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Permeability calculation and pore-network quantitative analysis in deformed porous carbonates by combining synchrotron X-ray computed microtomography and lattice-Boltzmann flow simulations

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In deformed porous carbonates, the architecture of the pore network may be modified by deformation or diagenetic processes varying the permeability with respect to the parent rock. The control exerted by the pore texture and morphology on permeability in porous rocks have been widely studied due to the importance during the evaluation of geofluids reservoirs. In this study, these effects are assessed by combining synchrotron X-ray computed microtomography (SR micro-CT) and lattice-Boltzmann flow simulations. The studied samples pertain to deformed porous carbonate grainstones highly affected by deformation bands (DBs) exposed in Northwestern Sicily and Abruzzo regions, Italy.
The high-resolution SR micro-CT images of the samples, acquired at the SYRMEP beamline of the Elettra - Sincrotrone Trieste laboratory (Italy), were used for simulating a pressure-driven flow by using the lattice-Boltzmann method (LBM). For the experiments, a multiple relaxation time (MRT) model with the D3Q19 scheme was used to avoid viscosity-dependent results of permeability. The permeability was calculated by using the Darcy's law once steady conditions were reached. After the simulations, the pore-network properties (effective porosity, specific surface area, and geometrical tortuosity) were calculated using the 3D images of the velocity fields. These images were segmented considering a velocity threshold value higher than zero.
After verifying the obtained permeability values are consistent with in situ and laboratory measurements, the control exerted by the pore network on the permeability in deformed porous carbonates has been investigated. The results allow to establish that permeability is controlled by a combined action of the effective porosity, the grains/pores size (specific surface area) and the tortuosity of the pore-network of the investigated rocks. The study showed that DBs represent important heterogeneity features which generate significant permeability anisotropy. Cataclasis and cementation process taking place within the DBs reduce the effective porosity and therefore the permeability. Contrary to this, pressure dissolution and faulting may generate connected channels which contribute to the permeability only parallel to the DB.

Keywords: Deformation bands, Tortuosity, Effective porosity, synchrotron X-ray computed microtomography, Lattice-Boltzmann Method.