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.

Measurements of organic carbon from the Lower Cretaceous Mowry Shale in Wyoming provide an illustration of the effects that can be obtained using different linear models in the regression. Relations between the distribution patterns and location of Lower Cretaceous hydrocarbon fields in this region can be shown graphically on the models.

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Exploration and Production Results of Offshore Extension of Mexican Cretaceous Golden Lane

The Cretaceous Golden Lane reef fields are in northeastern Veracruz state, east-central Mexico. They partly underlie the coastal plain and partly the adjacent submerged continental shelf of the Gulf of Mexico. This paper is concerned mainly with the offshore fields and, more specifically, with a 45-mi-long belt of the Golden Lane reef south of Arrecife Medio field.

For many years several geologists postulated that the spectacular Golden Lane fields are only one segment of an atoll whose eastern part is beneath the continental shelf of the Gulf of Mexico. This working hypothesis led to an extensive and detailed seismic exploration program which, complemented and integrated with the discovery of the fields herein described, confirmed the presence of the postulated atoll. In essence, the atoll is a Middle to Late Cretaceous feature with a maximum north-south diameter of about 85 mi and a minimum east-west diameter of about 40 mi.

The earliest seismic survey was begun in 1957, and the first discovery, Isla de Lobos No. 1-B, was completed on June 28, 1963. Several discoveries have been made since Isla de Lobos; all are on topographic and/or structural highs of middle Cretaceous reef or reef-associated limestone, which generally is overlain unconformably by strata that range in age from Late Cretaceous to Oligocene.

The various offshore fields are discussed from north to south. The Arrecife Medio field, drilled from August 1963 to November 1966, has 3 producers and 5 dry holes. Approximately 1,450 b/d of oil and 444 Mcf/d of gas are produced from the field. Isla de Lobos field—the first offshore discovery—drilled from May 1963 to July 1964, has eight producers. Approximately 7,300 b/d of oil and 1,200 Mcf/d of gas are produced. Tiburón field has been drilled since July 1964, and has 5 producers, 2 dry holes, and 1 well abandoned because of mechanical difficulties. Approximately 2,635 b/d of oil and about 470 Mcf/d of gas are produced. Atún field was discovered in 1967 and is being developed. Of the completed wells, 2 produce only gas, 2 produce oil and gas, and 1 was plugged because it reached the reef below the oil-water contact. This field presently can produce 6,856 b/d of oil and approximately 5,100 Mcf/d of gas.

The following wells are considered as discoveries of fields similar to some of those described. Esturión No. 1 produces 623 b/d of oil and 188 Mcf/d of gas; Bagre No. 1-A produces 950 b/d of oil and 614 Mcf/d of gas; Pez Vela No. 1 found a gas reservoir whose potential was not determined.

The following discoveries were considered noncommercial. Robalo No. 1 produced approximately 180 b/d of oil and 46 Mcf/d of gas; and Tintorera No. 1 produced approximately 55 b/d of oil and an insignificant amount of gas. Three wells found salt water, probably because of a low structural and/or paleotopographical position. These are Pulpo Nos. 1-A and 2 and Pargo 1.

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Regional Distribution of Late Jurassic Depositional Wedge, Upper Gulf Coastal Plain of Northeast Mexico and Southern United States

The writer reviews and compares Jurassic stratigraphy and sedimentation within the various Jurassic sedimentation provinces of northeast Mexico and the southern United States. Many of these provinces are being explored actively. Of great importance is the presence or absence of adequate reservoir rock, particularly within the Late Jurassic Smackover-Zuloaga equivalents. Before active exploration can begin, regional studies must be made to determine where porous facies are most likely to be present. Stratigraphic dip sections of the Jurassic section must be made, and the various units correlated. Dip sections cannot be made at random but must be located strategically. Lithofacies maps must be made to show in detail the lateral lithologic changes in the various units. Several producing fields in Texas, Arkansas, and Mississippi are good examples of the types of producing structures which may be expected. Economics and reservoir characteristics of the producing fields must be understood thoroughly before a particular structure or other type of trap is drillled. The understanding of economics and reservoir characteristics can be gained through detailed study of existing Jurassic fields.

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Comparison of Modern Island and Mainland Supratidal-Flat Carbonate Deposits, British Honduras

The usefulness of supratidal-flat sediments in paleogeographic reconstructions is decreased by the difficulty in distinguishing between island and mainland deposits. Holocene carbonate sediments in British Honduras form supratidal-flat deposits on shelf-margin islands and on the mainland. The vertical sequence and sedimentary structures of deposits in both areas are similar, reflecting similar modes of formation and physical settings, respectively.

Constituent compositions and the nature of nearby deposits differentiate these island and mainland supratidal carbonates. Shelf-margin islands are associated with backreef coralgal sand; fragments of corals and coralline algae are included in some island deposits. Mainland deposits lack these indicators of a shelf-edge environment but contain brackish-water organisms and terrigenous material, such as quartz and clay minerals. Furthermore early diagenetic dolomite occurs only in island sediments. These distinguishing compositional differences, though diagnostic for northern British Honduras, are not absolute. Rather, they illustrate types of characteristics which may be useful environmental indicators in other areas.

In the absence of compositional differences, lateral facies relations may distinguish island and mainland deposits if sufficient stratigraphic control is available. An island interpretation is favored where submarine shelf-lagoon deposits occur between discontinuous supratidal deposits which are separated by several miles,