Recent studies of the biology and ecology of large, living, algal symbiont-bearing foraminifera have vastly improved the potential for use of these organisms for paleoecologic interpretation and as sediment tracers. Using assemblage composition, size, shape, and lamellar thicknesses, the depth and habitat of the biocoenosis can be predicted from the thanatocoenosis. Robust, commonly spinose, forms are characteristic of the turbulent intertidal and shallow subtidal zone of modern carbonate environments. Robust forms are succeeded by intermediate forms on reef and lagoon slopes. Flatter, larger forms characterize depths approaching the limits of the euphotic benthos. Presence or absence of algal symbiont-bearing species also indicates the relative primary productivity of the paleoenvironment.

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Deltaic Systems and Associated Growth Faulting of Vicksburg Formation (Oligocene), South Texas

The Vicksburg Formation (Oligocene) in south Texas contains several geopressured giant gas fields. These fields occur in sandstone facies to a depth of 17,000 ft (5,182 m) and are associated with stacked deltaic systems complicated by growth faults.

Analysis of cores and electric logs from the McAllen Ranch field (Hidalgo County, Texas) indicate that the sandstones were deposited in shallow water. Cores from the field contain root traces and plant debris, trace fossils (e.g., *Ophiomorpha*), and other evidence of shallow-water deltaic environments. Maps of net sandstone thickness show outlines of high-constructive lobate deltas. Depocenters are developed along growth faults.

The structural style of growth faulting in the Vicksburg Formation is due to a combination of rapid sedimentation and diapirism of shales from the underlying Jackson Group. The displacement and number of growth faults increase with depth. Alternation of down- and up-to basin faults is characteristic, with tilting of beds related to thickness variations of depositional units.

A series of coarsening-upward sequences are recognizable on electric logs. These sequences have a maximum thickness of 1,500 ft (457 m) and good lateral continuity in the middle part of the formation, but are interrupted by numerous growth faults in the lower Vicksburg. Growth faults over structural highs associated with shale tectonism create gas traps for many gas fields.

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Depositional and Tectonic Evolution of a Basement-Bounded, Intracratonic Basin, Palo Duro Basin, Texas

Continental collision along the southern margin of the North American continent during Pennsylvanian time created northwesterly directed compressional stress that was transmitted to the continental interior along boundary faults of the southern Oklahoma and Delaware aulacogens. As a result, numerous basins and uplifts were formed in the aulacogens and edges of the craton, including the Anadarko, Delaware, Midland, and Palo Duro basins, the Amarillo-Wichita uplift, Matador-Red River arch, and Central Basin platform.

The Palo Duro basin is a basement-bounded, or yoked, shallow intracratonic basin filled largely with Pennsylvanian and Permian strata. Its tectonic-depositional history may be divided into four stages: (1) formation of the basin between basement blocks (Matador arch, Amarillo uplift) that were uplifted along boundary faults of the southern Oklahoma aulacogen during Early Pennsylvanian time, and subsequent deposition of basement-derived, fan delta "granite wash" around uplifts flanking the basin; (2) planation and burial of uplifts through Early Permian time, and infilling of the deep basin with shelf-margin carbonate and basinal facies; (3) encroachment of continental red-bed facies from sources in New Mexico and Oklahoma and deposition of thick Middle to Upper Permian marine evaporites in sabkha environments; (4) marine retreat during Late Permian time and development of a Triassic lacustrine basin brought about as a result of continental rifting and drainage reversal.

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Utah-Arizona Hinge Line–Thrust Belt—Potential New Hydrocarbon Province

The Overthrust-hinge line belt of central Utah is part of the Rocky Mountain orogenic complex. When viewed in its entirety, the hinge line extends many miles to the north and south, representing the western margin of the North American continent during Paleozoic time. Except for occasional eastward transgressions of the seas onto the continental shelf, the position of this transition zone remained closely confined through Triassic time.

An ancient continental margin with superimposed overthrusting and the ability to successfully explore such a setting have excited the petroleum industry.

The Overthrust-hinge line play has now been extended from southwest Utah-northwest Arizona to southeast Arizona and into Mexico. Recent geologic and geophysical work in Arizona indicates the presence of deep troughs and large anticlines that are locally covered by multiple thrust plates.

Much of southwest Arizona has previously been defined as part of the Basin and Range province. Many Tertiary-filled basins are bounded by mountain ranges (horsts) made up of allochthonous Mesozoic, Paleozoic, and Precambrian strata.

Some of the most favorable areas to explore for oil and gas have been defined within and below the allochthonous sequences. Deep regional grabens and rifts were probably filled with mostly marine sediments and some salt deposits. We believe that some of these salt sequences will be documented within the Jurassic system.

The marine sediments in the Sonora trough, just south of Arizona in Mexico, are more than 45,000 ft

(13,716 m) thick. It is believed that these sediments range from Pennsylvanian through middle Cretaceous. We project these Sonora trough marine sedimentary rocks to the northwest under the thrust plates exposed in southwestern Arizona.

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Depositional Setting of Middle Dolomite Unit in Metaline Formation, Metaline District, Washington

The middle dolomite unit of the Cambrian Metaline Formation in the Metaline district, Washington, was deposited in a low-energy, shallow-water environment. Deposition occurred as a complex mosaic of subtidal, intertidal, and supratidal environments in a restricted lagoonal and broad tidal-flat setting.

Where primary depositional features have not been masked by intense diagenesis, the middle dolomite unit is characterized by seven distinctive lithofacies. The vertical succession of these lithofacies differs from locality to locality and is laterally discontinuous. The seven lithofacies and interpreted depositional environments are: (1) black, birdseye dolomite, deposited in the supratidal zone; (2) cryptalgalaminate dolobindstone, deposited in the upper intertidal and supratidal zones; (3) laminated, intraclastic dolofloatstone, deposited in the outer intertidal zone; (4) gray massive to mottled dolomite, deposited in the intertidal and subtidal zone; (5) intraclastic-oncolitic dolofloatstone, deposited as lag deposits in tidal-flat channels; (6) oncolitic dolofloatstone, deposited in shoal areas in the upper subtidal zone; and (7) lenticular-bedded dolomite, deposited in the subtidal zone.

Changes in lithofacies over narrow vertical ranges were due more to changing hydrographic and sediment-supply conditions than to numerous minor eustatic sea level changes. Through time, however, there was a gradual rise in sea level, and subtidal sediments became dominant in the upper middle dolomite unit.

The low-energy nature of the middle dolomite unit was the result of either a very long wave fetch, which extended across many kilometers of shallow water, or a remote barrier, which effectively reduced the hydrokinetic energy below that expected in open-marine conditions.

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Wamsutter Arch Tight Gas Play, Southern Wyoming—New Look at Old Area

Efficiently exploiting the natural gas from the Upper Cretaceous Mesaverde Formation in the Wamsutter area of southern Wyoming has depended on new applications of existing technology. An understanding of trapping conditions and reservoir performance has required determination of reservoir rock types based on depositional environments and regional stratigraphy.

Two types of traps were discovered: (1) updip shale-outs of sandstones in the upper Almond and Ericson Formations, and (2) increased gas and water interfacial tension in the lower Almond Formation on the cooler updip flanks of the area.

Reservoir performance is strongly influenced by rock types and reservoir geometries. These are controlled by depositional environments which were determined early in the play by examination of slabbed cores. Productive sandstones were observed from the following environments: nearshore marine (upper Almond), high-energy fluvial (Ericson), and low-energy fluvial (lower Almond). Upper Almond sandstones have the best production because of generally good pore geometry and great lateral continuity. Ericson sandstones produce at high rates in a few areas, but tend to produce water because of their great lateral extent. In contrast, lower Almond sandstones rarely produce water, but only flow gas at low rates due to their poor pore geometry and very limited extent.

Drilling plans, completion procedures, and formation evaluation methods all were influenced by the understanding gained from this integrated geologic and petrophysical study.

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Brae Field Area, North Sea

Several hydrocarbon accumulations were discovered between 1975 and 1977 in Block 16/7 in United Kingdom waters along the western edge of the Viking graben. By 1978, 13 exploratory wells were completed, and development planning focused on the southern part of the area.

The southern part of the Brae area is unique compared with other documented North Sea fields. An oil column of about 1,500 ft (457 m) is contained in Upper Jurassic conglomerate and sandstone shed off the Fladen Ground Spur as it was uplifted by faulting and as the Viking graben subsided. This major fault zone places Upper Jurassic against Devonian rocks and is the important seal along the west flank of the field. The cap rock and likely oil source are provided by the Upper Jurassic Kimmeridge Clay, which drapes a low anticline and dips eastward into the basin.

Stratigraphic changes within the reservoir interval are abrupt. The depositional setting is interpreted as coalescing fan deltas spilled into the basin from adjacent uplands. Conglomerate and sandstone were deposited mainly subaerially on fan-delta surfaces, whereas laterally adjacent siltstone was laid down as fringing marine foresets. Complex diagenetic events have overprinted these facies.

Other hydrocarbon accumulations similar in setting to the Brae field undoubtedly await discovery.

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Conodonts—Models of Pragmatic Paleontology

The composition, size, diversity, and distribution of conodonts make them unique and invaluable geologic tools. These marine apatitic microfossils that evolved and spread rapidly throughout the Paleozoic and Triassic undergo visible color changes from 50 to 500°C as a