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Uncoupling of hydraulic and electric flow paths in sedimentary and volcanic rock samples

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Understanding the mechanisms which govern the circulation of fluids in geological materials is a crucial issue in petroleum exploration, hydrogeology, environmental geology, volcanology or seismogenesis. The main parameter that controls the underground fluid movements is the hydraulic permeability. As an example, a high permeability is of high interest for hydrocarbon extraction, but is disabling for waste disposal applications. But, to date, the effect of the rock microstructure, the influence of the heterogeneities at various scales or the effect of multiphase flow on the transport properties are not fully understood nor extensively experimentally studied - in particular for volcanic materials.

Here we performed a quantitative study of transport properties on a various set of lithologies. Sandstone, limestone and volcanic rock samples were fully characterised in term of microstructure, using image analysis of thin sections. The distributions of pore access radii were determined by means of mercury-porosimetry measurements. Then, rock parameters such as porosity, air and fluid permeability, relative permeabilities and electrical formation factor (i.e., the fluid conductivity divided by the saturated rock conductivity) were measured using a new apparatus. Finally, we carried out miscible displacement experiments (using saline fronts) to estimate the dispersion coefficient.

The results showed that the pore access radii distributions are mono-modal for sandstones, bi-modal for limestones and mono to tri-modal for volcanic materials. The permeability measurements underlined the fact that volcanic rocks do not behave hydraulically as sedimentary ones. From miscible displacements, we inferred that the percolation threshold depends more on the pore access radii size and on the connectivity than on the rock type. The evolution of the formation factor and the hydraulic dispersivity values revealed the existence of preferential transport paths.

Preliminary results of network modelling showed that the hydraulic and electrical flow paths become uncoupled as the heterogeneity degree (i.e., the width of the pore size distribution and its number of modes) increases. In other words, the electrical and hydraulic tortuosities increase with the complexity of the porous network, but not in the same way. Hence the use of the electrical tortuosity (deduced from the formation factor by Archie's relation), instead of the hydraulic one, to deduce the formation permeability may be inadequate in complex cases.