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FLUID PERMEABILITY STUDIES
OF SOME AUSTRALIAN RESERVOIR SANDS

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Introduction

The information contained in this Record was presented at the 1965 Annual Conference of the A.P.E.A. in Adelaide, S.A.

It has been recognised for some time that certain clays and mineral fines have a detrimental effect on the flow capacity of reservoir sands.

Research into this factor as it affects Australian reservoir sands was deemed a fitting project to be undertaken in the Petroleum Technology Section Laboratory of the Bureau of Mineral Resources, Geology and Geophysics.

The information here presented is the result of preliminary investigation only, and further research is desirable.

FLUID PREMEABILITY STUDIES OF SOME AUSTRALIAN RESERVOIR SANDS

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Introduction

Laboratory investigations and well drilling and completion experience have shown that certain clays and mineral fines have a detrimental effect on the flow capacity of reservoir sands when exposed to fresh water. Through the inter-action of water and some of the clays, especially the montmorillonites, swelling and consequent particle disruption and dispersion result and cause the clogging of pore channels.

During drilling, especially in deeper wells, formations which have been exposed to drilling mud flushing for some time may become saturated with mud filtrate. Zones containing oil or gas may eventually have their productive capabilities seriously impaired, and when the clay content of these intervals is high and filtrate invasion is severe, they may never be able to attain the initial productivity determined during early drillstem testing.

This paper contains the results and discussion of a preliminary laboratory investigation of the effect of fresh water on some of the Australian reservoir sandstones with clay content. The study involved the measurement of permeability damage induced by the flow of fresh water through kerosene (oil) saturated sandstone core samples and of the subsequent permeability improvement through the flushing with kerosene (oil) at a simulated high drawdown pressure.

This orientation study is preliminary to a more extensive work that may be carried out in future in respect of selected petroleum reservoirs in Australia.

Procedure and Apparatus

Ten sets of adjacent $1\frac{1}{8}$" diameter "horizontal" plugs were drilled out of cores from reservoir sandstones in seven Australian sedimentary basins. These twenty plugs were extracted and dried whereupon air and absolute or equivalent liquid permeabilities* (Klinkenberg) were determined on them.

(* See Page 5)

Each set of plugs was then saturated with saline water of 100,000 p.p.m. NaCl and distilled water respectively. Plugs saturated with saline water were marked as "Group A" and the adjacent plugs saturated with distilled water were marked as "Group B".

Using the apparatus shown in Figure 1, a fluid flow of each of the above water phases was induced through the plugs and permeabilities at a steady flow were determined.

The plugs were then thoroughly flushed with viscuous mineral oil until a single-phase flow of oil was obtained; the residual water saturations under these conditions were assumed to be equal to the formation or connate water saturations.

Each plug was then flooded with kerosene, then with distilled water and again with kerosene, simulating formation damage by fresh water and subsequent attempts at its repair by kerosene sweep at high displacement pressures. The effects of these simulation procedures were gauged by measuring permeability to each of these phases when the effluent from the sample was the respective invading fluid only.

Results and Discussion

The results of tests described above are shown in Table 1 and the corresponding Figure 2. Permeability values obtained with respect to various fluids are expressed as a percentage of the absolute or equivalent liquid permeability values determined prior to water saturation.

The following observations can be made on the basis of results obtained:

1. Permeability to saline water is generally greater than that to fresh water in adjacent samples. The majority of samples of "Group B" exhibited minor to severe reduction of permeability to fresh water. This reduction is explained by the swelling of clay matrix material and the dispersion of clay particles as evidenced by the difficulty experienced in obtaining stabilized fluid flow rates and by the slightly cloudy appearance of effluents. On the other hand, in the flow tests on samples of "Group A" stabilized flow rates were quickly attained and no dispersion of clay particles was evident.

2. Permeability to kerosene at connate water saturation generally showed only a slight increase in samples of "Group A" and a marked increase in the majority of the adjacent samples of "Group B". This is explained by the substantial reduction of clay swelling and the resultant decrease of pore blockage in the samples affected by fresh water; a good portion of bonded water was removed through the dynamic displacement, resulting in the reduction of layer spacing.

3. Both groups of samples showed a marked reduction of permeability (to near equity) when, after kerosene saturation, they were subjected to formation damage by the injection of fresh water. It may be explained that during these tests a displacement of a considerable portion of kerosene and, possibly, some connate water by the invading fresh water took place, enabling the "planar water" to enter between the clay platelets and to produce clay swelling. Permeability reduction was most pronounced in the samples which contained saline formation water and were not exposed to any previous contact with fresh water.

4. Permeability repair attempts by kerosene flushing of the "formation damaged" samples only partially improved their flow capacity. It would appear, that although the clay swelling has been substantially reduced by the dynamic displacement action of kerosene, there remained a certain amount of pore blockage brought about by clay particle dislodgement during the fresh water injection. Additional permeability reduction would have been caused by the capillary-size droplets of water (discontinuous water phase) which could not be removed from the pore channels during the kerosene sweep. This condition is most likely to occur when there is insufficient drawdown pressure available in the fine-grained reservoirs. Under these conditions, water saturation after the kerosene

(or oil) sweep (to repair permeability damage) is likely to exceed the connate water saturation existing before the damage.

5. The absolute liquid permeabilities determined with saline water of 100,000 p.p.m. NaCl on samples of "Group A" were generally lower than the equivalent liquid permeabilities determined with gas. Theoretically, the values in both cases should be the same, since a 10% NaCl solution is generally considered to be a "non-reactive" liquid, suitable for the suppression of clay swelling. Therefore, this apparent anomaly may be explained by factors such as different rock wettability, loose grain fines, capillary effects etc., not forgetting the possibility that the 10% NaCl solution may not be a completely inert liquid as far as these samples are concerned.

Conclusions

This study has shown that, generally, the sandstone reservoir samples which were tested have suffered a permanent permeability damage ranging in intensity from minor to severe, when subjected to the flow of fresh water.

Admittedly, the amount of data on which this orientation study was based was extremely small and samples were widely scattered. The results obtained during the study cannot, therefore, be considered as applicable to every sandstone reservoir. However, they demonstrate the real danger of a permanent permeability damage by fresh water of Australian sandstone reservoirs in general, and those with a significant clay content in particular.

In order to avoid this permanent permeability damage it is obviously necessary to exclude or to minimize the entry of fresh water into the sandstone reservoirs with any clay content whatever during drilling, completion and workover operations. It is considered that the discussion of this subject would be outside the limited scope of the present communication.

* 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 the point where this reciprocal equals zero.

The point of intersection of this line with the "zero" line of the reciprocal of mean pressure gives the value of liquid permeability to a non-reactive fluid in that sample.

TABLE I

SAMPLE NUMBER	ABSOLUTE OR EQUIVALENT LIQUID PERMEABILITY (MILLIDARCY)	MEASURED LIQUID PERMEABILITY		KEROSENE PERMEABILITY AT CONNATE WATER SATURATION		PERMEABILITY TO DISTILLED WATER AFTER FRESH WATER FLOOD		KEROSENE PERMEABILITY AT TERMINAL WATER SATURATION	
		PERCENTAGE OF EQUIVALENT LIQUID PERMEABILITY							
		GROUP A (10% BRINE)	GROUP B (FRESH WATER)	GROUP A	GROUP B	GROUP A	GROUP B	GROUP A	GROUP B
1A	630	100		95		12		57	
1B	720		18		59		8		40
2A	620	90		91		8		34	
2B	870		21		23		4		32
3A	58	52		59		5		22	
3B	80		11		27		2		21
4A	196	87		100		22		70	
4B	252		22		48		22		43
5A	228	19		33		14		21	
5B	135		0·9		7		1		3
6A	52	11		9		0·4		6	
6B	29		6		18		3		17
7A	58	4		4		0·0		0·0	
7B	58		0·0		0·0		0·0		0·0
8A	240	51		50		42		53	
8B	300		51		53		48		53
9A	46	37		37		35		35	
9B	50		58		56		36		50
10A	47	55		55		30		60	
10B	42		52		62		24		57

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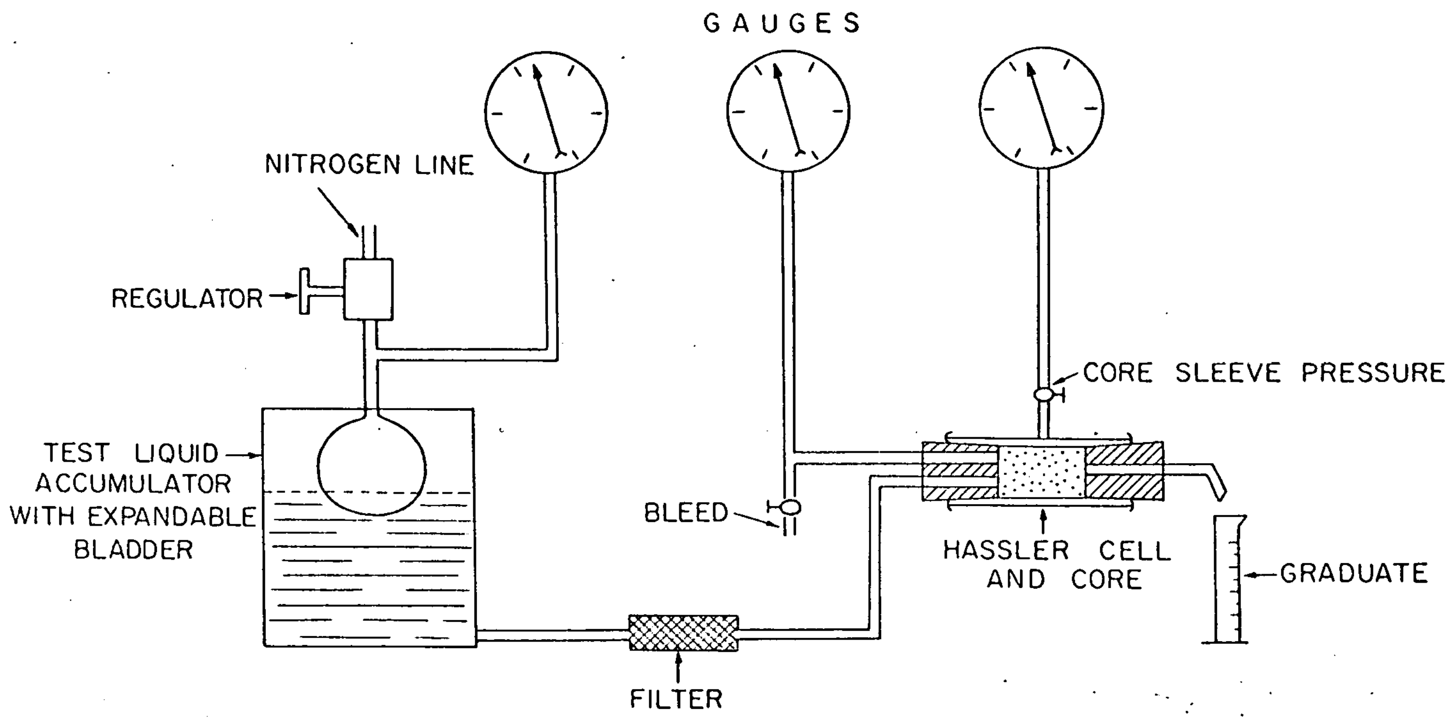
FIG. 1

FLUID PERMEABILITY APPARATUS



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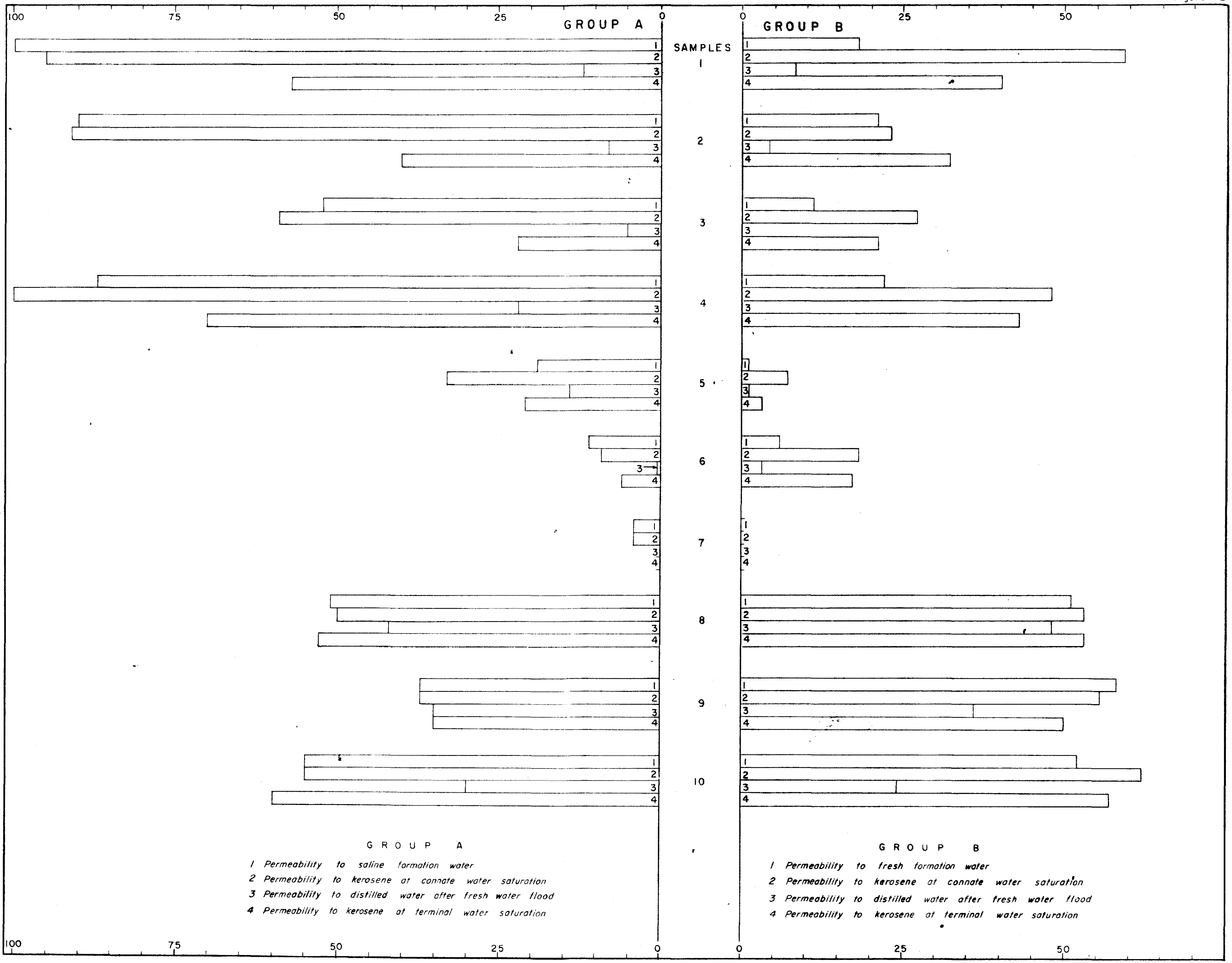
FLUID PERMEABILITY EXPRESSED AS A FUNCTION OF EQUIVALENT LIQUID PERMEABILITY
(TWENTY SAMPLES OF RESERVOIR SANDS FROM SEVEN AUSTRALIAN SEDIMENTARY BASINS)

Figure 2



FLUID PERMEABILITY (PERCENTAGE OF EQUIVALENT LIQUID PERMEABILITY)

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