Three-Dimensional Simulation of Basin Evolution, Geothermal History, and Hydrocarbon Generation and Accumulation Potential—New Tool in Petroleum Exploration

Increasing demand and decreasing supply of hydrocarbon products require increased activities in petroleum exploration and production and especially improvement in exploration success. Improvement in exploration success both in previously explored and unexplored areas can only be possible with the integration of all the information and data obtained from geologic, geophysical, geochemical, hydrodynamic, and thermodynamic studies.

A three-dimensional deterministic, dynamic model is constructed to calculate all the above measurable values with the help of mass and energy transport equations, and by equations describing the physical and/or physico-chemical changes in organic matter as a function of temperature in sedimentary sequences. Input data consist of heat flux, initial physical and thermal properties of sediments, paleobathymetric estimates, sedimentation rate and amount, and type of organic matter. Then, the model computes pressure, temperature, physical and thermal properties of sediments, maturity of organic matter, and generation and accumulation potential of hydrocarbons as a function of space and time.

This model has been successfully applied to four basins with different lithologies (clastics, carbonates, and cyclic sediments) and various structural patterns (halokinesis, faulting, and folding). The allowable error limits are ± 3°C for temperature, and ± 10% for maturity of organic matter.

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Petrology and Diagenesis of Early Miocene Deep-Sea Fan Deposits near Point Arena, California

Early Miocene deep-sea fan deposits of the Skooner Gulch and Gallaway Formations near Point Arena, California, were examined to determine which factors influence or control diagenesis in fine-grained turbidite deposits. Well-preserved sedimentary structures (including complete Bouma T_{a-e} beds) are nearly continuously exposed in a vertical sequence along the coast. This sequence is interpreted to represent outer fan depositional lobes, lobe fringe, and basin plain deposits.

Four representative stratigraphic sections were sampled and analyzed using the scanning electron microscope, energy dispersive X-ray, X-ray diffraction, nuclear magnetic resonance, electron microprobe, and thin section analysis. Rock types examined include medium to very fine-grained arkoses, lithic arkoses, mudstones, siltstones, and hemipelagites.

Diagenesis of a turbidite sequence is complex and does not involve uniform changes in detrital and authigenic minerals. Factors affecting diagenesis include variations in the original depositional environment, sediment composition, texture, stratification, frequency of interbedded shale beds, bioturbation, degree of compaction, and original porosity and permeability. Diagenetic changes recognized were: (1) alteration and resorption of unstable detrital grains, such as feldspar, rock fragments and detrital clay; (2) formation of authigenic quartz, potassium feldspar, and clay cements which reduced porosity and permeability; (3) formation of iron oxide and pyrite; and (4) incorporation of detrital and authigenic minerals in late-stage carbonate cement. All of the observed diagenetic changes can occur at relatively low temperatures and shallow to moderate burial depths.

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Methane Concentration and Distribution in Pressurized Core Samples from Mississippian Delta Sediments

Elevated concentrations of shallow biogenic methane are common in regions of rapid sediment deposition. A pressure core barrel was designed and implemented by Texas A&M University, in conjunction with the U.S. Geological Survey Mississippi Delta Project, to study these gas-charged shallow sediments of the continental shelf. Methane measurements were made on 10 pressurized cores taken in the South Pass region of the Mississippi delta. The results of these measurements indicated methane was present in concentrations ranging from 3,450 to 137,140 ppm (μl CH_4(STP)/l wet sediment). Methane values were generally higher than found in comparative samples taken with conventional wire-line equipment. However, these values were lower than predicted by theoretical calculations and also lower than pressure corrected saturation values for methane solubility in seawater. Stepwise decompression experiments were performed on selected samples to study the rate of methane release into the surrounding inert atmosphere of the pressurized sampling container. Results showed that at least 98% of the methane was released from the sediment matrix within 3 to 5 hours after opening the pressurized core. Samples containing higher total methane concentrations demonstrated no change in concentration with pressure during stepwise decompression while those containing lower total methane concentration demonstrated a marked change in concentration with pressure. These experimental results, successfully obtained with pressurized core barrel techniques, provide further insight into the physical and chemical properties of gas in sediments.

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File Management System for Resource Evaluation in Frontier Area—National Petroleum Reserves of Alaska Case Study

A computerized geologic data base can by used to evaluate petroleum resources in a frontier province. The National Petroleum Reserve of Alaska (NPRA) covers 37,000 sq mi (96,000 sq km) on the Arctic slope west of Prudhoe Bay. In 1977, the U.S. Geological Survey was assigned responsibility to determine the hydrocarbon and mineral resources in NPRA. Significant petroleum resources were thought to be present, but were not substantiated by sparse wildcat and stratigraphic test wells. A comprehensive data acquisition program including seismic, gravity, surface geology, stratigraphic test wells, geochemistry, paleontology, petrography, and borehole logs was defined to support the study. Although lower than 125 wells were involved, large and diverse amounts of interpretive data were generated and evaluated by associated field and laboratory analyses. Consequently, a computer data management system was developed to capture, edit, maintain, retrieve, and display various combinations of data on a minicomputer. The system includes an online daily drilling file, digital base map, well data file, digitized borehole logs, outcrop descriptions, organic geochemistry, paleontology, petrography, seismic, and gravity. Subsystems permit stratigraphers, paleontologists, and geochemists to process and display their individiual files. The data management system permits the interpreter to combine data from multiple files and to generate reports, histograms, maps, and graphical displays. Benefits of the computerized system for evaluation

of NPRA are defined and illustrated with examples of applications that are used to determine resource potential.

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Unstable Progradational Clastic Shelf Margins

Ancient shelf margins have generally been overlooked in some progradational clastic systems such as the northwestern Gulf of Mexico and the Niger delta. Apparently the contemporaneous structural deformation, particularly growth faulting, obscures depositional dips and foreset-topset geometry, making recognition of shelf breaks from these criteria virtually impossible. Nonetheless, their positions can be estimated from their association with characteristic microfaunal assemblages, with initiation of growth faulting, with facies changes, and with geopressure.

Rapid subsidence of progradational shelf margins results primarily from three processes: isotatic depression of the basement due to sedimentary loading, extensional thinning of the sedimentary wedge due to gravity tectonics, and compaction. Instability of the continental slope causes substantial basinward mass transport by deep-seated gravity sliding. This is manifested as down-to-basin listric growth faults originating at the outer shelf and upper slope (extensional regime), and shale and salt ridges and domes originating at the lower slope (compressional regime). The rapidly subsiding shelf margin acts as a major sediment trap, leading to accumulation of thousands of feet of shallow-water sediments, including deltaic sandstones, along a growth-faulted trend that may be hundreds of miles long.

Shelf-margin deltas differ substantially from shallow-shelf deltas in that they show thicker and better differentiated progradational units and steeper clinoforms. Sand geometry of shelf-margin deltas is influenced by two competing factors: absence of a broad shelf to attenuate wave energy, thus favoring wave dominance, and high sand continuity, versus rapid subsidence, which prevent lateral reworking and thus favor river dominance and low sand continuity. Rapid downfaulting of shelf-margin deltaic sandstones against dewatering slope shales leads to the accumulation of excess fluid pressure in deep fault-bounded reservoirs. Mapping of geopressure trends can therefore provide a generalized picture of shelf-margin progradation in Cenozoic basins.

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Effect of Regional Strain on Fault Patterns Produced by Doming: Experimental and Analytical Study

Experimental (clay) and analytical models suggest that regional strain, either extension or compression, significantly affects fault patterns produced by doming. Our models simulate the shallow deformation produced by gentle doming of a homogeneous material with and without a simultaneously applied, regional horizontal strain. The models show that without regional strain, randomly oriented normal faults develop on the crests, and radial normal faults form on the flanks of circular domes. With regional extension, normal faults on the crests and flanks of circular domes trend perpendicular to the applied extension direction, and strike-slip faults trending 60° from the regional extension direction form on the flanks. With regional compression, normal faults on the crests and flanks strike parallel to the applied compression direction. Strike-slip faults trending 30° from the regional compression direction also form on the flanks, and reverse faults striking perpendicular to the regional compression direction develop on the peripheries. Our models show that regional strain affects the fault patterns produced by elliptical doming.

This study has important implications for hydrocarbon exploration. The models provide guidelines for determining the strike of faults on domes and suggest that strike-slip and reverse faults, as well as normal faults, may form during doming. These faults may influence hydrocarbon migration and entrapment. Strike-slip faults develop on domes formed in the presence of regional extension (for example, many Gulf Coast domes). Strike-slip and reverse faults develop on domes formed in the presence of regional compression (for example, several domes of the Rocky Mountain foreland province).

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Stratigraphy and Paleobiology of Late Cretaceous "Fossil Forest," San Juan Basin, New Mexico

Exposures of the Fruitland Formation in the Bisti badlands contain an abundant fossil flora and fauna of Late Cretaceous age. Proposed development of Fruitland coal reserves has increased the need for adequate paleontologic data for mitigation purposes and has resulted in a cooperative investigation of a Fruitland "fossil forest" in the area of Split Lip Flats, south of Farmington, New Mexico.

The exposed stratigraphic sequence consists of approximately 26 m of interbedded shales, siltstones, channel sandstones, carbonaceous shales, and coal; the uppermost 5 m is probably part of the Lower Shale Member of the Kirtland Formation. The beds are laterally discontinuous although the carbonaceous shales and coal have greater lateral extent.

At least two, and possibly three, levels of in-situ tree stumps, fallen logs up to 20 m in length, and several leaf localities occur. Preliminary analysis indicates the presence of *Taxodium, Sequoia,* and palm. Within the study area, channel sandstones and mudstones have produced a large assemblage of turtles, lizards, crocodiles, and dinosaurs including ankylosaurs, hadrosaurs, ceratopsians, and carnosaurs. Fossil mammals, including multituberculates, marsupials, and insectivores, have been found at two sites in clay-pebble conglomerates. Mollusk-rich beds occur at three stratigraphic levels.

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Burial Cementation in Upper Devonian Kaybob Reef, Alberta, Canada

Analysis of the petrography and distribution of compositionally zoned ferroan calcite and dolomite cements in the Devonian Kaybob reef complex of Alberta, Canada, has demonstrated that porosity occlusion is predominantly a result of burial diagenesis to depths in excess of 4 km. Different but temporally related mechanisms of formation are indicated for the two cement types: coarsely crystalline dolomite and coarsely crystalline calcite. Calcite cement precipitational history, determined by correlation of compositional zones, demonstates that pressure solution along stylolites was the essential mechanism of calcite cementation in the reef-interior