Depositional Facies of Grayburg/San Andres Dolomite Reservoirs, Central Basin Platform, Permian Basin*

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Major Headings

DEPOSITIONAL FACIES OF GRAYBURG/SAN ANDRES DOLOMITE RESERVOIRS - CENTRAL BASIN PLATFORM, PERMIAN BASIN

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INTRODUCTION

Porous dolomites of the Grayburg/San Andres Formations (Permian, Guadalupian) form major hydrocarbon reservoirs along the eastern edge of the Central Basin Platform of the Permian Basin. Although Galloway and others (1983) and Ward and others (1986) have described the regional geological setting for these dolomites and summarized examples of field studies, a comparison of the facies and porosity types between fields lying along the trend as revealed by detailed study of conventional cores has not been presented. The following brief text and illustrations are an attempt to analyze the Grayburg/San Andres interval from three fields and to compare these examples with published data from additional fields.

The complexity of Grayburg/San Andres dolomite reservoir intervals on the Central Basin Platform has previously been demonstrated within the following fields located from south to north along a 105 mile portion of the eastern edge of the Central Basin Platform: (1) Yates Field (Donoghue and Gupton, 1957; Craig, 1985); (2) McElroy Field (Longacre, 1980, 1983; Harris and others, 1984); (3) Dune Field (Bebout and Leary, 1985); (4) Foster Field (Young and Vaughn, 1957); and (5) Means Field (George and Stiles, 1978). A comparison of the lithological descriptions and depositional models for these fields shows that although substantial local variation exists, the overall more generalized vertical sequence and particularly the occurrence of porous shoal grainstones is strikingly similar. It is this apparent regional similarity that has prompted us to conduct a pilot core study to investigate the vertical sequence a little more closely and compare facies and porosity types between fields.

REGIONAL STUDY

Data presented in this study comes from the following three wells (Fig. 1): the Gulf Oil J. T. McElroy Cons. 223-R, located in McElroy Field in Crane County; Gulf Oil E. N. Snodgrass No. 35, from Waddell Field in Crane County; and Gulf Oil C. A. Goldsmith et al. 1359-56, from Goldsmith Field in Ector County. Interpretations of depositional environment and general discussions are strengthened by multi-well core studies in both McElroy and Waddell Fields and ongoing studies in all three fields.

The reservoir-bearing dolomites in all three of the fields occur as part of a shallowing-upward carbonate-shelf sequence, some 250 to 300 feet thick. Figure 2 illustrates in simplified form the vertical sequence and reservoir quality for the three wells; the vertical extent of various facies is also shown, with more detailed illustration and description of the lithologies and porosity - permeability plots, in Figures 3 to 5. The generalized sequence that comprises the Grayburg/San Andres interval in the wells consists of three basic parts: (1) a basal open-shelf unit of bioturbated, subtidal dolowackestones/packstones that are varyingly skeletal and peloidal; (2) a middle unit of shallow shelf sub-tidal fusulinid dolowackestones overlain by subtidal-intertidal non-skeletal shoal dolopackstones/grainstones; and (3) an upper unit of intertidal/supratidal dolomudstones to grainstones, quartz siltstones to fine sandstones, and evaporites that grades upward into the more clastic and evaporitic Queen Formation. Reservoir zones occur predominantly in the middle unit of the sequence.

McELROY 223-R

Cores from the McElroy 223-R well contain rock types representative of all three depositional units of the Grayburg/San Andres interval as well as the lower portion of the overlying Queen Formation. Longacre (1980) divided the Grayburg/San Andres and lower Queen sections into 11 depositional facies through detailed core studies of the North McElroy Unit, but Harris and others (1984) subsequently proposed a more generalized facies subdivision for the McElroy Field. It is this more generalized facies scheme that is used there because the scale of the units is such that they are correlatable by both core and log methods.

Log top for the Grayburg/San Andres Formations in the McElroy 223-R well occurs at 2,723 feet. Open-shelf sediments at the base of the cored section are predominantly skeletal and peloidal

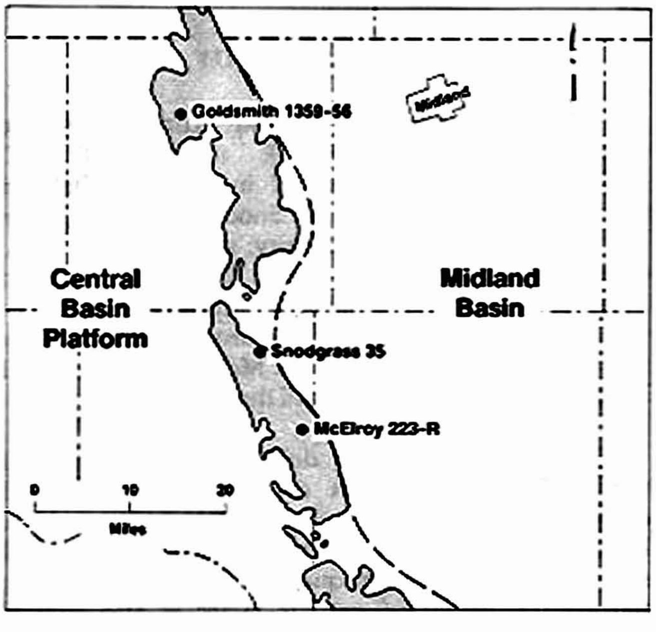

Figure 1. Location map for cores discussed in this paper. Some of the fields producing from the Grayburg/San Andres Formations in this portion of the Permian Basin are shown. These fields are aligned along the eastern edge of the Central Basin Platform. The Gulf Oil J. T. McElroy Cons. No. 223-R well was drilled in January 1983 in McElroy Field, Crane County (Sec. 203, Blk. F, 350 FNL and 984 FEL, CCSD and RGNG). The Gulf Oil E. N. Snodgrass (Tract A) No. 35 well was completed in August 1983 in Waddell Field, Crane County (Sec. 1, Blk. 25 PSL, 1650 FNL and 2200 FEL). The Gulf Oil C. A. Goldsmith et al. 1359-56 well was drilled in November 1981 in Goldsmith Field, Ector County (Sec. 15, Blk. 44, T-1-S, 100 FSL and 100 FWL, T & P Survey).

dolopackstones - grainstones (Fig. 3). The interval is extensively bioturbated; fusulinids and minor echinoderm fragments are scattered. Porosity types in order of importance are intercrystalline, moldic, microfracture, and fenestral. With only a few exceptions, plug analyses show porosities to be 4 percent or less as most of the fusulinid molds, microfractures, and fenestral pores are filled with anhydrite, gypsum, or dolomite cements. The overlying shallow-shelf and shoal deposits in the core are burrowed fusulinid and echinoderm dolowackestones and pelletal dolopackstones-grainstones. Vague cross-lamination is present in the carbonate sands, and in addition to peloids, ooids and rounded skeletal grains are present. Intercrystalline and moldic porosities are most common, and although many of the moldic pores are filled with anhydrite, the measured porosity values are between 10 to 20 percent and permeabilities are in the tens of millidarcys with exceptional values exceeding 100 md. The tidal-flat and evaporitic-flat sediments at the top of the core are the most variable vertically and consist of dolomudstones to sandy dolopackstones, siltstones, and nodular anhydrites. The dolopackstones are cross-laminated mixtures of ooids, rounded skeletal fragments, and clasts. Measured porosities are generally 3 percent or less for the dolomites and up to 6 percent for the sandier beds; much of the pore space including a few intervals with fenestral porosity has been plugged by anhydrite.

SNODGRASS 35

Galloway and others (1983) presented a structure map and log cross-section for Waddell Field, illustrating that the reservoir is very heterogeneous. Cores from the Snodgrass 35 well contain a similar suite of Grayburg/San Andres facies to that discussed for the McElroy 223-R well and also to that seen elsewhere in the Waddell Field as determined in other in-house core studies. The Snodgrass 35 cores differ, however, in that permeability is not well developed and cementation by anhydrite is exceptionally common even in the shoal dolopackstones-grainstones (Fig. 4). The lack of reservoir development in the core also corresponds to an off-structure location for the well. This illustrates that diagenesis is as important as facies in controlling reservoir-quality regionally in the Grayburg/San Andres interval.

Log top for the Grayburg/San Andres Formations in the Snodgrass 35 well is 3,255 feet. Open-shelf sediments at the base of the Snodgrass 35 cores (Fig. 4) are burrowed peloidal dolowackestones-packstones with minor fusulinids, pisolites, ooids, and quartz silt. Measured porosities are 5 percent or less except toward the base of the core where intercrystalline and moldic pores after fusulinids produce porosities of

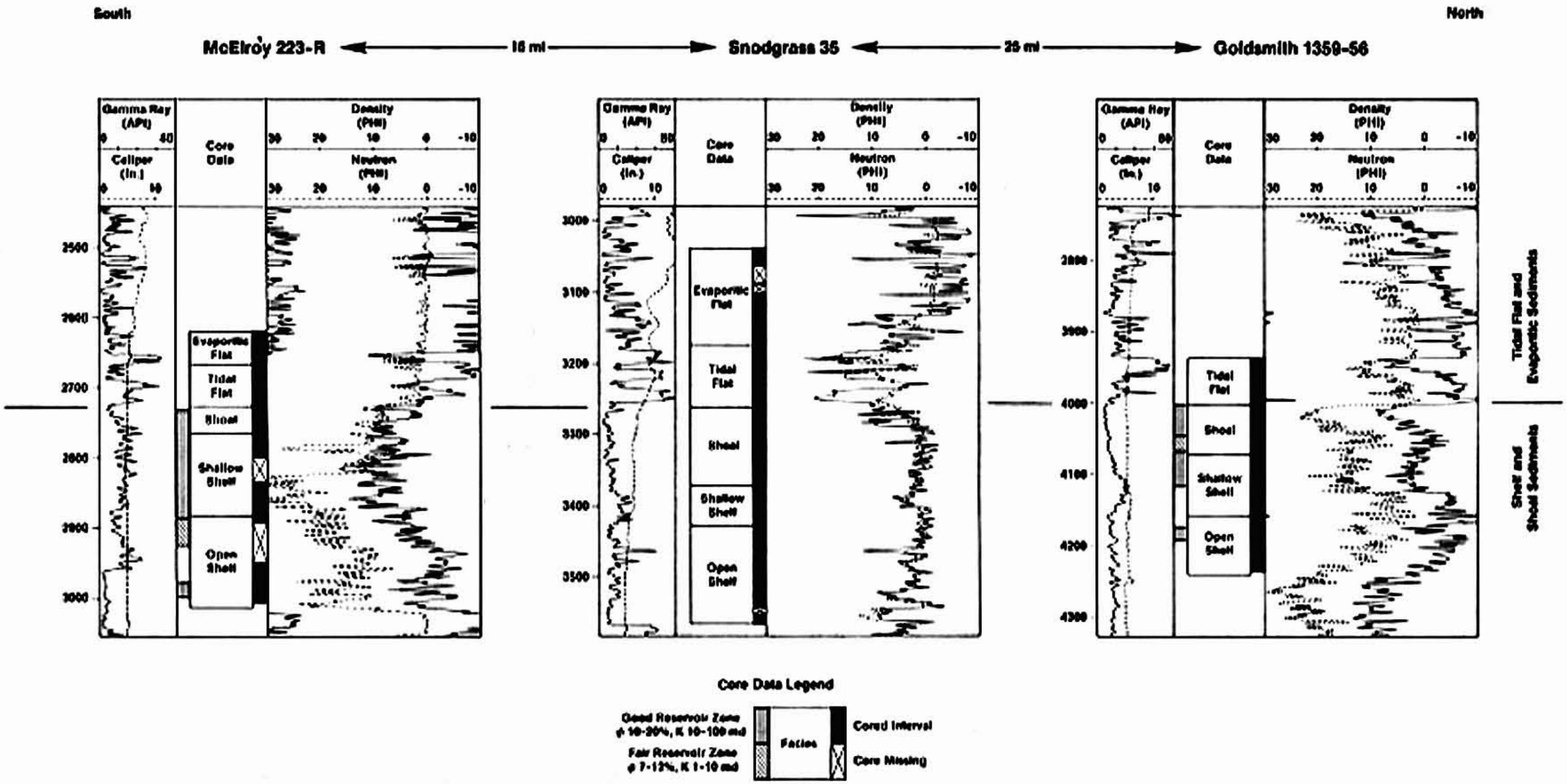

Figure 2. Wireline logs and core data from the McElroy 223-R, Snodgrass 35 and Goldsmith 1359-56 wells. The wells occur along a 41-mile portion of the eastern edge of the Central Basin Platform (see Fig. 1 for well locations). The blackened column under core data indicates the cored section; a small amount of the cored interval not available for lithological study is indicated by an "X." The major depositional facies as revealed by detailed core study are shown to the immediate left of the blackened column, and intervals of good and fair reservoir quality as defined by their measured porosity and permeability values are also indicated. A more detailed description of the lithologies as well as the porosity - permeability plots for each core are shown on Figures 3 to 5. The datum for Figure 2 is a lithological boundary that separates shelf and shoal sediments below (the lower and middle depositional units of the Grayburg/San Andres as described in the text) from tidal-flat and evaporitic deposits above (the upper depositional unit of the Grayburg/San Andres that grades upward into the Queen Formation). The lithological boundary is over 500 feet deeper in the Snodgrass 35 well than for the same pick in the McElroy 223-R well located approximately 16 miles to the southwest. Similarly, the same boundary deepens another 700 feet 25 miles further to the north at the location of the Goldsmith 1359-56 well. Note the porous and permeable section is best developed in shoal and shallow-shelf sediments in the McElroy 223-R and Goldsmith 1359-56 cores, but the Snodgrass 35 core lacks a reservoir zone due to low permeability.

nearly 10 percent. The overlying shallow-shelf and shoal interval contains burrowed peloidal dolowackestones/packstones grading upward into ooid and pisolite dolopackstones/grainstones and peloidal dolopackstones. The carbonate sands formed in an extremely shallow-water and periodically exposed setting as suggested by the occurrence of pisolites, algal and cement crusts, solution veins, and probable tepee structures. Porosity is around 5 percent for most of the unit, but increases toward the top to approximately 11 percent. The tidal-flat and evaporitic-flat deposits in the upper portions of the core consist of nodular anhydrites along with interbedded siltstones and silty dolowackestones/mudstones with intercrystalline and minor fenestral porosities of about 10 percent.

GOLDSMITH 1359-56

Log top for the Grayburg/San Andres interval in the Goldsmith 1359-56 well is at 3,742 feet. Cores contain burrowed fusulinid dolowackestones/packstones of open-shelf and shallow-shelf origin (Fig. 5). Measured porosities are approximately 15 percent where both moldic and intercrystalline pores occur and only 5 percent where moldic pores were subsequently filled with anhydrite. Permeability is variable but better towards the top of the shallow-shelf unit. Porosities are more consistently near 15 percent in the overlying shoal dolograinstones and permeabilities reach 100 md. or more. The tidal-flat deposits at the top of the core are anhydrite-cemented brecciated dolomudstones overlain by shaley dolowackestones-packstones containing rip-up clasts. Porosities in this upper unit are 5 percent or less.

DEPOSITIONAL MODEL

We interpret the depositional sequence present in cores from the McElroy 223-R, Snodgrass 35, and Goldsmith 1359-56 wells to have formed in a similar facies tract of shallow-water shelf and shoal environments and related tidal-flat and evaporitic (sabkha) sediments. The facies developed during easterly progradation across a deeper-water open shelf. Although some variability exists between cores described in this study as well as within the fields themselves, the major depositional environments represented in the cores and the overall

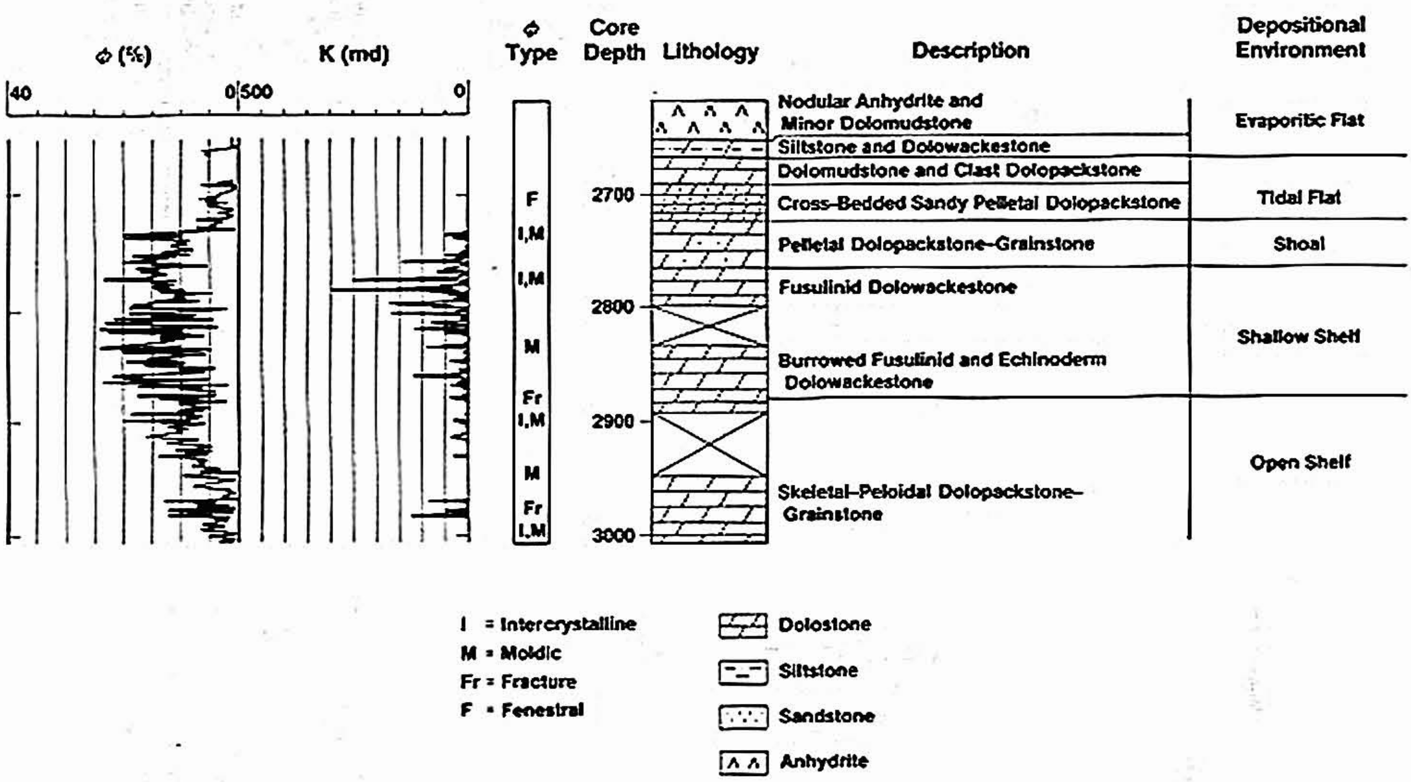

Figure 3. Lithological description and interpretation for the McElroy 223-R cores. Variable shelf and shoal dolostones change upward into more mixed-lithology tidal-flat sediments. Porosity and permeability determined by plug analysis are plotted and the porosity type as determined by core and thin-section analysis is shown. The porous-permeable zone is quite thick, and is best developed in the shoal and immediately underlying shallow-shelf intervals.

sequence in which they occur are similar. Core data and depositional models previously presented for Yates Field (Adams, 1930; Donoghue and Gupton, 1957), Foster Field (Young and Vaughn, 1957), and Means Field (George and Stiles, 1978) together with the more recent studies by Longacre (1980) and Harris and others (1984) of McElroy Field and those of Bebout and Leary (1985) for Dune Field suggest major portions of the eastern margin of the Central Basin Platform were dominated by carbonate sand-shoal and updip tidal-flat facies belts.

Our finds contradict those of Galloway and others (1983). They infer the principal reservoir facies in the fields along the eastern edge of the Central Basin Platform occur in dolostones having a structural framework dominated by sponges and algae and porosity formed by secondary solution. Longacre (1983) has indeed shown that a thick, shelf-margin reef section is present along a portion of the easternmost boundary of the North McElroy unit. But the continuity of the reef elsewhere along the margin of the Central Basin Platform is not yet proven nor does the reef interval contribute to the reservoir in North McElroy. Smaller patch reefs or mounds described by Longacre (1983) and Harris and others (1984) contribute only locally to the reservoir interval in McElroy Field in both the open-shelf and overlying shallow-shelf portions of the Grayburg/San Andres section. An interval of low-porosity sponge and algal framestone may contribute to the reservoir zone locally in some of the fields as described for Dune Field by Bebout and Leary (1985), but clearly, the examples described in this paper and comparisons with the results of most previous studies suggest to us that the reservoir intervals are not reefal in nature, but are part of a common association of shoal grainstones and packstones and related shallow-shelf sediments.

POROSITY AND DIAGENESIS

The porosity in the fields under discussion was formed by dolomitization and minor dissolution with perhaps greater solution being more important locally to the south as illustrated by karst formation in Yates Field (Craig, 1985). The best reservoir zones in the McElroy 223-R, Snodgrass 35, and Goldsmith

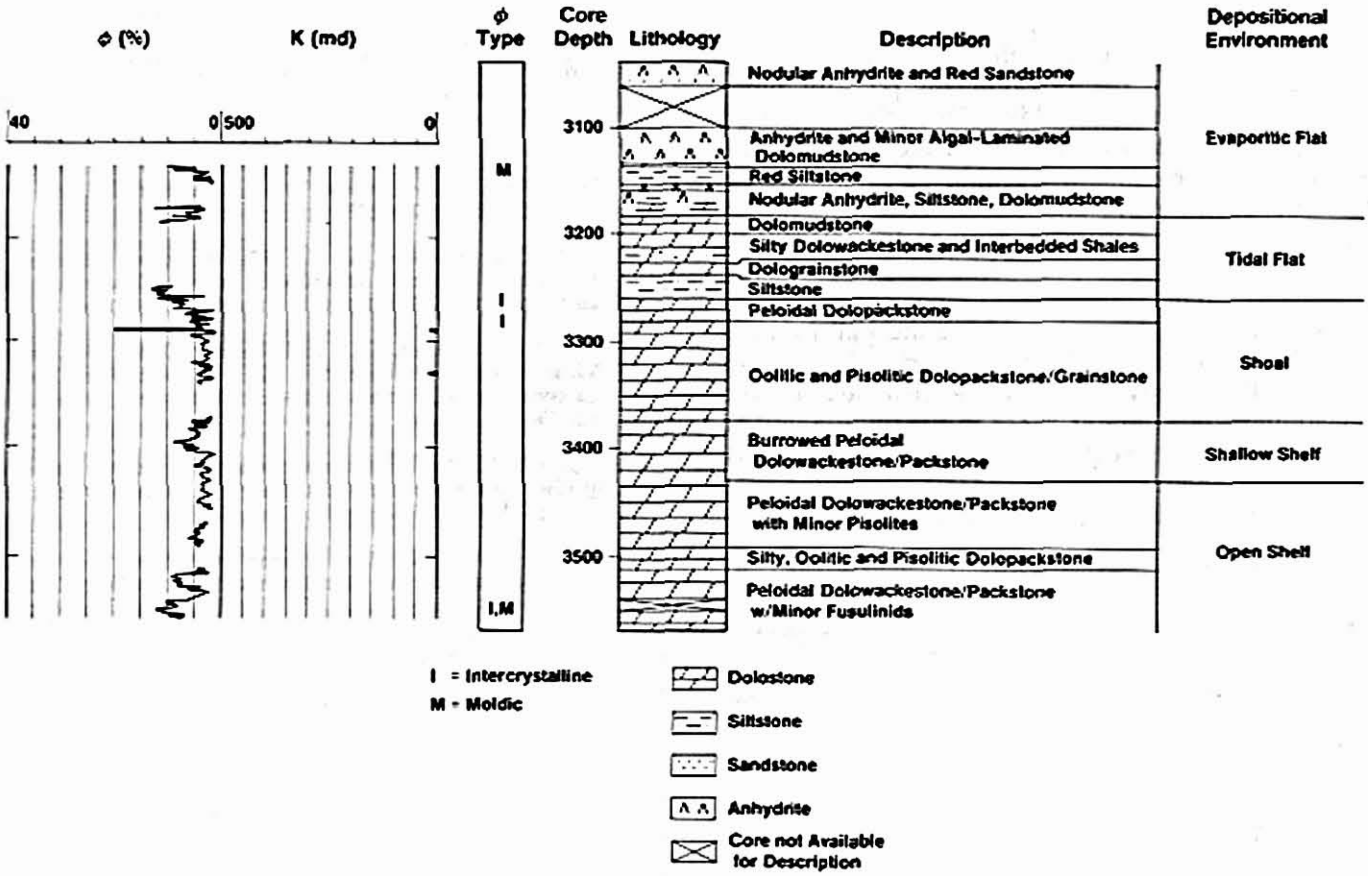

Figure 4. Lithological description and interpretation as well as porosity - permeability data for the Snodgrass 35 cores. The shoal unit is better developed and the open-shelf interval is more variable in the Snodgrass 35 core than in either the McElroy 223-R or Goldsmith 1359-56 cores. The Snodgrass 35 cores offer the best view of the capping tidal-flat and evaporitic-flat sediments. Porosity is developed in a few thin streaks but is not accompanied by any permeability.

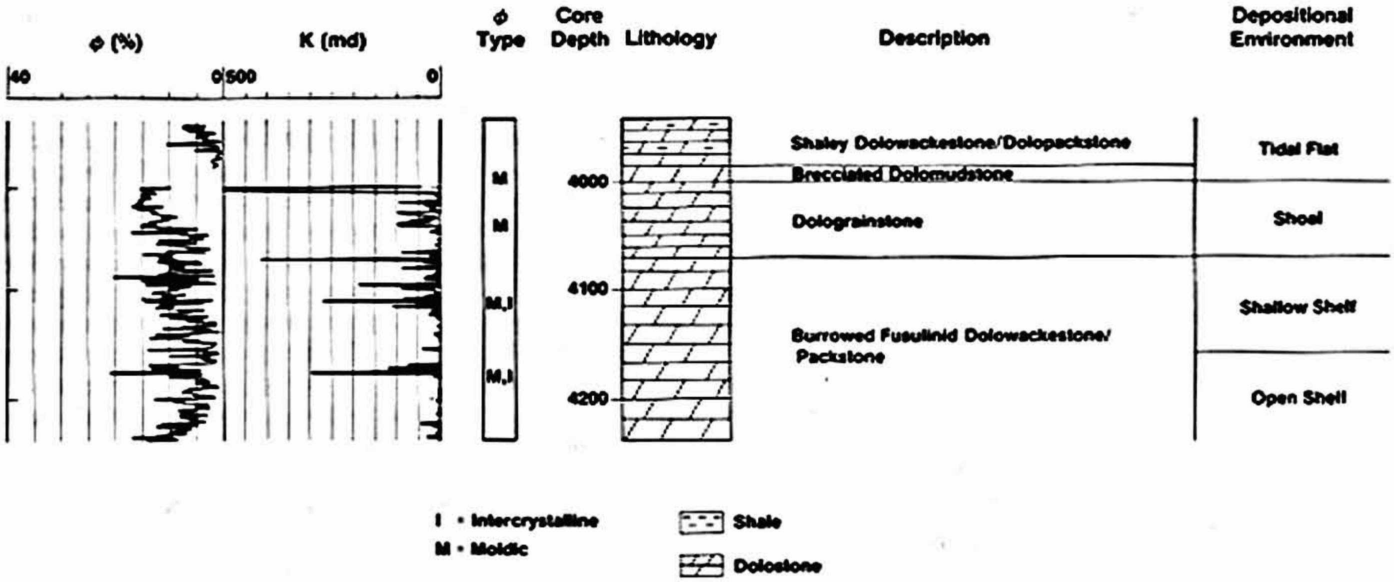

Figure 5. Lithological description and interpretation and porosity - permeability data for the Goldsmith 1359-56 cores. Open and shallow-water shelf dolowackestone/packstones are very similar. The capping tidal-flat section is more shaley in the Goldsmith 1359-56 well than in either of the other two cores described in the paper. Porosity and associated good permeability occur in a thick section of the shoal and shallow-water shelf interval.

1359-56 wells occur within the shoal and shallow-shelf facies where the predominant porosity types are intercrystalline and moldic. Diagenesis occurred in two major stages: (1) submarine cementation, pervasive dolomitization, leaching of grains, minor dolomite cementation, and sulfate cementation and replacement - all occurring during deposition and earliest burial; and (2) fracturing, anhydrite cementation, minor calcite replacement of anhydrite, and formation of gypsum and kaolinite - all forming near maximum burial depth and during subsequent uplift. The pervasive dolomite that led to the development of reservoir zones in the middle unit of our depositional sequence is commonly finely crystalline, anhedral to subhedral, inclusion-rich, and preserves original depositional texture.

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