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Pore Geometry Dependence of Hydraulic Properties of Fontainebleau Sandstone

I. Song (1) and J. Renner (1)

(1) Ruhr-University Bochum, D-44780, Germany (Insun.Song@ruhr-uni-bochum.de/++49 234 321 4181)

We present results of an experimental study on the correlation between pore geometry and hydraulic properties of Fontainebleau sandstone. We measured ultrasonic velocities, hydraulic permeability and specific storage of eight blocks of the sandstone sampled from different locations. Several cored samples, 30 mm in diameter and 60 mm in length, were prepared from each block for tests. The available blocks yield a range in porosity from about 3 to 11% with little variation within a given block. A scanning electron microscope analysis revealed a clayless-pure (>99% quartz), well sorted sandstone with different pore geometry for different blocks. The pore texture varies from spherical pores formed among grains possibly connected by tube-like conduits to sheet-like grain-separating pores. Ultrasonic velocity was measured on water-saturated samples at room temperature and atmospheric pressure. The variation of the ultrasonic velocity covers the full range between the lower and the upper Hashin-Shtrikman bounds. The velocity ranges relate to the pore geometry; e.g. high velocity in samples with isolated pores and low velocity in samples with isolated grains. Permeability and specific storage were determined by the linear pressurization method at different pore pressures up to 180 MPa for a given confining pressure of 180 to 200 MPa at room temperature. The permeability of tested samples varies from 10^{-13} m^2 down to 10^{-20} m^2 depending primarily on porosity, subordinately on effective pressure, defined as the difference between confining and pore pressure. The found permeability-porosity relation suggests that the low porosity sample is closer to the percolation threshold and the percentage of the network constituting dead storage is relatively larger than in the more porous sample. Permeability of samples with low ultrasonic velocity is more sensitive to effective pressure than of those with high velocities probably reflecting that sheet-like grain-separating conduits are easier to be closed by confining pressure than spherical and tube-like pores. In agreement, the pore-geometry factors estimated by Martyąŕs model (1994) for permeability-porosity relation yield two distinct groups (soft and stiff pore geometry) for the tested sandstone. Specific storage capacity determined by the linear pressurization method always exceeds the contribution of the compressible fluid alone. The excess corresponds to the contribution of the solid frame to specific storage. The effective pressure dependence of the storage capacity varies with the inferred pore geometry similarly to permeability. We calculated the four principle compressibilities (bulk volume changes as a result of either pore or confining pressure changes; pore volume changes as a result of either pore or confining pressure changes) of the samples relying on bounds of elasticity parameters of quartz. Thus, our precise determination of specific storage also provides important poro-elastic parameters such as Biot-Willis and Skempton coefficients, and undrained bulk compressibility which are crucial for estimating hydro-mechanical coupling in fluid-saturated porous media.