

ic waters percolating basinward from Tensleep outcrop areas also had the effect of forming a "tar seal" in the oil-water transition zone; this seal effected a "frozen" oil-water contact, further preventing re-adjustment of paleoaccumulations into crestal positions in the Laramide closures.

Anticlines on which production has been established in the Phosphoria, Tensleep, and older Paleozoic reservoirs, exhibit a common oil-water contact datum for each of the producing formations. Extensive vertical fracturing, allowing commingling of reservoir fluids, is a possible mechanism which would allow oil originating in the Phosphoria to accumulate in underlying formations and account for the common oil-water contact conditions.

Subsurface data presently available indicate a loss of porosity with increased depth in the Tensleep Sandstone. It is suggested that possibilities for locating adequate porosity at greater depths will be enhanced by exploration in those areas favorable to the accumulation of oil in primary traps which have not been modified greatly by Laramide folding.

LEE, PEI-JEN, and WINDER, GORDON C., University of Western Ontario, London, Ontario

FABRIC OF A MIDDLE ORDOVICIAN LIMESTONE AT COLBORNE, ONTARIO

The limestone of the Middle Ordovician Cobourg Limestone at Colborne, Ontario, occurs, in decreasing order of occurrence, as sparse biomicrite, fossiliferous micrite, biosparite, micrite, and packed biomicrite.

Individual beds display a sequence composed of graded bedding at the base, overlain by a zone of lamination, and structureless micrite. This resembles the sequence in terrigenous turbidites of the Alps and other places. Most disarticulated brachiopod and ostracod shells are convex upward in biosparite and convex downward in biomicrite and fossiliferous micrite. The percentage of brachiopod shells increases toward the bottom of the quarry; a variation in the percentage across the quarry has been found. The percentages of echinoderm, bryozoan, and ostracod fragments have a high positive correlation with the quantity of quartz grains, whereas the percentages of brachiopod shells and trilobite fragments do not. Orientation patterns of elongate fossils show two dominant trends, northeast-southwest and northwest-southeast.

Sedimentation of the Cobourg Limestone was characterized by weak currents. Strong currents were introduced sporadically to form graded and non-graded biosparites, which are suggested tentatively as products of turbidity currents.

All relations between geological entities were calculated by computer.

LING, HSIN-YI, University of Washington, Department of Oceanography, Seattle, Washington

Patagium AND SOME SPUMELLARIAN (RADIOLARIA) GENERA

Patagium is a unique structure found in some spumellarian Radiolaria and has been considered to be a diagnostic criterion at the generic level in the generally accepted scheme of classification. A continuous variation in degree of preservation and (or) developmental stages of this structure from complete to absent has been found in genera such as *Hymeniastrum-Dictyastrum* and *Euchitonina-Rhoparastrum* from northeast Pacific Ocean bottom sediments. The study of a rich radiolarian fauna in core samples from Java,

Mindanao, and Mariana trenches reveals similar features and indicates that such a complete sequence of variation is neither a rare phenomenon nor biogeographically significant.

The taxonomic value of *Patagium*, therefore, needs critical reconsideration. The degree of development or preservation of *Patagium* found in a specimen seems to be unrelated to radiolarian ontogeny, although its real significance can not now be determined.

Fragments of the diatom *Ethmodiscus rex* (Wallich) Hendey also are found abundantly and consistently in the middle and lower parts of the Mindanao trench subsurface section, whereas only a few sporadic occurrences are found in the Java and Mariana trench samples.

LIPPS, JERE H., University of California, Los Angeles, California

PLANKTONIC FORAMINIFERAL ZONATION OF CALIFORNIA "MIOCENE"

Planktonic Foraminifera occur abundantly in most California "Miocene" strata, but have not been studied previously in detail. By using these planktonic forms, 11 zones are recognized and are related to the existing "Miocene" stages which are based on benthonic species. Correlation of these zones with the standard reference sections of tropical regions is complicated by paleoecologic factors, which probably include regional variation in water temperature between the tropics and California. Stratigraphically lower zones correspond more closely than do higher ones, indicating a general cooling of the California seas throughout middle Cenozoic time.

Species of *Globigerina* and *Eoglobigerina* are abundant in the California "Miocene," whereas species of *Turborotalia*, *Globoquadrina*, *Globigerinoides*, *Globorotaloides*, *Protentella*, and *Candorbulina* are less common but provide bases for tentative correlation with the tropical zones. The "lower Miocene" Zemorrian and Saucasian stages are correlated with the *Globigerina sellii* through *Turborotalia kugleri* zones (Oligocene to Aquitanian); the "middle Miocene" Relizian and Lusian stages correlate with the *Catapsydrax dissimilis* through *Turborotalia johsi* zones (Aquitanian to Burdigalian); and the "upper Miocene" Mohnian and Delmontian stages correlate with the *Globorotalia lobata* through *Sphaeroidimella seminula* zones (Burdigalian to Sarmatian).

LUNDIN, ROBERT F., Arizona State University, Tempe, Arizona

OSTRACODES AND SILURO-DEVONIAN BOUNDARY IN SOUTH-CENTRAL OKLAHOMA

Detailed studies of the morphology, ontogeny, variation, and stratigraphic distribution of the ostracodes in the Henryhouse (Silurian) and superjacent Haragan (Devonian) Shales indicate the presence of an unconformity at the Siluro-Devonian boundary in the Arbuckle Mountains of Oklahoma. The ostracodes indicate a late Niagaran (early Ludlovian) age for the Henryhouse Shale and Helderbergian age for the Haragan Shale.

The ostracode faunas of both stratigraphic units are large and diversified. The Henryhouse Shale contains 46 species representing 28 genera and 17 families. The Haragan ostracode fauna consists of 53 species, 27 genera, and 16 families. These taxa are distinctive and readily identifiable.

Biostratigraphic evidence for the unconformity be-

tween the Henryhouse and Haragan follows. (1) At the specific level the two faunas are completely distinct; no species are common to both units. (2) Of the 28 genera in the Henryhouse, 13 are restricted to it. Twelve of the 27 Haragan genera are not present in the Henryhouse. (3) The two faunas are nowhere known to occur together or interfinger with one another. (4) The faunal change is abrupt. There is no evidence for an intermediate (gradational) fauna between the two distinct faunas recognized.

The stratigraphic distribution of ostracodes within the Henryhouse and Haragan Shales indicates no definite biostratigraphic zonation within either unit. Each species which is significantly abundant ranges throughout, or almost throughout, the unit in which it occurs. The Henryhouse and Haragan Shales are distinct and discrete stratigraphic units, each having its own ostracode fauna.

Detailed sampling of the Henryhouse and Haragan formations has been carried out in all the outcrop areas of the Hunton Group, which consists of four formations, in descending order: Bois d'Arc Limestone, Haragan Shale, Henryhouse Shale, and Chimneyhill Limestone. The ostracode faunas obtained are distinctive and readily identifiable. Eleven ostracode species previously described as Haragan species are now known to have come from, and to be restricted to, the Henryhouse Shale. The ostracode faunas are distinct and discrete. Therefore, the Siluro-Devonian contact in south-central Oklahoma is unconformable.

McBRIDE, EARLE F., The University of Texas, Austin, Texas

TEXTURES AND STRUCTURES IN CATAHOULA (GUEYDAN) TUFF, SOUTH-CENTRAL TEXAS

The Catahoula Tuff of Oligocene to early Miocene(?) age is composed almost entirely of volcanic rock debris or its alteration products. Pastel-colored tuffaceous clay predominates, but sandstone, conglomerate, bentonite, vitric tuff, and ash also are present. The rocks studied in outcrop have a maximum thickness of approximately 900 feet, and were deposited largely on a coastal plain not far from shore. Bed geometry and sedimentary textures and structures provide evidence that the coarse clastic sediments and some tuffaceous clay beds were deposited as mudflows. One bed of air-fall ash has been recognized by its geopetal fabric: conical piles of glass dust rest on flat shards.

Vitric tuff and tuffaceous clay beds deposited as mud flows are characterized by massive (structureless) beds 1-4 feet thick, lack of sorting in beds that have particles ranging from fine ash to pebble-size tuff intraclasts, orientation of shards in random or swirl patterns, and desiccation polygons. One variety of tuff is characterized by moderate induration and the presence of tuff pisolites. The pisolites are generally 1-5 mm. in diameter and comprise as much as 30 per cent of a rock. Pisolites differ from their matrix by having different amounts or different sizes of shards and, in places, an opaque rind. A few pisolites grade imperceptibly into matrix of identical composition and texture where part of the rind is absent. The pisolites developed in tuffs by soil-forming processes, probably in an arid climate with seasonal rainfall. Many pisolites were reworked into successive mud flows.

Another variety of tuff is well indurated and pervaded by sinuous tubules (up to 2 mm. in diameter) probably formed by plant roots. The tubules trend in

all directions but are predominantly vertical. Tubules in some beds are filled with zeolite (heulandite group) or montmorillonite.

Stream-deposited tuff is recognized by faint horizontal laminations and cross-bedding and by moderate sorting and sub-parallel orientation of elongate shards and tuff intraclasts. This type of tuff is friable, non-pisolitic, and lacks tubules. Pores in many of these tuffs are now reduced in size or filled by clay skins of montmorillonite that coat framework grains.

Bentonite is free of crystal fragments, has no relic texture, and has a random orientation of montmorillonite particles. The lack of orientation of clay particles suggests that they crystallized during the *in situ* argillation of beds of glass dust rather than by sedimentation of clay particles in quiet water.

Clay dikes from 1 mm.-2 cm. wide trend vertically through tuff and sandstone at some localities. Montmorillonite grains are well-oriented parallel with the dike walls, suggesting particle-by-particle deposition from injected slurries.

McGUIRE, WILLIAM H., Lexington, Kentucky
EXPLORATION OBJECTIVES IN THE CAMBRO-ORDOVICIAN OF KENTUCKY

The Cambro-Ordovician of Kentucky is a new frontier for petroleum exploration. Dolomite, limestone, and sandstone reservoirs, both proved and potential, provide the oil-seeker with a large number of objectives ranging in age from Early Cambrian to Middle Ordovician and are present at drilling depths of 1,000-14,000 feet.

Dolomite reservoirs associated with the pre-Chattanooga unconformity have produced more than 150 million barrels of oil in Kentucky. Present activity, directed toward the testing of the Knox Dolomite, is a logical extension of exploratory effort downward to the next major unconformity.

The pre-Chazy unconformity in Kentucky was developed on dolomite beds of the Beekmantown. Traps below the unconformity are associated with pre-Chazy structures—faulting, erosional remnants, and truncated porous zones. Vuggy, intercrystalline, and fracture porosity zones occur throughout the Knox Dolomite section, and in many instances appear to be related to specific stratigraphic zones.

The predominantly clastic Conasauga-Rome section below the Knox Dolomite includes potential, but unproved, sandstone and carbonate reservoirs of wide geographic extent. Thickness variations and structural relief in the order of several thousands of feet, coupled with facies changes and known shows of oil and gas, provide the incentive for exploration.

The best guide to exploration will be the reconstruction of Cambro-Ordovician tectonic frameworks and depositional environments. Large structural surface features must be evaluated on the bases of age and structural history.

All types of exploratory techniques, from surface geology to geophysics, are applicable to the search for Cambro-Ordovician oil in Kentucky.

McINTYRE, ANDREW, and BÉ, ALLAN W. H.,
Lamont Geological Observatory, Palisades, New York

COCCOLITHOPHORIDS AS ECOLOGIC INDICATORS IN OCEANIC SEDIMENTS

The minute, calcitic, skeletal elements (coccoliths) of the Coccolithophoridae constitute 5-20 per cent or