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EFFECT OF BARIUM SULPHATE PRECIPITATION IN A PRESSURIZED ENVIRONMENT

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Abstract. *Currently, the oil sector is facing new challenges, such as ultra-deep waters and pre-salt. One of the main concerns is the inorganic precipitation in production equipment. Precipitation can occur throughout the oil production chain, from the reservoir to the surface facilities. The most common type of scale in the region close to the reservoir is barium sulphate due to its low solubility. This work proposes an experimental study that aims to monitor the effect of barium sulphate precipitation on the petrophysical properties of Berea Buff type samples such as, porosity and permeability. Unlike other works in the area, this study used a simpler methodology to observe the impact of the precipitation reaction. At the end of the experiment, there was a reduction in the two petrophysical properties studied, porosity and permeability. In addition, the decay of the concentration of chloride ions, indicate the consumption of the reagents and the consequent production of barium sulphate in the porous medium. Were observed a reduction of 11,7% in the permeability and 7,9% in porosity. However, tomography analyses were needed to better understand which form and local barium sulfate form a scale in the porous medium.*

Keywords: *Barium sulphate, permeability, porosity, inorganic scale*

1. INTRODUCTION

Scales are present through all the petroleum production chain. Its formation is recognizing as one of the main problems that affect the flow during the hydrocarbons production (Arai; Duarte, 2010; Vazirian, Charpentier, Penna e Neville, 2016). Its occurrence in the near well region of the reservoir impacts on porosity and permeability in the porous medium, affecting the well surroundings and, consequently, the fluid flow (Vazirian et al., 2016). In general, the scale causes porosity and permeability a reduction, reducing the fluids production.

Among the main impacts of scale on the oil system, it is possible to cite the pores closing in the formation (around perforating, for example) and in completion equipment, such annular sand retaining screens and gravel pack. Scales reduces the equipment lifetime, in addition to affecting the components integrity such as subsurface control valves, submersible pumps, hydraulic actuators, pipelines, among others sensitive equipment (Foidaş, I, & Ştefănescu, 2017).

The scale can be organic or inorganic. Inorganic scale can occur due to mineral precipitation caused by pressure and temperature variations or by incompatible waters mix in the reservoir (Almeida Neto, 2012). This incompatibility occurs, mainly in offshore oilfield, due to the secondary recovery implementation. This is because water flood is one of the most applicable methods because its availability and ease of use. In Figure 1, is possible to observe the main points of scale occurrence.

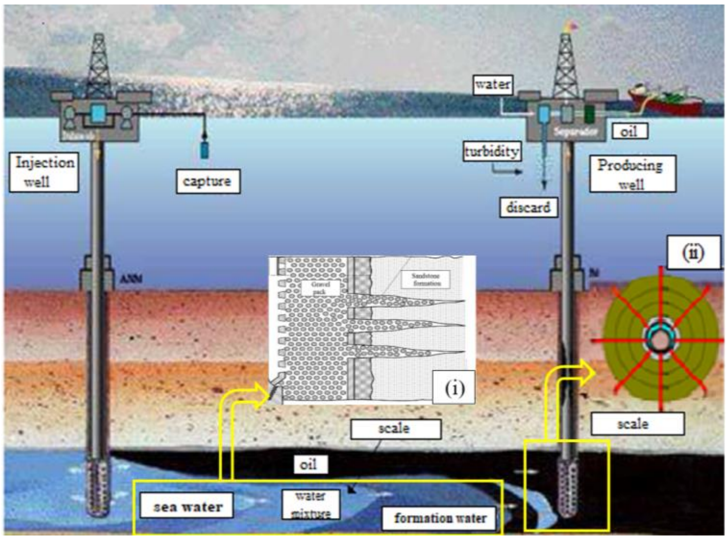

Figure 1. Offshore water flooding system. i. (reservoir) & ii. (near well). Common points of scales formation.

Among the mostly common inorganic scale, there are: barium, strontium and calcium sulphates and calcium carbonate (Patricio, 2006). The solubility of these inorganic salts is a key point to the knowledge of scaling potential of each one. The barium sulphate precipitation is the most seriously problem because it presents less solubility among the commonly found salts. In this context, this work aims to evaluate the influence of barium sulphate scaling on the porosity and permeability of a porous sandstone (Berea Buff). The tests were conducted at room temperature and 200 psi overburden pressure.

2. EXPERIMENTAL

This work proposes an experimental study that aims to monitor the effect of barium sulphate scaling in a sandstone porous medium under pressure in a core holder. The methodology for porosity and absolute permeability measurements of the porous medium is an adaptation of the methodology detailed in Dornelas et al. (2019). Figure 2 shows a schematic sequence for experimental procedure to the scaling test.

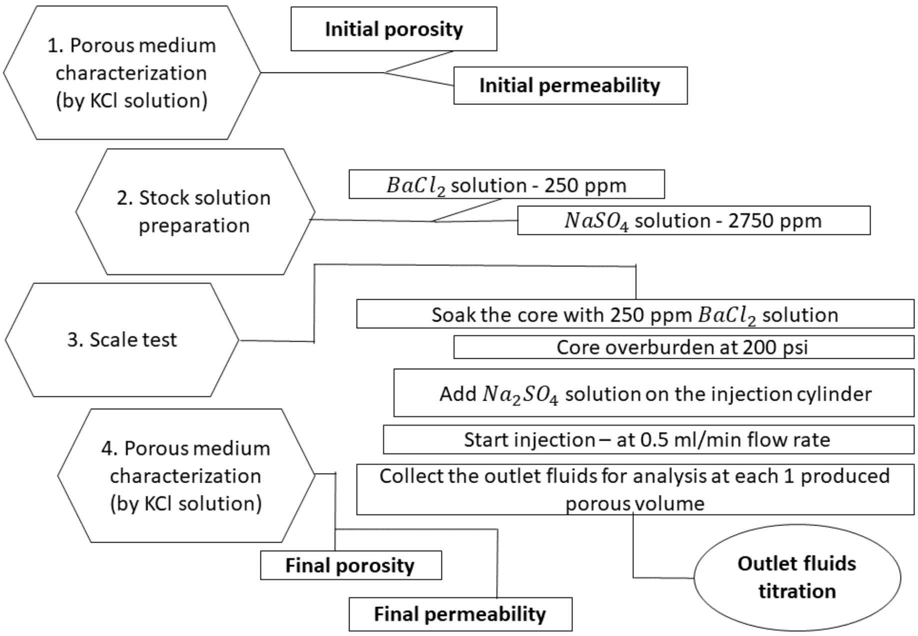

Figure 2. Experimental procedure methodology.

For porosity and absolute permeability (initial and final) calculations, 3% potassium chloride solution was applied as the saturation fluid. And the overburden pressure used was 200 psi, before and after the scaling test, aiming at barium sulphate scaling.

The cores used in the tests are synthetic porous medium acquired in the Kocurek – Hard Rock division industry.

Average porosity of the porous medium was measured as a function of the specific mass of saturation fluid, the mass (dry and saturated) of the porous medium and its volume as shown in Eq. 1.

$$\phi = \frac{m_{saturada} - m_{seca}}{\rho . V_r} \tag{1}$$

The absolute permeability of the rock was determined by de Darcy's equation, Eq. 2, in the beginning and after the barium sulphate scale test.

$$\kappa = \frac{q \mu L}{A \Delta P} \tag{2}$$

After determining the initial permeability, the barium sulphate precipitation reaction was carried out. The porous medium was saturated with a 250-ppm barium chloride solution and taken to the core holder for pressurization. Then, a 2750-ppm sodium sulfate solution was injected into the porous medium, so that the reaction would occur only in the rock. The reaction was monitored by ions chloride titration at the outlet of the core holder for each produced porous volume, Eq. 3.

$$C_{AgNO_3} . V_{AgNO_3} = C_{Cl^-} . V_{core\ holder\ outlet\ solution} \tag{3}$$

3. RESULTS AND DISCUSSION

The core samples used in the experiments have the following average dimensions, 0.0635 m of length and 0.0383 m of diameter. The samples are synthetic sandstones, Berea Buff (BB) type, acquired at Kocurek – Hard Rock division industries, see Fig. 3.

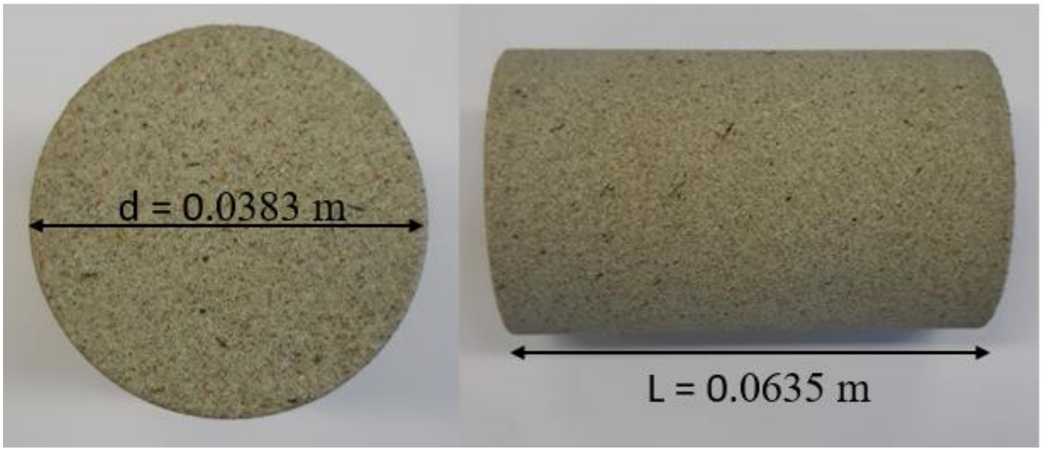

Figure 3. Berea Buff sandstone sample.

The sample characterization results in relation to porosity and absolute permeability are shown in Fig. 4.

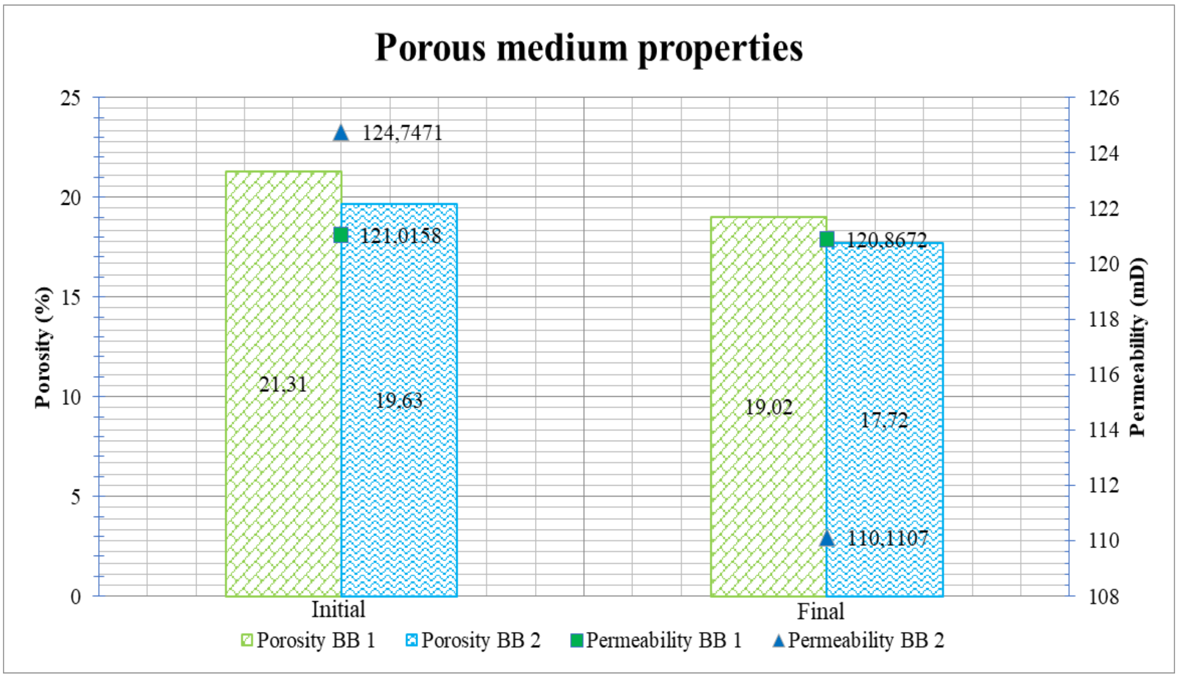

Figure 4. Porosity and absolute permeability characterization before (Initial) and after (Final) the scale test. (in green sample BB 1, in blue sample BB 2)

The sample is characterized before and after the scale test, regarding its porosity and absolute permeability, as to analyze the impact of barium sulphate scale in the porous medium. The results shown that the absolute permeability reduces 11.7% and porosity reduces 7.88%.

The impact of barium sulphate precipitation has a more effective influence on the porosity of both core samples studied. Showing a reduction of 7.88% and 6.83%, on samples BB 1 and BB 2, respectively. The effect on the absolute permeability has presented differ intensities between the samples. The sample BB 2 showed a more intense effect of absolute permeability reduction. Since the flow paths inside the porous medium are undefined, the scale can happen in a throat significantly important or not to the flow. Can be seen by the porosity reduction that barium sulphate was precipitated inside the core. However, the precipitated inorganic salt form scale in throats that do not interfere significatively on the flow. Nonetheless, tomography analyzes were needed to observe the crystal formation and consequent scale formation on the core samples.

The barium sulphate scale test was complemented with chloride ions titration of the fluid on the exit of the core holder, see Tab. 1.

Table 1. Experimental results from chloride ions titration

Sample	Porous Volume	Chloride ions concentration (mol/l)	Barium ions concentration (mol/l)	Barium mass (g)
BB 1	1	0.0150	0.0075	1.0292
	2	0.0043	0.0022	0.2957
	3	0.0036	0.0018	0.2473
	4	0.0022	0.0011	0.1520
	5	0.0025	0.0012	0.1704
BB2	1	0.0533	0.0267	3.6625
	2	0.0042	0.0021	0.2857
	3	0.0040	0.0020	0.2723
	4	0.0037	0.0018	0.2523
	5	0.0037	0.0019	0.2573

Barium sulphate precipitation occurs by one 2750 ppm of sodium sulphate solution injection into a pressurized porous medium previously saturated with a 250 ppm of barium chloride solution. When in contact, the reaction of the solutions creates solid barium sulphate, that because of its low solubility is expected immediately scale formation and produced aqueous sodium chloride at the exit of the core holder. Table 1 shows that the sample BB 2 has a bigger precipitated mass of barium sulphate, in comparison with sample BB 1. Figure 5 draft the behavior of chloride ions concentration as its flow happen inside the porous medium.

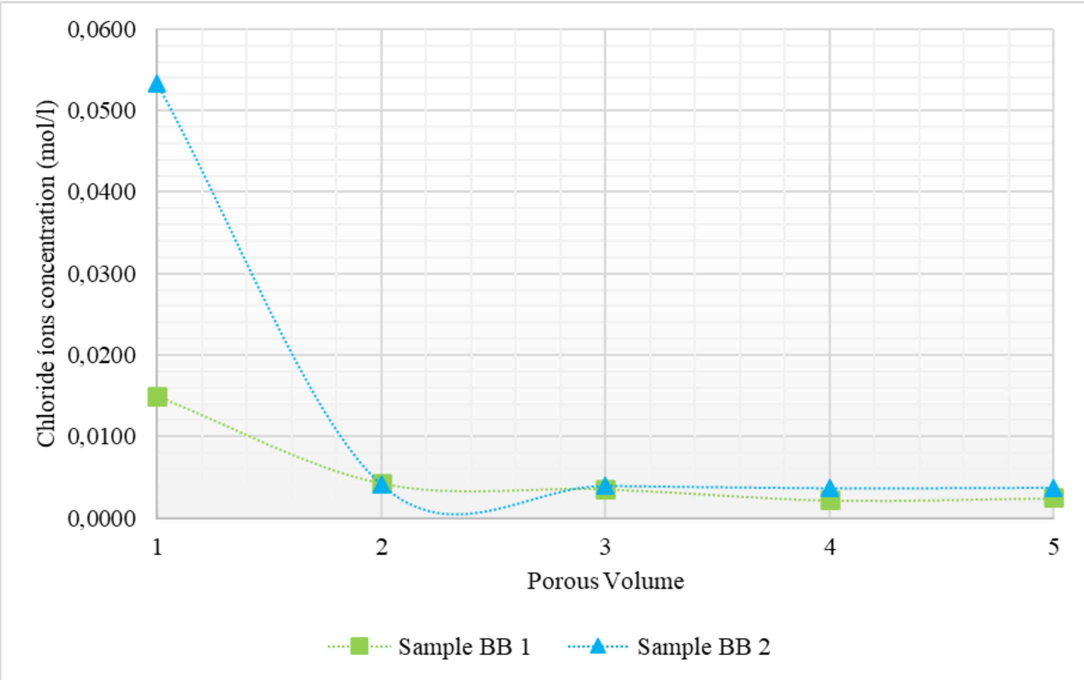

Figure 5. Experimental results from chloride ions concentration for porous volume.

The first porous volume collected show a bigger quantity of chloride ions as the follow volumes produced. The core sample is inserted in the core holder saturated with a solution of barium chloride. The sodium sulphate solution injected initially displaces the solution presented inside the core, the fluid that initially leaves the core did not suffer chemical reaction. After the collection of the first porous volume can be implied that the flow path is defined, and the fluids collected are product of the chemical reaction between the injected and saturated solutions. After the consumption of the limiting reagent, in this case, the saturation fluid, the quantity of chloride ions tends to stabilize.

4. CONCLUSION

The barium sulphate precipitation into a, 200 psi confined, sandstone porous medium, causes, porosity and absolute permeability reduction. The form, local and quantity of precipitated mass into the sample influence in the intensity of affect in the petrophysics parameters. Nevertheless, making particularly important the tomography analyzes of the samples. Is hoped that the tomography analyzes make possible to identify the crystal characteristics, form, and precipitation location, validating the observed results. The hypotheses to follow is that the scale can be formed in significant flow paths in the core. While in other sample the scale does not obstructs the flow path, but the scale still happen affecting the porosity.

5. ACKNOWLEDGEMENTS

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6. NOMENCLATURE

A = area
BB = berea buff sample
C = concentration
d = diameter
L = length
m = mass
P = pressure
q = flux rate

V = volume
Greek Letters
Δ = differential
κ = permeability
Φ = porosity
μ = viscosity
ρ = specific gravity
Index
r = reservoir
saturada = saturated
seca = dry
A_gNO_3 = silver nitrate
Cl^- = chloride ion

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8. RESPONSIBILITY NOTICE

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