Early Pennsylvanian sea transgressed. Its contours parallel paleostrike and ancient shoreline positions. Wells within a narrow 20-ft interval of this map penetrated a thin sand at the base of the basal Bend shale. These sandstones form elongate, lenticular bodies that parallel isopach contours and an ancient shoreline.

This critical isopach interval is interpreted as representing the depositional strike of a coastal marine bar system developed during a stillstand of the encroaching Early Pennsylvanian sea. These small, narrow bars are beyond the resolution of the sparse well control in the study area. Superimposition of known basal Bend bars on the basal Bend shale isopach, however, allows the projection of these narrow stratigraphic traps along an ancient shoreline into undrilled prospective areas.

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Stratigraphy of Eagle Ford Group (Upper Cretaceous) in East Texas Basin

The Eagle Ford Group of the Upper Cretaceous Gulfian Series is one of the most stratigraphically complex terrigenous units in the East Texas basin. At the type locality in Dallas County, Texas, the Eagle Ford consists of bluish-black, carbonaceous sediments exceeding 400 ft in thickness. In this area, the Eagle Ford includes the Tarrant, 15-20 ft of brownish-gray calcareous sandstone, the Britton, 250-300 ft of interbedded brown calcareous mudstone, and the Arcadia Park, 100-200 ft of dark gray calcareous mudstone.

Eastward into the basin, the Eagle Ford thickens to 500 ft as the upper Eagle Ford acquires 100 ft of Lake Crockett terrigenous clastics on top of the Arcadia Park. Westward out of the basin, the Eagle Ford thins by truncation and changes lithologic character; consequently the previously named subdivisions are no longer recognizable. Near Waco, the lower Eagle Ford consists of mostly montmorillonitic clays with disseminated calcium carbonate, called the Lake Waco Formation, and the upper Eagle Ford consists of dark gray, blocky shales, named the South Bosque Formation. The upper 30-50 ft of the South Bosque is completely noncalcareous. In the deepest portions of the basin near the Cretaceous continental margin, 150-200 ft of Eagle Ford and Woodbine are underlain by the Buda Limestone and overlain by the Austin Chalk.

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A Geochemical Strategy for Identifying Lower Paleozoic "Source" Units, Using Ellenburger Group of West Texas as a Case Study

Lower Paleozoic reservoir rocks generally have a predominantly carbonate lithology and are singularly lacking in organically rich dark shales. Attempts to trace the source for many such deposits have proven to be difficult because of the absence of routine techniques normally used in source rock evaluation. A good example is the occurrence of hydrocarbons in the Lower Ordovician carbonate strata of the Ellenburger Group. Very little information is available on the nature of the source rocks involved in generating the hydrocarbons found in the Ellenburger. One viewpoint remains untested, namely, that these hydrocarbons have been generated within the fine-grained carbonates of the lower Ellenburger rocks themselves and trapped in the upper porous portions of the formation. Several factors may be responsible for not accepting this hypothesis. Three of these are the following. (1) Do carbonates make good source rocks? Carbonates with algal or sapropelic matter make excellent source rocks; it also appears that the total organic carbon values of carbonates in ancient rocks could be as low as 0.2% for adequate generation. (2) With vitrinite absent, how can organic maturation in lower Paleozoic rocks be determined? Conodonts and acritarchs, as well as sapropelic organic matter, can be used to determine maturation with considerable accuracy. (3) Could hydrocarbons generate in rocks as old as the early Paleozoic and situated at great depths? Drilled data from several regions of the world support this viewpoint.

Recent field and theoretical considerations suggest that the source units for the majority of the lower Paleozoic hydrocarbon occurrences in carbonates, including those of the Ellenburger, are fine-grained carbonates, which are frequently in contact with the productive zones.

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Depositional Systems and Stratigraphic Relationships of Strawn Group (Pennsylvanian), Colorado River Valley, Central Texas

The Strawn Group (late Atokan-early Missourian) comprises a thick sequence of terrigenous clastic and carbonate facies that crop out in central Texas in two roughly triangular areas separated by Cretaceous overlap. The exposures in the Brazos River valley have been studied in detail and interpreted as fluvial, deltaic, and shallow marine deposits. The Strawn Group of the Colorado River valley has been cited in the literature, but little detailed work regarding subdivision or interpretation has been done.

The Strawn Group exposed in the Colorado River valley can be informally subdivided into two general stratigraphic units. The lower Strawn represents submarine fan and basin depositional systems that prograded southwestward. At least two but possibly several cycles of fan progradation are recognizable based on vertical succession of distal to more proximal middle-fan facies associations. In marked contrast, the upper Strawn represents three regressive and transgressive cycles of typical Pennsylvanian deltaic, perideltaic, and shallow submarine depositional systems.

Stratigraphic relationships of the Strawn Group are complex and reflect changes in the evolving Ouachita foldbelt and its associated tectonic features. The lower Strawn occurs only in the Fort Worth basin and apparently was deposited with a clinoformal relationship to the underlying basinal Smithwick Shale. It records foreland basin subsidence and regional block faulting synchronous with orogenesis. As active tectonic subsidence shifted westward, upper Strawn deltaic systems prograded to the west, onlapped the Concho platform, and truncated older units particularly on horst blocks. In the southeastern portion of the Concho platform, the overlying Canyon Group completely onlaps the Strawn Group and rests unconformably on the Marble Falls Limestone.

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Depositional Trends in Carbonate-Dominated and Clastic-Dominated Late Pennsylvanian Cycles in North Texas

Late Pennsylvanian cycles with thin, carbonate-dominated transgressive sequences and thick clastic-dominated regressive sequences have been considered the norm for cyclic sequences in north Texas, but they represent only a special case associated with higher rates of clastic sedimentation prevailing during falling sea levels. There are many cycles with carbonates in regressive as well as transgressive portions of cycles. Completely exposed cycles usually begin on an exposure surface and, between the exposure surface and the transgressive carbonate, have a thin clastic sequence showing upward change to normal marine conditions. Transgressive carbonates generally contain large amounts of clay muds and quartzose silts. The transgressive sequence culminates in a deeper water, dark-colored phosphatic shale. The regressive sequence is thicker, begins with a richly fossiliferous offshore marine shale, and continues upward into either limestone or sand-dominated sediments. Regressive limestones tend to be thicker and composed of more pure carbonate than transgressive ones, and to be capped with shoal calcarenites. These usually are overlain by nonmarine clastics, which may contain redbed layers, and a paleosol horizon at the top. In clastic-dominated regressive sequences, the offshore marine shales are overlain by an interval with upward-increasing sand content, and are capped by nonmarine deposits. Carbonate deposition in these cycles occurred only within a limited range of water depths. These cycles are similar to mid-continent cyclothems, and support the case for allogenic control and major fluctuations in sea level during cycle deposition.

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Depositional Environments and Facies Distribution of Millican Carbonate Buildup, Coke County, Texas

Millican field, located in northwest Coke County, Texas, is part of an extensive trend of Pennsylvanian carbonate buildups that exists on the flanks of the Midland basin, just seaward of the shelf edge. The Millican buildup is 900+ ft thick and is primarily a bank deposit composed of mud-baffling organisms.

Four cored wells in a section from the front to the back of the buildup were chosen for detailed study. Fusulinid-age dating of the cores shows a major unconformity dividing the Millican buildup. Primarily, the buildup is of early Missourian age except for its pinnacle which is of early Virgilian age. Eight limestone facies were also recognized across the buildup. Labeled according to their distinctive components, they are: (1) crinoidal, (2) foraminiferal, (3) bryozoan, (4) mollusk-phylloid algal, (5) peloidal, (6) foraminiferal-fusulinid, (7) high energy (intraclastic and/or oolitic), and (8) blue-green algal. From the facies distribution across the buildup, a depositional model can be formed.

Porosity development within the Millican buildup is also facies controlled. Virtually no primary porosity exists, and the majority of secondary porosity generation occurs in rocks that are almost entirely composed of phylloid algae and mollusks. This understanding of the facies, environments, and diagenesis across the Millican buildup should be an important tool in exploring for similar and more subtle traps.

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Late Abstract

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Perspectives on World-Class Carbonate Petroleum Reservoirs

A synthesis of geologic attributes and reservoir properties is provided for 41 carbonate petroleum fields. From throughout the world, 55 scientists developed detailed case studies of carbonate reservoirs ranging in age from Ordovician to Miocene and in size from 1.7×10^3 to 32.0×10^9 bbl initial oil in place (IOIP).

The objective was to focus on the detailed depositional and diagenetic history of a significant number of carbonate reservoirs, and secondarily to characterize their petrophysical evolution and reservoir volumetrics. An attempt was made to develop a complete "anatomy" of each field, which includes among many other attributes: regional paleosetting, tectonics, entrapping facies, source rocks, reservoir dimensions, and fluid data.

Using a chronological arrangement, broad trends through time become evident. A progression of reservoir types occurs through the Phanerozoic, from peritidal and subaerially exposed facies in Paleozoic examples, through a long-term sequence of shallow-shelf sands and reefs, to relatively deep-marine facies in the Cretaceous and Tertiary. These last range from periplatform debris flows to deep-shelf pelagic chalks and deep-basinal mixed lithofacies that have been diagenetically altered, mainly to dolomite. No trends are seen, however, in the occurrence of pinnacle or other reefs through the Phanerozoic.

Many of the largest fields occur in Tertiary mobile belts and other regions affected by Tertiary tectonics, principally in carbonates of Cretaceous to Miocene age. Furthermore, at least nine of the largest fields owe their reservoir productivity largely to fracturing, and at least ten smaller fields involve some fracturing.

In contrast, the great number and diversity of reservoirs of shallow-epeiric, platform, peritidal, and sabkha origins are also evident, with reserves between 70 and 700×10^6 bbl IOIP. Shallow reef-mound, atoll, or pinnacle reef fields of large magnitude, all in carbonates of phototropic, warm-water, marine origin, are common over structures, particulary those related to subjacent salt diapirs. Non-salt-supported shallow shelves and reefs have smaller fields of less than 200×10^6 bbl IOIP.

Future requirements include much more knowledge about (1) the extent, diversity, and recognition of deep-marine carbonates; (2) the frequency, size, orientation, and contribution to reservoir productivity of fractures; and (3) a large information base, generated by postmortem studies of the vast number of reservoirs which are destined to become candidates for supplemental recovery methods.