

Petroleum Exploration and Wrenching Model, Michigan Basin

The writer has previously proposed a wrenching model for the Michigan basin based on the close relation of lineaments gleaned from Landsat imagery to the geometry of shear faults and related shear folds anticipated in such a model.

Recent studies by colleagues have been focused on old linear oil producing structures where (1) the density of wells permits structure maps drawn on a small contour interval, and (2) sufficient well samples allow the construction of dolomite-limestone ratio maps. Geometry of dolomite distribution patterns in Middle Devonian carbonate rocks shows close comparisons to pay zone distribution coincident with shear faults and related shear folds, cross faults, and cross folds—all related to the wrenching model. Producing well patterns follow dolomite distribution patterns. Lateral displacement can often be detected along shear faults on structure maps. Some faults not detectable on the structure map are shown on the dolomite-limestone ratio map. The application of the wrenching model to future exploration for linear producing fields in the basin appears self evident; strike-slip faults in nearly horizontal rocks are elusive seismic targets. The shear faults generally show little vertical movement. Not all shear faults developed shear folds, as in the giant Albion-Scipio field (Ordovician).

Evidence suggests that movement along shear faults was episodic, with the axes of related shear folds showing some migration downward. Further testing of the shearing mechanics in this regard may assist in exploration for deeper targets.

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Shale—an Overview

Shale and mud form at least 60% of the world's sediments, have been deposited throughout geologic history, and occur in every major depositional basin. They are major source beds for hydrocarbons, hosts for metallic minerals, sources of ceramic materials, cause of unstable foundation conditions, and precursors of soils that produce our food. Yet the study of shales has lagged far behind that of other sedimentary rocks. Factors that have retarded the study of shales are: (1) we are presently unable to isolate, study, and deduce the histories of the single particles that form shales. Consequently we have had to rely on bulk properties which are based on the average of many particles of diverse origin; these combine the effects of source area, depositional environment, and post-depositional change; (2) we fail to recognize and interpret in shale the equivalents of the "vertical profiles" that have been so successful in the study of sandstones and carbonate rocks. Such sequences for shales should be based on the vertical variation of bedding, on bioturbation and fossils, and on the amount and type of organic matter. These properties most closely reflect primary depositional processes; (3) we rarely have an idea of the paleocurrent or

paleocirculation system of most shaly basins; (4) finally, we have not integrated our present knowledge of shales with the geometry of shale bodies nor has it been common to study the associated lithologies, bounding contacts, and positions of shale bodies within basins.

These factors, and others that will emerge, appear to be the directions in the future sedimentologic studies and interpretations of shaly basins.

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Drilling in San Andreas Fault

Research on earthquake prediction prior to 1978 depended largely on the gathering of geophysical observations prior to earthquakes. These include measurements of changes in seismicity, strain, magnetic field etc. Recently, however, in an attempt to relate these observations to a physical model of the pre-earthquake failure process, the U.S. Geological Survey has begun a program of direct measurement of the properties of faults through drilling holes in and near the active fault trace.

Laboratory data on failure of rocks show that non-linear strains develop just prior to rupture, but the character of the failure process is strongly dependent on material properties, pore-fluid pressure, and applied stresses. These parameters are virtually unknown in faults at depths where earthquakes occur. The drilling and in-situ measurements program was designed to determine these quantities and provide samples of the actual fault-zone materials.

Preliminary results from holes near the San Andreas fault can be tentatively interpreted to show that the level of shear stress on the fault is surprisingly low, about 100 bars. The fault-zone rocks at a depth of 600 m are a low-permeability clay-rich gouge in the first hole drilled along the creeping part of the fault. The hole is presently being deepened to allow measurements of stress and pore pressure at depths of 1 km.

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Paleogeography of Northern Arizona During Deposition of Permian Toroweap Formation

Stratigraphic and facies analyses of the Toroweap Formation have yielded reliable indicators of the paleogeographic conditions that existed in northern Arizona during the Permian. Four depositional environments have been recognized that are based on definitive facies. The four environments and their respective facies laterally from west to east are: (I) open marine; skeletal packstone and wackestone, pelletal wackestone; (II) restricted marine; aphanitic lime mudstone, dolomite mudstone, sandy dolomite; (III) sabkha; gypsum, horizontal and gnarly bedded sandstone; and (IV) eolian dune; cross-bedded sandstone.

A marine transgression encroached upon coastal and continental sabkhas eventually drowning a large eolian dune field in its eastward advance across northern Arizona depositing the Toroweap Formation. Eventually the sea slowly withdrew westward and thick prograding