Rock-Fabric Petrophysical Analysis of Core and Wireline-Log Data
Haradh 101 and Haradh 106
Ghawar Field, Saudi Arabia

F. Jerry Lucia and Michael A. Rahnis

Final Report

prepared to fulfill requirements of ASC
Contract No. 710315/00 between Aramco Services
Company and The University of Texas at Austin

Bureau of Economic Geology
Noel Tyler, Director
The University of Texas at Austin
Austin, Texas 78713-8924

3/27/98

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Please verify that you have a copy of this report. Thanks.
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ABSTRACT

Analysis of thin sections and core data demonstrates that rock fabrics can be grouped into petrophysical fields defined by porosity and permeability. Grainstones and large crystal dolostones fall within the petrophysical class 1 field of Lucia (1995). Permeability increases with increasing dolomite crystal size. The class 1 field is enlarged slightly to include large crystal dolostones with crystal sizes ranging to 300 microns. Grain-dominated and dolomitic mud-dominated fabrics containing more than 25 percent dolomite fall into the petrophysical class 2 field. The dolomitic mud-dominated fabrics plot in the class 2 field because progressive dolomitization increases pore size by increasing porosity in the intercrystal mud and by creating intercrystal pore space. Mud-dominated fabrics having less than 25 percent dolomite are mostly dense but, when permeable, plot in the petrophysical class 3 field. A global relationship between rock-fabric petrophysical class, interparticle porosity, and permeability that does not require fabrics being divided into specific petrophysical classes has been developed and is used in this analysis.

Permeability can be estimated from wireline logs according to the rock-fabric method. Interparticle porosity is estimated by subtracting total porosity from separate-vug porosity, which, in turn, is estimated from transit-time–porosity cross plots. Petrophysical classes can be identified from a cross plot of water saturation and porosity. The wells are far enough above the free-water level that reservoir height is not an important consideration. We identified boundaries between rock-fabric classes and multiple-regression analysis, using equations of the boundary lines, resulted in a relationship between petrophysical class, saturation, and porosity. Permeability is calculated by substituting log-calculated interparticle porosity and log-calculated petrophysical class into the global transform equation. These calculations compare well with core data and retain high and low permeability values.

It is important to retain the rock-fabric petrophysical class term in this calculation because it provides the link between petrophysical properties and geologic processes necessary to display

permeability, porosity, and water saturation in 3-D. Without the tie to stratigraphy, deposition, and diagenesis, log-calculated petrophysical properties cannot be realistically distributed in 3-D space. Identifying rock fabrics from log-calculated petrophysical classes requires additional information because (1) multiple rock fabrics are in each class, and (2) the saturation approach applies only to permeable intervals. Class 1 includes both large crystal dolomite and grainstone. Lithology can be used to distinguish between them. Class 2 includes grain-dominated packstones, dolomitic grain-dominated packstones, and dolomitic mud-dominated fabrics. Although lithology can be used to distinguish grain-dominated packstones, it cannot distinguish between dolomitic grain-dominated packstones and dolomitic mud-dominated fabrics. Class 3 includes mud-dominated fabrics having less than 25 percent dolomite. Because most dense samples are mud-dominated and dolomitic mud-dominated fabrics, low-porosity intervals are assigned to class 3.

The super k interval in well 101 appears to be producing from a touching-vug pore system composed of small caverns and fractures. The extensive amount of large crystalline dolostone around this touching-vug pore system suggests that this system also provided the flow path for dolomitizing fluids. Assuming that dolomitization is late, the pore space of the precursor limestone may have been similar to the present limestone, and the dolostone may have inherited its porosity values from the precursor limestone. The important impact of dolomitization is the increased pore size in the mud-dominated and grain-dominated packstone fabrics.

INTRODUCTION

This report was prepared to fulfill the requirements of ASC Contract No. 710315/00 between Aramco Services Company and The University of Texas at Austin. The goal of this project was to (1) describe thin sections from two wells in the Haradh area of Ghawar field, (2) correlate the rock fabrics having porosity and permeability and (3) develop methods for determining rock fabrics and permeability from wireline logs. The Haradh 101 and 106 wells were selected by Aramco (fig. 1).

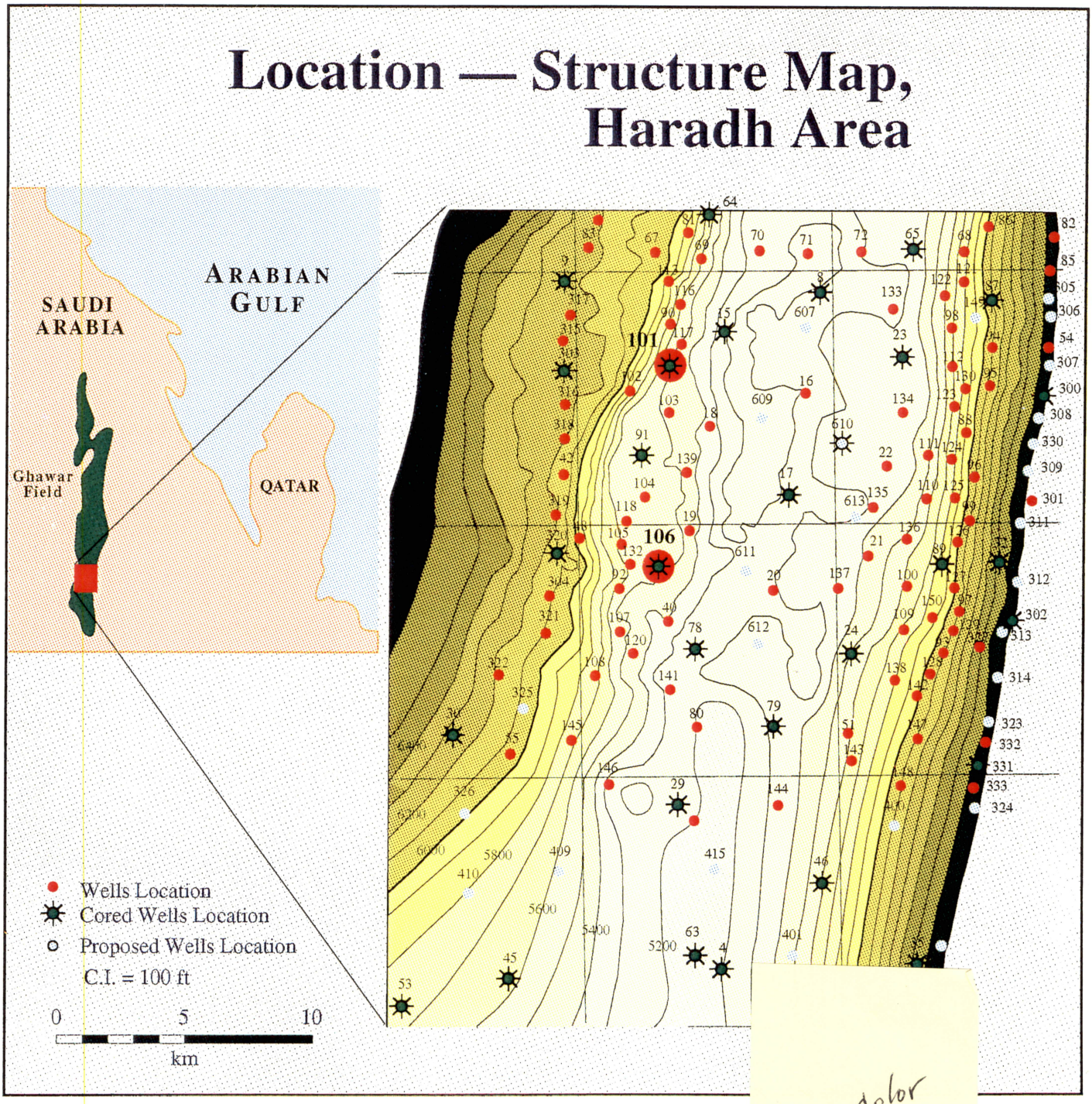


Figure 1. Location map of the Haradh area, Ghawar field, show rs and location of Haradh 101 and 106 wells (courtesy of Aramco).

Detailed results and interpretations are presented, including analysis of the thin-section descriptions and application of the results to wireline logs.

Statement of Problem

A key to predicting performance accurately using flow simulators is to capture the spatial distribution of high and low permeabilities in the reservoir. Permeability values routinely obtained by core analysis characteristically have an extremely high variance. This is true of the core data from Haradh 101 and 106 (fig. 2A), where permeability values vary from less than 0.01 to 7,000 md. The conventional method of dealing with this extreme variability is to correlate permeability with porosity and construct a porosity–permeability transform. It is generally agreed, however, that single porosity–permeability transforms tend to average out high and low permeabilities.

The method used in this study to maintain high and low permeabilities is referred to as the rock-fabric method. It is based on the fundamental concept that permeability is a function of pore-size distribution, which is directly related to particle size, sorting, interparticle porosity, and touching-vug pore systems (fig. 2B) (Lucia, 1995). Because separate-vug pore space does not contribute greatly to permeability, it must be identified and subtracted from total porosity to obtain interparticle porosity. The approach is to (1) relate core permeability values to rock fabric and interparticle porosity and develop multiple rock-fabric-specific interparticle-porosity, permeability transforms; (2) relate rock fabrics to water-saturation, porosity cross plots from wireline-log analysis; and (3) use rock-fabric-specific transforms to calculate permeability from wireline logs.

ROCK-FABRIC-SPECIFIC PERMEABILITY TRANSFORMS

Method

Rock fabrics are identified from descriptions of samples used to measure petrophysical properties. In this study, 1.25-inch-diameter core plugs were used and the rock-fabric descriptions

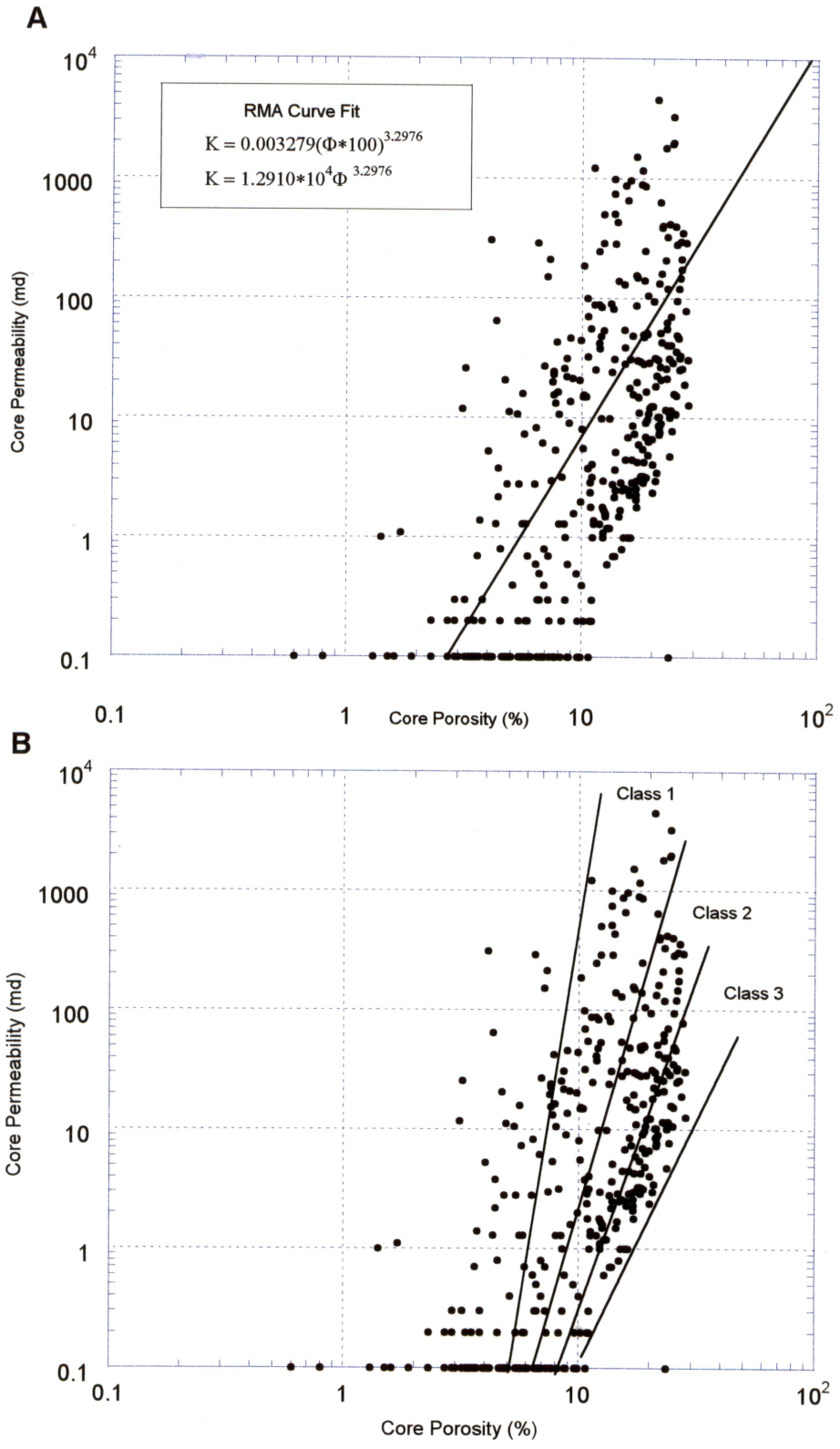


Figure 2. Cross plots of core data from Hardh 101 and 106. (A) Porosity–permeability cross plot showing a Reduced Major Axis fit to the data. (B) Porosity–permeability cross plot showing rock-fabric petrophysical classes that are defined by permeability, interparticle porosity, particle size, and sorting (Lucia, 1995).

are from thin sections of the plug ends. Although sample density is 0.5 ft, in most intervals thin sections were described every foot. A total of 421 thin sections were described and the descriptions are included in appendix 1. We determined percentages of pore types and minerals by 300 point counts per thin section according to mechanical stage. The first step in describing rock fabrics for petrophysical analysis is to divide the pore space into interparticle, separate-vug, and touching-vug pore types. Interparticle pores are visible between grains, dolomite crystals, and within the mud matrix. Separate vugs are found within fossil fragments (forams and *Cladocoropsis*) as grain molds and as intragrain microporosity in grain-dominated fabrics. No touching-vug porosity was noted, although some thin sections contained a few microfractures. Separate-vug porosity ranged from 0 to 7 porosity percent, averaging less than 1 percent. Although intragrain microporosity was found in small quantities in most grain-dominated packstones, it was abundant only in well 101 in the interval between 6,555 and 6,562 ft. Microporosity could not be point counted because of its small size, and estimates were made by counting grains that contained microporosity identified by observing traces of blue dye within the grains. Interparticle porosity was determined by subtracting separate-vug porosity from core-plug porosity. In most cases the difference between total and interparticle porosity was found to be small.

Other measurements that are important to petrophysical characterization are mineralogy, particle size, and sorting. Mineralogy is determined by point counting. Dolomite and calcite account for most of the mineral volume, along with occasional small amounts of anhydrite, chert, and clay. Average grain and crystal size is determined by an ocular micrometer. Sorting is characterized by the Lucia classification; that is, grainstone is well sorted, grain-dominated packstone is moderately sorted, mud-dominated packstones is poorly sorted, and wackestone and mudstone are considered to be well-sorted fine-particle-size fabrics.

Sampling Problems, Problems of Scale

A concern in this type of study is the degree to which the thin section represents the fabric of the sample that is used to measure the petrophysical property. Although rock-fabric categories are kept broad to cover a range of fabrics, small-scale heterogeneity may cause the plug to be unrepresentative. Examples are (1) patchy distribution of calcite cement, sulfate, dolomite, or micrite; and (2) very large particles, such as fossils. Patchy distribution often results in large differences between thin-section porosity and core-analysis porosity values. It can also be the cause of anomalous permeability values, permeability values that are either too high or too low for the measured porosity, and rock fabric. Two samples were discarded from the data set for this reason, and 38 samples were discarded because they contained large fragments of *Cladocoropsis*. Burrowing fabrics are present in grain-dominated packstones and mud-dominated fabrics, and dolomite is irregularly distributed in the dolomite limestones. These fabrics most likely produce much of the scatter seen within the rock-fabric groups.

A second concern is the difference between reservoir and ambient conditions. Studies have shown that in the Arab D Formation there is little difference between porosity values measured at ambient conditions and those measured under confining pressure (Harari and others, 1995). However, samples having well-developed stylolites commonly have higher than expected permeability values, probably because of the opening of pore space along the stylolites, which results from the reduction of confining pressure when they are brought to the surface. Twenty-eight samples were discarded from the data set because they contained well-developed stylolites.

The principal mineralogical consideration is percent of dolomite. Dolomite content ranges from 0 to 100 percent (fig. 3). For the purposes of this analysis, the samples are divided into limestone (0 to 10-percent dolomite), dolomitic limestone (10- to 80-percent dolomite), and dolomite (80- to 100-percent dolomite) for analysis. The 80-percent limit was chosen because Powers (1962) reported that porosity and permeability increased when between 80- and

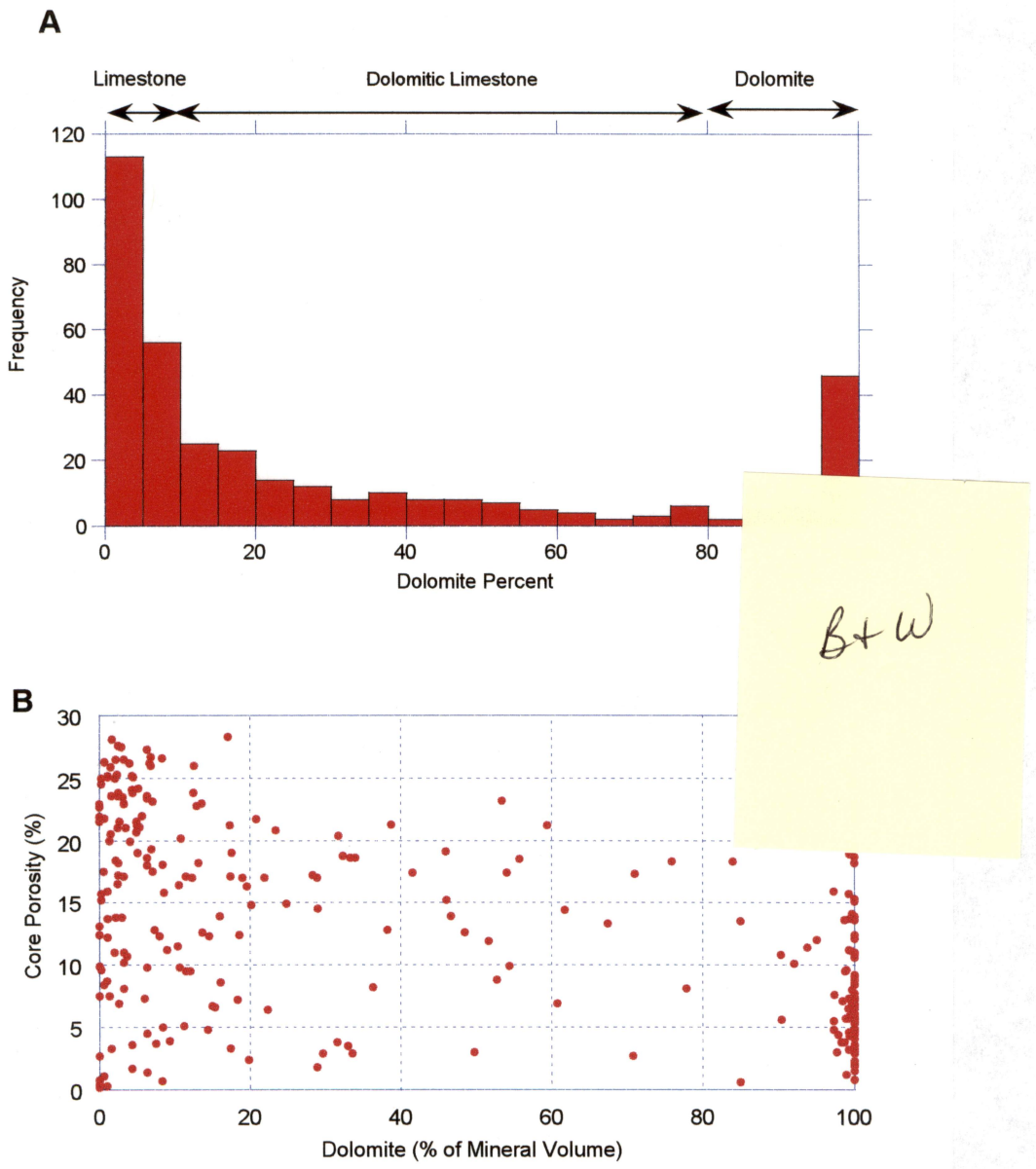


Figure 3. (A) Frequency plot of percent dolomite in samples from Haradh 101 and 106 showing lithology groupings. (B) Cross-plot of core porosity and percent dolomite for samples from Haradh 101 and 106. Although there is very little difference in the porosity range, the dolostone has more low porosity values than does the limestone.

100-percent dolomite was present. An increase in porosity with dolomitization has not, however, been observed in this data set (fig. 3).

LIMESTONE (0 TO 10-PERCENT DOLOMITE)

Grainstone

There are only 15 grainstone samples in the sample set, and 4 were discarded on suspicion of their being unrepresentative of the core plug. The 11 remaining samples are porous and permeable and plot in the class 1 field of Lucia (1995) (fig. 4). The grainstones can be divided into two types. The first type is found toward the top of the Arab D. It contains well-sorted, coated grains (200 to 400 mm) having isopachous calcite cement on multicrystal grains and syntaxial-overgrowth cement on single-crystal echinoderm fragments (fig. 5A). Compaction effects include grain interpenetration, grain crushing, and spalling of isopachous cement. As much as 7 percent moldic porosity is found in this grainstone. The second type of grainstone, found in the lower part of the Arab D, is a mixture of 200- to 400-mm and >500-mm peloids (fig. 5B). The grains are probably mudstone intraclasts because they are associated with intervals of mudstone and wackestone fabrics. No cement or separate vugs are apparent in the samples. There is, however, considerable grain penetration, suggesting considerable compaction and associated loss of porosity.

Grain-Dominated Packstone

There are 100 samples of grain-dominated packstones, most of which are porous and permeable. Of these samples, 20 were discarded for having large *Cladocoropsis* grains and 9 for the presence of stylolites. The remaining 71 samples plot within the class 2 field (fig. 6A). The stylolitic samples and a few of the *Cladocoropsis* samples plot to the left of the class 2 field (fig. 6B). The grain-dominated packstones show a wide variety of fabrics because of variations in the mud content related to burrowing of mud into grain-dominated fabrics and grains into mud-

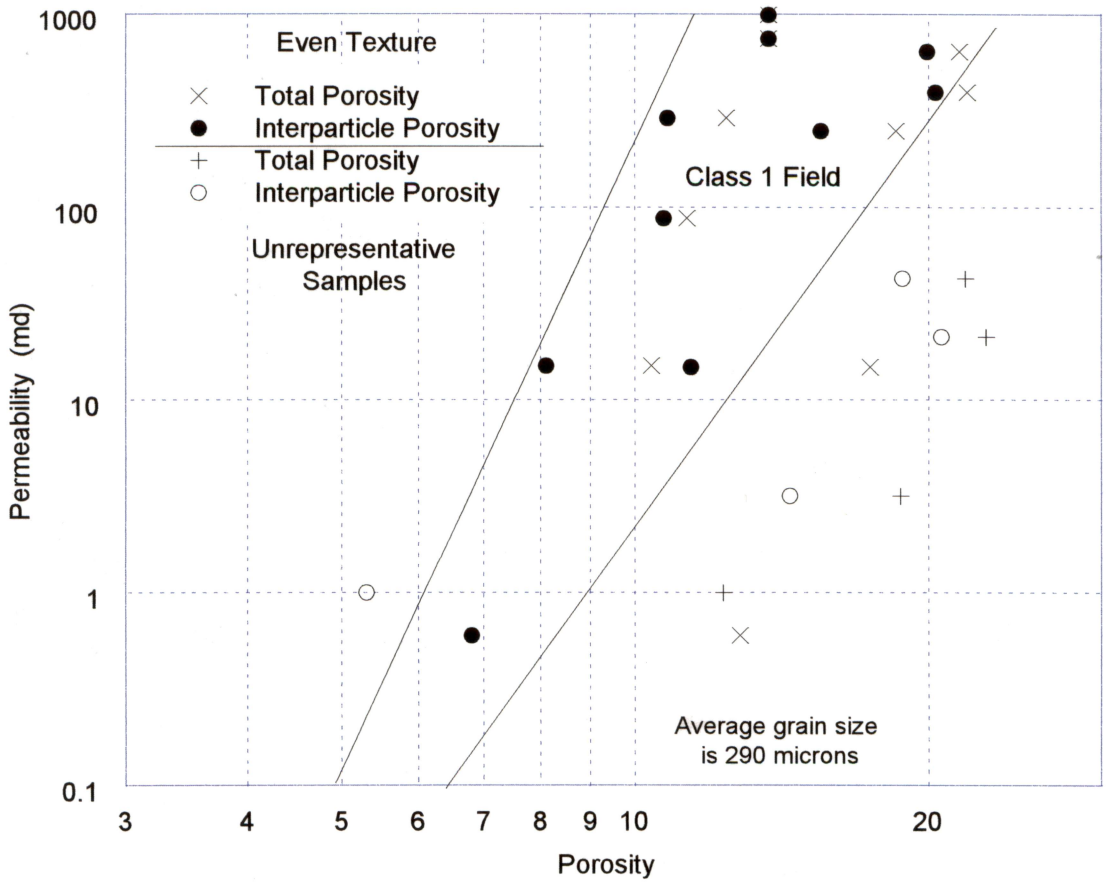


Figure 4. Porosity–permeability cross plot for grainstone, showing both total and interparticle porosity. The difference is separate-vug porosity determined by point counting thin sections. Several samples have 6-percent separate vugs and would plot in the class 2 field using total porosity. Four samples were discarded because the fabrics appear to be unrepresentative of the petrophysical values.

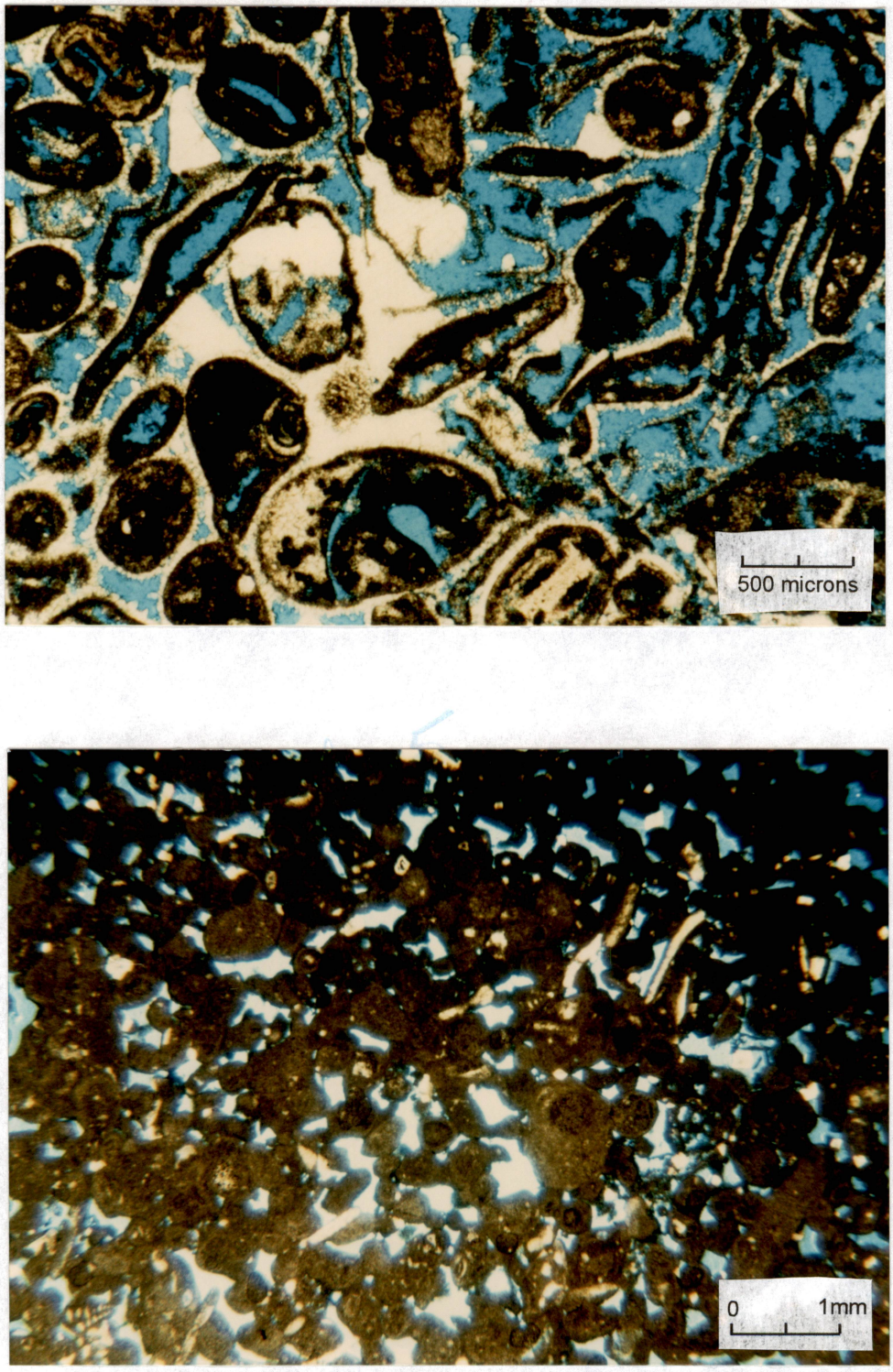


Figure 5. Photomicrographs of grainstone. (A) Fossil grainstone from PSS 8 zone. (ϕip = 11.4%, Svug = 6%, k = 14.9 md). (B) Peloid grainstone from lower interval (ϕip = 13.7%, k = 997.3 md).

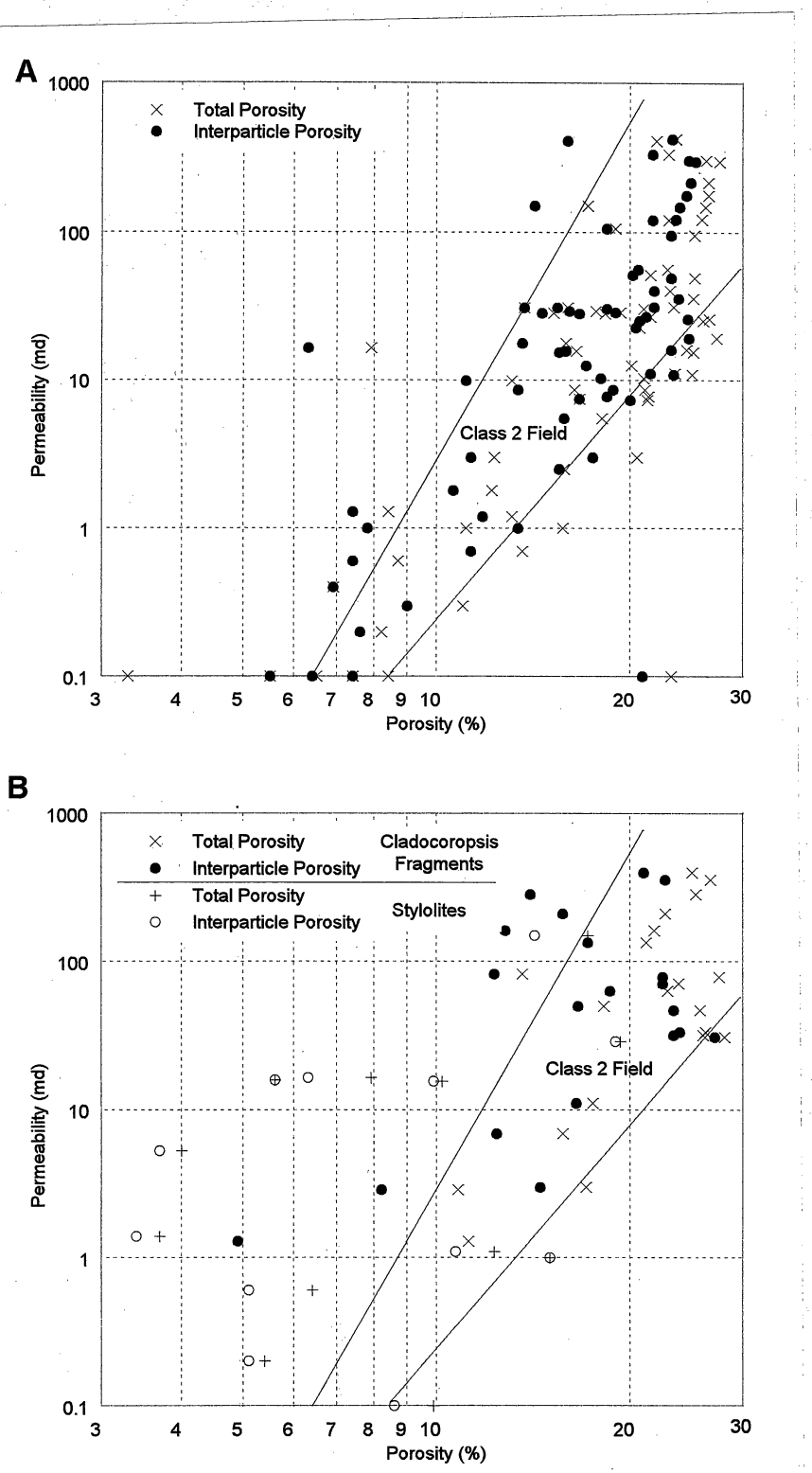


Figure 6. Porosity–permeability cross plot for grain-dominated packstone, showing both total and interparticle porosity. The difference is separate-vug porosity determined by point counting thin sections. (A) Plot of representative samples. These samples have very little vuggy porosity, and most of the samples fall into the petrophysical class 2 field. (B) Plot of samples containing stylolites and large *Cladocoropsis* fragments. Stylolitic and some *Cladocoropsis* samples fall to the left of the class 2 field.

dominated fabrics. Mud content ranges from 5 to 95 percent (fig. 7). Samples having more than 40 to 50 percent mud are mud-dominated fabrics having burrows filled with grain-dominated packstone (fig. 8). Petrophysically these samples belong to the grain-dominated packstone, petrophysical class 2, although depositionally they are most likely quiet-water deposits. Grains are mostly peloids or micritized grains and are difficult to identify. Grain size ranges from 150 to 300 microns, and mud size is less than 20 microns.

Grain-dominated packstones typically have syntaxial cement on echinoderm fragments and no isopachous cement (fig. 8). Interpenetration of grains suggests compaction. In general, these fabrics contain little separate-vug porosity. Intragrain microporosity is most abundant in well HRDH-101 between the depths of 6,555.7 and 6,562.7 ft, although individual samples at other depths have significant amounts of this separate-vug type. In fact, most samples contain at least a few microporous grains; forams in particular appear to be susceptible to leaching and are commonly microporous.

Mud-Dominated Fabrics

Mud-dominated fabrics are (1) mud-dominated packstone that has grains as a supporting fabric but whose intergrain space is filled with micrite, (2) wackestone that has micrite clearly as the supporting fabric, and (3) mudstone that has few observable grains (fig. 9). There are 52 samples of mud-dominated fabrics, 6 of which have been discarded for large *Cladocoropsis* fragments and 7 for stylolites. Of the remaining 35, only 10 are permeable and all but 3 plot in the petrophysical class 3 field (fig. 10). Stylolitic and *Cladocoropsis* samples plot to the left of the class 3 field. Mud-dominated fabrics have little separate-vug pore space. Commonly, however, a few calcisphere or fossil molds are present. In mud-dominated packstones calcisphere molds can be mistaken for interparticle porosity.

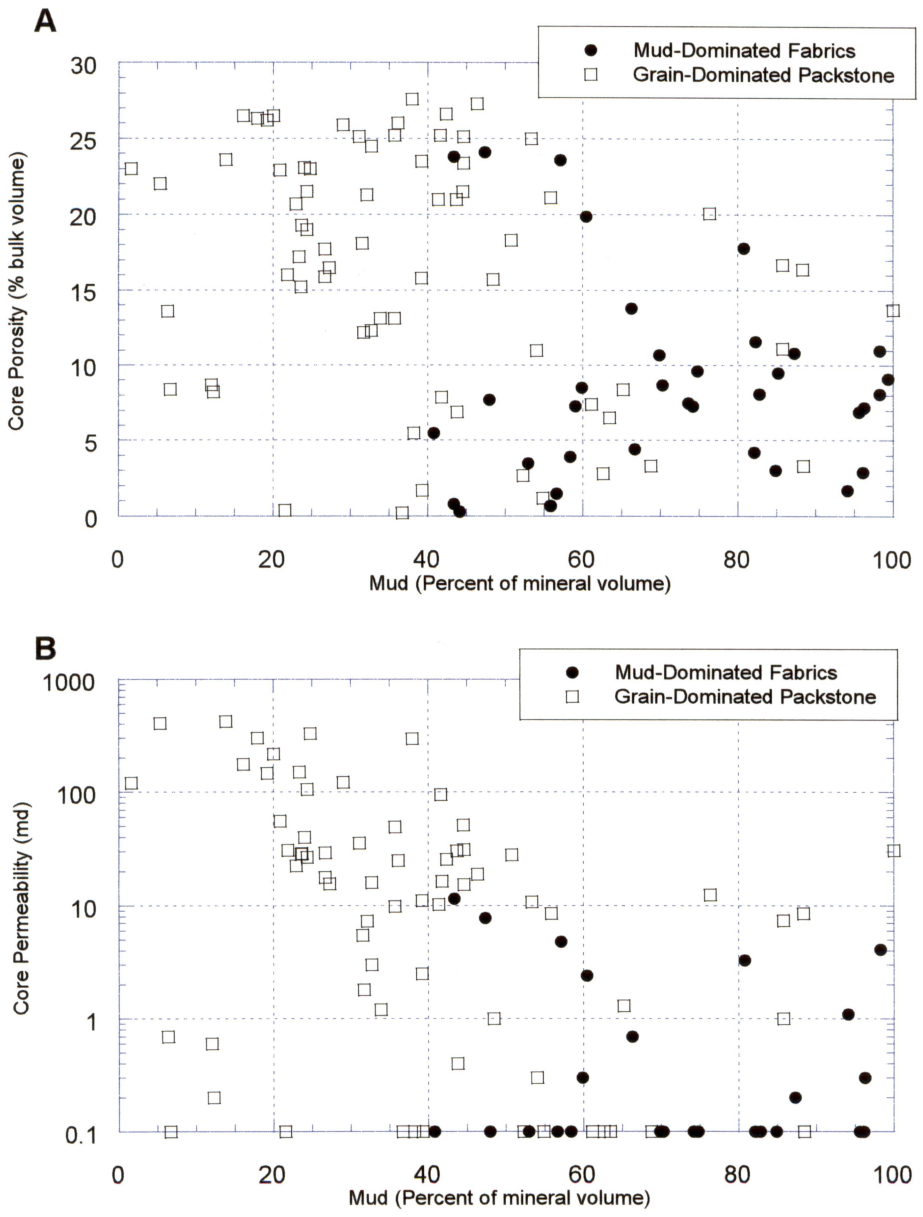


Figure 7. Cross plots of porosity and permeability against mud content for grain-dominated packstones and mud-dominated fabrics. High mud content in some grain-dominated packstones is the result of grain-dominated packstone filling burrows in mud-dominated fabrics. (A) Cross plot of core porosity and mud volume showing a porosity level in grain-dominated packstones different than in mud-dominated fabrics. However, there is little relationship between porosity and mud content within each fabric. (B) Cross plot of permeability and mud volume showing a distinct difference in permeability levels between grain-dominated packstones and mud-dominated fabrics. However, as with porosity, there is little relationship between permeability and mud content within each fabric.

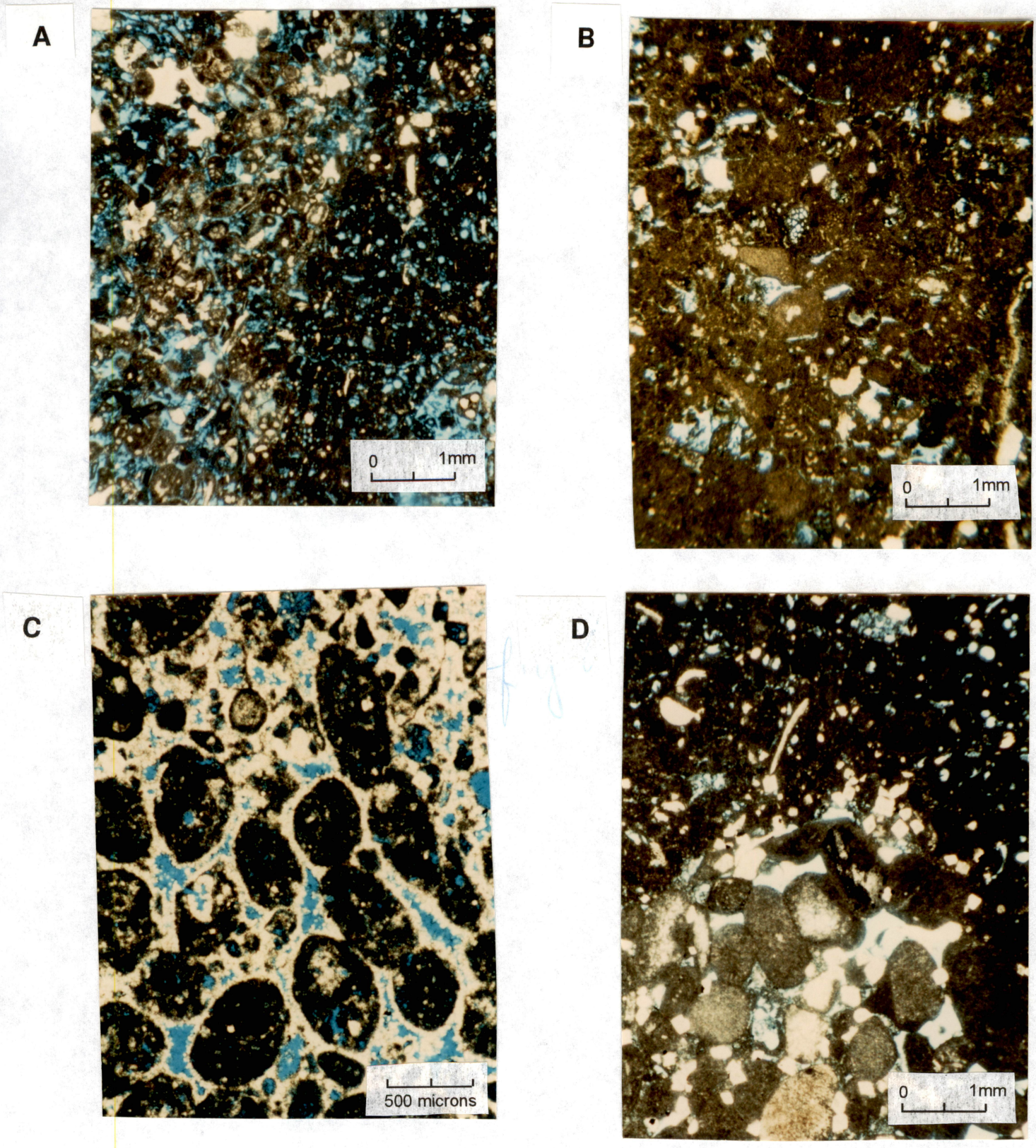


Figure 8. Photomicrographs illustrating range of fabrics classified as grain-dominated packstone. Notice syntaxial cement and grain interpenetration. (A) Grain-dominated packstone having 19 percent mud (ϕip = 19%, k = 43 md). (B) Grain-dominated packstone having 50 percent mud (ϕip = 17%, k = 28 md). (C) Grain-dominated packstone having intragrain microporosity. Twenty-seven percent of the grains are microporous (ϕip = 21%, Svug = 5%, k = 28 md). (D) Wackestone having grain-dominated packstone in burrow (ϕip = 8%, k = 1 md).

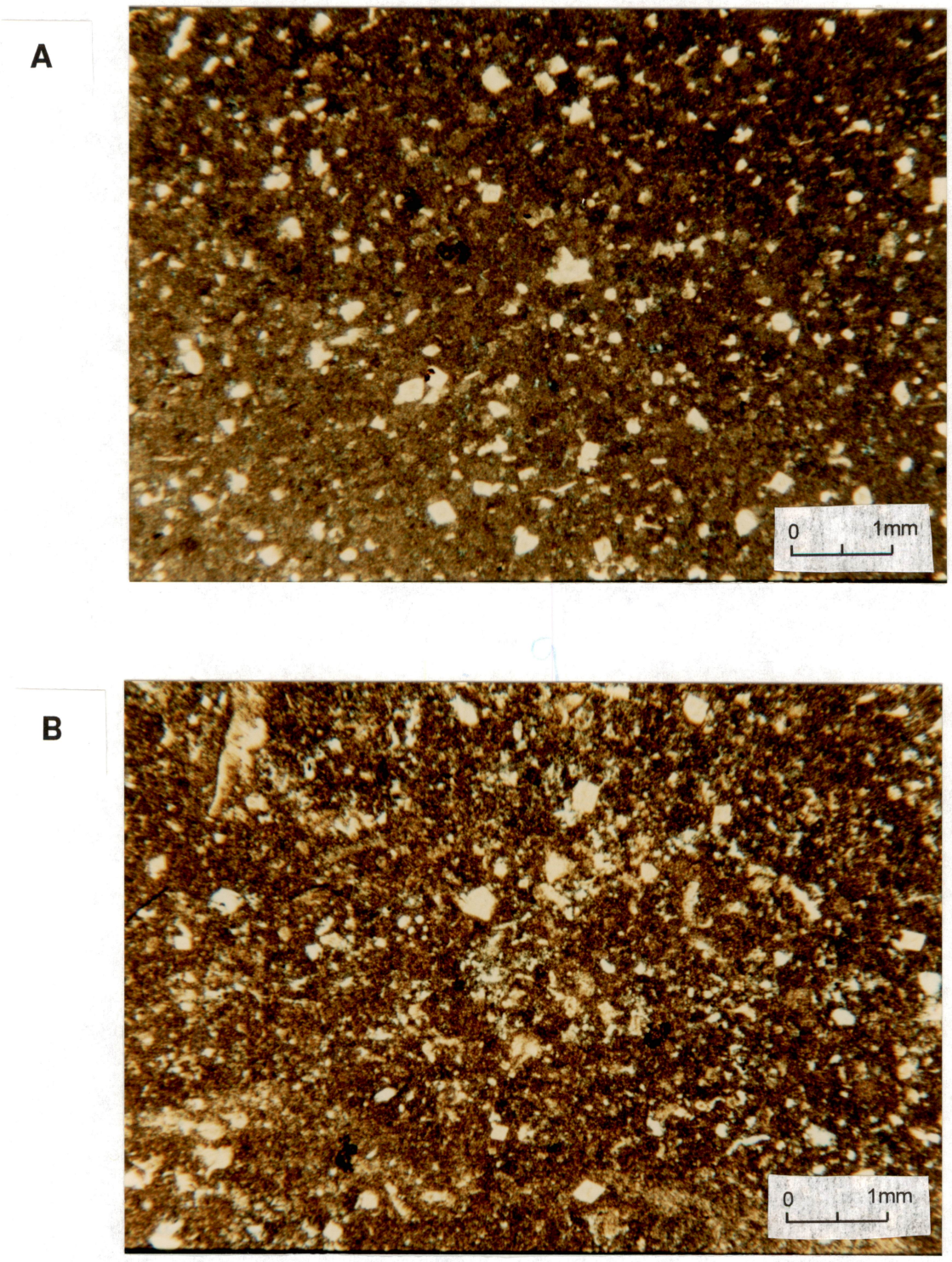


Figure 9. Photomicrographs of permeable mud-dominated fabrics. (A) Wackestone (ϕip = 13.8%, k = 0.7 md). (B) Mud-dominated packstone (ϕip = 23%, k = 4.8 md).

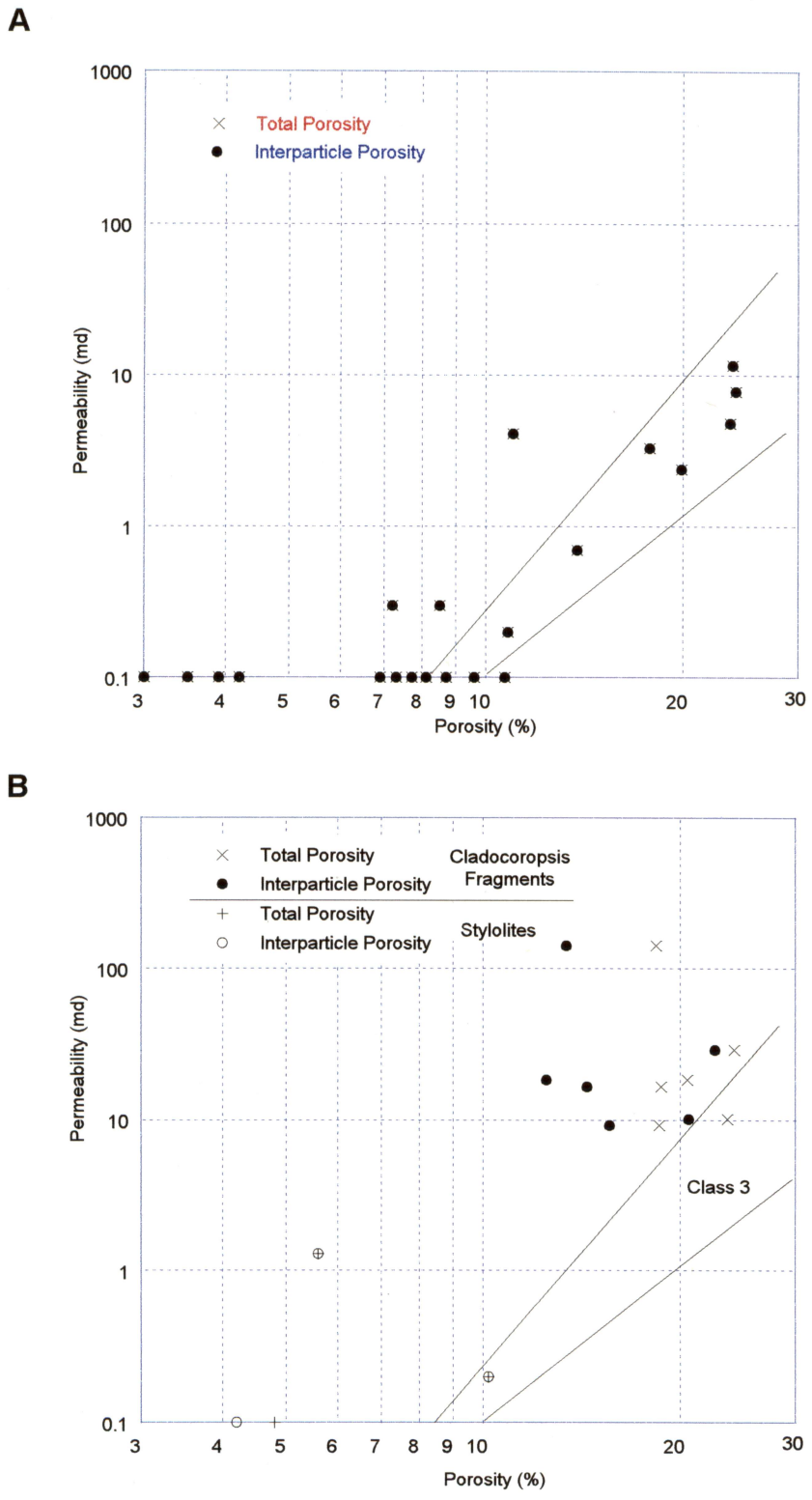


Figure 10. Porosity–permeability cross plot for mud-dominated fabrics, showing both total and interparticle porosity. There is less than 1 percent separate-vug porosity. (A) Plot of representative samples. Most of the samples have less than 0.1 md permeability, and most of the permeable samples fall into the petrophysical class 3 field. (B) Plot of samples having stylolites and large *Cladocoropsis* fragments. All these samples fall to the left of the class 3 field.

DOLOMITIC LIMESTONES (10- TO 80-PERCENT DOLOMITE)

Dolomitic Grain-Dominated Packstones

There are only 27 samples of dolomitic grain-dominated packstone, and all but 4 samples have less than 50 percent dolomite. The dolomite crystal size ranges from 80 to 200 microns. Most of the samples plot within the petrophysical class 2 field (fig. 11). The few low-porosity samples that plot to the left of the class 2 field may be the result of poor measurements. There does not appear to be any relationship between the amount of dolomite and porosity or permeability, suggesting that the partial replacement by large dolomite crystals has not altered the porosity or pore-size distribution (fig. 12).

Dolomitic Mud-Dominated Fabrics

Of the 63 dolomitic mud-dominated samples, 33 have less than 0.1 md permeability. The samples were divided into three groups: 10- to 25-percent, 25- to 50-percent, and 50- to 80-percent dolomite for analysis. There does not appear to be any relationship between the amount of dolomite and porosity. Permeability, however, does appear to have a relationship with amount of dolomite (fig. 13). Permeable samples having 10- to 25-percent dolomite tend to plot in the petrophysical class 3 field, along with mud-dominated fabrics. Permeable samples having 25- to 50-percent dolomite plot in the class 2 field, along with grain-dominated packstones. Permeable samples having 50- to 80-percent dolomite tend to be the most permeable for a given porosity and plot near the class 1 field.

The increase in permeability indicates an increase in pore size with dolomitization. The 33 dense samples, however, show no development of intercrystal porosity with increasing dolomitization. On the other hand, thin-section analysis of the permeability samples suggests an increase in porosity in intercrystal mud and dissolution of the intercrystal mud to form intercrystal

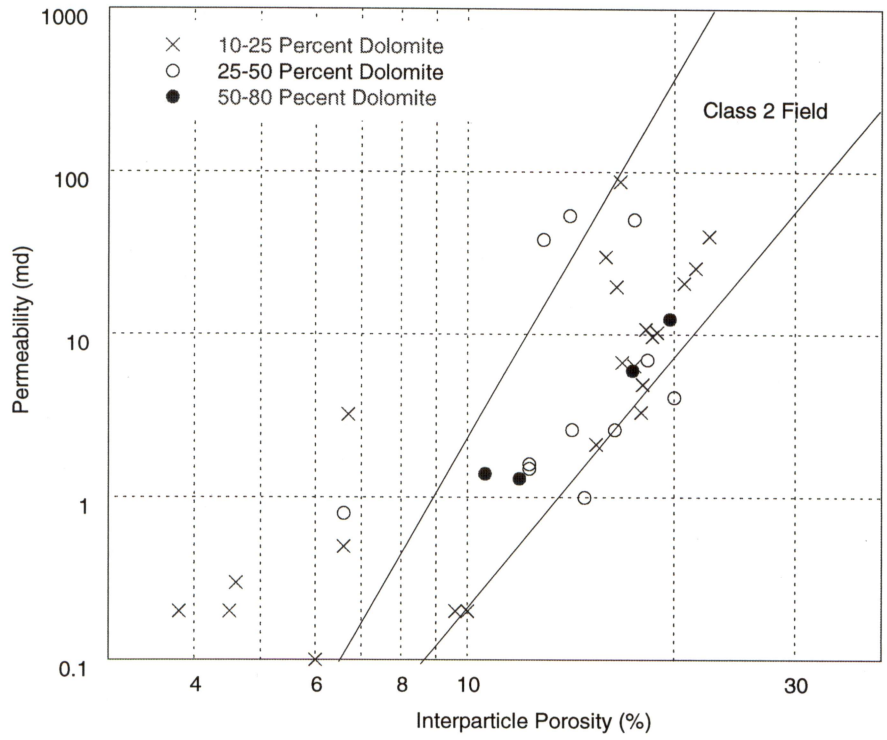


Figure 11. Porosity–permeability cross plot for dolomitic grain-dominated packstone (10 to 80 percent dolomite). Dolomite percentage is plotted in three groups, showing little relationship between dolomite percentage and porosity or permeability. Most samples plot in the class 2 field. Most of the low-porosity, high-permeability samples are wackestones having grain-dominated packstone in burrows, and the permeability will depend upon the volume and distribution of the burrows within the core plug.

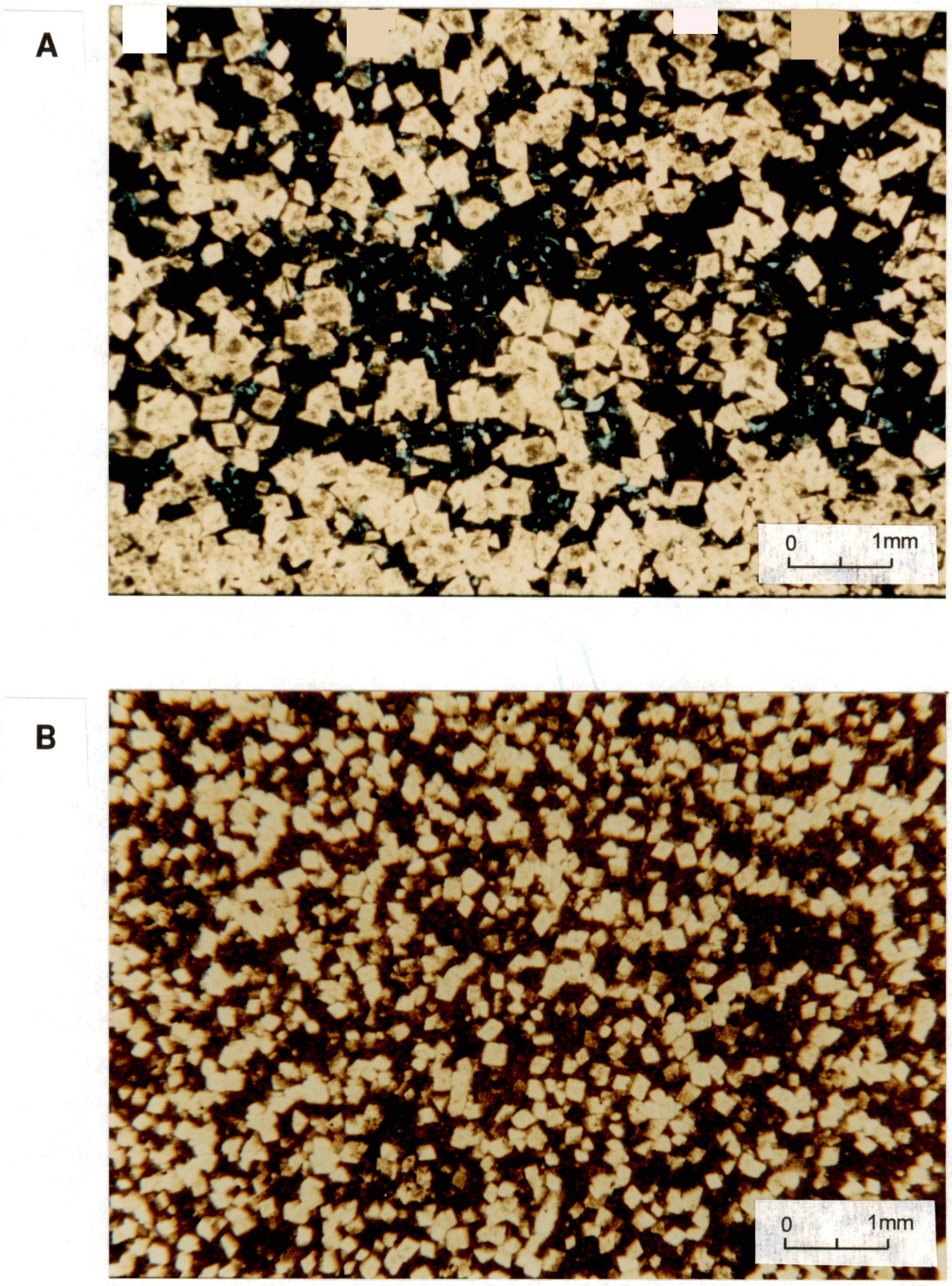


Figure 12. Photomicrographs of dolomitic limestones. (A) Dolomitic grain-dominated packstone having 54 percent dolomite. Dolomite crystal size is 140 microns. (ϕip = 17.4%, k = 6.0 md). (B) Dolomitic wackestone having 40 percent dolomite. Dolomite crystal size is 80 microns. (ϕip = 5%, k = <0.1 md).

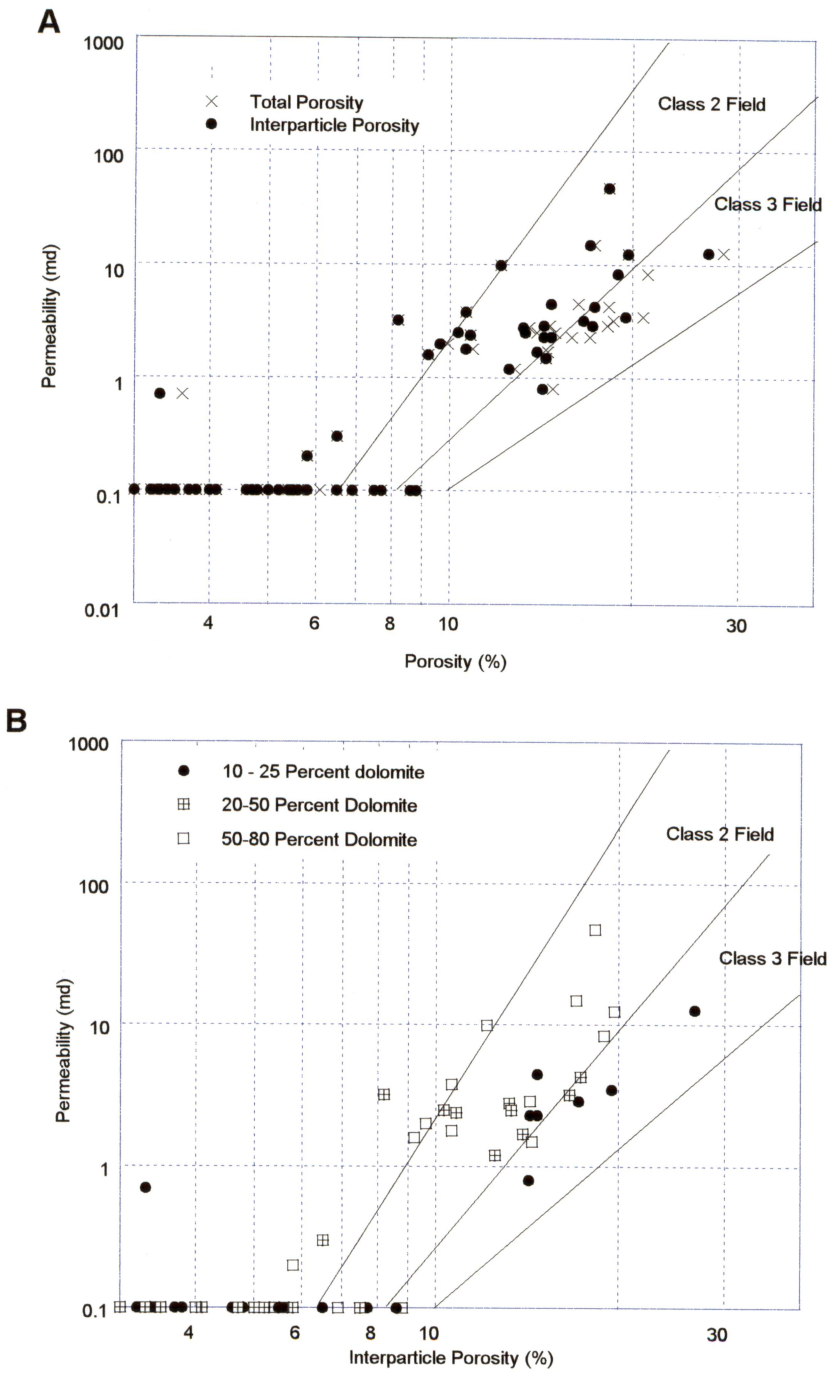


Figure 13. Porosity–permeability cross plot for dolomitic mud-dominated fabrics (10 to 80 percent dolomite). (A) Plot of total and interparticle porosity, showing little separate-vug porosity and most permeable samples plotting in class 2 field instead of in the class 3 field. (B) Plot showing dolomite percentage in three groups, which illustrates an apparent increase in permeability with increasing amount of dolomite. Samples having 10 to 25 percent dolomite plot in class 3 field, and the rest plot in the class 2 field.

pore space. For example, figure 14A shows 71-percent dolomite and porous intercrystal mud. Assuming that the dolomite crystals are nonporous, the measured porosity must be within the mud fraction. The measured porosity is 17 percent, and a simple calculation shows that the mud fraction has a porosity of 58 percent. The high porosity value equates to a larger pore size than found in a mud-dominated fabric having 17-percent interparticle porosity. Figure 14B illustrates a thin section where intercrystal mud has been partially dissolved to create intercrystal porosity space. It is possible that the increase in permeability with increasing mud content that Powers (1962) observed, is an increase in pore size with dolomitization rather than an increase in porosity.

DOLOSTONE

Dolostone samples are characterized by dolomite crystals that are more than 100 microns in size. Most are permeable and all plot in or to the left of the class 1 grainstone field (fig. 15). Porosity is intercrystal between dolomite crystals, ranging from 100 to 500 microns; intercrystal porosity ranges from 3 to 25 percent (fig. 16). Some samples have bimodal dolomite-size distributions. These samples have patchy areas of relatively tight, coarse (250 to 350 mm), cloudy dolomite crystals within porous areas of medium (150 to 250 mm) dolomite crystals having cloudy centers and clear rims. Several thin sections contain abundant skeletal dolomite. Other minerals found in the dolomite are small amounts of anhydrite in the form of laths, chert , and a green clay mineral (probably chlorite). Samples that have abundant chert or green clay were discarded from the data set.

Samples were divided into three groups according to crystal size: 100 to 200 microns, 200 to 300 microns, and 300 to 500 microns. The porosity–permeability cross plot shows that permeability increases as dolomite crystal size increases (fig. 15B). The plot also shows that a number of samples plot to the left of the petrophysical class 1 field. Most of these dolostones have dolomite crystals larger than 200 microns, indicating that the upper limit of class 1 should be moved left to accommodate these samples, as shown in figure 15B.

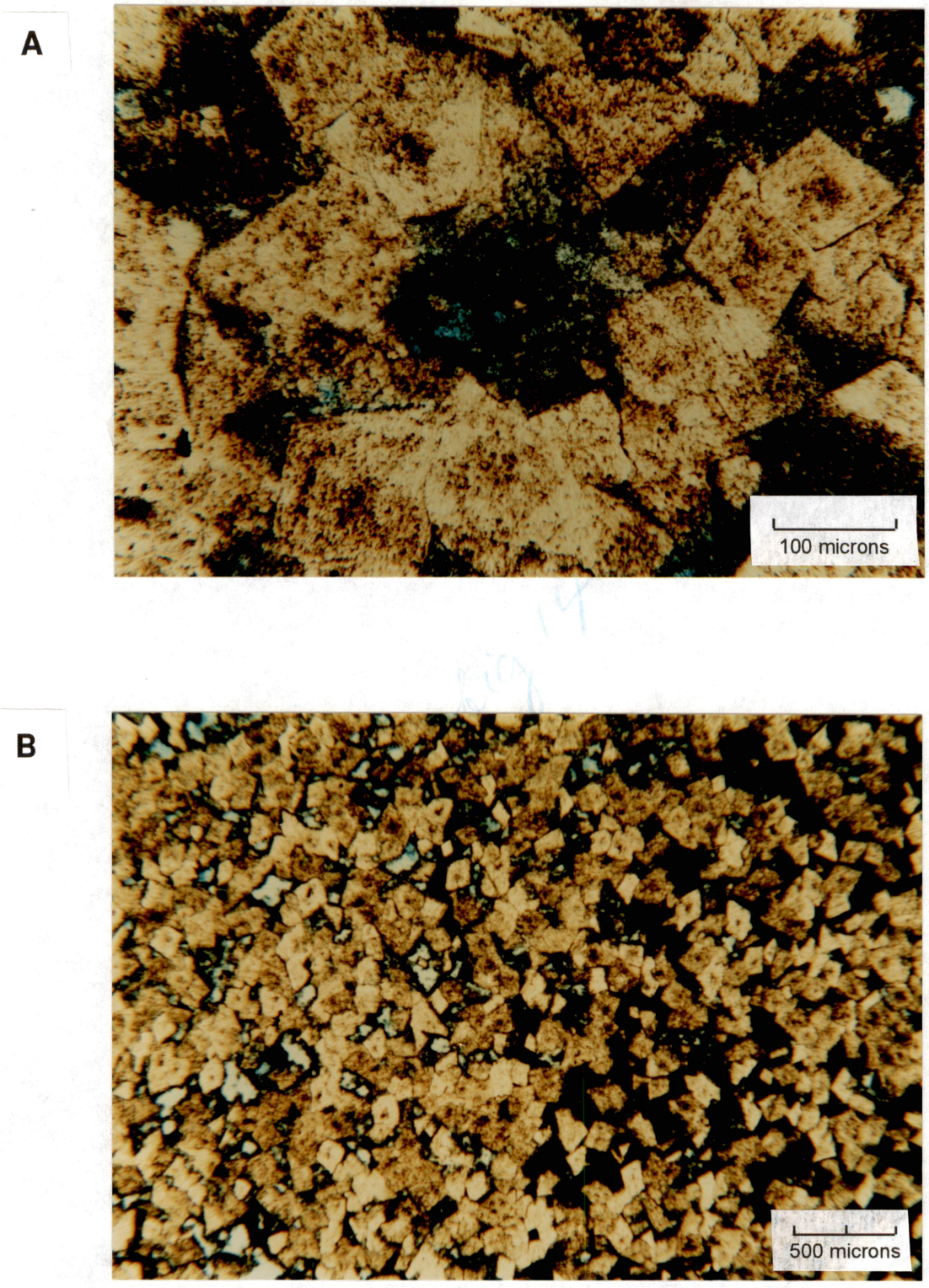


Figure 14. Photomicrographs of dolomitic wackestones illustrating the development of intercrystal porosity. (A) Sample showing increase in porosity in intercrystal mud (ϕip = 17%, k = 15 md). (B) Sample showing dissolution of intercrystal mud to form intercrystal pore space (fip = 18%, k = 47 md).

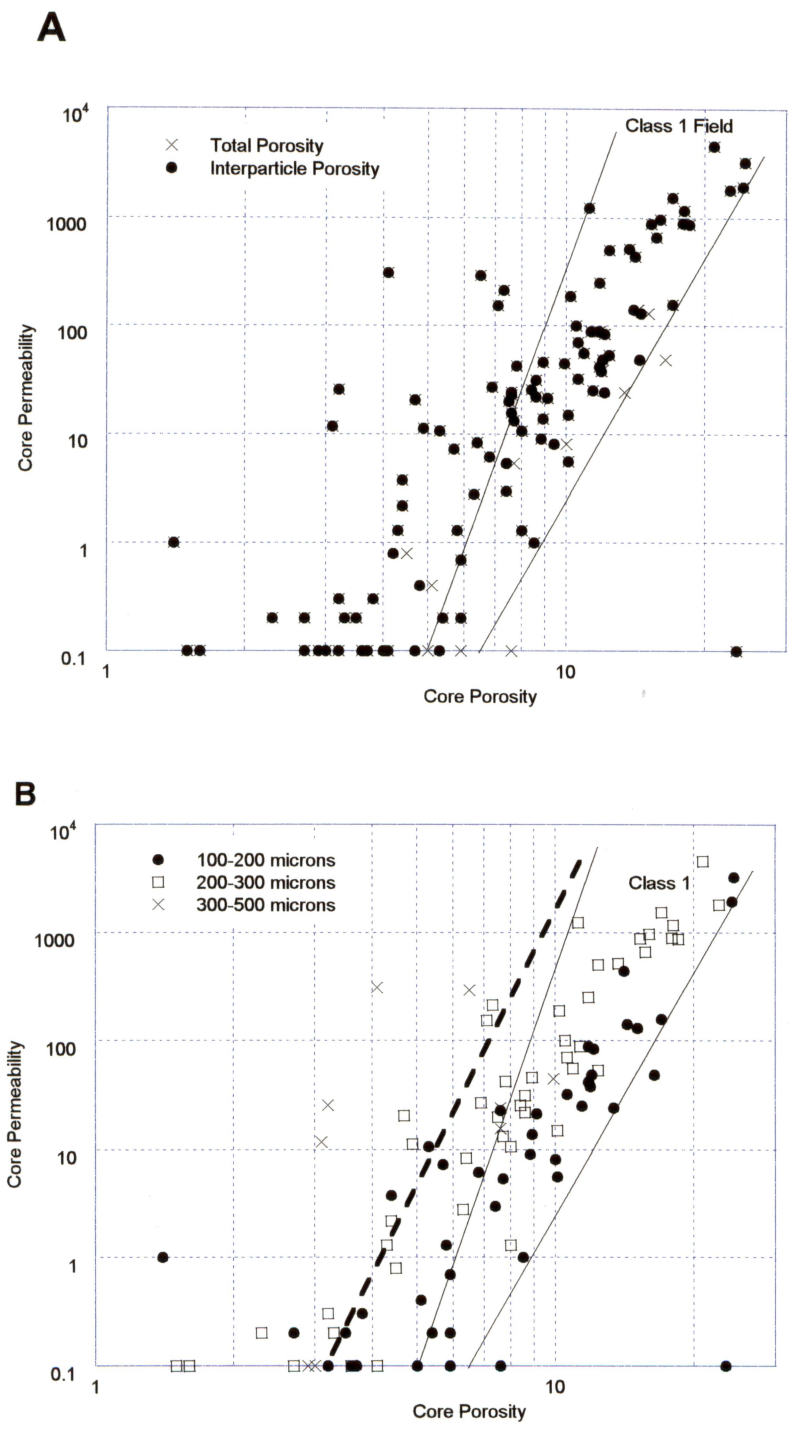


Figure 15. Porosity–permeability cross plot for dolostones. (A) Plot of total and interparticle porosity showing little separate-vug porosity. Most permeable samples plot in the class 1 field, but many plot to the left of the class 1 field. (B) Plot having dolomite crystal size in three groups, which shows an apparent increase in permeability with increasing dolomite crystal size. The class 1 field must be enlarged to accommodate the range of dolomite crystal sizes of from 100 to 300 microns.

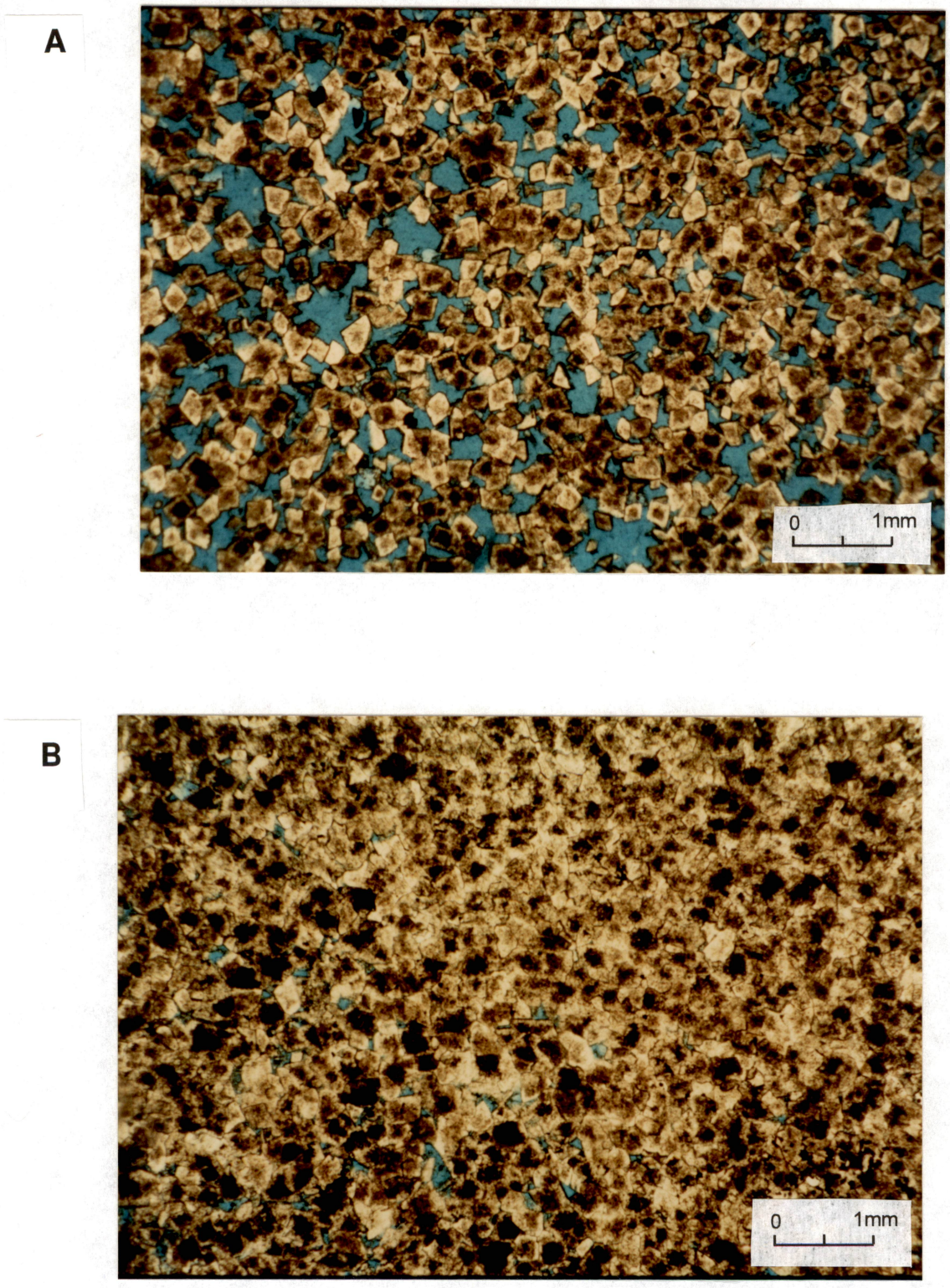


Figure 16. Photomicrographs of dolostone. The precursor fabric cannot be determined. (A) Intercrystal porosity in dolostone having 200-micron crystals. (ϕip = 24%, k = 3,279 md). (B) Dense dolostone having 200-micron crystals (ϕip = 3%, k = <0.1 md).

POROSITY–PERMEABILITY TRANSFORMS

Analysis of thin section and core data demonstrates that rock fabrics can be grouped into petrophysical fields according to porosity and permeability (fig. 17). Grainstones and large crystal dolostones fall within the petrophysical class 1 field of Lucia (1995). The permeability of the dolostones increases with increasing crystal size. The class 1 field is enlarged to include dolostones having crystal sizes larger than 200 microns. Grain-dominated and dolomitic grain-dominated packstones plot within the petrophysical class 2 field of Lucia (1995). Dolomitic mud-dominated fabrics having more than 25 percent dolomite also fall in the class 2 field because of the increase in pore size related to the dolomitization process. Mud-dominated fabrics having less than 25 percent dolomite are mostly dense but, when permeable, plot in the petrophysical class 3 field.

The three generic rock-fabric-specific porosity–permeability transforms developed by Lucia (1995) can be used to calculate permeability for this suite of rocks. The permeability of the dolomites, however, may be understated because the class 1 transform does not account for the larger-than-200-micron crystal size. Although fabrics are divided into three petrophysical classes, in nature there is no boundary between the classes. Instead, there is a continuum from mudstone to grainstone and from 5-μm mud-dominated dolostones to 500-μm mud-dominated dolostones. Therefore, there is also a complete continuum of rock-fabric-specific porosity–permeability transforms.

To model such a continuum, the boundaries of each petrophysical class are assigned a value (0.5, 1.5, 2.5, and 4) (fig. 18) and porosity–permeability transforms are generated. An equation relating permeability to a continuum of petrophysical classes and interparticle porosity is developed by multiple linear regression. The resulting global transform is

$$\text{Log}(k) = (A + B \times \text{Log}(\text{Class})) + (C + D \times \text{Log}(\text{Class})) \times \text{Log}(\Phi ip),$$

where

$A = 9.7982,$

$B = 12.0838,$

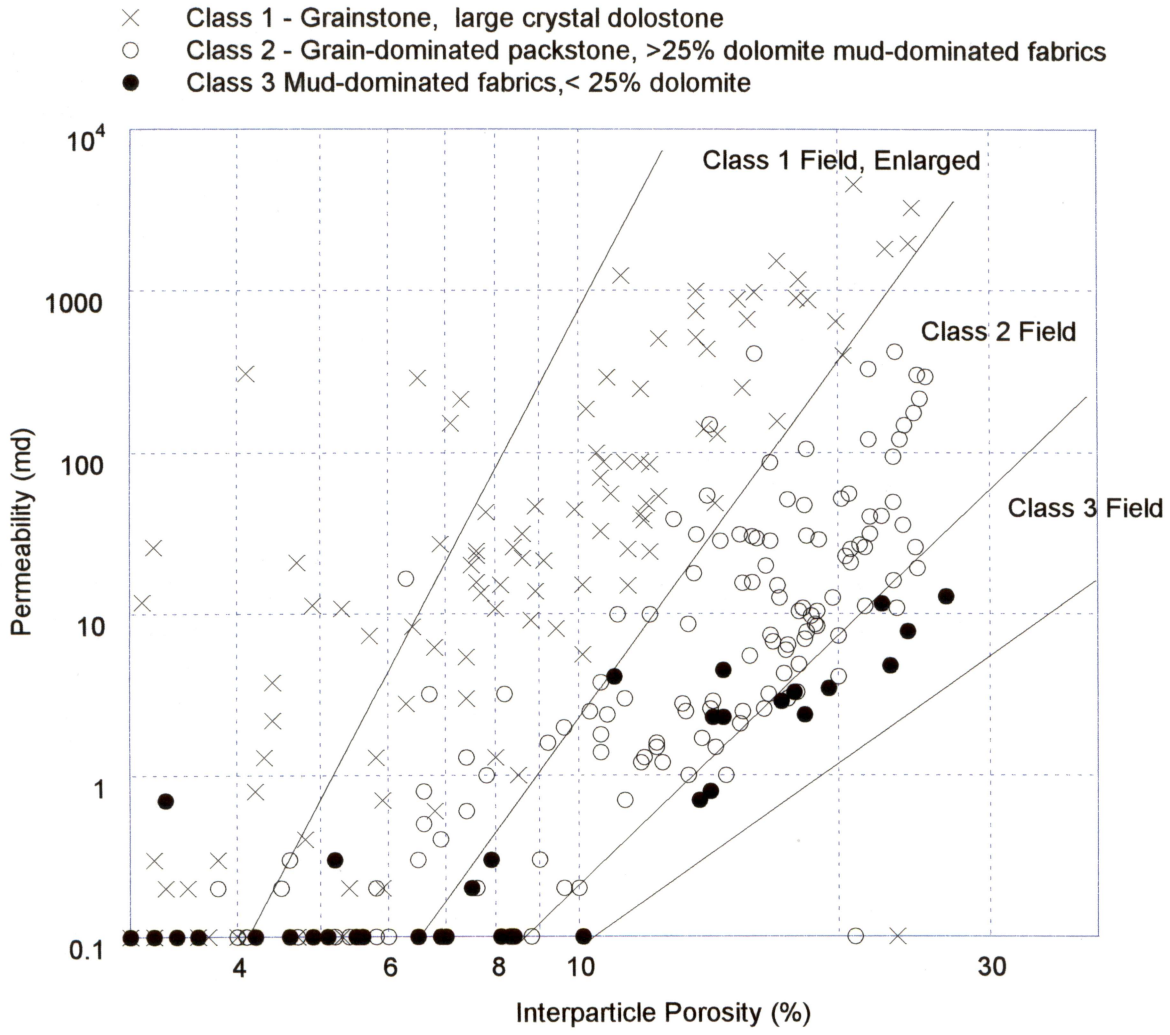


Figure 17. Porosity–permeability cross plot of all representative samples showing rock-fabric petrophysical classes.

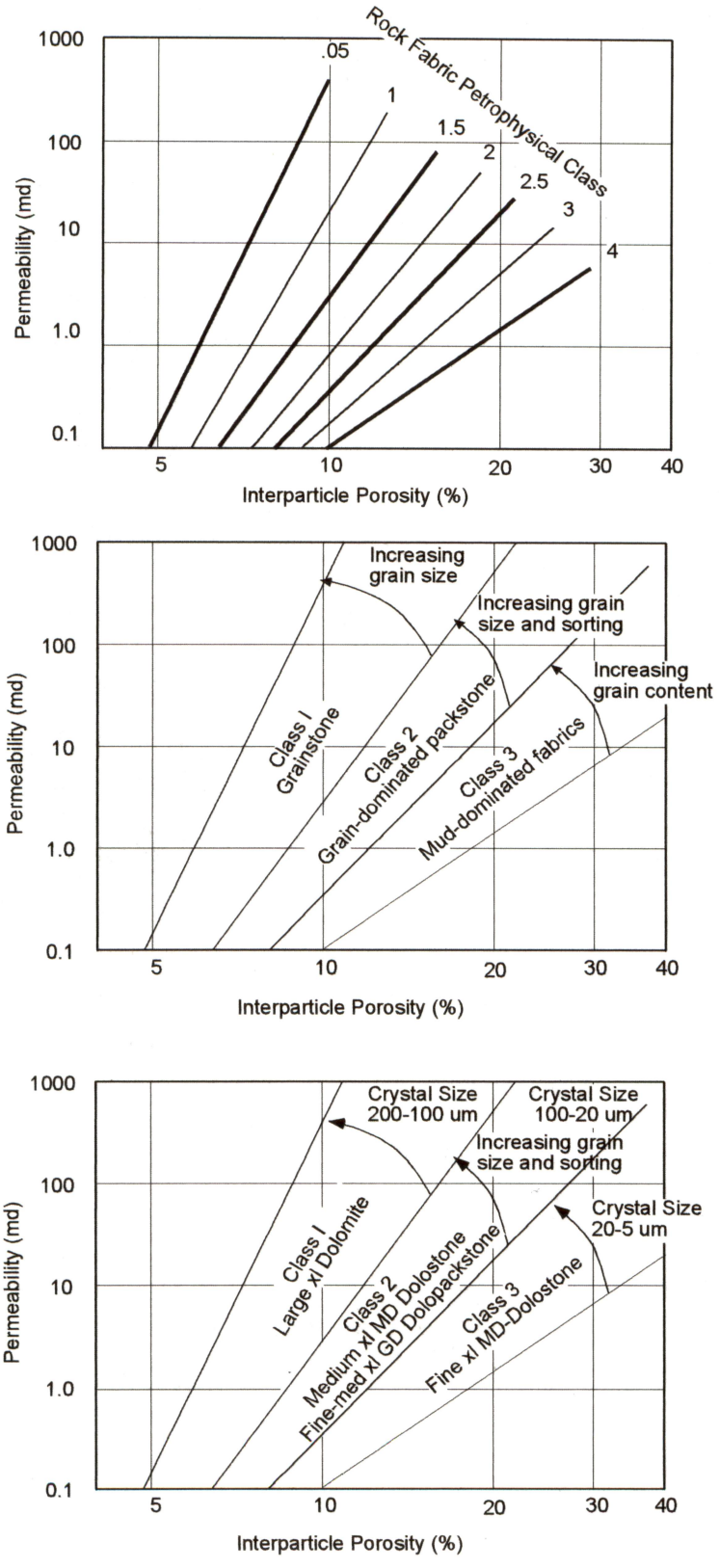


Figure 18. Continuum of rock fabrics and associated porosity–permeability transforms. (A) Rock-fabric petrophysical classes ranging from 0.5 to 4 defined by class-average and class-boundary porosity–permeability transforms. (B) Fabric continuum in nonvuggy limestone. (C) Fabric continuum in nonvuggy dolostone.

C = 8.6711,

D = 8.2065,

and

Class = Rock-fabric petrophysical class ranging from 0.5 to 4, and

Φip = Fractional interparticle porosity.

Mud-dominated limestones and fine crystalline mud-dominated dolostones occupy classes from 4 to 2.5 (fig. 18a, b). The class number decreases with increasing dolomite crystal size from 5 to 20 microns in mud-dominated dolostones and increasing grains in mud-dominated limestones. Grain-dominated packstones, fine to medium crystalline grain-dominated dolopackstones, and medium crystalline mud-dominated dolostones occupy classes from 2.5 to 1.5 (fig. 18a, b). The class value decreases with increasing dolomite crystal size from 20 to 100 microns in mud-dominated dolostones and with decreasing amounts of intergrain micrite, as well as increasing grain size in grain-dominated packstones and fine to medium crystalline grain-dominated dolopackstones. Grainstones, dolograinstones, and large crystalline dolostones occupy classes 1.5 to 0.5 (fig. 18a, b). Class value decreases with increasing grain size from 100 to 500 microns, and dolomite crystal size from 100 to 200 microns.

PERMEABILITY FROM WIRELINE LOGS

Approach

No wireline log measures permeability. Instead, permeability is estimated according to empirical relationships between wireline log values and permeability, most notably porosity. In the rock-fabric method, rock fabrics are determined by porosity, water saturation, and reservoir-height cross plots. Rock-fabric-specific porosity–permeability transforms are then used to estimate permeability. Permeability, however, has been shown to be related to interparticle porosity, not total porosity (Lucia, 1983). Separate-vug porosity must therefore be determined and subtracted

from total porosity before permeability can be estimated. Acoustic-porosity cross plots are used to make this determination.

Calibrating log data with core data and rock-fabric descriptions requires matching core depths and log depths as closely as possible. Although no depth shift was made in well 106, a large adjustment was made in well 101. Matching core data with log data exactly is nearly impossible and accounts for much of the imprecision that results from comparing core and log data. In addition to matching core and log depths, there is a large scaling problem between wireline-log measurements, core measurements, and thin-section descriptions. Wireline logs average data over intervals of several feet, whereas core data are measured on core plugs or 6-inch whole core samples, and thin-section descriptions are made on 1-inch × 30-micron slices of core. In order to scale rock-fabric descriptions to wireline logs, it is necessary to find intervals of uniform fabric covering more than 3 ft.

Calculation of Interparticle Porosity

Interparticle porosity is calculated by subtracting separate-vug porosity from total porosity. Total porosity can be calculated from neutron, density, and acoustic logs by means of various algorithms. In this study, flame porosity values provided by Aramco were used. Separate-vug porosity is estimated from cross plots of transit time (from acoustic logs) and total porosity. The assumption is that porosity and transit time follow the Wyllie time-average curve if separate-vug porosity is constant. Relationships for limestones and for anhydritic dolomite have been derived (Wang and Lucia, 1993). These relationships have the form

$$Svug = 10^{a + b(\Delta t + 141.5 \times \phi)},$$

or

$$Svug = A \times e^{B(\Delta t + 141.5 \times \phi)}.$$

For limestones,

$A = 13{,}406$, and

B = –0.2987.

For anhydritic dolomite,

A = 8,920, and

B = –0.3254.

The slopes are very similar, and the intercept varies with lithology. The lithology effect is expressed in the Δt term at zero porosity. The Arab D limestone has a Δt of 48 μsec /ft at zero porosity (fig. 19), which is characteristic of most limestones, and the constants for limestone are used to calculate separate-vug porosity. The dolostone has little separate-vug porosity. Assuming that the dolostone has an average separate-vug porosity of 0.01, the Δt at zero porosity at 0.01 is 40 μsec/ft (fig. 19). Assuming a constant slope (B constant) (fig. 19), an intercept value of 4,953 is calculated. The constants for calculating separate-vug porosity in dolostone are, for Arab D dolomite (no anhydrite),

A = 4,953, and

B = –0.3254.

The lithology of the Arab D is variable, and a relationship between the mineral fraction that is dolomite and transit time, porosity, and separate-vug porosity was developed:

$$Svug = (13{,}406 - D_f \times 8{,}753) \times e^{-0.32(\Delta t + 141.5 \times \phi)},$$

where

D_f = dolomite fraction.

An algorithm using neutron and density curves determined dolomite percentages. Comparisons of calculated and core separate-vug porosity values according to vertical profiles show a good correlation (fig. 20). Spikes in the thin-section data are due partly to small-scale variability averaged out by wireline logs. In well 106, deviations between core and calculated separate vugs are thought to be a scaling problem. In well 101, intervals of high separate-vug porosity from log calculation may be touching-vug horizons. The flow meter from well 101 shows 60 percent of the flow from a 10-ft interval (6,575 to 6,585) and an additional 20 percent from the interval 6,585 to 6,610. There are no core data from this interval. The interval does, however, lie

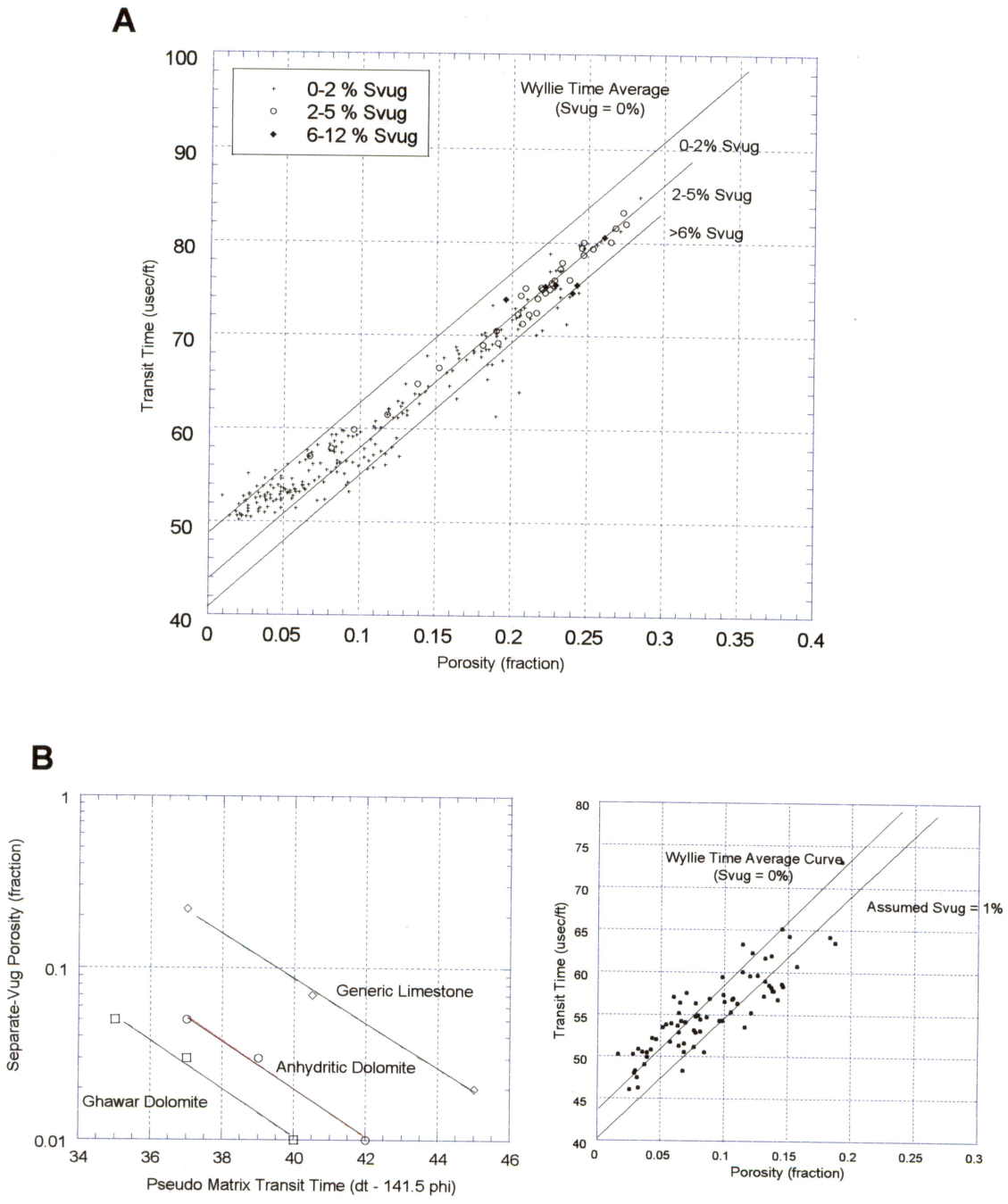


Figure 19. Acoustic, porosity, separate-vug relations from wells HRD 101 and 106. (A) Cross plot of transit time and porosity for limestones and dolomites showing a Wyllie time-average curve having a matrix Δt of 48 μs/ft for limestone having no Svug porosity and a matrix Δt of 45 μs/ft for dolomite, assuming an average of 0.01 Svug porosity for the dolomite results in a pseudomatrix Δt of 40 μs/ft. (B) Cross plot of pseudomatrix Δt and separate-vug porosity for limestone, anhydritic dolostone, and Ghawar dolostone.

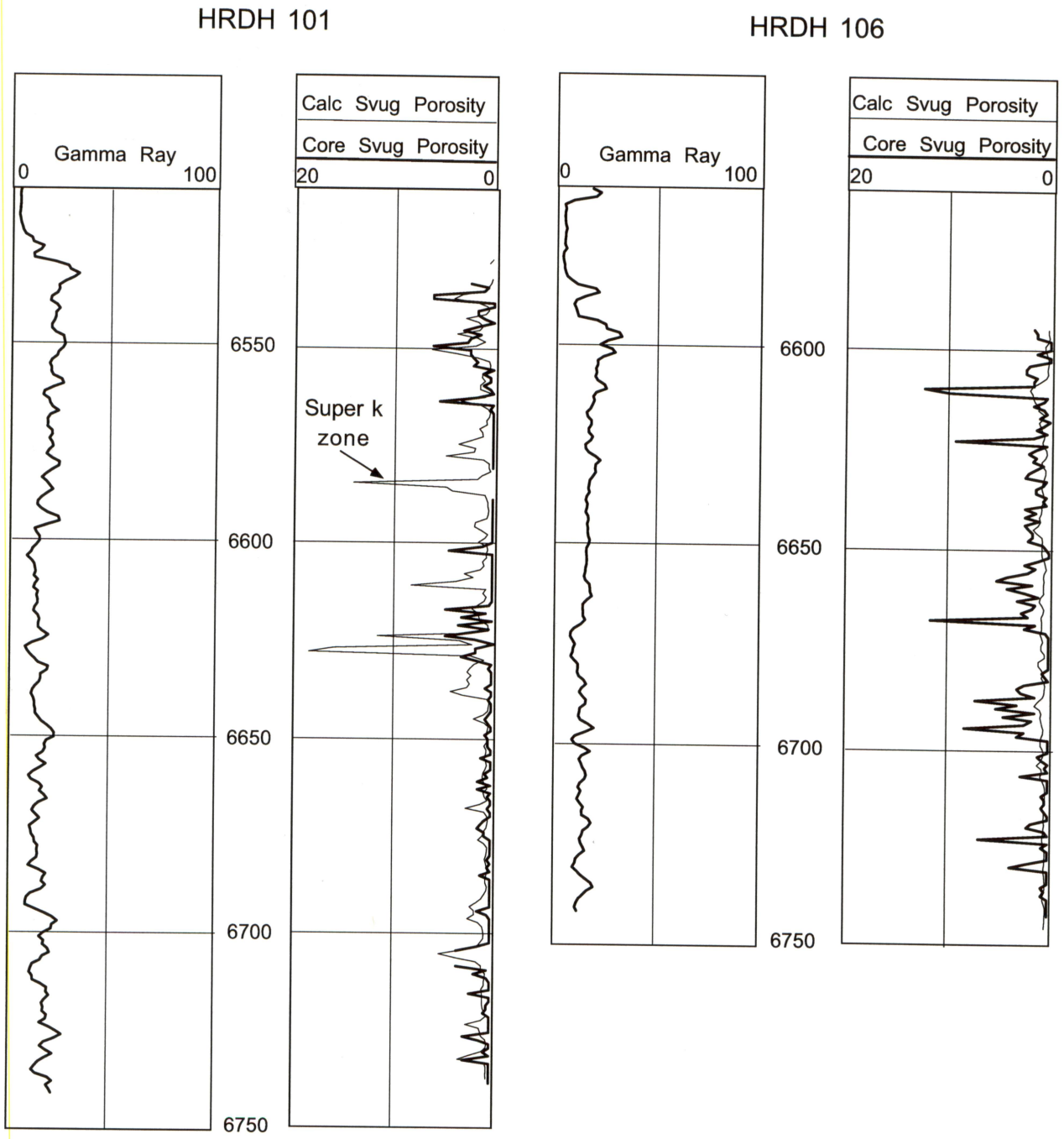


Figure 20. Comparison of separate-vug porosity from logs and thin sections in wells HRDH 101 and 106. High log-calculated separate vugs in well 101 are thought to be caused by touching-vug pore systems. In well 106, the spikes for core descriptions are thought to be caused by small-scale heterogeneity.

within a zone of large crystal dolostone, the porosity log calculates to as much as 30-percent porosity, and the caliper shows a slight hole enlargement. These observations all suggest the presence of a touching-vug pore system composed of enlarged fractures and small cavities. The high separate-vug porosity values in well 101 are therefore incorrect and reflect acoustic response to fractures and caverns.

Determination of Rock-Fabric Petrophysical Class

Rock-fabric petrophysical class is determined from cross plots of water saturation and porosity. Wells 101 and 106 are sufficiently high above the free-water level that reservoir height can be ignored. Flame porosity and water-saturation values provided by Aramco were used in this analysis. Only fabrics having more than 0.1 md permeability were used to calibrate the cross plot, and only that area of the cross plot having greater than 5-percent porosity was used in the analysis. Large crystal dolostone and grainstone (class 1) form a field characterized by low water saturation, and the coarser dolostones tend to have lower water saturations. The lower limit of this field was assigned a class of 0.5 and the upper limit a class of 1.5 (fig. 21). Grain-dominated packstones and mud-dominated fabrics that have 25- to 80-percent dolomite form a prominent trend and contain a majority of the data points. This prominent trend was assigned a class of 2 (fig. 21). There are only a few permeable mud-dominated fabrics, and in general they are too thin for log calibration. However, two intervals of permeable mud-dominated fabrics were large enough to be used to calibrate the cross plot: 6,691 to 6,696 in well 106 and 6,702 to 6,705 in well 101. The boundary between the grain-dominated packstones and mud-dominated fabrics was assigned class 2.5, the class 3 line was drawn through a small group of mud-dominated fabrics, and the upper limit of the mud-dominated fabrics (class 4) was spaced above the group (fig. 21). A relationship between rock-fabric petrophysical class, water saturation, and porosity was developed by multilinear regression on the equations for the class boundaries. Calculated and core rock-fabric petrophysical classes show a good correlation:

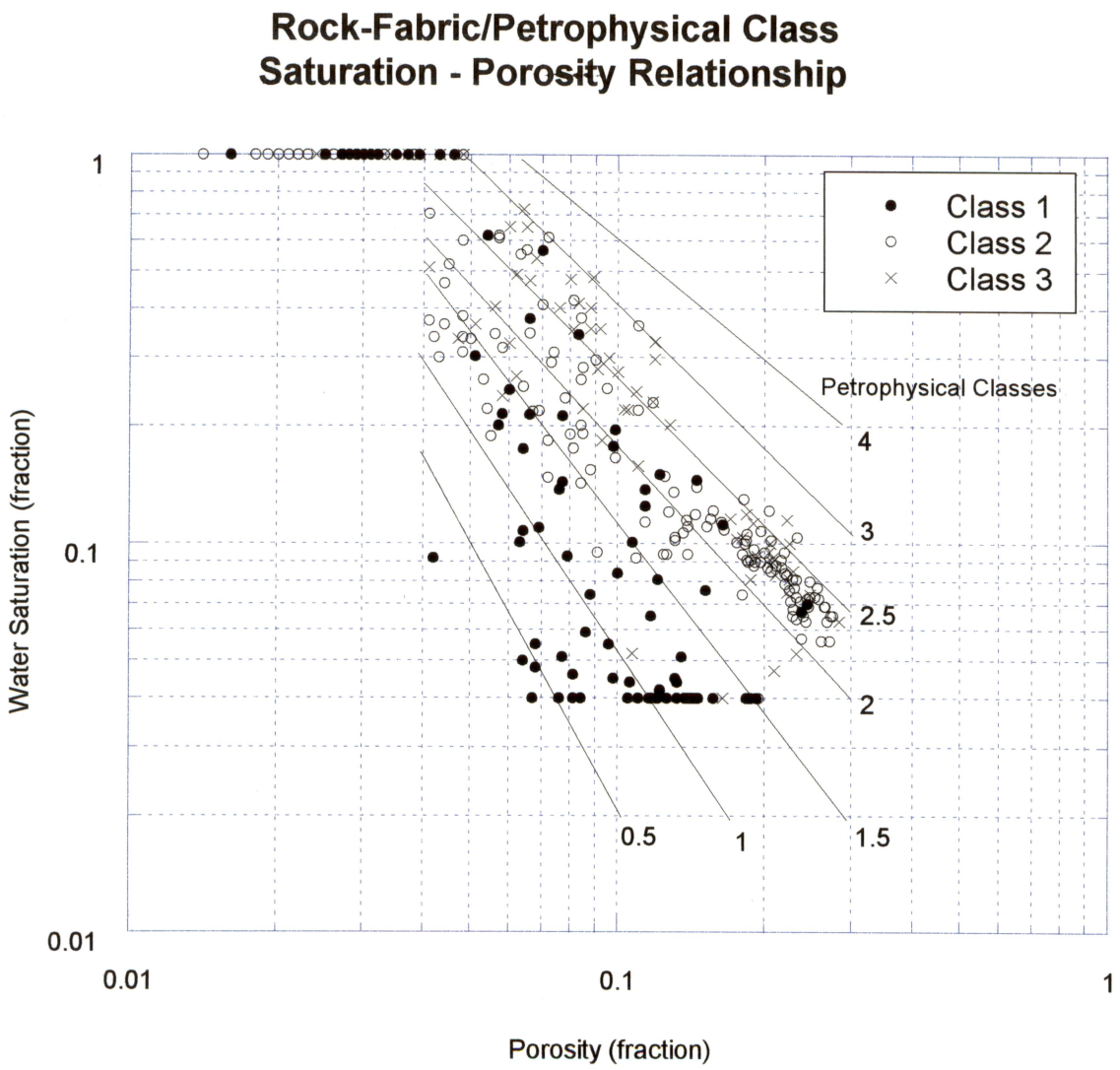


Figure 21. Cross plot of porosity and water saturation showing rock-fabric petrophysical classes. The curves are used to construct an equation relating saturation and porosity to petrophysical class for input into the global, interparticle-porosity, permeability transform equation.

$$\text{Log (Class)} = (A + B\log(\phi) + \log(Sw))/(C + D\log(\phi)),$$

where

Class = Rock-fabric petrophysical class ranging from 0.5 to 4

A = 3.1107

B = 1.8834

C = 3.0634

D = 1.4045

The use of this equation is limited to permeable intervals and porosity above 5 percent. In most cases, because samples with less than 5-percent porosity are mud-dominated fabrics or petrophysical class 3, log readings of less than 5-percent porosity were arbitrarily given a petrophysical class of 3.

Calculated and core rock-fabric petrophysical classes show a good correlation. The calculated classes are a continuum, whereas the core classes are specific. The calculated classes in general fall within the range of the specific classes from thin-section description. The continuous profile from log calculations shows interesting detailed vertical patterns not seen in thin-section descriptions. How the patterns relate to rock-fabric successions has not been determined.

In well 101 (fig. 22) there is a major discrepancy around 6,580 that is probably due to the presence of a touching-vug pore system composed of enlarged fractures and small cavities. Water-saturation values are higher than expected for this interval, and the higher water saturation results in a lower petrophysical class than expected. An m value of 1 is required to obtain reasonable water-saturation values. Touching-vug pore systems are not amenable to this type of analysis.

In well 106 (fig. 23) the correlation between log-calculated and thin-section rock fabrics is very good. The two principal dolomite intervals (class 1) are identified, and the upper interval of grain-dominated packstone and the lower interval of alternating grain-dominated packstone and mud-dominated fabrics are clear. The thin, mud-dominated intervals are averaged out of the wireline-log calculations.

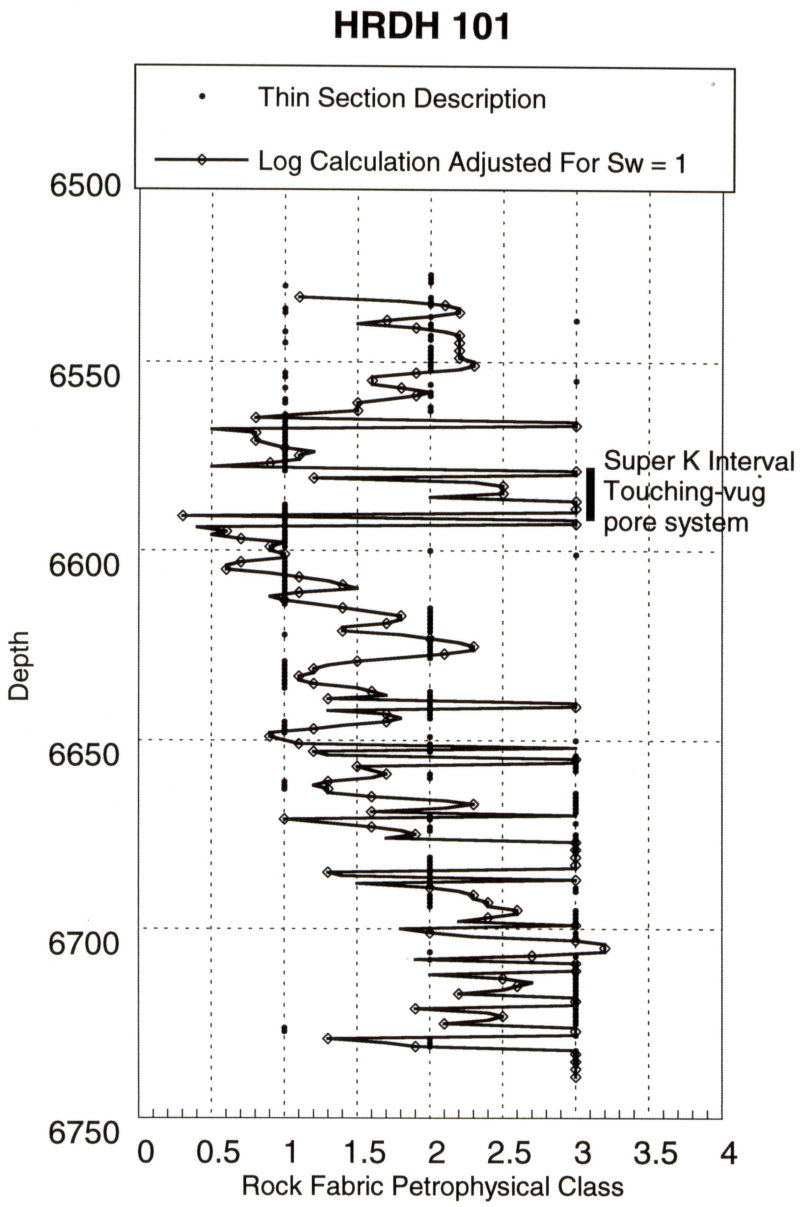


Figure 22. Comparison of petrophysical classes from logs and thin sections for well HRDH 101. Petrophysical classes are incorrectly calculated in the super-k interval because water saturation is incorrectly calculated.

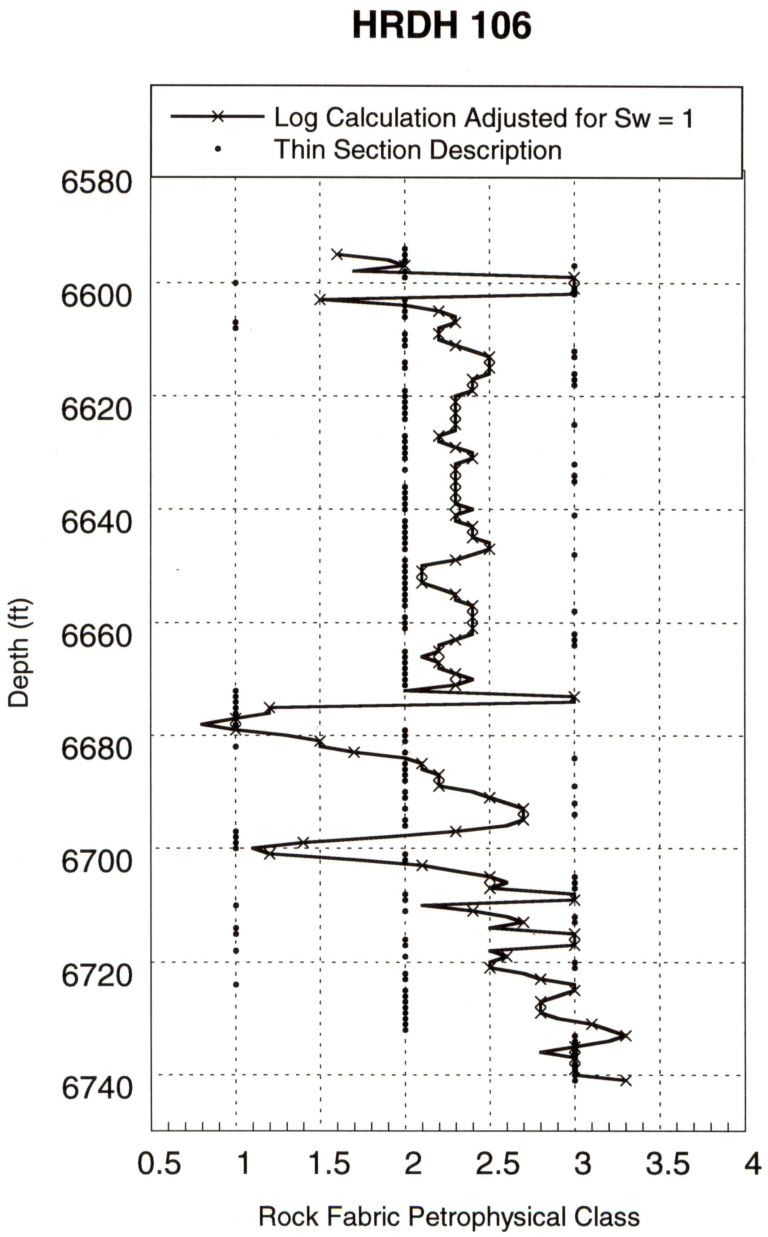


Figure 23. Comparison of petrophysical classes from logs and thin sections for well HRDH 106.

Permeability Calculation from Wireline Logs

Permeability is calculated from wireline logs by substituting petrophysical class and interparticle porosity into the global permeability transform equation. Because of the suspected effect of touching vugs on acoustic-log response in well 101, total porosity was used instead of interparticle porosity from the acoustic log. The rock-fabric term could be eliminated, resulting in a relationship between permeability, saturation, porosity, interparticle porosity, and reservoir height. The link between petrophysical properties and geological parameters, however, is maintained by including the rock-fabric term. This inclusion is important because geological parameters, such as rock fabrics, are required to extrapolate petrophysical properties into 3-D space.

Comparing log-calculated permeability with core permeability shows a good correlation (fig. 24, 25). The high- and low-permeability values are retained in this analysis. Spikes in the core data caused by small-scale heterogeneity are smooth because the logs average over a 2- to 3-ft interval. In well 101, calculated permeability values in interval 6,575 to 6,595 are lower than expected. This interval is interpreted to contain a touching-vug pore system composed of enlarged fractures and small cavities. The rock-fabric petrophysical-class approach does not apply to this pore type. The calculated water saturation is too low, resulting in a petrophysical class that is too low and a calculated permeability that is too low. The rest of the calculated permeability values compare well with core values.

CONCLUSIONS

Analysis of thin sections and core data demonstrates that rock fabrics can be grouped into petrophysical fields defined by porosity and permeability (fig. 26). Grainstones and large crystal dolostones fall within the petrophysical class 1 field of Lucia (1995). Permeability increases with increasing dolomite crystal size. The class 1 field is enlarged slightly to include large crystal dolostones having crystal sizes as much as 300 microns. Grain-dominated and dolomitic mud-

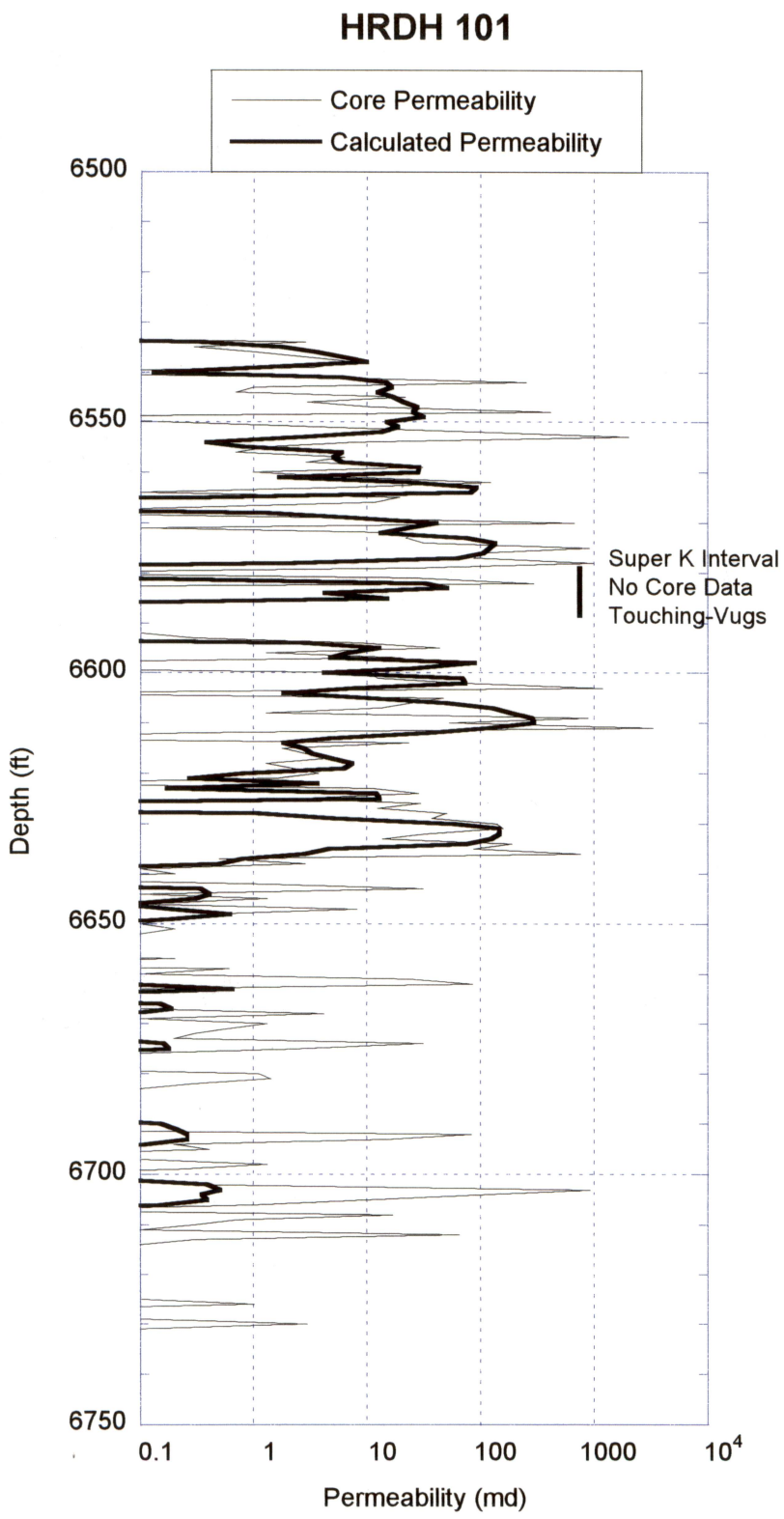


Figure 24. Comparison of core and log-calculated permeability values for well HRDH 101. Permeability values in the super-k interval of HRDH 101 are too low because water saturation and petrophysical class are incorrectly determined.

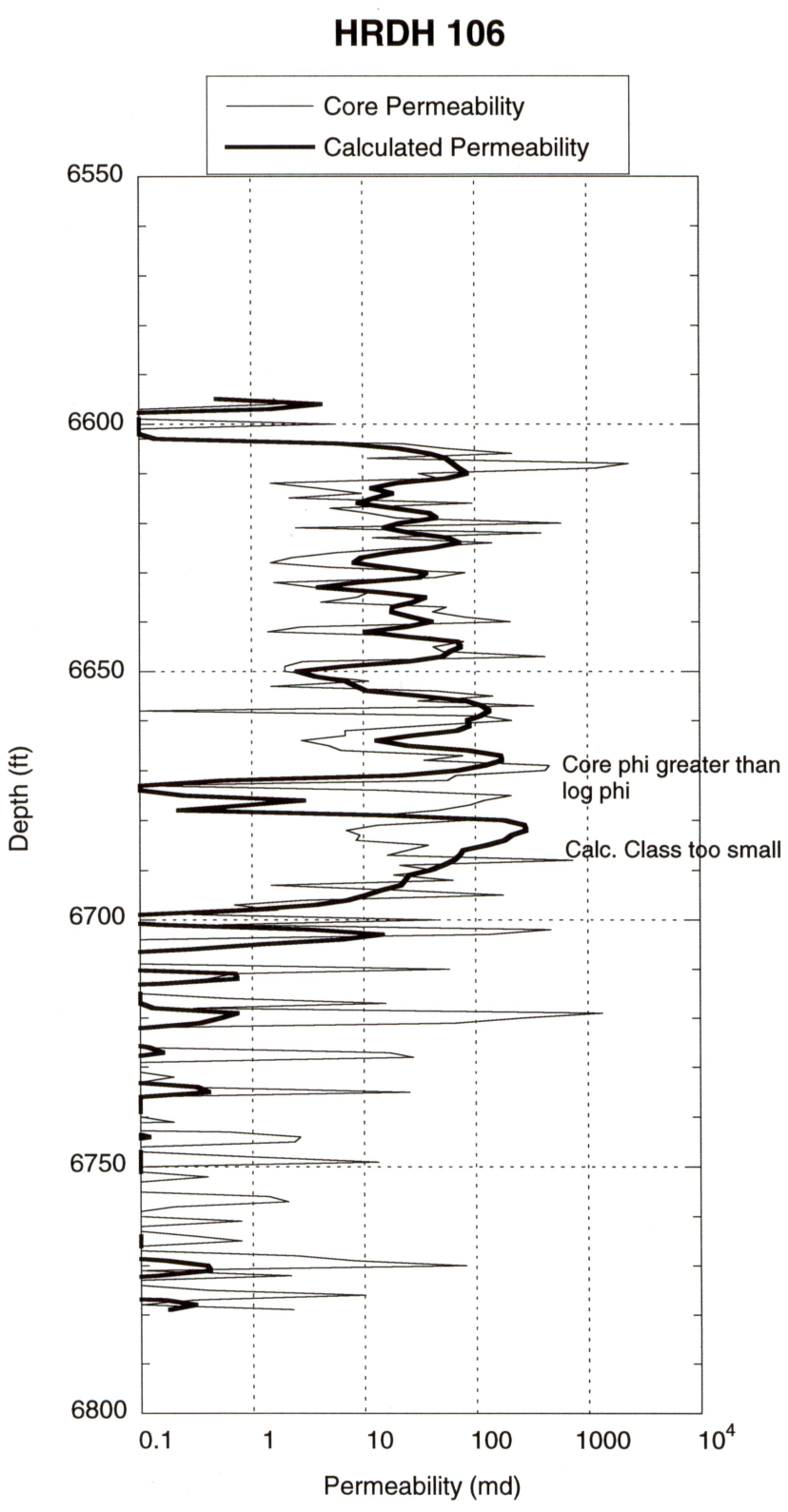
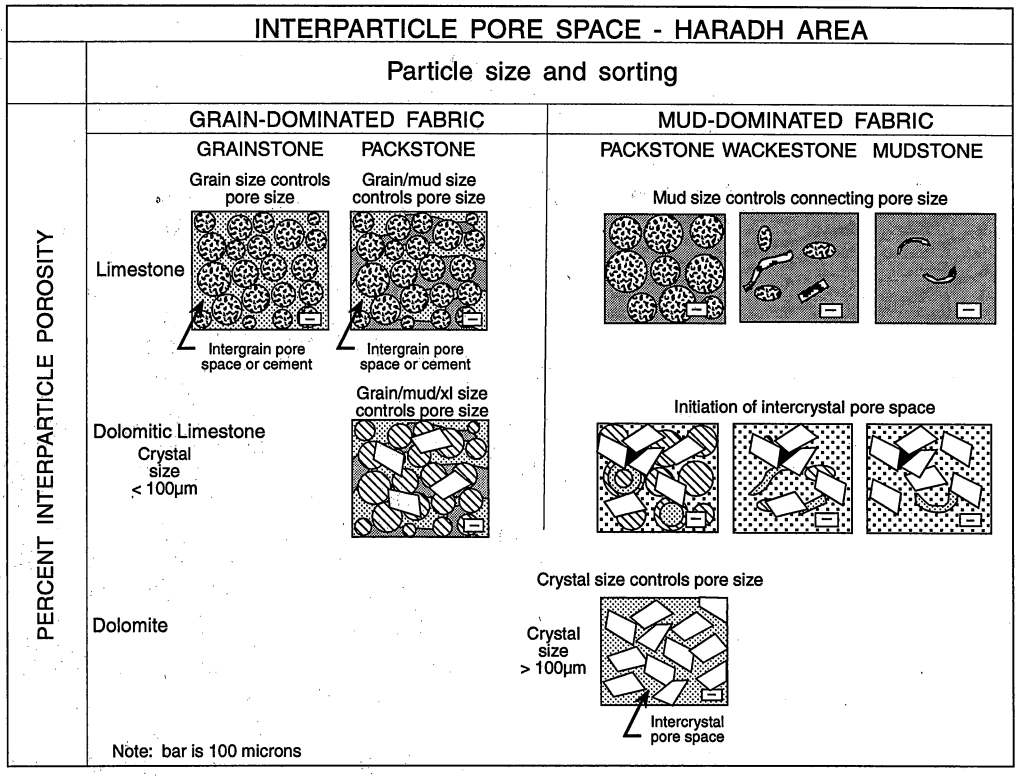


Figure 25. Comparison of core and log-calculated permeability values for well HRDH 106. Permeability in the dolomite interval is too low because log porosity is lower than core porosity.



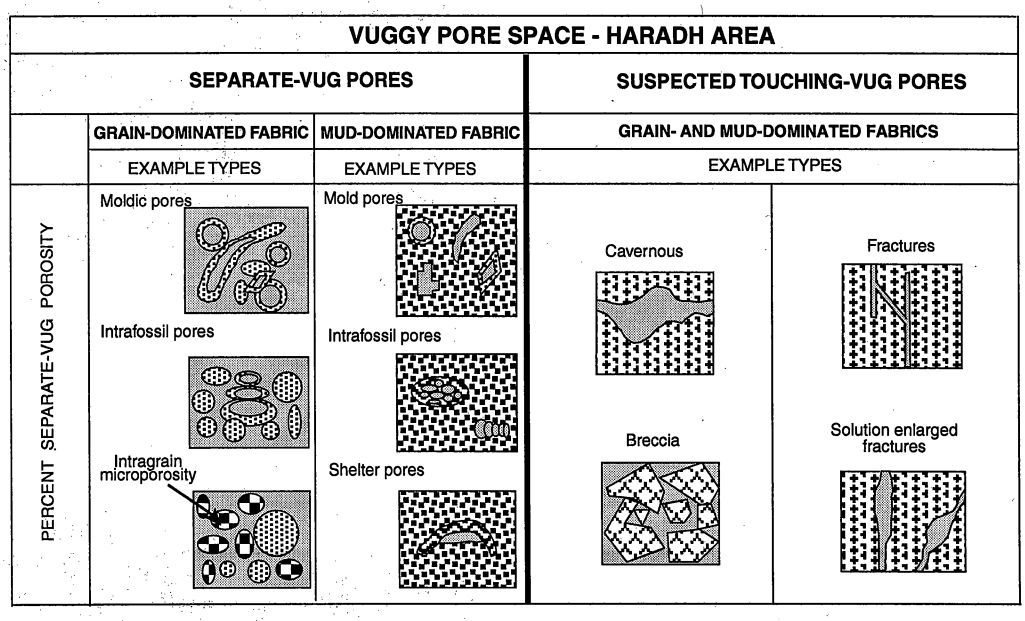


Figure 26. Diagram summarizing rock fabrics found in thin sections of wells HRDH 101 and 106.

dominated fabrics having more than 25 percent dolomite fall into the petrophysical class 2 field. The dolomitic mud-dominated fabrics plot in the class 2 field because progressive dolomitization increases pore size by increasing porosity in the intercrystal mud and by creating intercrystal pore space. Mud-dominated fabrics that have less than 25 percent dolomite are mostly dense, but when they are permeable, plot in the petrophysical class 3 field.

The three generic rock-fabric porosity–permeability transforms developed by Lucia (1995) can be used for this suite of rocks. The permeability of the dolomite, however, may be understated because the class 1 transform does not account for larger than 200-micron crystal size. A global relationship between rock-fabric petrophysical class, interparticle porosity, and permeability that does not require fabrics to be divided into specific petrophysical classes has been developed and is used in this analysis:

$$\text{Log}(k) = (A + B \times \text{Log}(\text{Class})) + (C + D \times \text{Log}(\text{Class})) \times \text{Log}(\Phi ip),$$

where

$A = 9.7982,$

$B = 12.0838,$

$C = 8.6711,$

$D = 8.2065,$

and

Class = Rock-fabric petrophysical class ranging from 0.5 to 4

Φip = Fractional interparticle porosity

Permeability can be estimated from wireline logs by using the rock-fabric method. Interparticle porosity is estimated by subtracting total porosity from separate-vug porosity, which, in turn, is estimated from transit-time–porosity cross plots according to the following general equation, which incorporates lithology changes from limestone to dolostone:

$$\text{Svug} = (13{,}406 - D_f \times 8{,}753) \times e^{-0.32(\Delta t + 141.5 \times \phi)}.$$

Petrophysical classes can be identified from a cross plot of water saturation and porosity. The wells are far enough above the free-water level that reservoir height is not an important consideration. Well data from various structural positions and capillary-pressure data should, however, be used in the future to incorporate a reservoir-height term in the equation given next. Boundaries between rock-fabric classes were identified and multiple-regression analysis was used to develop the following relationship between petrophysical class, saturation, and porosity:

$$\text{Log (Class)} = (A + B\log(\phi) + \log(Sw))/(C + D\log(\phi)),$$

where

Class = Rock-fabric petrophysical class ranging from 0.5 to 4,

A = 3.1107,

B = 1.8834,

C = 3.0634, and

D = 1.4045.

Identifying rock fabrics from log-calculated petrophysical classes requires additional information because (1) there are multiple rock fabrics in each class and (2) the saturation approach applies only to permeable intervals. Class 1 includes both large crystal dolomite and grainstone. Lithology can be used to distinguish between them. Class 2 includes grain-dominated packstones, dolomitic grain-dominated packstones, and dolomitic mud-dominated fabrics. Lithology can be used to distinguish grain-dominated packstones but not to distinguish between dolomitic grain-dominated packstones and dolomitic mud-dominated fabrics. Class 3 includes mud-dominated fabrics that have less than 25 percent dolomite. Because most dense samples are mud-dominated and dolomitic mud-dominated fabrics, low-porosity intervals are assigned to class 3.

Permeability is calculated by substituting log-calculated interparticle porosity and log-calculated petrophysical class into the global transform equation. These calculations compare well with core data and retain high and low permeability values. It is important to retain the rock-fabric petrophysical class term in this calculation because it provides the link between petrophysical properties and geologic processes necessary to display permeability, porosity, and water saturation

in 3-D. Without the tie to stratigraphy, deposition, and diagenesis, log-calculated petrophysical properties cannot be realistically distributed in 3-D space.

The super k interval in well 101 appears to be producing from a touching-vug pore system composed of small caverns and fractures. The extensive amount of large crystalline dolostone around this touching-vug pore system suggests that the touching-vug pore system also provided the flow path for dolomitizing fluids. The large size of the dolomite crystals is consistent with burial or late origin for the dolomite. Assuming the dolomitization is late, the pore space of the precursor limestone may have been similar to the present limestone, and the dolostone may have inherited its porosity values from the precursor limestone. This would explain why the limestone, dolomitic limestone, and dolostone have similar porosity ranges. The important impact of dolomitization is increased pore size in the mud-dominated and grain-dominated packstone fabrics to a size similar to or larger than that of permeable grainstones.

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Well No.			Dolomite		Calcite	Sulfate		Accessories		Texture					Psv				Core Analysis			Comments
	Plug#	Depth	%	Size(um)	%	% Anh	Type	%	Type	Name	%Grain	%Mud	GrnSize	%Pip	%Psv	Type	%IGu Grains	Class	% Por	%P-%Psv	Perm	
106	2	6586.7	8.3	60	86.4	4.6	PF			MDP	44.1	55.9	<20	0.0	0.0		0.0	3	0.7	0.7	0.0	Grains flattened; patchy anh.
106	4	6587.8	1.0	40	96.7	2.3	PF			MDP	55.9	44.1	<20	0.0	0.0		0.0	3	0.3	0.3	0.0	
106	6	6594.6	1.1	70	98.6	0.0				GDP	68.3	31.7	150	4.0	1.6	MO,IF	1.3	2	12.2	10.6	1.8	
106	8	6595.6	0.0	40	99.7	0.0				GDP	50.1	49.9	150	0.3	1.3	IF	0.6	2	9.9	8.6	0.1	stylolite
106	10	6596.6	0.0	60	99.7	0.0				GDP	66.1	33.9	150	2.3	1.3	MP	0.3	2	13.1	11.8	1.2	Burrow
106	12	6597.6	0.0		100.0	0.0				MDP	44.2	55.8	<20	0.0	0.0		0.0	3	0.7	0.7	0.0	burrow/mud
106	14	6598.6	0.0		100.0	0.0				GDP	63.3	36.7	200	0.0	0.0	IF,MO	0.0	2	0.2	0.2	0.0	
106	16	6599.7	0.0		100.0	0.0				GDP	78.5	21.5	250	0.0	0.0	IF,MO	0.0	2	0.4	0.4	0.0	Very close to grstn; grain breakage
106	18	6600.7	0.0		100.0	0.0				Grainstone	99.0	1.0	350	0.6	1.3	MO,IF	1.3	1	2.7	1.4	0.1	
106	20	6601.7	6.3	40	93.7	0.0				Wacke	39.9	60.1	<20	0.0	0.0		0.0	3	1.4	1.4	0.0	Stylolite
106	22	6602.7	0.0	50	100.0	0.0				MDP	56.6	43.4	<20	0.0	0.0	IF		3	0.8	0.8	0.0	
106	24	6603.7	0.0	50	100.0	0.0				GDP	64.3	35.7	150	2.3	2.0	MO,IF	2.3	2	13.1	11.1	9.9	Burrows
106	26	6604.7	0.3	40	99.7	0.0				GDP	51.5	48.5	150	1.3	2.3	MO,IF	0.6	2	15.7	13.4	1.0	
106	28	6605.7	0.0	50	100.0	0.0				GDP	79.1	20.9	200	7.0	2.3	IF,MO	1.0	2	22.9	20.6	55.9	near class 1 but has foram squash
106	30	6606.7	0.3	50	99.7	0.0				GDP	67.3	32.7	100	1.6	1.3	IF,MO	2.3	2	24.5	23.2	16.0	
106	32	6607.7	0.0		100.0	0.0				Grainstone	95.2	4.8	200	14.3	1.6	IF,MO	0.6	1	21.9	20.3	395.7	grain crushing;cladocoropsis
106	34	6608.7	0.0	70	100.0	0.0				Grainstone	92.1	7.9	150	12.6	1.6	IF,MO	0.0	1	21.5	19.9	642.7	
106	36	6609.7	10.8	90	87.7	0.0				GDP	72.7	27.3	150	1.6	12.0	IF,MO	.6+	2	20.2	8.2	94.7	Large Cladocoropsis
106	38	6610.7	1.1	90	98.7	0.0				GDP	55.4	44.6	<20	1.3	9.6	MO,IF	0.0	2	25.1	15.5	15.4	
106	40	6611.7	4.9	120	94.7	0.0				GDP	75.6	24.4	200	6.3	0.3	IF,MO	0.6	2	21.5	21.2	26.8	Burrow
106	42	6612.7	20.2	90	79.7	0.0				Wacke	22.9	77.1	<20	0.0	0.6	IF,MO	0.0	3	14.8	14.2	0.8	
106	44	6613.7	4.1	80	95.8	0.0				MDP	39.5	60.5	<20	1.0	1.6	IF,MO	0.0	3	19.9	18.3	2.4	Burrow/mud; patch w/ hi Psv
106	46	6614.7	5.1	90	94.5	0.0				GDP	75.6	24.4	150	8.3	0.6	IF	0.0	2	19.0	18.4	105.7	
106	48	6615.7	12.3	110	87.0	0.0				GDP	76.0	24.0	200	5.3	0.3	IF	0.3	2	17.0	16.7	87.0	
106	50	6616.7	13.2	90	86.6	0.0				MDP	39.3	60.7	<20	0.6	1.0	IF,MO	0.0	3	18.2	17.2	2.9	
106	52	6617.7	4.3	120	95.7	0.0				MDP	52.6	47.4	<20	0.3	0.0	MO,IF	0.0	3	24.1	24.1	7.8	burrow/mud
106	54	6618.7	1.6	90	98.4	0.0				MDP	42.9	57.1	<20	0.6	0.6	IF	0.3	3	23.6	23.0	4.8	
106	56	6619.7	3.2	110	96.6	0.0				GDP	75.2	24.8	200	4.3	1.3	IF,MO	0.0	2	23.0	21.7	330.3	
106	58	6620.7	8.6	120	91.1	0.0				GDP	60.8	39.2	250	3.0	0.3	IF	1.0	2	15.8	15.5	2.5	
106	60	6621.7	6.3	90	93.5	0.0				gdp	55.4	44.6	150	2.6	1.6	IF,MO	0.0	2	23.4	21.8	31.3	
106	62	6622.7	0.7	110	98.9	0.3	L			GDP	76.0	24.0	250	4.3	9.0	IF,MO	0.0	2	21.8	12.8	162.4	cladocoropsis; fluorite
106	64	6623.7	2.4	110	97.1	0.0				GDP	86.1	13.9	150	16.3	0.3	IF	1.3	2	23.6	23.3	421.9	burrow
106	66	6624.7	12.5	120	87.1	0.0				gdp	56.9	43.1	150	2.3	1.3	IF,MO	0.0	2	23.8	22.5	40.5	
106	68	6625.7	33.3	130	66.2	0.0				MDP	36.9	63.1	<20	0.0	2.0	IF,MO	0.3	3	18.6	16.6	3.2	
106	72	6627.7	19.0	90	80.6	0.0				GDP	33.0	67.0	<20	0.3	1.6	IF,MO	0.0	2	17	15.4	2.1	burrow
106	74	6628.7	28.9	120	70.7	0.0				GDP	55.6	44.4	150	1.3	0.6	IF	0.0	2	17	16.4	2.6	Burrow
106	76	6629.7	7.1	120	92.4	0.0				GDP	76.0	24.0	150	5.6	1.3	IF	0.3	2	23.1	21.8	40.3	Burrow
106	78	6630.7	3.1	120	96.7	0.0				GDP	60.8	39.2	150	3.0	2.0	IF,MO	0.6	2	23.5	21.5	11.1	burrow
106	80	6631.7	17.3	140	82.0	0.0				GDP	57.8	42.2	<20	1.6	2.3	IF,MO	1.0	2	21.2	18.9	10.3	Burrow
106	82	6632.7	38.2	120	61.7	0.0				MDP	50.0	50.0	<20	0.0	0.3	IF	0.3	3	12.8	12.5	1.2	
106	84	6633.7	17.4	120	82.0	0.3				gdp	66.2	33.8	150	1.3	0.6	IF	0.0	2	17.1	16.5	19.8	
106	86	6634.7	4.4	90	95.4	0.0				MDP	56.6	43.4	150	1.3	1.3	IF	0.6	3	23.8	22.5	11.6	
106	88	6635.7	23.4	110	76.2	0.0				MDP	53.7	46.3	<20	0.3	1.3	IF,MO	0.3	3	20.8	19.5	3.5	
106	90	6636.7	6.9	120	92.9	0.0				GDP	76.3	23.7	150	3.3	0.3	IF,MO	0.3	2	19.3	19.0	28.8	stylolite
106	92	6637.7	31.7	130	67.3	0.0				GDP	63.7	36.3	250	3.6	0.6	IF,MO	0.6	2	20.4	19.8	31.7	stylolite
106	94	6638.7	34.0	140	65.1	0.3				gdp	58.9	41.1	200	1.6	0.3	IF	0.6	2	18.6	18.3	7	
106	96	6639.7	1.5	130	98.3	0.0				GDP	71.0	29.0	200	9.3	2.3	IF,MO	0.0	2	25.9	23.6	121.5	
106	98	6640.7	2.5	90	97.4	0.0				GDP	66.4	33.6	150	4.6	1.3	IF,MO	1.0	2	23.8	22.5	70.5	Cladocoropsis
106	100	6641.7	21.9	130	77.6	0.0				MDP	34.2	65.8	150	0.3	2.3	IF,MO	0.0	3	17	14.7	2.3	
106	102	6642.7	17.6	120	81.9	0.0				GDP	57.4	42.6	90	2.3	1.0	IF,MO	0.0	2	19	18.0	4.9	
106	104	6643.7	6.7	120	93.0	0.0				GDP	67.4	32.6	120	2.6	2.3	IF,MO	1.6	2	26.2	23.9	33	cladocoropsis
106	106	6644.7	8.3	120	91.3	0.0				gdp	57.6	42.4	<20	2.0	2.0	IF,MO	0.3	2	26.6	24.6	25.8	
106	108	6645.7	3.3	130	96.3	0.0				GDP	80.0	20.0	150	8.3	1.6	IF	1.0	2	26.5	24.9	215.8	
106	110	6646.7	0.7	120	99.2	0.0				GDP	82.0	18.0	150	11.0	1.6	IF,MO	1.0	2	26.3	24.7	302.8	
106	112	6647.7	1.1	140	98.8	0.0				GDP	64.3	35.7	150	7.0	2.0	IF,MO	0.0	2	25.2	23.2	49.3	Burrow, cladocoropsis
106	114	6648.7	29.0	130	70.7	0.0				MDP	49.6	50.4	<20	0.6	0.6	IF,MO	0.0	3	14.5	13.9	1.7	
106	116	6649.7	48.5	140	51.0	0.0				Wacke/gdp	55.3	44.7	<20	1.3	0.3	IF,MO	0.0	2	12.6	12.3	1.6	burrow/gdp
106	118	6650.7	51.7	140	47.9	0.0				MDP/gdp	54.9	45.1	<20	1.3	0.0	IF,MO	0.0	2	11.9	11.9	1.3	Burrow/gdp dolomitized

Well No.			Dolomite		Calcite	Sulfate		Accessories		Texture					Psv				Core Analysis			Comments
	Plug#	Depth	%	Size(um)	%	% Anh	Type	%	Type	Name	%Grain	%Mud	GrnSize	%Pip	%Psv	Type	%IGu Grains	Class	% Por	%P-%Psv	Perm	
106	120	6651.7	54.1	140	45.7	0.0				gdp	60.8	39.2	<20	1.0	0.0	IF,MO	1.0	2	17.4	17.4	6	
106	122	6652.7	46.1	150	53.4	0.0				MDP/gdp	62.0	38.0	<20	0.6	1.0	IF,MO	0.6	2	15.2	14.2	2.6	Burrow/gdp
106	124	6653.7	8.4	130	91.3	0.0				GDP	68.5	31.5	<20	2.0	2.3	IF,MO	0.6	2	18.1	15.8	5.5	
106	126	6654.7	32.3	140	65.8	0.0				GDP	74.6	25.4	150	6.6	1.3	IF	0.3	2	18.8	17.5	51.2	burrow dolomitized
106	128	6655.7	2.2	120	97.5	0.0				GDP	83.9	16.1	200	9.0	2.0	IF	1.0	2	26.5	24.5	176.5	
106	130	6656.7	6.8	170	92.4	0.0				GDP	74.0	26.0	150	7.6	4.0	IF	0.6	2	26.7	22.7	358.4	Cladocoropsis
106	132	6657.7	2.9	120	96.7	0.0				GDP	69.8	30.2	120	6.3	5.0	IF,MO	0.3	2	27.5	22.5	78.4	Cladocoropsis, burrow, leaching
106	134	6658.7	17.1	80	82.4	0.0				MDP	49.8	50.2	<20	1.3	1.6	IF,MO	1.0	3	28.3	26.7	12.8	
106	136	6659.7	0.3	110	99.6	0.0				GDP	70.9	29.1	200	4.0	4.0	IF,MO	1.0	2	25	21.0	402.3	Cladocoropsis
106	138	6660.7	2.5	110	97.2	0.0				gdp	62.0	38.0	200	6.6	2.3	IF,MO	0.6	2	27.6	25.3	295.3	burrow, cladocoropsis
106	140	6661.7	1.7	110	98.3	0.0				GDP	54.7	45.3	200	2.6	1.0	IF,MO	0.0	2	28.1	27.1	30.8	Cladocoropsis
106	142	6662.7	6.3	110	93.4	0.0				MDP	63.1	36.9	<20	2.0	3.0	IF,MO	2.0	3	18.6	15.6	9.2	Cladocoropsis
106	144	6663.7	28.3	130	71.0	0.0				MDP	57.3	42.7	<20	2.0	1.3	IF,MO	0.3	3	17.2	15.9	4.3	Cladocoropsis, burrow
106	146	6664.7	19.6	110	79.6	0.0				MDP	45.1	54.9	<20	3.0	1.6	If,MO	0.6	3	16.3	14.7	4.5	Odd Texture
106	148	6665.7	6.8	110	90.6	2.0	L			GDP	59.5	40.5	200	4.3	2.6	IF,MO	3.3	2	26	23.4	31.7	Cladocoropsis
106	150	6666.7	4.3	120	95.4	0.0				GDP	58.4	41.6	200	4.6	2.0		3.0	2	25.2	23.2	95.1	
106	152	6667.7	2.3	110	97.3	0.0				GDP	83.4	16.6	250	2.6	11.3	IF,MO	1.0	2	25.3	14.0	286.7	Cladocoropsis
106	154	6668.7	12.9	120	86.6	0.0				GDP	60.3	39.7	200	2.6	1.3	IF,MO	0.6	2	22.8	21.5	25.8	burrow dolomitized
106	156	6669.7	4.0	120	96.0	0.0				GDP	80.8	19.2	200	7.6	2.3	IF	3.0	2	26.2	23.9	147.6	
106	158	6670.7	4.9	110	94.9	0.0				GDP	77.0	23.0	150	4.6	0.3	IF	1.3	2	20.7	20.4	22.6	
106	160	6671.7	61.7	140	38.3	0.0				Mud	6.0	94.0	<20	0.0	0.0		0.0	2	14.4	14.4	1.5	
106	162	6672.7	100.0	120	0.0	0.0				Dolostone	0.0	0.0		5.0	0.0		0.0	1	2.1	2.1	0	Bad epoxy?
106	164	6673.7	92.1	120	0.0	0.0		7.6	Chert	Dolostone	0.0	0.0		2.6	0.0		0.0	1	10.1	10.1	5.6	Silicified mud?
106	166	6674.7	97.3	130	2.6	0.0				Dolostone	0.0	100.0	<20	2.0	0.0		0.0	1	4.8	4.8	0	
106	168	6675.7	93.8	120	5.6	0.0				Dolostone	0.0	100.0	<20	9.6	0.0		0.0	1	11.4	11.4	25.2	small stylolites
106	170	6676.7	100.0	140	0.0	0.0				Dolostone	0.0	0.0		11.6	0.0		0.0	1	9.1	9.1	21.3	
106	172	6677.7	85.0	130	0.0	0.0		15.0	Chert	Dolostone	0.0	0.0		0.0	0.0		0.0	1	0.6	0.6	0.1	definitely chert
106	174	6678.7	95.0	130	4.6	0.0				Dolostone	0.0	100.0	<20	8.0	0.0		0.0	1	12	12.0	48.3	
106	176	6679.7	75.9	120	23.5	0.0				Mud	0.0	100.0	<20	3.3	0.0		0.0	2	18.3	18.3	47.4	Mud seems to cling to dolomite
106	178	6680.7	20.8	110	79.1	0.0				Wacke	24.0	76.0	<20	0.0	0.6	IF	0.0	2	21.7	21.1	9.1	Cladocoropsis
106	180	6681.7	71.0	110	28.9	0.0				Wacke	14.9	85.1	<20	0.0	0.3	IF,MO	0.0	2	17.3	17.0	15	Photo a hi phi mud between xls
106	182	6682.7	98.5	200	0.0	1.3	L			Dolostone	0.0	0.0		10.6	0.0		0.0	1	7.1	7.1	152.2	
106	184	6683.7	59.4	130	40.0	0.0				Wacke	31.3	68.7	<20	0.0	2.3	IF	0.0	2	21.2	18.9	8.4	
106	186	6684.7	6.3	80	93.3	0.0				MDP	49.4	50.6	<20	2.3	3.0	IF,MO	1.3	3	23.6	20.6	10.2	Cladocoropsis
106	188	6685.7	3.5	110	96.3	0.0				MDP/gdp	56.3	43.7	<20	2.6	2.6	IF,MO	1.0	2	21	18.4	30.5	Burrow/gdp
106	190	6686.7	4.5	80	95.4	0.0				gdp	68.9	31.1	200	2.0	1.3	IF,MO	0.3	2	25.1	23.8	35.7	
106	192	6687.7	0.0	110	99.6	0.3				GDP	86.2	13.8	200	16.0	7.0	IF,MO	0.3	2	22.7	15.7	211.1	Cladocoropsis
106	194	6688.7	2.4	160	97.5	0.0				gdp	58.6	41.4	<20	1.6	3.0	IF,MO	1.9	2	21	18.0	10.3	
106	196	6689.7	2.2	120	97.6	0.0				MDP	68.8	31.2	300	3.0	5.0	IF,MO	0.3	3	18.4	13.4	141.6	Clado,intraclasts
106	198	6690.7	2.7	120	97.2	0.0				GDP	55.5	44.5	300	2.0	1.3	IF,MO	0.3	2	21.5	20.2	51.6	burrow, clado frags
106	200	6691.7	3.2	110	96.6	0.0				GDP	52.6	47.4	<20	1.6	4.3	IF,MO	2.0	2	22.9	18.6	63	Clado, burrow
106	202	6692.7	5.2	120	94.7	0.0				MDP	44.8	55.2	300	1.3	1.6	IF,MO	3.0	3	24.2	22.6	29	Cladocoropsis, burrow
106	204	6693.7	5.3	80	94.5	0.0				gdp	44.1	55.9	<20	2.6	2.3	IF,MO	0.6	2	21.1	18.8	8.6	
106	206	6694.7	1.5	80	98.3	0.0	L			MDP	53.5	46.5	<20	4.6	8.0	IF,MO	1.6	3	20.5	12.5	18.4	clado., huge
106	208	6695.7	1.1	80	98.9	0.0				gdp	73.3	26.7	200	3.0	2.3	IF,MO	1.6	2	15.9	13.6	17.8	burrow, clado. frag.
106	210	6696.7	2.5	110	96.1	0.0				MDP	76.6	23.4	200	4.3	3.0	IF,MO	2.3	2	17.2	14.2	150	stylo, 1.4 insol.residue
106	212	6697.7	100.0	120	0.0	0.0				Dolostone	0.0	0.0		6.0	0.0		0.0	1	5.4	5.4	0.2	
106	214	6698.7	100.0	120	0.0	0.0	L			Dolostone	0.0	0.0		5.6	0.0		0.0	1	4.4	4.4	3.8	Relict burrow?
106	216	6699.7	99.4	110	0.0	0.6	L			Dolostone	0.0	0.0		3.0	0.0		0.0	1	5.9	5.9	0.2	
106	218	6700.7	100.0	120	0.0	0.0				Dolostone	0.0	0.0		4.6	0.0		0.0	1	3.5	3.5	0.2	
106	220	6701.7	8.0	130	91.6	0.0				GDP	67.3	32.7	400	3.6	1.0	IF	1.0	2	12.3	11.3	3	
106	222	6702.7	2.4	80	97.5	0.0				GDP	72.7	27.3	150	3.3	0.6	IF	1.3	2	16.5	15.9	15.7	
106	228	6705.7	1.3	60	98.7	0.0				Wacke	26.4	73.6	<20	0.0	0.0	IF	0.0	3	7.5	7.5	0	
106	230	6706.7	12.1	90	87.1	0.3	L			MDP	35.6	64.4	<20	1.3	2.6	IF,MO	0.6	3	9.5	6.9	0.5	Burrow pref dolomitized
106	232	6707.7	14.4	80	85.6	0.0				MDP	48.2	51.8	<20	0.3	0.0	IF,MO	0.3	3	4.8	4.8	0	
106	234	6708.7	2.6	80	97.4	0.0				gdp	56.2	43.8	300	0.0	0.0	IF,MO	0.0	2	6.9	6.9	0.4	burrow, calcite poikilotopes
106	236	6709.7	4.3	70	95.7	0.0				gdp	60.7	39.3	<20	0.0	0.0	IF	0.0	2	1.7	1.7	0	
106	238	6710.7	1.1	120	98.9	0.0				Grainstone	88.8	11.2	300	6.3	0.0	IF	0.3	1	13.7	13.7	997.3	intraclasts

Well No.			Dolomite		Calcite	Sulfate		Accessories		Texture					Psv				Core Analysis			Comments
	Plug#	Depth	%	Size(um)	%	% Anh	Type	%	Type	Name	%Grain	%Mud	GrnSize	%Pip	%Psv	Type	%IGu Grains	Class	% Por	%P-%Psv	Perm	
106	240	6711.7	0.3	70	99.7	0.0				GDP	76.4	23.6	150	4.0	0.6	IF,MO	1.3	2	15.2	14.6	28.4	
106	242	6712.7	6.0	70	94.0	0.0				Wacke	25.8	74.2	<20	0.0	0.3	IF,MO	0.0	3	7.3	7.0	0.1	
106	244	6713.7	9.3	80	90.6	0.0				Wacke	41.6	58.4	<20	0.0	0.3	IF,MO	1.0	3	3.9	3.6	0.1	
106	246	6714.7	99.0	110	1.0	0.0				Dolostone	100.0	0.0		0.3	0.6		1.0	1	1.2	0.6	0	Skeletal dolomite
106	248	6715.7	98.9	110	1.0	0.0				Dolostone	100.0	0.0		5.3	0.3		1.0	1	5.7	5.4	0	Skeletal dolomite in burrow shape
106	250	6716.7	33.0	60	67.0	0.0				Wacke	13.6	86.4	<20	0.0	0.0	IF,MP	0.0	2	3.5	3.5	0	burrow, little stylo.
106	252	6717.7	49.7	60	50.3	0.0				Mud	3.2	96.8	<20	0.0	0.0		0.0	2	3	3.0	0.1	stylo.
106	254	6718.7	0.0	110	100.0	0.0				Grainstone	94.1	5.9	300	7.0	1.6	IF,MO	1.3	1	12.4	10.8	290.9	Crushing micrite rims
106	256	6719.7	15.3	70	84.4	0.0				GDP	50.4	49.6	<20	0.0	2.0	IF,MO	0.0	2	6.6	4.6	0.3	
106	258	6720.7	10.7	50	82.3	0.0				MDP	40.0	60.0	<20	0.3	0.3	IF,MO	0.0	3	9.8	9.5	20.5	Stylo., 7.0 insoluble res., intraclast
106	260	6721.7	11.3	50	88.7	0.0				Mud	3.0	97.0	<20	0.0	0.0	IF.MO	0.0	3	5.1	5.1	0.1	
106	262	6722.7	7.5	140	91.1	0.0				GDP	83.2	16.8	<20	0.0	6.6	IF	0.0	2	3.7	-2.9	0	clado. bryozoan encrusted
106	264	6723.7	60.7	80	39.0	0.3	L			Mud	0.0	100.0	<20	0.0	0.0	IF	0.0	2	6.9	6.9	0	
106	266	6724.7	99.7	110	0.0	0.3	L			Dolostone	0.0	0.0		7.3	0.6	Sk.dol	0.0	1	5.9	5.3	0.1	Skeletal dolomite
106	268	6725.7	67.4	120	32.0	0.6	L			Mud	0.0	100.0	<20	0.0	0.0	IF	0.0	2	13.3	13.3	90	Why hi k?
106	270	6726.7	52.7	90	47.3	0.0				Mud	0.0	100.0	<20	0.0	0.0		0.0	2	8.8	8.8	0.1	
106	272	6727.7	46.6	90	53.3	0.0				Mud	5.6	94.4	<20	0.0	0.0	IF,MO	0.0	2	13.9	13.9	289.5	Why hi k?
106	274	6728.7	0.6	160	99.3	0.0				GDP	93.3	6.7	300	5.0	2.0	IF,MO	4.6	2	8.4	6.4	0	
106	276	6729.7	97.4	90	2.3	0.0				Dolostone	100.0	0.0		6.3	3.6		2.3	2	7.6	4.0	0.1	Lamination:sm.sk.dol./coarse dol.
106	278	6730.7	77.8	90	21.6	0.0				Mud	0.0	100.0	<20	0.0	0.0		0.0	2	8.1	8.1	0.1	
106	280	6731.7	36.3	70	63.6	0.0				Mud	3.6	96.4	<20	0.0	0.0		0.0	2	8.2	8.2	3.2	
106	282	6732.7	16.1	60	83.9	0.0				GDP	7.6	92.4	<20	0.0	0.0		0.0	2	8.6	8.6	0	
106	284	6733.7	3.3	50	96.7	0.0				Wacke	20.4	79.6	<20	0.0	0.0	IF,MO	1.0	3	10.2	10.2	0.2	Stylo.
106	286	6734.7	3.7	70	96.3	0.0				Wacke	30.1	69.9	<20	0.6	0.6	IF,MO	0.3	3	10.7	10.1	0.1	
106	288	6735.7	1.0	60	99.0	0.0				Wacke	29.7	70.3	<20	0.0	0.3	IF,MO	0.0	3	8.7	8.4	0.1	
106	290	6736.7	8.4	60	90.7	0.6				Wacke	50.6	49.4	<20	0.0	0.6	IF,MO	0.0	3	5	4.4	0	stylo. big
106	292	6737.7	29.7	50	70.3	0.0				Mud	0.0	100.0	<20	0.0	0.0		0.0	3	2.9	2.9	0	Calc.-filled veins
106	294	6738.7	28.9	70	70.5	0.0				Mud	0.0	100.0	<20	0.0	0.0		0.0	3	1.8	1.8	0	stylo., calc-filled veins
106	296	6739.7	18.3	70	81.6	0.0				Mud	6.0	94.0	<20	0.0	0.0	IF	0.6	3	7.2	7.2	0.7	Stylo.
106	298	6740.7	15.0	60	85.0	0.0				Mud	0.7	99.3	<20	0.0	0.0		0.0	3	6.7	6.7	0.1	Stylo.
106	300	6741.7	3.3	50	96.7	0.0				Mud	1.7	98.3	<20	0.0	0.0		0.0	3	8.1	8.1	0	
101	1	6527.4	23.7	70	76.3	0.0	PF			GrDomPack	52.7	47.3	100	1	0		0	2	4.5	4.5	0.2	burrow
101	2	6527.9	8.6	80	91.1	0.0	PF			GrDomPack	15.0	85.0	100	0	0	MO	0	2	5.6	5.6	15.9	stylolite
101	3	6528.4	6.0	60	93.4	0.0	PF			GrDomPack	30.6	69.4	200	2	0.3	MO	0	2	4	3.7	5.3	stylolite
101	4	6532.1	0.0	70	100.0	0.0	PF			Grainstone	85.2	14.8	200	9.6	2.3	MO,WF	0	1	10.4	8.1	15.1	
101	5	6532.6	6.3	100	93.1	0.6	PF			GrDomPack	45.1	54.9	150	6.6	2.3	MO,WF	0	2	1.2	-1.1	0	
101	6	6533.1	5.0	80	94.7	0.0	PF			GrDomPack	11.5	88.5	50	0.6	0.6	MO,WF	0	2	3.3	2.7	0.1	Burrow
101	7	6533.6	17.4	70	82.6	0.0	PF			GrDomPack	43.5	56.5	80	10.3	1.3	MO,WF	0	2	5.4	4.1	2.8	thin section phi high to core
101	8	6534.1	15.2	70	84.8	0.0	PF			GrDomPack	43.0	57.0	90	5	1	MO,WF	0	2	11	10	0.2	Burrow
101	9	6534.6	2.0	70	98.0	0.0	PF			GrDomPack	46.0	54.0	150	14.6	2	MO,WF	0	2	11	9	0.3	
101	10	6535.1	1.0	80	98.0	1.0	PF			Grainstone	89.3	10.7	200	11.6	6	MO,WF	0	1	12.8	6.8	0.6	grain crushing
101	11	6535.6	0.0		100.0	0.0	PF			Grainstone	99.5	0.5	300	13.6	7	MO	0	1	12.3	5.3	1	grain crushing; P vis. different from core
101	12	6536.1	0.3	80	99.7	0.0	PF			Grainstone	100.0	0.0	400	12	6	MO	0	1	17.4	11.4	14.9	grain crushing
101	13	6536.6	0.0		100.0	0.0	PF,L			Grainstone	97.8	2.2	500	1	4.3	MO	0	1	18.7	14.4	3.2	P vis. different from P core
101	14	6537.1	26.7	70	72.7	0.6	PF			Wack/gdp	16.7	83.3	90	0.6	0	MO	0	2	20	20	4.1	Burrow/gdp
101	15	6537.6	1.3	60	98.4	0.3	PF			GrDomPack	14.2	85.8	100	0	0		0	2	16.7	16.7	7.4	
101	16	6538.1	2.0	60	98.0	0.0	PF			GrDomPack	19.6	80.4	90	0.3	0		0	2	15	15	1	stylolite
101	17	6538.6	1.6	50	98.1	0.0				MudDomPack	19.2	80.8	150	0	0		0	3	17.8	17.8	3.3	
101	18	6539.1	1.0	60	99.0	0.0	PF			GrDomPack	59.8	40.2	200	2.3	1.6	MO	0	2	12.3	10.7	1.1	stylolite
101	19	6539.6	3.3	70	96.7	0.0	PF			GrDomPack	37.4	62.6	250	4.3	2.6	MO	0	2	2.8	0.2	0	
101	20	6540.1	6.6	70	92.8	0.6	PF			GrDomPack	31.2	68.8	100	4	1.6	MO	0	2	3.3	1.7	0.1	Burrow
101	21	6540.6	17.5	70	82.5	0.0				GrDomPack	20.7	79.3	100	2.3	4.3	MO,WF	0	2	11	6.7	3.2	Burrow
101	22	6541.1	44.1	80	55.9	0.0	PF			GrDomPack	6.2	93.8	100	1.3	1	MO	0	2	15.1	14.1	54.3	burrowed, dolomite may control
101	23	6541.7	0.0	100	100.0	0.0	PF,POIK			Grainstone	93.1	6.9	200	20	3	MO	0	1	18.5	15.5	251.3	burrow
101	24	6542.2	55.7	150	44.3	0.0	PF			GDP	1.4	98.6	150	0	0		0	3	19.7	19.7	12.5	

APPENDIX 1
Petrographic Data for Wells HRDH 101 and 106

2/19/98

Well No.			Dolomite		Calcite	Sulfate		Accessories		Texture					Psv			Core Analysis			Comments
	Plug#	Depth	%	Size(um)	%	% Anh	Type	%	Type	Name	%Grain	%Mud	GrnSize	%Pip	%Psv	Type	%IGu Grains	Class	% Por	%P-%Psv	Perm	
101	25	6542.7	46.0	130	54.0	0.0	PF			GrDomPack	26.4	73.6	130	3.3	1.3	MO	0	2	16.1	14.8	1	
101	26	6543.2	24.8	150	75.2	0.0				GrDomPack	76.9	23.1	200	10.3	1.6	WF	0	2	19.1	17.5	6.4	Burrow
101	27	6543.7	2.0	120	98.0	0.0				GrDomPack	93.6	6.4	200	12	2.3	WF	0	2	13.6	11.3	0.7	near class 1 but has foram squash
101	28	6544.2	9.5	140	90.5	0.0				Grainstone	81.8	18.2	250	13	3	MO	0	1	21.8	18.8	43	burrow; fluorite
101	29	6544.7	0.6	120	99.4	0.0				Grainstone	95.6	4.4	300	19.3	2.3	MO,WF	0	1	22.9	20.6	21.3	burrow; cladocoropsis, fluorite
101	30	6545.2	6.0	140	94.0	0.0	PF			GrDomPack	67.9	32.1	200	7.6	1.3	MO	0	2	21.3	20	7.3	near class 1 but has foram squash; fluorite
101	31	6545.7	1.0	110	99.0	0.0				GrDomPack	93.0	7.0	200	18.3	3	MO,WF	0	2	20.5	17.5	3	near class 1 but has foram squash; fluorite
101	32	6546.2	17.5	150	82.5	0.0				GrDomPack	72.1	27.9	150	12.3	2.3	MO,WF	0	2	18.9	16.6	50	cladocoropsis
101	34	6547.2	5.6	150	94.4	0.0				GrDomPack	81.2	18.8	200	10	2.6	WF	0	2	17.1	14.5	3	cladocoropsis
101	35	6547.7	0.0	130	100.0	0.0				GrDomPack	94.6	5.4	150	12.6	6	MO,WF	0	2	22	16	409.4	near class 1 but has foram squash
101	36	6548.2	1.0	150	99.0	0.0				GrDomPack	80.1	19.9	200	15	4	WF	0	2	21.2	17.2	134.5	cladocoropsis
101	37	6548.7	1.3	100	97.1	1.6	PF			gdp	99.5	0.5	300	19.6	2.3	MO,WF	0	2	23.2	20.9	0.1	grain crushing; fluorite; bad analysis?
101	38	6549.2	2.0	150	94.9	3.0	L			GrDomPack	86.3	13.7	350	14.6	2.3	MO,WF	0	2	25.7	23.4	46.4	cladocoropsis, leached anh laths
101	39	6549.7	4.3	170	95.4	0.3	L			GrDomPack	75.6	24.4	300	14	2	MO,WF	0	2	24.4	22.4	2001.5	cladocoropsis
101	40	6550.2	45.7	120	54.3	0.0				GrDomPack	44.2	55.8	120	8.3	2.3	MO,WF	0	2	15.2	12.9	38.6	Burrow,dolomite may control
101	41	6550.7	7.1	120	92.9	0.0	PF			GrDomPack	94.7	5.3	150	13.3	3	WF	0	2	21.4	18.4	7.7	
101	43	6551.7	74.0	170	26.0	0.0	PF			MDP/gdp	0.0	100.0	170	3.6	0.6	MO	0	2	11.2	10.6	1.4	dolomitized burrow/gdp (photo)
101	44	6552.2	44.8	140	55.2	0.0	PF			Wack/gdp	4.0	96.0	140	5.3	1.6	MO,WF	0	2	9.5	7.9	0	Burrow/gdp (photo dol burrow)
101	45	6552.7	84.0	170	0.7	0.0	PF	15.3	Chert	Dolomudstone	0.0	100.0	170	1.6	0		0	1	5.9	5.9	0.7	
101	46	6553.2	99.2	170	0.0	0.8	PF			Dolostone?	0.0	0.0	170	22	2		0	1	16.4	14.4	48.7	chert cement/evap repl?
101	47	6553.7	100.0	190	0.0	0.0	PF			Dolostone?	0.0	0.0	190	9.9	0		0	1	6.8	6.8	6.2	
101	48	6554.2	78.2	200	20.5	1.3	L			Dolo mudstn	1.5	98.5	200	2.3	0		0	2	10.6	10.6	3.8	Burrow, anh laths in sol'n enlarged fractur
101	49	6554.7	54.4	200	45.6	0.0				Wackestone	9.5	90.5	200	0	0.3		0	2	14.6	14.3	2.9	
101	50	6555.2	29.8	160	70.2	0.0				MudDomPack	22.5	77.5	160	1.3	1	MO,WF	0	2	18.3	17.3	4.3	
101	51	6555.7	24.8	200	75.2	0.0	PF			GrDomPack	81.2	18.6	300	4	1.3	WF	6.6	2	17.2	15.9	30.2	
101	52	6556.2	35.6	160	64.4	0.0	PF			GrDomPack	69.8	29.4	250	4	0.3	WF	9.6	2	13.9	13.6	5.2	cladocoropsis
101	53	6556.7	85.0	170	15.0	0.0	PF			Dolomudstone	0.0	100.0	170	0	0		0	1	8.5	8.5	1	
101	54	6557.2	16.0	180	84.0	0.0	L			GrDomPack	83.3	16.3	250	4	0.3	WF	16.6	2	18.9	18.6	9.7	
101	55	6557.7	18.6	170	81.4	0.0				GrDomPack	66.2	32.9	250	3	3	MO,WF	8.3	2	19.8	16.8	6.7	
101	56	6558.2	13.7	140	86.3	0.0				GrDomPack	81.7	18.0	250	5.3	1	WF	10.6	2	21.7	20.7	20.8	
101	57	6558.7	2.6	70	97.1	0.3				GrDomPack	98.4	1.6	300	13	1.3	MO,WF	10	2	23	21.7	120.8	microporosity>10%
101	58	6559.2	22.3	170	77.7	0.0				Wack/gdp	22.1	75.2	170	1	0.3		5	2	18.2	17.9	3.3	burrow w/ GDP
101	59	6559.7	100	190	0.0	0.0	L			?Dolostone	0.0	0.0	190	5	0		0	1	5.7	5.7	7.3	
101	60	6560.2	97.3	190	0.0	2.7	L			?Dolostone	0.0	0.0	200	2.6	0		0	1	3.6	3.6	0.1	
101	61	6560.7	88.3	170	0.0	11.7	L,PF			?Dolostone	0.0	0.0	170	3	0		0	1	23.4	23.4	0.1	
101	62	6561.2	6.1	180	93.9	0.0	L			GrDomPack	42.0	53.4	200	3.3	1.6	WF	17.3	2	25	23.4	10.8	microporosity>10%
101	63	6561.7	2.6	200	97.4	0.0				GrDomPack	48.2	46.4	200	4.6	2.6	MO,WF	29	2	27.3	24.7	19.1	microporosity>10%, corroded dolo
101	64	6562.2	2.3	200	97.7	0.0				GrDomPack	60.8	36.1	200	8	5.3	MO,WF	27.6	2	26	20.7	25.1	microporosity>10%
101	66	6563.2	55.2	180	44.8	0.0				Dolo/Wack	1.4	98.6	180	0.6	0	WF	0	2	12.1	12.1	9.9	
101	67	6563.7	100.0	230	0.0	0.0				Dolostone?	0.0	0.0	230	0.6	0		0	1	3.2	3.2	0.3	
101	68	6564.2	99.7	220	0.0	0.3				Dolostone?	0.0	0.0	220	5	0.3		0	1	4.5	4.2	0.8	zoned dolo
101	69	6564.7	94.7	170	0.0	0.0		5.3	Chert	Dolostone?	0.0	0.0	170	0	0		0	1	1.1	1.1	0	evap silicification?
101	70	6565.2	83.5	200	0.0	0.0		16.5	Chert	Dolostone?	0.0	0.0	200	1	0		0	1	3.6	3.6	0.1	chert cement
101	71	6565.7	100.0	170	0.0	0.0				Dolostone?	0.0	0.0	170	13	0		0	1	7.4	7.4	3	
101	72	6566.2	100.0	180	0.0	0.0				Dolostone?	0.0	0.0	180	3	0		0	1	3.7	3.7	0.1	
101	73	6566.7	100.0	200	0.0	0.0				Dolostone?	0.0	0.0	200	21.3	0		0	1	15.7	15.7	664.2	oilstain
101	74	6567.2	100.0	190	0.0	0.0				Dolostone?	0.0	0.0	190	2.3	0		0	1	2.7	2.7	0.2	
101	75	6568	100.0	200	0.0	0.0				Dolostone?	0.0	0.0	200	1.6	0		0	1	1.5	1.5	0.1	
101	76	6568.5	100.0	200	0.0	0.0	PF			Dolostone?	0.0	0.0	200	0.6	0		0	1	1.6	1.6	0.1	
101	77	6569	100.0	220	0.0	0.0	PF			Dolostone?	0.0	0.0	220	11.6	0		0	1	8.4	8.4	25.7	
101	78	6569.5	98.3	190	0.0	0.0	L,PF			Dolostone?	0.0	0.0	190	5.3	0.3		0	1	7.7	7.4	5.4	
101	79	6570	100.0	210	0.0	0.0	L			Dolostone?	0.0	0.0	210	8	0		0	1	8.6	8.6	22	
101	80	6570.5	99.2	200	0.0	0.8	L			Dolostone?	0.0	0.0	200	19.6	0		0	1	20.9	20.9	4561.6	
101	81	6571	100.0	220	0.0	0.0				Dolostone?	0.0	0.0	220	7.6	0		0	1	8.6	8.6	31.2	strange stylolites
101	82	6571.6	100.0	230	0.0	0.0				Dolostone?	0.0	0.0	230	24	0		0	1	17.9	17.9	897.6	
101	83	6572.7	99.3	220	0.0	0.7	L			Dolostone?	0.0	0.0	220	8	0		0	1	10.5	10.5	99.6	
101	84	6573.2	97.8	180	0.0	2.2	L			Dolostone?	0.0	0.0	180	26.3	0		0	1	14.1	14.1	436.2	big vugs small dolomite
101	85	6573.7	100.0	180	0.0	0.0	PF			Dolostone?	0.0	0.0	180	11.3	0		0	1	11.8	11.8	88.2	

APPENDIX 1
Petrographic Data for Wells HRDH 101 and 106

2/19/98

Well No.			Dolomite		Calcite	Sulfate		Accessories		Texture					Psv			Core Analysis			Comments
	Plug#	Depth	%	Size(um)	%	% Anh	Type	%	Type	Name	%Grain	%Mud	GrnSize	%Pip	%Psv	Type	%IGu Grains	Class	% Por	%P-%Psv	Perm	
101	86	6574.2	100.0	210	0.0	0.0				Dolostone?	0.0	0.0	210	14.6	0.5	MO	0	1	10.4	9.9	0	
101	87	6574.7	100.0	200	0.0	0.0	L			Dolostone?	0.0	0.0	200	10.6	0		0	1	16	16	973.6	
101	88	6575.2	98.8	200	0.0	1.2	L			Dolostone?	0.0	0.0	200	17	0		0	1	17	17	1532.9	
101	89	6575.7	98.6	220	0.0	1.4	L			Dolostone?	0.0	0.0	220	6.6	0		0	1	6.9	6.9	27.1	bad epoxy
101	90	6576.2	100.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	4.3	0		0	1	4.7	4.7	20.7	
101	91	6576.7	99.7	250	0.0	0.3	L			Dolostone?	0.0	0.0	250	1.3	0		0	1	3.8	3.8	0	zoned dolomites
101	92	6577.2	100.0	300	0.0	0.0	PF			Dolostone?	0.0	0.0	300	2.6	0		0	1	3.1	3.1	11.8	zoned dolomite
101	93	6577.7	100.0	300	0.0	0.0	PF			Dolostone?	0.0	0.0	300	0.6	0		0	1	3.2	3.2	25.7	skeletal dolo near fracture
101	94	6578.2	100.0	300	0.0	0.0	L			Dolostone?	0.0	0.0	300	5.3	0		0	1	4.1	4.1	308.5	zoned
101	95	6578.7	99.7	300	0.0	0.3	L			Dolostone?	0.0	0.0	300	5.6	0		0	1	6.5	6.5	289.8	zoned
101	96	6579.2	99.4	280	0.0	0.6				Dolostone?	0.0	0.0	280	3.6	0		0	1	4.9	4.9	11.2	zoned
101	97	6579.7	100.0	250	0.0	0.0				Dolostone?	0.0	0.0	250	4.3	0		0	1	2.7	2.7	0.1	zoned
101	98	6580.2	100.0	400	0.0	0.0				Dolostone?	0.0	0.0	400	3.3	0		0	1	3.4	3.4	0	zoned
101	99	6580.7	100.0	400	0.0	0.0				Dolostone?	0.0	0.0	400	2.3	0		0	1	2.9	2.9	0.1	
101	100	6581.2	100.0	200	0.0	0.0				Dolostone?	0.0	0.0	200	6	0		0	1	4.1	4.1	0.1	relict textures
101	101	6581.7	100.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	10	0		0	1	3.2	3.2	0.3	
101	102	6582.2	99.7	230	0.0	0.3	PF			Dolostone?	0.0	0.0	230	6	0		0	1	2.3	2.3	0.2	
101	103	6582.7	89.9	250	0.0	9.1	L			Dolostone?	0.0	0.0	250	15	0		0	1	6.4	6.4	8.3	good breccia (i think) w/ oilstain
101	104	6583.2	97.9	250	0.0	1.1	L			Dolostone?	0.0	0.0	250	18	0		0	1	8	8	10.7	
101	105	6583.7	100.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	18	0		0	1	7.8	7.8	42.7	
101	106	6584.2	99.7	250	0.0	0.3	L			Dolostone?	0.0	0.0	250	3	0		0	1	3.3	3.3	0.2	relict textures?
101	107	6584.7	99.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	8	0		0	1	4.3	4.3	1.3	
101	108	6585.2	99.7	300	0.0	0.3	L			Dolostone?	0.0	0.0	300	8	0		0	1	2.7	2.7	0	
101	109	6585.7	96.4	220	0.0	3.6	L			Dolostone?	0.0	0.0	220	15	0		0	1	7.5	7.5	19.9	breccia textures
101	110	6586.2	100.0	300	0.0	0.0	L			Dolostone?	0.0	0.0	300	22	0		0	1	9.9	9.9	44.5	
101	111	6586.7	100.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	3	0		0	1	3.7	3.7	0	
101	112	6587.2	99.4	250	0.0	0.6	L			Dolostone?	0.0	0.0	250	3.6	0		0	1	4.3	4.3	0	
101	113	6587.7	99.7	220	0.0	0.3	L			Dolostone?	0.0	0.0	220	5	0		0	1	7.3	7.3	213.3	
101	114	6588.2	98.1	250	0.0	1.9				Dolostone?	0.0	0.0	250	15	0		0	1	12.4	12.4	505.3	bad epoxy
101	115	6588.7	98.8	250	0.0	1.2	L			Dolostone?	0.0	0.0	250	19.6	0		0	1	13.7	13.7	513.6	abundant oilstain
101	116	6589.2	100.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	9	0		0	1	11.2	11.2	1235.7	
101	117	6589.7	100.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	19.3	0		0	1	15.3	15.3	879.4	
101	118	6590.2	100.0	250	0.0	0.0				Dolostone?	0.0	0.0	250	9.6	0		0	1	11.8	11.8	248.6	
101	119	6590.7	100.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	10.3	0		0	1	6.4	6.4	0	
101	120	6591.2	100.0	300	0.0	0.0				Dolostone?	0.0	0.0	300	1.6	0		0	1	3	3	0.1	xmas tree dolo
101	121	6591.7	19.8	350	80.2	0.0				GrDomPack	11.8	85.3	60	0.3	1	MO,WF	4	2	19.2	18.2	10.8	
101	122	6592.2	9.1	250	90.9	0.0				MudDomPack	50.5	48.2	200	2.3	4.3	WF	5.6	3	18.7	14.4	16.6	cladocoropsis
101	123	6592.7	37.3	350	62.7	0.0				MudDomPack	45.6	52.3	3000	0	3	MO,WF	8	3	19.4	16.4	12.2	big cladocoropsis
101	124	6593.2	100.0	220	0.0	0.0				Dolostone?	0.0	0.0	220	9.3	0		0	1	10.2	10.2	0	stylolites?
101	125	6593.7	100.0	200	0.0	0.0	L			Dolostone?	0.0	0.0	200	19.3	0		0	1	10.6	10.6	70	
101	126	6594.2	99.3	250	0.0	0.7	L			Dolostone?	0.0	0.0	250	11	0		0	1	10.9	10.9	55.5	
101	127	6594.7	99.7	250	0.0	0.3				Dolostone?	0.0	0.0	250	8.3	0		0	1	18	18	1171.1	dolomitized cladocoropsis
101	128	6595.2	100.0	250	0.0	0.0	L			Dolostone?	0.0	0.0	250	10.3	0		0	1	10.1	10.1	15.1	
101	129	6595.7	100.0	200	0.0	0.0				Dolostone?	0.0	0.0	200	14.3	0		0	1	9.8	9.8	0	dolomitized cladocoropsis
101	130	6596.2	100.0	250	0.0	0.0				Dolostone?	0.0	0.0	250	5.6	0		0	1	6.3	6.3	2.8	
101	131	6596.7	100.0	250	0.0	0.0				Dolostone?	0.0	0.0	250	7	0		0	1	8.9	8.9	46.3	
101	132	6597.2	100.0	300	0.0	0.0				Dolostone?	0.0	0.0	300	2	0		0	1	7.6	7.6	15.6	
101	133	6597.7	97.7	300	0.0	2.3				Dolostone?	0.0	0.0	300	14.3	0		0	1	7.6	7.6	24.4	
101	134	6598.2	100.0	250	0.0	0.0				Dolostone?	0.0	0.0	250	1.6	0		0	1	4.4	4.4	2.2	
101	135	6598.7	100.0	250	0.0	0.0				Dolostone?	0.0	0.0	250	8	0		0	1	7.7	7.7	13.3	
101	136	6599.2	99.2	150	0.8	0.0				Dolostone?	0.0	100.0	150	11.3	0		0	1	11.8	11.8	41.7	
101	137	6599.7	89.4	200	0.0	0.0		8.5	Clay	Dolomudstone	0.0	0.0	30	2.3	0	WF	0	1	8	8	1.3	8.5%Green clay in pores
101	138	6600.2	100.0	200	0.0	0.0				Dolostone?	0.0	0.0	200	18	0		0	1	22.7	22.7	1812	
101	139	6600.7	100.0	200	0.0	0.0				Dolostone?	0.0	0.0	200	11.3	0		0	1	18.5	18.5	870.1	
101	140	6601.2	100.0	200	0.0	0.0				Dolostone?	0.0	0.0	200	11.3	0		0	1	11.3	11.3	88.2	
101	141	6601.7	100.0	250	0.0	0.0				Dolostone?	0.0	0.0	250	9.3	0		0	1	12.4	12.4	53.8	
101	142	6602.2	100.0	180	0.0	0.0				Dolostone?	0.0	0.0	180	22.3	0		0	1	24.2	24.2	1956.8	
101	143	6602.7	100.0	180	0.0	0.0				Dolostone?	0.0	0.0	180	21.3	0		0	1	24.4	24.4	3269.6	

Well No.			Dolomite		Calcite	Sulfate		Accessories		Texture					Psv				Core Analysis			Comments
	Plug#	Depth	%	Size(um)	%	% Anh	Type	%	Type	Name	%Grain	%Mud	GrnSize	%Pip	%Psv	Type	%IGu Grains	Class	% Por	%P-%Psv	Perm	
101	144	6603.2	99.7	180	0.0	0.3				Dolomudstone	0.0	0.0	180	5.6	0		0	1	5.3	5.3	10.7	relict fabric?
101	145	6603.7	96.6	180	0.0	0.0		2.8	Chert	Dolomudstone	0.0	0.0	120	5	0		0	1	3.8	3.8	0.3	0.6% insoluble residue
101	146	6604.2	91.1	180	0.0	0.0		8.3	Chert	Dolomudstone	0.0	0.0	80	3.3	0		0	1	8.8	8.8	9.1	0.6% insoluble residue
101	147	6604.7	98.7	180	0.0	0.0		1.3	Chert	Dolomudstone	0.0	0.0	120	0.3	0		0	1	3.3	3.3	0	
101	148	6605.2	90.4	180	0.0	0.0		9.6	Chert	Dolomudstone	0.0	0.0	80	0.3	0		0	1	7.3	7.3	0	
101	149	6605.7	97.3	150	2.7	0.0				Dolomudstone	0.0	100.0	60	7.3	0		0	1	7.6	7.6	23	
101	150	6606.2	69.8	150	30.2	0.0				dolo/Wacke	4.3	95.7	40	0	0.3	WF	0	2	9.9	9.6	2	Burrow
101	151	6606.7	58.5	180	41.5	0.0				dolo/Wacke	16.0	84.0	30	0	0.3	WF,IFM	0	2	10.9	10.6	1.8	cladocoropsis
101	152	6607.2	42.5	150	57.5	0.0				dolo/Wacke	0.6	99.4	10	0	4.6	MO,WF	0	2	14.9	10.3	2.5	Burrow
101	153	6607.7	41.7	150	58.3	0.0				dolo/Wacke	9.2	90.8	10	0	0.3	MO,WF	0	2	13.5	13.2	2.8	Burrow
101	154	6608.2	39.4	150	60.6	0.0				dolo/Wacke	6.7	93.3	10	0	0.6	MO	0	2	13.9	13.3	2.5	Burrow
101	155	6608.7	31.5	150	68.5	0.0				Wackestone	15.9	83.4	10	0	1.3	MO,WF	1	3	15.3	14	4.5	cladocoropsis
101	156	6609.2	4.3	80	95.7	0.0				GrDomPack	10.0	88.4	10	1	3	MO,WF	2	2	16.4	13.4	8.6	
101	157	6609.7	8.7	120	91.3	0.0				GrDomPack	11.0	88.2	10	1.6	6.3	MO,WF	1	2	11.2	4.9	1.3	cladocoropsis
101	158	6610.2	61.6	120	38.4	0.0				Wackestone	0.8	99.2	20	0	0	MO,WF	0	2	12.4	12.4	1.7	Cladocoropsis
101	160	6611.2	8.4	120	91.6	0.0				GrDomPack	18.7	74.4	10	0.6	3.3	MO,WF	13	2	15.7	12.4	6.9	cladocoropsis
101	161	6611.7	29.3	120	70.7	0.0				MudDomPack	24.8	74.7	10	0.6	1.3	MO,WF	1	2	13.8	12.5	3.7	cladocoropsis
101	162	6612.2	28.7	140	71.3	0.0				GrDomPack	25.6	74.4		1.0	0.3	MO,IF	0.0	2	12.6	12.3	1.5	Burrow
101	164	6613.2	77.3	190	22.7	0.0	L			MDP	0.0	100.0		0.3	0.0		0.0	2	9.2	9.2	1.6	Burrow
101	166	6614.2	99.4	190	0.0	0.3	L			Dolostone?	0.0	0.0		1.0	0.0		0.0	1	1.6	1.6	0.0	
101	168	6615.2	8.4	150	91.6	0.0				GrDomPack	45.2	54.8		3.3	1.0	MO	0.0	2	17.5	16.5	11.1	cladocoropsis
101	170	6616.2	3.2	190	96.8	0.0				GrDomPack	49.2	50.8		4.3	1.6	MO	0.0	2	18.3	16.7	28.3	
101	172	6617.2	18.7	160	81.3	0.0				Wacke	8.8	91.2		0.3	1.6	IF,MO	0.0	3	15.9	14.3	2.3	
101	174	6618.2	5.0	170	95.0	0.0				GrDomPack	73.3	26.7		7.0	1.6	IFMO	0.0	2	17.7	16.1	29.4	
101	176	6619.2	4.8	140	95.2	0.0				GrDomPack	23.6	76.4		0.6	3.0	MO	0.0	2	20.1	17.1	12.5	Burrow
101	178	6620.2	2.1	110	97.9	0.0				GrDomPack	42.1	57.6		2.3	1.6	MO	1.0	2	18.2	16.6	49.9	cladocoropsis
101	180	6621.2	41.3	150	58.7	0.0	L			Wacke	7.8	92.2		0.0	0.0		0.0	2	4.7	4.7	0.1	
101	182	6622.2	99.6	150	0.0	0.4	L			Dolostone?	0.0	0.0		14.3	0.6	SkDol	0.0	1	15.1	14.5	130.3	
101	184	6632.2	100.0	120	0.0	0.0				Dolostone?	0.0	0.0		12.0	0.0		0.0	1	11.9	11.9	38.0	
101	186	6633.2	100.0	110	0.0	0.0				Dolostone?	0.0	0.0		12.6	0.3	IF	0.0	1	14.3	14.0	140.3	
101	188	6634.2	100.0	130	0.0	0.0				Dolostone?	0.0	0.0		12.3	0.0		0.0	1	17.0	17.0	157.1	
101	190	6635.2	100.0	140	0.0	0.0				Dolostone?	0.0	0.0		9.6	0.0		0.0	1	10.6	10.6	32.3	
101	192	6636.2	99.3	150	0.0	0.7	L			Dolostone?	0.0	0.0		9.6	0.0		0.0	1	8.9	8.9	13.8	
101	194	6637.2	99.3	200	0.0	0.7				Dolostone?	0.0	0.0		16.0	0.0		0.0	1	10.2	10.2	186.9	
101	196	6638.2	2.2	150	97.1	0.7				Grainstone	73.1	26.8	400	8.6	0.6	IF	1.3	1	11.3	10.7	87.8	
101	198	6639.2	0.6	160	99.4	0.0				Grainstone	87.8	12.2	400	6.6	0.0	IF,MO	0.0	1	13.7	13.7	748.0	
101	200	6640.2	23.7	120	76.3	0.0				Wacke/gdp	36.8	63.2	250	0.3	0.0		0.0	2	6.6	6.6	0.5	Burrow/gdp
101	202	6641.2	46.2	120	53.8	0.0				MudDomPack	41.0	59.0	250	0.0	0.3		0.0	2	4.8	4.5	2.8	stylolite
101	204	6642.2	38.2	130	60.8	0.0				MudDomPack	34.0	66.0	200	0.3	0.0		0.0	2	4.9	4.9	0.1	1.0 insoluble res in sty
101	206	6643.2	63.4	110	36.6	0.0				MudDomPack	5.5	94.5	250	0.0	0.0		0.0	2	5.8	5.8	0.2	
101	208	6644.2	77.4	150	22.6	0.0				Wackstone	14.6	85.4	300	0.0	0.0		0.0	2	5.6	5.6	0.0	
101	210	6645.2	37.8	150	62.2	0.0				MDP/gdp	34.4	65.6	300	0.0	0.3		0.0	2	6.9	6.6	0.8	Burrow/gdp
101	212	6646.2	2.5	110	97.5	0.0				GrDomPack	78.1	21.9	200	8.3	0.6		0.0	2	16.0	15.4	31.0	
101	214	6647.2	42.5	90	57.5	0.0				Wacke	2.3	97.7	300	0.0	0.3	IF	0.0	2	6.1	5.8	0.1	
101	216	6648.2	90.3	130	9.7	0.0	L			Dolostone?	20.8	79.2		1.0	0.0		0.0	1	5.8	5.8	1.3	
101	218	6649.2	100.0	140	0.0	0.0	L			Dolostone?	0.0	0.0		1.0	0.0		0.0	1	3.2	3.2	0.1	
101	220	6650.2	98.9	140	0.0	1.1	L			Dolostone?	0.0	0.0		10.0	0.6		0.0	1	10.0	9.4	8.1	
101	222	6651.2	98.7	150	0.0	1.3	L			Dolostone?	0.0	0.0		1.3	0.3		0.0	1	5.1	4.8	0.4	
101	224	6652.2	9.6	150	90.4	0.0				GrDomPack	42.6	57.4	250	0.0	0.3		0.0	2	5.4	5.1	0.2	stylolite
101	226	6653.2	29.7	80	70.3	0.0				mdp	25.7	74.3	200	0.0	0.3	IF	0.0	3	5.5	5.2	0.1	
101	228	6654.2	14.6	90	85.4	0.0				MDP/gdp	24.2	75.8	300	0.0	0.0	IF	0.0	2	3.8	3.8	0.2	Burrow/gdp
101	230	6655.2	22.3	120	77.7	0.0				MDP/gdp	24.8	75.2	250	0.0	0.0	IF	0.0	2	6.0	6.0	0.1	Burrow/gdp
101	232	6656.2	9.6	90	90.4	0.0				GDP	36.5	63.5	300	1.6	1.0	IF	0.0	2	6.5	5.5	0.1	Burrow
101	234	6657.2	37.6	80	62.1	0.0				Mudstone	1.6	98.4	<20	0.0	0.0		0.0	3	4.1	4.1	0.1	
101	236	6658.2	21.3	80	78.7	0.0				Mudstone	4.7	95.3	<20	0.0	0.0		0.0	3	3.2	3.2	0.0	
101	238	6659.2	26.3	60	73.7	0.0				Mud	0.8	99.2	<20	0.0	0.0	IG	0.0	3	3.3	3.3	0.0	
101	240	6660.2	13.8	90	85.9	0.3	L			Mud	52.4	47.6	400	0.6	0.6	IF	0.0	3	7.3	6.7	0.2	Cladocoropsis
101	242	6661.2	36.1	80	63.9	0.0				Mudstone	6.8	93.2	<20	0.0	0.3	IF	0.0	3	5.3	5.0	0.0	Burrow

APPENDIX 1
Petrographic Data for Wells HRDH 101 and 106

2/19/98

Well No.			Dolomite		Calcite	Sulfate		Accessories		Texture					Psv			Core Analysis			Comments
	Plug#	Depth	%	Size(um)	%	% Anh	Type	%	Type	Name	%Grain	%Mud	GrnSize	%Pip	%Psv	Type	%IGu Grains	Class	% Por	%P-%Psv	Perm	
101	244	6662.2	4.8	110	95.2	0.0				GDP	53.7	46.3	180	2.0	1.3	IF,MO	0.0	2	6.4	5.1	0.6	stylolite, 0.6 insoluble residue
101	246	6663.2	70.7	130	29.3	0.0				Mudstone	0.0	100.0		0.0	0.0	IF	0.0	2	4.0	4.0	0.1	
101	248	6664.2	99.7	140	0.0	0.3	L,PF			Dolostone?	0.0	0.0		7.3	1.3	SkDol	0.0	1	13.4	12.1	24.3	Skeletal dolomite
101	250	6665.2	99.3	140	0.0	0.7	L			Dolostone?	0.0	0.0		10.0	0.0		0.0	1	12.1	12.1	84.4	
101	252	6666.2	100.0	150	0.0	0.0	L			Dolostone?	0.0	0.0		2.3	0.3		0.0	1	5.0	4.7	0.1	
101	254	6667.2	9.0	120	91.0	0.0				Wacke	17.2	82.8	<20	0.0	0.0	IF,SH	0.0	3	8.1	8.1	0.1	
101	256	6668.2	6.3	120	93.7	0.0				Wacke	17.7	82.3	300	0.0	0.0	IF	0.0	3	11.6	11.6	0.0	
101	258	6669.2	4.1	80	95.9	0.0				Wacke	14.8	85.2	200	0.0	0.3	IF	0.0	3	9.5	9.2	0.0	
101	260	6670.2	6.3	80	93.7	0.0				Wacke	17.9	82.1	400	0.0	0.0	IF	0.0	3	4.2	4.2	0.1	
101	262	6671.2	7.6	60	92.4	0.0				Mudstone	1.7	98.3	<20	0.0	0.0	IF	0.0	3	11.0	11.0	4.1	
101	264	6672.2	6.4	80	93.6	0.0				MDP	43.4	56.6	200	0.6	0.6	IF	0.0	3	1.5	0.9	0.1	
101	266	6673.2	7.4	80	92.6	0.0				Wack/GDP	34.8	65.2	300	0.0	1.0	IF	0.0	2	8.4	7.4	1.3	burrow/GDP (PHOTO)
101	268	6674.2	0.6	80	94.1	5.3	L			GrDomPack	88.0	12.0	300	3.6	1.3	IF	0.0	2	8.7	7.4	0.6	
101	270	6675.2	1.3	80	98.7	0.0				MDP	40.1	59.9	300	1.0	0.6	IF	0.0	3	8.5	7.9	0.3	PHOTO MDP
101	272	6676.2	0.3	80	99.7	0.0				GrDomPack	87.7	12.3	400	7.0	0.6	IF	0.0	2	8.2	7.6	0.2	
101	274	6677.2	8.3	60	91.7	0.0				Mudstn/GDP	0.0	100.0	<20	0.0	0.0	MO	0.0	2	13.7	13.7	31.0	burrow/GDP (PHOTO)
101	276	6678.2	31.6	80	68.4	0.0				Mudstone	0.4	99.6	<20	0.0	0.0		0.0	3	10.8	10.8	2.4	Unclear why porosity so high
101	278	6679.2	33.6	80	66.4	0.0				Mudstone	0.0	100.0	<20	0.0	0.0	IF	0.0	3	1.3	1.3	0.1	
101	280	6680.2	22.3	70	77.7	0.0				Mudstone	0.0	100.0	<20	0.0	0.0		0.0	3	3.7	3.7	0.0	
101	282	6681.2	23.0	80	77.0	0.0				Mudstone	2.6	97.4	<20	0.0	0.0		0.0	3	3.8	3.8	0.0	burrows
101	284	6682.2	9.1	80	90.9	0.0				Wacke	33.3	66.7	<20	0.3	0.3	IF	0.0	3	4.4	4.1	0.0	
101	286	6683.2	7.3	80	91.1	1.6	PF,L			Wacke	5.9	94.1	<20	0.0	0.0		0.0	3	1.7	1.7	1.1	
101	288	6684.2	8.7	80	91.3	0.0	L			GDP	38.8	61.2	300	4.0	0.3	MO	0.0	2	3.7	3.4	1.4	stylolite, burrows w/dolomite
101	290	6685.2	45.8	80	53.9	0.3	L			Mudstone	0.0	100.0	<20	0.3	0.0		0.0	2	6.5	6.5	0.3	
101	292	6686.2	53.9	90	45.8	0.3	L			Wacke	9.5	90.5	<20	0.0	1.0	MO	0.0	2	5.7	4.7	0.1	Burrow, Silt
101	294	6687.2	41.6	80	58.4	0.0				Mudstone	0.0	100.0	<20	0.0	0.0		0.0	2	7.5	7.5	0.0	
101	296	6688.2	53.4	90	46.3	0.3				Mudstone	0.0	100.0	<20	0.0	0.0		0.0	2	5.4	5.4	0.1	
101	298	6689.2	17.1	80	82.9	0.0				Mudstone	1.9	98.1	<20	0.3	0.0	IF	0.0	3	5.6	5.6	0.1	Burrows
101	300	6690.2	17.7	80	82.3	0.0				Wacke	4.1	95.9	<20	0.3	0.0	IF	0.0	3	5.5	5.5	0.1	Burrows
101	302	6691.2	2.7	120	97.3	0.0				GDP	38.5	61.1	500	1.0	0.0	IF	1.0	2	7.4	7.4	0.0	Big mud clasts
101	304	6692.2	0.3	150	98.0	0.6	L			GrDomPack	85.7	14.3	500	3.3	1.3	MO,IF	0.6	2	13.6	12.3	81.6	cladocoropsis,Clasts
101	306	6693.2	4.7	110	95.3	0.0				GDP	31.7	68.3	500	2.0	0.3		0.0	2	10.2	9.9	15.5	Stylo, burrows
101	308	6694.2	19.0	80	81.0	0.0				Mudstone/gdp	1.6	98.4	<20	0.0	0.0		0.0	2	9.6	9.6	0.2	GDP in burrow
101	310	6695.2	19.0	80	80.7	0.0				Mudstone	0.0	100.0	<20	0.0	0.0		0.0	3	10.0	10.0	0.4	Stylolite
101	312	6696.2	14.6	70	85.4	0.0				Mud	0.0	100.0	<20	0.0	0.0		0.0	3	7.7	7.7	0.0	
101	314	6697.2	13.6	70	86.4	0.0				Mud	0.0	100.0	<20	0.0	0.0	IF	0.0	3	6.5	6.5	0.1	
101	316	6698.2	8.3	60	91.7	0.0				Mud	4.7	95.3	<20	0.0	0.0		0.0	3	5.6	5.6	1.3	Stylolite, burrows
101	318	6699.2	3.6	90	95.5	0.6				Mud	1.0	99.0	<20	0.0	0.0		0.0	3	2.9	2.9	0.2	Wkstn in dolo burrows (photo)
101	320	6700.2	6.0	90	93.4	0.6				GDP	47.7	52.3	500	0.0	0.0	IF	0.0	2	2.7	2.7	0.0	Clasts
101	322	6701.2	5.1	110	94.5	0.3				MDP	25.2	74.8	<20	0.3	1.3	IF,MO	0.0	3	9.6	8.3	0.1	
101	324	6702.2	2.1	60	97.5	0.0				Wacke	12.5	87.3	<20	0.3	3.3	MO,IF	0.3	3	10.8	7.5	0.2	
101	224	6703.7	3.0	60	97.0	0.0				Wacke	33.7	66.3	<20	0.0	0.0	IF	0.0	3	13.8	13.8	0.7	V.small burrow
101	326	6706.0	1.0	90	98.9	0.0				Wack/GDP	14.2	85.8	<20	0.6	3.3	MO,IF	0.0	2	11.1	7.8	1.0	burrow/gdp photo
101	330	6708.0	2.4	90	97.6	0.0				GDP	58.2	41.8	200	1.3	1.6	MO	0.0	2	7.9	6.3	16.5	stylolite
101	332	6709.0	13.7	90	86.3	0.0	PF			MDP	12.1	87.9	<20	0.0	0.3	MO,IF	0.0	3	3.6	3.3	0.7	burrow
101	334	6710.0	19.6	70	79.0	0.0				Wacke	3.3	96.7	<20	0.0	0.0	IF	0.0	3	2.9	2.9	0.3	burrow
101	336	6711.0	3.6	80	95.4	0.3	L			Wackstn	15.1	84.9	<20	0.0	0.0	IF,MO	0.0	3	3.0	3.0	0.1	Burrow, Clasts
101	338	6712.0	8.3	80	91.4	0.0				Mud	4.4	95.6	<20	0.0	0.0	MO	0.0	3	4.3	4.3	64.5	Induced Fracture (photo of mud)
101	340	6713.0	0.0	60	100.0	0.0				Mud	3.7	96.3	<20	0.0	2.0	MO,IF	0.0	3	7.2	5.2	0.3	burrow/mud, stylolite
101	342	6714.0	0.6	40	99.4	0.0				Mud	4.4	95.6	<20	0.0	0.0	IF	0.0	3	6.9	6.9	0.1	
101	344	6715.0	51.4	80	48.6	0.0				Mud	0.0	100.0	<20	0.0	0.0		0.0	3	2.3	2.3	0.1	burrow
101	346	6716.0	0.6	50	99.4	0.0				Wacke	17.9	82.1	<20	0.3	0.3	IF,MO	0.0	3	5.8	5.5	0.0	Stylolite
101	348	6717.0	1.6	60	98.4	0.0				Wacke	47.0	53.0	<20	0.0	0.3	IF	0.0	3	3.5	3.2	0.1	
101	350	6718.0	2.8	80	97.0	0.0		tr	Clay	Wackstone	59.2	40.8	300	1.0	0.6	IF,MO	0.0	3	5.5	4.9	0.1	0.3 Kaolinite
101	352	6719.0	22.6	80	77.3	0.0				MDP	38.2	61.8	<20	0.0	0.0	IF	0.0	3	3.4	3.4	0.1	burrow, Dolo in mud between grains
101	354	6720.0	79.7	120	20.3	0.0				Mud	0.0	100.0	<20	0.0	0.0		0.0	2	0.8	0.8	0.1	burrow
101	356	6721.0	12.6	80	87.4	0.0				Mud	0.0	100.0	<20	0.0	0.0		0.0	3	8.6	8.6	0.0	
101	358	6722.0	6.3	60	93.7	0.0				Mud	0.6	99.4	<20	0.0	0.0	IF	0.0	3	9.1	9.1	0.0	

APPENDIX 1
Petrographic Data for Wells HRDH 101 and 106

Well No.			Dolomite		Calcite	Sulfate		Accessories		Texture					Psv				Core Analysis			Comments
	Plug#	Depth	%	Size(um)	%	% Anh	Type	%	Type	Name	%Grain	%Mud	GrnSize	%Pip	%Psv	Type	%IGu Grains	Class	% Por	%P-%Psv	Perm	
101	360	6723.0	0.6	40	99.4	0.0				MDP	41.0	59.0	<20	0.0	0.0	IF	0.0	3	7.3	7.3	0.0	compacted GDP?
101	362	6724.0	1.7	60	98.3	0.0				Wacke	51.8	48.0	300	0.3	2.6	IF	1.0	3	7.7	5.1	0.1	
101	364	6725.0	13.1	120	86.5	0.0				MDP	64.9	35.1	300	2.6	1.0	IF,MO	0.0	3	6.7	5.7	0.1	cladocoropsis, clasts
101	366	6726.0	100.0	80	0.0	0.0				Dolostone	0.0	0.0		0.0	0.0		0.0	1	1.4	1.4	1.0	
101	368	6727.0	100.0	110	0.0	0.0				Dolostone	0.0	0.0		1.0	0.0		0.0	1	2.7	2.7	0.0	strange relict shape
101	370	6728.0	9.1	90	90.4	0.0				MDP	47.2	52.8	<20	0.3	0.6		0.0	3	4.8	4.2	0.1	stylolite 0.3 insoluble residue; burrow
101	372	6729.0	5.7	90	93.4	0.0				GDP	61.8	38.2	250	0.6	0.0	IF,MO	0.0	2	5.5	5.5	0.1	
101	374	6730.0	0.6	80	99.0	0.0				GDP	81.3	18.6	300	1.0	2.6	IF,MO	0.6	2	10.8	8.2	2.9	cladocoropsis frags
101	376	6731.0	38.7	80	61.3	0.0				Mud	2.6	97.4	<20	0.0	0.0		0.0	3	1.6	1.6	0.1	
101	378	6732.0	25.1	80	74.3	0.0				Wacke	18.0	82.0	<20	0.0	0.0		0.0	3	2.4	2.4	0.0	burrow
101	380	6733.0	7.0	60	93.0	0.0				Mud	3.9	96.1	<20	0.0	0.0		0.0	3	2.9	2.9	0.1	
101	382	6734.0	13.6	90	85.7	0.0				MDP	8.9	91.1	<20	0.0	0.0	MO,IF	0.0	3	4.6	4.6	0.1	burrow
101	384	6735.0	43.4	60	56.3	0.0	L			Wacke	26.4	73.6	<20	0.0	0.0		0.0	2	3.0	3.0	0.1	burrow
101	386	6736.0	55.4	80	44.6	0.0	L			Mud	1.3	98.7	<20	0.0	0.0		0.0	2	1.9	1.9	0.1	burrow