bly also served as intermittent avenues for migration of sub-fault oil into producing structures above the fault. (*Paschall*)

DICKINSON, KENDELL A., U. S. Geological Survey, Denver, Colo.

PETROLOGY OF BUCKNER MEMBER OF HAVNESVILLE FORMATION IN ADJACENT PARTS OF TEXAS, LOUISI-ANA, AND ARKANSAS

The Buckner Member of the Haynesville Formation is an evaporitic mudstone unit of Late Jurassic age that is present only in the subsurface around the margin of the Gulf Coast embayment. It has been divided informally into two parts, lower and upper.

The most common rock types in the Buckner are nodular anhydritic mudstone and nodular anhydrite. The nodules consist of swirls of lathy anhydrite in a matrix of blocky to anhedral crystals. The mudstone matrix consists of a red or gray non-laminated or poorly laminated mixture of silt and clay minerals. The clay minerals are mostly illite and chlorite. The next most common rock type is light gray crypto- to micrograined laminated anhydrite that is largely confined to the lower part. This type contains scattered minute rounded dolomite grains, clay mineral grains, and fine-grained sand and silt. Some less common rock types in the Buckner are oölitic and detrital limestone, rock salt, micrograined dolomite, and medium-grained dolomite.

The member was deposited around the margin of the Gulf Coast embayment in linear basins. Contemporaneously growing salt-cored anticlines along the seaward margin caused restricted circulation with the open sea. The lower part was deposited mainly in standing bodies of water and the upper part was deposited on a tidal mud flat that was, from time to time, flooded by both marine and non-marine water. The sea generally was regressing during deposition of the Buckner.

Micrograined anhydrite is associated with rock salt and is considered to be primary. Nodular anhydrite is associated with brackish-water fossils and was probably deposited as gypsum.

DIETZ, ROBERT S., Institute for Oceanography, ESSA, Silver Spring, Md.

GEOMORPHIC EVOLUTION OF CONTINENTAL MARGINS

Continental margins are important realms of gas and oil accumulation; 20 per cent of United States production already is offshore. It is necessary, therefore, to try to understand the genesis of continental margins and their subsequent geomorphic evolution. The writer suggests that continental margins are young (generally not older than mid-Mesozoic) and may be classified into two types: (1) accretionary margins caused by the collapse of continental rises and the associated accretion of new fold belts to the continents (Pacific-type); and (2) modified rift scars remaining after continental drift (Atlantic type). Most of the margins around the Atlantic and Indian Oceans are of the latter type but the bulge of Africa and the bight of North America are regarded as Pacific type. One can expect the two types to develop somewhat differently insofar as sedimentary modification and geomorphic evolution are concerned. They are either sites of mountain building and hence uplift, or are subsiding isostatically and accumulating a capping wedge of sediments and a thick continentalrise prism. These two elements (the terrace wedge and

the rise prism) are "living" examples of the miogeosyncline and the eugeosyncline, respectively. Continental-rise prisms probably are petroliferous, but the petroleum is lost through metamorphism when the rise is collapsed into a eugeosyncline; terrace wedges also are petroliferous, and this petroleum is not lost with time because the presence of sial beneath prevents intense metamorphism. In equating terrace wedges with miogeosynclines, it is to be noted that both have a wedge-shape rather than the form of a syncline. This is regarded as a natural consequence of continentalmargin sedimentation. In the search for oil in miogeosynclines, geologists should be aware that they were not closed basins but one-sided "basins" open toward the sea. Thus, instead of basin deposits, one finds mainly those sediments deposited during the prograding and retrograding of paralic-zone sediments.

DILL, ROBERT F., U. S. Navy Electronics Laboratory, San Diego, Calif.

PROCESSES OF SUBMARINE EROSION IN LA JOLLA FAN-VALLEY AND THEIR RELATION TO SEDIMENT-DIS-TRIBUTION PATTERNS

Observations from *Deepstar*, a research submersible, indicate that submarine erosional processes are actively modifying the main channel of La Jolla fan-valley. Internal terraces, slump scars, scour depressions around isolated erratic boulders up to 3 feet across, and a lack of talus deposits at the base of the steep walls of the main channel indicate an over-all downslope movement of the sedimentary fill on slopes of less than 1° in depths to about 4,000 feet. Cobble beds, probably deposited as part of the La Jolla fan in depths greater than 2,000 feet, presently are being eroded. The redistribution of the eroded products is evident in box cores which contain rounded balls of semi-consolidated deep-sea clay in a coarse sand matrix. The patchy distribution of different types of sediment along the axis of the fan-valley indicates that the processes currently active in moving coarse-grained sediment down the canyon were not a continuous event. The occurrence of a 2-4-inch-thick layer of fine-grained silt and day overlying a medium- to coarse-grained sand indicates an abrupt change in the type of sedimentation active in the fan-valley approximately 1,100 years ago

DONAHUE, JACK, Department of Geology and Geography, Queens College, Flushing, N.Y.

DEPOSITIONAL ENVIRONMENTS OF SALEM LIMESTONE (MISSISSIPPIAN) OF SOUTH CENTRAL INDIANA

Five major environments of deposition were present along the outcrop trend of the Salem Limestone in south-central Indiana. These environments are based on lithic and biologic distributions.

Three separate regions existed during deposition of lower and middle Salem sediments. The northern region was restricted, as indicated by the presence of argillaceous, dolomitic, bryozoan calcarenite. This was a shallow sea which connected with the Michigan basin where evaporite deposition was occurring. The central outcrop region was one of open circulation where algal-mollusk and echinoderm-bryozoan sparry calcarenite was deposited. Distribution of the calcarenite indicates a regression toward the south. The Indiana building stone is quarried mainly from this facies. The southern region was the site of extensive large-scale (30 feet of relief) sparry calcarenite sand bars as indicated by the existence of macro-cross-beds. Inter-sand-bar deposits consist of carbonaceous dolosiltite which does not contain skeletal grains. A sample transect from sand-bar crests to inter-bar basins shows a continuous, progressive gradation from sparry calcarenite to dolosiltite.

During deposition of upper Salem sediments, a finegrained calcisphere calcarenite overlapped all three facies described above. This facies was deposited in restricted, shoaling conditions, as indicated by the presence of dolomite, quartz silt, and clay minerals.

The final phase of Salem deposition is represented by a thin but persistent, laminated, argillaceous dolosiltite. Scour-and-fill structures, dolomite rhombs, and a lack of fossil grains indicate that this was an intertidal mud flat deposit comparable with New York Devonian "waterlimes."

DOWDS, JOHN P., Consultant, Oklahoma City, Okla. EXPLORATION DECISION-MAKING: TEN-YEAR FORECAST

AND CASE HISTORY ON ANADARKO SHELF, 1956–1966

An 8,000-square-mile area of the Anadarko basin shelf in Oklahoma and Kansas was studied in 1956 to provide a forecast that hydrocarbons would be found in 50-80 per cent of a series of drilling ventures. Since 1956, more than 1,000 square miles have been proved productive and have been developed with a success ratio in excess of the predicted 50-80 per cent.

Conventional geological and reservoir engineering methods were used, augmented by probability/statistical theory which quantified and codified an exploration strategy to guide in the acquisition of leases. The deterministic versus the probabilistic approach to finding productive hydrocarbons is the problem. Because geology/land/engineering/economics are interrelated and inexact sciences in the oil business, more reliance must be placed on probability and statistics. There is no sharp demarcation between the beginning of one discipline and the beginning of another. The ideas on probability theory that commonly fall into disuse or misuse can be powerful mathematical tools in the search for hydrocarbons.

Geological maps, sections, and intervals are based on the original work. Rock and hydrocarbon distributions are then examined as a practical problem in statistical geometry by information theory, Bayesian methods, and the Laplace law of succession, much as a meteorologist can study cloud and weather patterns.

a meteorologist can study cloud and weather patterns. Regarding engineering, the pressure decline versus cumulative production of the predominantly gas reservoirs can be correlated statistically with the entropy of the shelf by random well sampling, or from wells selected by rigid, fixed patterns.

The economics and conversion to dollars can be figured through time by the amount of gas produced and the price paid by the pipeline companies. Leasehold and drilling costs are further related to the original forecast.

The mathematics serve well to predict the present status of this gigantic gas province from a small amount of data available in 1956. The continuing and expansive development of the reserves is testimony to the integrity of the approach through operations research methods.

DYK, ROBERT, Consultant, London, Eng. EXPLORING NORTH SEA

Exploration for oil and gas in the North Sea has been carried on at a high level since the first licenses were granted in 1964. Several commercial gas fields have been discovered in British waters. The North Sea basin has been a depositional site for potentially productive sediments at different times since the early Carboniferous. Interpretation of seismic data is complicated by variable thicknesses of Permian salt overlying the older productive strata.

- DYMOND, J., Lamont Geological Observatory, Columbia University, New York, N.Y., L. LIDZ, and E. BONATTI, Institute of Marine Science, University of Miami, Miami, Fla.
- Absolute Age, Stratigraphic Correlation, and Mineralogy of Ash Layers in Tertiary Sediments from Atlantic off Florida

Volcanic ash layers were penetrated in three of the sediment cores recovered during 1965 off Florida as part of the JOIDES deep drilling program. The ash in these cores consists of shards of fresh acidic glass with a size distribution centered in the 30-60-micron fraction. In all samples, the ash is in Oligocene strata, as indicated by planktonic Foraminifera such as *Chiloguembelina cubensis, Globoanomalina micra, Globorotalia postcretacea*, and *G. yeguaensis.* Such a fauna is typical of the Vicksburg Group of the United States, and other Oligocene sections in Europe and Africa. Potassium-argon dates of the ashes provide absolute ages for the Oligocene. These JOIDES ash layers appear not to be correlative with ash beds found in the Tertiary Oceanic Formation of Barbados.

- ECHOLS, DOROTHY J., Department of Geology, Washington University, St. Louis, Mo., and AR-THUR E. WEGWEISER, Department of Geology, Edinboro State College, Edinboro, Penn.
- NAKED FORAMINIFERA FROM SHALLOW-WATER EN-VIRONMENTS

Abundant live and dead Foraminifera having different degrees of calcification were found in samples collected in bays, marshes, and lagoons along the northeastern coast of the United States. Live standing crops of uncalcified, "chitin-like" Foraminifera have not been discussed previously in detail, and specific reasons for the occurrence of abundant multi-chambered "chitinous" inner linings have not been postulated.

The bottom sediment at all locations from which a large live standing crop of uncalcified Foraminifera or abundant inner "chitinous" linings was recovered consists of fine silt and clay with abundant fecal pellets and (or) decomposed vegetation. This supports previous observations that low pH conditions are important in the occurrence of these forms.

However, results of the present study make it possible to suggest that the presence of a particularly acid alga which lives in the areas collected may be a specific cause of local lack of calcification in live standing crops of Foraminifera, and that bottomdwelling invertebrates play a significant role in the local environment by consuming calcareous Foraminifera and excreting their "chitinous" linings.

EVERNDEN, J. F., 6621 Wakefield Drive, Alexandria. Va.

RADIOMETRIC DATING OF CENOZOIC EPOCHS

As a result of (1) careful selection of datable samples in close and demonstrable correlation with fossiliferous beds and (2) perfection of radiometric dating techniques, an excellent understanding of the time scale of the Cenozoic epochs has been achieved. This knowledge extends from the base of the Paleocene to