Phase III is characterized by changes in rock fabric rather than mineralogy. Fractures and vugs that have developed through the Holocene epoch have been partially filled by bladed to micritic calcite cements that were precipitated in the meteoric phreatic and vadose zones.

Present-day values of some elements, notably Sr, in calcite cements and micrite are relatively low but do reflect original mineralogy. Higher Sr values within internal sediments (micrite), backreef micrite, and recrystallized mollusk fragments indicate an original high-Sr aragonite mineralogy. In addition, lower permeabilities of micrite prevented effective removal or flushing of Sr from the rocks by the modern ground-water system.

All the early fresh-water diagenetic features at Pipe Creek are thought to have evolved during burial. The small amount of diagenesis is attributed to subaerial exposure during deposition only affected perireef lime grainstones. Because of pervasive submarine diagenesis, reef beds appear to have much lower permeability than adjacent grainstones, although vuggy porosity is well-developed in the reefs. Many features in Cretaceous rudist reefs that have been attributed to syndepositional meteoric water diagenesis may have been developed during burial. Waters responsible for diagenesis may have flowed downdip from emergent land areas, or in an updip direction preceding or in conjunction with hydrocarbon migration.

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CARBON AND OXYGEN ISOTOPIC EVOLUTION OF WHOLE ROCK AND CEMENTS FROM THE STUART CITY TREND (LOWER CRETACEOUS, SOUTH-CENTRAL TEXAS)

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ABSTRACT

The Stuard City Trend consists of a shelf-margin buildup of Middle Cretaceous carbonates, now buried to depths of 10,000 to 18,000 ft in south central Texas. Whole rock analyses of 92 samples from 16 wells along a 250 mile stike section show a δO^{18} range of -5.9o/oo to -2.7o/oo and a δC^{13} range of -.7o/oo to +5.1o/oo relative to PDB. Oxygen isotopes become lighter toward the southwest. Whole rock values of δc^{13} indicate that vadose diagenesis was not volumetrically important.

Individual cements were also analyzed. The two predominate cement sequences are: 1) fibrous crust, 2) inclusion-rich radiaxial, and 3) clear spar; or 1) fibrous crust, 2) inclusion-rich spar, 3) clear spar. Inclusion-rich radiaxial cements show δ O^{18} values closely grouped about a mean of -2.6o/oo PDB and δC^{13} values between -29.1o/oo to +3.2o/oo PDB. Inclusion-rich spar cements likewise show δO^{18} values closely grouped about the mean of -2.8o/oo PDB and δC^{13} values ranging from -7.4o/oo to +3.8o/oo PDB. In contrast, the clear blocky spars exhibit a wider range of O^{18} values, from -6.6o/oo to -2.3o/oo with a mean of -5.2o/oo PDB; δC^{13} values range from -5.5o/oo to +4.5o/oo PDB. No significant isotopic differences were observed in the final generation of clear blocky spar cement, between depths of 10,300 and 20,400 ft.

The whole rock and cements are not in oxygen isotopic equilibrium with sampled formation fluids. Individual cements maintain an isotopic memory of successive cementation events during burial.

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DIAGENETIC PATTERNS OF THE AUSTIN GROUP AND THEIR CONTROL OF PETROLEUM POTENTIAL

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ABSTRACT

The chalk of the Austin Group shows striking regional variations in porosity, permeability, and trace element and isotopic geochemistry. Porosities and permeabilities are highest across the San Marcos arch, where average values of 15 to 30 percent porosity and 0.5 to 5 md (millidarcies) matrix permeability are measured. These values decrease slightly to the north (into the northeast Texas embayment). In northern Mexico, the Austin and its equivalents have about 3 to 8 percent porosity and permeabilities of 0.01 md or less. Porosity and permeability also decrease in downdip sections of the Austin when traced from outcrop to about 4,500 m deep.

The geochemical properties follow similar trends. Outcrop studies show that samples from the San Marcos arch and Sabine uplift have bulk oxygen isotopic values in the range of -2.7 to -4.0 per mil (relative to PDB). In the Rio Grande embayment of south Texas and northern Mexico, these values have shifted to -5.0 to -7.0 per mil, whereas in the northeast Texas embayment they range from -3.5 to -5.0 per mil. In downdip sections near the San Marcos arch, the oxygen isotopic values shift from about -2.8 at the surface to about -8.0 at 4,500 m. Average Sr trace element values for the Austin Group on the San Marcos arch are 350 to 975 ppm, whereas in the Rio Grande embayment and the northeast Texas embayment, they range from 950 to 1,775 ppm.

All chalk undergoes both mechanical and chemical compaction (pressure solution and reprecipitation) when subjected to sufficient differential stress. This stress is generally induced by addition of overburden but can also be influenced by tectonic stresses and pore-fluid pressures. The presence of fresh (Mg-poor) water in chalk, in conjunction with elevated differential stress has been shown, both theoretically and in nature, to accelerate chemical compaction greatly. Thus, the lateral and downdip variations in the petrophysical and geochemical properties of the chalk of the Austin Group presumably reflect differences in original thickness of overburden or proximity to zones of major deformation. The noted reduction in porosity between the San Marcos arch and the Rio Grande embayment could have been produced, in the presence of Mg-poor fluids, by about 500 m difference in maximum overburden between the two areas. Greater overburden differences would have been required had marine (or other Mg-rich) pore fluids been present; less overburden difference would have been needed if differential tectonic stresses were important.

The isotopic and trace element values listed previously are compatible with these conclusions but do not uniquely distinguish among the possible explanations. The smooth shift of isotopic values, as a function of present burial depth in downdip sections and of probably paleoburial depths in lateral outcrop sections, indicates that maximum burial depth is the critical factor in porosity loss or retention. Only the *rate* of porosity loss is affected by water chemistry. Carbon isotopic analyses also rule out vadose diagenesis as having influenced porosity reduction in the Austin to any significant degree.

Oil production from the Austin Group is concentrated in the areas of the San Marcos arch and the Sabine uplift in a belt that is parallel to the outcrop trend and that ranges in depth from 200 to 2,000 m. Cumulative production from all fields in the Austin Group in Texas totals about 25 million barrels (as of January 1976). Production of oil and gas from chalks other than the Austin has been significant both on the sabine uplift and from areas on the eastern side of the Mississippi embayment. Some of these reservoirs, however, may include sandy, calcarenitic, or other impure chalks.

Wells completed in the Austin have a long history of production at rates far lower than initial production. Indeed, the initial discovery well of the Pearsall field, drilled in 1936, was still producing at a rate of more than 200 barrels per month as of 1976. Most recently drilled Austin wells have initial production rates of 200 to 500 bbls of oil per day, which decline within months to about 40 bbls per day. These production histories indicate that most oil production from the Austin is from fractures. Yet, the concentration of production in areas of least diagenetic alteration, in association with the long histories of slow production, indicate that extended production is probably the result of very slow drainage of oil from the rock matrix. Artificial fracturing, a completion method used on virtually all current Austin wells, enhances both initial and long-term production by allowing shorter drainage paths through a larger number of fractures.

The best future oil and gas discoveries in the Austin and equivalent lithologies will probably be concentrated in three types of areas:

(a) where the chalks may have had any type of pore fluid but have not been deeply buried (that is, between 0 and 2,000 m);
(b) where marine pore fluids were retained and fresh water was excluded. In such areas, significant matrix porosity can be retained to as much as 3,000 m deep;
(c) where abnormally high pore fluid pressures have reduced effective compressive stresses. Under this condition, burial depth is no longer the controlling factor in porosity loss, and porous chalks can be found at depths from 0 to greater than 4,000 m.

Other production may come from areas that have low matrix porosity but intense fracturing (as along sharp flexures or faults) or from areas of abnormal lithology (e.g., bioherms, intrusive volcanic rocks, calcarenites).

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LOWER CRETACEOUS DEPOSITIONAL SYSTEMS, WEST TEXAS

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ABSTRACT

Two surface stratigraphic cross sections of Lower Cretaceous rocks in West Texas contain four depositional systems: coastal plain, carbonate shelf, platform-shelf margin, and shelf basin. These systems consist of lithofacies, megafossil paleocommunities, and palynomorph assemblages that represent specific environments. The vertical succession of deeper and shallower, or low- and high-energy facies indicates depocenter cycles of subsidence and progradation. The diversity and abundance of palynomorph morphotypes seem to be reliable environmental tools because they vary with other environmental indicators.