and to a lesser extent in the reef-slope facies. Zoned dolomite cements are, in contrast, the major cement type in the reef-margin and reef-slope facies; a basinal source for dolomite-precipitating fluids is indicated. It is suggested that the composition of basin-derived pore waters was controlled by temperature-dependent clay mineral reactions as a function of progressive burial.

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Miocene Deep-Sea Benthic Foraminiferal Faunal Changes in Pacific

Miocene deep-sea benthic foraminifera, analyzed from numerous Pacific DSDP sites, are found to respond to climatically induced oceanic variations by: (1) changes in depth distribution with time; (2) changes in species proportion within assemblages; and (3) becoming extinct. Because benthic species are long-ranging, many species occurring today were present in the Miocene and provide a basis for studying Miocene paleo-oceanographic changes. Analyses of δO^{18} and δC^{13} compositions of benthic foraminifera which record fluctuations in paleotemperatures and in the marine HCO_3 pool reveal major changes between the early and late Miocene.

Shifts in benthic foraminiferal populations and isotopic compositions during the Miocene imply the following water mass changes: (1) early Miocene deep waters appear to have been warmer with older, light δC^{13}; and (2) a sharp middle Miocene increase in δO^{18} which we interpret to be a major bottom water cooling concomitant with Antarctic glacial buildup and thickening of the Antarctic bottom waters, restructuring the Miocene ocean and increasing the equatorial thermal gradient. Benthic fauna species dominance, species assemblage, and water depth indicate that by the late Miocene, both modern benthic foraminiferal assemblages and modern oceanographic conditions were approached. Intensification of the oxygen minimum zone in the late Miocene is supported by the dominance of *Uvigerina* fauna in the west Pacific.

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Algae, Carbonate Facies, and Petroleum Geology

Algae have been a significant part of carbonate deposition for much of the earth's sedimentary history. They are all important in some circumstances. In recent years the growing understanding of calcareous algae has become increasingly relevant to petroleum geology.

Marine calcareous algae have been the source of vast quantities of carbonate sediment, principally muds and sands, on continental shelves and in the deep ocean basins. Encrusting calcareous algae have created rigid frameworks and are important elements in Mesozoic and Cenozoic reefs. Noncalcareous filamentous algae have been influential in stabilizing fine-grained carbonate sediment, thereby forming distinctive sedimentary laminated structures.

The ecologic requirements of benthic calcareous algae have been used with success in the interpretation of environments in which ancient carbonate sediments accumulated. Drawing upon detailed studies of modern ecosystems, definitive depth-distribution patterns of living coralline algae have been established that have value in determining Cenozoic paleobathymetry.

Rapid evolutionary changes undergone by calcareous planktonic aglae, together with their abundance and widespread distribution, have led to their extensive use in stratigraphy. Coccolithophorids provide the basis for a remarkable high-resolution biostratigraphy in Mesozoic and Cenozoic marine sediments. Zones with time spans averaging one million years (minimums of a few hundred thousand years) have been established for the Cenozoic era.

Although the remains of calcareous algae are the major grain constituents in some carbonate reservoir rocks and associated facies, their principal uses are in establishing fine-scale stratigraphic frameworks, interpreting paleoenvironments, and understanding the diagenetic history of reservoir facies. Fossil algae, often considered an obscure field of knowledge, are assuming a more pragmatic position in petroleum geology.

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Late Neogene and Recent Bathyal Foraminifera of Mediterranean

Multivariate statistical analyses of recent deep-water benthic foraminifera of the Mediterranean reveal a bathymetric and geographic distribution that can be ascribed to water-mass distribution and bottom topography. Three bathyal zones were detected: upper (500 to 1,300 m), intermediate (1,300 to 2,800 m), and lower (> 2,800 m). The eastern Mediterranean (Ionian and Levantine Basins) displays significantly fewer species, fewer individuals, and shows lower species equitability than does the western Mediterranean. The Holocene foraminiferal distribution patterns provide a framework against which late Miocene and Pliocene foraminiferal dynamics were evaluated.

The late Miocene (Messinian) salinity crises eliminated bathyal faunas from the Mediterranean. Pliocene foraminifera which repopulated the Mediterranean (1) are remarkably similar to pre-Messinian faunas of the middle upper Miocene Mediterranean sediments; (2) appear in the sedimentary record very soon after initiation of Pliocene sedimentation and attain population stability within 0.5 million years; (3) were derived predominantly from the Atlantic Ocean; and (4) migrated across the Mediterranean from the west to east. Population differences between the eastern and western Mediterranean faunas suggest the presence of Pliocene sills, especially in the Sicilian area. The geographic differences between Pliocene population structures were less significant than they are today. This phenomenon can be explained by Pleistocene tectonism which further restricted water circulation.

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Petrophysical Engineer's View of Reservoir Delineation

From imperfect measurements of a few physical properties representing a tiny fraction of the reservoir, significant interpretations are made by geologists, engineers, and geophysicists. As the geophysicist begins to focus more on field delineation rather than broad exploration, it becomes even more important to understand the potential as well as limitations of borehole measurements.

Basic physical measurements in the borehole provide far more information than the usual reservoir parameters such as porosity, fluid type, and saturation. Log responses such as self potential, natural radioactivity, resistivity, acoustic travel time, and density also provide invaluable clues to lithology,

depositional environment, and correlation. Wireline measurements together with direct measurements of the rock in the form of cuttings and cores must be understood by the geologist and geophysicist using them to achieve the proper confidence in their interpretation.

Examples of some of the limitations of borehole measurements illustrate a wide variety of problems that can occur. However, with understanding of these limitations, remarkably sound interpretation can be made.

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Carboniferous-Permian Boundary Sequence of Northern Oquirrh Basin, Idaho-Utah

The Carboniferous-Permian boundary occurs in the middle of the Oquirrh Group in the northern part of the Oquirrh basin, the largest basin formed east of the Antler tectonic belt during the middle Carboniferous. Good sequences of fusulinid faunas for the northern part of the basin are exposed in the Sublett and Deep Creek Ranges of southern Idaho, a position midway between the basin's bathymetric low and the basin edge. In the Sublett Range, Late Pennsylvanian-Early Permian fusulinids occur through 1,500 m of mixed quartose sands and limestones of the Trail Canyon Formation and basal part of the overlying Hudspeth Cutoff Formation. The Missourian interval is thin relative to the Virgilian interval. Near the base of the Trail Canyon Formation, possible Missourian fusulinid faunas appear containing *Triticites* and *Eowaeringella,* and extend through a 250-m section, which is overlain by a 400-m section with Virgilian fusulinids, including *Triticites* sp. aff. *T. cullomenensis* and *T.* sp. aff. *T. subventricosus.* The Carboniferous-Permian boundary occurs at about the top of the middle limy unit of the Trail Canyon Formation, and Wolfcampian fusulinids, including *Schwagerina and Pseudoschwagerina,* occur through 800 m of section. *Pseudofusulinella* is common through Virgilian and Wolfcampian interval on the western side of the Sublett Range, but has not been found in this interval on the eastern side. Leonardian fusulinids have yet to be found here, contrary to earlier published reports.

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Formation and Evolution of Nonmarine Petroleum in Songliao Basin, China

We will discuss the geochemical characteristics of the formation of nonmarine petroleum and its evolution regularities in the Songliao Basin and put forward the most favorable conditions for the formation of petroleum of nonmarine origin. The nonmarine kerogen of China can be classified into three types with two subtypes by composition and three types with six subtypes by both origin and composition.

In large lake basins, source rocks containing combined sapropelic kerogen have a high transformation ratio and a high genetic potential for petroleum. They offer the material basis for the formation of a large nonmarine oil field. On the basis of geologic and geochemical data and the results of thermal simulation of kerogen, we confirm that the maturation sequence of kerogen is Type-1, Type-2, and Type-3. The petroleum formation from combined sapropelic kerogen has its own characteristics, and it is necessary to set up a new model.

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Elmworth Gas Field, Alberta, Canada: Depositional Environments and Diagenetic Consideration of Low Permeability Gas Reservoir

Elmworth is a giant gas field in low permeability sedimentary rocks and is considered part of the Deep Basin in Alberta, Canada. Gas production is obtained mostly from conglomerates with unusually high permeability but with some difficulties in producing from lower permeability zones. The study of Falher conglomerate and sandstone (Lower Cretaceous) reveals that this low permeability gas reservoir owes its origin to an unique combination of depositional environments and diagenetic processes.

A detailed study of Falher A and B units shows that sediments were deposited during a regression in the following coastal environments: beach, shore, lagoon-bay, coastal plain, and fluvial. Cyclic patterns of vertical sequences indicate an oscillating shoreline and five such sequences are recognized.

Conglomerate and coarse sandstone occur in beach facies, while fine sandstone rich in detrital clays and organic matter predominates in shore facies. Detrital dolomite is characteristically distributed in shore facies and this is taken to indicate the direction of transport. Conglomerate and sandstone are overlain by carbonaceous shale and coal deposited in a swamp environment.

Vitrinite reflectance data indicate that the sediments were subjected to deep burial and associated important diagenetic processes.

Authigenic minerals are found to be most significant in Falher sediments. Quartz in the form of overgrowths and microcrystalline crystals is most extensively developed in sand-supported conglomerates and mineralogically mature sandstones in various environments. Kaolinite is predominant in most conglomerates and in sandstone, which show high primary porosity and permeability. Illite is more common in sandstone than in conglomerate though this trend is obscured by detrital clays in shoreface sandstone. Carbonate cement, mostly calcite and dolomite, is important, as it reduces porosity drastically. Diagenetic processes are strongly related to the depositional environments and their study is important not only in understanding the nature of the reservoir but in delineating the reservoir quality.

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Wrench-Related Folds in Neogene Sediments Developed Along Offshore Sandspit Fault Trend, Queen Charlotte Basin. British Columbia

Net movement on the Sandspit fault, which marks the western edge of the Queen Charlotte basin, is a combination of dextral strike slip movement with significant downdrop of the east block. Evidence of Neogene-Holocene strike slip on Queen Charlotte Islands includes slickensides and offset drainage patterns, topographic features, and geochemical anomalies. The northwest-trending fault parallels the better documented Rennel-Louscoone wrench fault system and the Queen Charlotte transform fault.

Continuous reflection seismic and magnetic profiling in western Hecate Strait was conducted to investigate the offshore extension of the fault zone. A broad magnetic trough in Hecate subbasin, colinear with the Sandspit trend, suggests a crustal dislocation developed in "basement" Cretaceous sediments and Upper Jurassic volcanic rocks. En echelon, gen-