ASSESSMENT OF SIDEWALL CORES FOR ROUTINE AND SPECIAL CORE ANALYSES

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ABSTRACT

This paper assesses the authenticity of the petrophysical measurements made on core plugs taken with a new downhole sidewall coring tool that can acquire core-plugs of 1.5” diameter and lengths of 2.5”, 3.0” and 3.5”. For this purpose, one block of Indiana limestone and one block of Berea sandstone were used. These blocks were characterized with a minipermeameter through acquisition of minipermeability grid points.

Two types of twin plugs were cut from each block at locations having similar permeability range. The first set of plugs was cut from each block using the new downhole rotary sidewall coring tool with a dimension of 1.5” diameter and 2.5” length. The second, twin set of plugs was cut with a conventional rotary core-plugging device used by commercial core laboratories. Both types of plugs were full-size scanned using micro-CT and measured for routine core properties. Resistivity and NMR measurements were also made after brine saturation.

The results of the measurements made on the new sidewall-coring plugs were found to be comparable with the measurements made on the plugs acquired with the conventional core-plugging device. It can be concluded that the new sidewall cores are suitable for RCA and further SCAL analyses.

INTRODUCTION

Routine (RCA) and Special Core Analyses (SCAL) are important for field development projects. One of the main sources of data for this purpose comes from rock samples which are acquired in the form of drill cuttings, continuous whole cores and sidewall cores. The most established and well accepted of these rock sample sources is the continuous whole core - sidewall cores have not gained such acceptance yet. The most probable reasons may include non-standard dimensions of such cores and their potential alteration in the process of acquisition.

In the past, the samples from rotary sidewall coring were limited in size, resulting in limited laboratory evaluation. Recently, a new coring tool has been developed to obtain

1.5” diameter sidewall core samples equivalent to standard laboratory core plugs. With this new coring capability, operators can fully characterize an extended reservoir interval in a single sidewall coring descent instead of multiple sidewall coring descents or multiple stands of whole core retrieval. There are no published documents proving that these core samples can provide good routine core analysis data. The purpose of this study is to compare core analysis data from samples obtained from a conventional lab plugging machine and from the rotary sidewall coring tool (Figure 1):

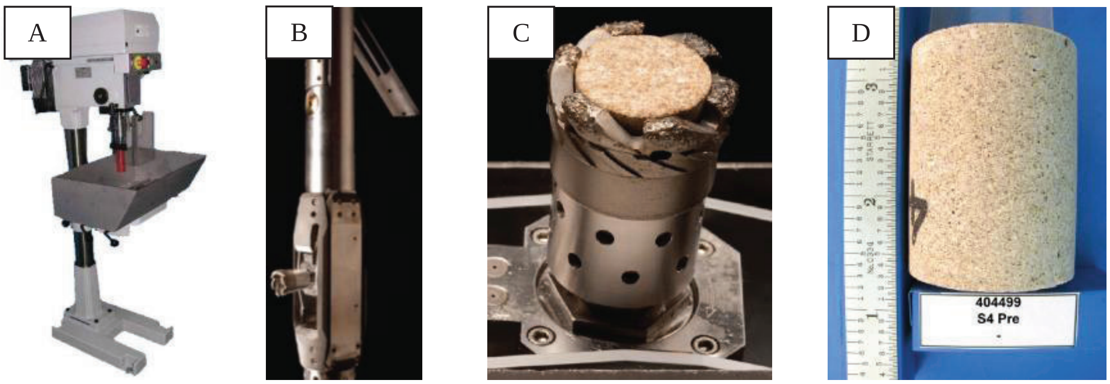

Figure 1: Conventional laboratory plugging machine (A), rotary sidewall coring tool (B), 1.5” diameter core within the drill bit (C) and 3.5” length sidewall core (D)

ROCK SAMPLES

Two rectangular cross section outcrop blocks were selected for the study: one block of Indiana limestone and one block of Berea sandstone. These blocks were indexed into a grid system (rows R and columns C (Figure 1). For each grid section local gas permeability data were obtained with a mini-permeameter in a first step with the objective to identify several zones with similar permeability prior to coring. This ensured the reliability of the comparisons between the core analysis data obtained from twin samples plugged with the two different techniques.

The permeability range for the Berea sandstone block was found to be between 500 and 800 mD whereas the permeability for the Indiana limestone block ranged from 15 to 150 mD. Figure 2 shows a picture of the Indiana limestone block which was plugged with both laboratory plugging machine and rotary sidewall coring tool:

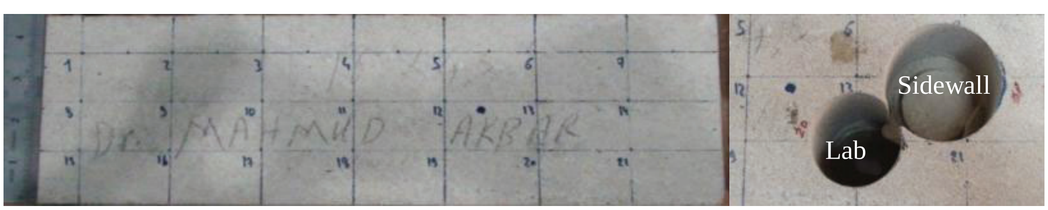

Figure 2: Indiana limestone block and mini-permeability gridding (left), block after coring with conventional laboratory plugging machine and rotary sidewall coring tool (right)

Four core plugs were cut from each block (Berea and Indiana): on each block, two core plugs were cut using the conventional laboratory plugging machine, two using the rotary sidewall coring tool. They were all drilled in zones of close permeability. Tap water was used as drilling fluid.

The integrity of the plugs did not seem to be affected by the way the plugs were drilled (Figure 1, D), at least qualitatively. Results of additional measurements are described in detail below to prove that the properties of plugs cut with the rotary sidewall coring tool and with conventional plugging machine are not affected by the coring method.

EXPERIMENTAL RESULTS

All outcrop samples were first Soxhlet cleaned and dried before being measured for routine core properties.

Grain density ρ, ambient helium porosity ϕ (based on Boyle's law), gas and Klinkenberg permeabilities Kg and Kkl (using the pressure falloff method), were performed on all samples. Data results are listed in Table 1:

Block	Mineralogy	Sample Id	Coring type	ρ_g g/cc	ϕ %	Kg mD	Kkl mD	ε_m
Berea	sandstone	BS1	lab	2.64	25.09	704	696.6	4.77
Berea	sandstone	BS2	lab	2.65	25.95	706	698.0	---
Berea	sandstone	BS3	sidewall	2.65	24.84	592	585.2	---
Berea	sandstone	BS4	sidewall	2.65	25.32	699	690.9	4.68
Indiana	limestone	IL4	lab	2.69	15.75	22.4	21.2	8.13
Indiana	limestone	IL10	sidewall	2.69	15.65	58.2	56.21	---
Indiana	limestone	IL14	sidewall	2.70	16.48	29.10	27.74	8.18
Indiana	limestone	IL20	lab	2.69	15.74	33.46	31.97	---

Table 1: Dry core plug properties

Grain density and dry matrix permittivity cannot highlight the presence or absence of micro-fractures. The measured grain density ranges from 2.64 g/cc to 2.65 g/cc for the sandstone samples and from 2.69 g/cc to 2.70 g/cc for the limestone samples. The dry matrix permittivity of four samples was also measured and was found to be in the expected range (around 4.7 for pure quartz and 8.5 for pure calcite from literature – values in dielectric unit).

As to porosity and permeability, the presence of induced fractures can increase both values. The porosity ranges from 24.8% to 25.3% for the sandstone samples and from 15.4% to 17.2% for the limestone samples, gas permeability from 585 mD to 728 mD for the sandstone samples and from 30.4 mD to 56.2 mD.

While three out of the four samples within a group (group BS for Berea Sandstone, group IL for Indiana Limestone) show very good agreement in permeability and porosity, the overall range of porosity and permeability data obtained within the group can be attributed to natural anisotropy. No evidence is apparent that the sidewall coring tool has damaged the rock during the coring process.

The core plugs were then scanned using X-ray micro-Computed Tomography (micro-CT) techniques. Figure 3 shows typical 2D cross-sections of two Indiana limestone samples, one obtained from the conventional laboratory plugging machine (IL4), one from the rotary sidewall coring tool (IL14):

Figure 3: Typical 2D micro-CT cross-sections obtained from conventional sample IL4 (A) and from sidewall sample IL14 (B)

Micro-CT was used to image core plugs with resolution of 42µm/voxel. A high voltage X-ray tube and different zoom-in objectives allow samples with higher resolution to be scanned (5µm/voxel without physical core mini-plug cutting). Micro-CT image processing and analysis were carried out by using commercial software and in-house developments. 3D pore structure representations of samples IL4 and IL14 are shown in Figure 4:

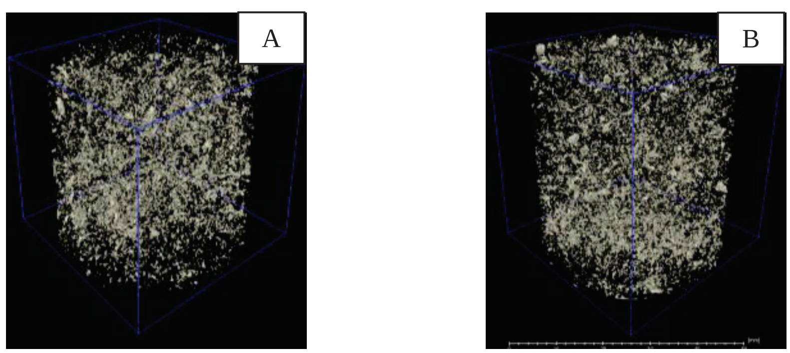

Figure 4: 3D volume rendering from conventional sample IL4 (A) and from sidewall sample IL14 (B)

Both images and 3D volumes in Figure 3 and Figure 4 are very similar. There is no visual evidence of rock structural alterations such as mini-fractures induced by the coring method.

MICP data can also highlight the presence of tiny fractures due to the coring process: tests were run on four end trims from rocks drilled with the two different methods. Figure 5 represents both capillary pressure and pore throat size distribution of two Indiana limestone and two Berea sandstone rock chips obtained from the end-trims of the samples cut from the conventional laboratory plugging machine (IL4 and BS1) and from the rotary sidewall coring tool (IL14 and BS4):

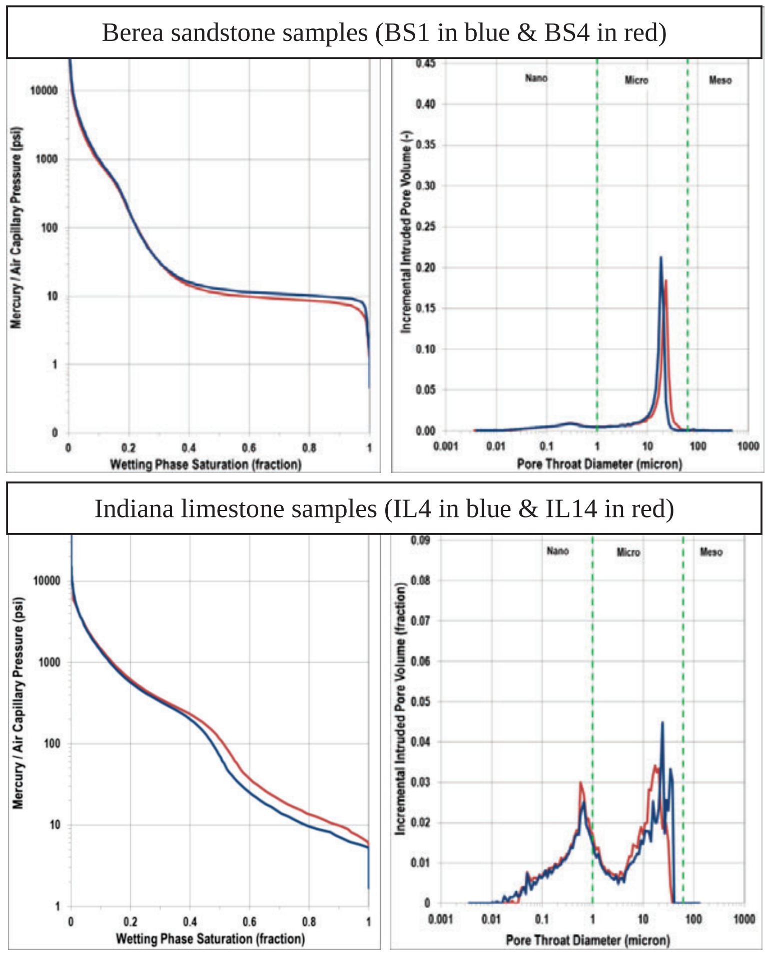

Figure 5: Mercury injection capillary pressure (MICP) and pore throat size distribution

Figure 5 shows that capillary pressure curves Pc and pore throat size distribution curves of sidewall and laboratory samples are very similar - there is no evidence of potential micro-fracture or rock damage due to the coring process.

The MICP parameters obtained from both types of curves are presented in Table 2:

Sample Id	Hg ϕ (%)	Nanopores 1nm<Dia.<1μm (%PV)	Micropores 1nm<Dia.<1μm (%PV)	Mesopores 62nm<Dia.<4μm (%PV)	Hg/air Pe (psi)	Swanson Kg (mD)
IL4	15.8	42.7	57.3	0	6.24	35.7
IL14	16.7	41.0	59.0	0	5.55	38.3
BS1	26.3	19.3	80.0	0.74	1.68	518
BS4	25.4	19.0	80.1	0.85	1.34	616

Table 2: MICP data results

Note that MICP porosity and permeability are close to the ones obtained on core plugs.

Four core samples were then saturated with brine (200 kppm equivalent NaCl). Brine permeability was run on the samples in addition to resistivity and NMR measurements.

Block	Sample Id	Coring type	Brine perm mD	FF @ 1 KHz	m @ 1 KHz	NMR ϕ %
Berea	BS1	lab	536	13.5	1.96	24.2
Berea	BS4	sidewall	532	13.4	1.96	24.0
Indiana	IL4	lab	24.0	53.0	2.16	14.8
Indiana	IL14	sidewall	33.2	48.5	2.10	14.3

Table 3: Brine saturated core plug properties

Table 3 shows that all values (sidewall versus laboratory) are essentially the same for each couple of cores, with cementation factors equal to 2.0 for sandstone and 2.1 for limestone. If fractures would have been induced, the permeability and cementation factor on sidewall cores would have been found respectively higher and lower.

The NMR porosity was obtained from T_2 distribution measurements (Figure 6).

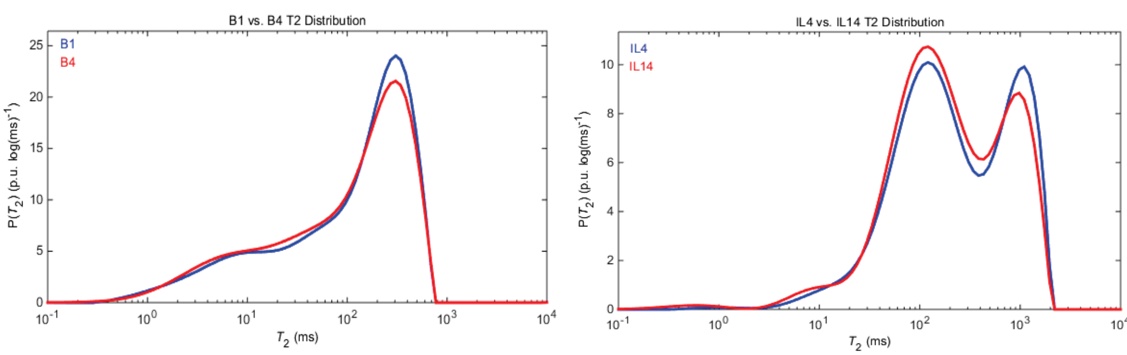

Figure 6: NMR T_2 distributions of BS1 and BS4 (left), and IL4 and IL14 (right)

The NMR porosity is slightly lower than the helium porosity, maybe due to some evaporation during the ambient NMR tests. However, the results are still in agreement with the laboratory porosity. T_2 distributions do not show a difference between sidewall and conventional samples, showing again that the rocks were not altered by the way they were cut.

CONCLUSIONS

Core plugs of different rock types were cut using both a standard laboratory plugging machine and a new rotary sidewall coring tool. All samples were full-size scanned using micro-CT and measured for routine core properties, resistivity, NMR and dielectrics. The results of the measurements made on the new sidewall-coring plugs were found to be comparable with the measurements made on the plugs acquired with the conventional core-plugging device. It is concluded that the sidewall cores are suitable for RCA and SCAL analyses. The SCAL work is in progress at the Houston Schlumberger Reservoir Laboratory; the preliminary results confirm the good quality of the sidewall cores. To summarize, the new rotary sidewall coring tool is now an alternative for acquiring high quality downhole core samples with proper core size for laboratory analyses.