Constraints on Flow Regimes in Unsaturated Fractures

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In recent years, significant advances have been made in our understanding of the complex flow processes in individual fractures, aided by flow visualization experiments and conceptual modeling efforts. These advances have led to the recognition of several flow regimes in individual fractures subjected to different initial and boundary conditions. Of these, the most important regimes are film flow, rivulet flow, and sliding of droplets. The existence of such significantly dissimilar flow regimes has been a major hindrance in the development of self-consistent conceptual models of flow for single fractures that encompass all the flow regimes. The objective of this study is to delineate the existence of the different flow regimes in individual fractures. For steady-state flow conditions, we developed physical constraints on the different flow regimes that satisfy minimum energy configurations, which enabled us to segregate the wide range of fracture transmissivity (volumetric flow rate per fracture width) into several flow regimes. These are, in increasing order of flow rate, flow of adsorbed films, flow of sliding drops and bridges, rivulet flow, stable film flow, and unstable (turbulent) film flow. This work was supported by the U.S. Dept. of Energy under Contract No. DE-AC03-76SF00098.