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Correlations of magnetic pore fabrics with pore fabrics derived from high-resolution X-ray computed tomography and with permeability anisotropy in sedimentary rocks and synthetic samples

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Magnetic pore fabrics (MPF) are an indirect measure of the 3D pore structure. They are defined by measuring anisotropy of magnetic susceptibility after samples have been impregnated with ferrofluid. Previous studies proposed that MPFs target pores down to 10 nm. Therefore, the method complements X-ray computed tomography (XRCT) datasets, with resolution on the order of 1-10 µm. Empirical relationships exist between MPF and pore fabric, and between MPF and permeability anisotropy. This study investigates quantitative correlations between these three properties, and between measured quantities and digital-rock-model-simulations of permeability anisotropy and MPF. Samples used for this study include natural sedimentary rocks and synthetic samples. Sediments are Plio-Pleistocene calcarenite (Apulia, Italy) with ~50% porosity and complex pore structure, and Upper Marine Molasse sandstone (Belpberg, Switzerland) with 10-20% porosity and relatively homogeneous pore space properties. Synthetic samples were made from quartz sand and calcite powder in different proportions, to simulate sandstone and carbonate rocks. Samples were characterized by pycnometry, XRCT scans, MPF determination and directional permeability measurements to obtain porosity, digital rock models, MPFs and permeability anisotropy. Porosity, permeability anisotropy, and MPFs were also computed based on digital rock models derived from XRCT data, and compared to direct measurements. Permeability anisotropy and MPF are both second-order tensors, representing the average property of the entire sample. To directly relate the XRCT-derived individual pore properties to these second-order tensor quantities, a total shape ellipsoid was computed by adding the second-order tensors reflecting the best-fit ellipsoids of single pores. Once all properties were described by second-order tensors, they were correlated in terms of fabric orientation, degree and shape of anisotropy. The MPF and total shape ellipsoids are coaxial when the samples have sufficiently large pores to be resolved, and good impregnation efficiency, and as expected, total shape ellipsoids have larger anisotropy degree. Preliminary results further indicate that the permeability anisotropy is partly consistent with total shape ellipsoids and MPFs. The defined quantitative relationships facilitate the interpretation of MPF data, thus making the method more applicable to geological and fluid migration studies.