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JURASSIC GEOLOGY OF FLOMATON FIELD AREA OF SOUTHERN ALABAMA

Flomaton field, in Escambia County, Alabama, is the first major gas condensate discovery from the Jurassic Norphlet Formation in Alabama. Structurally the field is a NW-SE trending, low-relief salt feature bounded on the north and east by a major down-to-the-basin fault which is part of the Pickens-Gilbertown-Pollard regional fault system. The Norphlet sandstone reservoir is about 60 ft thick and produces CO_2 and sour gas with a high condensate yield.

The paleostructural history of the area indicates that movement of Louann salt and faulting occurred, probably as a result of gravity slide and basinward salt creep, forming structures capable of trapping hydrocarbons. Jurassic deposition was affected by these early structural features and by presalt topography that existed updip from the Flomaton area.

Norphlet clastics were derived from the northeast and deposited by braided stream systems. As the Jurassic Smackover seas transgressed the area, the upper part of the Norphlet was partly reworked. In the Flomaton area, the overlying Smackover Formation is a dark-brown, dense, micritic limestone. Above the Smackover, the Haynesville Formation can be subdivided into upper and lower members with the upper Haynesville consisting of predominately red, coarse clastics and the lower member being fine, red clastics and evaporites. At Flomaton, over 300 ft of bedded salt has been drilled in the lower Haynesville causing many drilling and completion problems. The Cotton Valley Group marks the top of the Jurassic and consists primarily of coarse, gravelly clastics.

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STRATIGRAPHIC EXPLORATION SYMPOSIUM—SUMMARY

Despite the existence of some truly giant oil and gas fields as well as numerous smaller ones in stratigraphic traps, purposeful search for such traps has been less rewarding than exploration for structural ones. Seismic exploration has been successful in mapping reefs, but definition of wedgeouts of porous clastic reservoirs is generally beyond the limits of resolution of seismic methods.

Basins with a record of tectonic instability, with important unconformities and overlaps, and with alternations of marine, paralic, and fluviatile facies are likely to contain numerous clastic stratigraphic traps. Stable but continually subsiding evaporite basins or stable shelves bordering evaporite basins or troughs where fine clastics were deposited are the chief sites for reef development. In the parts of basins where structural relief is low, most of the hydrocarbons are likely to have been trapped stratigraphically.

Systematic search for stratigraphic fields, coordinating the results of seismic surveys with detailed stratigraphic studies, followed by drilling of wells by operators who are willing to assume higher than normal dry hole risk, will continue to be the principal exploration method for finding stratigraphic oil and gas fields unless a direct method of oil finding is discovered. Contributors to this symposium have shown how improvement of the techniques of stratigraphic analysis are enabling explorationists to identify their objectives with greater precision.

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ENVIRONMENTAL MODEL FOR SOME SEDIMENTARY QUARTZITES

Precambrian, Cambrian, and Ordovician orthoquartzites in Scotland, California, and Nevada are characterized by primary features that are indicative of sediment transport by tidal currents. Sedimentary structures in these quartzites are grouped as follows. *Association 1.* cross-stratification organized into herringbone sets with bipolar-bimodal orientation; parallel laminae; *Association 2.* reactivation surfaces; multimodal frequency distributions of cross-strata set thicknesses; bimodal frequency distributions of cross-strata dip angles; *Association 3.* interference ripples; ripples superimposed at 90 and 180° on underlying cross-strata and slip faces of dunes and sand waves; *Association 4.* tidal bedding; flaser bedding; lenticular bedding; and *Association 5.* burrows, including escape structures.

Suggested tidal transport mechanisms are: *Association 1.* reversing tidal current bedload transport; *Association 2.* time-velocity asymmetry of tidal current bedload transport; *Association 3.* ebb-emergent sheet-runoff; *Association 4.* alternation of tidal bedload and mud suspension deposition; and *Association 5.* organic reworking.

These observations indicate that some orthoquartzites are analogs to modern tidal sand bodies. Association of orthoquartzites with (1) mudstones containing flaser, tidal, and lenticular bedding, and (2) shallow subtidal, intertidal, and supratidal carbonates, indicates that perhaps many orthoquartzites are tidalites (sediments deposited by tidal bedload transport, tidal fluctuations, alternation of bedload and suspension deposition, and suspension slack water deposition). A tidal sediment transport model for sedimentary quartzites is consistent with their extensive areal distribution patterns (averaging 23,000 sq km) on Paleozoic and Mesozoic platforms.

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LOWER TRIASSIC LITHOFACIES OF CORDILLERAN MIOGEOSYNCLINE, WESTERN UNITED STATES

The Lower Triassic marine formations of the Cordilleran miogeosyncline (Dinwoody, Thaynes, and Moenkopi) make up a wedge-shaped body that intertongues on the east with redbed shelf deposits (Chugwater and Moenkopi). The miogeosynclinal strata are limestones with minor amounts of shale, siltstone, and sandstone. The shelf deposits are redbeds with tongues of nonred siltstone, sandstone, dolomite, limestone, and evaporites.

Carbonate tongues in the redbeds in eastern Utah consist of oolites and poorly sorted echinoderm-rich limestones. There are no obvious lateral facies changes and the deposits appear to have formed in a shallow, laterally extensive sea.

In most areas, however, lacustrine or shallow-marine redbed environments passed westward into a sand channel—oolite bar complex or into tidal flats with intraformational conglomerate channels. Seaward, lagoons (burrowed muds) and offshore banks (echinoderm-rich wackestones and oolites) were present. Farther seaward open marine (gray bioclastic limestones and tan calcareous siltstones) and euxinic basin (black limestones and shales) conditions existed.

Thin chert-rich conglomerates and sandstones and the absence of much of the Lower Triassic in eastern Nevada indicate a positive area in that region. Evidence of Lower Triassic volcanism is present in western Utah and eastern Nevada.

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SEDIMENT FACIES PATTERNS AND GEOLOGIC HISTORY OF COASTAL MARSH

Preliminary facies studies in the Great Marsh, on the southwestern shore of Delaware Bay, show a complex history of marsh-lagoonal facies forming the leading edge of the late Holocene marine transgression. A molluscan fauna (*Crassostrea virginica, Macoma balthica,* and *Nassarius obsoletus*) found in a dark-gray sand-mud, indicates a tidal creek–shallow coastal lagoon environment surrounded below, landward, and above by medium-dark-gray organic mud with variable amounts of *Spartina* grass and peat. Shallow cores, supplemented by deeper auger borings and reflection seismic surveys, indicate that the morphology of the Holocene transgression wedge and the present drainage patterns are a reflection of topography on a deeply eroded pre-transgression unconformity incised into Pleistocene sediments.

Late Holocene geologic history and the resulting sediment facies patterns therefore are associated closely with fluvial drainage patterns on the pretransgression surface. A relative sea-level-rise curve has been used to place facies patterns and vertical sequences into a time-space perspective showing the migration of environments landward and upward over this dendritic erosion surface. The initial transgression of the fringing marsh and tidal creeks, and their widening into lagoons were followed by an increased sedimentation rate. This increase led to infilling of lagoons and formation of the present tidal creek-marsh system.

The transgressive sequence, because of continuing sea-level rise, is being partly obliterated and buried by a rapidly advancing washover barrier and shallow marine-estuary complex (Delaware Bay).

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EARLY EVOLUTION OF OCEANS—A WEATHERING MODEL

The long-term chemical composition of seawater is controlled by the generalized reaction: primary igneous rocks + water + acid volatiles = sediments + oceans + atmosphere. Unstable crustal minerals are weathered by water and acid volatiles, and local equilibrium between the products of the reaction—oceanic sediments, seawater and the atmosphere—is attained.

To obtain a better picture of the evolution of the oceans as this reaction proceeds (minerals formed, mass transfers involved, changes in seawater composition), we simulated with a model calculation on a high speed computer the irreversible attack of "average igneous rock"—represented by an idealized mineral assemblage—by water and acid volatiles. We assumed a single-stage degassing process under reducing conditions at 25°C and 1 atm. The predicted final solid products at equilibrium, ranked according to decreasing mass, are amorphous silica (chert), clay minerals, carbonates, and K-feldspar. The predicted composition of the early ocean resembles that of present seawater except that (1) the dissolved sulfur is in reduced form, (2) the solution is saturated with amorphous silica, and (3) the salinity is about twice that of today because of nonremoval of NaCl as evaporites.

Extension of these results to more realistic systems can at best be semiquantitative because of lack of sufficient thermochemical data. Furthermore, the recycling of sediments makes it very difficult to estimate early environmental conditions from present remnants of Precambrian sediments. Some generalizations can nevertheless be made with confidence. A more basic initial crustal material such as oceanic basalt would lead to larger amounts of clays and carbonates in the sediments at the expense of chert, and to a large concentration of dissolved ferrous iron in the ocean. Degassing of water preferentially to other volatiles would not affect the outcome of the weathering process unless the escape rates of the volatiles differed by several orders of magnitude. Although our model clearly represents one extreme, rapid degassing, the available geologic evidence does not preclude its having taken place. It is encouraging that the results of the calculation are in general accord with what has been reported previously.

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DEEP-SEA CHERT IN GULF OF MEXICO

Chert from at least 9 different stratigraphic zones, ranging in age from Cenomanian (Late Cretaceous) through late Oligocene, was recovered at 4 sites in the southeastern Gulf of Mexico during Leg 10 of the Deep Sea Drilling Project. The sites are on the northern and eastern edges of the Campeche Scarp, in the Catoche Tongue area of the Yucatan Channel, and on the western approach to the Straits of Florida.

Chert formation in all locations took place by late postdepositional replacement of deep-water, calcareous, foraminiferal nannoplankton oozes. At each site the degree of silicification of the carbonates increases with increasing age. Depth of burial and/or thickness of the overlying water mass appears to be independent of the degree of silicification.

Preliminary petrographic analyses of the cherts reveal the presence of amorphous (opaline) silica; fibrous quartz (variety chalcedony); fibrous cristobalite; and anhedral, subequant, microcrystalline quartz. The type of silica present is dependent upon the stage of silicification and on the composition and texture of the components being replaced. Finely comminuted plant material and other forms of organic detritus are locally common but are unaltered by silicification.

The exact source of silica for these cherts is not presently established. Radiolaria and other siliceous organisms are generally common in overlying sediments and may be important silica sources. Although drill-core data in the Gulf of Mexico are incomplete and far from conclusive, there is a suggested increase in the amount of silica both in the form of siliceous organisms and in chert—in the southeastern Gulf of Mexico.

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HISTORY OF CIRCULATION IN PACIFIC OCEAN

Present evidence indicates that the Pacific Ocean is the remnant of a larger, pre-Mesozoic ocean basin, since restricted by drifting continents. Similar Paleo-