eas where positive changes to the limits might be expected, and (4) obtain "directionality" from the forecast.

THOMPSON, JACK H., JR., U.S. Geol. Survey, Miami Beach, Fla.

Effects of an Offshore Drilling Mud on Selected Corals

Seven species of coral—*Dichocoenia stokesii, Montastrea annularis, Agaricia agaricites, Acropora cervicornis, Porites furcata, P. astreodes,* and *P. divercata*—were experimentally exposed to three concentrations of drilling mud obtained from an offshore oil well in the Gulf of Mexico. The whole mud, collected from the mud pit of a well at a drilling depth of 4,000 m, was diluted with seawater to produce concentrations of 100, 316, and 1,000 μL/L. Corals were exposed to each of the three concentrations and control seawater for 96 hours to observe behavioral response. Response to drilling-mud concentrations was measured as percent of polyps retracted. Some experiments were conducted in laboratory aquaria with Gulf Stream water, but the most significant experiments were conducted at Carysfort Reef, Florida Keys, using similar aquaria located in 3 m of water. Polyp behavior was determined with serial close-up photography which allowed counting of retracted, partially retracted, and nonretracted polyps in each colony.

All species except *Montastrea annularis* and *Agaricia agaricites* survived exposure to 1,000-μL/L mud during the period of testing. In two tests with *Acropora cervicornis,* one group survived exposure to the mud and the other died. All other corals except *Dichocoenia stokesii* and *Porites divercata* showed significant ($p<0.05$) polyp retraction during exposure to 100-μL/L mud concentration, whereas 316-μL/L mud was the minimum concentration which induced significant polyp retraction in *Porites divercata.* Polyps of *Dichocoenia stokesii* did not react to any of the three concentrations.

THOMPSON, K. F. M., Atlantic Richfield Co., Dallas, Tex.

Light Hydrocarbons of Petroleum; Internal Evidence of Thermal History

A diverse suite of 76 oils was analyzed for light C_4 to C_7 hydrocarbons (LHC). Indices of paraffinicity, termed the "heptane value" (HV) and "isoheptane value" (IV) were examined. These paraffin-to-naphthene concentration ratios had provided reliable measures of the catagenetic grade of sedimentary rocks, also a means of determining paleotemperatures, employing autochthonous LHC. The goal of the present study was an assessment of the conditions of generation of oil.

Heptane values in the sampled oils range from 0.5 to 60.9, but possess a near-normal distribution. The principal group (31 samples, 41%) is within the range 18.0 to 22.0. The modal class (HV 19.0 to 20.0) comprises 14%. The isoheptane value is similarly distributed about a modal class (18%) of 0.90 to 1.0. It is concluded that most oils retain evidence of generation in an extremely limited range of subsurface temperatures. The temperatures are of the order of 280 to 300°F (138 to 149°C), assessed from curves relating HV and IV to maximum-attained subsurface temperature for sediments bearing aliphatic, petroleum-source kerogens.

The oils of the principal group (HV 18.0 to 22.0) are termed "normal, paraffinic." Twenty percent of the analyzed oils are naphthenic (HV 0.0 to 18.0). Their compositions differ from those of low-temperature sediment extracts: they are identified as biodegraded, not immature, oils. Forty percent of the oils have an HV exceeding 22.0 (mature oils); some exceed 30.0 (supermature oils). Both classes have undergone protracted heating. The analytic methods and parameters provide a scheme of oil classification containing substantial geologic information. In addition, the plot of HV versus IV for sediment extracts provides clear distinction between aromatic, coaly kerogens and aliphatic, sapropelic kerogens.

THOMPSON, THOMAS L., Univ. Oklahoma, Norman, Okla.

Exploration Research Along Ardmore-Anadarko Basin Trend

Consideration of southern Oklahoma geologic history in the context of plate-tectonic analogies to present continental margins suggests several avenues of investigation that help explain some oil and gas accumulations and could lead to more discoveries. Postulated origin as the abandoned arm (aulacogen) of a rift triple junction in the late Precambrian and early Paleozoic suggests the potential for fault-controlled sedimentation and early generation of oil and gas by magmatic heating. Collision-related late Paleozoic deformation suggests displacement of early Paleozoic reservoirs by wrench faulting and the formation of traps by wrench-controlled thrust faulting. The search for fracture reservoirs involves facies relationships to the precollision continental margin, fracturing during collision, and prediction of open fractures based on stress orientation related to formation of the Gulf of Mexico. Position of the early Paleozoic continental margin with its unrealized potential for oil and gas accumulation remains an enigma concealed by late Paleozoic emplacement of the Ouachita thrust complex unknown distances over the edge of the early Paleozoic continental edge and subsequent burial by Mesozoic sediment during formation of the Gulf of Mexico.

THOMSEN, HARRY L., Consulting Geologist, Denver, Colo.

Oil and Gas Resource Appraisal—State of the Art

The art of appraising oil and gas resources has been maturing rapidly during the past few years. This welcome development has come about because of a growing awareness that petroleum resource estimates are required for the development of reasonable energy policies and long-range plans.

Published appraisals of oil and gas resources in the United States date back at least 70 years. Since that time many estimates have been made available to the public. In the 20-year period following 1955 the amounts resulting from these appraisals varied widely,

giving rise to much confusion and controversy. Attempts to compare these forecasts reveal that many of them were poorly documented and utilized different assumptions, definitions, methods, geographic boundaries, and data bases. During recent years increased effort has been directed toward resolving some of these major problems, and there is evidence that progress has been made.

Events triggered by the Arab-Israeli war of 1973 focused attention on the world's energy problems and on the inherent uncertainty of resource estimates. It is evident that many nations need forecasts of future petroleum supplies and that these should be based on reliable estimates of the distribution and magnitude of oil and gas resources throughout the world. This situation calls for a high level of domestic and international cooperation among resource appraisers. Communication lines need to be improved; how to accomplish this quickly and effectively is one of the major problems facing us today.

THORNHILL, RON R. D., Amoco Canada Petroleum Co. Ltd., Calgary, Alta.

Distribution of Clay in Recent Sands

Shallow cores and surface samples from a beach, point bar, and channel mouth near Pascagoula, Mississippi, were used to study clay distribution in sand-rich sediments. Air photos, permeability measurements, grain-size data, photomicrographs, and X-ray diffractograms provided the data base.

Data from clay-silt-sand separations show that, in general, the clay/silt ratio increases as the sand content increases. The clay/silt ratio increases from 0.12 to 5.92 in beach samples as the "percent sand" increases from 52.6 to 99.9, from 0.25 to 9.05 in point-bar samples as the "percent sand" increases from 48.5 to 98.8, and from 0.08 to 1.19 in channel-mouth samples as the "percent sand" increases from 59.9 to 97.8.

The highest clay/silt ratios are in subaerially exposed sediments with generally high vertical permeabilities. Clay/silt ratios in the berm crest of the beach increase to about 5 as permeability increases to about 5 darcys. Clay/silt ratios in the beach portion of the point bar increase to about 9 as the permeability increases to about 1.4 darcys.

Scanning electron microscope (SEM) photomicrographs show that the clay can occur as coatings on much larger grains and as composite grains (aggregates of clay, silt, and sand). Only one possible example of authigenic growth in the clay fraction was observed with the SEM.

It is concluded that clay may be deposited in sand-rich environments through the settling of large clay-coated grains, as composite clasts, and as floccules. In-situ percolation of clay suspensions and biogenic activity may add to the clay content of sediments.

TILLMAN, ROD W., Cities Service Oil Co., Research, Tulsa, Okla.

Sedimentology and Synergy of Deltaic Sandstone; Admire 650-Foot Sandstone, El Dorado Field, Kansas

The Permian Admire "650-ft" sandstone reservoir occurs at shallow depths (650 ft; 197 m), is thin (11 to 23 ft; 3 to 7 m), and has produced 48.7 million bbl of oil through primary and conventional secondary-recovery methods in the El Dorado field, Kansas. A micellar-polymer tertiary oil-recovery pilot project being conducted by Cities Service Oil Co. and DOE is aimed at recovering half of the 71.5 million bbl of oil still in the reservoir.

The 51-acre (20 ha.) block being tested for enhanced recovery at El Dorado field was initially assumed to be a generally homogeneous reservoir. A Phase 1 geologic analysis of seven slabbed and polished cores indicated the reservoir was, instead, heterogeneous and that it contained at least two vertically stacked layers with variable production characteristics. Considerable areal variability was also observed.

In Phase 2, a total of 24 cores was used to build a detailed geologic model. Various facies associated with a delta system were defined. Reservoir facies are distributary-channel sandstones, splay sandstones, and natural-levee deposits. Interdistributary-bay (in part intertidal), silty shales are present below, interbedded with and lateral to the sandstones. A classic subdelta model similar to that described by J. Coleman for West Bay in the Mississippi delta is demonstrated for the Admire. The deltaic model developed through geologic interpretation of cores allows prediction of the effectiveness of the tertiary oil recovery.

Pressure-transient analysis has been used to define sandstone trends further and to analyze directional properties of the reservoir. Interference tests yield directional pressure:transient ratios ranging up to 14 in areas of definite sandstone lineation. The high pressure:transient ratios result from strongly contrasting, mutually perpendicular transmissibility values. Many areas of strong, preferred transmissibilities are confined within geologic-facies boundaries.

TIPPIT, PHYLLIS, and EMILE A. PESSAGNO, JR., University of Texas-Dallas, Richardson, Tex.

Radiolaria from Oman Mountains

Much of the Oman Mountains was formed from allochthonous thrust sheets of the Semail Ophiolite and Hawasina Series, remnants of a basin which existed north and east of the Arabian shield during most of Mesozoic time. Cherts and siliceous mudstones collected from the various formations of the mountains range from Late Triassic to Late Cretaceous in age. A 1,445-ft (440 m) measured section was made of sediments of the Halfa Formation, the most distal facies in the Hawasina Series. The lowest part of the section is no older than Middle Jurassic (Callovian), on the basis of presence of *Archaeospongoprunum* sp., and the highest well-preserved sample is Early Cretaceous (Valanginian) in age, on the basis of the presence of *Cecrops septemporatus*. Although Radiolaria are abundant throughout the section, preservation is strongly related to the color of the cherts and mudstones in which they are found—the green cherts and mudstones showing very poor preservation whereas the red show fair to excellent preservation. Halfa samples at other localities yielded Radiola-