Experimental Studies of Vaporizing Flows in Unsaturated Fractures

Timothy J Kneafsey (TJKneafsey@lbl.gov)
Karsten Pruess (K_Pruess@lbl.gov)

Earth Sciences Division, Ernest Orlando Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA, 94720, USA

Water flow in partially saturated fractures subjected to thermal drive may lead to fast flow along preferential localized pathways and to heat pipe conditions. At the potential high-level nuclear waste repository at Yucca Mountain, water flowing in fast pathways may ultimately contact waste packages and transport radionuclides to the accessible environment. To examine liquid flow in fractures under partially saturated thermal drive conditions, a series of laboratory experiments was conducted in transparent (two transparent fracture faces) or semi-transparent (one transparent fracture face mated to the corresponding natural rock face) fracture models manufactured from glass, epoxy replicas of natural fractures, and a fractured specimen of Topopah Spring tuff. Various flow regimes were observed including continuous rivulet flow for high flow rates, intermittent rivulet flow and drop flow for intermediate flow rates, and film flow for low flow rates and wide apertures. These flow regimes were present in glass fracture models and the epoxy fracture replica, but not all were observed in the rock-replica assembly due to limiting experimental conditions. Spatially resolved thermal monitoring was performed in seven of the experiments to examine heat pipe formation. Heat pipe conditions indicated by low thermal gradients were observed in five experiments. Conditions conducive to heat pipe formation include the presence of an evaporation zone, condensation zone, adequate space for vapor and liquid to travel, and appropriate fluid driving forces. Video and graphic experimental results demonstrating various flow regimes and heat pipe formation will be presented. Data collected and referenced in this work were collected under the LBNL YMP Quality Assurance Program. Conclusions drawn from this work are based on qualified data.