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 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,