EVENING MEETING—SEPTEMBER 14, 1981

JEFF DRAVIS—Biographical Sketch

Jeff Dravis received his BS in Geology from St. Mary's University, San Antonio, Texas in 1971 and his MS in Marine Geology from the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences in 1977. His Master's thesis delineated Holocene sedimentary facies and diagenetic trends across Eleuthera Bank, a high-energy Bahamian Platform.

In 1976, Jeff entered Rice University to pursue a doctorate in geology. His dissertation concentrated on the sedimentology and diagenesis of the Austin Chalk Formation in south Texas and northern Mexico. In January, 1979, Dr. Dravis began his professional career with Exxon Production Research Company in Houston where he is currently a senior research geologist. His major research interests are Mesozoic and Paleozoic carbonate reservoirs.

DEPOSITIONAL SETTING AND POROSITY EVOLUTION OF THE UPPER CRETACEOUS AUSTIN CHALK FORMATION SOUTH-CENTRAL TEXAS (Abstract)

The Austin Chalk Formation in south-central Texas represents an "impure" depositional chalk deposited within an environmental framework characterized by distinct paleobathymetric variations. Relatively shallow-water, highly fossiliferous chalks containing appreciable quantities of aragonitic material were generated on a platform coincident with the ancestral San Marcos Arch. Deeper-water basinal settings off this platform, areas of more typical chalk deposition, periodically received influxes of adjacent platform sediments. Primary mineralogies resulting from this unique depositional system are, in part, responsible for the diagenetic history and porosity evolution of the Austin Chalk.

Austin Chalk ranges in age from Coniacian to Santonian. Formation thicknesses range from less than 100 feet to 600 feet in outcrop and several hundred feet up to 1000 feet in the subsurface of Texas. The San Marcos Arch is a structural extension off the Llano Uplift in central Texas and served as a paleotopographic high during most of the Cretaceous. Its influence on Austin Chalk deposition is noted by the abrupt thinning of sediments from the ancestral Gulf of Mexico onto the arch and by documented distinct lithological variations across it.

The Austin Chalk Formation is ideal for systematically evaluating chalk diagenesis and porosity evolution because of its unique depositional setting and variations in burial depth across the trend. This study is based both on outcrop and eleven core studies in south Texas as well as outcrop studies in southwest Texas and northern Mexico. This regional approach places the Austin Chalk's depositional setting into perspective, permitting a more accurate evaluation of its diagenetic history.

Overall, the Austin Chalk is a highly fossiliferous detrital chalk. It is composed of a distinct planktonic microfossil assemblage (chiefly foraminifera and calcispheres) and finer nannofossils (coccoliths) which comprise much of the chalk's micritic matrix. These stable low magnesium calcite constituents are the principal components of typical chalk sequences. The Austin Chalk also contains a notable coarser benthic fauna dominated by molluscs, echinoderms and foraminifera. Abundant primary aragonitic constituents in the Austin Chalk are atypical for a detrital chalk. Texturally, the Austin Chalk is a skeletal wackestone to packstone; mudstones are rare.

In south-central Texas, Austin Chalk lithologies are highly variable and related to depositional setting. Two broad depositional environments can be recognized: (1) a relatively shallow-water platform (shelf) corresponding to the ancestral San Marcos Arch in the Austin-San Antonio area and (2) a relatively deeper-water, more basinal environment away from the shelf toward the ancestral Gulf of Mexico (Figure 1). Transition from shelf to basin is very gradual as indicated by the absence of sharp lateral facies changes and probably represents a carbonate ramp system.

Relatively shallower-water Austin Chalk shelf sediments are light-colored and contain an abundant and diverse macrofaunal assemblage in addition to typical chalk components (planktonic microfossils and nannofossils). Many of these coarser skeletal constituents were originally aragonitic. These deposits also lack rhythmic bedding, a striking contrast to the deeper-water part of the trend in southwest Texas and northern Mexico where monotonous rhythmic bedding is extremely well developed. Large oyster bioherms and calcisponges are quite common in these outcropping deposits and much of the coarser skeletal fraction has been highly biocorroded. Finally, these sediments are dominated by a distinct shallow-water trace fossil, *Thalassinoides*.

In contrast to the shelfal sediments, the more basinal deposits exhibit more color variability and generally are darker. Bedding is more rhythmic but poorly developed. These sediments lack the abundant and diverse macrofaunal assemblage present in shelf sediments except at scattered intervals. These intervals are interpreted as allochthonous debris flows or partial turbidite sequences of shallower-water sediment transported off the shelf into more basinal settings. A distinctive deeper-water trace fossil assemblage dominated by *Planolites, Chondrites* and ring burrows is common in these more basinal chalks.

Consideration of these sedimentary parameters collectively indicates the shelf chalk sediments were deposited above wave base in waters a few tens of meters deep or less. Off the San Marcos Arch, water progressively deepened toward the ancestral Gulf of Mexico. The subsurface, more basinal chalks here were deposited in waters ranging in depths from tens of meters to a hundred meters or less. Periodically, the shallower-water shelf sediments were transported into deeper-water areas of the trend.

Recognition of the depositional setting provides an important framework for evaluating Austin Chalk diagenesis and porosity evolution across the trend in south-central Texas. Further, it helps explain how the initially high porosities (70-80%) of this fine-grained deposit have been reduced to the low values observed today.

Relatively shallow-water Austin Chalk sediments outcropping in the Austin-San Antonio area average 20% porosity and 0.3 millidarcies permeability but have never been deeply buried. Porosity reduction is attributed to early physical

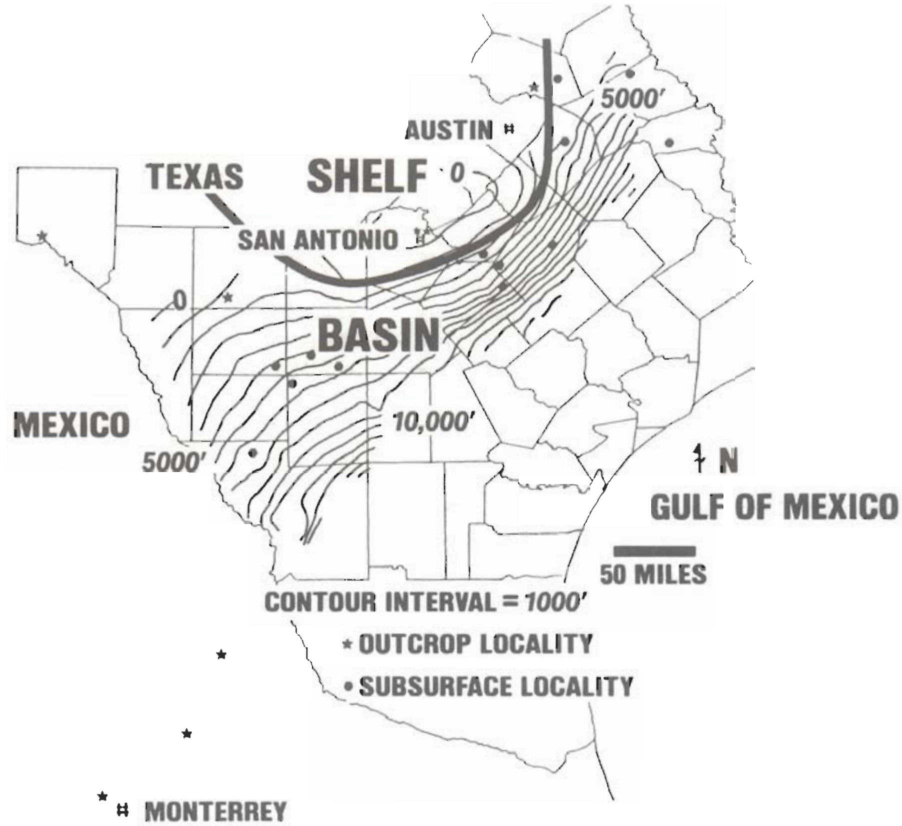

Figure 1. Depositional environments for the Upper Cretaceous Austin Chalk Formation in south-central Texas and northern Mexico. Coarse, highly fossiliferous chalks containing appreciable amounts of aragonitic material were deposited on the shallow-water shelf. Periodically, these sediments were transported basinward.

compaction (dewatering) followed by exposure to fresh water and dissolution of abundant aragonitic skeletal grains. Intimately related to this dissolution was a cementation event which occluded primary intraparticle porosity in microfossils, secondary moldic porosity, as well as fine microporosity in the micritic matrix. Cements are non-ferroan calcites. Relatively low bulk iron (average 370ppm) and strontium (average 620ppm) concentrations resulted from this diagenesis and support petrographic evidence for fresh water diagenesis.

Deeper-water, more basinal buried Austin Chalk sediments exhibit porosities ranging from less than a few percent to about 16%. Permeabilities are usually less than 0.05 millidarcies and in many cases, less than 0.01 millidarcies. These values are derived from cores obtained between present-day depths of 1,000-7,500 feet. The oil-productive Austin Chalk averages about 5% porosity.

Porosity reduction in the Austin Chalk subsurface trend is attributed to three diagenetic processes: (1) early physical compaction (dewatering); (2) cementation related to the stabilization of aragonitic material (where present) during burial; and (3) pervasive pressure solution and concomitant cementation. There is no evidence of fresh water diagenesis.

Early physical compaction can account for a 20-30% porosity reduction simply by expelling pore fluids. As burial proceeds and ambient temperatures rise, any aragonite in the system can be expected to convert to stable low magnesium calcite, prior to the onset of pressure solution. In most cases, this transformation involves dissolution of aragonitic skeletons, creation of moldic porosity and generation of calcite cement. Because the conversion of aragonite to calcite involves over an 8% volume increase, this diagenetic process can play a significant role in occluding the chalk's porosity, depending, of course, on the abundance of aragonitic material. In some deposits, cementation related to stabilization of aragonite created a lithified sediment framework sufficiently rigid to retard later porosity loss by pressure solution.

The major diagenetic process responsible for porosity reduction in the subsurface Austin Chalk trend is pervasive pressure solution and associated cementation. Well-developed stylolites, extensive interpenetration of grains and numerous wispy microstylolites document the large amount of pressure solution these deposits have been subjected to. The latter structures are the most common expression of pressure solution in the buried Austin Chalk. Wispy microstylolitic seams are not primary clay laminae contorted by compaction but are diagenetic seams along which carbonate material dissolves. These seams are composed of insoluble material, chiefly pyrite and organic matter.

Calcium carbonate released by pressure dissolution is believed to reprecipitate locally as cement. Cements in these buried chalks are predominantly calcites and often are ferroan-rich. They occlude any remaining coarser primary intraparticle or secondary moldic porosity. More importantly, from a reservoir quality standpoint, much of the microporosity in the micritic matrices of these deposits is filled by micron-to submicron-sized overgrowth cements which precipitate on remaining matrix components. Preserved porosity in the buried Austin Chalk is dominantly microporosity. Relatively higher bulk iron (average 900ppm) and strontium (average 1000ppm) concentrations resulted from this burial diagenesis.

With progressive burial diagenesis, the Austin Chalk overall shows a decrease in porosity, an increase in the

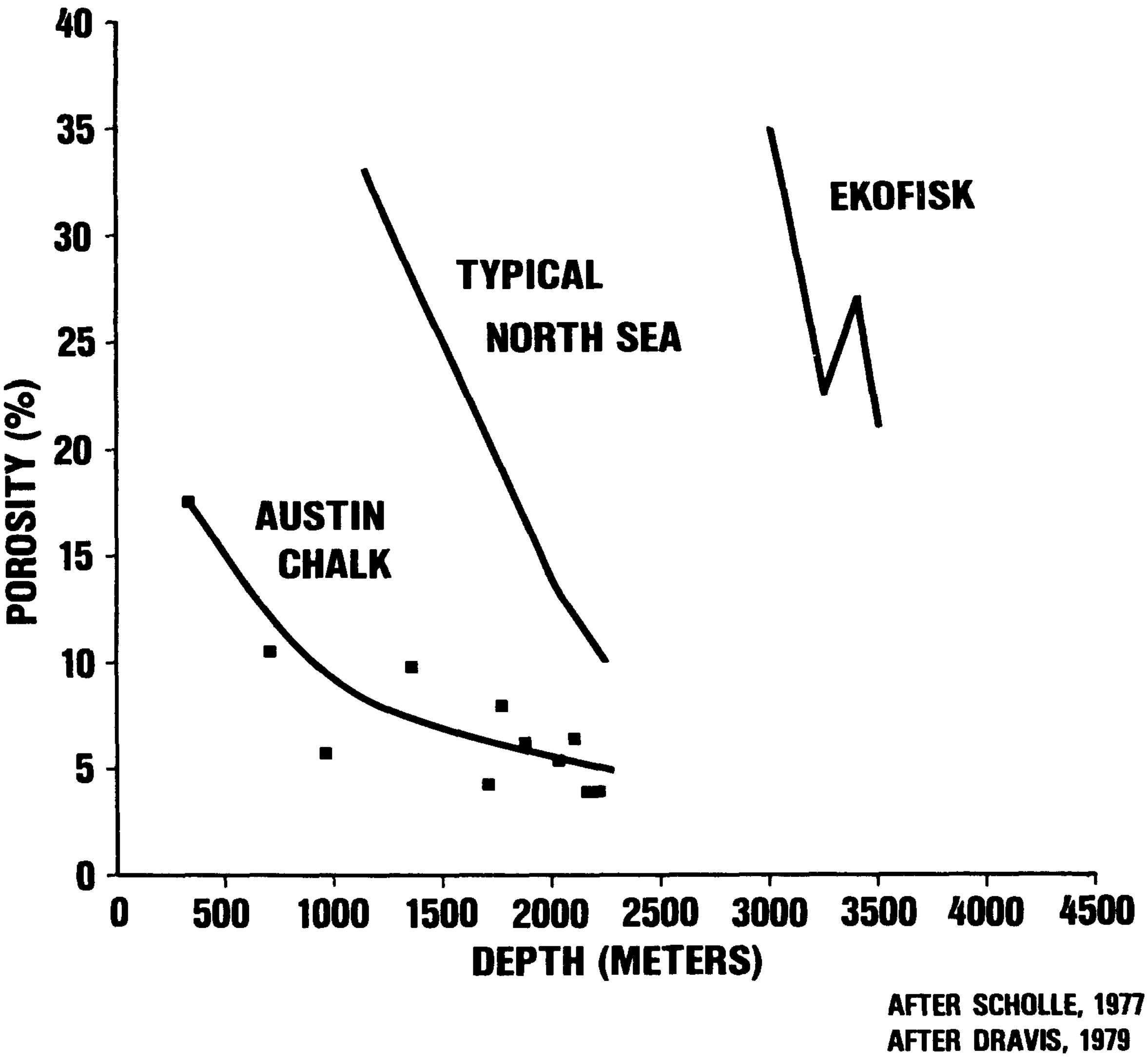

Figure 2. Plot of porosity versus depth for the buried Austin Chalk of south central Texas and North Sea Chalks. Porosity in the Austin Chalk was lost relatively quickly earlier in its burial history and at shallower burial depths compared with typical normally pressured North Sea Chalks. Ekofisk chalks are overpressured. Squares represent mean porosity values for eleven Austin Chalk cores analyzed. North Sea Chalk data is from Scholle, 1977.

alteration of micritic matrix fabrics and depletion of oxygen-18. As the fine-grained, coccolith-bearing micritic matrix is progressively buried, primary coccoliths are gradually obliterated by pressure solution and microporosity is reduced by micron-sized overgrowth calcite cements. The general trend is for the deeply buried chalks to preserve relatively little (if any) coccolith material in the micritic matrix while retaining only very low microporosities. As a reflection of this diagenetic trend with burial, oxygen-18 is depleted from the system and bulk δO_{18} values become progressively lighter with increasing burial. Anomalous porosity and δO_{18} values do exist for deposits at similar burial depths, however. This fact implies that processes other than burial depth alone can influence Austin Chalk diagenesis and porosity evolution.

Porosity and geochemical trends support petrographic evidence that the Austin Chalk underwent a greater degree of diagenesis than did European and North Sea Chalks of similar age. Porosity in the buried Austin Chalk was destroyed earlier in its burial history and at shallower depths relative to typical North Sea Chalks (Figure 2). This porosity evolution reflects the Austin Chalk's primary mineralogical composition and the high degree of burial diagenesis it has undergone. Overall, the Austin Chalk exhibits a stable isotopic imprint distinctly different from typical monomineralic (low magnesium calcite) European Chalks but similar to shallow-water marine limestones, possibly confirming the presence of primary aragonite and its role in Austin Chalk diagenesis.

Although the Austin Chalk is capable of producing solely from its preserved (albeit low) matrix porosities, fracturing clearly enhances production. Natural fractures invariably are thin (millimeter or less), and vertical to sub-vertical in orientation. Not all cores studied were fractured nor did fractures occur continuously through a fractured core. Generally, fractures are present as multiple sets with lengths ranging from several centimeters up to a meter. Fractures are late-stage diagenetic events and most are healed by calcite cements. The occurrence of fracturing is difficult to predict but notably, argillaceous chalks did not fracture.

The Austin Chalk of south-central Texas represents a unique fine-grained carbonate play type that sources and seals at least some of the hydrocarbons it now reservoirs.