# Fractures sustain dynamic microbial hot spots in the critical zone

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While most freshwater on Earth resides and flows in groundwater systems, these deep environments are often assumed to have little biogeochemical activity compared to near-surface environments. Here we demonstrate from field observations and a quantitative mechanistic model that fracture-induced microbial hot spots can occur over a broad reactive zone that extends hundreds of meters below the surface. While seasonal fluctuations are generally thought to decrease with depth, we found that meter-scale changes in water table level can move the depth of the reactive zone hundreds of meters. The role of fractures in deep microbial hot spot formation was supported by the chemical and metagenomic analysis of fracture fluid at different depths in a bedrock aquifer. A five fold increase in iron-oxidizing bacteria abundance was observed at depths ranging from 40 to 55 meters, far below the shallow mixing zones where most microbial activity is believed to occur.

This deep biogeochemical hot spot formed at the intersection of bedrock fractures, allowing fluids with contrasting redox chemistry to mix. Because fractures can mix fluids of extremely different residence times, they significantly enhance the range of depths where microbial communities thrive. Given the ubiquity of fractures at multiple scales in the critical zone, such deep hot spots may significantly influence global biogeochemical cycles.