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Linking Texture and Diagenesis to Porosity and Permeability of Sandstones

Porosity and permeability are sediment properties most important in petroleum applications. Porosity determines how much fluid can be stored in rock and permeability determines how fast it can flow. The sediment transport mechanism (air, water, and gravity forces) determines the initial texture whose quantitative measures are grain size, sorting and grain shape. The post-depositional alteration and diagenesis change the texture by compaction, cementation, replacement, and re-crystallization. All these factors affect the pore-space topology, thus porosity and permeability. We quantify the effect of the initial texture and consecutive alteration on permeability by directly simulating viscous fluid flow through the pore space in 3-D. The simulation is based on the Lattice-Boltzmann numerical method that allows us to accurately describe fluid flow through the pore space of any complexity, without replacing actual pores with idealized shapes such as pipes and spheres. We construct 3-D digital rock by first numerically constructing the basic grain of desirable shape and size. Next, we vary the size of the basic grain within a given range to simulate sorting and randomly fill the space with the particles thus constructed to achieve the desirable porosity. The compaction and diagenesis effects are simulated by bringing the grains closer together and digitally depositing cement on the grain surface, respectively. The permeability/porosity curves are computed for digital sediments of varying sorting and grain shape and also during the digital compaction and diagenesis processes. The resulting trends are validated by comparing them to laboratory data obtained on sandstone samples of varying initial texture and degree of diagenesis.