ing that the salt of a stock moves vertically upward in several unit cylinders called "spines." Observations in the salt mines of the Five Islands trend in south Louisiana confirm this interpretation. In some places the spines are defined by sedimentary gouge (shale, sand, limestone), which becomes included in the salt core and clearly marks the spine boundaries. These boundary shear zones can extend from the edge of the salt to the very center of the stock. Shear zones that have a diameter of 1,000 to 4,000 ft have been observed in four of the five mines. Every gradation exists from relatively simple, thin (15 ft), linear shear zones, to wider (400 ft) ones that have been twisted and sheared into the salt in complicated patterns by later salt movements.

The shear zones can be traced upward through the salt to surface irregularities in the salt-stock surface, and into topographic irregularities on the ground surface (generally valleys). Disruptions of the overlying domal sedimentary rocks also can be recognized, and Balk and Muehlberger suggested these as the cause of the irregular salt motion. The present analysis suggests, however, that the salt spines cause the overlying strata disruptions.

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Model Study of Morphologies Caused by Exploding Superheated Vapor and Possible Lunar Analogues

Hypervelocity cosmic bodies impacting on the lunar surface create volumes of vaporized rock materials which react in thermal agitation with the lunar soils. Water drops falling onto a surface of hot silt provide a model for the thermal agitation process, and produce several distinctive types of craters which appear to have exact analogues on the lunar surface. Surprisingly, the interaction between the silt and vaporizing water is not always the same and at least three types of reaction occur, each producing a distinctive crater morphology.

In one type of reaction the blast triggers the formation of an outwardly expanding rolling ring of vapor and rock debris. The expanding ring digs a crater which has slump features around the rim, and the inwardly rolling motion piles up materials in the center to form a cone. If the depth of silt is shallow, the same reaction creates a flat-bottomed crater with slump rings.

A second type of reaction occurs where the vaporized materials rotate horizontally in a swirling motion. This type of action creates concentric multiple craters and chains or lines of coalesced craters. Swirl-like slumps of debris are left in the bottoms of some of the craters whereas in others the wall may be breached and the material flows away leaving a rillelike trail.

A third reaction occurs where the impact is violently explosive, and the materials are blown from the crater. These craters have blast rays and generally have smoothly sloping bottoms which contain a minimum of debris.

Photographs of features observed in the model studies compare with photographs of analogous features on the surface of the moon and have implications as to the origin of the lunar surface.

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Dual Spacing Thermal Neutron Decay Time Log: Cased-Hole Exploration Tool

Geologists are being called on to find more oil and gas, much of it in existing fields. Schlumberger's dual spacing thermal neutron decay time log helps locate bypassed oil and gas productive zones. It can be used to evaluate these zones and to evaluate other zones which were not analyzed properly before initial completion of the well. The dual spacing thermal neutron decay time log also may be used to monitor reservoirs during their productive life to assure maximum production.

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Oil Industry Experience in Louisiana Offshore, 1946-1972

This study covers industry's activities in the State and Federal parts of the Louisiana offshore from the first State lease sales immediately after the close of World War II through the Federal sales held in 1972. Estimates of future exploration and development on these leases are included and a model of the operation during the remainder of the productive life is used to evaluate the outcome.

The area has become an important producing province (1973 production was about 450 million bbl of oil and condensate and 3.9 Tcf of gas) and the leases acquired through 1972 may result in the discovery of as much as 8.4 billion bbl of oil and condensate and 70.4 Tcf of gas. Lease purchase and exploration costs (including future costs on leases acquired prior to the end of 1972) total about 8.2 billion dollars and development costs will be at least 11.4 billion when these leases are developed fully. The profitability of the venture for industry will depend on future product prices. At the end of 1973, 48 percent of the oil and 37 percent of the gas had been produced.

When the original study was done in mid-1973, two future price cases were analyzed. Case I incorporated the mid-1973 revenue levels through the remainder of the productive life. In Case II, oil prices were increased 5 percent per year and gas, 6.50 percent. These increases were based on published estimates of future world oil priced by Federal agencies and major banks. An additional case will be presented using future prices in keeping with recent events in the world oil market. This case also will incorporate any changes in the industry tax structure as a result of legislation now pending in Congress.

Industry's overall results have been poor except for the early years. The latter period, 1968-1972, will yield a poor return under almost any reasonable assumption of future prices. The deterioration in profitability from the early to late period is partly due to a moderate decline in field quality as well as higher development and operating costs. (The newer fields are generally in deeper water and farther from shore.) However, the major cause is the much higher prices paid for leases at the more recent sales. Even in Case II, about ⅔ of the operating profit from the 1968-1972 period will be paid to the Federal treasury in the form of bonus, rentals, royalty, and income tax. Depending on future prices, this can amount to as much as 50 percent of gross revenue. This does not include any provision for excess profits or excise taxes which would increase the Federal share or benefits to the consumer as a result of price constraints on domestic production to keep revenues below world oil prices.

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Wave Characteristics with Restricted Fetch: Case Study of Lake Okeechobee

In the design of earth work constructions along rivers and lakes, it is important to know the relations between wind and the waves. Such observations are a first stage in a complete investigation of wave effects on beaches and earth structures of different shapes and materials. The generally used form of these relations deals with deepwater conditions, where the fetch is unlimited. Such relations cannot be applied to small lakes and protected bays.

The earliest work in this field was that of Johnson on Clear Lake, California. He concluded that wind duration but not fetch was the controlling factor in any kind of change in wave characteristics. Later, on the basis of the study of Abbots Lagoon, California, Johnson showed that the dimensionless term gf/u^2 is useful in estimating wave conditions within certain limits. Burling compared the wave data from Staines reservoir with the data

of Johnson, Bretschneider, and Sverdrup and Munk. Whereas the curves are of the same form, there is a great amount of discrepancy. Burling's line is 15-25 percent below the other lines. Data from Lake Okeechobee, Florida, indicate that there is a transitional region between deep water and shallow water, where the wave height is affected by combinations of wavelength and depth of water.

The data from Lake Okeechobee align closely with Burling's results. However, Burling's observations were from a reservoir where the maximum fetch was about one km. In Okeechobee the fetch ranges up to 60 km. The Okeechobee study reveals that the proper method to define shallow-water waves should include fetch and wind velocities as well as the depth of water. The wave heights are lower than expected for lower wind velocities and higher than expected for higher wind velocities in shallow water, with limited fetch.

NORWOOD, E. M., JR., and D. S. HOLLAND, Pennzoil Co., Marine Division, Houston, Tex.

Lithofacies Mapping, a Descriptive Tool for Ancient Delta Systems of Louisiana Outer Continental Shelf

Rocks of the Pliocene and Pleistocene Systems of the Louisiana outer continental shelf are divisible into three rock facies—massive sand, alternating-sand-shale, and massive shale. Similar to older Tertiary rocks of the inner shelf and coastal plain, these facies are related genetically to delta depositional systems. A description of the facies distribution for a discrete time interval can indicate the location of deltaic progradations and the approximate shape and seaward extent of their delta plains. The mapping technique requires a working definition of the individual rock facies to facilitate division of log-correlative time intervals into component facies. Separate isofacies contour maps are drawn simultaneously for each time interval, recognizing that deltaic progradations are shown by the massive sand isofacies map. The final lithofacies display map shows data relating to all three rock facies and thickness contours showing the distribution of massive sand and alternating-sand-shale facies.

An important interrelation exists between rock facies, structure, abnormal pore-fluid pressure, and the presence of hydrocarbons. Seismic techniques reliably can predict structure and abnormal pressure, and this knowledge can be integrated qualitatively into facies mapping where well control is lacking. Optimum sites for hydrocarbon accumulation can be localized by the recognition of deltas, the locale of their stillstands, and favorable structural and hydrodynamic trapping mechanisms.

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Paleodepositional Environments in Upper Jurassic Zuloaga Formation (Smackover), Northeastern Mexico

The Zuloaga Formation (Late Jurassic) is well exposed in the mountains of northeastern Mexico. It is stratigraphically equivalent to the Smackover Formation of the northern Gulf Coast. From 16 Zuloaga outcrops and a petrographic analysis of samples 12 distinct lithofacies are recognized within the formation.

The lithofacies and their inferred depositional environments are as follows (numbers 1 through 9 are shallow-water to supratidal deposits): (1) detrital facies—littoral marine to marginal marine to arid playa; (2) clean oolite facies—high-energy bar, shoal, or shelf; (3) muddy oolite facies—lagoon or shelf, washover; (4) clean pellet-fossil facies—medium to high-energy shoal and storm washover; (5) muddy pellet-fossil facies—intertidal to shallow subtidal; between shoals; (6) burrowed lime-mud facies—low-energy lagoon or low-energy shelf; (7) algal-laminated facies—very shallow subtidal to intertidal, possible supratidal; (8) oncolite facies—medium- to low-energy subtidal; (9) limestone-breccia facies—intertidal to supratidal storm deposit; (10) dolomite facies—environment unknown, possibly intertidal to supratidal; (11) evaporite facies—environment unknown, probably shallow, restricted lagoon; and (12) pelagic fossil lime-mud facies—low-energy shelf, deeper than facies 1 through 9.

The general range of paleoenvironments suggests a very shallow, slowly subsiding, trough-shaped epicontinental sea, the Mexican "geosyncline." A sequence of depositional environments, similar to those represented in the Mexican geosyncline area, may be expected east of the Tamaulipas Peninsula in the Mexican Gulf coastal plain. The Zuloaga Formation was deposited during a major marine transgression with many minor sea-level fluctuations.

The Zuloaga and Smackover Formations are very similar in lithology and depositional environments. Detailed studies of the Zuloaga may aid in defining facies relations in the Smackover, which is more difficult to examine because it does not crop out.

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Anomalous Brine Maps Yield Rapid Prospect Leads

Sediments in predominantly sand-shale basins have abnormally high salinity near faults and in the edgewater surrounding hydrocarbons. Anomalies can be seen readily when countywide maps are prepared on brine concentration at the top of the hydrocarbon-bearing zone. Faulting tends to yield a linear zonation of strong brines, whereas hydrocarbon anomalies appear similar to structural contours. About 80 percent of Gulf Coast fields have anomalous salinity waters in edge wells which are no more than 2,000 m from commercial production. Productive wells have redox potential which reduces SP and prevents accurate analysis.

Water composition is just one of the major variables used to evaluate a subsurface system. When combined with pressure gradients, temperature gradients, and redox-potential data, the hydrocarbon environment may be located within 2,000 m and classified with a rough production-probability index. Temperature gradients are influenced strongly by faulting and geopressure, whereas pressure anomalies correlate with the occurrence of gas and condensate production. For example, some counties in the Wilcox trend have most productive fields located over geopressure anomalies. The brine anomalies are on the edge of the abnormal pressure-gradient anomaly, which is opposite to the source of migration.

OXLEY, M. L., and DANIEL E. HERLIHY

Bryan Field—a Sedimentary Anticline

Although the Bryan field has existed as a producing structure since 1958, this is the first published data detailing the geologic history and origin of the structure. Drilling of the discovery well for the Jurassic (Cotton Valley) sediments was preceded by a detailed seismic program, which outlined an anticlinal feature corresponding to the shallow (Cretaceous) production.

On the assumption that the structure was a salt-cored anticline, the discovery well was permitted for 17,000 ft but was drilled to 21,105 ft before reaching salt. A reevaluation of the data reveals the Bryan field as a classic example of the sediment-cored anticline or turtleback structure. An unusual thickness of Haynesville sediments and a continued outward flow of salt into nearby salt-cored anticlines combined to produce the sedimentary structure which is the subject of this study.

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Preliminary Survey of Freshwater Early Tertiary Invertebrates from Trans-Pecos Texas

Freshwater invertebrates of early Tertiary age have been collected from eight scattered locations in Presidio and Brewster Counties in Trans-Pecos Texas. Most specimens are internal