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Evolution of matrix and pore fabrics in marls at different deformation states.

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Clay rocks have a great economic interest. When they are rich in organic matter, they are both host rocks and reservoir rocks because gas and hydrocarbons can be trapped inside the micro pores. These rocks are also highly studied in the case of geological storage projects. The characterization of rock matrix, including quartz, calcite and clays, and pores, enables to better understand the physical properties of these rocks and to evaluate their potential for various applications in geosciences.
We present the characterization of matrix and pore fabrics of Hecho marls at various degrees of deformation. Hecho marls are exposed in an exceptional geological zone in Sigues (Aragon, Spain), where deformation can be closely monitored over nearly one kilometer. Deformation is marked by the development of oblique cleavage with respect to the sub-horizontal bedding. Three deformation stages are studied; from no cleavage, to pencil cleavage, up to pervasive slaty cleavage.
The feature-sizes in Hecho marls range typically from nanometer to millimeter scale. Their study requires experimental techniques permitting a 3D, high resolution structural and chemical characterization. High-resolution X-ray computed tomography (XCT), by its non-destructive nature, enables inner inspection of the structure of the scanned sample in 3D. Energy dispersive X-ray spectroscopy (EDS) provides a cartography of chemical elements. In this study, we characterize the fabric of quartz, calcite and pores by combining both XCT and EDS on the same sample. Unlike other microstructural approaches that generally provide bulk fabric of minerals, the combination of XCT-EDS allows the extraction of hundreds of ellipsoids, each of these mimicking the shape of a mineral or pore. The 3D representation of ellipsoids provides the fabric of both minerals and pores and their relation.
The 2D EDS images are first registered on the 3D X-ray scans. Then, the information obtained on the chemical elements highlighted by the EDS images are used as markers and are associated with the phases defined in the XCT tomographic volume. Finally, this information is propagated into the entire 3D XCT volume.
The fabric of calcite, quartz, and pores have been compared successfully with bedding, cleavage and also with clay fabric, measured by the anisotropy of magnetic susceptibility. More specifically, in stage 1 (no cleavage), quartz and calcite are poorly organized, marking a broad foliation plane parallel to the bedding. In stage 2 (pencil cleavage), quartz and calcite are well organized, with the development of a foliation parallel to the bedding. The shape of the minerals remains however unchanged. In stage 3 (slaty cleavage), both the shape of the minerals and their spatial organization are changing; the foliation being parallel to cleavage.
The combination of XCT-EDS techniques is therefore a promising approach to characterize matrix and pore fabrics in marls, opening a new way to quantify the deformation.