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How Dual-Scale Diffusive Property Heterogeneity Affects the Effective Matrix Diffusion Coefficient in Fractured Rock

Yingqi Zhang, Hui-Hai Liu, Quanlin Zhou and Stefan Finsterle

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Earth Science Division
Lawrence Berkeley National Laboratory
University of California
Berkeley, CA 94720

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Matrix diffusion can significantly retard solute transport in fractured formations. Understanding matrix diffusion is crucial for predicting the arrival time, peak concentration, and tail of a contaminant breakthrough curve. Previous studies show that the effective matrix diffusion coefficient may be scale dependent. This study examines how heterogeneities of diffusion properties affect the effective matrix diffusion coefficient. Two types of heterogeneity in a channelized flow system are considered in the study: (1) interchannel heterogeneity, and (2) intrachannel heterogeneity. The objectives of this study are (1) to examine if it is appropriate to use a single, effective matrix diffusion coefficient in a standard solution model to predict breakthrough curves (BTC) in a fractured formation, (2) if so, how this effective value is related to the degree of the matrix diffusion coefficient variability; and (3) to examine if the observed scale dependence of the effective matrix-diffusion coefficient is caused by heterogeneity in diffusion properties. The results show that the use of a single effective matrix diffusion coefficient is appropriate only if the inter- and intrachannel variability of diffusion properties is small. The scale dependence of the effective matrix diffusion coefficient is not caused by either type of the studied heterogeneity.