parts of carbonate rocks. Reasonably small samples also can be used to obtain semiquantitative insoluble residue data. The combined procedures yield accurate classifications and descriptions of carbonate sediments. The data are plotted as varying ratios in obtaining curves which are susceptible to visual correlation. These procedures yield common denominators which are applicable equally to surface rocks. They also equate with electric logs so that detailed analysis of all sections is unnecessary.

Reliable correlations generally place considerable dependence on a genetic interpretation of the sediments involved. The data permit some generalizations regarding the origin of carbonate rocks, particularly dolomite, as well as forming a basis for the interpretation of the carbonates in the northern part of the Michigan basin.

A continuous core for beginning the study was available from Grand Traverse County and surface exposures also occur in the northern part of the basin. The core from Carter Oil Company No. 1 Lemcool included all but the top 17 ft of the Niagaran and extended into the Alexandrian. Some rotary samples and surface collections also are being analyzed. In all, approximately 475 analyses are available at the writing of this abstract.

On the basis of the analytical data, subdivision of the subsurface sections into stratigraphic units is possible although this becomes difficult if formations are dolomitized extensively. The process of dolomitization appears to result in unconformity of some of the parameters and implies chemical equilibrium within these rocks so that correlation is more dependent on the residues.

Although the subsurface stratigraphic units appear to correlate with surface stratigraphy, these are not necessarily time correlations in a strict sense. Layers with arenaceous foraminifers do not appear to have equivalence. The petrogenesis of the rocks can be interpreted and facies relations determined but the correlation of time-stratigraphic units, at least in this area, may be an ephemeral concept.

SANFORD, ROBERT M., Hunt International Petroleum Co., Dallas, Tex.

Sarir, Libya: Desert Surprise

The Bunker Hunt-British Petroleum's Sarir oil field of Libya appears to be truly one of the 10 or 12 supergiants of the world. Credited with approximately 12 to 15 billion bbl of in-place oil, it is a water-drive field that could and probably will eventually recover nearly 50 percent of the total oil present. There is a maximum 300-ft oil column and an area of surface closure of 155 sq mi. The field was discovered in November 1961 on a seismograph-defined structure. Development drilling was steady throughout the next 4 yr, and culminated with pipeline, loading terminal, and first actual production in late 1966. The oil reservoir is a Cretaceous sandstone on basement, the oil source being the several hundred feet of overlying marine Cretaceous shale. Structurally, the field is a combination anticline and high fault-block complex within a broad structural low.

There appears to be a good fluid communication throughout the reservoir. Average porosity values are about 18–19 percent and permeability values average several hundred millidarcys, with some 2–3 d streaks. All production is water-free. It is a sweet, sulfur-free oil, though of high paraffin content.

More than 100 wells have been drilled. About 70 are on production; 12 to 14 are waiting on gathering lines; and most of the remainder are observation wells for pressure or fluid control. There has been some decline of reservoir pressure during the first year of production; however, in most of the field a sustained water drive is developing. Individual well-producing capacities range from a few thousand barrels daily up to estimates of 28,000 to 30,000 bbl daily in the best wells. The field went on production at 100,000 bbls daily. This figure rose to 300,000 bbls within the first year. Additional field facilities will permit even greater increases in the future.

SCHMALZ, ROBERT F., Pennsylvania State University, University Park, Pa.

Evaporite Deposition in Deep Water

Reasoning by analogy with modern salinas, most geologists believe that ancient marine evaporite deposits were formed in shallow, slowly subsiding basins in regions of arid or semiarid climate. When this "Salina" model is applied to several well-studied ancient salt deposits, however, inconsistencies arise which suggest the need for an alternative hypothesis.

Sedimentation rates inferred for the Zechstein salts of Germany and the Salina of Michigan appear compatible with temperate rather than arid climates. More significantly, the thickness of evaporite salts in each of these localities requires either extremely rapid subsidence of the evaporite basin or salt deposition during a period of time substantially greater than that permitted by existing stratigraphic control. In addition, the petrography and bromine content of the halite in both basins may be reconciled with the "Salina" model only with great difficulty.

Most of the inconsistencies observed may be overcome by postulating salt deposition in a basin several hundred to several thousand feet deep. A "deep basin" model of evaporite deposition is developed in detail. The model is shown to be both geologically and oceanographically reasonable, and to be consistent with at least part of the depositional history of both Zechstein and Michigan evaporite basins. Direct stratigraphic evidence of deep-water evaporite deposition in the Midland basin is cited in further support of the model.

The Elk Point evaporites of Alberta are examined in the light of the deep basin model, and certain implications of the model for the exploration geologist in this region are developed

SLOSS, L. L., Dept. of Geology, Northwestern University, Evanston, Ill

Simultaneous Evaporite–Carbonate Deposition?

It is widely accepted that carbonates, especially where these give evidence of origin as banks or reefs, and the primary evaporites with which they are associated closely, represent two distinct successive phases of deposition: (1) a stage of carbonate bank or reef deposition under conditions of normal marine circulation, followed by, (2) a time of sulfate and chloride accumulation under conditions of restricted circulation. Examples of the application of this concept are found in the literature and in current discussions of

the Silurian of Michigan, the Middle Devonian of Alberta and Saskatchewan, and the Permian of Germany, among several evaporite-carbonate complexes. Support for the two-stage concept derives from interpretations of physical relations, geochemistry, the ecologic requirements of contributing organisms, the relative rapidity of evaporite deposition, and the assumed time-stratigraphic significance of extrapolated biostratigraphic data.

When the carbonate-first—evaporite-later model is applied to specific cases, at both local and regional scales, there emerge patterns of thickness distribution, water depth, and paleogeography that appear bizarre in view of the epeiric setting of the deposits. Further, demonstrable evaporite-carbonate intertonguing and lateral intergradation require an explanation other than accumulation in two successive, temporally distinct phases.

Consideration of diffusion rates compared with discharge rates required for evaporite deposition leads to the development of a model in which the density stratification of the waters is such as to permit the simultaneous deposition of chlorides and biogenic carbonates, including isolated "pinnacle" reefs, in the same basin, perhaps in close juxtaposition. The concept involved is implicit in several older papers on classic evaporite occurrences. Newer data permit a restatement in more quantitative terms.

STANLEY, THOMAS B., JR., Humble Oil and Refining Co., Oklahoma City, Okla.

VICKSBURG FAULT ZONE, TEXAS

One of the prominent structural features of the Gulf basin of North America is the down-to-basin Vicksburg fault zone. Located in the Rio Grande embayment of south Texas, this tectonic feature has controlled the accumulation of more than 3 billion bbl of oil and 20 trillion cu ft of gas, and it has done so in an effective and efficient manner.

During a period of maximum faulting which coincided with the deposition of petroliferous Oligocene Vicksburg and lower Frio beds, a greatly thickened and downbent, downthrown block was formed. The downbending occurred in a direction opposite to the regional dip, contributing to the formation of anticlinal closures which were present to trap the earliest migration of oil. The paper describes the nature of this trapping mechanism.

STÄUBLE, A. J., AND G. MILIUS, Nederlandse Aardolie Maatschappij, The Hague, Netherlands

GEOLOGY OF GRONINGEN GAS FIELD, NETHERLANDS

The Slochteren No. 1 well discovered in 1959 what is now known as the Groningen gas field in the northern Netherlands. The field is on a culmination of the large, regional Northern Netherlands high which was formed during the late Kimmeric tectonic phase (Late Jurassic-Early Cretaceous). However, there is some evidence that the structure existed as a positive element during earlier periods; *i.e.*, during Triassic and possibly even in late Carboniferous time.

The reservoir overlies unconformably the truncated and strongly faulted coal-bearing Pennsylvanian strata which are considered to form the main source of the Groningen gas. The reservoir consists of fluviatile and eolian sandstone and conglomerate of the Rotliegendes formation (Lower Permian), 300–600 ft thick. These coarse clastics are overlain by a few thousand feet of Permian Zechstein evaporites, notably rock salt and to a lesser extent anhydrite and dolomite, which constitute the very effective reservoir seal. Because of intensive salt movements, the thickness of the overlying Mesozoic and Cenozoic strata ranges from 3,000 ft to more than 6,500 ft.

The field covers an area of 180,000 acres and the reserves presently are estimated at 58 trillion cu ft. Present production potential is 2 Bcf of gas per day from 9 "clusters" of about 6 closely spaced wells each. The favorable reservoir properties of the sandstone allow, at least for the time being, drainage of the field from the structurally highest southern part.

STEVENS, CALVIN H., Dept. of Geology, San Jose State College, San Jose, Calif.

WATER-DEPTH CONTROL OF FUSULINID DISTRIBUTION

Detailed field study of a thin sequence of Middle Pennsylvanian rocks in central Colorado reveals that faunas comprising abundant mature fusulinids lived in water deeper than 40 ft. Juveniles rarely became established in water as shallow as 15 ft, but unfavorable conditions associated with shallow water precluded development to maturity. Absolute depth figures are based on: (1) knowledge of the position of the shore of maximum transgression, (2) knowledge of the form of the surface on which marine beds were deposited, and (3) interpretation that distribution of faunal and floral groups in central Colorado was controlled by depth or by factors directly affected by depth.

STOREY, T. P., Scurry-Rainbow Oil Ltd., Calgary, Alberta

EVAPORITE BASIN CONFIGURATION—STRUCTURAL *versus* SEDIMENTARY INTERPRETATION

This paper presents different interpretations of the structural and/or stratigraphic criteria which are the bases for understanding evaporite-basin sedimentation and its subsequent role in oil exploration.

The gross profile and configuration of Devonian Famennian, Givetian, and Eifelian evaporite basins in North America have induced the *a priori* conclusion that these lenses and wedges are the result of differential sedimentary tectonics with contemporaneous evaporite-carbonate deposition. Such basins are viewed as culminating in uniform subsidence and conformable deposition of superjacent successions—generally of open-marine and nearshore facies.

Although this hypothesis deserves equal consideration with any other as a basis for interpreting evaporite-basin sedimentation, its preponderant acceptance without benefit of local and regional detailed stratigraphic studies hardly endows it with any real validity. In testing, this hypothesis should be examined seriously by the following considerations: (1) Walther's Law of Correlation of Facies demands that an unconformity must be recognized between the evaporites and the overlying transgressive redbed, sand, and/or carbonate succession; (2) related to Walther's Law—contemporaneous carbonate-evaporite deposition generally is impossible; the concept of cyclical superposition is much more rational; and (3) the offset "basin" axes of superjacent successions demand