southern extension is deeply buried and unknown. A down-to-the-southwest fault system had been suggested previously as the updip limit for much of the early Mesozoic sequence along the northwestern edge of the salt basin. However, 4 seismic profiles show the loss of section to be primarily the result of thinning and convergence of beds. Jurassic deposition was affected by the uplift, which served as a source for clastic material.

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DEPOSITIONAL SYSTEMS IN WOODBINE FORMATION (UPPER CRETACEOUS), NORTHEAST TEXAS

The Woodbine Formation (Upper Cretaceous) in northeast Texas is a sequence of terrigenous clastic rocks derived largely from Paleozoic sedimentary and mildly metamorphosed sedimentary rocks exposed in the Ouachita Mountains of southern Oklahoma and Arkansas and deposited in a complex of nearshore environments along the margins of a broadly subsiding basin. On the basis of a regional outcrop and subsurface investigation in which external geometry of framework sands was integrated with observations of lithology, sedimentary structures, fossil occurrence, and bounding relationships, 2 principal depositional systems are recognized in Woodbine rocks—a fluvial system and a highly destructive delta system.

The tributary-channel facies and the highly meandering channel facies, both components of the fluvial system represented by massive sand and gravel bodies of the lower Woodbine (Dexter) lithosome, are dominant north and northeast of a line from Dallas to Tyler. On the south and southwest, the highly destructive delta system is persistent throughout the entire section. The 4 component facies of the delta system includes: progradational distributary-mouth bar facies; coastal-barrier sand facies, developed either lateral to or basinward of the distributary mouth; prodelta mud facies; and embayment-strandplain facies, developed laterally adjacent to principal deltaic facies.

Following or near the end of deposition of Woodbine rocks and before their transgression by Eagle Ford Shale, emergence of the Sabine uplift resulted in erosion of Woodbine material and its redeposition along the margins of the uplift in a lithosome designated the "Harris Sand."

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GULF OF MEXICO BASIN: INTERACTIONS AMONG TECTONICS, SEDIMENTATION, AND HYDROCARBON ACCUMULATION

The eastern and western carbonate platforms of the Gulf of Mexico have subsided about 5,000 m since the middle part of Late Jurassic time; about 7,000 m beneath the Isthmian (Isthmus of Tehuantepec) Cenozoic terrigenous clastic sequence south of the Bay of Campeche (in the Northern Central American orogen); and 15,000–16,000 m beneath the Jurassic through Holocene Gulf Coast geosyncline of the northern Gulf rim.

Carbonate-platform sequences are present in eastern Mexico (Tamaulipas platform; includes Tampico-Tuxpan and Veracruz basins) and in Yucatán and Florida (Yucatán and Florida platforms), because terrigenous clastic provenances either were not available, or because barriers prevented the transport of terrigenous materials into these regions. In contrast, the terrigenous sedimentary piles of the Isthmian basin and Gulf Coast geosyncline regions had important provenances for terrigenous debris. The Isthmian section differs from that of the Gulf Coast geosyncline because (1) the provenance and, therefore, the sediment supply was smaller, and (2) the Cenozoic basin is part of an orogenic belt. In contrast to the Isthmian region, the provenance area for the Gulf Coast geosyncline is huge, and the basin is on a stable continental margin, well removed from active orogenic belts.

The central oceanic plate of the Gulf of Mexico sank at the same time and at about the same rate as its margins. This conclusion is substantiated by several observations. (1) Seismic data suggest that the Mohorovičić discontinuity is at least 17–18 km below s.l. (2) The same seismic data show that a minimum thickness of 5,000 m of sedimentary strata is present beneath the Gulf of Mexico floor. This amount is 5–10 times the normal thickness of sediments on oceanic crust. (3) The "normal" depth of an oceanic abyssal plain is 5,000 m, yet the depth of the Sigsbee abyssal plain is only 3,500 m below s.l. Thus the base of the sedimentary column at the Gulf center is about 8,500 m below s.l. If the "normal" abyssal plain depth is assumed to have prevailed once in the Gulf, one may subtract the figure of 5,000 m from 8,500 m and arrive at a minimum of about 3,500 m subsidence for the center of the Gulf. However, seismic data suggest that the *average* sediment thickness beneath the Gulf exceeds 6,500 m, and locally reaches 9,000 m. If the 6,500-m figure is used, the Gulf has subsided at least 5,000 m, or about the same amount as the carbonate platform areas on the eastern and western margins of the deep basin.

This amount of subsidence shows that the Gulf was an oceanic basin during Late Jurassic time. One must accept this choice, assume that the Gulf was 8,500–10,000 m deep during Late Jurassic time, or adopt the position that its subsidence rate has been about twice that of the surrounding land areas. The simple geometric argument presented here to show that the Gulf most probably has been oceanic from Late Jurassic to the present time is supported strongly by the geology of the surrounding continental areas. Subsurface and surface data indicate that the Gulf is at least as old as Late Mississippian-Early Pennsylvanian. New data just obtained from the deep Gulf support this minimum date. The writers believe that the Gulf basin has been an oceanic plate since the beginning of earth history.

The much greater subsidence of the Gulf's northern margin resulted from the huge accumulation of sediments along that margin. This much greater subsidence beneath the Gulf Coast geosyncline imparts to the Gulf oceanic plate and the Mohorovičić discontinuity an overall northward tilt. Yet the flanking Yucatán and Florida platforms on the east and Tamaulipas platform on the west show no conspicuous northward tilt. This fact indicates that a hinge-type, north-south-oriented, scissorslike, differential movement has taken place along the western and eastern flanks of the deep Gulf basin. This movement presumably is manifested now by the Florida scarp, the western Campeche scarp, DeSoto and Campeche canyons, and the north-south belt of salt-anticline ridges along the western side of the Gulf. This same hypothesis and the predominance of clastic deposition explain the markedly different topography of the northern margin of the Gulf and along the southern side of the Bay of Campeche—the two prominent "hummocky" topography zones of the Gulf of Mexico.

Very large and substantial petroleum reserves remain to be found and exploited in this region. Some of them are not exploitable at present, but ultimately the technology to drill commercial wells in very deep water will be developed, and the petroleum reserves of the continental slopes will be produced. Among the many trends which can be drilled and which remain to be tested and exploited are the post-Ouachita facies Paleozoic marine strata of the northern Gulf and the area north of the Northern Central American orogen. Mesozoic reefs, atolls, and carbonate banks still are only partly tested. Late Tertiary and Quaternary reserves of the northern Gulf and the southern part of the Bay of Campeche still must be drilled and exploited. The two "hummocky" zones of the continental slope offer particular promise. Finally, the diapiric structures of the deep Gulf and the salt ridges of the western Gulf must be tested thoroughly, though at present they are not economic objectives.

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EARLY DIAGENESIS OF SEDIMENTS AND THEIR INTERSTITIAL FLUIDS FROM CONTINENTAL SLOPE, NORTHERN GULF OF MEXICO

A geochemical investigation of sediments and their interstitial waters was made on cores taken from the northern Gulf of Mexico slope in 1966. Cores from the top 1,000 ft were taken at 36 locations in water depths from 677 to 4,777 ft.

Measurements of water content and bulk density show that most of the slope sediments have been compacted under normal overburden pressure. Exceptions are those that were deposited either very slowly or very rapidly.

Away from salt domes, minor changes in the incorporated seawater in sediments have taken place with 1,000 ft of burial, suggesting mainly the loss of water through compaction, and the loss of dissolved sulfate through bacterial action. Near salt domes, interstitial water has high salinity that apparently is derived from the water moving, in response to compaction near salt bodies and caprock, past the salt and upward through the sediment above the dome, and displacing the original interstitial water.

Interstitial waters of the sediments near salt domes have characteristics similar to those of some deep oilfield brines. It is probable that some subsurface waters in deep sediments have developed high salinity by coming into contact with salt bodies and their associated caprocks.

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FORAMINIFERA AS INDICATORS OF SOME NEARSHORE PROCESSES

Development of an inner-coastal-lagoon fauna is due to the slow rate of exchange in a large lagoon. The inner lagoon assemblage is less diverse than the outer lagoon assemblage. A high rate of foraminiferal reproduction off river mouths results in an abundant population dominated by 1 or 2 species and specimens of small size; the number of specimens per unit volume of sediment may be diluted by fast deposition. Accumulation of abundant foraminiferal tests suggests slow deposition of detrital sediments.

Marsh faunal zones are related to mean tidal ranges, and this relation can be used to estimate lagoon hydrodynamics. High diversity marsh faunas are present in low runoff areas, and low diversity faunas are found in high runoff areas. Calcareous specimens are common in many marshes, but may not be preserved in the sediments.

Nearshore open-ocean faunas differ from lagoon faunas, and have an apparent depth zonation related to water turbulence. Beach and sandy lagoon-barrier sediments contain robust open-ocean Foraminifera and may have lagoon and marsh species. Mixed faunas may be present on one or both sides of a lagoon inlet and reflect lagoon size and dominant direction of flow. Transport of marsh species into the nearshore area is a result of high runoff. Mixing of assemblages results from rise or fall of sea level, and also from upslope transport from the turbulent zone.

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POSSIBLE FUTURE PETROLEUM PROVINCES OF UNITED STATES WESTERN GULF BASIN—PLEISTOCENE[1]

Hydrocarbons in sediments of Pleistocene age have been found in 56 fields located mainly offshore from Louisiana. The Pleistocene section of the western Gulf basin has potential for significant additional reserves of hydrocarbons. The sequence consists of 3 gross depositional facies, in ascending order, (1) deep-water bathyal sediments, (2) neritic sediments, and (3) continental deposits. The maximum thickness of the Pleistocene exceeds 10,000 ft near the outer edge of the continental shelf in the western Gulf basin. The lithologic characteristics, facies, and types of traps in which the accumulations are present are similar to those of the underlying Pliocene and Miocene beds, which contain major reserves.

The greatest potential is in an area of 15,000 sq mi on the outer continental shelf offshore from Louisiana and Texas. In this area, the overall objective section, the neritic interbedded sandstone and shale facies, is from 3,000 ft to more than 8,000 ft thick. Approximately ⅓ (4,300 sq mi) of this area is in an early stage of development, and ⅔ (10,700 sq mi) is unexplored. Most of the reserves found to date are in the continental and neritic facies of the lower Pleistocene.

The area of greatest potential is indicated by several factors. Potential source and reservoir rocks of the Pleistocene neritic facies are similar to those of the older, highly productive Tertiary section. Structural and stratigraphic conditions favoring the entrapment of oil occur as commonly in the most favorable Pleistocene area as in nearby areas of prolific Tertiary fields. The area of favorable stratigraphy on the outer continental shelf is underlain by many diapiric structures. Significant discoveries from marine Pleistocene sediments in recent years afford direct evidence that the section is a major objective for future exploration. In the past, this section as a potential source of hydrocarbons has been downgraded by some workers because of its relatively young age.

Drilling and producing capabilities are now sufficiently advanced to permit economical operations over most of the continental shelf. However, major hydrocarbon reserves are required to justify the extremely high operating expenses in the deep-water area. The continental slope of the Gulf of Mexico offshore from Texas and Louisiana is also underlain by a large volume of Pleistocene sediments, but its potential cannot be assessed at our current state of knowledge.

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