Heterogeneous flow paths in the subsurface may explain the lab vs. field weathering rate conundrum

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Weathering plays a critical role in our daily lives and the global climate cycle. It provides the soils which we depend on to grow food, and over longer timescales, it consumes atmospheric CO_2 which regulates the Earth's climate. Many studies have been completed to understand the rate that weathering occurs at the Earth's surface, including field studies and laboratory studies. However, there is a consistent discrepancy between rates measured in the lab and those measured in the field, sometimes the difference is several orders of magnitude. Despite many attempts to reconcile this difference in rates, we still do not fully understand the mechanisms that create the observed large discrepancy. Previously, researchers have proposed that these differences are a result of unrealistic lab conditions, such as high water to rock ratios, fluids far from equilibrium, or enhanced available reactive surface area. Others have proposed that the flow path of water through the subsurface provides the main control on weathering in the field; however, lab weathering experiments are typically done in batch reactors or in homogeneously packed columns that eliminate the flow path component. This study investigates how heterogeneous flow paths in fractured bedrock control the weathering rates observed at the hillslope scale using reactive transport simulations. Fractures are modelled discretely and as equivalent porous media to investigate the level of complexity needed to understand the importance of the heterogeneity in the subsurface. Ultimately this research has (1) determined that heterogeneous flow paths in fractured rocks can account for at least some of the orders of magnitude difference between lab and field measured weathering rates, (2) defined fracture orientation and density as important fracture network parameters that determine observed weathering rates, and (3) provided evidence that suggests that many field sites are transport limited.