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PRELIMINARY RESULTS OF POROSITY AND PERMEABILITY OF CORES FROM DOE WELLS IN THE PALO DURO BASIN, TEXAS PANHANDLE

by

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CONTENTS

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INTRODUCTION

Information on permeability and porosity of the Deep-Basin Brine Aquifer is important for describing flow pattern and flow velocity of deep-basinal fluids. Permeabilities were estimated from drill-stem tests, pumping tests, and published values of equivalent geologic materials. In addition, permeabilities and porosities of different lithologies were determined from laboratory tests of cores. The objectives of core analysis are: (1) determine porosities and permeabilities of the different geologic lithofacies, (2) relate porosities to petrographic description of pore types and lithology, (3) obtain vertical and horizontal distribution of porosity and permeability from the analyzed core intervals, (4) compare core permeabilities to drill-stem test and pumping test analyses, and (5) compare core derived porosity value with porosities from neutron-density cross plots.

PRESENT STATUS OF CORE STUDY

Porosity and permeability measurements were performed on 58 core plug samples selected from cored intervals of the DOE Mansfield #1, Sawyer #1, and Zeeck #1 wells. The cores consist of dolomites, limestones, and granite wash of Wolfcampian age. In addition, a whole core section from DOE well J. Friemel #1 consisting of granite-wash deposits of Pennsylvanian age (Test Zone 3) was analyzed for porosity and permeability. Four individual 1-inch diameter core plugs were cut from this interval and analyzed. Presently, four additional

whole core sections from J. Friemel #1 (in Test Zones 1, 2, 5, and 7) are being analyzed at Core Laboratories, Incorporated, for permeability and porosity. Further, approximately 65 core plug samples from J. Friemel selected at depths, ranging from 5,670 ft to 8,283 ft are being prepared for core analyses. Besides using general lithologic core descriptions, a more detailed petrographic study of the individual core plugs has been initiated which uses thin sections from core plugs and from whole core sections to describe the lithology and pore space distribution of the samples.

CORE ANALYSIS PROCEDURE

A total of 58 one-inch diameter, cylindrical core plug samples representing various depth intervals of the Deep-Basin Brine Aquifer at the DOE Mansfield #1, Sawyer #1, Zeeck #1, and J. Friemel #1 well locations were prepared according to standard procedures by Core Laboratories, Incorporated. Permeability to air and Boyle's law porosity (using helium as the gaseous medium) were determined for each core plug. Core plugs which exhibited sufficient permeability to air (0.15 md minium) and sufficiently large pore volumes (above 1% porosity) were selected for specific permeability to water determinations, using a brine containing 150,000 ppm total dissolved solids (80% NaCl, 20% $CaCl_2$).

Liquid permeability was measured under effective overburden pressures representative of the depth range of the selected core plugs in each well: (1) 2,000 psi for Sawyer #1, (2) 3,100 psi for Mansfield #1, (3) 3,500 psi for Zeeck #1, and (4) 3,000 psi (whole core), and 4,500 psi and 200 psi (core plugs) for J. Friemel #1. The core plugs from J. Friemel were subjected to different overburden pressures to investigate possible ranges in permeability.

RESULTS AND DISCUSSION OF CORE ANALYSES

Air and Liquid Permeability

Tables 1 to 4 summarize the results of laboratory tests for selected core plugs and whole core section obtained from DOE wells. The differences between air permeability and liquid permeability for each core generally increases with decreasing permeability (fig. 1). The general trends of air to liquid permeability for the different lithologies as shown by the slopes of the regression lines are similar. Sandstone cores (granite wash), however, indicate the greatest difference between air and liquid permeabilities. Dolomite cores with permeabilities of more than 100 md do not show any significant variation in permeability.

One possible explanation of the difference between air and liquid permeability is the slip effect of gas (Klinkenberg, 1941). This effect results in higher values of air permeabilities as compared to the "true" permeability due to the physical behavior of gas. It was found that with decreasing permeability the slip effect increases, resulting in greater discrepancy of permeability values (Heid and others, 1950). As stated by Core Laboratories, air pressures applied during the permeability tests are adjusted to minimize the slip effect which decreases with increasing mean gas pressure (Klinkenberg, 1941).

The difference in permeabilities could also result from the applied overburden pressure during liquid permeability testing which results in a general decrease in porosity and permeability. Although the reduction in pore space in sand due to overburden has been shown to be relatively small (Botset and Reed, 1935), its effect on permeability could be significant for low permeable media such as tight gas sands (Walls and others, 1982). Core permeabilities derived from the DOE wells under different overburden pressure do not suggest a relationship between reduction of liquid permeability with increasing overburden pressure. In fact, most of the sandstone cores in figure 1 are from the DOE Sawyer #1 well subjected to the lowest overburden pressures and show the largest difference between air and liquid permeability. Core samples from J. Friemel #1 wells show very large differences between air and liquid permeabilities, which was related to plugging by mobile fines and by trapped air resulting in lower liquid permeabilities (Core Laboratories, pers. comm.). Core plug samples 1A and 1B (Table 1) appear to be damaged by the applied overburden pressure, resulting in unusually high permeabilities. Permeabilities of core plug samples 1C and 1V do not show a significant difference in permeabilities when tested under 4,500 psi and under 200 psi overburden pressures. It can be expected that the effect of overburden pressure on porosity and permeability for limestone and dolomite cores is less than for sandstone cores, because of the more rigid matrix of the cores.

Although a carefully conducted laboratory test could reduce the impact of the effects discussed above, they cannot be ruled out. A combination of various factors including the gas slippage (higher air permeabilities), the effect of overburden pressures, plugging of pores by mobile fines or trapped air, and experimental errors of the measurements could produce erroneous results.

Core Permeability and Field Permeability

In figures 2 to 4, permeabilities of horizontally oriented cores are compared with average permeabilities obtained from pumping test and drill-stem test analyses at specific depth intervals for the DOE Sawyer #1, Mansfield #1, and Zeeck #1 wells. It should be emphasized that interpretations of core permeabilities and permeabilities derived from drill-stem and pumping tests are preliminary, considering the limited data available at the present status of the study.

Bulnes and others (1944) compared vertical permeability profiles between limestone and sandstone formations. They concluded that many limestone formations consist of complexes of extensive low permeable bodies interconnected by relatively thin zones of a more porous type of considerably greater permeability or by fissures. In contrast, zones of low permeability in sandstones are relatively thin as compared to the zones of higher permeability. The distribution of permeability in sandstone is more dependent on sedimentation, stratification and structure than it is in limestones (Bulnes and others, 1944). Although the presented permeability data for the different wells are rather limited, figure 2 indicates a greater range of air permeability for limestones and dolomites than for sandstones.

Limestone and dolomite cores in DOE Zeeck #1 well (fig. 4) show a permeability range of more than 4 orders of magnitude from 10^{-1} md to over 10^{3} md within a depth interval of 75 feet. In general, both air and liquid permeabilities of cores cluster around the average permeability value derived from drill-stem and pumping tests. Hydrologic testing in test zone 3 of J. Friemel #1 well yielded a permeability value of 148.7 md (Table 6). In comparison, core analyses from this zone yielded permeabilities ranging from 830 md (air) to 26 md (liquid) for the whole core and from 764 md (air) to 23 md (liquid) for core plug samples 1C and 1V (Table 1). (Permeability data from core plug samples 1A and 1B were discarded because of damaged core.)

In other investigations, Olson and Daniel (1982) compared hydraulic conductivity of fine-grained soils measured in the field and from cores in the laboratory. They documented that field permeabilities are generally higher than laboratory permeabilities. A similar result was obtained by Fogg and others (1983) who compared permeabilities derived from unconsolidated sand cores with permeabilities based on pumping tests in the corresponding intervals. A possible reason for the higher values of field permeabilities is the tendency to select core plugs at less permeable sections (Olson and Daniel, 1982). Because the distribution of permeability is typically log-normal for geologic materials (Freeze, 1975), random plug samples could preferentially represent the lower permeable sediments (Fogg and others, 1983).

In the selection of core plugs from DOE wells under consideration, we attempted to minimize this effect by selecting core plugs in more permeable sections. With the exception of the Mansfield #1 well, the core permeabilities cluster around the DST of pumping test permeabilities. The relatively high field permeabilities in Mansfield #1 (fig. 3) may be caused by fracture permeability, which is unaccounted for in core plug analyses. Abundant fractures are present in cored intervals of the Mansfield #1 well, which strongly suggest the possibility of significant fracture permeability in correlatable intervals.

Porosity-Permeability Trends

In general, a broad relationship exists between porosity and permeability of a formation. Archie (1950) identified individual trends for different formations and lithologies though the data scatter is generally great (fig. 5). Other studies by Bulnes and others (1944), Kelton (1949), and Ryder (1948) also documented a general increase of permeability with increasing porosity for different formations. The data distribution is also characterized by a wide scatter or lack of close correlation.

Permeability-porosity trends of cores from selected DOE wells show a general increase of permeabilities with an increase in porosities. The porosity-permeability trends for the different lithologies are significantly different as indicated by the different slopes of the regression lines in figure 6. Linear regression was also computed for the permeability porosity trends for the individual wells and shown in Table 5. The amount of core data from the individual wells is limited, which results predominantly in low confidence values of the computed correlation coefficients and in a large standard error of estimation of the linear regression lines. For the combined core data, the relation of porosity and permeability is statistically significant with correlation coefficients ranging from 0.8656 for dolomite cores to 0.8354 for limestone cores, to 0.7304 for sandstone (granite wash) cores (Table 5). The regression lines in figure 6 indicate that dolomites are characterized by the greatest increase in permeability with increasing porosity as compared to sandstone (granite wash) and limestone (Table 5).

Individual porosity-permeability trends for the three DOE wells, Sawyer, Mansfield, and Zeeck, are shown in figures 7 to 9. Generally, the limited available core data indicate slightly different trends of porosity and permeability of the individual lithologies for the three well locations. Differences in porosity-permeability trends are also suggested by the range in measured permeabilities in the different DOE wells. Dolomite core plugs from the Zeeck #1 well have measured permeabilities of up to 1,890 md, while limestones from Mansfield #1 have intermediate permeabilities on the order of 10 md, but relatively high porosities of up to 28 percent. In thin section,these limestones are characterized by predominantly oomoldic porosity, which is apparently not well interconnected, resulting in relatively low permeability. Sandstone (granite wash) cores from the Wolfcamp strata in the Sawyer #1 well are more fine grained, representing distal granite-wash deposits as compared to proximal granite wash of Pennsylvanian age in the J. Friemel #1 well. Air permeabilities of core plug samples from the Sawyer #1 well are less than

10 md, except samples 17 and 19 (Table 2) which exceed 100 md. In comparison, air permeability from J. Friemel cores are significantly higher (830 md), suggesting a difference in the hydrogeologic characteristic of distal and proximal granite-wash deposits.

Log-Derived Porosity and Core Porosity

One objective of this study is to obtain a detailed description of the porosity and permeability distributions within the Deep-Basin Brine Aquifer. The first step is to obtain porosity-permeability relationships for the different lithologies, as described above. The second step is to compare porosity measured from core plugs with porosity and lithology derived from geophysical logs (Conti and Wirojanagud, 1984) as shown in figure 10. Porosities derived from the cross-plotting technique which incorporates neutron and density logs (Schlumberger, 1972) agree reasonably well with porosities measured from core samples (fig. 11). Accordingly, log-derived porosities can be used to generate porosity distributions of individual units within the Deep-Basin Brine Aquifer (Conti and Wirojanagud, 1984), from interpreting geophysical logs from throughout the basin. The third step planned for this study will incorporate established porosity-permeability relationships of the different lithologies to derive permeability distributions based on the log-derived porosity distributions.

SUMMARY

Interpretations of the presented data have to be considered preliminary, because not all of the selected core plugs have been analyzed. However, preliminary results indicate statistically significant porosity-permeability trends for the different lithologies based on analyses of core plugs from DOE

wells in the Deep-Basin Brine aquifer. Comparison of permeabilities obtained from cores, pumping tests, and drill-stem tests suggests extreme heterogeneity within the test intervals. The generally higher permeabilities in the Mansfield #1 well obtained from pumping tests and drill-stem tests as compared to core permeabilities may be the result of fracture permeability.

Porosity values derived from geophysical logs correlate reasonably well with core-derived porosities, supporting the validity of log-derived porosity distributions which are compiled in the Wolfcamp Series. Porosity distributions can then be extrapolated to permeability trends within the Deep-Basin Brine Aquifer using the porosity-permeability relationships established by core plug analyses.

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FIGURE CAPTIONS

Figure 1. Comparison of air permeability and liquid permeability as determined from core plugs. With decreasing permeabilities, the discrepancy between air and liquid permeability is increasing.

Figure 2. Air permeability and liquid permeability of horizontally oriented core plug samples from the Sawyer #1 well compared to average permeability based on pumping tests and drill-stem tests.

Figure 3. Air permeability and liquid permeability of horizontally oriented core plug samples from the Mansfield #1 well compared to average permeability based on pumping tests and drill-stem tests.

Figure 4. Air permeability and liquid permeability of horizontally oriented core plug samples from the Zeeck #1 well compared to average permeability based on pumping tests and drill-stem tests.

Figure 5. Average relation between porosity and permeability for different formations (after Archie, 1950).

Figure 6. Relationship of porosity and air permeability of horizontally oriented core plug samples from all four DOE wells. Regression lines show different porosity-permeability trends for the different lithologies.

Figure 7. Relationship of porosity and air permeability of horizontally oriented core plug samples from the Sawyer #1 well.

Figure 8. Relationship of porosity and air permeability of horizontally oriented core plug samples from the Mansfield #1 well.

Figure 9. Relationship of porosity and permeability of horizontally oriented core plug samples from the Zeeck #1 well.

Figure 10. Comparison of porosity measurements from core plug samples of different lithologies and porosity values and lithology obtained from cross-plotting neutron and density geophysical logs.

Figure 11. Plot of measured porosities obtained from cores and porosities derived from Neutron-Density cross-plotting technique.

TABLE CAPTIONS

Table 1. Results of porosity and permeability measurements from a whole core section and core plug samples in the J. Friemel #1 well.

Table 2. Results of porosity and permeability measurements of core plug samples in the Sawyer #1 well.

Table 3. Results of porosity and permeability measurements of core plug samples in the Mansfield #1 well.

Table 4. Results of porosity and permeability measurements of core plug samples in the Zeeck #1 well.

Table 5. Statistical analysis of porosity-permeability trends based on core plug analyses.

Table 6. Permeability results based on hydrologic well testing in the J. Friemel #1 well.

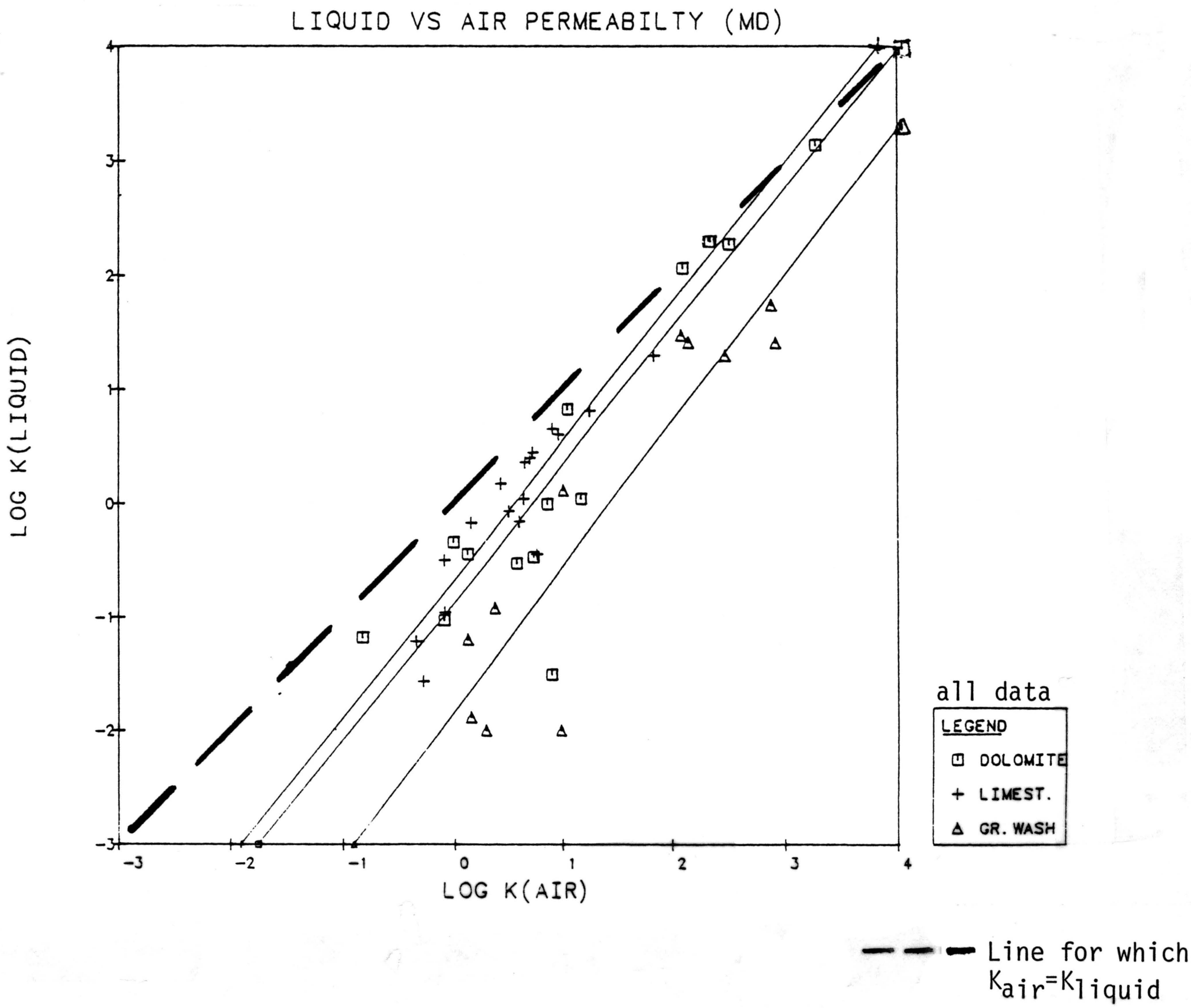
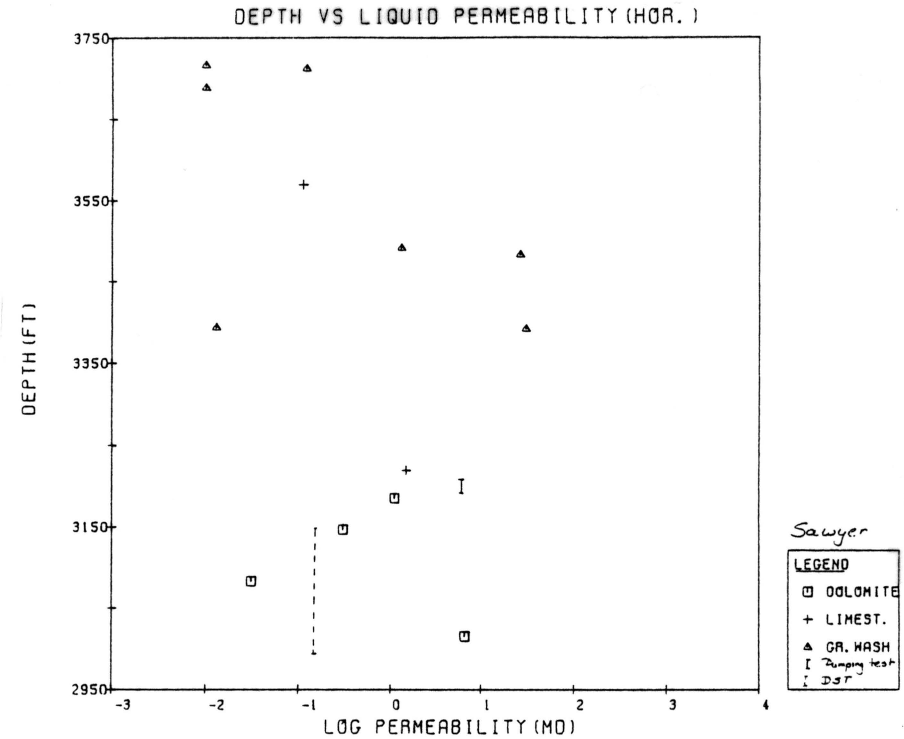


Figure 1. Comparison of air permeability and liquid permeability as determined from core plugs. With decreasing permeabilities, the discrepancy between air and liquid permeability is increasing.



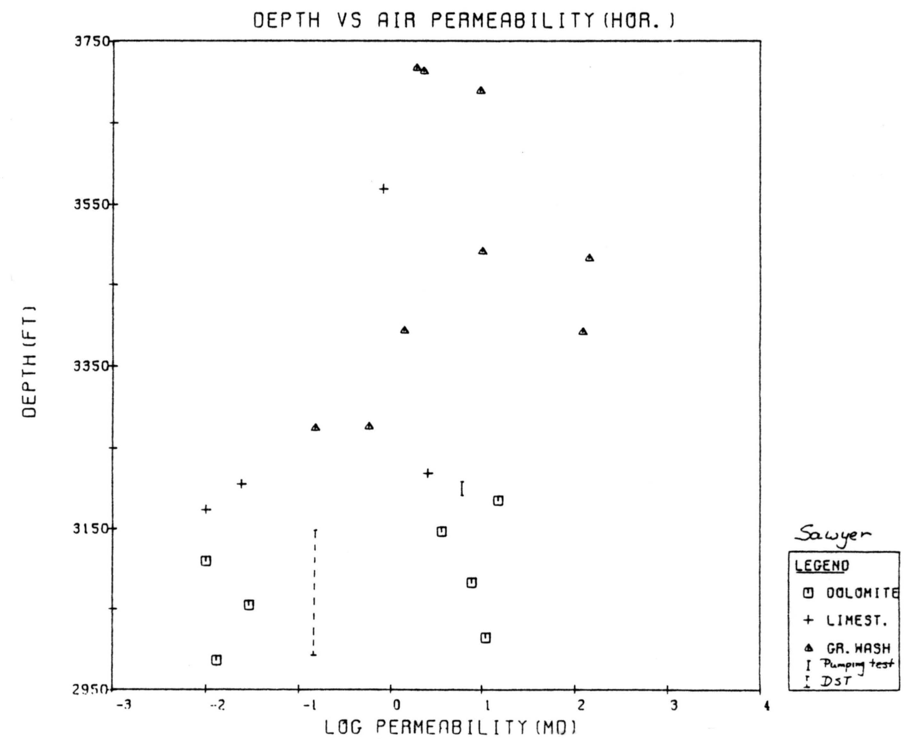


Figure 2. Air permeability and liquid permeability of horizontally oriented core plug samples from the Sawyer #1 well compared to average permeability based on pumpong tests and drill-stem tests.

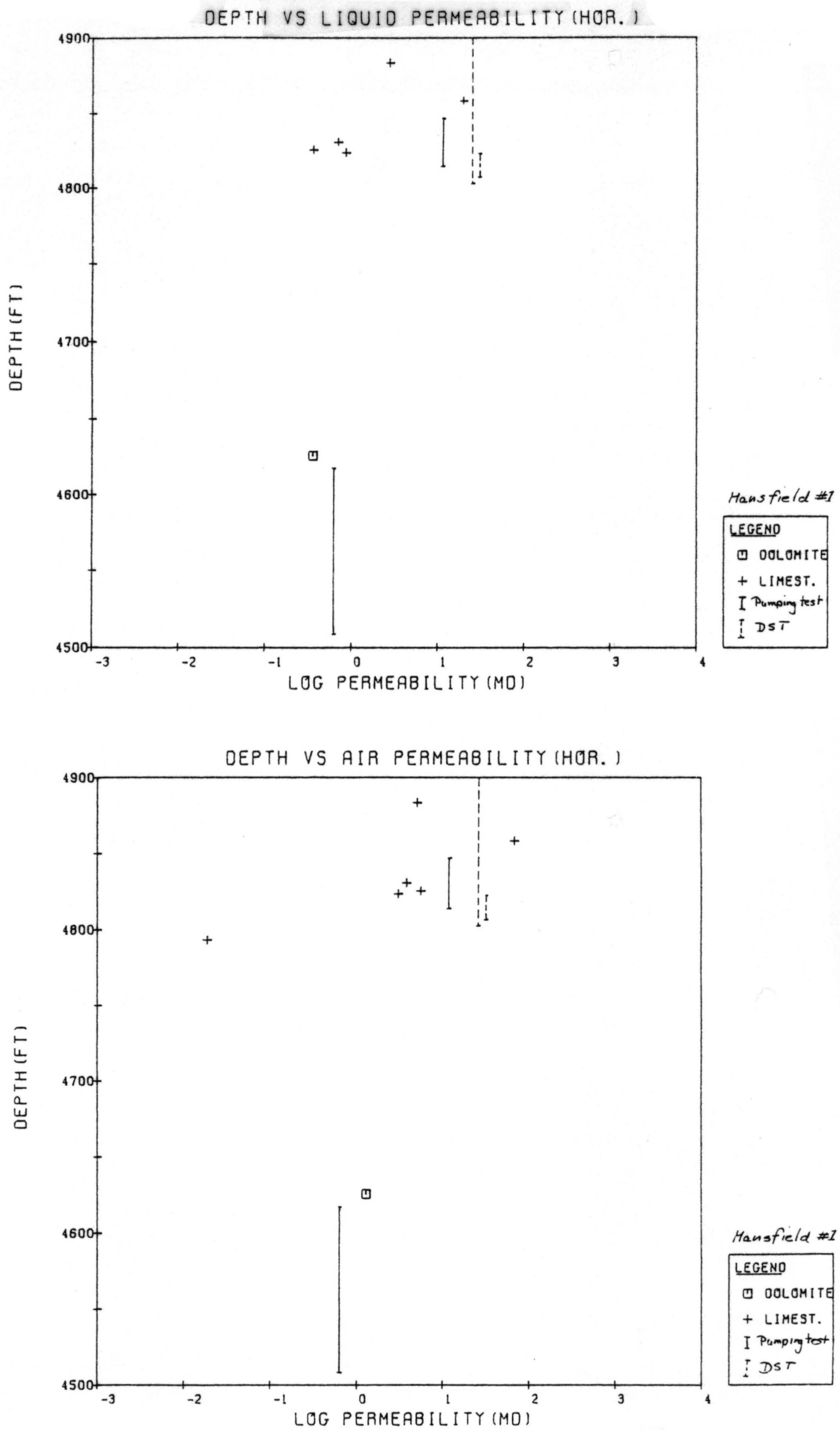
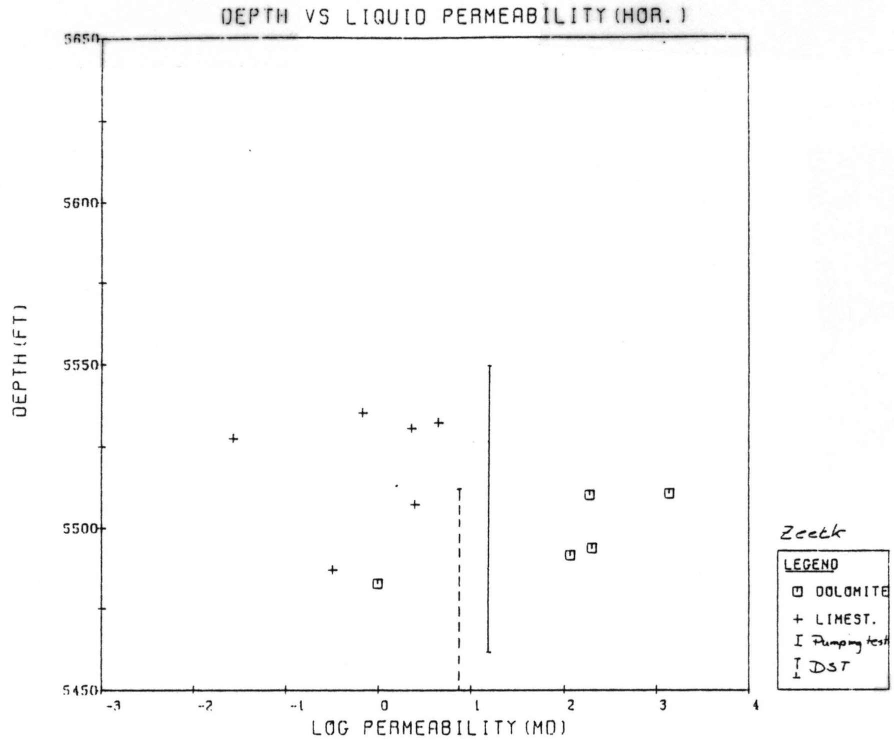


Figure 3. Air permeability and liquid permeability of horizontally oriented core plug samples from the Mansfield #1 well compared to average permeability based on pumping tests and drill-stem tests.



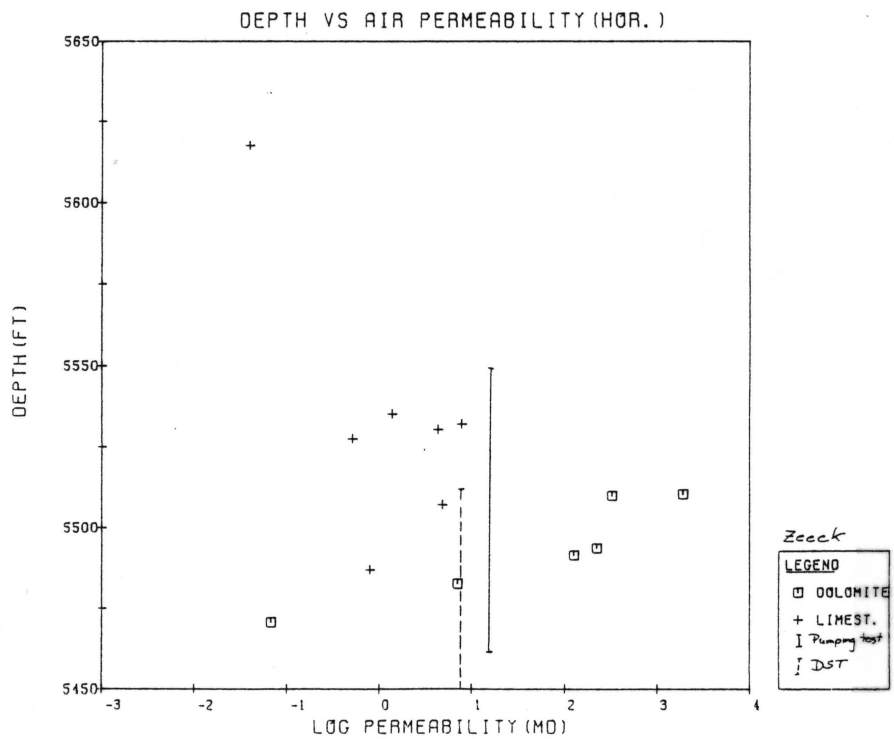


Figure 4. Air permeability and liquid permeability of horizontally oriented core plug samples from the Zeeck #1 well compared to average permeability based on pumpong tests and drill-stem tests.

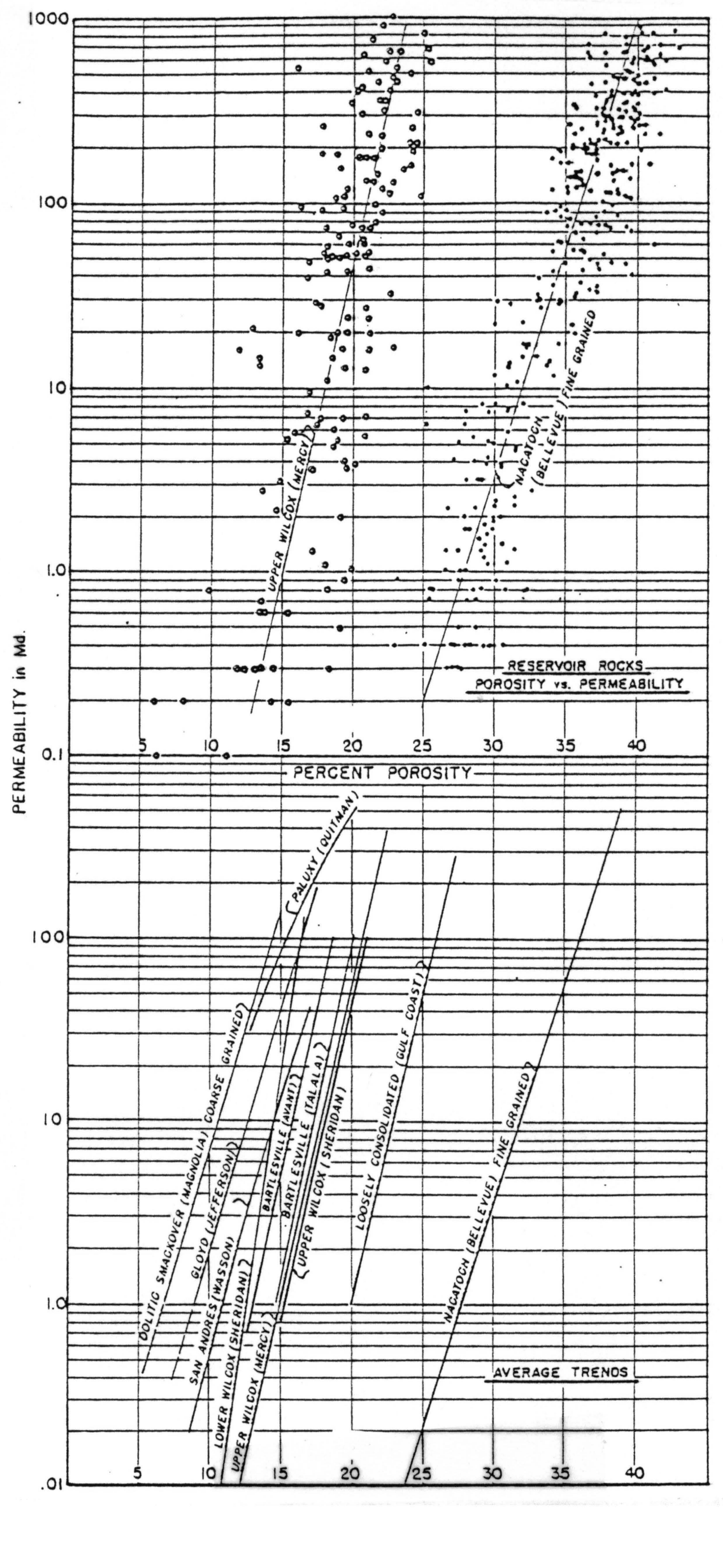


Figure 5. Average relation between porosity and permeability for different formations (after Archie, 1950).

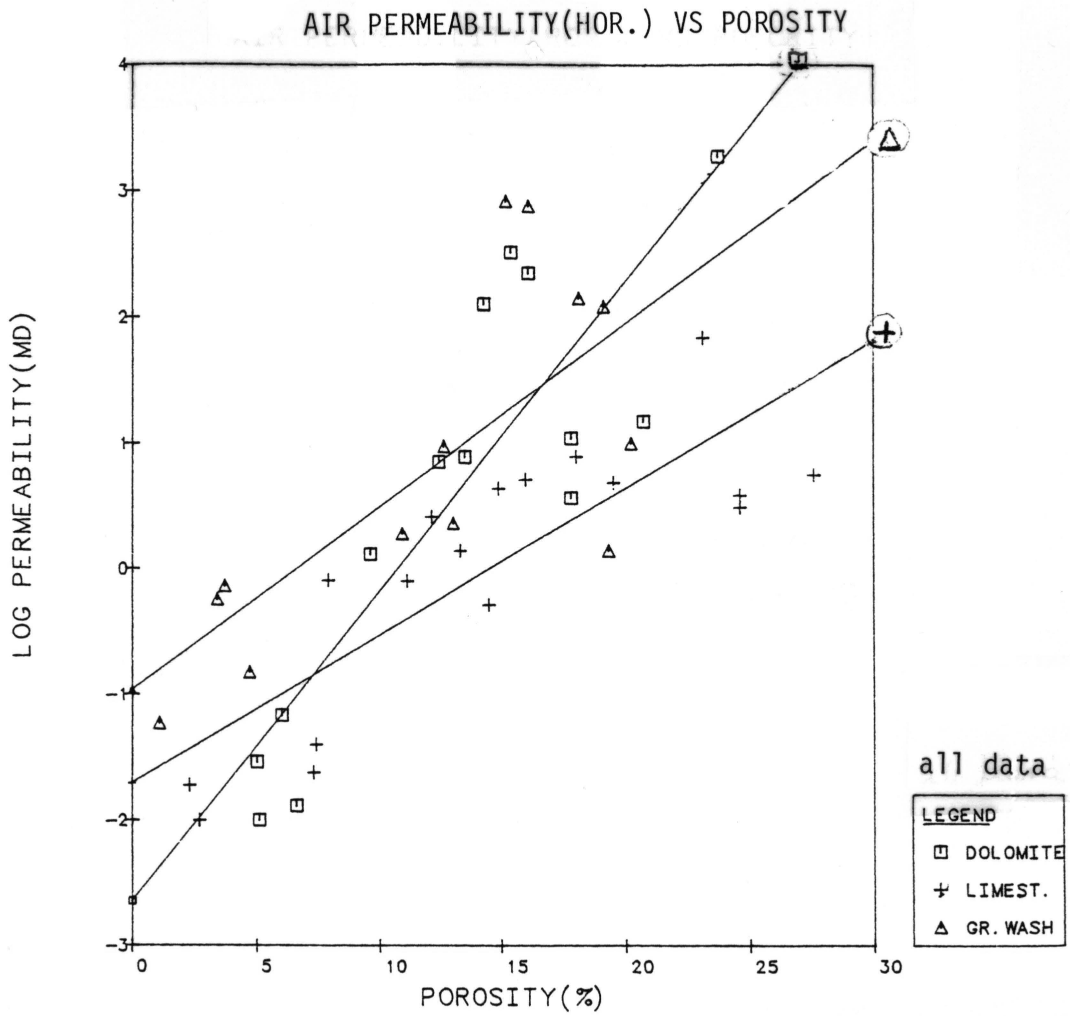


Figure 6. Relationship of porosity and air permeability of horizontally oriented core plug samples from all four DOE wells. Regression lines show different porosity-permeability trends for the different lithologies.

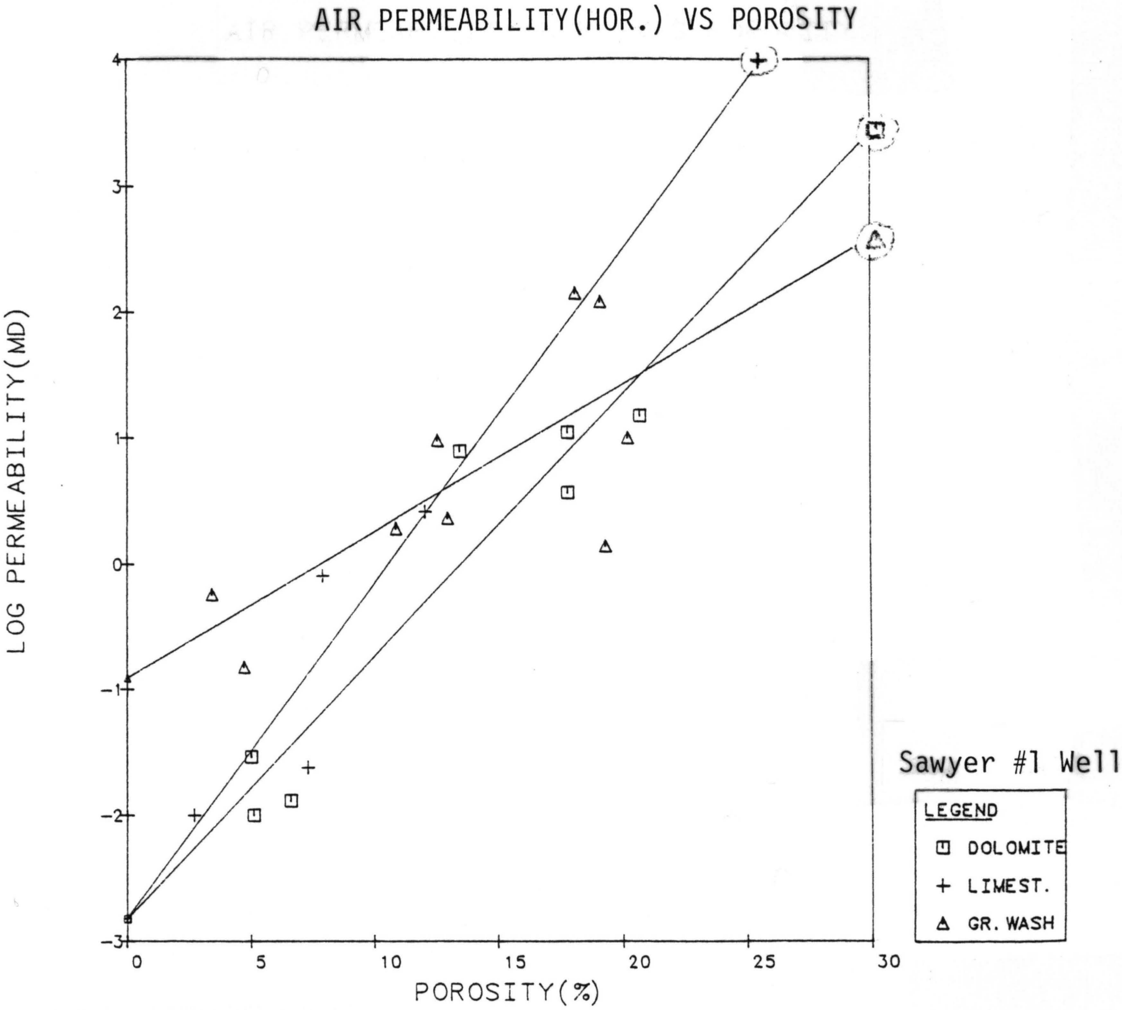


Figure 7. Relationship of porosity and air permeability of horizontally oriented core plug samples from the Sawyer #1 well.

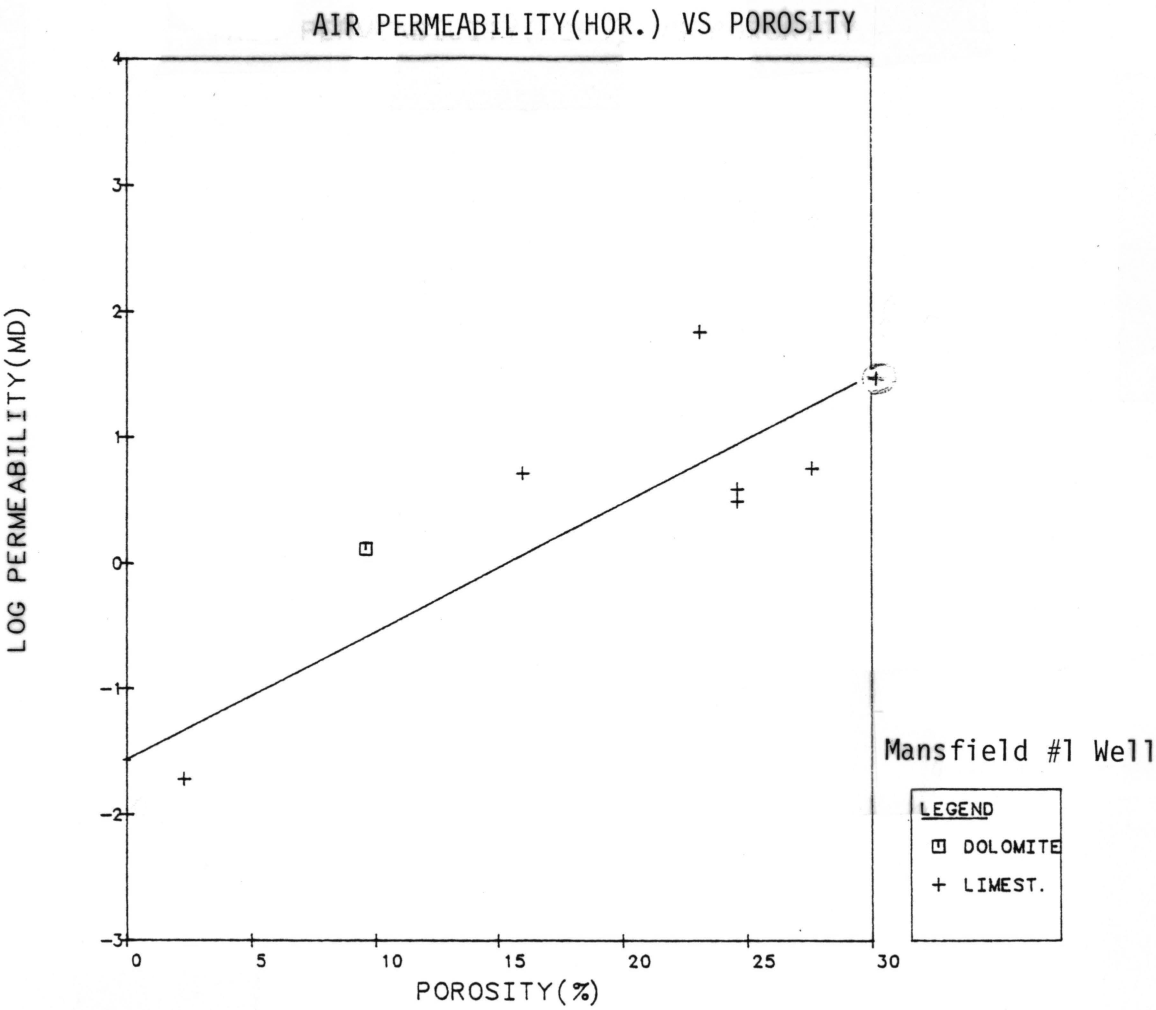


Figure 8. Relationship of porosity and air permeability of horizontally oriented core plug samples from the Mansfield #1 well.

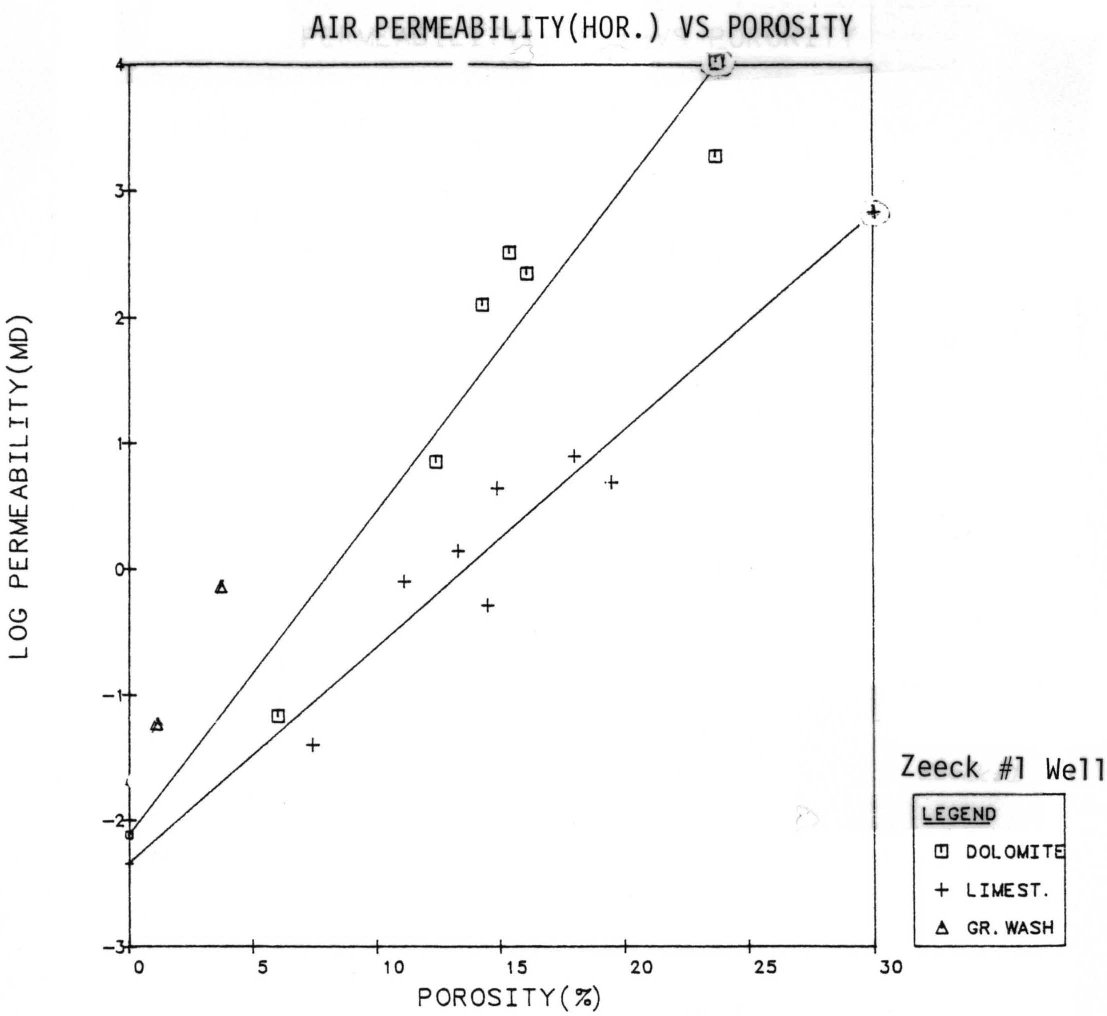


Figure 9. Relationship of porosity and permeability of horizontally oriented core plug samples from the Zeeck #1 well.

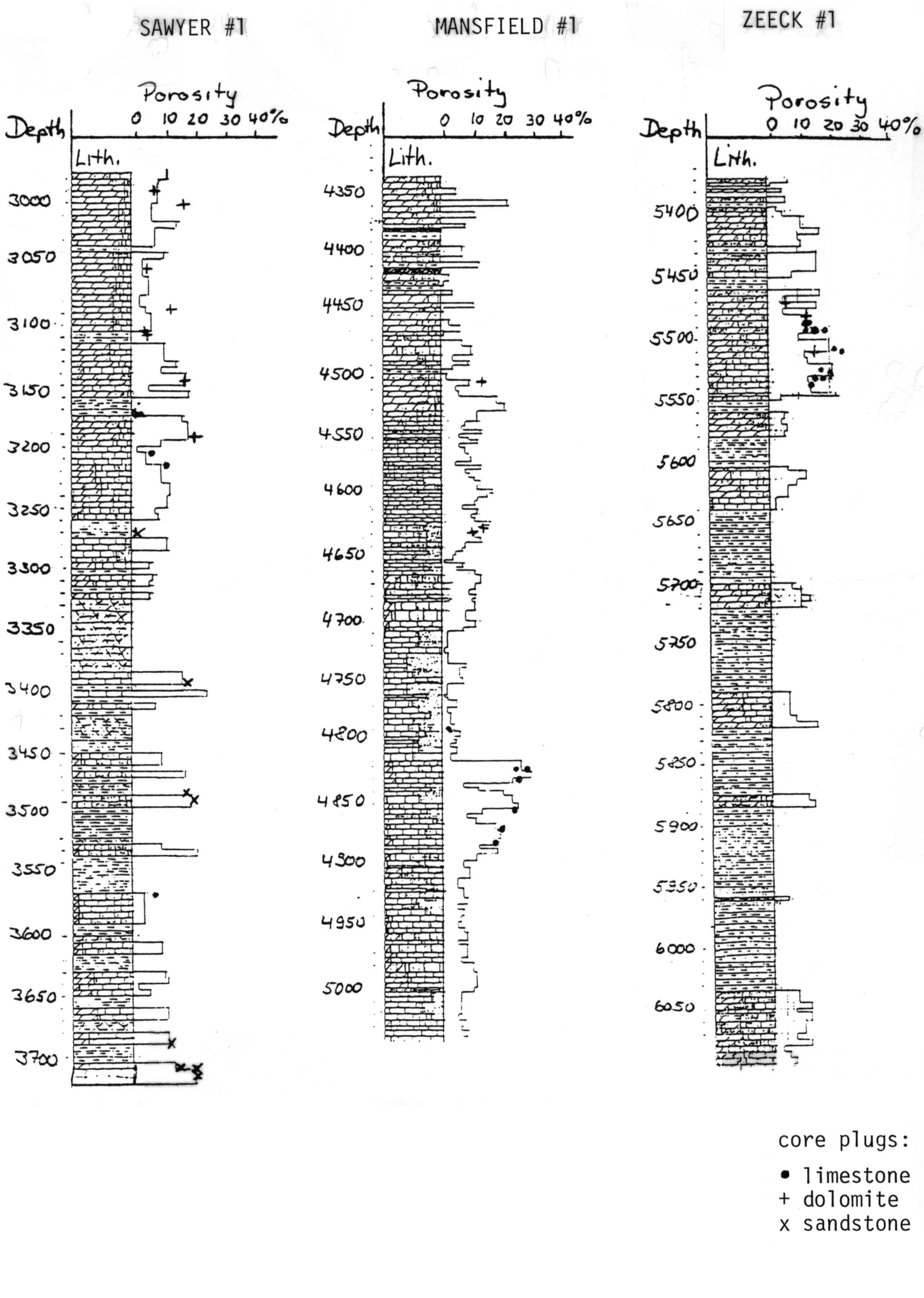


Figure 10. Comparision of porosity, lithology using Neutron Density Crossplots and porosity, lithology of core plug samples.

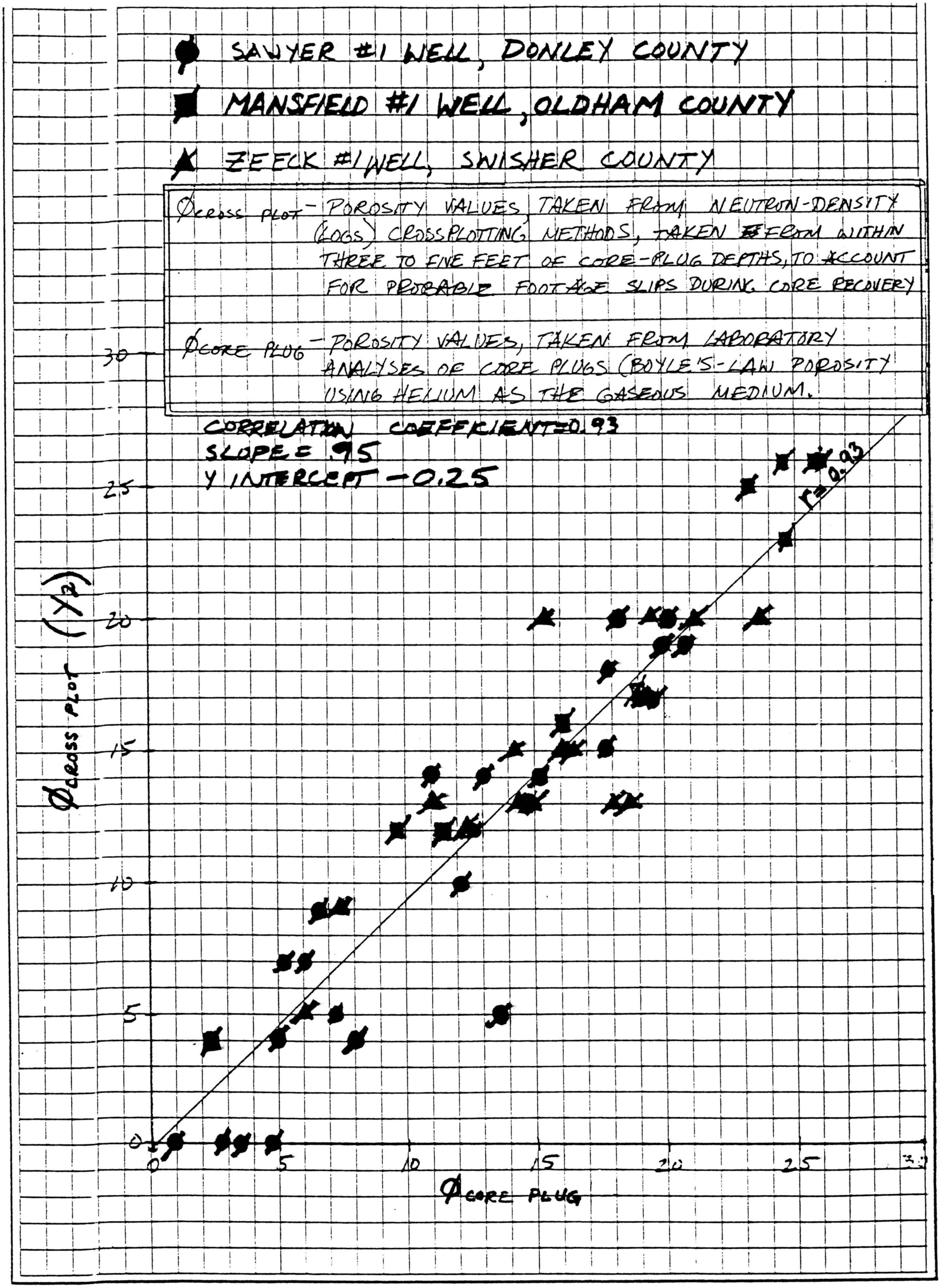


Figure 11. Plot of measured porosities obtained from cores and porosities derived from Neutron-Density cross-plotting technique.

SPECIFIC PERMEABILITY TO WATER

Bureau of Economic Geology
Unidentified Well
Granite Wash Core

Water Identification: 150,000 ppm total dissolved solids brine (80%NaCl/20%$CaCl_2$)

Overburden Pressure: 3000 psi

Sample I.D.	Depth, feet	Porosity, percent	Permeability to Air, millidarcys	Specific Permeability to Water, millidarcys	Permeability Ratio, water/air
10D*	8047-8047.5	15.2	830	26	0.031
				Reverse flow	
				27	0.033

Sample I.D.	Plug Orientation	Porosity percent,	Permeability to Air, millidarcys	Specific Permeability to Water, millidarcys — Overburden Pressure: 4500 psi — Forward Flow — Immediate	After 100 ml.	Reverse Flow — Immediate	After 100 ml.	200 psi — Forward Flow
1A	Horizontal; top of core	17.9	2050	267	189	245	248	420
1B	Horizontal; middle of core	17.1	1040	99	98	99	97	147
1C	90° angle to 1A and 1B	16.1	764	53	51	57	58	54
1V	Vertical; bottom of core	17.5	296	16	16	21	23	21

Table 1. Results of porosity and permeability measurements from a whole core section and core plug samples in the J. Friemel #1 well.

SPECIFIC PERMEABILITY TO WATER

Bureau of Economic Geology
Well: Sawyer

Water Identification: 150,000 ppm total dissolved solids
(80% sodium chloride, 20% calcium chloride)

Sample Identification		Depth, feet	Porosity, percent	Permeability to Air, millidarcys	Specific Permeability to Water, millidarcys	Permeability Ratio, water/air
1	Dolo	2987.1	6.6	0.013		
2	Dolo	3015.2	17.8	11	6.7	0.609
3V	Dolo	3015.4	22.6	0.15	0.066	0.440
4	Dolo	3054.8	5.0	0.029		
5	Dolo	3083.0	13.5	7.8	0.031	0.0040
6	Dolo	3109.7	5.1	<0.01		
7V	Dolo	3110.0	6.1	0.011		
8	Dolo	3147.1	17.8	3.7	0.30	0.081
9	Ls	3173.3	2.7	<0.01		
10V	Ls	3173.5	0.9	<0.01		
11	Dolo	3185.8	20.7	15	1.1	0.073
12V	Dolo	3186.1	19.9	5.3	0.34	0.064
13	Ls	3205.8	7.3	0.024		
14	Ls	3219.4	12.1	2.6	1.5	0.577
15	Sst	3274.3	4.7	0.15		
16	Sst	3276.4	3.4	0.57		
17	Sst	3392.7	19.1	121	30	0.248
18	Sst	3393.7	19.3	1.4	0.013	0.0093
19	Sst	3484.2	18.1	141	26	0.184
20	Sst	3491.3	20.2	10	1.3	0.130
21	Ls	3569.4	7.9	0.81	0.11	0.136
22	Sst	3688.9	12.6	9.5	<0.01*	
23V	Sst	3712.6	15.1	1.3	0.063	0.048
24	Sst	3712.7	13.0	2.3	0.12	0.052
25	Sst	3716.5	10.9	1.9	<0.01*	

Table 2. Results of porosity and permeability measurements of core plug samples in the Sawuer #1 well.

SPECIFIC PERMEABILITY TO WATER

Bureau of Economic Geology
Well: Mansfield

Water Identification: 150,000 ppm total dissolved solids
(80% sodium chloride, 20% calcium chloride)

Sample Identification		Depth, feet	Porosity, percent	Permeability to Air, millidarcys	Specific Permeability to Water, millidarcys	Permeability Ratio, water/air
26V	Dolo	4519.1	14.6	0.80	0.094	0.118
27	Dolo	4625.8	9.6	1.3	0.36	0.277
28V	Dolo	4626.4	11.4	0.97	0.46	0.474
29	Ls	4793.0	2.3	0.019		
30	Ls	4823.4	24.6	3.1	0.86	0.277
31V	Ls	4825.2	25.7	4.3	1.1	0.256
32	Ls	4825.3	27.6	5.7	0.36	0.063
33	Ls	4830.5	24.6	3.9	0.70	0.179
34	Ls	4858.3	23.1	69	20	0.290
35V	Ls	4859.1	19.0	18	6.5	0.361
36	Ls	4883.4	16.0	5.2	2.8	0.538

'V' : Vertical orientation of core plugs

Table 3. Results of porosity and permeability measurements of core plug samples in the Mansfield #1 well.

SPECIFIC PERMEABILITY TO WATER

Bureau of Economic Geology
Well: Zeeck

Water Identification: 150,000 ppm total dissolved solids
(80% sodium chloride, 20% calcium chloride)

Sample Identification		Depth, feet	Porosity, percent	Permeability to Air, millidarcys	Specific Permeability to Water, millidarcys	Permeability Ratio, water/air
37	Dolo	5470.7	6.0	0.068		
38	Dolo	5482.7	12.4	7.1	0.99	0.139
39	Ls	5486.9	11.1	0.80	0.32	0.400
40	Dolo	5491.5	14.3	126	116	0.921
41V	Dolo	5492.1	16.5	213	200	0.939
42	Dolo	5493.7	16.1	223	200	0.897
43	Ls	5507.2	19.5	4.9	2.5	0.510
44V	Ls	5507.6	21.2	9.0	4.0	0.444
45	Dolo	5510.1	15.4	326	188	0.577
46	Dolo	5510.6	23.7	1860	1370	0.737
47	Ls	5527.5	14.5	0.52	0.027	0.052
48V	Ls	5529.2	18.7	0.45	0.061	0.136
49	Ls	5530.5	14.9	4.4	2.3	0.523
50	Ls	5532.3	18.0	7.9	4.5	0.570
51	Ls	5535.2	13.3	1.4	0.68	0.486
52	Ls	5617.5	7.4	0.040		
53	Sst	7318.2	3.7	0.73		
54	Sst	7326.5	1.1	0.059		

'V' : Vertical orientation of core plugs

Table 4. Results of porosity and permeability measurements of core plug samples in the Zeeck #1 well.

Table 5. Air Permeability vs. Porosity

	No. of Core-Plug Samples	Correlation Coefficient	Significance	Linear Regression Analysis Slope	Intercept	Standard Error of Estim.
Combined DOE Wells:						
All	44	0.7104	0.001	0.145	-1.516	0.993
Dolomite	14	0.8656	0.001	0.246	-2.645	0.887
Limestone	17	0.8354	0.001	0.117	-1.706	0.612
Sandstone	13	0.7304	0.002	0.146	-9.666	0.966
Sawyer #1:						
All	20	0.8351	0.001	0.175	-2.034	0.735
Dolomite	7	0.9471	0.001	0.208	-2.824	0.519
Limestone	4	0.8756	0.062*	0.266	-2.817	0.691
Sandstone	9	0.7375	0.012*	0.117	-0.915	0.721
Mansfield #1:						
All	7	0.7905	0.017*	0.091	-1.258	0.721
Limestone	6	0.8192	0.023*	0.102	-1.569	0.749
Zeeck #1:						
All	15	0.7769	0.001	0.183	-1.730	0.937
Dolomite	6	0.9288	0.004	0.258	-2.120	0.659
Limestone	7	0.8926	0.003	0.172	-2.343	0.388

*below 90% confidence

Table 5. Statistical analysis of porosity-permeability trends based on core plug analyses.

J.FRIEMEL HYDROLOGIC WELL TEST DATA

TEST ZONE	DEPTH(FT)	FORMATION	TEST ID #	K (MD)	MULTIPLE TEST STATISTICS		
						ARITHMETIC MEAN	STANDARD DEVIATIO
1	8168 - 8204	GRANITE WASH	RECOVERY 1	43.6			
			RECOVERY 2	39.0			
			RECOVERY 3	42.7	ZONE 1	44.7	4.4
			RECOVERY 4	49.7			
			RECOVERY 5	48.4			
2	8122 - 8132	GRANITE WASH	RECOVERY 1	122.3			
3	8040 - 8050	GRANITE WASH	RECOVERY 1	148.7			
4	7896 - 7904	GRANITE WASH	RECOVERY 1	41.9			
			RECOVERY 1A	37.4	ZONE 4	40.2	2.4
			RECOVERY 2	41.3			
5	7707 - 7711 7729 - 7734	GRANITE WASH	RECOVERY 1	254.3			
6	7300 - 7326	PENNSYLVANIAN L.S.	RECOVERY 1	97.1			
			RECOVERY 6	81.7	ZONE 6	89.1	7.7
			RECOVERY 7	88.4			
7	5825 - 5926	WOLFCAMP L.S.	RECOVERY 1	0.91			
			RECOVERY 2	0.93			
			RECOVERY 3	0.85	ZONE 7	0.89	0.04
			RECOVERY 4	0.85			

J FRIEMEL DRILL STEM TEST PERMEABILITY DATA

TEST NUMBER	DEPTH	FORMATION	CALCULATED PERMEABILITY
6	5630 - 5909	WOLFCAMP L.S.	1.1 MILLIDARCY

Table 6. Permeability results based on hydrologic well testing in the J. Friemel #1 well.