COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

RECORD No. 1966/43

BARROW ISLAND NO. 1, LIQUID PERMEABILITY AND WETTABILITY TESTS ON SAMPLES OF CORES FROM THE JURASSIC RESERVOIR SANDSTONE

by

B.A. McKAY

15928/65

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

PETROLEUM TECHNOLOGY LABORATORY

1966/43

BARROW ISLAND NO. 1

LIQUID PERMEABILITY AND WETTABILITY TESTS ON SAMPLES OF CORES FROM THE JURASSIC RESERVOIR SANDSTONE

by

B. A. McKay

BARROW ISLAND NO. 1

LIQUID PERMEABILITY AND WETTABILITY TESTS ON SAMPLES OF CORES FROM THE JURASSIC RESERVOIR SANDSTONES

This report presents the results of liquid permeability and wettability determinations performed on some core samples from the Barrow Island No. 1 well in the Carnarvon Basin, Western Australia. The work was carried out in the Petroleum Technology Laboratory of the Bureau.

Procedure and Apparatus:

Eleven samples, 1¼ inches in diameter were drilled-out horizontally from several permeable sections of cores taken from the Jurassic oil sandstone in this (Barrow Island No. 1) well. After extraction and drying of the plugs, porosity and permeability determinations were made on them. Equivalent liquid permeability (Klinkenberg*) was then measured on the plugs in a flexible rubber-sleeved Hassler cell.

Separate permeability tests using de-areated kerosene, 10% NaCl brine and fresh water respectively were then carried out on the plugs. Each of the flow tests was preceded by a thorough extraction and drying of the samples; additionally, dry weight and dry air permeability of each plug was checked between tests. Although minor grain losses were detected, no significant change in dry air permeability was found to have occurred between tests.

Finally, because of the nature of the permeability results obtained, imbibition tests were conducted on four of the samples, in order

---

* The equivalent liquid permeability is found by the following procedure -

The permeability of a sample is measured at several different mean pressures (upstream plus downstream pressure divided by two) using a gas (generally air) as the flowing medium. Each value of permeability is then plotted as a function of the reciprocal of the mean pressure, whereupon the straight line drawn through the plotted points is extrapolated to infinite pressure (or zero reciprocal mean pressure). The intersection of this line with the "zero" ordinate of reciprocal mean pressure gives the value of liquid permeability to a non-reactive liquid in that sample.

.../2

to determine their preferential fluid wettability. This was accomplished by immersing samples saturated with fresh water-in oil, and the adjacent samples, saturated with oil - in fresh water. The relative wettability was determined by noting the type and volume of liquid displaced from the core sample by the immersion fluid.

Discussion of Results.

The results of tests are shown in Tables I and II, and in Figures 1, 2, 3 and 4. Table I summarizes the sample permeability values obtained with respect to various fluids used. Each of these values has also been expressed as a percentage of the corresponding equivalent liquid permeability (Table I and Figures 1, 2, and 3). Table II represents results of the imbibition tests conducted on four of the samples over a period of six days. The position of samples is shown in Figure 4.

Permeabilities determined on each of the samples with respect to kerosene, 10% brine and fresh water were all characterized by values considerably lower than those of the corresponding equivalent liquid permeabilities. This was particularly noticeable in flow tests with fresh water; the average permeability to this phase was found to be only 59% of the equivalent liquid permeability. Additionally, difficulty in obtaining stabilized flow rates during tests with this fluid was experienced. Since permeability value in respect of the 10% NaCl brine averaged a higher 77% of the equivalent liquid permeability, the presence and movement of some swelling clays and other mineral fines which could cause damage to the formation upon flushing with fresh water is strongly indicated in the samples.

Unexpectedly, permeability to 10% brine in each of the samples equalled or exceeded the permeability to kerosene. Rapidly stabilized flow rates in separate tests with these two fluids precluded likelihood of this permeability difference being caused by the movement of mineral fines. Imbibition tests were, therefore, conducted on four of the samples to determine the nature of the wettability present and to consider its possible effect on the flow capacity.

As suspected, all the samples tested showed strong affinity for water. After only 24 hours, water was imbibed into the oil-saturated samples to the extent of 30% to 40% of the pore volume. The volume of oil ultimately displaced by water after 6 days had essentially stabilized at a maximum of 36% to 47% of pore volume. The tests of adjacent water-saturated samples for imbibition of oil was, naturally, negative.

The information gained in these tests indicates that this reservoir would produce efficiently under water (brine) drive, and that ultimate oil recovery by such a mechanism would be fairly high. However, in view of the results obtained, in the presence of a strong water drive, some permanent damage would result should production be carried above the maximum efficient rate. Under these conditions, the relative permeability to water would increase rapidly throughout an artificially extended transition zone near the well bore, leading to "coning", early high water cuts and by-passing of considerable oil in the less permeable sections of the reservoir.

Conclusions.

The following conclusions can be drawn from the results of these tests.

1. Permeability to 10% brine in the samples gave the best approximation of the equivalent liquid permeability determined with respect to nitrogen.
2. The greatest reduction in flow capacity occurred with respect to fresh water indicating the presence of some swelling clays and possible particle dislodgement within the samples.
3. Sample permeability with respect to 10% brine equalled or exceeded that to kerosene in all cases.
4. The samples showed a strong preferential wettability to water, with 30% to 40% of the oil-saturated pore volume displaced within first 24 hours.
5. Permeability to oil and brine were generally in closest agreement in those samples with the lowest equivalent liquid permeability.

.../4

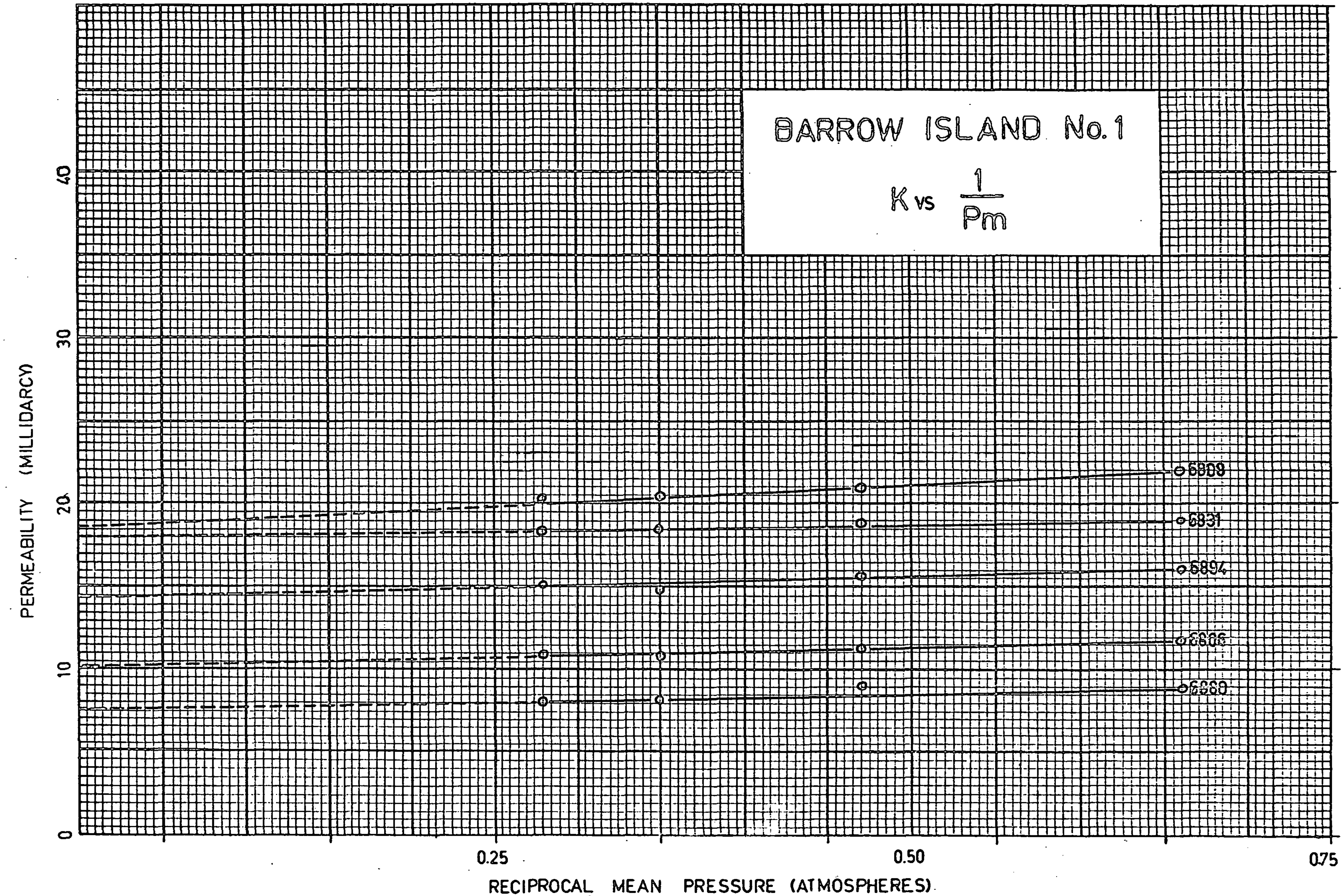
TABLE I

Well Name and Number	Sample Depth (feet)	Porosity (% BV)	Dry-air Permeability (MD)	Equivalent Liquid Permeability (MD)	Permeability to Kerosene (MD)	Permeability to 10% NaCl Brine (MD)	Permeability to fresh water (MD)	Permeability to kerosene (% Equivalent Liquid Permeability)	Permeability to 10% NaCl (% Equivalent Liquid Permeability)	Permeability to fresh water (% Equivalent Liquid Permeability
Barrow Island No. 1	6764	28	176	163	94	134	101	58	82	62
"	6768	26	48	44	31	34	33	70	77	75
"	6806	23	13	10	8	8	7	80	80	70
"	6808	22	23	19	15	16	9	79	84	47
"	6831	24	20	18	13	14	9	72	78	50
"	6837	25	115	102	70	82	61	69	80	60
"	6845	26	63	58	40	45	33	69	78	57
"	6866	26	98	87	57	66	50	66	76	58
"	6880	23	10	8	5	6	4	63	75	50
"	6886	27	65	60	39	40	41	65	67	68
"	6894	28	17	14	10	10	8	71	71	57
							AVERAGES.............	68	77	59

TABLE II

Well Name and Number	Core Number	Sample Depth (feet)	Dry Air Permeability (MD)	Porosity (% BV)	Saturating Medium	Vol. Water Imbibed (% Pore Volume)			
						1 Day	2 days	3 days	6 days
Barrow Island No. 1	23	6758	31	29	Kerosene	31.0	37.5	38.8	39.0
"	27	6808	23	22	"	33.6	38.0	39.5	39.5
"	29	6845	63	26	"	43.5	44.8	47.3	47.3
"	30	6866	98	26	"	28.8	33.8	36.3	36.3

FIGURE 1



BARROW ISLAND No. 1
K vs 1/Pm
PERMEABILITY (MILLIDARCY)
0
10
20
30
40
0.25
0.50
0.75
RECIPROCAL MEAN PRESSURE (ATMOSPHERES)
6808
6831
6894
6606
6660

FIGURE 2

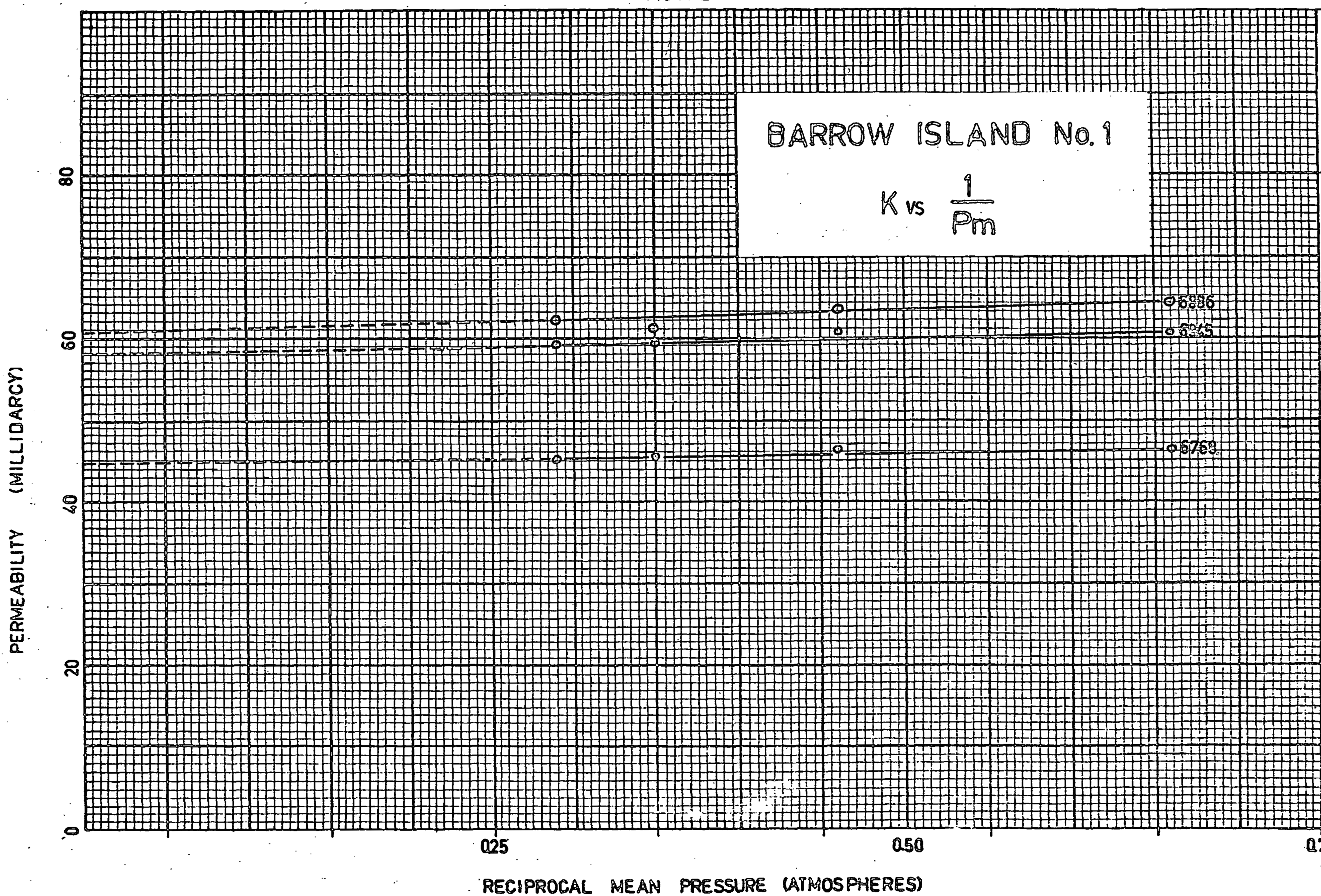
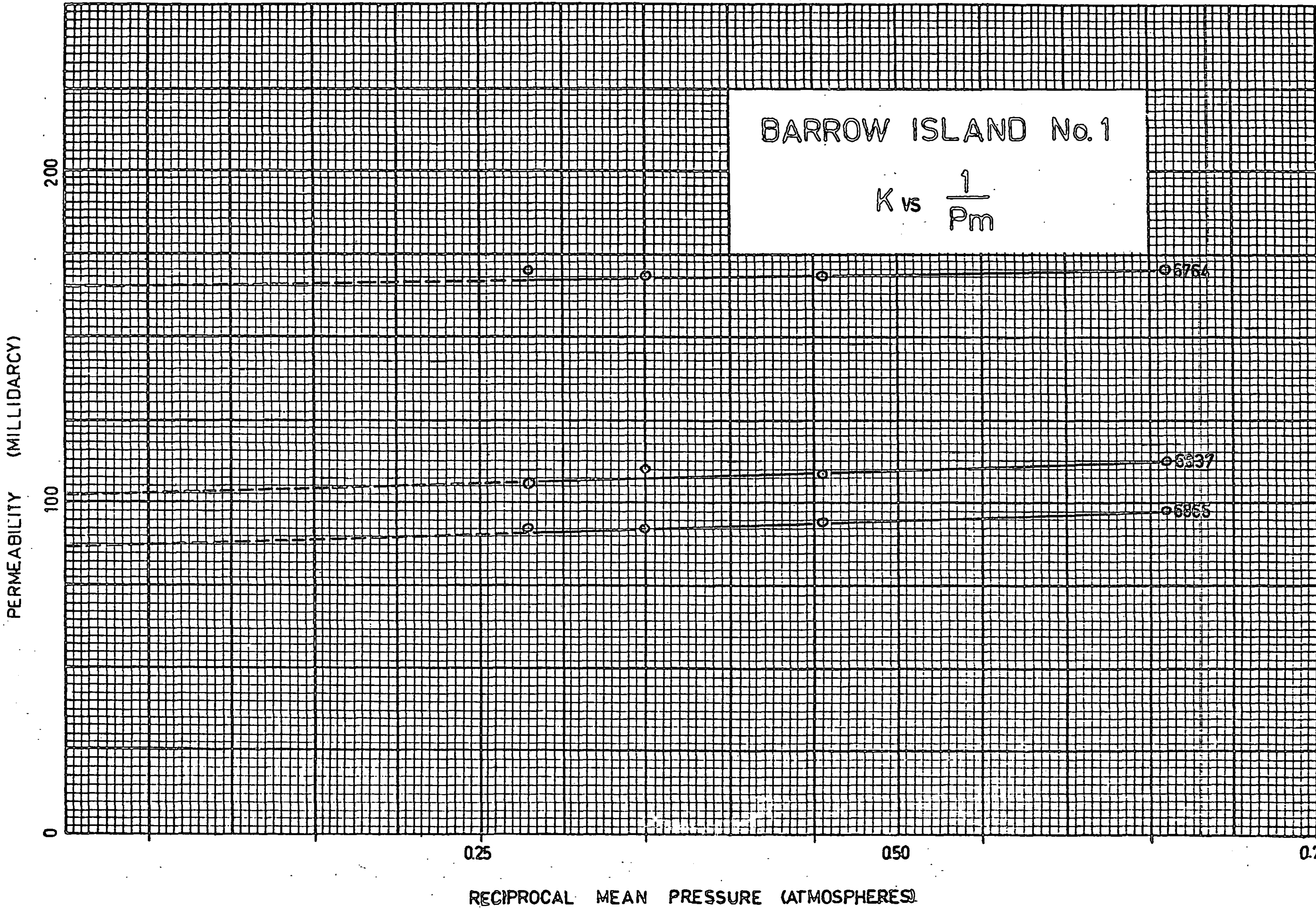

BARROW ISLAND No. 1
K vs 1/Pm
6886
6768
0
20
40
60
80
PERMEABILITY (MILLIDARCY)
0.25
0.50
0.75
RECIPROCAL MEAN PRESSURE (ATMOSPHERES)

FIGURE 3



BARROW ISLAND No. 1
K vs 1/Pm
6764
6837
6855
200
100
0
0.25
0.50
0.75
PERMEABILITY (MILLIDARCY)
RECIPROCAL MEAN PRESSURE (ATMOSPHERES)

FIGURE 4

INDUCTION ELECTRICAL LOG

BARROW No 1