in the Pitkin suggests transport of fine clastics around the southeast flank of this uplift. The Illinois basin was an active Chesterian depocenter and during periods of maximum transgression fine clastics may have passed through a seaway southwest into northern Arkansas. As shoaling proceeded, the shoreline regressed south with the advancing carbonate sand sheet, cutting off the avenue of fine clastics. Quartz sand, probably derived from a thick sequence of lower Paleozoic sandstones exposed along the uplift by the retreating sea, became admixed with oolite across the newly built platform. These shoaling cycles are the product of slow, steady, subsidence along a northern Arkansas shelf punctuated by episodes of relatively rapid carbonate sand sedimentation and clastic influx. A similar tectonic and depositional setting must have given rise to other such deposits that occur in the geologic record.

DOYLE, L. J., Univ. South Florida, St. Petersburg, FL

Massive Siliciclastic Deposits Juxtaposed Against Massive Carbonate Bodies: Paradox of Eastern Gulf of Mexico

The eastern Gulf of Mexico is the location of a major and dramatic transition from siliciclastic to carbonate deposits and deposition. The massive lutites that make up the Mississippi Cone are juxtaposed against the equally massive carbonates intercalated with evaporites that make up the western portion of the Florida Platform. The region now occupied by the continental margin of the eastern Gulf has been cut off from clastic sedimentation since Late Jurassic or Early Cretaceous time, and over 5,000 m (16,404 ft) of predominantly carbonate sediments have built up.

Surficial sediments of the carbonate portion of the transition zone are called the West Florida Lime Mud Facies. A foraminifera-coccolith ooze is still being deposited in water depths as shallow as 200 m (656 ft); this facies covers over 40,000 km² (15,444 mi²) and in many respects resembles a deep-sea ooze. However, in some places shelf carbonate debris, including whole valves of mid-shelf oysters, have cascaded over the shelf-slope break and are incorporated into the slope ooze. Composition, rates of accumulation, and relatively shallow deposition suggest that this sedimentary body may be an analog of some of the chalk deposits of northwestern Europe.

It has long been considered axiomatic that planktonic foraminifera and coccolith oozes are deep-sea deposits that accumulate at rates of a few tens of millimeters per thousand years. However, radiocarbon dates show that the eastern Gulf margin ooze has accumulated rapidly. Prior to the last rise in sea level, deposition rates were as high as 65 cm/1,000 years (25 in./1,000 years); and ever since sea level began to rise sedimentation rates have still been as high as 20 cm/1,000 years (8 in./1,000 years). Such a rapid buildup of the carbonate sediments has led to widespread mass wasting and all forms, from creep to massive multiple slide deposits containing thousands of cubic kilometers of material, are represented in our set of high resolution seismic profiles.

The actual contact between carbonates and siliciclastics occurs in a variety of styles. Carbonate rubble is found in a terrigenous lutite matrix at the base of the West Florida Escarpment. Farther west on the Mississippi Cone the brown and yellow-brown siliceous lutites contain carbonate turbidites with provenance the West Florida slope. Another type of contact is shown in some piston cores with carbonate ooze in normal and alternating deposi-