The slope sediments were sampled at water depths ranging from 667 to 4,777 ft, and in test holes penetrating as much as 1,000 ft of sediment, mostly coccolith-foraminiferal ooze and terrigenous clay. Dolomite is most common in Pleistocene, Pliocene, and some Miocene sediments.

Two general groups of dolomite occur: (1) a northern suite of "ideal" composition, silt-size, abraded and ragged, rhombic dolomite crystals; and (2) a southern suite of calcium-rich, sand-size, euhedral, rhombic dolomite crystals that show no evidences of abrasion or corrosion. Sediments containing the northern suite of dolomite crystals have high percentages of terrigenous clay material; associated dolomite appears to be of detrital origin, and transported to the depositional site together with the clay. The calcium-rich dolomite of the southern suite is interpreted as authigenic and probably formed in water depths similar to present depths. From analysis of interstitial waters, this dolomite probably formed from water similar in composition to normal seawater.

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BREEDLOVE FIELD, MARTIN COUNTY, TEXAS

The Breedlove field is in northwest Martin County, Texas, approximately 30 mi north of Midland. The field is only a few miles east of the axis of the Midland basin and on the east flank of the ancient Tobosa basin. Stratigraphically, the field is northeast of the limit of Devonian carbonate deposition and the Silurian carbonate section (major producing zone in the field) has a maximum thickness of 550 ft near the field and thins north and east toward the margin of Tobosa basin—a result of pre-Woodford erosion and nondeposition. The Silurian section is overlain by the Woodford Shale of Devonian and Early Mississippian ages, has an average thickness of 100–120 ft, and is separated from the underlying Ordovician Montoya Formation by the Sylvan Shale that ranges in thickness from 0 to 10 ft.

The field was discovered in July 1951 with the completion of the Pan American Production Company No. 1 Breedlove. This well, 660 ft from the south and 4,620 ft from the east lines of League 258, Briscoe County School Land Survey, tested (flowing) 2,341 b/d of 40° oil at 60°F through a ¾-in. choke from perforations between 12,078 and 12,118 ft after washing with 600 gal of mud acid. The productive zone is in the upper part of the Silurian.

The Silurian reservoir consists predominantly of white to light-gray, finely to coarsely crystalline dolomite. Production is on an asymmetric anticline which plunges southwest. The accumulation is controlled on the north by a porosity barrier and on the south by the closure of the fold. A stratigraphically controlled, tilted water table is in the field.

Currently, there are 42 wells producing from the Silurian. Through January 1, 1968, these had produced 14,883,391 bbl. Other production in the field includes: (1) Spraberry (6 wells), cumulative production to January 1, 1968, 502,702 bbl; (2) Wolfcamp (2 wells), cumulative production, 41,528 bbl (abd.); and (3) Strawn (1 well), cumulative production, 94,370 bbl (abd.).

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(To be announced)

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PHYLLOID ALGAL BANKS

Phylloid algal banks form reservoir rocks in Upper Pennsylvanian shelf carbonates in many oil provinces of the United States. They are of special exploration interest in the Strawn (Desmoinesian) of West Texas and eastern New Mexico. Furthermore, the quantity of hydrocarbons in major fields which produce from these stratigraphic traps compares favorably with that produced from structural traps.

Phylloid algal banks were studied by the writer. Data were derived from studies of surface and subsurface occurrences of these carbonate buildups. The stratigraphic and regional distribution of these algal banks, their mode of formation, their environmental dependencies, and their synecological associations with other fossil assemblages were studied together with the evaluation of reservoir properties, such as formation and destruction of porosity, log characteristics, production data, and statistics on primary and secondary reserve estimates of major representative fields.

Algal mounds are formed by the sediment-baffling action of leaf-like (*i.e.*, "phylloid") algae of the *Ivanovia* group, a branch of $CaCO_3$-secreting green algae of the family Codiaceae. The dense, pitchy growths of these algae on local shoals on the sea floor form an efficient sediment baffle. Fine-grained carbonate sediment accumulates between the algal blades where it is sheltered from winnowing by wave and current action. This results in the gradual building of a mound-like accumulation of sediment in those places where dense growths of these algae occurred. Thus, these algal mounds are biogenic banks, which, if preserved in the geologic record, would be bioherms and biostromes.

Lithologic and paleontologic evidence indicates that these algal banks preferred shallow-water, wave-sheltered shelf environments in areas of clean carbonate deposition, distant from sources of land-derived clastics. Changes of water depth during transgressive and regressive cycles apparently exercised a sensitive control on the growth of these algae. The most luxuriant growth of these algae is obviously confined to an energy level below wave base, although these algae probably could endure intermittent higher wave action. Whenever the water became too shallow and the algal growths were above wave base, the algal mound development was interrupted. In many places, algal mounds are interbedded with layers of cleanly winnowed, well-sorted calcarenite or oölite.

Phylloid algae have been reported in the United States from areas in southeast Kansas, the Panhandle of Oklahoma, north-central Texas, the eastern shelf of the Midland basin, the northwestern shelf of the Delaware basin, Hueco Mountains, Franklin Mountains, Sacramento Mountains, Robledo Mountains, and the Four Corners area. These phylloid algae range in age from Morrowan to Wolfcampian in the United States, and to early Middle Permian in Europe. The major occurrences of these algal banks in the Permian basin area are in strata of Desmoinesian, Virgilian, and Wolfcampian ages.

In general, algal banks show evidence of a high primary porosity which formed when the highly warped algal blades were piled into a mound having a loose, or open fabric. The presence of such high primary porosity and permeability commonly leads to the development of secondary leaching porosity. Most commonly, the $CaCO_3$ mud matrix between the algal blades is leached. Selective leaching of the algal blades is less common. Recrystallization of the $CaCO_3$ mud matrix also is a common source for secondary porosity development. The combined amounts of primary and secondary porosity and the resulting permeability values may be large. In Greater Aneth field, Four Corners area, porosity values range from 3.5 to 26.2 percent, with an average of 10 percent. Permeability values reach a maximum of 932 md, with an average of 25 md. Estimated primary and secondary petroleum reserves may amount to 500 million bbl.

Porosity destruction is caused primarily by secondary sparry calcite vug filling. Extensive leaching in the upper zones of an algal bank forms solutions which are oversaturated in $CaCO_3$. When these supersaturated solutions percolate downward into the lower zones of the mound, precipitation of sparry calcite commonly begins. A rarer type of porosity destruction is that which results from a total collapse of the algal fabric. A relatively rapid diagenetic hardening of the $CaCO_3$ mud matrix apparently is required to prevent collapse of the algal fabric under the weight of overlying sediment. In some places, anhydrite caused porosity occlusion. In one example, the porosity in a core had been destroyed completely by vug fillings composed of isolated small dolomite rhombohedra.

Synecological fossil assemblages associated with algal mounds or mound-associated facies have different compositions in mounds of different stratigraphic and regional settings. The following groups of fossils were recorded in algal banks: Foraminifera, including ophthalmid and encrusting Foraminifera, and fusulinids, ostracods, fenestellid and fistuliporoid Bryozoa, crinoids, echinoids, gastropods, tetracorals, brachiopods, sponges, *Chaetetes* (tabulate corals), *Komia* (questionable stromatoporoid), *Girvanella* (blue-green algae), and *Ungdarella* (red algae).

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LUMINESCENCE PETROGRAPHY OF SANDSTONES

(No abstract submitted)

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OBSERVATIONS ON SANDSTONE CEMENTATION

Comparative study of Permian and modern caliche, laterite, bauxite, and beach rock have shown that vadose cement, regardless of composition, can be distinguished from cementation below the water table or sediment-water interface.

Phreatic and connate cementation which occurs beneath the water table or sediment-water interface is more coarsely crystalline than vadose cement and is interstice-filling rather than grain-coating. Early carbonate cement precipitated from water-filled voids at shallow depths consists of sparry calcite and may push apart and replace quartz and feldspar to produce "floating" textures. Silica cement occurs as void-filling overgrowths on quartz grains. After deep burial uncemented sand grains become tightly packed, the depositional texture is modified, and late aqueous cement occupies smaller interstices.

The following characteristics and stages of intensity of vadose cementation can be distinguished.

1. *Initial stage.*—The original depositional texture is lost as precipitation of fine-grained evaporitic films of carbonate, iron oxide, or aluminum hydroxide forces the grains apart so that films separate grains at former contact points. Sedimentary structures such as beach laminae and current ripple cross-bedding still may be preserved in this stage.

2. *Intermediate stage.*—"Floating" textures are produced as grains become pushed apart by evaporite cement and by replacement of quartz and feldspar by carbonate. Coalescence of evaporite films around clusters of grains forms small pisolitic concretions. Sedimentary structures become obliterated or greatly obscured.

3. *Late stage.*—Extreme floating textures and large composite pisolites form by addition of more cement and replacement of quartz and feldspar. Brecciated caliche anticlines (also known as teepee structures) are formed by expansion resulting from the addition of large volumes of carbonate cement.

Extreme caution must be employed in interpreting the genetic significance of rocks classified as sandy micrite, wackestone, and boundstone or biolithite. Transformation of quartzose sand into sandy carbonate, consisting of up to 90% fine-grained carbonate (micrite) which commonly is pisolitic (strongly resembling algal boundstone), is well documented by numerous examples. Similarly, accumulations of oöliths, clasts, skeletal fragments, pellets, and calcarenaceous material may be transformed into rocks which could be identified as oömicrite, intramicrite, biomicrite, pelmicrite, wackestone, and boundstone or biolithite (pisolitic) by vadose processes (calichefication).

Many so-called oölitic iron ores represent vadose concentrations of iron oxide and hydroxide.

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CANADIAN (EARLY ORDOVICIAN) EL PASO GROUP, SOUTHERN FRANKLIN MOUNTAINS, EL PASO COUNTY, TEXAS

The El Paso Group and at least the upper part of the underlying Bliss Sandstone at their type sections in the southeastern Franklin Mountains probably is the most complete Canadian section exposed in northern Chihuahua, New Mexico, and west Texas.

The El Paso Group represents deposits of a general, but complex, west-to-east transgression of the Cambrian and Early Ordovician seas across Arizona, New Mexico, and west Texas. The group thins to a featheredge in central New Mexico as a result of post-Canadian erosion of the upper part of the sequence.

Flower (1964) has given 10 formational names for the El Paso Group that represent not only rock-stratigraphic units, but also distinct sequential biostratigraphic units.

Seven of these El Paso Group units are regional in extent and recognizable in the southern Franklin Mountains. They are (in order from oldest to youngest): the early Canadian Sierrite Formation; the middle Canadian Cooks, Victorio Hills, and Jose Formations; and the late Canadian McKelligon Canyon, Scenic Drive, and Florida Mountains Formations. The basal middle Canadian Big Hatchet Formation may be present and unrecognized because of facies changes in the southern Franklin Mountains area. The uppermost middle Canadian Mud Springs Mountain and Snake Hills Formations are believed to be absent because of nondeposition or erosion.

The El Paso Group overlies the Bliss Sandstone disconformably. The Late Ordovician Montoya Group overlies the El Paso Group with a regional angular unconformity in the west Texas-New Mexico area. The