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 older sediments where morphology and sedimentary structures are less well preserved, and where the effects of weathering are more severe.

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PALEOCURRENT PATTERNS ALONG CONTINENTAL MARGIN OF CENTRAL CALIFORNIA DURING CRETACEOUS TIME

Cretaceous turbidites exhibiting numerous paleocurrent features crop out across a 300 sq mi area long the northeastern flank of the Diablo Range in central-western California. More than 400 pieces of data on sole marks, sandstone and conglomerate grain fabrics, carbonaceous fragment orientation, and parting lineation were used to deduce the trend and sense of the ancient turbidity currents which deposited the beds.

In the northern part of the area the sense of current movement was from northwest to southeast (same as Ojakangas farther north in the Sacramento Valley), though some data indicate an opposite sense of movement. In the central part of the area the sense of movement was northeast-southwest and southeast-northwest. In the southern part of the area the sense of current movement was northwest-southeast and northeast-southwest.

Possible source areas include an ancient craton on the east and an offshore island arc, such as that visualized by Kay, or possibly Klamath Island, Mohavia, and Salinia as visualized by Reed. Coalescing submarine fans with apexes pointing north, east, and southeast toward an ancient craton seem to fit best the observed paleocurrent pattern. The paleocurrent data provide no evidence for a Cretaceous source area, such as Salinia or an island arc, west or southwest of present-day central-western California.

The sequence of beds studied is more than 20,000 ft thick, and ranges in age from Aptian to Maestrichtian; older strata may be present. Current trends show little variation with stratigraphic position.

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GEOLOGY OF VENTURA BASIN, CALIFORNIA, AS AN APPROACH TO EXPLORATION OF CONTINENTAL MARGIN

Although present water depths locally exceed 6,000 ft, the tectonic and stratigraphic history of the southern California continental margin is related more closely to that of the mainland than to the oceanic basin. The exploratory approach presently used in the Ventura basin can be expected to be a model for exploration of the rest of the offshore borderland. Such an approach was used to prepare for the 1968 Federal offshore lease sale. A totally integrated exploration program was required, and included stratigraphic tests, modern geophysical surveys for purposes other than, but including structural mapping, paleontologic studies, onshore surface-geologic mapping, and ocean-floor geologic mapping and sampling by divers and diving submersibles.

The Ventura basin, two thirds of which is offshore, is an east-west-trending synclinal trough containing 40,000–50,000 ft of principally Tertiary marine clastic rocks. Structurally, it is characterized by major east-west thrust faults and tightly folded anticlinal trends. Although anticlinal accumulations provide the largest part of the Ventura basin petroleum, significant reserves occur in a wide variety of traps, including stratigraphic, fault, unconformity, and combination traps. Pliocene turbidite sandstone is the principal reservoir in the eastern part of the basin, and has yielded approximately 1 billion bbl of oil from onshore fields. Miocene, Oligocene, and Eocene marine to nonmarine clastic rocks are objectives on the west.

On February 6, 1968, industry bid a record $1.3 billion and spent $603 million for 383,341 acres; 50% of the acreage is in water deeper than 600 ft. Deep-water drilling technology is advancing rapidly as evaluation is underway.

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DELTAIC ENVIRONMENTS

Deltas are zones of interaction between fluvial and marine processes, and their deposits are transitional between terrestrial-alluvial and open-marine sediments. Initial inspection of a deltaic sedimentary wedge suggests the presence of a hopelessly complex interfingering sequence of beds; however, closer examination reveals an orderly arrangement of environmentally determined facies. In vertical sequence predictable progradational and transgressive sequences can be recognized and related to cyclic growth and deterioration of the delta system. Areal distribution of facies can be related best to three major components of the delta: the upper deltaic plain, lower deltaic plain, and subaqueous delta. Marginal deltaic basins and marginal deltaic plains also may be developed as "appendices" to the delta. Within this gross framework distinctive facies assemblages are recognizable, reflecting different environmental conditions in both modern and ancient deltas; *i.e.*, the assemblage of environments and resulting lithofacies and biofacies within any major component is different in each delta and depends on such factors as climate, tectonic activity, nature and quantity of transported load, tidal influence, sea-state conditions, *etc.* With this working concept it is no longer essential to search for modern analogs to each deltaic sequence found in ancient rocks, but rather a flexible delta model may be developed which will accommodate all variations in nature and intensity of processes acting on the delta. Utilizing such a process-form model, examples of modern deltaic facies and ancient rock counterparts can be analyzed.

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PETROLEUM PROSPECTS OF AUSTRALIAN CONTINENTAL SHELF

The presence of several large areas of thick sediments has been established on the Australian continental shelf by aeromagnetic surveys and reconnaissance seismic surveys. The more significant areas are seaward extensions of onshore sedimentary basins, but they include large thicknesses of Tertiary and Mesozoic sediments. These areas—the Gippsland, Bass, and Otway basins between Victoria and Tasmania, the Perth, Carnarvon, and Canning basins off Western Australia, the Bonaparte Gulf basin off Western Australia and Northern Territory, the Papuan basin in the Gulf of Papua, and the Sydney basin off New South Wales—include an area of about 250,000 sq mi and a sediment volume of more than 650,000 cu mi.