decreases northward from the mountain front. Twenty anticlines have been tested, and favorable reservoirs in the Cretaceous seem to be limited to narrow nearshore facies.

Pre-geosynclinal rocks are at drillable depths near the edge of the Brooks Range and on the basement rise. Folding and overthrusting make the Mississippian to Triassic rocks along the mountains difficult to evaluate without intensive subsurface exploration. In the north, geophysical data suggest that the basement rise trends southeast from Barrow and may even be an arch with northward regional dips offshore. Recent private exploration resulted in test wells on two presumably separate structures along the trend of the rise. Reservoir rocks between the Upper Triassic and basement were penetrated by the Colville well, and produce oil and gas in the wells at Prudhoe Bay. These Triassic terrigenous clastic and Mississippian carbonate rocks are part of a sequence of deposits that seem to transgress regionally northward across an unconformity and regress southward away from the source. Additional reservoirs on the rise may be present if Devonian(?) carbonate rocks, that discordantly underlie the Mississippian at the front of the northeastern Brooks Range, are preserved below the unconformity.

Transportation facilities necessary for the development of large petroleum resources in northern Alaska will make the development of the extensive coal deposits there more likely and will improve the potential of known phosphate and rich but limited oil-shale deposits.

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Recognition of Alluvial-Fan Environments in Stratigraphic Record

Alluvial fans are orogenic deposits whose geometry is influenced by the rate and duration of uplift of the adjacent mountains and by climatic changes.

Three longitudinal shapes are common. A fan may be a wedge that is thickest (or thinnest) near the mountains, or it may be lenticular.

An alluvial fan may consist of water-laid sediments, debris-flow deposits, or both. Water-laid sediments occur as channel, sheetflood, or sieve deposits. Main stream channels commonly are backfilled with coarse-grained sediments. Sheets of finer grained sediments are deposited downslope from the channel. The fine-grained sediments may be cross-bedded, massive, or thin bedded; the coarse-grained sediments may be imbricated, massive, or thick bedded. Sieve deposits consist of intertonguing lobes of very permeable gravel.

Debris flows are poorly sorted and may have graded bedding or preferred particle orientation. Boulders weighing many tons may be present in an unsorted matrix. Mudflows are fine-grained debris flows. Platy fragments are oriented parallel with the bedding in low-viscosity flows. In high-viscosity flows, fragments are oriented vertically, and normal to the direction of flow.

Individual beds may be traced for long distances along radial sections, and channel deposits are scarce. Cross-fan sections reveal beds of limited extent that are interrupted by cut-and-fill structures, which are most common near the fan apex.

Logarithmic plots of the coarsest 1-percentile and median-particle size make patterns which are distinctive of fan environments. Sinuous patterns indicate tractive-current environments. Rectilinear patterns indicate mudflow environments.

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Deep-Water Drilling—Sigsbee Salt Diapirs

(No abstract submitted)

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Foraminiferal Densities and Environmental Variables: Use of Statistical Models to Examine Estuarine Environment

Many environmental variables have been suggested to explain species distributions. However, species distributions generally cannot be evaluated statistically because of inadequate sampling procedures. The purpose of the present study is to outline a method of analysis using statistical models.

A pilot study in the Choptank River, Maryland, indicated that *Elphidium clavatum* density decreases progressively upstream, whereas *Ammobaculites exiguus* and *Ammonia beccarii* densities change very little. From this pilot study, three stations were selected for detailed analysis.

Four foraminiferal samples were taken monthly at each station for a year. Temperature, salinity, oxygen, and chlorophyll *a*, *b*, and *c* were measured each month at every station. A general multiple regression-analysis of variance model was constructed containing 21 parameters for environmental variables, station differences, overall periodic differences, and interaction of station and periodic differences. This model was compared with several containing fewer parameters. Restricted models containing 15 parameters sufficiently accounted for observed species densities in each example.

The set of environmental variables is significant at the 95% level for all species, but none is significant individually. However, relatively large values of regression coefficients for chlorophylls, especially *b*, suggest that food (amount and kind) is important in determining species densities. Each species exhibits periodicity, and for each, periodicity differs at the three stations.

Results indicate that the use of statistical models permits greater understanding of relations between foraminiferal species and environments. Such understanding will be of great value in paleoecology.

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Delineation of some Outer Deltaic Plain Subenvironments Based on Sedimentary Properties in Vertical Section

A small wedge of detrital sedimentary rocks (deposits of the outer part of a deltaic plain) was investigated to delineate subenvironments. The rock unit (Middle Pennsylvanian age) is as thick as 40 ft and occupies an area of about 300 sq mi in western Pennsylvania, where intense strip mining provides excellent continuity of outcrop. Criteria for defining rock subfacies are vertical sequences of bed-thickness properties of sandstone and siltstone, together with minor sedimentary structures and fossil content—in brief, those properties observable in smaller exposures or subsurface records.

Lateral relations of the vertically defined rock subfacies, exposed in continuous cut faces, delineate five distinct lithologic facies. The composite properties of these facies imply deposition in subenvironments associated with an outer, predominantly subaqueous deltaic plain—distributary-channel, distributary-mouth-bar, crevasse, reworked and probably drifted bar-sand, and open-bay subenvironments.

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TRACE FOSSILS, BASIN MIGRATION, SEDIMENTATION, AND BATHYMETRY OF OUACHITA GEOSYNCLINE OF OKLAHOMA

Flysch-type *Nereites* trace-fossil associations, paleocurrent data, and relatively numerous, thick sandstone beds with fluted soles, graded tops, contorted and convolute lamination, and ripple-drift indicate a continuous deep-water (bathyal-abyssal) axis for the Ouachita geosyncline during the deposition of the Stanley Group, Jackfork Group, Johns Valley Shale, and Atoka Formation of Oklahoma.

Eventual migration of the basin onto the shelf is suggested by the west, northwest, and north overlap of the Atoka Formation on the Johns Valley Shale, Springer Formation, Chickachoc Chert, and Wapanucka Limestone, and by a transitional, shoal- to deep-water facies developed over the Chickachoc Chert and Wapanucka Limestone in the Atoka Formation.

The transitional facies consists of a thick shale which is thought, on the basis of modern analogues, to have been deposited on a slope. Thin sandstone beds are present in this shale and are more numerous upward in the section. The sandstone beds are characterized by a trace-fossil association similar to a trace-fossil association in the basin axis, and by tooled soles, contorted lamination, ripples, and little grading. Downslope, the transitional facies grades into the axial facies in which thick-bedded, axial-type sandstone becomes dominant.

North of the Ouachita Mountains in the Arkoma basin, the top of the Atoka Formation is preserved. Physical-sedimentary structures and molasse-type *Cruziana* trace-fossil associations indicate shoal and near-shoal conditions. Toward the base of the section, there is no evidence for intermediate or deep-water facies. The older transition and deep-water facies are concealed in the thick Atoka section of the Arkoma basin or are farther south, beneath the Choctaw thrust which borders the west, northwest, and north margins of the Ouachita Mountains.

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STRUCTURAL AND TEXTURAL DESCRIPTIONS OF MARINE SEDIMENTS

It is commonly difficult to make accurate structural and textural descriptions of marine sediments because of the plasticity of the material and the significant but subtle property differences. Several methods, however, can be applied.

X-ray radiography, both stereo and normal, allows the nondestructive examination of the sample. Structures may be mapped and anomalous features identified before other tests are carried out.

Electric-logging procedures, both in the laboratory and "at sea," are used to correlate cores and relate sample sites. Spontaneous potential, resistivity, and other logging techniques also can be used.

Cholesteric liquid crystals are applied to the investigation of fine structural and textural changes. The ability of these solutions to delineate thermal conductivity differences is used to map structural, textural, and lithological differences. By changes in color in response to minor temperature changes, thermal resolution of 20 line pairs per millimeter is achieved.

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SAN ANDRES (PERMIAN) FACIES AND DIAGENESIS IN REEVES FIELD, YOAKUM COUNTY, TEXAS

The Reeves zone is about 500 ft below the top of the Permian San Andres Formation and includes low-energy and high-energy facies in repeated cycles. Lithologic types represented are (1) carbonate mudstone, (2) wackestone, (3) packstone, and (4) oölitic grainstone. Two types of cycles recognized are (1) shelf-edge cycles which culminate in well-developed oölites, and (2) back-shelf cycles which culminate with stromatolitic mudstone.

Three major diagenetic processes that altered the Reeves field carbonate rocks are (1) leaching, (2) dolomitization, and (3) gypsum precipitation—but not necessarily in this order. The grain-supported rocks contained approximately 25% depositional porosity, most of which was infilled by anhydrite; 80% of the perforations are in mudstone-supported facies which, according to core analyses, are permeable and porous. Postdepositional processes have reversed the depositional porosity pattern.

Reeves is a typical Permian basin San Andres field. It was discovered in 1957 and has reserves estimated at 20 million bbl.

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COMPARISON OF STRATIGRAPHIC AND MICROSCOPIC EVIDENCE FOR ORIGIN OF VIRGINIA "TERRACE" SEDIMENTS

Post-Miocene stratigraphic units on the coastal plain of southeastern Virginia consist of nearshore marine, beach, backbarrier, and fluvial facies. Electron-microscope studies of surface features on quartz grains from these stratigraphic units suggest origins which correlate closely with information obtained independently from stratigraphic studies.

Superposed surface features were used to establish the depositional history of sand grains affected by more than one environment. Relative ages of stratigraphic units were determined from degree of surface etching on quartz grains. The presence of surface features characteristic of glacial action has been used to differentiate Pleistocene from pre-Pleistocene stratigraphic units. The contact between beach and dune sand, as determined by electron microscopy, has been used, together with independent stratigraphic data, to determine the maximum elevations of Pleistocene sea levels associated with the stratigraphic units and morphologic features on the Virginia coastal plain.

This study shows a close correspondence between inferences based on electron-microscope studies of quartz-grain surface textures and independent data obtained from field studies of morphology and stratigraphic relations. The correlation suggests that electron-microscope studies may be useful in interpreting