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Understanding heterogeneous and anisotropic porous media based on geometric properties extracted from three-dimensional images

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Natural porous media is generally heterogeneous and anisotropic. The structure of porous media plays a vital role and is often the source of heterogeneity and anisotropy. In a physical process such as fluid flow in porous media, a small number of major features here referred to as wide channels, are responsible for the majority of the flow. The thickness and orientation of these channels often determine the characteristics of the permeability. Typically, the identification of such major features is conducted through time-consuming and expensive simulations. Here we propose a prompt approach based on geometric properties extracted from three-dimensional (3D) images. The size or radius of the major features is obtained via distance maps, and their orientations are calculated by Principal Component Analysis. We then visualize these features with color and color brightness according to their orientation and size, together with their location and distribution in 3D space, and the simultaneous visualization of anisotropy (orientation) and heterogeneity (size) in one plot provides a straightforward way to enhance our understanding. Furthermore, we propose a refined stereographic projection to statistically illustrate heterogeneity and anisotropy. Based on this understanding, we show a new way to compress model size in numerical simulation, therefore significantly reducing computational cost, while retaining its essential characteristics.

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