face but also to be able to explain geologic concerns and solutions in terms understandable to engineers. Therefore, the geologic work in these fields is conducted at two levels. At the basic scientific level, interpretations of regional settings, depositional environments, facies distribution, and diagenetic and porosity trends are being carried out. At the applied level, this knowledge is integrated with engineering plans and modeling studies for projects such as delineation and infill drilling, well completions, waterflood, and enhanced oil recovery.

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Generation, Migration, and Entrapment of Hydrocarbons on Southern Norwegian Shelf

The Southern Norwegian Shelf (56°-58° 30′N) has proved to be one of the most prolific hydrocarbon provinces in Europe. Recoverable reserves of about 4.8 billion bbl of oil plus oil equivalent are found predominantly in Upper Cretaceous and Danian-age chalk and Jurassic sandstones. The excellent quality of seismic data, moderate to dense well control, and the detailed geochemical evaluations of the Kimmeridge Clay, the principal source rock, make the Southern Norwegian Shelf an ideal area for hydrocarbon generation studies.

A geochemical analysis of the area contained five basic steps: (1) construction of a nine-layered three-dimensional grid summarizing the burial history of the sediments by using well control and seismic data, (2) calculation of geothermal gradients, (3) source rock analysis to investigate variations in thickness and richness of the Kimmeridge Clay study area, (4) maturation study based on the results of the three initial steps, and (5) volumetric analysis and prospect evaluation.

Major factors affecting hydrocarbon accumulations in the structural and stratigraphic closures of the study area include the amount of oil generated within the catchment areas of the various closures and, particularly in the case of the chalk fields, the level of hydrocarbon generation of the Kimmeridge Clay directly under the crest of the structure and presence of faults to act as conduits for vertical migration of hydrocarbons from the Upper Jurassic Kimmeridge Clay to the Upper Cretaceous Danian chalk. The expulsion and migration efficiency (hydrocarbons in place/hydrocarbons generated within the catchment area of individual closures) for tested closures average approximately 8% for the study area, with individual culminations having values as high as 40% or as low as 0%, based in part on the previously mentioned factors.

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Carbonate Sequence Stratigraphy and Controls on Carbonate Platform Development—Case Study from Permian of West Texas-New Mexico

Integration of seismic stratigraphic concepts with detailed field studies and geohistory analysis provides powerful interpretation leverage for deciphering the complex geologic history of carbonate platform-basin areas. Changes in carbonate productivity as well as platform growth and the resultant facies distribution are controlled most importantly by changes in relative sea level.

The structural history of the Permian basin during the Permian shows two subsidence cycles of 10-20 m.y. duration. These subsidence cycles were major factors in the long-term (10^6 - 10^7 m.y.) development of the Permian carbonate platforms. During periods of relatively rapid subsidence, aggradation was dominant; during periods of slow subsidence, major platform progradation occurred.

Superimposed on the long-term tectonic cycles is a series of third-order eustatic cycles (0.5-3 m.y.), which controlled development of 27 depositional sequences. Each sequence is composed of three depositional systems tracts: (1) a lower basin-restricted wedge interpreted to have been deposited during a relative fall and lowstand of sea level, (2) a transgressive systems tract of variable thickness, and (3) an upper, relatively thick, aggradational-to-progradational carbonate platform system, which includes significant allochthonous deposition in the basin and is interpreted to have been deposited during a relative highstand in sea level. The lowstand systems tracts are composed dominantly of quartz sandstone, commonly intercalated with carbonate debris beds at the toe of the slope. Sequence boundaries display erosional truncation (subaerial on platform or at platform margin, subaqueous on slope) and/or subaerial exposure. Erosion and debris deposition occurs both within and outside submarine-canyon feeder systems.

Two highstand depositional styles are differentiated here: (1) a keep-up system, which represents a relatively rapid rate of accumulation able to keep pace with periodic rises in sea level and displays a mounded-oblique stratal geometry at the platform margin, and (2) a catch-up system, which represents a relatively slow rate of accumulation and displays a sigmoid profile at the platform margin. Individual strata units of the platform margin and slope area of the catch-up carbonate system have a much longer sea-floor residence time and display significantly greater amounts of early submarine cement. The underlying transgressive systems tract tends to have a keep-up or give-up (i.e., thin, drowned) depositional style.

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Carbonate Platforms, Sequence Stratigraphy, and Sea Level

Besides tracing reflectors, the mapping of stratigraphic sequences marks a major advance in seismic interpretation. However, construction of sea level curves from sequence stratigraphy is complicated by other factors besides sea level influencing sequence geometry. One such factor is lithology. This point is examined by comparing siliciclastic systems and carbonate platforms.

During the Pleistocene, the siliciclastic sediment supply to the deep sea was at its maximum during glacial lowstands of sea level. Pleistocene carbonate platforms were exactly in antiphase to this rhythm. They produced and exported most sediment during interglacial highstands when the platforms were flooded ("highstand shedding"). In the Bahamas and other platforms, accumulation of both bank-derived fines and sandy turbidites is higher by a factor of 2 to 9 during the interglacials, and turbidites tend to cluster in these highstand intervals. Highstand turbidites also differ in composition from their lowstand counterparts. Turbidite abundance and composition together provide a faithful record of the Pleistocene sea level cycles not easily erased by diagenesis. Geometrically, platforms respond to sea level by forming highstand turbidite wedges and lowstand drapes of pelagic sediment—the opposite of siliciclastic systems.

Drowning unconformities are another example for the significance of lithologic change in sequence stratigraphy. Flanks of carbonate platforms are generally steeper than siliciclastic slopes. When carbonate platforms are drowned and buried by siliciclastics, an unconformity ensues because the clastics are unable to assume the steep carbonate slope angle or because they are shed from other directions than the carbonates. Examples of drowning unconformities include the Lower Cretaceous platforms off West Africa and off eastern North America as well as the middle Cretaceous unconformity in the Gulf of Mexico.

Highstand shedding and drowning unconformities of platforms illustrate that not all depositional systems respond alike to changes in sea level and that sequence boundaries may be caused by lithologic change. These lithologic turning points need not be related to sea level. In a very general way, sequence boundaries can be viewed as changes in the pattern of sediment input and dispersal in a basin. Sea level fluctuations are one way to induce such changes, but tectonic movements and environmental change represent important alternatives, demonstrated by the seismic stratigraphy of the deep Gulf of Mexico.

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Reservoir Description for Exploration and Development: What is Needed and When?

The biggest challenge for geologists, geophysicists, and petroleum engineers now and in the decades ahead is to significantly improve hydrocarbon recovery from all new and previously discovered reservoirs. Keystone of the methodology required to improve oil and gas production, as well as to evaluate and delineate new reserves, is a detailed reservoir description. This is a characterization of the reservoir and nonreservoir rock-fluid system that is appropriate in content and