

Permeability estimation of hydrocarbon reservoirs samples using Spectral Induced Polarization (SIP) and Nuclear Magnetic Resonance (NMR): a laboratory investigation

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Introduction

Recently, the relationships between geophysical parameters and hydraulic properties have been investigated extensively. Geophysical exploration techniques are used extensively to obtain the properties of saturated and unsaturated zones. Electromagnetic Conductivity, Resistivity and Ground Penetrating Radar methods are used widely in order to derive the lithological boundaries in the hydrological studies and develop of hypothetical models of subsurface materials. For example dependence of dielectric constant of saturated soils on the porosity are known very well (Bychak et al., 1974). The relation between electrical conductivity (σ) and porosity is also known by the law of Archie (Archie, 1942).

In this study, we aim to investigate a relationship between permeability of sample plugs (obtained from a reservoir) and electrical, hydraulic parameters (quadrature conductivity, porosity, surface area per unit pore volume, grain size distribution and pore throat size etc.). 30 plug samples have been provided by Iranian Offshore Oil Company (a subsidiary of National Iranian Oil Company). These relatively unconsolidated sandstone plugs have been cored from Soroush oil field located in Persian Gulf. As fluids, brine (for SIP) and tap water (for NMR) is used for experiments.

Material and Methods

First, it is desired to study the effect of water saturation on NMR and SIP responses. It is planned to saturate plugs with water (0 to 100%) and perform NMR and SIP tests at each step. For instance, a plug is saturated with brine (NaCl solution) up to 100% and, then, NMR and SIP responses are measured. The same measurement will be performed at lower water saturations (75%, 50% and 25%). The following measurements were made on the consolidated sample (13-32H) and one unconsolidated sample (12-4H):

- 1) Weighting the sample (dry sample weight).
- 2) Leaving the consolidated sample (13-32H) in the desiccator for one day (Fig. 1.a),
- 3) Injecting the NaCl solution (conductivity 100 mS/m) (for SIP) and tap water (for NMR) into the desiccator in order to saturate the sample and left it for one or two days. A water pump was used to saturate the unconsolidated sample (12-4H) (Fig. 2.a). The schematic diagram for this purpose is shown in the Fig. 2.b.
- 4) Taking out the sample from the water and weighting it (saturated sample weight).
- 5) Running the SIP and NMR measurements in 4 different saturation degrees (100%, 75%, 50% and 25%) (Fig. 1.b and 2.c).

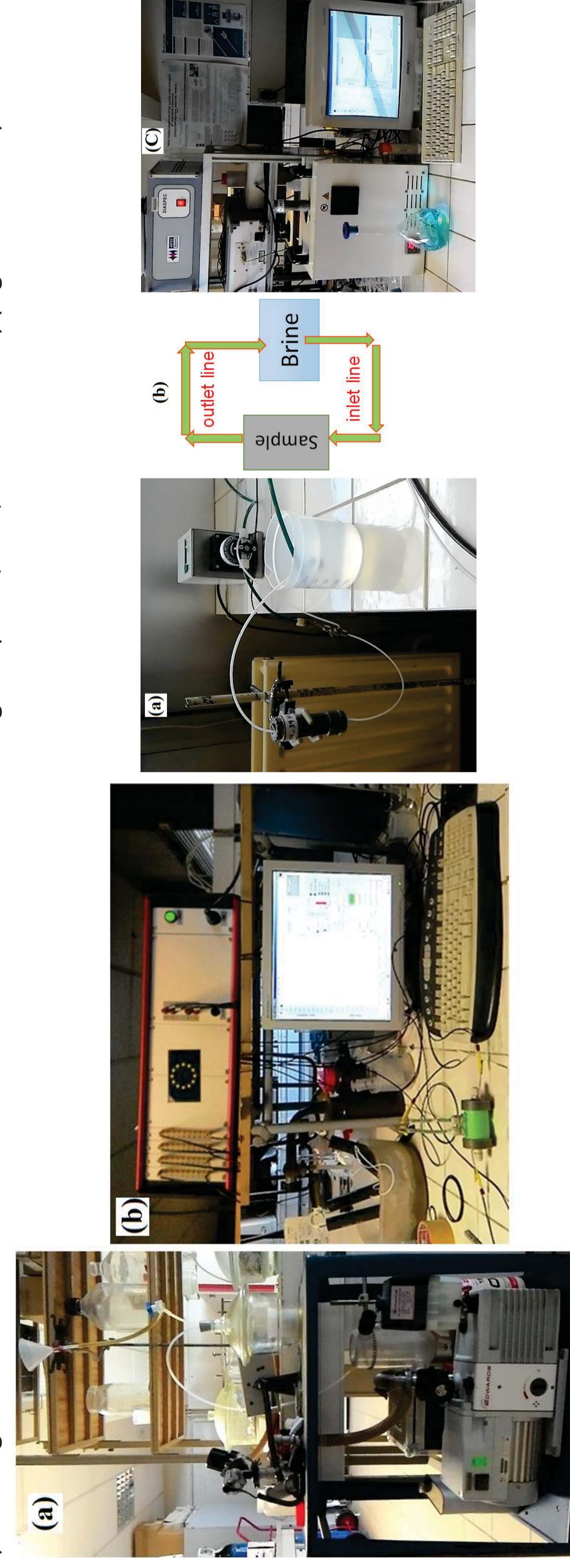


Figure 1. a) Experimental setup for water displacement in order to saturate the unconsolidated sample (12-4H); b) Schematic diagram of experimental setup for water displacement in order to saturate the unconsolidated sample (12-4H); c) NMR instrument (ARTEC System).

Results

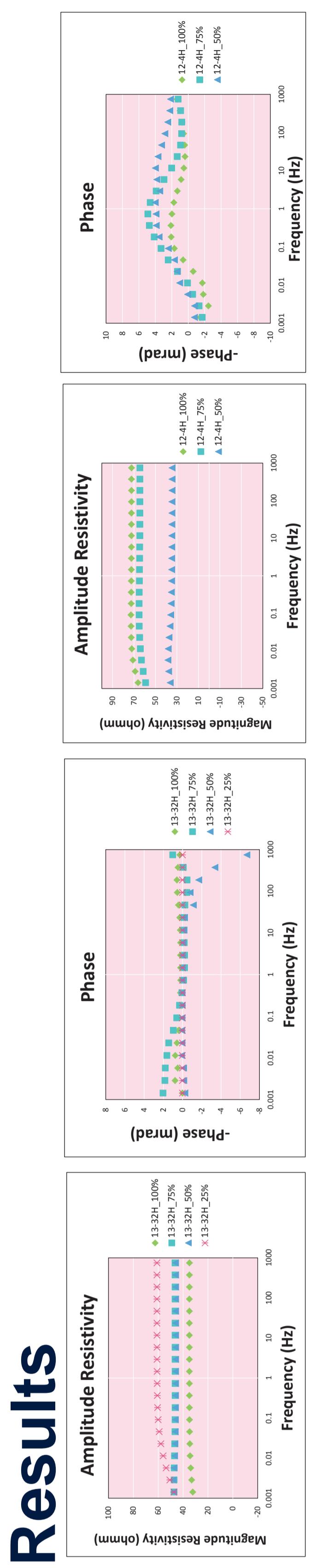


Table 1. Predicted and measured permeability on the consolidated and unconsolidated samples (12-4H)

Predicted Permeability (mD) (13-32H) $K_{SIP} = \frac{D_{T_0}}{9F^3}$ (Revil and Florsch, 2014)	Measured Permeability(mD) (13-32H)	Predicted Permeability(mD) (12-4H) $K_{SIP} = \left(\frac{D_{T_0}}{4m^2(F-1)^2}\right)^{\frac{1}{3}}$ (Revil and Florsch, 2014)	Measured Permeability(mD) (12-4H)
7809.826762	8606.37171	41010.98839	39377.4956

Table 1. Magnitude Resistivity and Phase angle spectra for consolidated (13-32H) and unconsolidated sample (12-4H)

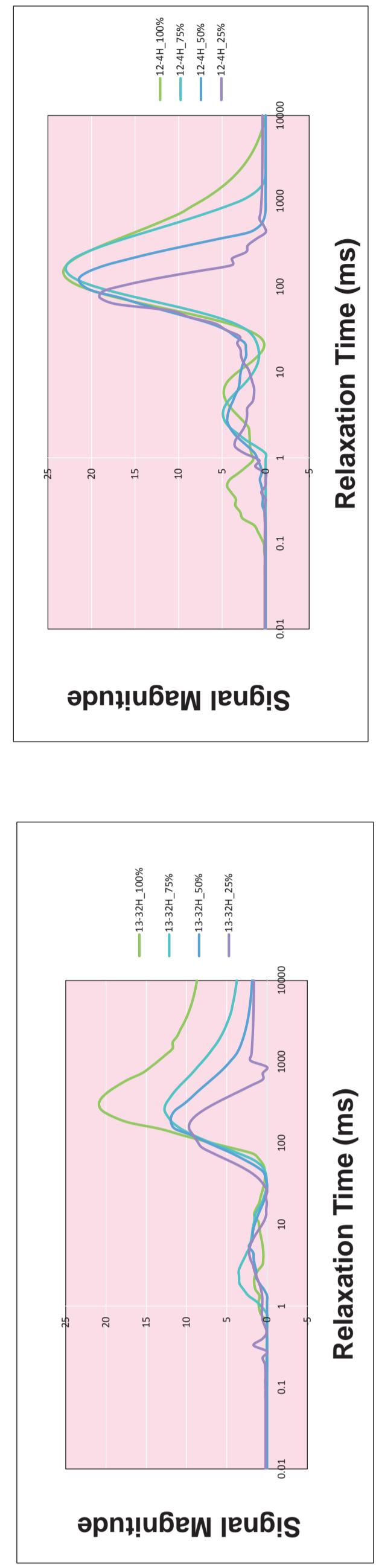


Figure 3. T2-distributions determined from the data collected during drainage for consolidated (13-32H) and unconsolidated sample (12-4H).



Table 2. Predicted and measured permeability on the consolidated and unconsolidated samples by NMR method

Predicted Permeability (mD) (13-32H) $K_{NMR} = 9.351 \times 10^{-10} \times \bar{T}_2^2 \times \delta^4$ (Weller et al. 2011)	Measured Permeability(mD) (13-32H)	Predicted Permeability(mD) (12-4H) $K_{NMR} = 9.351 \times 10^{-10} \times \bar{T}_2^2 \times \delta^4$ (Weller et al. 2011)	Measured Permeability(mD) (12-4H)
8876.69701	8606.37171	35959.9763	39377.4956

Conclusions

In this work we studied on 2 samples; one consolidated sample (sandstone) and one unconsolidated sample (sand)(obtained from a petroleum reservoir) by 2 geophysical methods (SIP and NMR). Our aim is finding a relationship between permeability of sample plugs and electrical and hydraulic parameters using a joint model between SIP and NMR measurements. Our results shows there is a good relationship between predicted permeability by SIP (K_{SIP}) and NMR (K_{NMR}) and measured permeability of these sample.

References

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