[PS]Acoustic Characterization of Sub-Seismic Scaled Heterogeneities in Carbonate Reservoirs: Example of Barremian Microporous Limestone from Southeast France: An Analog of Middle East Hydrocarbon Reservoirs*

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Abstract

Carbonate rock physics properties are difficult to assess due to their biogenetic diversity and the overprint of a complex diagenetic history which can alter porous carbonates porosity during the whole life of these reservoirs. Common scales to characterize the latter are seismic profiles and well log data. Despite seismic methods that, in some cases, fail to characterize reservoir units for example because of seismic detection limit (≈20 m) or low impedance contrast between two lithified carbonate units, good relationships have been established between elastic properties and reservoir properties of these reservoirs. Nevertheless, elastic properties often in-lab determined, are measured on small-scaled (≥ 2 inch.) samples which are not always representative of the heterogeneity of the sampled units, leading in some cases to wrong interpretations.

In this study, we propose to assess acoustic properties at an intermediate scale in terms of both seismic frequency (SF) and investigated area (IA), between seismic scale (SF:101-102 Hz, IA: km) and laboratory scale (SF:104-106 Hz, IA: cm). We designed, two acoustic probes which enabled us to perform crosshole acoustic measurements up to ultrasonic frequencies (SF: 102-104 Hz), between two wells located in a gallery from an underground laboratory (LSBB†, France). Confining pressure within the wells is ≈4-to-6 MPa and the studied formation are located in the unsaturated zone of the aquifer. The wells were 2 m spaced and 20 m deep. Here we present a HR acoustic log (Δz = 10 cm) covering an inter-wells area of 30 m^2 composed of tight and microporous reservoir units of Urgonian platform limestones. The key results of this experiment are: (1) Sub-seismic scaled heterogeneities such as diagenetic horizons within a same sedimentary facies or layer and related to porosity variations up to 10% can be successfully characterized using our methodology, (2) Potential diagenesis-induced seismic reflectors can be identified between and within layers under conventional seismic detection limits, and (3) Tight units, regardless to their composition, display different fractures density, they show the same average P-wave velocity but scattering of the values is a function of the underwent deformations. Finally, coupling *in situ* HR acoustic log to conventional lab measurements can fill the gap in terms variations of acoustic response observed between field seismic and synthetic profiles used for the inversion of reservoir properties.

Acoustic Characterization of Sub-Seismic Scaled Heterogeneities in Carbonate Reservoirs: Example of Barremian Microporous Limestones From SE France, An Analog of Middle East Hydrocarbon Reservoirs

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Introduction

Early Cretaceous **"Urgonian" limestones from Provence** are **outcropping analogues of Middle East hydrocarbon reservoirs** such as Thamama, Kharaib and Shuaiba formations, Alsharhan & Nairn, (1997). Age, facies, paleoenvironments and reservoir properties are some of the common characteristics between these formations and their french analogs (Borgomano et al., 2002; Sallier and Hamon, 2005; Sallier, 2006; Fournier et al., 2011, Léonide et al., 2014).

We propose to **assess acoustic properties** of Urgonian microporous limestones (UML) **at multi-meter scale** which is an intermediate scale between conventional seismic and laboratory methods.

FIVE CONCLUSIONS CAME OUT OF THIS STUDY:

(1) **Sub-seismic scaled heterogeneities** can be successfully detected and geologically **characterized using crosshole acoustic measurements**;

(2) Elastic properties of a given carbonate rock can vary with the sample's scale. **Lab-calibrated petrophysical properties** are representative of the matrix properties but **"ignore" the impact of fractures and meter-scale heterogeneities**;

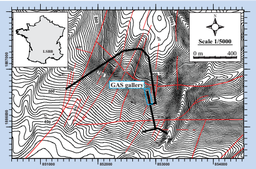
(3) Apertures and density of **fracturing** can be **deduced from the analysis of P-wave** velocities;

(4) **Porosity** is the **main control** on **P-wave velocity** in **non-fractured** UML;

(5) For fractured UML, the **"matrix-related"** acoustic **signal** is strongly **overprinted by** a **"fractured-rock related" signal**.

Experimental settings and methods

Context



Key features:

- Underground facility : LSBB* Laboratory
- Direct access (in subsurface) to a carbonate reservoir
- Unsaturated part of an acquifer
- 5 cored boreholes (20 m) / optical and wireline logging

Laboratory approach

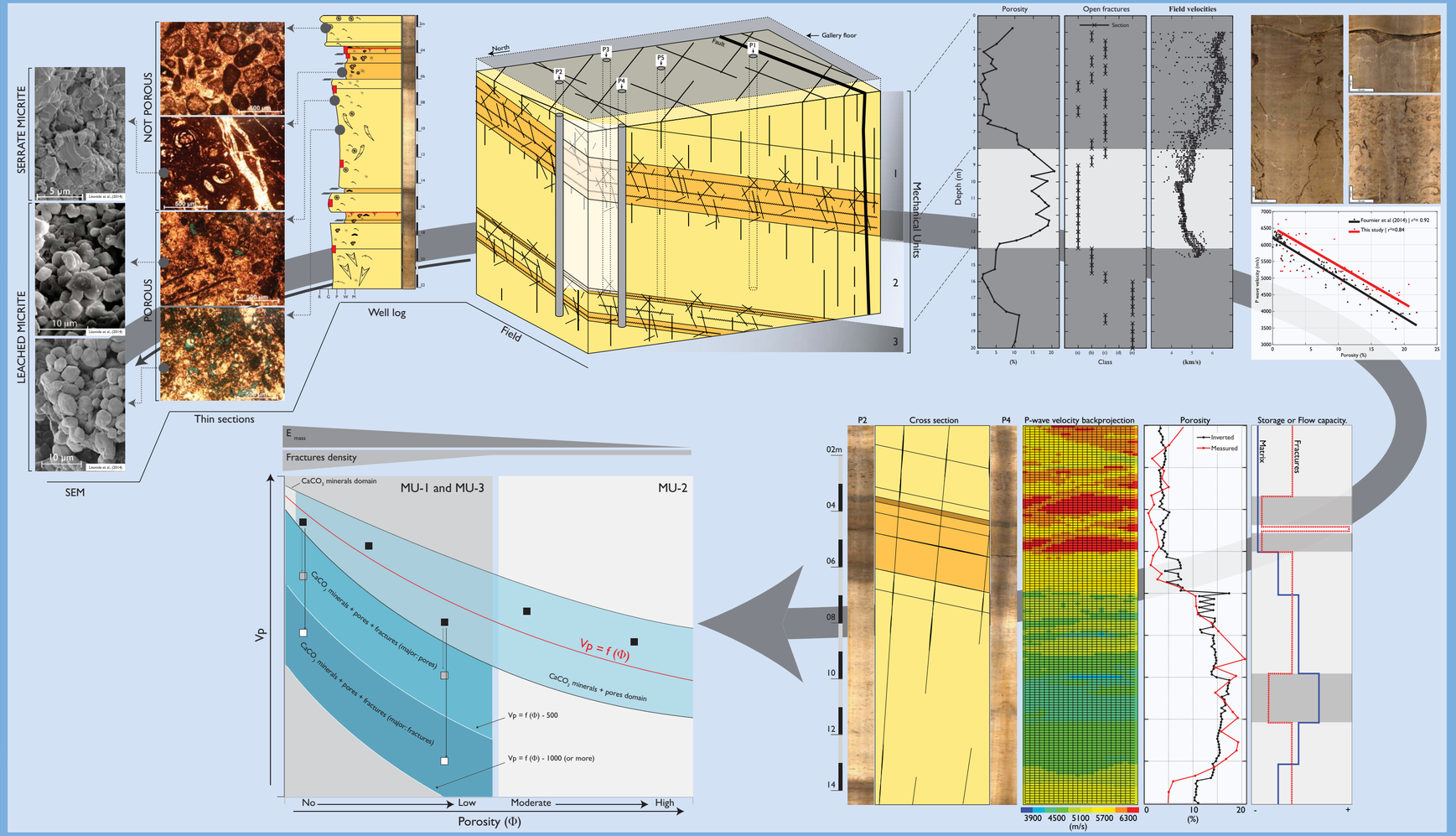
Key features:

- 6 cores (Ø = 12.5 cm; L = 15 - 80 cm) representative of facies & fracturing
- Extensive acoustic meas. (ΔZ = 1 cm; Δθ = 5 - 10°)

Field approach

Key features:

- Crosshole logging: ▶ Wells distance = 2 m
  ▶ Depth = 1 - 14.5 m
- 2 acoustic probes designed on purpose
  - Mechanichally coupled to borehole wall
  - Live-monitored (and adjusted) orientation
- Full-waveform records
- 2176 waveforms (stacked 100 times each)



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