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.

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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.

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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.

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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.

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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

interdepositional tectonics and not subsidence contemporary with sedimentation.

The above three points support the validity of the concept that the Devonian Famennian, Givetian, and Eifelian evaporite-basin configurations are not simply the result of differential sedimentary tectonics but are mainly eroded structural remnants. Supporting this concept are detailed stratigraphic subdivisions suggesting that these basins or lenses are only remnants of originally much more expansive evaporite depositional regions.

These basins are analogous to structural basins in contemporaneous open-marine sedimentary provinces. Post-depositional epeirogenic movement and vast areal erosion have left thick broad lenses or wedges of evaporite sections—regionally defined as evaporite provinces of deposition.

In searching for hydrocarbon accumulations among structural and stratigraphic traps within the evaporite complex, one has to consider these critical factors—the supra-evaporite basin unconformities and their tectonic origin.

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ANOMALOUS MORROWAN-CHESTERIAN CORRELATIONS IN WESTERN ANADARKO BASIN

Fossils recovered from cores of a thin lignitic shale and a coal in two widely separated wells in the western Anadarko basin show that the shale and coal beds are time-equivalent. Spore-pollen assemblages from the two intervals are identical and indicate a late Morrowan age.

Coal from one well in the western Oklahoma Panhandle is from an interval generally considered as late Morrowan; the lignitic shale from a well near Liberal, Kansas, however, is from rocks widely accepted as early Chesterian—almost Meramecian.

Considering that there is a span of several million years between early Chesterian and late Morrowan, two possible interpretations are presented. Either (1) identical spore-pollen assemblages are not sufficient evidence to distinguish between early Chesterian and late Morrowan or (2) some rocks currently accepted as of Chesterian age in the western Anadarko basin actually are limestone-shale facies of the Morrow Formation, and the relation between Morrowan sandstone-shale and "Chester" limestone-shale would not be one of onlap on an unconformable surface but, instead, a major facies change. In the two wells the interval between the Meramecian St. Genevieve Limestone and the Atokan "13-finger" limestone is nearly equal and analysis of the geologic history of this interval lends support to the facies interpretation. Either interpretation is provocative and could have economic consequences.

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SEDIMENTARY FACIES IN AREA OF MIXED TERRIGENOUS-CARBONATE DEPOSITION, ARLINGTON REEF COMPLEX AND ADJACENT AREAS, NORTHERN GREAT BARRIER REEF

The northern Great Barrier shelf can be divided into 3 major bathymetric zones: (1) the nearshore zone, extending to depths of 5 fm; (2) the inner shelf, extending to depths of 20 fm; and (3) the marginal shelf extending to the shelf edge at 40–50 fm. In the area studied, reef development is concentrated on the inner two thirds of the marginal shelf.

Sedimentary facies in this area reflect three major influences: (1) source (terrigenous and carbonate); (2) hydrography; and (3) relic facies. On the inner shelf, nearshore terrigenous sand is succeeded seaward by dominantly terrigenous mud which transgresses two pre-Recent facies: (1) terrigenous sand in the north and (2) shell gravel in the south. Mixing of pre-Recent sediments, terrigenous mud, and modern carbonates (molluscan and foraminiferal) complicates the basic pattern. Both pre-Recent facies extend to within 1 mi of the reef with no significant dilution by modern reef-derived debris.

Major interreef channels are floored by fine-grained, mixed terrigenous-carbonate sediment. The terrigenous material (30–50 percent) is dominantly silt and clay size. The identifiable, carbonate fraction is composed mainly of planktonic and benthonic Foraminifera, juvenile and larval mollusks, and skeletal debris. Most of this channel-floor sediment apparently is derived either from the inner shelf or from the open ocean; little appears indigenous.

The main reef complex is built on a 16-fm platform, and encloses a central area of about 64 sq mi. Much of the interior platform is covered by low coral growth or by dead coral with a thin cover of worn, broken, and stained skeletal grains, mainly large Foraminifera, *Halimeda,* and coralline algae. Major sediment accumulation occurs only in the lee of the main reef where quiet-water conditions allow the deposition of carbonate mud with up to 18 percent fine terrigenous detritus. The sparse coarse fraction is molluscan, Foraminifera increasing in abundance near the reef. Reef-derived sediment is abundant only on and directly adjacent to the reefs.

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YELLOW BANK, BAHAMAS: A STUDY OF MODERN MARINE CARBONATE LITHIFICATION

An 1,800-sq-mi area of the New Province platform in the Bahamas was studied in an attempt to evaluate an occurrence of modern marine lithification.

Studies of samples collected from the surface and from vertical profiles of modern carbonates have demonstrated the following: (1) facies variations are more pronounced vertically than horizontally; (2) recrystallization cannot be detected in samples as old as 6,700 yr B.P. that are 8 ft below the water-sediment interface; (3) aragonite is the only form of carbonate cement; and (4) lithification appears to be restricted by depth of water between 9 and 16 ft deep, and is absent in water deeper than 19 ft.

In all localities where lithification occurs, water-sediment bioherms are present. Although these bioherms do not extend into the overlying water, they are present in the sediments to a depth of 3 ft below the water-sediment interface.

For paleoecologic data, bioherms in ancient carbonates should be restudied in an attempt to determine if they actually stood above the water-sediment interface as is so commonly pictured.