PASICAM

A Joint Industry Project

Petroacoustic signature of carbonate rocks microstructure

Objectives

Rocks usually show a strong correlation between wave propagation velocities (V_p and V_s) and porosity (Φ). The corresponding variation law is used for interpreting seismic data in terms of reservoir petrophysical characteristics. However, carbonate rocks do not appear to follow any specific relationship. Two limestones of same mineralogy and porosity can have V_p values differing by up to 1000 m/s. This disparity can be related to different microstructures.

The objective of this JIP is twofold:

- to establish correlations between the microstructure and the petroacoustic signature of carbonate rocks;
- to validate a numerical approach which could ultimately allow the computation of an advanced porosity log, and potentially a permeability log, for carbonate reservoirs using density and sonic logs combined with microstructure data obtained from thin sections.

Methodology

Complementary experimental and modeling approaches will be followed to infer relationships between carbonate microstructure characteristics and dynamic elastic moduli, namely the dry bulk modulus K_{dry} and the shear modulus μ.

The first step will be to thoroughly characterize the studied carbonate formations, which involves petrographic and diagenetic analysis, petrophysical characterization and petroacoustic measurements. Microscanner observation will provide three-dimensional images (see Fig. 1), which can be divided into three phases: the solid phase, the porous space and the microporosity.

This partitioning will allow the definition of finite elements meshes, which include both the solid phase and the microporosity. Finite Elements Modeling (FEM) can then be used to calculate K_{dry} and μ for the identified rock structure. This part of the study will help to quantify the relative impact of microporosity and macroporosity on carbonate elastic properties.

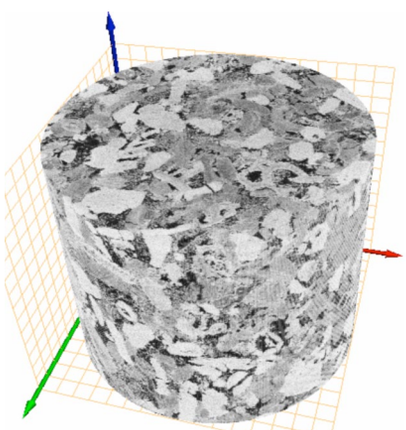

Figure 1: Microscanner image of an Estaillades limestone sample.

A second modeling approach based on homogenization techniques will moreover be followed. The samples will be modeled by an assemblage of constituents, representing either grains or pores. The objective of this approach is to define a mapping of K_{dry}-Φ and μ-Φ spaces as a function of microstructure characteristics.

When considering a new carbonate formation, given the main pore types observed on thin sections and the dynamic elastic moduli deduced from seismic data and/or logs, the established charts could be used to constrain the porosity estimation. Provided the petrophysical measurements allow the definition of k-Φ laws according to the microstructure, the permeability itself could also be estimated.

Program

The technical program of this project is divided into two phases. The first phase aims at assessing the validity of the global methodology, using carbonate samples already available at IFP Energies nouvelles. In the second phase this methodology will be applied to reservoir core samples provided by the project sponsors.

Phase 1

- Experimental characterization and microscanner imaging of available samples (see Fig. 2);
- Computation of dynamic elastic moduli K_{dry} and μ (Finite Elements Method and homogenization approach);
- Comparison with experimental petroacoustic signatures;
- Selection of new representative samples (core samples provided by partners or outcrop samples).

Phase 2

- Experimental characterization and microscanner imaging of new samples;
- Computation of dynamic elastic moduli K_{dry} and μ with the methods validated in Phase 1;
- Validation of the representativeness of the homogenization approach to model the elastic response of carbonate rocks from mineral properties and microstructure data;
- Data analysis to infer relationships between petroacoustic and microstructure characteristics.

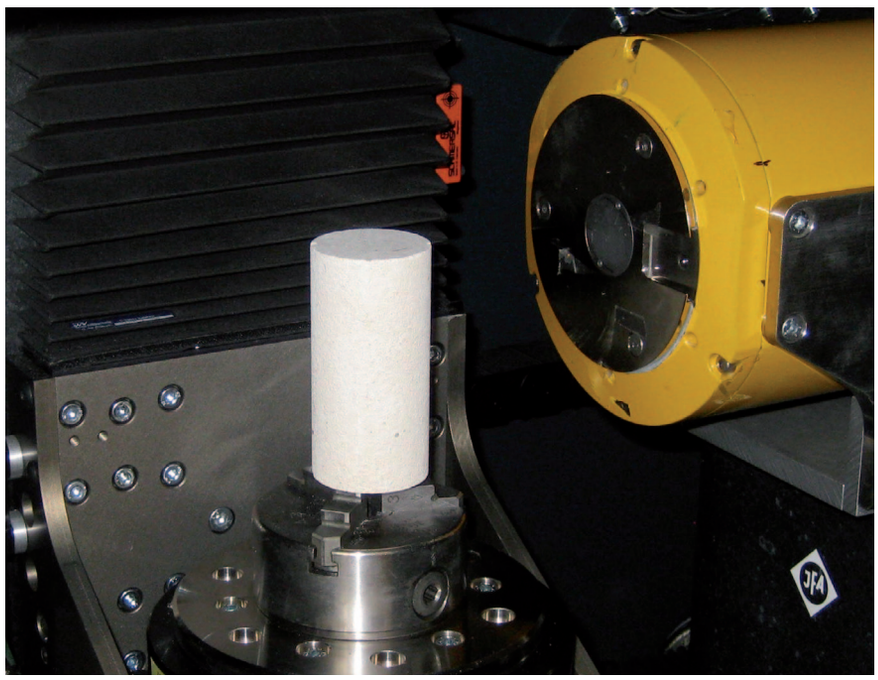

Figure 2: Observation of a carbonate sample in IFP Energies nouvelles microscanner.

Deliverables

Phase 1

- Report on samples characterization and modeling approach;
- Database (Excel files) for Phase 1 samples;
- Microscanner images and finite elements meshes.

Phase 2

- Final report on samples characterization and modeling approach (after removal of any indication of sample origin);
- Database (Excel files) for the whole set of samples (after removal of any indication of sample origin);
- Microscanner images and finite elements meshes.

Each partner will additionally receive a specific report including the detailed results obtained on his own samples.

JIP Leader

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