carbonate rock. The primary matrix porosity averages about 3%. However, weathering during the early Tertiary enlarged fractures and previously existing porous zones to a depth of 100 to 150 m below the top of the carbonate rocks. This secondary porosity, in combination with an extensive fracture network, has converted the otherwise dense carbonate rock into a commercially exploitable reservoir.

A contour map on the top of the eroded Mesozoic carbonate reservoir defines a closure 11 by 2.5 km. The field is elongated parallel to and bounded by Miocene faults with an overall configuration of a rounded limestone ridge.

The ridge is covered by middle Miocene organic rich shales, the oil source. These and younger shales cap the accumulation.

The use of a paleogeomorphic model aids the interpreter in mapping data in the Casablanca area which otherwise would seem uninterpretable, or at least difficult to interpret. The model may be of use in other carbonate areas.

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Stratigraphic and Paleo-Oceanographic Significance of Early Pliocene to Middle Miocene Radiolarian Assemblages from California to Baja California

Comprehensive studies of radiolarian faunal assemblages recovered from outcrop sections at Centerville Beach, Newport Back Bay, Palos Verdes Hills, and Chalk Hills in California and at Bahia Tortugas and Maria Madre Island, Baja California, provide the data base for regional paleo-oceanographic and stratigraphic analyses of Monterey and associated siliceous sediments of middle Miocene to early pliocene age within Neogene California marginal basins.

The sequential succession and development of characteristic radiolarian assemblages and the temporal and spatial variance in environmentally sensitive species in Luisian, lower and lupper Mohnian, and "Delmontian" sediments provide significant insight to regional paleo-oceanographic evolution. Documentation is provided by interpretation of paleoclimatic trends, variation in sediment accumulations rates, changes in water-mass interaction and distribution, and upwelling and productivity events.

Stratigraphically important species of radiolarian genera such as *Theocorys, Lamprocyrtis, Stichocorys, Diartus, Eucyrtidium, Cyrtocapsella,* and *Botryocyrtis* are used to differentiate potential biohorizons which are useful for inter- and intra-basinal and broad regional correlations. Within key intervals, radiolarians provide accurate identification of the low latitude *Dorcadospyris alata* and *Diartus petterssoni* Zones in lower Monterey formation sediments.

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Relation of Unconformities, Tectonics, and Sea Level Changes, Cretaceous of Western Interior, United States and Canada

Intrabasin tectonics have influenced patterns of deposition and geographic distribution of major unconformities within the Cretaceous of the Western Interior. Eight major regional to subregional unconformities have been identified. Five of these have been related by previous workers to sea level changes and to well-documented regressive-transgressive cycles.

New studies of recurrent movement on basement-controlled fault blocks suggest a synchronous relation among fault block movement, sea level changes, and unconformities. Which fault blocks moved on the basin floor, and when, can be explained by stress fields generated by direction and rates of plate motion. Unconformities associated with north-northwest fault trends are caused by more westerly movement, and those associated with east-northeast trends by more northerly plate motion. Expansion of the Gulf of Mexico, the Atlantic Ocean, or the Arctic Ocean during these plate motions may account for associated sea level changes. The 81 to 82 m.y. unconformity and shoreline regression in the Western Interior and synchronous volcanic events on the northern margin of the Gulf of Mexico illustrate the relations.

Uncertainty exists in dating many of the unconformities. However, by use of the time scale of Obradovich and Cobban, the approximate dates for unconformities are estimated as follows: (1) late Neocomian to early Aptain, >100 m.y.; (2) late Aptian-early Albian, 100 m.y. ±; (3) Albian, 96 to 97 m.y.; (4) early Cenomanian, 93 m.y. ±; (5) Turonian to early Coniacian, 87 to 88 m.y.; (6) late Coniacian-early Santonian, 81 to 82 m.y.; (7) late Campanian 71 to 74 m.y.; and (8) late Maestrichtian, 64 to 69 m.y.

Several billion barrels of oil have been found in sandstones associated with unconformities in the Cretaceous. Future stratigraphic trap exploration will be guided by a knowledge of tectonic influence on sedimentation during sea level changes and how these factors controlled distribution of source rock, migration patterns, reservoir rock, and seal.

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Ground-Water Potential for Oil Shale Development in Northwestern Colorado

Rocks in northwestern Colorado contain large amounts of oil shale which constitutes perhaps the richest hydrocarbon resource in the United States. Efforts to develop oil shale will increase demand for water in a region where surface water is fully appropriated. To meet additional water needs associated with industrial and population growth, sources of ground water need to be investigated.

It has been 15 years since investigators determined that large quantities of ground water occur above, within, and below rich oil shale deposits in the Eocene Green River Formation in the Piceance basin of northwestern Colorado. Estimates of the amount of ground water stored in the Piceance basin are as much as 25 million acre-ft. The specific conductance of ground water discharged during the drilling of 24 test holes ranged from 100 to 50,000 micromhos per cm at 25°C.

Another potential major source of ground water in northwestern Colorado may be the Leadville Limestone of Mississippian age. Solution cavities in the outcrop of the Leadville Limestone in northwestern Colorado indicate that the formation may store and transmit large quantities of water. Where fractured and near the surface, the Leadville Limestone has been exposed to ground-water movement, resulting in the development of solution cavities that have enhanced the hydraulic conductivity and storage capacity of the aquifer. Where the Leadville is exposed on or near various structural uplifts in northwestern Colorado, the opportunity for groundwater recharge, movement, and storage may be extensive. Other potential aquifers such as the Dakota Sandstone and the Entrada Sandstone are also under consideration.

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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