To: Randy Thompson

From: David De Witt

Re: Preliminary Evaluation of Permeability/Porosity data from GMF 87-13

SUMMARY

A cursory evaluation of the results from matrix permeability tests of cores from GMF 87-13 shows several features: 1. there is a positive correlation between the maximum determined permeability and permeabilities measured orthogonally to the maximum permeability. 2. there is a positive correlation between maximum determined permeability and the vertical permeability. 3. there appears to be a poor correlation between permeability and porosity that may exists at very high porosities.

These features suggest that the matrix of most of the reservoir rock is relatively homogeneous, particularly at low porosities. It is suspected that core samples which exhibited a high permeability probably have microfractures or a large number of interconnected vesicles.

From the results of the test, the matrix permeability of the reservoir rock falls in the range of 0.1 to 0.2 md. The pervasive nature of the rock alteration is probably responsible for the rather uniform permeability of the reservoir rock. It may be implied that from this data that fracture permeability is the main mechanism by which the well produces.

DISCUSSION

Twenty-seven samples of core recovered from the GMF 87-13 Deepening were sent to the TerraTek Laboratories, Salt Lake City, Utah for permeability and porosity measurements. The cores were selected to cover a wide spectrum of rock types, alteration and visible porosity. Whole cores were subjected to permeability tests in three different axis, using nitrogen as the pressure medium. Porosities were determined by standard analytical procedures. Water saturations were also determined; however, these numbers are suspect since the cores were very hot and quickly dried when they were removed from the core barrel. Summaries of the properties of the core samples are shown in Table 1. Four samples were selected for 1" plugs to be taken from the core and to be used for additional testing. The permeability results from these cores are found in Table 2.

Figures 1 and 2 are depth-porosity and depth-permeability plots from GMF 87-13. It is obvious from the depth-porosity plot that no distinct correlation can be found between depth and porosity. The wide variation in porosity is due to the large variety of rock types. Permeabilities, on the other hand, are relatively restricted to 0.1 to 0.2 md. Variations from those values are probably the result of microfractures or interconnected vesicles found in the original rock. Figure 3 is the comparison of porosity and permeability for each sample. Again, there is no obvious relationship between these parameters.

A comparison was made between the maximum permeability and at 90° to the maximum (Figure 4) as well as maximum permeability compared to the vertical permeability (Figure 5). There is a strong correlation (note the 1:1 reference line) between all these parameters, suggesting that permeabilities are similar in all directions. Since the porosity is highly variable and the permeability is not, it is suggested that pervasive alteration of the reservoir rock has resulted in a homogeneous permeability.

If the permeabilities of samples thought to have microfractures or other forms of mechanically induced permeability are eliminated from the data set, then a poor correlation between permeability and porosity appears to exist. Figure 6 shows the cross-plot relationship, but note that it has an extremely steep slope with large variations from the projected correlation line. The steep slope and poor correlation makes the use of this data questionable for reservoir calculations.

Using an extremely simple approach, if the matrix permeability is 0.2 md and the thickness of the reservoir is 3500' (the maximum), then the Kh value is only 1750 md-ft. Calculated Kh values from two flow tests indicate Kh values of 17,000 - 21,000 md-ft (which also includes a skin calculation) were appropriate for the well. This large difference can be attributed to wellbore flow from fractures. This is no surprise, since the lost circulation zones and visible fractures in the core are indicative of this type of flow.

Storage of reservoir fluids is an important parameter for simulation studies. Average porosities are nearly 10% (Table 1) which is quite encouraging. The major problem is trying to get the stored fluid through relatively tight rock into the wellbore. Fracturing of the reservoir rock may be feasible and helpful, but the large amount of pervasive clay alteration may limit the effectiveness of this procedure.

TABLE 1. GMF 87-13 WHOLE CORE POROSITY AND PERMEABILITY DATA

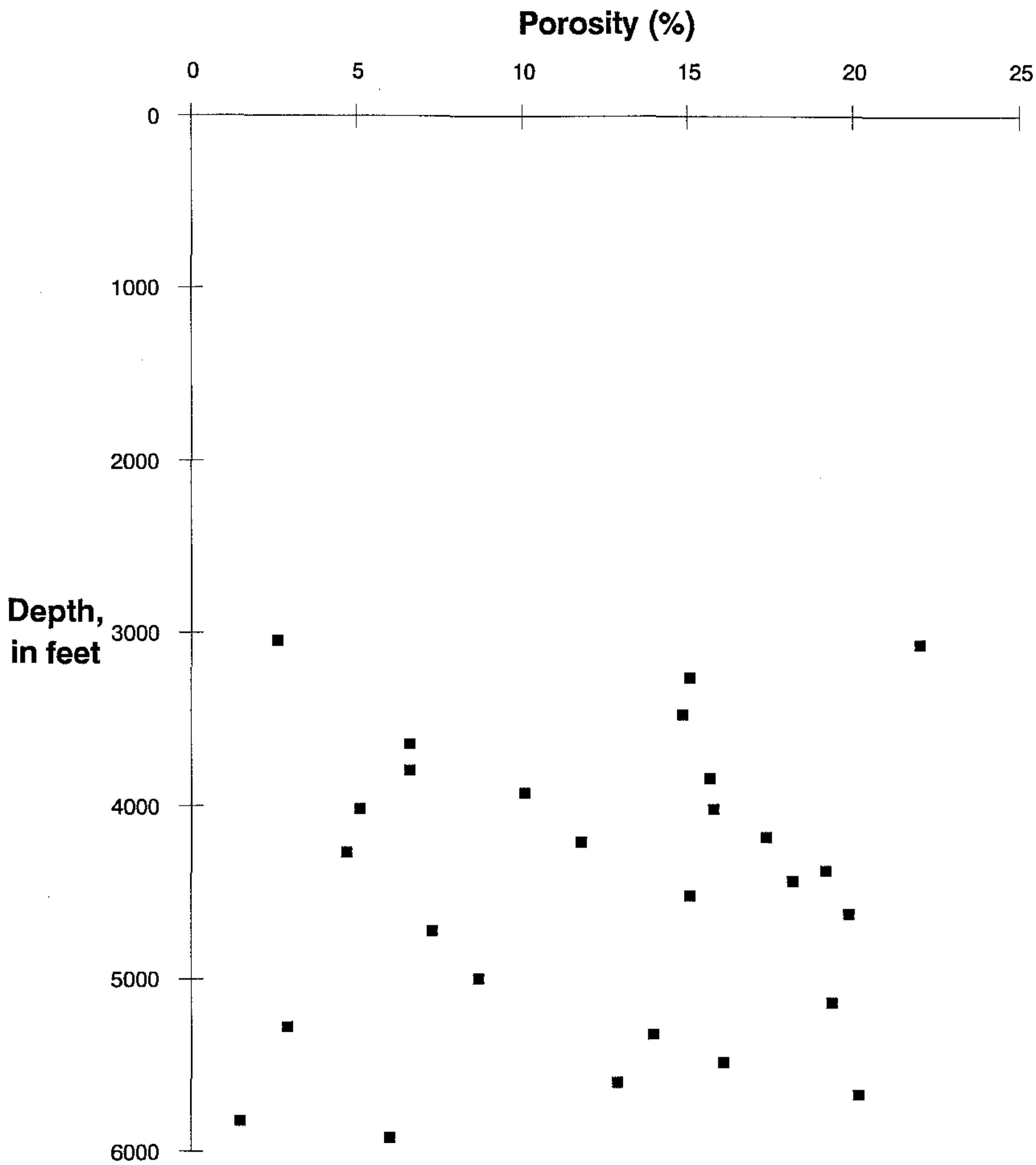
DEPTH (FEET)	KMAX (MD)	K-90 (MD)	VERT (MD)	POROSITY (%)	SATURATION H20 (%)	DENSITY (GM/CC)	RANKING (1-4)*
3047	2.6	0.01	1.3	2.6	67.9	2.84	1
3067	0.13	0.12	0.12	22	7.2	2.79	3
3256	0.06	0.06	0.04	15.1	11.3	2.78	2
3468	0.1	0.07	0.06	14.9	8.5	2.76	2
3643	0.04	0.005	0.01	6.6	34.2	2.87	1
3793	0.02	0.01	0.005	6.6	11.6	2.81	1
3836	0.64	0.35	0.46	15.7	8.4	2.68	3
3923	0.12	0.1	0.08	10.1	8.4	2.66	4
4010	0.12	0.11	0.13	15.8	7.1	2.82	2
4015	0.06	0.01	0.02	5.1	50.8	2.79	2
4175	0.85	0.54	0.2	17.4	8.1	2.78	3
4202	0.1	0.1	0.1	11.8	10.5	2.71	3
4268	0.01	0.01	0.005	4.7	13.9	2.83	1
4367	0.22	0.07	0.4	19.2	12.3	2.85	2
4427	0.89	0.89	0.71	18.2	6.5	2.84	3
4509	0.04	0.03	0.03	15.1	18.1	2.82	3
4615	1.8	1.7	1.5	19.9	4.7	2.74	3
4719	0.01	0.005	0.005	7.3	11.1	2.85	1
4993	0.01	0.005	0.01	8.7	10.8	2.8	2
5130	0.42	0.41	0.32	19.4	7.1	2.93	3
5281	0.06	0.02	0.005	2.9	79.2	2.91	1
5319	3.1	1.1	1.3	14	5	2.66	3
5478	1.7	0.48	0.44	16.1	9.9	2.94	4
5596	0.11	0.05	0.02	12.9	12.2	2.85	2
5663	0.19	0.19	0.14	20.2	7	2.88	2
5825	0.03	0.01	0.03	1.5	62.6	2.86	1
5920	0.005	0.005	0.005	6	11.8	2.8	2
AVERAGES	0.50	0.24	0.28	12.21	18.75	2.81	
WTD. AVG.	**0.38**	**0.13**	**0.21**	**10.29**	**23.60**	**2.82**	

TABLE 2. GMF 87-13 PLUG POROSITY AND PERMEABILITY DATA

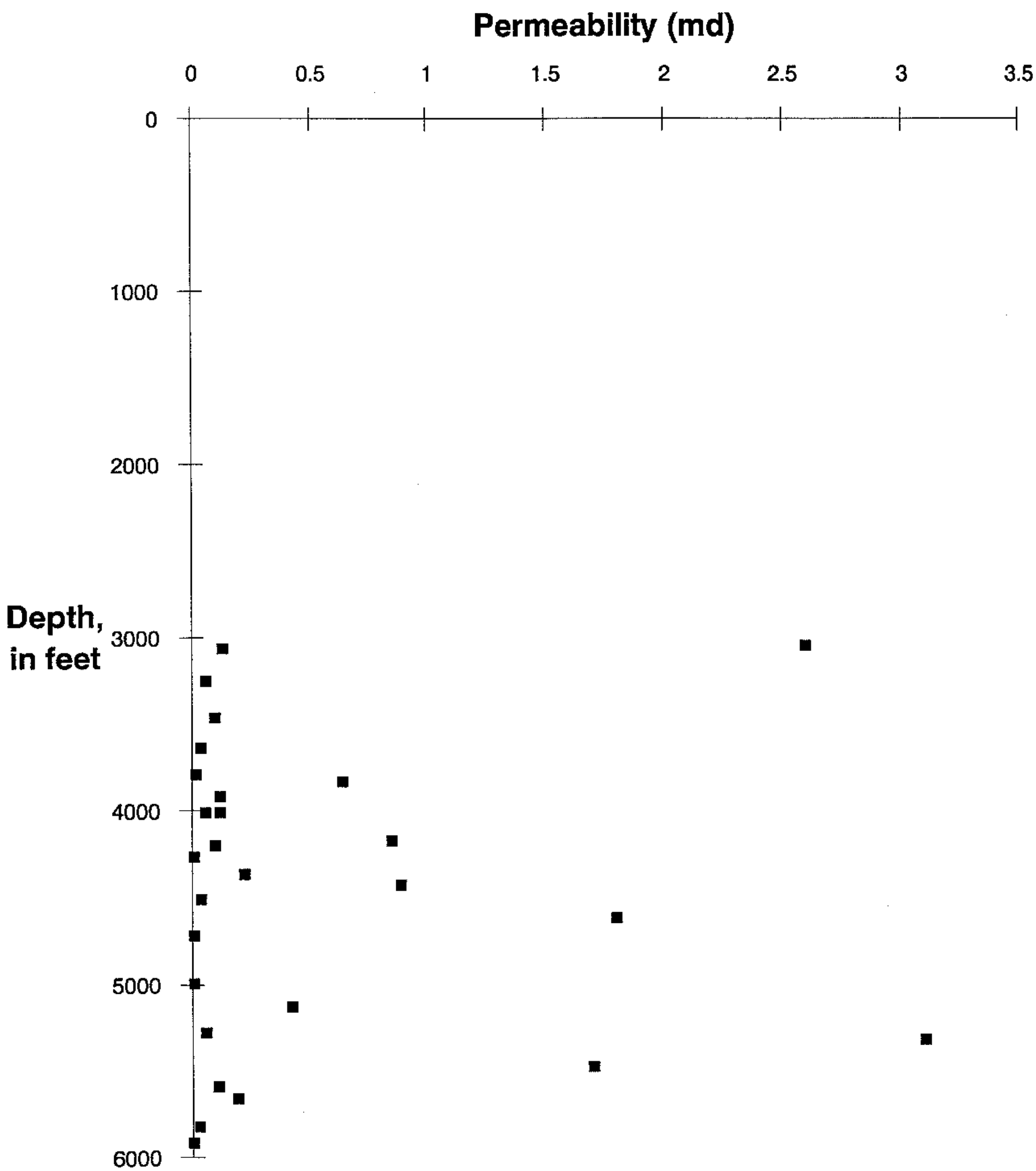
DEPTH (FEET)	K-HORZ (MD)	K-90 (MD)	VERT (MD)	POROSITY (%)	SATURATION H20 (%)	DENSITY (GM/CC)	RANKING (1-4)*
3256	0.11	-	-	15.9	25.3	2.77	2
3923	0.21	-	-	13.7	48.8	2.71	4
4367	0.1	-	-	20.5	23.2	2.9	2
4719	0.04	-	-	5.3	21.4	2.82	1
AVERAGES	0.12			13.85	29.68	2.80	
WTD. AVG.	**0.09**			**12.24**	**24.60**	**2.81**	

*By visual estimates, the core was divided into a 1 to 4 ranking, with 1 being the estimated lowest porosity, and 4 the estimated highest porosity. The core was estimated to be comprised of 40% with a 1 ranking, 40% at 2, 15% at 3, and 5% of the core with a 4 ranking.

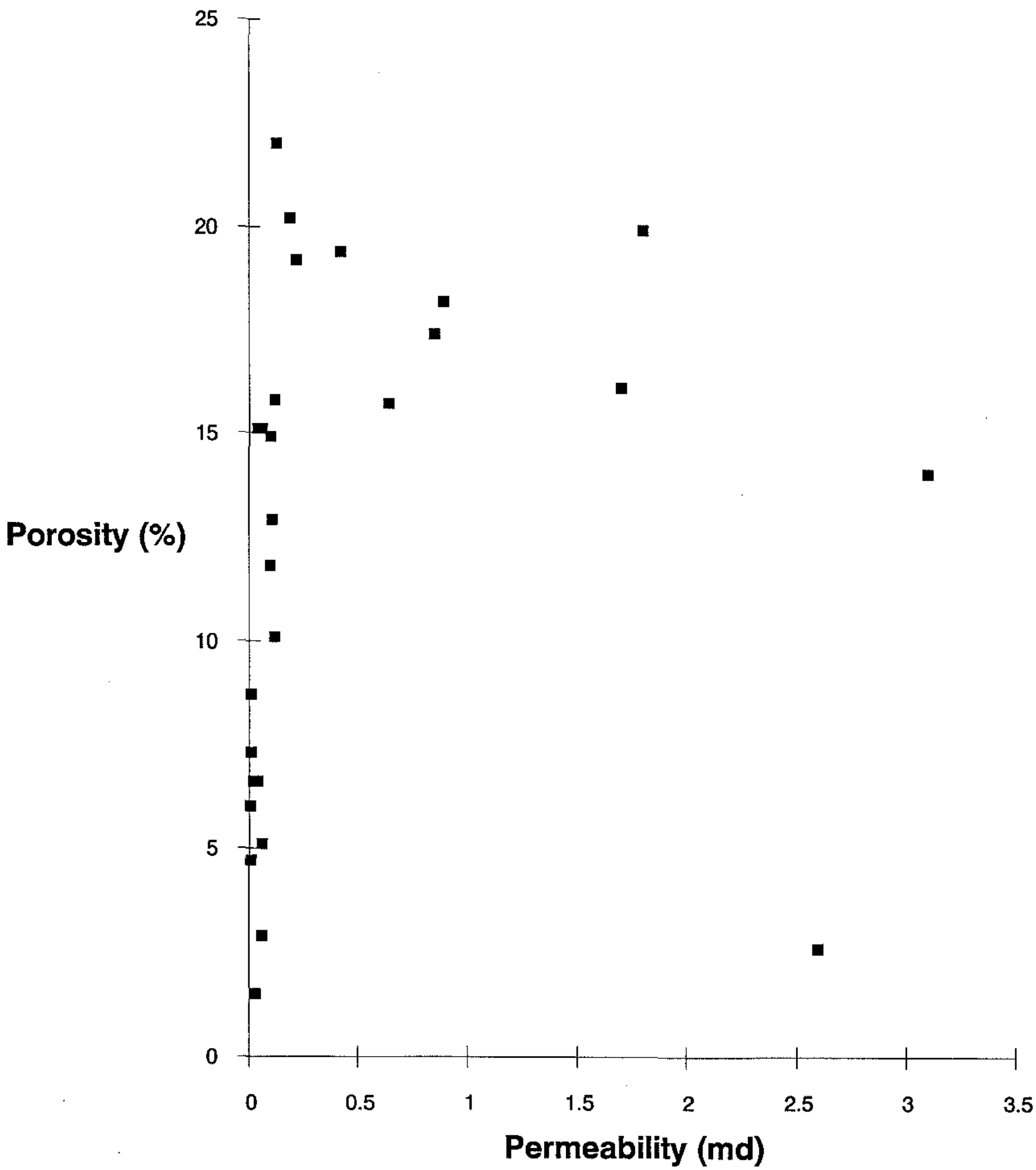
GMF 87-13


Porosity (%)
0
5
10
15
20
25
0
1000
2000
3000
4000
5000
6000
Depth, in feet

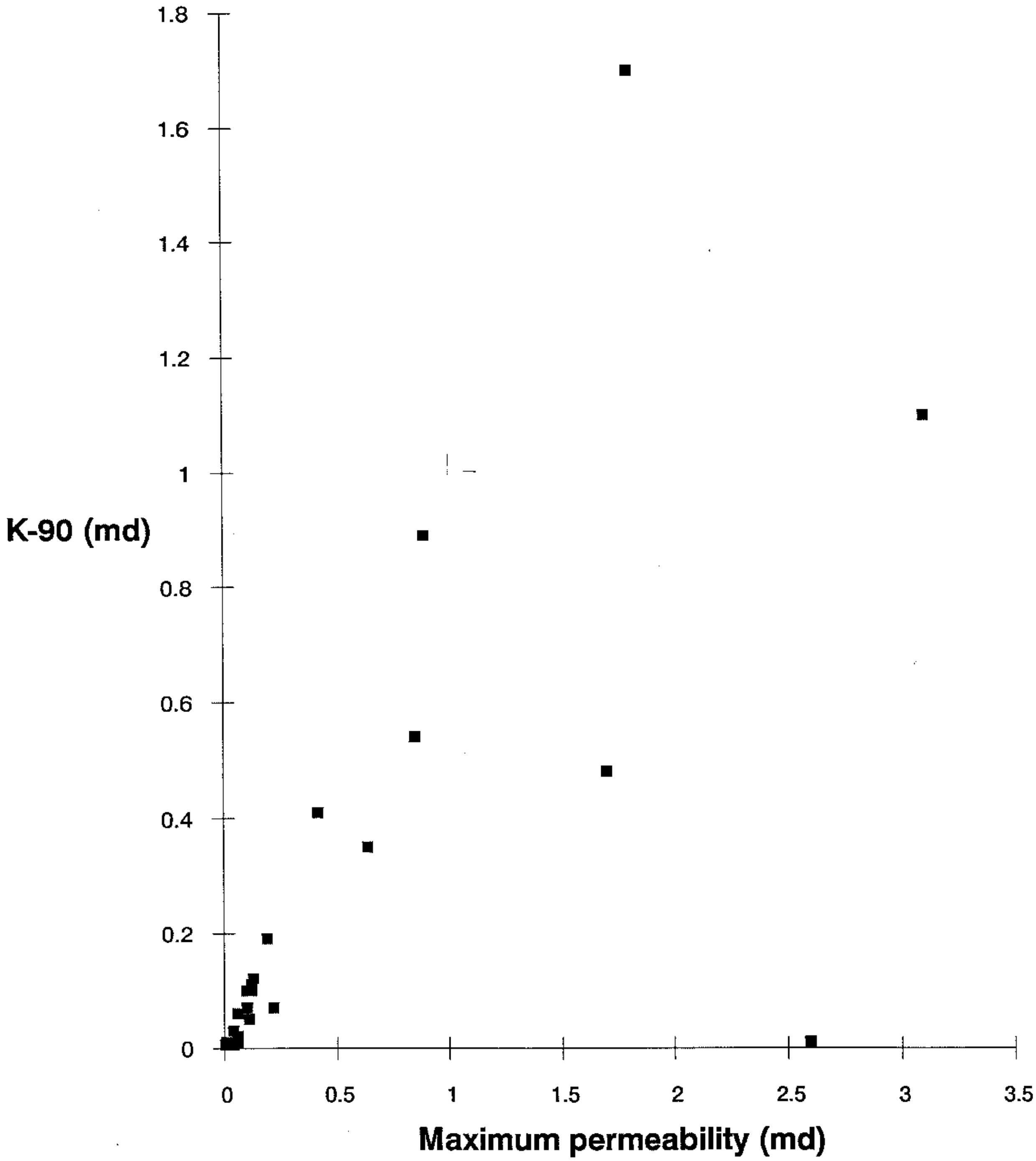
GMF 87-13


Permeability (md)
0
0.5
1
1.5
2
2.5
3
3.5
Depth, in feet
0
1000
2000
3000
4000
5000
6000

GMF 87-13

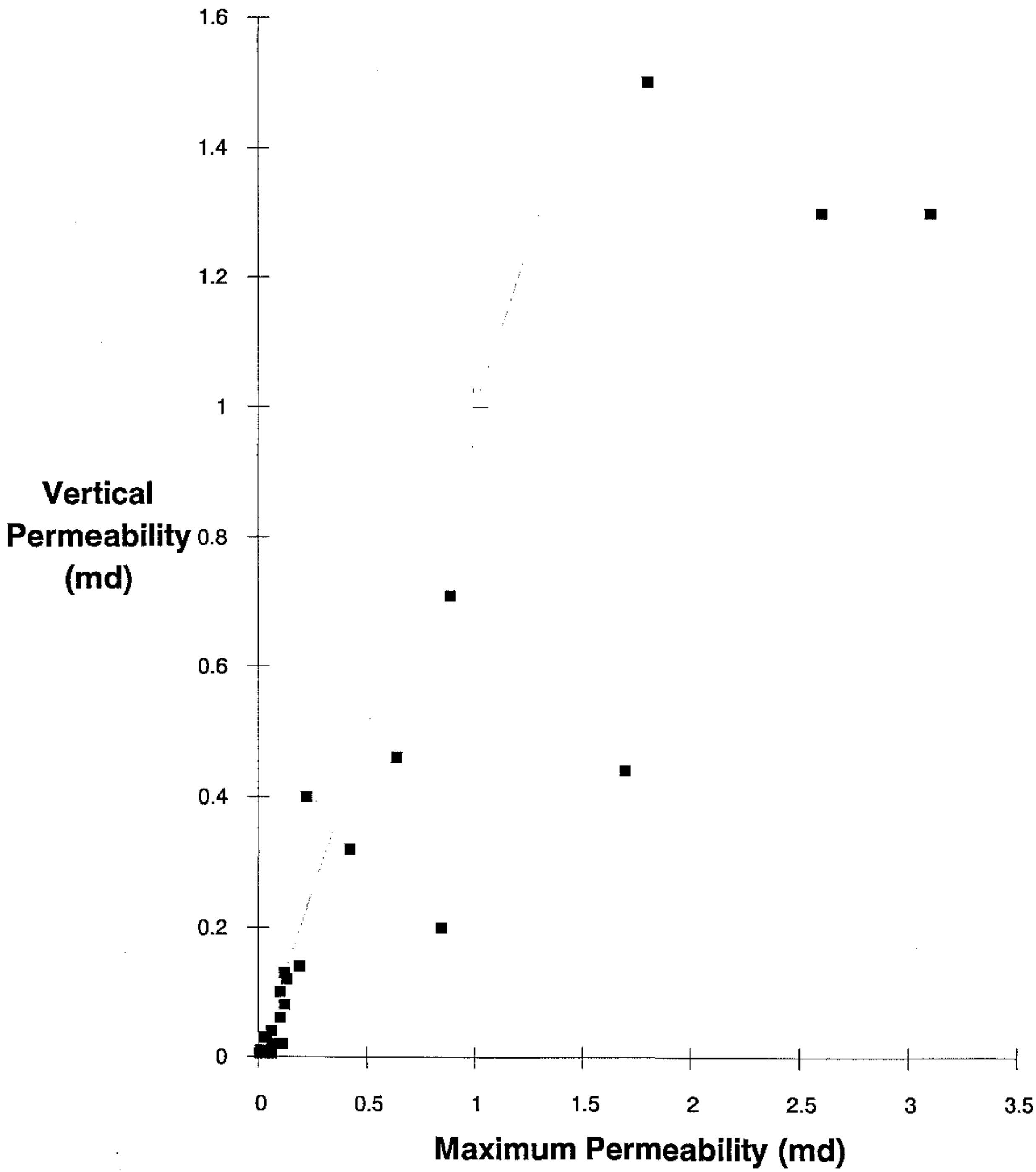


GMF 87-13

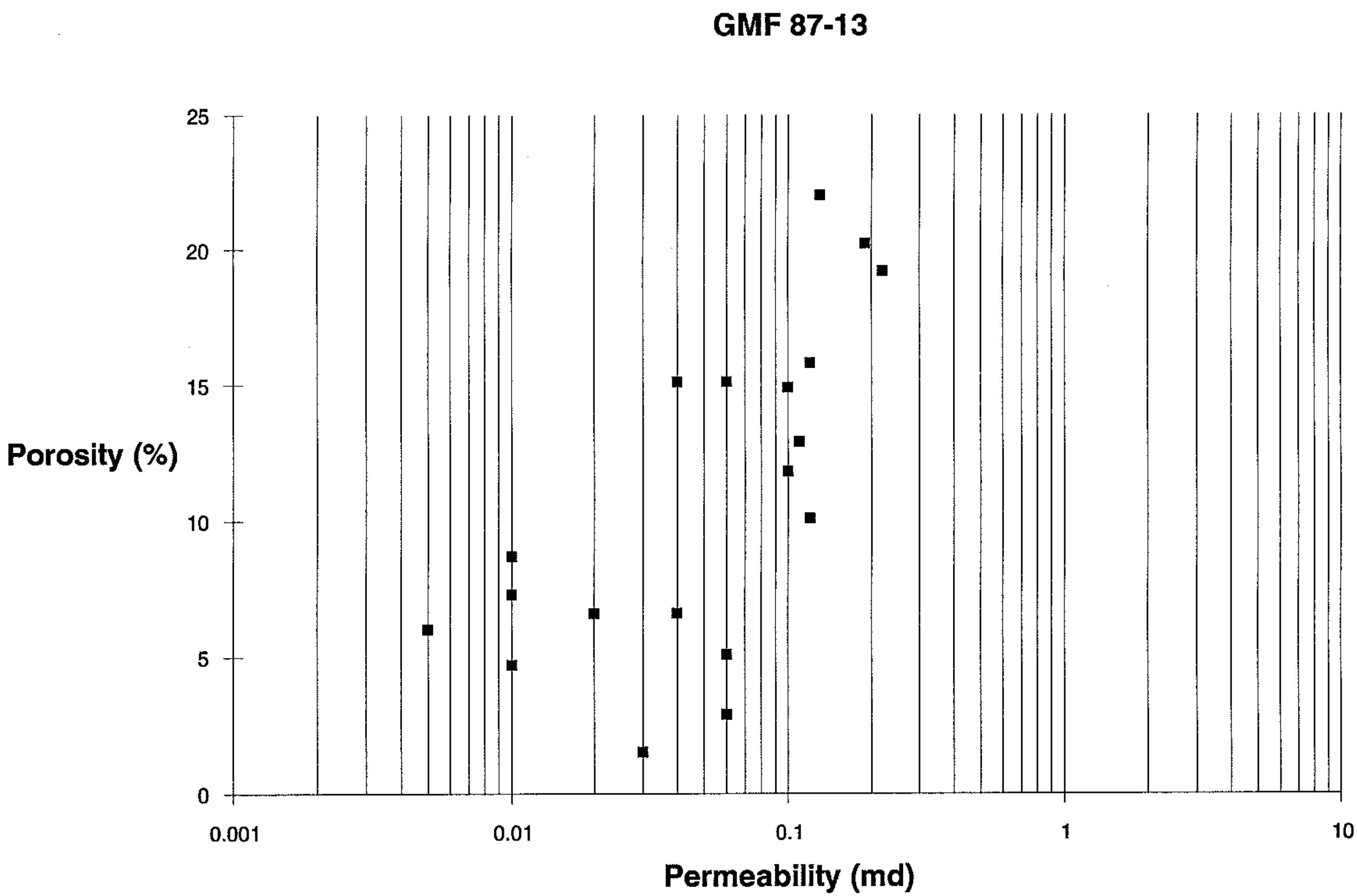


K-90 (md)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
2.5
3
3.5
Maximum permeability (md)

GMF 87-13



Vertical Permeability (md)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
Maximum Permeability (md)



GMF 87-13
Porosity (%)
25
20
15
10
5
0
0.001
0.01
0.1
1
10
Permeability (md)

maybe leave off the lines - very confusing to look at

GMF 87-13

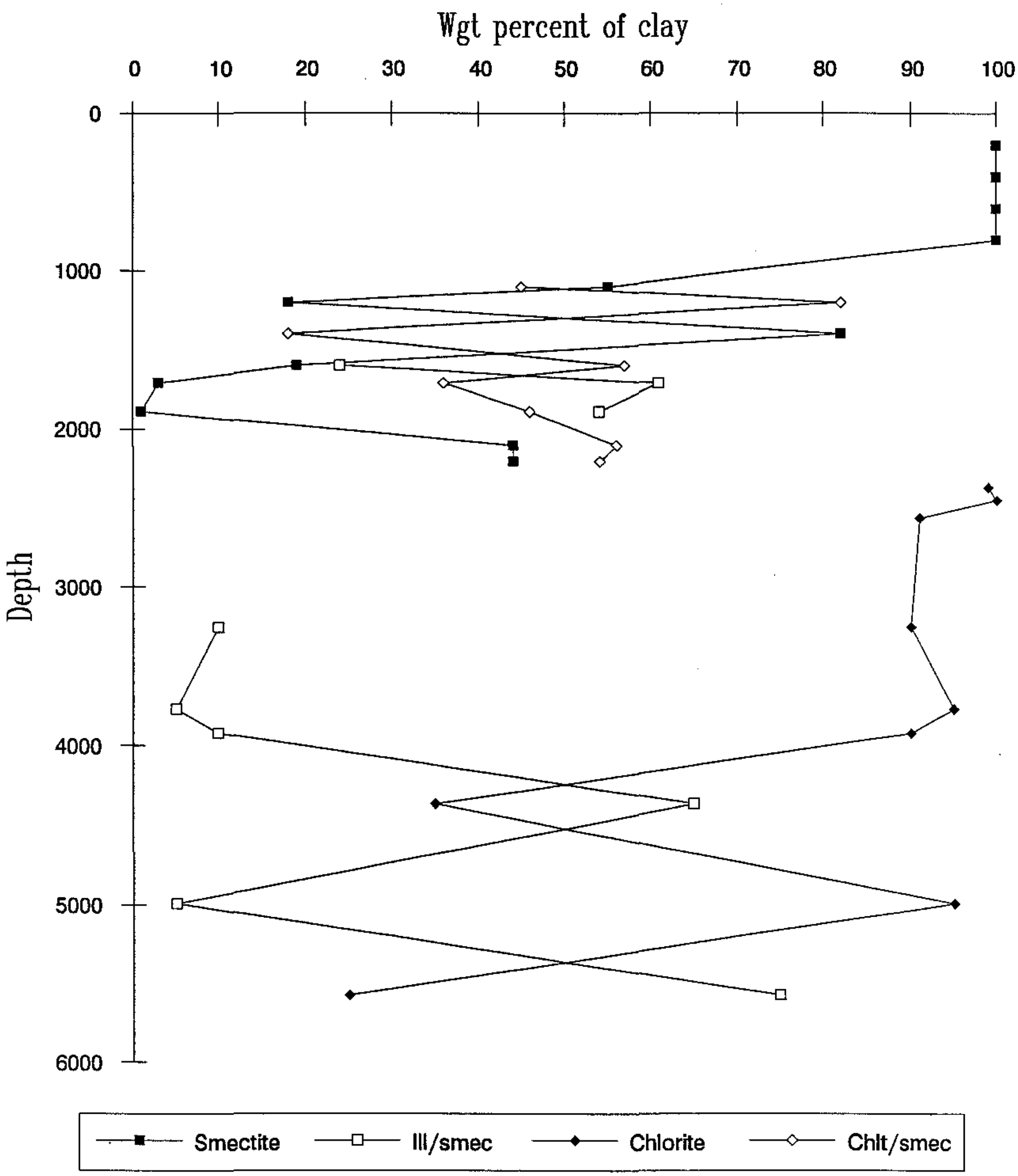


FIG 2

GMF 87-13 Fluid Mineral Equilibria