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Seals for Major Middle East Fields

The Middle Jurassic to Turonian sequence in the central part of the Arabo-Persian Gulf presents a concise and well-documented hydrocarbon habitat that demonstrates the controlling role of seal development and preservation in the spatial distribution of oil and gas accumulations.

Geochemical and geologic data indicate two source formations to be present within this sequence, the Upper Jurassic Hanifa, and the Aptian Shuaiba, where developed in intrashelf restricted basinal facies. The terminal Jurassic Hith Anhydrite and the Albian Nahr Umr Shale are the two principal regional seals.

Hydrocarbon accumulations are concentrated in reservoirs located beneath the two regional seals. Where these are absent through non-deposition or are breached by faulting, oil has migrated upward and is now trapped beneath higher seals. Geochemical fingerprinting and maturation studies provide clues as to which source rock has generated the reservoir oils, and support the geologic inferences with regard to seal efficiency and its control on the distribution of accumulations.

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Simulation Model for Petroleum Exploration and Its Applications

A computerized simulation model was constructed to synthesize the processes of petroleum generation, migration, and accumulation under relatively simple conditions. The model successfully simulated petroleum accumulation in an existing anticlinal gas field, and was used to estimate the possibility of fault and stratigraphic entrapment nearby.

A geologic cross section of the area is divided into a series of vertical columns that are sectioned into rectangular cells representing successive intervals of time and corresponding strata. Four geologic processes are sequentially performed on each cell or pair of adjacent cells. First, sediment is deposited in a cell with its original thickness restored by removing the effects of compaction (deposition). Then, for each time-stratigraphic unit, the compaction caused by increasing time and depth of burial is calculated; the system also estimates the amount of petroleum generated, assuming it to be a function of temperature (compaction and petroleum generation). Primary migration is assumed to occur when petroleum saturation of source beds exceeds the residual amount normally present in thermally mature shale. Secondary migration is assumed to result from buoyancy alone; any petroleum which exceeds the hydrostatic trapping capacity of the shale seal is either allowed to migrate into a cell located along some upward path or escape to the surface (petroleum migration).

The model was applied to the anticlinal East Niigata field, Japan, using carefully selected input parameters. Results made it possible to estimate migration paths and timing of entrapment in each producing zone. The model may also be applied to exploration problems. For example, it was used to estimate the possibility of petroleum entrapment in strata near the East Niigata field. Results of this experiment show that the simulation method is potentially useful for estimating the possibility and places of entrapment, especially for stratigraphic traps.

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Seismic-Stratigraphy of Santa Monica Basin Fill, Southern California Borderland

Seismic-stratigraphic analysis of 3, 1, and 0.25 sec reflection records has permitted an interpretation of the depositional history in Santa Monica basin at several dimensions and time scales. The present form of the basin was established during orogenic episodes in late Miocene and late Pliocene time. Subsequent deformation of the onlapping Quaternary basin fill has been relatively minor. Beneath the basin plain the fill is 640 m thick and is divisible into two units. The lower unit (400 m) represents a pre-Pasadenan accumulation of sediment delivered to the basin through Hueneme, Mugu, Dume, and Redondo submarine canyons. Transport through Santa Monica canyon was inhibited by a structural barrier at the mouth of the canyon. Post-Pasadenan strata (240 m) represent overflow from the Los Angeles and Ventura basins. This latter stage of basin filling is characterized by a significant increase in the rate of sedimentation and extensive growth of the Hueneme and Mugu canyon-fans. During this time, sediment delivery to the basin through Dume and Redondo canyons was diminished, occurring only intermittently. The secular pattern of canyon activity and sedimentation appears to be tectonically controlled.

Glacio-eustatic effects have been secondary. Examination of high-resolution echo characteristics indicates a general southward decrease in the amount of surficial coarse-bedded sediment and that the major transport path since Wisconsinan time has been through Hueneme canyon. Large-scale mass movement, which is an important depositional process in several adjacent basins, is relatively unimportant in Santa Monica basin and is restricted to the canyons.

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Quantitative Investigation of Trapping Effect of Unfaulted Caprock

With the objective in mind to estimate the possible hydrocarbon columns, a statistical analysis has been made of 160 reservoirs in structural traps in several basins. Care was taken to assemble data in those areas where hydrocarbon charge is so abundant that underfilled structures imply seal deficiency. Likewise faulted anticlines and doubtful traps were avoided.

A multivariate statistical analysis was made by defining the dependent variable to be the differential pressure that the hydrocarbon column exerts at the culmination of the trap. This allowed the simulataneous analysis of data comprising oil, gas, and combined columns at different depths. Columns in reservoirs full to spillpoint were considered to indicate minimum (censored) values for the differential pressures. Other situations led to maximum values for the trapping efficiency, while in only a minority of places a column was believed to be in equilibrium with the sealing capacity and hence providing a real (uncensored) observation.

A special regression program that allows censored observations for the dependent variable has been used to relate differential pressure to a set of independent geologic parameters (X-variables). The important X-variables considered here are seal lithology, thickness, and depth of reservoir.

Significant statistical results support the idea that lithology of seal is of considerable importance. Sealing capacity is also correlated with seal thickness and depth.

These statistical results have been helpful in creating a quantitative assessment of hydrocarbon retention expectation for exploration prospect appraisals.

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Waulsortian Mounds and Lithoherms Compared

Lithified bioherms (lithoherms) in the northern Straits of Florida have been compared with the Waulsortian mounds of the Early Carboniferous of Europe. The lithoherms occur at 400 to 600 m in the presence of moderate bottom currents. A zoned coral-octacoral-crinoid community appears to build into the current as concomitant cementation provides a diagenetic framework. Coral debris, pelagics, bank-derived muds and cements compose the mound material. Exposed downcurrent surfaces are undergoing bioerosion.

The ancient mounds in the Belgium type area are composite structures with a lower (Tournaisian) sparry "blue vein" facies of fenestellid bryozoans cemented by marine calcite crusts and relatively little micrite. This is overlain by a Visean phase of micritic facies, still rich in fenestellids, with steep depositional slopes suggestive of subsea cementation. Outside Belgium, the mounds are predominantly micritic. They contain stromatactoid cavities which have also been associated with marine cementation. Work by others suggest that filamentous algae, including *Girvanella,* had some part in local generation of lime mud. Mound facies pass laterally into shaly limestones and shales with chert, which locally may be rich in algae.

Early Carboniferous continental reconstructions place the ancient mounds in a general equatorial carbonate margin or near margin. The paleo-oceanographic consequences suggest a light shallow mixed layer within which shallow equatorial upwelling could maintain moderate surface biologic productivity while not mixing deeply enough to fully oxygenate the slope and basin bottoms.

Ancient mounds, in contrast to the modern lithoherms, appear to have accumulated largely from submarine cementation of products of in-situ origin, in a setting of slower currents and possibly reduced oxygen levels on a bottom that may have been shallow enough to extend at times into the lower photic zone.

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Faunal Succession Within Deep-Water Coral Mounds North of Little Bahama Bank

Deep-water coral mounds of 5 to 40 m relief occur at depths of 1,000 to 1,300 m over a 2,500 sq km area of the lower slope north of Little Bahama Bank. These coral/gorgonian buildups, apparently unlithified, have yielded radiocarbon ages of 860 ± 50 and 940 ± 40 years for the best preserved corals and gorgonians, and preliminary dates of 22,100 years for the most intensively bored corals, the youngest deep-water coral mounds ever reported. Eight genera of deep-water coral represent the highest diversity recorded from a single locality. These ahermatypes are predominantly solitary, although branching and weakly branched forms are also present. The colonial ahermatypes from the mounds possess large-diameter corallites and relatively few corallites per specimen. Several of the coral general, most notably *Thecopsammia,* have significant stereomal deposits in the skeleton, a feature common among deep-water corals. The scleractinians are associated with a diverse fauna. The primary framework builders of the mounds, however, appear to be branching corals and gorgonians.

Based on the relative amounts of boring and Mn-oxide coating on coral specimens recovered from dredge hauls, there appears to be a crude faunal succession within the mounds. Branching colonial corals and gorgonians seem to be the pioneer forms, colonizing hardgrounds. These initial coral thickets form a baffle for sediment as well as substrates for later stages of attached and free-lying ahermatypes such as *Desmophyllum, Stephanocyathus,* and *Deltocyathus.* Thus the mounds grow through a combination of sediment trapping and colonization by a greater diversity of coral and other invertebrates. The coarse nature of intermound sediments and the presence of scour and ripple marks in underwater photographs indicate that bottom currents are vital to the development of these deep-water coral structures.

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Permian and Triassic Boundary of Southwestern Utah

The Permian and Triassic boundary, southwestern Utah, is marked by a topographic unconformity associated with a number of minor unconformities. The Harrisburg Member, Kaibab Formation, is the uppermost Permian unit. At its base a chert limestone is overlain by a gypsum in the west and a collapse breccia in the east. A fossiliferous limestone overlying the gypsum and collapse breccia is contorted over the collapse breccia, and is of a constant thickness suggesting that the evaporites were dissolved after its deposition. Above the medial limestone a siltstone is overlain by a limestone that partly fills topographic depressions in the medial limestone. Dissolution of the gypsum continued producing additional relief that was filled by another siltstone and limestone sequence. In the Beaver Dam Mountains gypsums are present above the medial limestone. Conglomeratic lenses (Rock Canyon Conglomerate) derived from the west and southwest are equivalent to both the Permian and Triassic sediments representing a major erosional cycle after the last retreat of the Permian seas and the advance of the Middle Triassic seas. The Timpoweap Member, Moenkopi Formation, was deposited on top of the underlying limestones and conglomerates developing a horizontal plane. It thins to a featheredge west of the Hurricane Cliffs and east of the Utah-Arizona state line suggesting that a positive area was present west of the Hurricane Cliffs during the Early Triassic. Thinning of the lower Red Member of the Moenkopi Formation also occurs west of the Hurricane Cliffs but in places it is absent, reflecting the topographic nature of the Permian and Triassic boundary. It was not until the deposition of the Virgin Limestone member of the Moenkopi Formation that Triassic seas covered the western part of Utah.

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Diagenetic Effects and Pore System Evolution

Permeability/porosity relations obtained from core measurements and well logs from numerous sandstone