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The Effect of Conduction and Thermal Dispersion on Heat Transport in a Discrete Fracture

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In typical theoretical or experimental studies of heat migration in discrete fractures, conduction and thermal dispersion are commonly neglected from the fracture heat transport equation, assuming heat conduction into the matrix is predominant. In this study analytical and numerical models are used to investigate the significance of conduction and thermal dispersion in the plane of the fracture for point and line sources geometries. The analytical models account for advective, conductive and dispersive heat transport in both the longitudinal and transverse directions in the fracture. The heat transport in the fracture is coupled with a matrix equation in which heat is conducted in the direction perpendicular to the fracture. In the numerical model, the governing heat transport processes are the same as the analytical models; however, the matrix conduction is considered in both longitudinal and transverse directions. Firstly, we demonstrate that longitudinal conduction and dispersion are critical processes that influence heat transport in fractured rock environments, especially for small apertures (eg. 100 microns or less), high flow rate conditions (eg. velocity greater than 50 m/day) and early time (eg. less than 10 days). Secondly, transverse thermal dispersion in the fracture plane is also observed to be an important transport process leading to retardation of the migrating heat front particularly at late time (eg. after 40 days of hot water injection). Solutions which neglect dispersion in the transverse direction underestimate the locations of heat fronts at late time by a significant margin. Finally, the results of this study also suggest that the geometry of the heat sources has significant effects on the heat transport in the system. For example, the effects of dispersion in the fracture are observed to decrease when the width of the heat source expands.