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.