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# Multi-geophysical approach to characterize fracturation and characterize the transport properties of carbonate rocks

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## Introduction

In a context of energy transition and overexploitation of water resources, studying the critical zone appears to be a major preoccupation. In order to address these scientific questions, the *Observatoire des transferts dans la Zone Non-Saturée* (OZNS - Observatory of transfers in the Vadose Zone) of Beauce (Orleans, France) has been designed in order to characterize Beauce limestone and monitor the aquifer pollution. In the same time, the site ensures its perfect evaluation thanks to several geoscience methods (geology, geophysics, hydrogeology, hydrology, etc.).

The lacustrine Beauce limestone, main reservoir of the Beauce aquifer in the region (Lorain, 1973), is located between 10 and 20 m deep and presents important heterogeneous facies (microporosity, cracks, fractures, karstification). Its characterization requires multi-method and multi-scale (field and laboratory) studies. The presented project focuses on a laboratory study based on a multi-geophysical approach using samples coming from the O-ZNS site. The main objective is to carry out a characterization of the petrophysical and the transport/transfer properties of the Beauce limestone by combining ultrasound acoustic method (Bourbié, Coussy, & Zinszner, 1987) and complex resistivity (SIP and/or TDIP) method (Chelidze & Gueguen, 1999) (Craig & Peter, 1998). Major challenges to tackle: the complementarity of these both geophysical parameters knowing that each of them having different petrophysical sensitivity and resolution.

## Material and methods

Four blocks (4-6 Kg from O-ZNS site) of different depth have been selected based on well logs analysis carried out on 4 well datasets acquired on the O-ZNS site, which made it possible to identify several facies of the Beauce limestone. In these blocks, samples have been cored considering two different diameters:

- samples of 4 cm in diameter with a length varying around 10 cm
- samples of 2.5 in diameter with a length less than 5 cm.

Samples of 4 cm-diameter (2 per facies) will be used to carry out a complete characterization including petrophysical measurement such as porosity (triple weighing, mercury porosimeter), and permeability (water and air permeability), and geophysical measurements coupling acoustic, SIP and TDR measurements.

The ultrasound acoustic measurements will be carried out in dry and saturated conditions with longitudinal (P waves) and transverse (S waves) piezoelectric transducers (PZT) at different frequencies ranging from 1 MHz to 50 KHz.

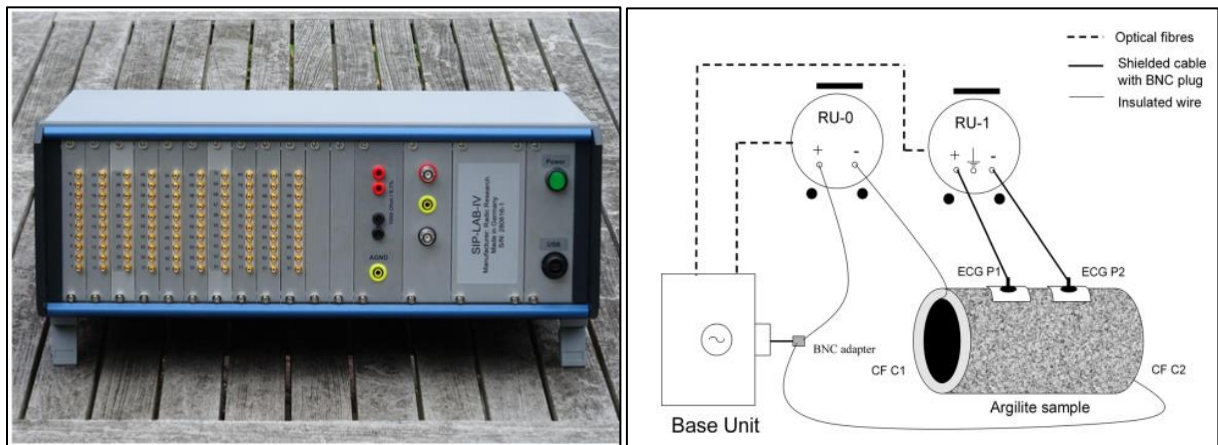
The SIP measurements will be carried out with the SIP-LAB-IV apparatus using a 4-electrode configuration [fig. 1, (Cosenza & Ghorbani, 2007)] where the potential electrodes are non-polarizable Ag/AgCl electrocardiograms (ECG) and the current electrodes are made of carbon films.

The other samples (2.5 cm-diameter) will be used for a further petro-acoustic study where the frequency effect as a function of heterogeneities will be looked for.

## Expected results

The expected results are the following:

- a new or an updated petrophysical model of Beauce limestones
- a relationship between the petrophysical model and the geophysical parameters (acoustic velocities, complex resistivity, dielectric permittivity) at laboratory scale for Beauce limestone
- Relationship between the microstructure and the petrophysical model
- An understanding of the frequency effect on the acoustic limitations to characterize different heterogeneity sizes and a comparison to electrical frequency effects
- Extrapolation to field scale of the developed petrophysical model



**Figure 1:** picture of the SIP-LAB-IV apparatus (left). Schematic presentation of the 4 electrodes configuration after P. Cosenza and al. (right): RU-0: Remote Unit 0 (or Transmitter); RU-1: Remote Unit 1 (or Receiver). ECG P1 and ECG P2: electrocardiogram Ag/AgCl electrodes as potential electrodes; CF C1 and CF C2: Carbon films as current electrodes.

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