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Characterization of elastic properties of micrites microstructure from nano-indentation tests and upscaling schemes

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Introduction

Microporous limestones, characterized by a microporous intercrystalline matrix of calcite crystals smaller than 4 µm (i.e. micrite), represent many carbonate petroleum reservoirs, especially in the Middle East (e.g. Alsharhan and Nairn, 2003). The porosity of these reservoirs is moderate to excellent (8% to 30%), whereas their permeability is poor to moderate (0.1mD to 200mD) (Kaldi, 1989; Moshier, 1989; Deville de Periere et al., 2011). However seismic and acoustic properties of these limestones are still poorly documented. Recently, Regnet et al. (2015) provided some acoustic P-wave velocities data on limestone cores primarly made of one micrite microstructure type: by sorting the data by micrite microstructure type, on a P-wave velocity versus porosity crossplot, a clear clustering is observed, though sub-rounded micrites display a wide range of P-wave velocity data. To better study the link between micrite microstructure type and elastic response, we are using nano-indentation technique, which provides elastic moduli at the micro-metre scale. We couple this study with scanning electron microscopy imaging of the same probed surface. We are furthermore investigating schemes and workflows to upscale these data obtained at the micro-meter scale to the core and log scales.

Methods

Studied samples are three limestones from the Oxfordian aquifer of the eastern part of the Paris Basin, made of nearly pure calcite (> 99%). Micrite content and microstructure type was previously determined by point-counting and image analysis from thin-sections and SEM (Regnet et al., 2015). Each of the four selected samples is assumed to be representative of one type of micrite microstructure, using the micrite texture terminology developed by Deville de Periere et al. (2011), namely rounded, anhedral compact and fused, with porosity of 23%, 7% and 3%, respectively.
Samples were room-dried and consisted of a small disk, a few mm thick, taken from core plugs 2.54cm in diameter, and polished with sandpaper to make their surface flat at ± 4µm. Nanoindentation tests were performed on a IBIS nanoindentation system (Fischer-Cripps Laboratories Pty. Ltd) with a Berkovitch type indenter (triangular indent), a constant maximum loading force of 10 mN, an initial contact force of 0.15 mN, a spatial step of 10 µm between two adjacent measurements. 400 measurements per samples were acquired. Indentation moduli are extracted from the force-displacement curves by $M \overset{def}{=} \frac{\sqrt{\pi}}{2}\frac{S}{\sqrt{A_c}}$ with

S is the unloading indentation stiffness $S = (dP/dh)_{h=hmax}$ and A_c the contact area (A_c=24.5.h^2_{max}).

Results

Figure 1 displays the distribution of the indentation moduli for each of the three samples.

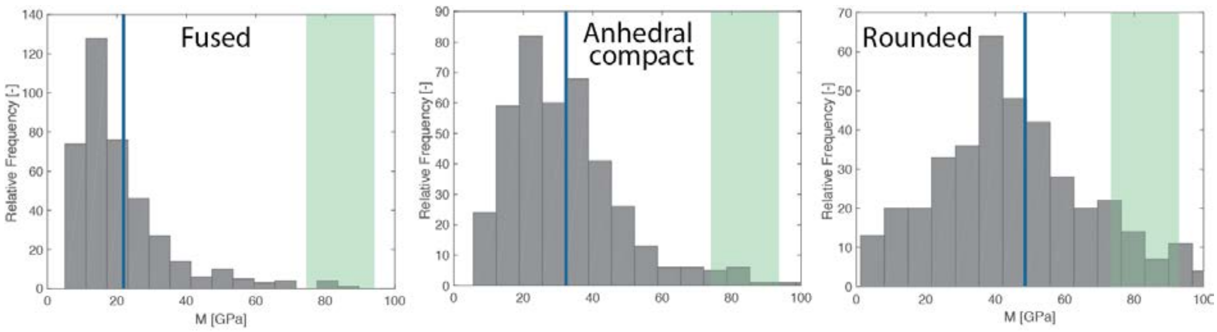

Figure 1: histograms of indentation moduli for each of the studied samples. The mean is indicated in blue and the moduli range given by the solid anisotropic calcite crystal is in green.

Discussion and conclusions

Nano-indentation technique appears to be a powerful technique for differentiating the different types of micrite microstructures, as illustrated in the histograms Figure 1. More data are though needed to be statistically representative of each micrite type. Furthermore, we will present several upsaling schemes, from simple volume averaging to the use of X-ray micro-CT imaging and analysis combined with rock physics modelling. The ultimate aim of this study is to provide a robust method for upscaling elastic properties of carbonates from the micrometer scale to the core scale and the log scale, and hence to relate rock fabric to seismic data in a quantitative way. This will significantly improve seismic data interpretation for carbonate reservoir characterization.

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References

Alsharhan, A.S., and Nairn, A.E.M. (2003) Sedimentary Basins and Petroleum Geology of the Middle East, Elsevier, Amsterdam.

Deville de Periere, M., Durlet, C., Vennin, E., Lambert, L., Bourillot, R., Caline, B. and Poli,E. (2011) Morphometry of micrite particles in cretaceous microporous limestones of the Middle East: Influence on reservoir properties, Mar. Pet. Geol., 28, 1727–1750, doi:10.1016/j.marpetgeo.2011.05.002.

Kaldi, J. (1989) Diagenetic microporosity (chalky porosity), Middle Devonian Kee Scarp reef complex, Norman Wells, Northwest Territories, Canada, Sediment. Geol., 63, 241–252.

Moshier, S. O. (1989) Microporosity in micritic limestones: A review, Sediment. Geol., 63, 191–213.

Regnet, J.B., Robion, P., David, C., Fortin, J., Brigaud, B., and Yven, B. (2015) Acoustic and reservoir properties of microporous carbonate rocks: Implication of micrite particle size and morphology, J. Geophys. Res. Solid Earth, 120, doi:10.1002/2014JB011313.