LATTICE-BOLTZMANN AND MONTE CARLO SIMULATIONS OF FLOW IN PORE NETWORKS WITH EVOLVING POROSITY

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Abstract. For a broad range of applications the most important transport property of porous media is permeability. Here we calculate the permeability of pore network approximations of porous media as simple diagenetic or shrinking processes reduces their pore spaces. We use a simple random bond-shrinkage mechanism by which porosity is decreased; a tube is selected at random and its radius is reduced by a fixed factor, the process is repeated until porosity is reduced either to zero or a preset value. For flow simulations at selected porosity levels we use the lattice-Boltzmann method with a 9-speed model on two-dimensional square lattices and 15-speed and 19-speed models on three dimensional lattices. Calculations show a simple power-law behavior, $k \propto \phi^m$, where k is the permeability and ϕ is the porosity. The value of *m* relates strongly to the shrinking extension, and hence to the skewness of the pore size distribution, which varies with shrinking, and weakly to pore sizes and shapes. Smooth shrinking produces pore space microstructures resembling the starting primitive material; one value of m suffices to describe k vs. ϕ for any value of porosity. Severe shrinking however produces pore space microstructures that apparently forget their origin; the $k-\phi$ curve is only piecewise continuous, different values of *m* are needed to describe it in the various porosity intervals characterizing the material. The power law thus is not universal, a well known fact. An effective pore length or critical pore size parameter, l_c, characterizes pore space microstructures at any level of porosity. For severe shrinking l_c becomes singular, indicating a change in the microstructure controlling permeability, and thus flow, thus explaining $k-\phi$ power law transitions. Continuation of the various $k-\phi$ pieces down to zero permeability reveals pseudo percolation thresholds $\phi_c^{'}$ for the porosity of the controlling microstructures. New graphical representations of k/l_c^2 vs. $\phi-\phi_c^{'}$ for the various ϕ intervals display straight and parallel lines, with a slope of 1. Our results confirm that a universal relationship between k/l_c^2 and ϕ should not be discarded. Results here are compared with precise Monte Carlo data for the same media.