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.

Drilling has begun only in the Papuan, Gippsland, Bass, Otway, Carnarvon, and Canning basins but the few wells that have been drilled confirm the prospects and have resulted in commercial discoveries of oil and gas in Cretaceous and Jurassic rocks at Barrow Island, oil and gas in Eocene and Cretaceous rocks in Gippsland basin, and gas in Miocene rocks in Papuan basin.

Many large anticlinal, reef, and delta-form structures are known but have not been tested. In addition, large areas have not been surveyed geophysically. Wells drilled offshore have not penetrated rocks older than Triassic. Therefore, the sedimentary areas of the Australian continental shelf must be regarded as good prospects for oil and gas.

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PATTERNS OF PERMO-TRIASSIC SEDIMENTATION, SOUTHEASTERN AUSTRALIA

Fluvial, deltaic, and marine-shelf sediments were deposited in a 100 × 200 mi, north-south-oriented trough centered around Sydney where as much as 18,000 ft of strata accumulated during the Permo-Triassic. The trough is between and was filled by debris from two major blocks of older, deformed Paleozoic rocks. The northern block consists mainly of radiolarian chert, volcanic graywacke, and mudstone, intermediate-composition volcanics, and Permian granite. The southern and western block consists mainly of quartzose sediments, silicic volcanic rocks, quartzite, granite, and Permian basaltic rocks. Short transport distances and relatively slight reworking of these diverse rock types within the basin of deposition yielded a petrographically complex sequence but one in which contributions from southern, western, and northern sources can be distinguished readily.

Lower Permian sediments apparently were derived mainly from the southern and western blocks and, except for small deltas in the nearshore area, were principally marine-shelf deposits having an abundant fauna of thick-shelled pelecypods, brachiopods, and bryozoans. Most of the marine sandstone and siltsone deposits contain a very large proportion of lithic fragments but some, apparently representing subaqueous bars, are mainly quartzose. During the Middle Permian the sequence was covered by a rapidly prograding sedimentary sequence derived from the northern block, which until Middle Triassic time provided most of the sediments to the trough. The principal sediment complexes derived from this northern system were two fluviatile wedges. One wedge each was deposited on either side of a basement high, and the two wedges coalesced southward into a deltaic plain facing a shallow sea. Close borehole control within the fluvial system establishes the presence of channel-bar sandstone beds 50–200 ft thick. These grade laterally into levee and lacustrine siltstone and back-swamp coal beds. The alluvial deposits grade seaward into delta-plain deposits consisting of distributary-mouth bar sandstone beds 30–50 ft thick which interfinger laterally with interdistributary "bay fills." "Bay fill" sequences generally grade from fine- to coarse-grained upward and commonly are overlain by intensely burrowed sandstone or "root-clay" and coal beds. Delta-front sandstone flanks the delta-plain deposits and merges with mottled gray siltstone of the open shelf.

Several episodes of delta outbuilding separated by periods of marine transgression can be delineated. The last, most widespread progradation was followed in early Middle Triassic time by an equally extensive marine transgression. Fluvio-deltaic deposits which formed during this latest episode lack coal, and the sedimentary sequence is dominated by an orthoquartzitic barrier bar-tidal delta system, locally 1,000 ft thick, which grades laterally into marine red claystone and gray tidal-flat siltstone and fine-grained sandstone. The mineral composition of the latter sediments shows an increasing quantity of basaltic detritus from the south and a concurrent reduction of sediment influx from the north.

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COMPACTION EFFECTS IN OÖLITIC GRAINSTONE

A survey of the packing density in oölitic grainstone from surface and subsurface samples shows compaction ranging from zero in unburied Pleistocene Bahamian oölite to nearly 90% for parts of the Late Jurassic Smackover Formation at a depth of about 10,000 ft in the Haynesville field, northern Louisiana. Mississippian oölitic grainstone which crops out has been compacted as much as 59% in the Greenbrier Formation of West Virginia, contrasted with only 10% in the Ste. Genevieve (Levias Member) of Indiana. Commonly, Smackover thin sections show amounts of compaction between 50 and 70%.

Grain fracturing, cementation of broken grains, stylolitization, partial dolomitization, and authigenic quartz formation can be related to the degree of compaction in favorable circumstances. Noteworthy is the observation that authigenic quartz apparently formed after as much as 60% compaction had taken place in Smackover oölite. In addition, final calcite cementation apparently occurred in a Smackover sample after grain compaction of 61% and fracturing, an example of very late cementation.

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IDENTIFICATION AND INTERPRETATION OF UPPER CRETACEOUS FLUVIAL AND DELTAIC SANDSTONES

Well-developed fluviatile and deltaic characteristics are present in the Upper Cretaceous Ferron Sandstone Member of the Mancos Shale in east-central Utah. Detailed stratigraphic relations and sedimentary structures not only provide criteria for paleoenvironment identification, but also form the basis for semiquantitative estimation of paleogeographic parameters.

The fluviatile facies consists of 100–700 ft of alternating sandstone, shale, and coal in units of inconstant lateral continuity and thickness. The fine- to medium-grained sandstone beds are in distinct channels or more laterally continuous sheets as thick as 60 ft. The sandstone beds have sharp bases, fining-upward sequences, dominantly trough cross-lamination, and large-scale, point-bar-migration cross-beds. A generally northerly transport direction is shown by decreasing unit thicknesses, decreasing grain size, and by current-oriented sedimentary structures.

The deltaic facies is mainly an inclined series, 20–40 ft thick, of delta-front sheet-sandstone beds that thin and become finer grained down the 5–10° depositional foreslope. Beds in the sequence are thin,