interpretation indicated the crest of a deep closure had not been penetrated. The Sun 27 G. T. Brooking, drilled in December 1972, found new deep production. New reservoirs also were discovered in the previously drilled upper part of the Frio section.

The improved logging techniques used in the wells allowed a more quantitative look at all the sandstones. Combination logging tools providing a simultaneous recording of induction resistivity, acoustic velocity, and computed Rwa curve were used exclusively. Using the Rwa curve as a hydrocarbon indicator, low resistivity sandstones that appeared wet from casual examination were tested and found productive. Other sandstones which appeared to have no vertical separation from overlying water sandstones were tested and found productive.

Twelve new wells were drilled from 1972 through 1974. The drilling program resulted in a significant increase in the daily gas and oil production. Multiple recompletion opportunities also were recognized.

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Deformational Processes in Delta-Front Deposits

River-mouth depositional patterns are modified by sediment deformational processes of sufficient magnitude to endanger severely bottom-supported structures. Several types of deformations are present and include (a) peripheral slumping, (b) differential weighting and diapirism, (c) graben faulting, (d) mass wasting by sediment degassing, and (e) deep-seated flowage. High depositional rates are present near the river mouth and decrease seaward; with time, the bar front oversteepens and rotational slump planes form peripheral to the bar front, moving sediment into deeper water. These blocks have longitudinal dimensions of approximately 200 to 2,000 ft and lateral dimensions of 600 to greater than 2,000 ft. Differential loading by denser bar sands overlying low-density clays results in vertical and seaward flowage of the clays contemporaneously with seaward bar progradation. Diapiric folds and spines (mudlumps) intrude into delta-front sediments on the seaward side of the deforming load, vertical movement affecting sediments to depths in excess of 500 ft. The seaward extrusion and continued movement of clays arch the overlying delta-front sediments, and this stress is relieved by small graben faults oriented radially to the deforming load or delta lobe. The grabens have widths from 150 to 1,500 ft and lengths of several miles. The finer grained river-mouth sediments contain high percentages of methane and CO_2 gases, formed by bacterial decomposition of organics. Passage of hurricane waves produces bottom-pressure perturbations, forcing the entrapped gas upward, causing loss of sediment strength and allowing mass movement. The weight of the modern delta has depressed underlying Pleistocene sands about 400 ft, causing squeezing and flowage of clays onto the continental shelf at water depths greater than 300 ft. Large-scale slumping and faulting near the continental shelf result from this clay flowage. These processes are contemporaneous with deposition and play an important role in initiating a depocenter.

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Sand Leakage around Rocky Headland at Niteroi, Brazil

A statistical study of foreshore sediments from two adjacent open-ocean pocket beaches near Niteroi, state of Rio de Janeiro, Brazil, was undertaken to investigate sand leakage around the rocky headland separating the beaches. According to May and Tanner, the rocky headland theoretically could act as a cell boundary. A statistical analysis should reveal whether or not the rocky headland is a cell boundary.

Three samples collected from beach 1 (NE of headland) and seven samples collected from beach 2 (SW of headland) were sieved and the four moment measures were determined for each of the samples. The moment-measure analysis was marked by the following pertinent points: (1) mean phi size increases in both directions away from the headland; (2) mean phi size for beach 1 (1.577 phi) is significantly different from the mean phi size for beach 2 (1.297 phi); (3) sorting for both beaches appears to improve weakly toward the headland (0.370 ± 0.020 to 0.450 ± 0.020); (4) skewness increases from a negative minimum (-0.150 ± 0.020) away from the headland to a positive maximum (0.100 ± 0.020) at the headland; (5) kurtosis decreases away from the headland (1.000 ± 0.020 to 0.200 ± 0.020); (6) two-factor regression analysis of the four moment measures (y) versus linear distance (x) away from the headland revealed a weak positive linear trend for mean phi size, a weak negative linear trend for sorting, and strong negative linear trends for skewness and kurtosis; (7) analysis of variance indicated that the variation in mean phi size is significantly different between the two beaches.

Interpretation of the statistical analysis forces one to conclude that the rocky headland is a cell boundary (*e.g.*, little or no leakage) separating two pocket beaches, each of which is in dynamic equilibrium.

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Multivariate Statistical Approach to Sedimentary Environmental Analysis

A multivariate statistical strategy employing cluster analysis, ordination, and gradient analysis was used to determine the depositional environment of Barataria Bay, Louisiana. Cluster analysis of sediments suggests the existence of five sedimentary facies: (1) beach sand, (2) foreshore sand, (3) silty channel sand, (4) silty channel-margin sand, and (5) organic silt and mud. Ordination was used to depict the gradational relations among individual samples and among facies defined by cluster analysis. Gradient analysis suggests a wide range of environmental conditions operating within the bay and substantiates Klovan's factor analysis.

Gradient analysis shows that ordination extracts, successively with each axis, the most variable combination of the original variates. The ordination coordinates become new objectively created variables which are efficient measures of the original grain-size curve.

This multivariate statistical approach to sedimentary environmental analysis may prove useful for partitioning other sediment samples into facies and for examining the interaction between these facies and their environment of deposition.

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Towed Horizontal Resistance and Spontaneous Potential Survey off Sabine Pass, Texas

A program of electrical measurements on unconsolidated marine sediments was started by the geologic oceanographers at Texas A&M University in 1968. It consisted of measuring resistance and spontaneous potential on extruded cores and *in situ* in the field, and correlating the electrical values with various sediment and geotechnical properties. The present phase of research concentrates on delimiting and defining sediment lithologies using a towed horizontal array. Several combinations and electrode spacings were tried across Heald Bank, off Sabine Pass, Texas. Bottom-water and sediment samples were collected from well-defined submarine lithologies.

Preliminary results indicate that the spontaneous potential is uniformly highest in mud and clay areas. Large variations occur over shelly sands and shell debris. Resistance is largely uniform across Heald Bank, with relative values depending on electrode

separation. Towed electrical measurements are complementary to high-resolution subbottom profiling.

Sediment samples collected from Heald Bank were placed in a small wooden trough to appraise some of the properties that control the sediments' resistance and spontaneous potential as well as to obtain insight into the relation between depth of measurement with various electrode spacings. The experimental electrical studies show the same spontaneous potential variations as were found over Heald Bank.

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Clay Mineralogy of Lewisville Member of Cretaceous Woodbine Formation in Arlington, Tarrant County, Texas, Area

One hundred clay-sized samples selected from two cores and two measured sections of the Lewisville Member, three samples from the overlying Arlington Member, and five from the underlying Dexter Member of the Cretaceous Woodbine Formation in eastern Tarrant County, Texas, were analyzed. The amounts of each clay mineral present were calculated from X-ray diffractograms of natural, ethylene glycol–saturated, and heated samples. The average clay mineral assemblage was approximately 28 percent illite, 36 percent kaolinite, and 36 percent expandable lattice clays.

Floral and faunal assemblages and sedimentary structures demonstrate that the Lewisville Member in the Arlington area is part of a deltaic interdistributary complex association where admixing of fresh and saline water creates a transition zone. Vertical changes in clay-mineral distributions correlate well with the changes in depositional environments from fluvial to swamps and bays and finally to marine by the end of Lewisville deposition. Apparently for the Lewisville Member specifically, and probably for the Woodbine Formation in general, clay-mineral distributions are environmentally significant.

The predominant expandable lattice clay in the Lewisville Member is Ca-Mg montmorillonite. In his studies of the Woodbine in east-central Texas, Beall found these exchangeable cations to be most abundant in nearshore sediments with Na+ cation content increasing basinward, reflecting the more marine character of the sediments.

Kaolinite is the most abundant clay mineral in the five Dexter Member samples and in samples from the lower 5 to 10 ft of the Lewisville Member. Several lenticular channels, extensive sands, and interbedded silts and clays provide evidence that the Dexter Member is part of the meander-belt facies. The basal Lewisville marks the transition between a fluvial environment below and swamp and bay environments above.

Randomly interstratified montmorillonite/illite is present throughout the sampled intervals, but no clear relation between this type of clay and depositional environment is apparent, as the semiquantitative method used in this investigation is useful only in determining the relative amounts of the end members of the mixed-layer clay.

An increase in kaolinite and expandable-lattice clays with respect to the average composition in the upper Lewisville and in three Arlington Member samples reflects an increase in transport energy and a westward shift in the strandline.

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East Cameron Block 270, Pleistocene Field

Exploration of the Pliocene-Pleistocene in the Gulf of Mexico since 1970 has resulted in the discovery of significant hydrocarbon reserves. One of the better gas fields has been the Block 270 East Cameron field. Utilization of a coordinated exploration plan with Schlumberger has allowed Pennzoil as operator to develop and put on production the Block 270 field in minimum time.

Block 270 field is a north-south trending faulted nose at 6,000 ft. At "G" sand depth (8,700 ft) the structure has closed, forming an elongated north-south structure with dip in all directions from the Block 270 area. Closure is the result of contemporaneous growth of the east-bounding regional fault.

Structural and stratigraphic interpretations from dipmeters were used to help determine the most favorable offset locations. The producing zones were found to consist of various combinations of barlike, channellike, and distributary-front sands. The sediment source for most of the producing zones was southwest of the area. However, two zones are exceptions and derived sediments from the north through a system of channels parallel with the east-bounding fault.

Computed logs were used to convert conventional logging measurements into a more readily usable form for evaluation. The computed results were used for reserve calculations, reservoir quality determinations, and confirmation of depositional environments as determined from other sources.

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Modern and Ancient Reef Complexes and Associated Limestone Diagenesis of San Andres Island, Colombia

San Andres is a small coralline island 136 km east of the Caribbean coast of Nicaragua. Surface mapping and paleontologic data indicate reefs have been growing actively in the area at least since early Miocene time. Because of the offlap relations of the ancient reef complexes, accessibility of progressively younger rocks is simplified.

Field and laboratory examination of both modern and ancient reef complexes indicates five major bottom facies: (1) forereef flank, (2) reef, (3) backreef platform, (4) backreef lagoon with patch reefs, and (5) shore area. Principal builders of the reefs were *Millepora* and lime-secreting algae with abundant *Acropora, Diploria, Montastrea*, and *Porites*.

From X-ray and petrographic studies of the limestones, a sequence of carbonate diagenesis has been determined for the San Andres area. During early stages of diagenesis, sediments initially are cemented by grain welding and aragonite precipitation between grains. This early type of cementation is most common in the supertidal and intertidal zones. Subsequent calcite cementation occurs by dissolution-precipitation after aragonite. After calcite precipitation, no evidence can be found of the preexisting aragonite cement. Although inversion of aragonite to calcite commonly occurs in grain material, dissolution-precipitation seems to be the major process of cementation.

During the diagenetic sequence, four responses may be expected: (1) magnesium is removed and high-magnesium calcite stabilizes to low-magnesium calcite, (2) aragonite can stabilize to calcite, (3) aragonite may be dissolved, and (4) sediments may become dolomitized. The time required for any of these reactions is variable and depends on the chemical environment. X-ray analyses indicate that all samples older than middle Pleistocene have stabilized to low-magnesium calcite or dolomite. The result of the diagenetic sequence is the development of a low-magnesium calcite limestone, a dolomite, or a combination of the two.

Porosity in the San Andres area is primary, secondary, or occluded and development depends on exposure of carbonate material to a subaerial environment before mineral stabilization occurs.

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Shear Zones in Salt-Dome Stocks Delineate Spines of Movement

Ever since Balk's studies of the 1940s, the idea has been grow-