14. LEE H. MELTZER, Consultant, New Orleans, La.

GEOLOGY OF WEST BASTIAN BAY FIELD, PLAQUEMINES PARISH, LOUISIANA

West Bastian Bay field, one of the largest gas fields in the south Louisiana Gulf Coast area, produces from beds of late Miocene age between 6,950 and 15,500 ft. Structurally, the field is an anticline on the southern downthrown side of a fault whose throw exceeds 3,000 ft. The center of uplift moved progressively northwestward for a distance of 2 mi. from its "X" Sand position near the southeastern edge of the field. The fairly recent development of a new locus of uplift near the eastern edge of the field has given the field a double closure at the level of the uppermost Miocene beds. A small, long-quiescent fault with 60–100 ft. of throw across the axis of the fold and the eastern part of an axial fault separate the deep reservoirs in the northeastern segment of the field from the deep reservoirs in the other segments. The fact that gas columns in this area are thinner than elsewhere along the apex of the fold is believed to be the result of the presence of the nearby East Bastian Bay field and the eastward shaling out of the "W" and "X" Sands.

15. ARTHUR S. DICKINSON, Goldrus Drilling Company, Houston, Tex.

PALEOSTRUCTURAL ANALYSIS AND APPLICATION OF LATER STRUCTURAL TILTING

It is reasonable to conclude that hydrocarbons begin to form soon after the organisms from which they are derived are buried with the sediments that constitute both source rock and reservoir bed. Therefore, structural-mapping methods used to define likely areas of accumulation should be used to reconstruct the geologic history from the time of deposition by analyzing both the initial structural growth and the later structural tilting that influenced the migration and entrapment of the hydrocarbons.

Structural mapping methods, commonly used today, locate "structure" as it presently appears without regard for (1) initial local structural uplift which influenced the movement of hydrocarbons as they began to migrate, or for (2) later structural tilting which tended to breach the original "paleostructural" trap and possibly caused the original accumulation to move to another place. Therefore, it is possible, using customary structural mapping methods, to map a high properly that has no accumulation because no trap existed at the critical time of initial migration. Likewise, it is also possible that the initial structural closure has no accumulation today because it was breached by later structural tilting.

The purposes of this paper are (1) to demonstrate a logical method of paleostructural mapping by use of carefully selected isopachous intervals, and (2) to define *later structural tilting* and to present a practical method of applying it to understand and define better the likely areas of accumulation.

Examples of application at North Francitas field, Jackson County, Texas, and at Rayne-Bosco-Ossun fields, Acadia and Lafayette Parishes, Louisiana, are presented.

16. B. ROSS WHITE AND JERRY R. SAWYER, Placid Oil Company, Shreveport, La.

BLACK LAKE FIELD—BEFORE AND AFTER

The conditions of the surface and subsurface in and around the area now encompassed by the Black Lake field, Natchitoches Parish, Louisiana, are reviewed. Numerous dry holes had been drilled in the vicinity of the field before the discovery; the dry holes are in close proximity to the now-established productive limit. The factors leading to the discovery in an area long thought to be barren of oil or gas possibilities by most oil men are presented.

The production in the Black Lake field comes from a biohermal-type reef of the Pettit Formation, which is of Early Cretaceous (Sligo) age.

The unique aspect of this field is the manner in which the operators have handled the development. Unitization was established before competitive production was allowed. The field has been shut-in since discovery, and facilities are being installed in preparation for inauguration of a full pressure-maintenance gas-cycling operation.

The discovery of the Black Lake field has triggered a flurry of exploration activity across central Louisiana. There have been numerous exploratory wells drilled along the Pettit trend since Black Lake field's discovery—all without success. Even with the new activity, subsurface control is sparse and the existence of additional Black Lake field-type accumulations is possible.

17. JACK LEE GREGORY, Tenneco Oil Company, Houston, Tex.

LOWER OLIGOCENE DELTA IN SUBSURFACE OF SOUTHEASTERN TEXAS

A lower Oligocene (middle Vicksburg) delta is delineated in the subsurface of southeastern Texas. The middle Vicksburg delta, composed of interbedded sandstone, siltstone, and shale, has an areal extent of approximately 1,100 sq. mi. and a maximum thickness of 300 ft. It is now buried beneath 2,500 ft. to more than 9,000 ft. of younger deposits, mainly sandstone and shale.

The sandstone distribution suggests that the sediment was brought into the Vicksburg basin from the north by two rivers or by a single river that frequently changed course. A broad deltaic plain existed at the mouth of the river and prograded much farther seaward than the adjacent contemporaneous alluvial and inter-deltaic sandstone beds on the east and west.

Two major axes of thickening are apparent: the axis normal to the shoreline represents the sand-filled alluvial valleys and the seaward extension of the delta; and the axis parallel with the shoreline represents longshore current deposition (beaches, barrier islands, and dunes). The data suggest that longshore currents flowed westward and deposited considerably more sand on that side of the delta.

Production from sandstone beds of the middle Vicksburg is restricted to the seaward extension of the delta, the area most favorable for oil and gas generation and preservation. The most favorable traps in the marine extension of the delta are positive structures that existed during Vicksburg deposition.

18. B. J. SLOANE, Monrich Oil & Gas, Inc., Lafayette, La.

STRUCTURAL HISTORY OF HOUMA EMBAYMENT

The Houma embayment is a structural downwarping of the middle Miocene continental shelf which was filled contemporaneously with a northward-thickening wedge of deltaic-plain sandstone and deep-marine shale. The embayment wedge is terminated on the north by an arcuate, down-to-the-coast, growth-fault system. Toward the south, the wedge thins to a few hundred feet where it is down-faulted below existing well control by post-embayment faulting. A series of paleostructural maps demonstrates that the basin subsided by northward rotational tilting into the boundary-fault system. Hydrocarbons accumulate where regional north dip is interrupted by local south dip or, as in most cases, where northward-plunging noses are terminated on the south by faulting. It is the thesis of this paper that regional north dip and thickening of rotational blocks into arcuate down-to-the-coast growth faults can be observed in all similar embayment-type structures, of which there are many in south Louisiana. The Houma embayment is at relatively shallow depths, and the presence of major hydrocarbon accumulations in the embayment wedge has encouraged a great amount of deep drilling. Information obtained from the deep drilling allows the structural history of the Houma embayment to be reconstructed accurately and used as a model for deep exploratory drilling in other areas.

19. WILLIAM R. PAINE, University of Southwestern Louisiana, Lafayette, La.

STRATIGRAPHY AND SEDIMENTATION OF HACKBERRY SHALE (MIDDLE OLIGOCENE) AND ASSOCIATED BEDS OF SOUTHWESTERN LOUISIANA

The Hackberry shale section of the middle part of the Frio Formation of southwestern Louisiana is one of the four deeper-water shale wedges in the post-Vicksburg Tertiary Gulf Coast section. The Hackberry section can be divided into two parts. The upper section ranges in thickness from zero to more than 3,000 ft., and consists predominantly of shale containing an outer-neritic (deep-water) assemblage; several thin, erratically distributed sandstone bodies are present. The lower zone ranges from zero to 700 ft. and consists mainly of sandstone.

To understand better the geological history of the Hackberry shale wedge, a discussion of the stratigraphy and structure of the Frio section has been included.

The complicated Frio stratigraphy of northern Jefferson Davis and Calcasieu Parishes is caused partly by a complex early (Frio) tectonic history and partly by variations in regional deposition of the Hackberry section. The geological history of the area is summarized as a sequence of eight steps. It should be emphasized that these eight stages are a *general* sequence of events, that they probably overlap one another, and that they may have occurred at slightly different times in different areas.

The steps are: (1) deposition of Vicksburg and *Textularia seligi* Zone of lower Frio; (2) development of lower unconformity (this may be a local unconformity); (3) deposition of lower Frio and Hartburg sequence; (4) uplift, folding, erosion, and development of pre-Hackberry unconformity; (5) tilting of unconformity surface and renewed erosion which formed channels; (6) deposition of basal Hackberry channel sandstone bodies; filling of channels which resulted in the development of a flat-surface sequence; (7) deposition of Hackberry with "arenaceous" fauna at the base; and (8) deposition of remainder of Frio.

The earlier structural movements formed folds and faults which then were truncated by regional erosion. On this eroded surface, large channels (600 ft. deep) were cut and later filled. The mechanism which cut and filled these channels is uncertain, but may be turbidity flows. The structural movements, history of erosion, and the complex stratigraphy of the Hackberry make exploration for Hackberry sandstone reservoirs a high-risk economic decision, but one which may pay high dividends.

20. PAUL S. FREEMAN, Union Oil Co. of California, New Orleans, La.

EXTRUSIVE SHALE MASSES: NEW GULF COAST EXPLORATION FRONTIER

Many Gulf Coast shale masses are extrusive deposits formed by the processes of "sedimentary volcanism." "Sedimentary volcanic" deposits have been recognized only recently in Tertiary strata of the Gulf Coast. Diagnostic evidence for this phenomenon is found at outcrops of the Catahoula Formation (middle Tertiary) in the south Texas counties of Live Oak, McMullen, Duval, and Webb. The absence of *active* "sedimentary volcanism" in the Gulf Coast and the difficulty of recognizing this phenomenon in ancient rocks are causes for a general omission of this subject from the American geologic literature; consequently, explorationists are overlooking diapiric and possibly extrusive origins for numerous Gulf Coast shale masses.

The ultimate relation of a buried extrusive shale mass to adjacent and overlying beds is determined by the amount of mudflow buildup and preservation during the time of deposition of the nearby normally deposited beds. If the sum of mudflow deposition (with accompanying erosion) greatly exceeds the sedimentation of the adjacent beds, large mudflow domes and ridges may form prominent topographic features. Conversely, if the rate of sedimentation of adjacent beds equals or exceeds that of the mudflow accumulation, an ill-defined mudflow facies is formed. Most thick, extrusive shale bodies probably are composite masses of both rapidly and sporadically extruded mudflows interfingered with normally deposited beds.

Growth of an extrusive dome is attained by a sequence of mudflows extruded from clusters of mudcones. Dips of mudflow layers increase as each succeeding layer is extruded and a domal topographic feature forms. Slopes of active mudcones are commonly 30–40°, depending on the mud viscosity; cones are known to exceed 1,500 ft. in height. Commonly, mudflows range in thickness from several inches to 50 ft. and extend as much as 2 mi. from their parent vent. Mudflow extrusions may take place simultaneously for many miles along a fault system. Active mudflow ridges 20 mi. long are known in West Pakistan. These flat-topped ridges are hundreds of feet thick and have steep sides with 40–70° slopes.

Erratic rocks commonly are brought up thousands of feet stratigraphically by mudflows. Erratics up to 3 ft. in maximum dimensions are common, and rarer occurrences of blocks with 50-ft. dimensions are known. Microfossils, thousands of feet out of place, occur in many places within extrusive mudflows or shale masses. Diagnostic evidence of diapiric clastic rocks includes: erratic fossils, churned shale pellets, gas bubbles, and disrupted rock frameworks.

Revised exploratory thinking is required to search successfully for and to recognize subsurface diapiric shale masses. Diapiric shale masses are formed in specific basins, along certain trends, and during favorable geologic times. Although intrusive shale plugs exhibit the same pronounced structures as salt plugs, buried extrusive shale masses are not associated generally with pronounced radial faulting, sharply up-