THE EFFECT OF PORE STRUCTURE ON PRIMARY DRAINAGE CAPILLARY BEHAVIOUR

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INTRODUCTION

This work records the results of a special core analysis (SCAL) project performed by the author at the Integrated Core Consultancy Services (ICCS) laboratory facility at Sunbury-on-Thames, London, UK.

The present study tries to explain the difference of irreducible water saturation between drainage capillary pressure curves obtained from two techniques (mercury injection and porous plate combined with GASM). With this goal, a series of drainage experiments was systematically achieved. Each test consisted of measuring capillary pressure by two techniques on two adjacent samples : mercury injection with capillary pressure values up to 60.000 psia was used on one sample and air/brine porous plate under conditions of reservoir confining stress utilizing a developed gamma ray (GASM) monitoring system. For this system, sources and detectors are mounted in fixed positions so that the core holder and core matrix remain unchanged during the displacement test.

All of the samples (06) chosen for study had previously been characterized in terms of pore structure by basic mercury intrusion testing. The origin of the modes of microporosity known to be present after this characterization was confirmed by X-ray diffraction mineralogical assay. As many samples were chosen as was feasible to characterize within the overall time constraints of the project, whilst possessing as much variety in pore structure and mineral content as possible.

Standard values of contact angle and interfacial tension given in nomenclature were used to convert mercury data to equivalent air/brine capillary data.

$$P_{c(A/B)} = P_{c(Hg)} \, (g_{A/B} \, Cos \; j_{A/B} \, / \, g_{Hg} \, Cos \; j_{Hg})$$

Using mercury injection, theoretical estimate of sample permeability can be made, by combining Darcy's law with Poiseuille's equation :

$$K_t \approx K_2 g_{Hg} Cos \; j_{Hg} f^m \int D^2 ds \approx K_2 g_{Hg} Cos \; j_{Hg} f^m \sum_{i=0}^{n} D_i^2 \Delta s_i \qquad (1)$$

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RESULTS AND DISCUSSION

Table 1 presents summary properties derived from high mercury intrusion and a broad rock type classifications confirmed by XRD mineralogy is given in table 2. A brief description on the basis of the mineral and pore structure characterization is given below for each sample in order :

Sample 1 **: clean sand** is dominated by intergranular porosity with significant mesoporosity and a very little microporosity.

Sample 2 **: cherty sand** shows that 50% of porosity is intergranular (mesoporosity) and 50% intragranular (microporosity) which is associated inside the grains (chert).

Sample 3 **: quartz-arenite** is characterized by low total porosity but large pores with significant mesoporosity and very little microporosity.

Sample 4 : **chalk** is characterized by the absence of clay, very sharp distribution but low intergranular pore size so very low absolute permeability (0.089 mD) and high threshold pressure (100 psia).

Sample 5 : **chloritic sand** is characterized by 50% of microporosity with chlorite.

Sample 6 : **kaolinitic / illitic sand**, about 67 % of porosity is non intergranular characterized by the presence of illite, kaolinite and some unknown minerals.

The air/brine capillary pressure curves combined with GASM and compared with curves derived from high pressure mercury intrusion (Fig.1) show an agreement in the macroporous region (2) for all the samples followed by the same agreement for quartzite samples, but we notice a departure at higher drainage pressures for the samples 4, 5 and 6. The separation of the curves is a measure of microporosity content (3), since vacuum (not a true wetting phase) will drain from occluded pores associated with diagenetic clay phases. Table 3 shows the comparison of irreducible water saturation obtained by using two different techniques, the difference is proportional to the microporosity content (4) and is really high for the samples 4, 5 and 6.

An agreement between two techniques was extremely good for quartzite samples. However, mercury intrusion is not representative in chalk and clay rich sandstones. These latter, show that irreducible water saturation is underestimated by using this technique in high capillary pressure region (5).

CONCLUSIONS

Based on six comparative tests, the following conclusions and recommendation can be drawn :

1. Both high mercury intrusion and capillary pressure with GASM can produce precise results- but only if careful and rigorous procedures are employed.

2. Mercury intrusion is suitable in clean and cherty sandstones but is not representative in chalk and clay rich sandstones.
3. Uncertainty in mercury intrusion appears to correlate with volume of microporosity.

RECOMMENDATION

Correlations should be developed between drainage capillary pressure curves obtained from mercury injection and porous plate combined with GASM for various rock types.

NOMENCLATURE

A/B	Subscript denoting Air/Brine interface
D	Pore diameter
D_i	Pore diameter at each pressure increment
i	Index ($1 \leq i \leq n$)
K_t	Theoretical permeability
m	Cementation factor
n	Number of pressure/intrusion pairs recorded
Pc	Capillary pressure
S	Mercury saturation
S_i	Mercury saturation at each pressure increment
S_{wi}	Irreducible water saturation
γ	Surface Tension
ϕ	Porosity
φ	Contact angle

CONSTANTS

γ_{Hg}	0.485 N/m (SI Units); 485 dynes/cm (Oil-field units)
$\gamma_{A/B}$	0.072 N/m (SI Units); 72 dynes/cm (Oil-field units)
φ_{Hg}	140°
$\varphi_{A/B}$	0°
K_2	1 (SI Units); 10.24 (Oil-field units)

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Tab.1 Principal Basic Sample Properties

Sample	Lithotype	Kt (mD)	Phi Hg (%)	Phi He (%)	r (g/cc)
1	Clean Sand	1070	27.9	28.0	2.653
2	Cherty Sand	247	21.2	21.8	2.652
3	Qtz - Arenite	140	5.9	5.8	2.651
4	Chalk	0.089	15.3	15.2	2.690
5	Chlorite sand	75.1	30.4	31.1	2.690
6	Kaolinite/Illite sand	70	27.4	26.4	2.659

Tab. 2 Semi-Quantitative Whole Rock XRD Results

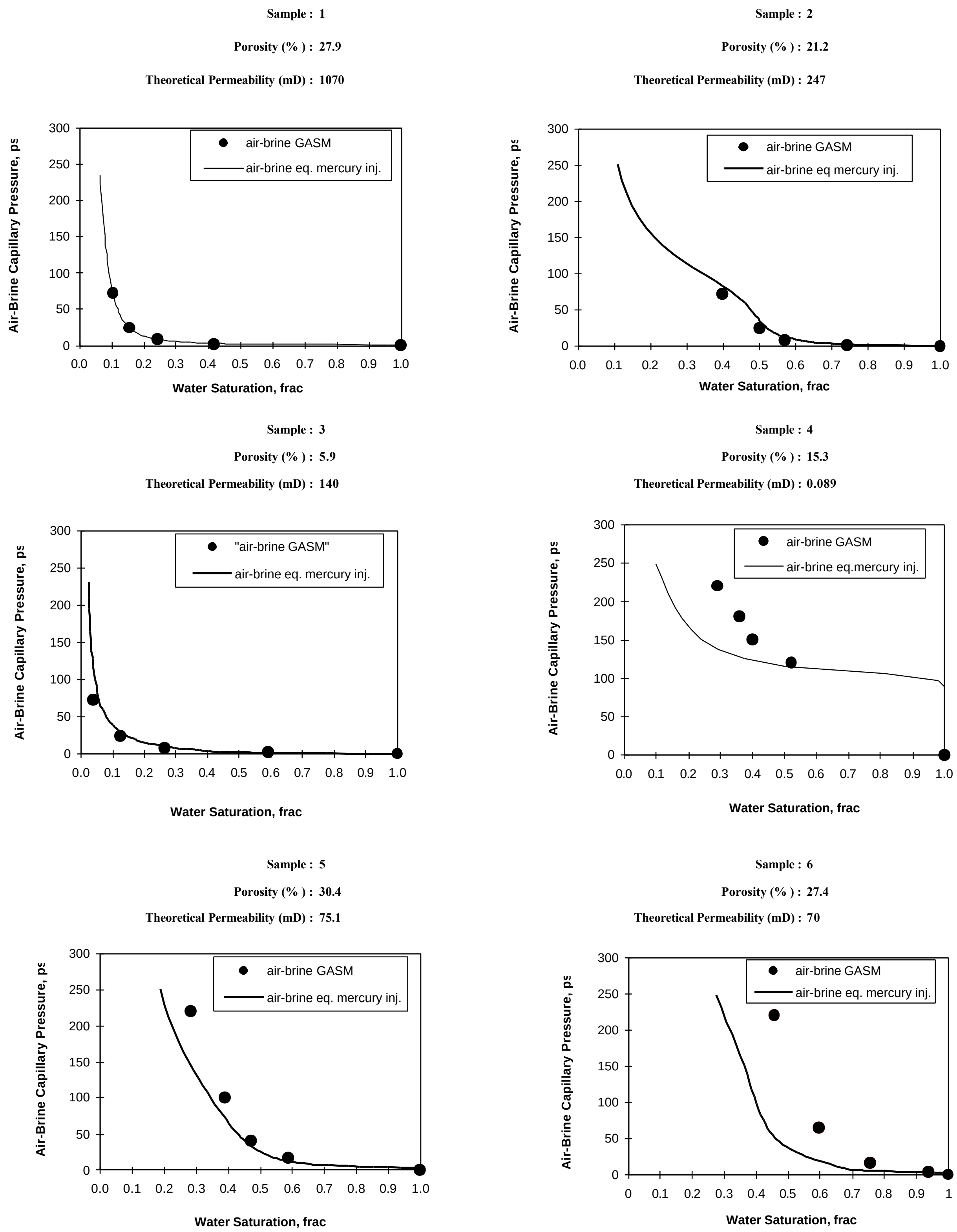
	Sample 1 Clean Sand	Sample 2 Cherty Sand	Sample 3 Quartz/Arenite	Sample 4 Chalk	Sample 5 Chlorite Sand	Sample 6 Kaolinite/Illite
Mica+Illite	1%	0%	0%	0%	3%	1%
Kaol+Chl.	2%	2%	1%	0%	4%	2%
Quartz	91%	96%	99%	3%	81%	81%
K-Feldspar	2%	0%	0%	0%	6%	6%
Plagioclase	3%	0%	0%	0%	4%	2%
Calcite	1%	0%	0%	87%	2%	0%
Ankerite	0%	0%	0%	0%	0%	2%
Dolomite	0%	0%	0%	10%	0%	0%
Siderite	0%	1%	0%	0%	0%	0%
Unknown	0%	0%	0%	0%	0%	5%
Total	100%	100%	100%	100%	100%	100%

The values quoted are correct to the nearest whole number and may not add up to 100 %

Tab. 3 Comparison of Irreducible Water Saturation obtained by two Techniques Mercury/GASM

Sample	Lithotype	Swi (GASM)	Swi (Hg)	SHG:SHM
1	Clean sand	10.42	10.42	1.00
2	Cherty sand	39.95	42.12	1.03
3	Qtz - Arenite	4.01	5.42	1.01
4	Chalk	29.06	11.63	0.80
5	Chlorite sand	28.35	20.06	0.90
6	Kaolinite/illite sand	45.72	28.93	0.76

Fig.1: Comparison of Drainage Curves by Mercury Injection and GASM



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