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, consist of alternating very fine- to medium-grained sandstone, and are characterized by even, parallel laminae.

Detailed analysis of Ferron fluvial sandstone, following relations developed by Schumm, Simons, and others, provides reasonable paleogeographic estimates. Large rivers carried mixed sediment loads under lower flow-regime conditions in meandering channels of intermediate sinuosity northward to a deltaic plain, debouching into a shallow embayment in the Late Cretaceous coast. For selected channel sandstones, ranges can be specified for channel depth, current velocity, rate of discharge, channel sinuosity, and other flow parameters.

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Geology of San Andres (Permian) Reservoir of Part of Wasson Field, Gaines and Yoakum Counties, Texas

The Wasson San Andres Field is in Gaines and Yoakum Counties, Texas, on the southeastern edge of the North Basin platform. It was discovered in 1936 and, after producing 394 MM bbl of oil, was unitized in November 1964 into seven waterflood projects. The Denver Unit, which is about 45% of the field area, is the subject of the writer's study. The results are based on examination of more than 4,000 ft of slabbed core from 17 wells, supplemented by detailed log correlation.

The Wasson accumulation is controlled structurally by a NW-SE-trending pre-Permian structural axis and by the buried Wichita-Albany shelf margin. An additional control is imposed by a porosity decrease toward the northwest.

The sediments composing the San Andres reservoir were deposited in a far backshelf, restricted, marine environment. The sedimentary sequence was deposited during a regression, and the entire reservoir interval has been dolomitized completely. Porosity is developed most favorably in the restricted marine facies, but also is present in the intertidal facies. The reservoir is capped by a nonporous supratidal facies. Permeable porosity in the marine facies is developed primarily in particulate, generally unsorted, sediments. Destruction of porosity by secondary anhydrite is common. Individual porous beds are very thin and discontinuous, but generally appear to be better developed near the axes of buried structural features.

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Classification of Sedimentary Environments[1]

Geologic literature contains material from which a variety of working classifications of sedimentary environments may be constructed according to the geologist's need. The range of approaches to environmental classification is evident in the use of terms derived from places of deposition, processes and media of deposition, and materials deposited. Much of the diversity has a basis in practicality and is partly retained in the present classification. In this classification nonmarine, transitional, and marine categories of environments are divided into classes of environments; the further division into subenvironments is limited largely to areas of published recent investigations. Although the classification is incomplete and lags behind unpublished knowledge, it may provide a frame of reference for discussions of specific environments.

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Stages in Fracture-Porosity Development

Prediction of fracture development in fractured reservoirs is made difficult by the wide range of geologic conditions which may lead to development of fracture porosity and permeability. The choice of fracture characteristics that can be employed in a study of the fracturing process also is wide; reliance commonly has been placed on geometrical properties such as fracture orientation. Various other characteristics, including surface features, fracture termini, and fracture spacing, also are pertinent. Use of these features is facilitated by dividing the very broad process of fracturing into several separate but related stages: (1) initiation of fractures, (2) propagation of fractures, (3) development of fracture sets and systems, (4) intensification of fracture spacing, and (5) dilatation of fractures.

Effects to be anticipated in the first stage of this process are illustrated by laboratory deformation experiments at elevated pressures. Using a silica-cemented sandstone as test material, the writer noted that incipient fractures may occur within grains or at grain margins. Experiments suggest the possibility that cataclastic deformation contributes significantly to the failure mode at high confining pressure, even in rocks that are considered to be incompetent and ductile.

Development of an open fracture network that is sufficient to provide reservoir porosity and permeability depends on geologic conditions during later stages—specifically, the conditions between the time of fracture propagation and fracture dilatation. However, an understanding of these final events requires prior understanding of the initial stages in fracture development.

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Distribution of Hydrocarbons in Three Dimensions

The areal distributions of hydrocarbons and other components of rock bodies have been mapped in an attempt to relate their distributions to economic concentrations of hydrocarbons and other components. These components are dispersed three-dimensionally; their vertical distribution may be as important as (or more important than) their areal concentration. Distribution patterns in three dimensions are difficult to portray; this has handicapped efforts to relate the distribution patterns to economic drilling objectives.

Response surface analysis provides a rapid method of displaying three-dimensional relations within rock bodies. The variable of interest—for example, percent organic carbon—is regressed upon a linear combination of the three geographic axes. The resulting linear equation is a least-squares expression of the relation between the dependent variable and the spatial coordinates. In practice, a polynomial expansion of the linear equation commonly is used to provide a better representation of the data. Other linear equations may be more appropriate in specific cases; trigonometric functions, for example, may be introduced to simulate the effect of bedding.

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[1] Publication authorized by the Director, U.S. Geol. Survey.